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FOREWORD

The four independent reviewers estimated each paper and recommended 77 articles for publishing at the proceedings consisted of 2 volumes, which started life as presentations at the Annual 22nd International Scientific Conference "Research for Rural Development 2016" held at the Latvia University of Agriculture, in Jelgava, on 18 to 20 May 2016.

In the retrospect of four months later, we can count the Conference as a great success. The theme – Research for Rural Development - attracted participation more than 160 researchers with very different backgrounds. There were 125 presentations from different universities of Poland, Turkey, Tajikistan, Lithuania, Croatia, Czech Republic, Kazakhstan, Mexico and Latvia.

Thank you for your participation! I'm sure that you have learned from the presentations and discussions during the conference and you can use the outcomes in the future.

The cross disciplinary proceedings of the Annual 22nd International Scientific Conference "Research for Rural Development 2016" (2 volume since 2010) are intended for academics, students and professionals. The subjects covered by those issues are crop production, animal breeding, agricultural engineering, agrarian and regional economics, food sciences, veterinary medicine, forestry, wood processing, water management, environmental engineering, landscape architecture, information and communication technologies. The papers are grouped according to the sessions in which they have been presented.

Finally, I wish to thank Organizing and Scientific Committee and the sponsors for their great support to the conference and proceedings.

On behalf of the Organizing Committee
of Annual 22nd International Scientific Conference
"Research for Rural Development 2016"

Ausma Markevica
Latvia University of Agriculture

CONTENTS

CERAL VARIETY MIXTURES AND POPULATIONS FOR SUSTAINABLE AGRICULTURE: A REVIEW

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Abstract
Modern varieties developed under conventional plant breeding programs do not always perform well under organic and low-input growing conditions. Therefore, organic farmers need varieties adapted to variable environmental conditions. This means emphasis on traits such as nutrient uptake and use efficiency, good weed suppression ability and disease resistance and can be achieved via extended genetic diversity within the varieties: variety mixtures and populations of self-pollinating crops.
The aim of the present study was to review published scientific literature about importance and research results on this topic. Scientific articles about the necessity of such studies and results of investigations performed in different countries have been studied. The main results show that variety mixtures have advantages in terms of disease control and yield stabilization and performance of mixtures may be affected by various factors – choice of components and its number, interactions between plants of components, manner of the mixing and growing technology. Depending on parental material, populations contain greater genetic diversity than variety mixtures. There are trends observed in the studies that yield of populations increased over generations and they are more stable than modern varieties, but there is no evidence that they would be significantly more productive.
This research direction has recently become topical and is not sufficiently widely covered in the world agricultural science. The obtained results are inconsistent.
Key words: variety mixtures, composite cross populations, genetic diversity.

Introduction

Genetically uniform varieties produced from simple crosses in barley (*Hordeum vulgare* L.), wheat (*Triticum aestivum* L.) and other self-pollinated crop species, give both high and stable yields, and such varieties dominate in commercial production (Soliman & Allard, 1991). However, these varieties are not high yielding by themselves. Such varieties can provide high yield under conventional growing conditions with applications of mineral fertilizers and pesticides, but do not have an ability to adapt to unstable environmental conditions, compete with weeds and effectively uptake nutrients from the soil if their amount is limited (Wolfe *et al*., 2008).

Demand for agricultural products grown without chemically synthesized substances is increasing in the world (Wolfe *et al*., 2008) and human activities are now increasingly influencing changes in global climate, and availability of non-renewable resources is decreasing (Chakraborty & Newton, 2011). Considering the above mentioned, it is necessary to understand which strategy is the most appropriate for the future of agricultural production (Østergård *et al*., 2009). One of the factors in the changing environment for sustainable agriculture is that wider adaptation is needed, and that this can be achieved via extended genotypic diversity of plants within variety (Döring *et al*., 2011; Tooker & Frank, 2012).

Increasing genetic diversity in crops can ensure yield stability and adaptability, reduce disease distribution and improve competitive ability with weeds and nutrient uptake efficiency (Döring *et al*., 2011). Significant positive effect of the diversity level (pure line varieties – variety mixtures – composite cross populations) was shown on grain yield, yield stability and several other traits in winter wheat (Döring *et al*., 2015). One of the ways to increase genetic diversity of varieties is growing of variety mixtures (Lopez & Mundt, 2000). Another solution for increasing genetic diversity in varieties of self-pollinating cereals is creation of composite cross populations, which include higher levels of diversity if compared to pure lines and mixtures and are able to develop itself in time by adapting to the respective environment (Wolfe *et al*., 2008).

European commission noted that genetic diversity in agriculture is associated with a wide range of environmental and economic benefits, which are essential for sustainable agricultural production and paid attention to practice orientated activities including action on investigating agricultural genetic resources (European Commission. Report SWD (2013) 486 final).

The aim of the present study was to summarize the results of research and potential benefits and drawbacks of the use of cereal variety mixtures and populations in the process of the agricultural production.

Materials and Methods

Monographic method has been used for this review. Scientific literature from different journals, monographs and PhD thesis has been used in it.

Literature includes information about the necessity for such studies and information from investigations performed in Latvia, Poland, Scotland, England, Denmark, France, Canada, USA, Slovakia and China.

Results and Discussion

Variety mixtures: yield and its stability

The impact of breeding on grain yield over the years was confirmed by the results of study on barley adaptation using 188 landraces, old genotypes and current modern varieties. It was concluded that landraces were generally better adapted to stress prone environments, while old and modern varieties to non-stress environments, and current barley selection is leading to specifically adapted genotypes (Pswarayi *et al*., 2008).

One of the ways to increase adaptability to environmental stress factors is to use variety mixtures. It is a relatively unexplored measure for maintaining and stabilizing yields for both organic and conventional producers (Kaut *et al*., 2008; Kiær, Skovgaard, & Østergård, 2012; Zhou *et al*., 2014). Yield of cereals is forming gradually during vegetation and depends not only on variety genotype but also on environmental conditions. It is not possible to predict what mixture component will provide advantage in the respective year and environment while sowing variety mixtures, but compensation mechanism can provide stability (Kaut *et al*., 2008).

The results of the research confirm that growing variety mixtures may have several advantages over pure crops under both organic and conventional farming systems (Kaut *et al*., 2008). For example, field trials conducted in Canada show that spring wheat variety mixtures may provide greater stability with little or no reduction in yield. Unpredictable environmental variation factors are the main impediment in choosing the right variety or variety mixture. It is unclear how many varieties should be used to compose the mixtures. In the investigation mentioned before two-variety mixtures yielded more than three-variety mixtures at one organic location, but were not different at the other organic and conventional locations (Kaut *et al*., 2008). Other investigation carried out for two years in Canada tested 16 three-variety spring barley mixtures in a range of possible combinations of three varieties in different proportions. Selected varieties had a range of morphological and phenological differences. All mixtures gave significantly higher yields than the lowest yielding pure stand variety while no mixture had higher yield than the highest yielding pure stand. Using two methods of analysis of yield stability two mixtures were identified as having superior yield stability (Juskiw, Helm, & Burnett, 2001).

Essah and Stoskop (2002) in Canada studied two-variety mixtures performance of phenotypically contrasting barley varieties. The results of this study indicate a possible 13-14% yield advantage of mixtures compared to pure stands means, whereas the experiment carried out in Poland including two- and three-variety mixtures shows no evidence that variety mixtures would give higher yield if compared to pure stands on one site; however, on the other site 1-15% yield increase was found (Tratwal *et al*., 2007). In a Danish investigation, one of six tested two-variety mixtures out-yielded all of its component varieties in almost half of the 17 trial environments (Kiær, Skovgaard, & Østergård, 2012). The contrasting results show that yields of mixtures may be affected by various factors, also by the manner of mechanical seed handling during the mixing. In an investigation carried out in the UK three winter barley varieties were mixed in equal proportions but using techniques giving different patterns of plant spatial heterogeneity. Results show that mixtures mixed directly in the seeder hopper prior to sowing gave a yield advantage if compared to the average of individual components in two out of three years, while the mixture which was pre-mixed most homogeneously gave no significant yield advantage (Newton & Guy, 2009).

Mille *et al*. (2006) report that winter barley mixtures composed of four and two components performed better than average of individual pure line components and the best yielding pure stand variety was not the best contributor to the mixtures. They recommend that mixtures of two components should be screened to remove unfavorable variety pairs and those mixtures that show complementarity should be selected in order to construct mixtures of four components. Furthermore, Mundt *et al.* (1994) in Oregon, USA, compared four barley varieties as pure stands and in 11 two-, three- and four-variety mixtures in all possible combinations. Generally, the mixtures did not increase yield relative to the mean of the pure stands; just one two-variety mixture consistently increased yield and other two-variety mixture had consistently lower yields than the mean of the pure stands. Also Zhou *et al.* (2014) in China investigated two and three-variety mixtures of spring wheat during four years and concluded that variety mixtures tend to increase and stabilize yields. Yield stability of three-variety mixtures exceeded that of the pure varieties and consistently out-yielded the means of the respective components over different growing conditions. Similar results achieved Cowger and Weisz (2008) in North Carolina, USA, by testing two and three-variety mixtures of winter wheat. Yield stability of mixtures exceeded that of pure stands and average yield across environments significantly surpassed their respective components. Döring *et al.* (2015) showed that multi-component mixtures of winter wheat significantly out-yielded the mean of

the respective components across 12 environments by 3.6%.

Fang *et al.* (2014) in China evaluated grain yield and water use efficiency in mixtures consisting of an old landrace and a modern variety. They suggest that the use of a mixture of such varieties in a serious drought season will ensure greater availability of water after stem elongation stage, resulting in better water use efficiency and higher yields than in cultivars grown as a pure stand.

The experimental evidence of more stable yields of mixtures than the average of their pure stand component varieties may justify cultivation of variety mixtures in variable environments, such as organic farming systems. However, mixtures would be even more advantageous to farmers in general if in addition mixture yields were comparable to the highest yields of the component varieties (Kiær, Skovgaard, & Østergård, 2012).

Variety mixtures: leaf diseases

The traits controlling diseases are particularly advantageous where zero or low use of synthetic pesticides is permitted such as in organic or low input systems, respectively (Newton *et al*., 2012; Kiær, Skovgaard, & Østergård, 2012). In mixtures initially the attention was paid to advantages regarding to reduction of leaf disease infection, which can reach a level when usage of fungicides is economically unreasonable. It reduces also the risk that resistance genes can lose the efficiency (Mundt, 2002).

Several studies revealed that variety mixtures may be used as added elements of functional diversity to reduce levels of fungal diseases and thus provide benefits to cereal production. For example, in Slovakian three year investigation, three-variety mixtures of winter wheat were tested and lower infection with brown rust (caused by *Puccinia recondite*), powdery mildew (caused by *Blumeria graminis*) and leaf spots but no differences in respect to yellow rust (caused by *Puucinia striiformis*) in comparison with pure stands was found (Muchova & Fazekašova, 2010). Tratwal, Law, & Philpott (2007) concluded that winter barley two-variety mixtures combined with different fungicide treatments can reduce the powdery mildew occurrence compared to pure stands and can constitute an alternative way of growing winter barley, especially at low-input and organic agriculture. Newton and Guy (2009) who investigated three winter barley varieties mixed in equal proportions for three years, but in different ways to give different patterns of spatial heterogeneity, showed that most mixtures which were mixed directly in the seeder hopper prior to sowing significantly reduced rhynchosporium (caused by *Rhynchosporium secalis*), powdery mildew and net blotch (caused by *Pyrenospora teres*) if compared to the mean of the components, while the mixture which was pre-mixed most homogeneously, gave a significant reduction in net blotch in one year only. A five year investigation in the UK compared two, three and four-variety mixtures of winter barley in different levels of tillage. Rhynchosporium infection level was decreased in most mixtures in comparison to the pure stand mean in all years and tillage conditions. In addition, three and four-variety mixtures gave around 32% less disease than two-variety mixtures (Newton *et al*., 2012). Spring barley varieties with mildew resistance genes were used to compose three and four-variety mixtures in Scotland. Data from this study showed that reduction in powdery mildew infection was not significant compared with the component pure stand mean. There was a trend towards greater reductions at low fertilizer level (Newton & Guy, 2011)including plot size, and its interaction with fertiliser level and barley germplasm on mixture efficacy in controlling powdery mildew were investigated. Two groups of cultivars, one from cultivars grown in the UK and the other from cultivars grown in Poland, along with all their respective three-component mixtures, were grown in three field trials, one with 13.5 m^2 plots, one with 0.4 m^2 plots, and the third in intermediate size plots, which included a mixture of all the cultivars in both groups in equal size treatments of structured spatial arrangements. Another trial utilised similar structured spatial arrangements to trial 3 was carried out using a combination of cultivars with appropriate matching virulence levels (trial 4. Mundt, Hayes, & Schon (1994) in Oregon, USA, investigated 11 possible mixtures of two susceptible and two moderately resistant advanced breeding lines of barley in equal proportions in the presence of scald and net blotch. The variety mixtures restricted leaf disease development during three seasons by 12% on average. However, mixtures of susceptible and moderately resistant line reduced disease severity by 20-32%.

Variety mixtures have been suggested as a means of controlling foliar diseases in cereals, but little information is available on how to choose components for use in the variety mixtures (Mille *et al*., 2006). Disease intensity strongly depends on a year (Tratwal, Law, & Philpott, 2007; Nemecek *et al*., 2011) and on the particular component varieties used in the mixture (Nemecek *et al*., 2011).

Variety mixtures: weed suppression ability

Weed suppression ability is another necessary trait for obtaining stable yields with good quality under organic growing conditions as well as other farming systems that aim to limit the use of herbicides (Hoad, Topp, & Davies, 2008). In variety mixtures interaction between plants is related not only to competitiveness

with weeds but also between the crop plants that can reduce the ability to suppress weeds. There are no sufficient investigations made yet about plant traits according to which mixture components should be selected in order to positively interact with each other and also successfully compete with weeds. It was approved that barley mixtures can be more effective in weed suppression than the varieties in pure sowings and the effect depends on the composition of the mixture (Didon & Rodríguez, 2006).

Kaut *et al.* (2008) tested two and three-variety mixtures and concluded that, although variety mixtures varied for grain yield, they did not suppress weeds better than their pure components. Only one from nine two–variety mixtures had low total weed biomass in plots indicating improved competitive ability. Kiær, Skovgaard, & Østergård (2012) and Kaut *et al.* (2008) observed a tendency that mixtures of varieties with varying straw length have an actual advantage in terms of weed suppression. In addition, Kiær, Skovgaard, & Østergård (2012) noticed that mixing effects within the mixtures tended to be smaller, when the level of suppression of tall annual weeds by component varieties was more diverse indicating that the yield advantage of mixing varieties is lower if one component is particularly effective or particularly poor at suppressing these weeds.

In connection with plant traits potentially related to competitive ability, Döring *et al.* (2015) found significantly higher leaf area index, straw height and head density but no difference in early ground cover in multi-variety mixtures compared to the mean of components while testing under two organic and two conventional sites.

Competition has large negative effects on yield under organic management and thus both weed suppression and high yields must be considered when choosing variety mixture components taking into account that unpredictable year dependent environmental variation factors are the main impediment in choosing the right ones. If variety mixtures are to be profitably employed by organic producers, they must be competitive enough to suppress weeds to the same degree as, or preferably more than pure stand (Kaut *et al*., 2008).

The topic about weed suppression ability is relatively new and there are not a lot of research results available on it. Research projects are going on, but results are not yet published (personal communication with weed researcher Mg.Sc. Dace Piliksere).

Populations

Another solution besides mixtures for increasing genetic diversity in varieties of self–pollinating cereals is populations. They include higher levels of diversity if compared to pure lines and mixtures and are able to develop itself in time by adapting to the respective environment (Wolfe *et al*., 2008).

Depending on the number of parents and the way of crossing several population types exist: simple populations obtained by crossing only two parents and more complex populations where a larger number of parents is used. Composite cross populations (CCP's) consist of bulked dialell crosses among the definite group of parents (Brown, Caligari, & Campos, 2014).

The principle of CCP's is to intercross in all combinations a number of varieties with different useful characteristics to generate a population. This is then exposed to natural selection at field sites to allow adaption. The objective is to generate a reservoir of genetic variation that can buffer the crop against a wide range of environmental variations, more than would be possible in pedigree line varieties or in physical mixtures based on single genotypes (Döring *et al*., 2011). There are continuous changes in populations going on and no possibility to obtain and market constant seed material (Brown, Caligari, & Campos, 2014). The diversity of the genotypes in the population changes over the time. Starting with the maximal degree of diversity of population there is a possibility that diversity will decrease over the time, because genotypes poorly suitable to the respective environmental conditions will decrease in frequency. If environmental variation is large, diversity will remain in the population for a longer period of time because selection pressure is less severe on those genotypes performing best away from the environmental mean. Similarly, including genotypes with broader ecological tolerance will keep the diversity of genotypes longer in the population (Döring *et al*., 2011).

Harry Harlan began to make CCP's from many diverse barley varieties originating from around the world in 1920. For example, composite cross II (CC II) was a population developed by Harlan in 1929 using 28 varieties crossed in all possible combinations. These populations were planted and harvested each year under standard agronomic conditions over a period of 50 years. No artificial selection was conducted, but the populations were exposed to multiple environmental stresses. Results from numerous studies on these populations show steady increases in grain yield, disease resistance and yield stability (Hagparast *et al*., 2010).

In 2002, three CCP's were developed by The Organic Research Centre in the UK based on 20 diverse winter wheat parents. All possible crosses of nine high yielding parents and of 12 parents selected for their milling potential were crossed to produce three CCP's: (1) high yield, (2) quality and (3) yield-quality and are extensively researched in a number of studies in different countries (Kassie, 2013; Döring *et al*., 2015).

The effects of natural selection on grain yield of barley CCP's were investigated by Soliman and Allard (1991). They tested several generations of three populations created from a large number of parent varieties (28, 30 and more) including the previously mentioned CC II. This population was compared to six commercial varieties and showed a marked yield increase over generations, perhaps as a result of increased adaptation. The average yield over six years of the most productive population was only 85% in comparison to the best yielding commercial variety, but CCP's were in general more stable than commercial varieties. So these authors suggest if disease resistance and yield stability are two main objectives of a particular breeding program, the CCP approach is an efficient breeding method. On the other hand, if yield potential is a major goal, the CCP approach, as demonstrated by this study, is unwarranted; however, the year of creation had to be taken into account. They recommend that individual pure lines derived from the later CCP generations would be evaluated as potential breeding material and developed to varieties for low-yielding environments.

Danquah and Barrett (2002) also investigated several generations of the CCP mentioned above and developed from 30 parents. The study revealed that, on average, the control variety out-yielded the composite cross generations over the two year period in Cambridge environment. The highest yielding composite cross generation over the period of the experiment yielded only 78% of the control variety. It is interesting to note that in one season three out of nine composite cross generations performed better than control. There was a long period of drought, which probably has affected the control variety more than the composite cross populations. Kassie (2013) based on the study in a single location during four growing seasons reports that more recently created winter wheat CCP's crated of nine, twelve and twenty parents showed similar yield potential as the pure line standard variety and no significant differences were observed between the generations of CCP's in the grain yield potential and yield components. Furthermore, the standard variety had better ground shading ability (Kassie, 2013), which is one of the important traits of varieties for weed suppression (Hoad *et al*., 2008), than the CCP's. Decrease in ground shading capacity of the CCP's over the four generations was observed. Based on these results one cannot state that the CCP's are the best varieties for the organic growing conditions (Kassie, 2013). On the other hand, Döring *et al*. (2015) found a significantly higher average early ground cover, leaf area index and straw height in CCP's of the same origin in comparison to the mean of the parental varieties.

Within populations a major force is competition between different genotypes. These competition effects may limit what populations can achieve (Döring *et al*., 2011). Kassie (2013) reported that CCP's compared to pure line variety had lower number of spikelets per spike and lower spike compactness which likely influenced yield.

Soliman and Allard (1991) concluded that the CCP's offer an opportunity to produce varieties that do not show a large genotype – environment interaction for yield because of the genetic diversity in the populations, but when they become more homogeneous, their stability is decreased. Yield advantage by 2.4% on average over 12 environments and higher yield stability for CCP's in comparison to parental mean was shown (Döring *et al*., 2015).

Genotypically diverse populations are also known to better resist diseases, because they contain a greater range of genotypes having reduced susceptibility to pathogens; therefore, diseases will not spread that easily through the populations (Mundt, 2002). Muona, Allard, & Webster (1982) analyzed genetically changes in resistance to scald disease, caused by *Rhynchosporium secalis*, which occurred in barley CC II over 45 generations. They reported that recombination which has occurred in population has given an increase to numerous novel multiresistant genotypes. Maroof, Webster, & Allard (1983) tested the same CC II for reaction to three barley pathogens, *Blumeria graminis, Pyrenophora teres* and *Rhynchosporium secalis.* They concluded that many families carrying combinations of multiple resistances not observed among the parents were found in the later generations. On the other hand, Döring *et al*. (2015) did not find a significant advantage for winter wheat CCP's for foliar disease infection with *Septoria* compared to the mean of parents scored during one season in four sites.

The key for the success of populations concerns the number and choice of parental genotypes for the establishment of CCP. There are two extremes – on the one hand, one could use only two different parent varieties, on the other – as many parents as physically possible to cross with each other (Döring *et al*., 2011). Strazdiņa *et al.* (2012) investigated barley populations originated from simple crosses and wheat populations from crosses between two or three parental varieties and concluded that yield of barley populations was in between the levels of parents and insignificant yield gain was obtained only in some cases and mostly under organic growing conditions. Some wheat populations showed a tendency to higher yield under conventional conditions; however, under organic conditions the yield of populations was between or less the range of parents. The authors explain these not very promising results by relatively low diversity of the investigated

populations than that of CCP's researched in other studies.

Some studies have been carried out to measure the necessity minimum number of parents to establish populations. Kovács (2008, cited from Döring *et al*., 2011) reported about experience with bread wheat using different number of parents and suggest that the necessary minimum for the establishment of a successful population is around seven parents, and the optimum is around 12 parents. Döring *et al*. (2015) suggest that establishing CCP's from smaller sets of high-performing parent lines might optimize their yielding ability.

The seeds of CCP's cannot be marketed under the existing legal framework, and registration of such varieties is not possible due to non-compliance to the requirements of distinctness, uniformity and stability (DUS). However, a temporary experiment is being currently carried out in the EU allowing experimental marketing of wheat, barley, oat and maize CCP's created by crossing of five or more varieties in all possible combinations (Official Journal of the European Union. Directive 66/402/EEC).

Conclusions

1. Mixtures can easily reconstitute and they have an advantage of being legal under current legislation, whereas the trading of non-uniform crop populations is presently possible only due to the temporary experiment providing for certain derogations for the marketing of populations.
2. Most of the studies show that mixtures have advantages in terms of leaf disease control and yield stabilization in comparison to the average of components. In respect to grain yield, it might be essential to assess the combinative ability of the components.
3. While creating mixtures, it is possible to generate much larger quantities of seed early on, whereas crop populations will need a phase of seed multiplication before they can be used on a farm. However, populations have the advantage of a much larger pool of genetic diversity.
4. Advantage of populations can be the ability to adapt to specific growing environments and thus to be unique for each farm. Populations are more likely to be superior in extreme environments like drought or low nutrient availability.
5. This research direction is not sufficiently covered in the world and reports on the results are inconsistent. Further studies about the possibilities to increase sustainability and competitive ability of the varieties by increasing the genetic diversity are needed. It is essential to understand what plant traits are most important in the mixtures, and additional research in this direction is required.

References

1. Brown, J., Caligari, P., & Campos, H. (2014). Plant Breeding (2nd ed.) (p. 209). United Kingdom: Wiley Blacwell.
2. Chakraborty, S., & Newton, A.C. (2011). Climate change, plant diseases and food security: An overview. *Plant Pathology*, 60(1), 2-14. DOI: 10.1111/j.1365-3059.2010.02411.x.
3. Cowger, C., & Weisz, R. (2008). Winter wheat blends (mixtures) produce a yield advantage in North Carolina. *Agronomy Journal*, 100(1), 169-177. DOI: 10.2134/agronj2007.0128.
4. Danquah, E.Y., & Barrett, J.A. (2002). Grain yield in Composite Cross Five of barley: effects of natural selection. *Journal of Agricultural Science*, 138(Ccv), 171-176. DOI: 10.1017/s0021859601001678.
5. Didon, U., & Rodríguez, E.E. (2006). Designed mixtures of barley cultivars-influence on weeds. In Implications for production and products, 13-14 June 2006 (pp. 42-43). La Besse, France.
6. Döring, T.F., Knapp, S., Kovacs, G., Murphy, K., & Wolfe, M.S. (2011). Evolutionary plant breeding in cereals-into a new era. *Sustainability*, 3(10), 1944-1971. DOI: 10.3390/su3101944.
7. Döring, T.F., Annicchiarico, P., Clarke, S., Haigh, Z., Jones, H. E., Pearce, H., … Wolfe, M.S. (2015). Comparative analysis of performance and stability among composite cross populations, variety mixtures and pure lines of winter wheat in organic and conventional cropping systems. *Field Crops Research*, 183, 235-245. DOI: 10.1016/j.fcr.2015.08.009.
8. European Commission. (2013). Agricultural Genetic Resources – from conservation to sustainable use. (SWD(2013)486final). Retrieved March 9, 2016, from http://ec.europa.eu/agriculture/genetic-resources/pdf/com-2013-838_en.pdf.
9. Essah, S.Y.C., & Stoskopf, N.C. (2002). Mixture performance of phenotypically contrasting barley cultivars. *Canadian Journal of Plant Science*, 82, 1-6. DOI: 10.4141/P01-043.
10. Fang, Y., Xu, B., Liu, L., Gu, Y., Liu, Q., Turner, N.C., & Li, F.M. (2014). Does a mixture of old and modern winter wheat cultivars increase yield and water use efficiency in water-limited environments? *Field Crops Research*, 156, 12-21. DOI: 10.1016/j.fcr.2013.10.013.
11. Haghparast, R., Rahmanian, M., Roeentan, R., Ghffari, A., Tahkeri, A., Rahman, R., ... Cecarelli, S. (2010). Reviving beneficial genetic diversity in drylans agriculture – a key issue to miligate climete change

negative impacts. In Food security and climate change in dry areas, 1 – 4 Februaru 2014 (pp. 204-208). Amman, Jordan: International Center for Agricultural Research in the Dry Areas.
12. Hoad, S., Topp, C., & Davies, K. (2008). Selection of cereals for weed suppression in organic agriculture: A method based on cultivar sensitivity to weed growth. *Euphytica,* 163(3), 355-366. DOI: 10.1007/s10681-008-9710-9.
13. Juskiw, P.E., Helm, J.H., & Burnett, P.A. (2001). Three-component barley mixtures: Ratio effects in replacement series. *Canadian Journal of Plant Science*, 81(4), 651-656. DOI: 651-656, 10.4141/P00-145.
14. Kassie, M.M. (2013). Comparison of several generations of winter wheat composite cross populations with modern cultivar under organic farming. Doctoral dissertation, Wageningen University, Wageningen, The Netherlands.
15. Kaut, A.H.E.E., Mason, H.E., Navabi, A., O'Donovan, J.T., & Spaner, D. (2008). Performance and stability of performance of spring wheat variety mixtures in organic and conventional management systems in western Canada. *Journal of Agricultural Science,* 147(2), 141-143. DOI: 10.1017/S0021859608008319.
16. Kiær, L.P., Skovgaard, I.M., & Østergård, H. (2012). Effects of inter-varietal diversity, biotic stresses and environmental productivity on grain yield of spring barley variety mixtures. *Euphytica*, *185*(1), 123-138. DOI: 10.1007/s10681-012-0640-1.
17. Lopez, C.G., & Mundt, C.C. (2000). Using mixing ability analysis from two-way cultivar mixtures to predict the performance of cultivars in complex mixtures. *Field Crop Research*, 68(2), 121-132. DOI: 10.1016/S0378-4290(00)00114-3.
18. Maroof, M.A.S., Webster, R.K., & Allard, R.W. (1983). Evolution of resistance to scald, powdery mildew, and neck blotch in barley composite cross II populations. *Theoretical and Applied Genetics,* DOI: 10.1007/BF00251159.
19. Mille, B., Belhaj Fraj, M., Monod, H., & De Vallavieille–Pope, C. (2006). Assessing four-way mixtures of winter wheat cultivars from the performances of their two-way and individual components. *European Journal of Plant Pathology*, 114(2), 163-173. DOI: 10.1007/s10658-005-4036-0.
20. Muchova, D., & Fazekašova, D. (2010). The contribution of variety mixture utilizatilon for enhancing the resilience of agro-ecosystems. *Journal Article,* 59, 509-512.
21. Mundt, C.C., Hayes, P.M., & Schön C.C. (1994). Influence of barley variety mixtures on severity of scald and net blotch and on yield. *Plant Pathology,* 43, 356-361.
22. Mundt, C.C. (2002). Use of multiline cultivars and cultivar mixtures for disease management. *Annual Review of Phytopathology,* 40, 381-410. DOI: 10.1146/annurev.phyto.40.011402.113723.
23. Muona, O., Allard, R.W., & Webster, R.K. (1982). Evolution of resistance to Rhynchosporium secalis (Oud.) Davis in barley composite cross II. *Theoretical and Applied Genetics*, 61(3), 209-214. DOI: 10.1007/BF00273776.
24. Nemecek, T., Dubois, D., Huguenim–Elie, O., & Gaillard, G. (2011). Life cycle assessment of Swiss farming systems: I. Integrated and organic farming. *Agricultural Systems,* 104(3) 217-232. DOI: 10.1016/j.agsy.2010.10.002.
25. Newton, A.C., & Guy, D.C. (2009). The effects of uneven, patchy cultivar mixtures on control and yield in winter barley. *Field Crops Research*, 110(3), 225-228. DOI: 10.1016/j.fcr.2008.09.002.
26. Newton, A.C., & Guy, D.C. (2011). Scale and spatial structure effects on the outcome of barley cultivar mixture trials for disease control. *Field Crops Research*, 123(2), 74-79. DOI: 10.1016/j.fcr.2011.05.002.
27. Newton, A.C., Guy, D.C., Bengough, A.G., Gordon, D.C., McKenzie, B.M., Sun, B., … Hallett, P.D. (2012). Soil tillage effects on the efficacy of cultivars and their mixtures in winter barley. *Field Crops Research,* 128, 91-100. DOI: 10.1016/j.fcr.2011.12.004.
28. Official Journal of the European Union. (2014). Council Directive 66/402/EEC. Retrieved February 28, 2016, from http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014D0150&from=LV.
29. Østergård, H., Finckh, M.R., Fontaine, L., Goldringer, I., Hoad, S.P., Kristensen, K., … Wolfe, M.S. (2009). Time for a shift in crop production: Embracing complexity through diversity at all levels. *Journal of the Science of Food and Agriculture*, 89(9), 1439-1445. DOI: 10.1002/jsfa.3615.
30. Pswarayi, A., Eeuwijk, F.A., Ceccarellis, S., Grando, S., Comadran, J., Russel, J.R., ... Romgosa, I. (2008). Barley adaptation and improvement in the Mediterranean basin. *Plant Breeding*, 127(6) 554-560. DOI: 10.1111/j.1439-0523.2008.01522.x.
31. Soliman, K.M., & Allard, R.W. (1991). Grain yield of composite cross populations of barley: Effects of natural selection. *Crop Science,* 31(3), 705-708. DOI: 10.2135/cropsci1991.0011183X003100030032x.

32. Strazdiņa,V., Beinaroviča, I., Legzdiņa, L., & Kronberga, A. (2012). Are there any advantages of genetically diverse material in cereal breeding programmes for organic farming? *Proceedings of The Latvian Academy of Science,* 66(4/5), 152-162. DOI: 10.2478/v10046–012–0003–2.
33. Tooker, J.F., & Frank, S.D. (2012). Genotypically diverse cultivar mixtures for insect pest management and increased crop yields. *Journal of Applied Ecology*, 49(5), 974-985. DOI: 10.1111/j.1365-2664.2012.02173.
34. Tratwal, A., Law, J., & Philpott, H. (2007). The Possibilities of Reduction of Winter Barley Chemical Protection By Growing Variety Mixtures. Part I. Effect on Powdery. *Journal of Plant Protection Research,* 47(1), 65-77.
35. Tratwal, A., Law J., Philpott, H., Horwell, A., & Garner, J. (2007). The possibilities of reduction of winter barley chemical protection by growing variety mixtures. Part II. Effect on yield. *Journal of Plant Protection Research,* 47(1), 79-86.
36. Wolfe, M.S., Baresel, J.P., Desclaux, D., Goldringer, I., Hoad, S., Kovacs, G., … Lammerts Van Bueren, E.T. (2008). Developments in breeding cereals for organic agriculture. *Euphytica*, *163*(3), 323-346. DOI: 10.1007/s10681-008-9690-9.
37. Zhou, K.Q., Wang, G.D., Li, Y.H., Liu, X.B., Herbert, S.J., & Hashemi, M. (2014). Assessing variety mixture of continuous spring wheat (*Triticum aestivum* L.) on grain yield and flour quality in Northeast China. *International Journal of Plant Production,* 8(1), 91-105.

ESTIMATION OF YIELD STABILITY FOR FLAX GENETIC RESOURCE USING REGRESSION AND CLUSTER ANALYSIS

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Abstract
Flax (*Linum usitatissimum* L.) fibre and seeds are widely used to produce healthy and environmentally friendly products. It is known that the main factors that influence flax fibre' and seeds' yield are genotype and growing conditions. The main task of the Latvian flax breeding program is to develop flax genotypes that are highly productive (both fibre and seeds) and well adaptable to changing environmental conditions. Goal of this study is to identify high yielding genotypes with good adaptation to local variable agro-ecological conditions. The agronomically important traits, such as yield of stem and seeds, total and technical plant height and fibre content were evaluated for 13 Latvian origin flax lines and standard variety 'Vega 2'. The field trials have been carried out over the period from 2012 to 2015 at the Agricultural Scientific Centre of Latgale. The regression, correlation, coefficient of variation and cluster analysis between yield and yield provided components were used for identification of high yielding genotypes with good adaptation. On the basis of cluster analysis the genotypes were classified in two groups by lower and higher yield of stem, fibre content, total plant height and technical plant height. The line 'I18-1' was identifying as genotype with the highest average yield of stem (751.25 g m^{-2}) as well as highest yield against other genotypes in moisture and drought years. Most valuable by the average technical plant height was line 'L26-1' (73.05 cm).
Key words: flax, genetic resource, adaptation.

Introduction

Flax (*Linum usitatissimum* L.) is an important industrial crop with ancient farming history, but only in the last century breeding for fibre use (fibre flax) or seed use (linseed flax) has resulted in two plant types which differ considerably in morphology, anatomy, physiology and agronomic performance (Diederichsen & Ulrich, 2009). Compared to oilseed cultivars, fibre flax is typically taller, with less branching and lower seed production (Booth *et al*., 2004). The flax fibre is soft and flexible, and it is stronger than cotton or wool fibre. The flax fibre is used for manufacture of textiles, raw flax fibre is also used to make high quality paper and components for the motor industry (Berger, 1969; Bakry *et al*., 2014). Production of flax fibres left over huge number of by-products such as the cuticle, shiver and fibre fragments that currently increase interest in production microcrystalline cellulose from plants and their potential as value-added products ranging from biocomposites for medical devices to solidified liquid crystals (Akin, 2013).

Flax is highly self-pollinating, with outcrossing rates from 0.3 to 2% under normal circumstances (Booker *et al*., 2014). Taking into account the facultative cross-pollination, the development of genetically stable lines could take more than 15 years (Rashal & Stramkale, 1998). Major breeding objectives of Latvia's flax breeding are to create early or mid-early ripening varieties of flax with the improved yield (seed or fibre) and oil content, high fibre quality, resistance to lodging diseases (Grauda, Stramkale, & Rashal, 2004). Flax requires abundant moisture and cool weather during the growing season (Berger, 1969; Bakry *et al*., 2014). The cultivation techniques, weather and soil conditions as well as the flax stem processing (scratching, hackling) have a great impact on fibre quality (Grashchenko, 1963; Karpunin, 1995; Polonetskaya, Panifedova, & Sakovich, 2001; Wretfors, 2005). Harvesting of flax on the early stage of yellow ripeness allows to obtain fibres of higher quality. Flax early sowing significantly increases fibre bundles and the number of elements of fibre in the bundles. Technical plant height is characterized by the most valuable part of stem from which the long fibre is obtained (Ivanovs & Stramkale, 2001).

The ability to develop high yielding stable cultivars is a primary focus in most breeding programs and is ultimately more important than the identification of unstable cultivars. Understanding of the environmental responses of flax lines is fundamental to improving efficiency of flax production. Cluster analysis is widely used in agriculture to data processing for different crops as rapeseeds (Rameeh, 2015), barley (Fotakian *et al*., 2014), as well as flax (Bakry *et al*., 2014). Cluster analysis divides data into clusters. That is important to the strategy of classifying variability on a large number of varieties, or to reveal the genetic diversity among varieties and their response to the environmental conditions. In this way, cluster analysis is a suitable solution to group and select desirable genotypes. The correlation, regression analysis and coefficient of variation were used to determine yield stability and ecological plasticity in changeable environmental conditions (Mustăţea *et al*., 2009;

Kazmi & Rasul, 2012). Objectives of this study are evolution and investigation of Latvian fibre flax genetic resources' diversity and identification of high yielding genotypes suitable for cultivation in local variable agro-ecological conditions.

Materials and Methods

Field experiments

The field trials were conducted over the period from 2012 to 2015 at the Agricultural Scientific Centre of Latgale. Experimental material for present study consisted of 13 fiber flax lines as well standard variety 'Vega 2' was used. Plants were grown in random block plots 2 m^2 with a distance between rows 10 cm, 1700 flax seeds per 1 m^2 were sown by hand with sowing depth 1.5-2 cm in three replications. Prior to that sowing seeds' germination tests were performed for all used genotypes. Experimental plots were separated by one meter wide buffer zones. Seeds were sown between 1st and 2nd decades of May.

Flax was grown in humi-podzolic gley soil. The main agrochemical parameters of the arable soil layer were following: humus content – 6.5%, pH_{KCl} – 6.4-7.0, available P_2O_5 – 130-145 mg kg^{-1} and available K_2O – 118-124 mg kg^{-1} soil (by results of State Plant Protection Service). Complex fertilizer NPK 16:16:16 - 300 kg ha^{-1} was applied after first soil cultivation. For plants' further development a surface fertilizer – ammonium nitrate 30 kg N ha^{-1} in "fir tree" phase was applied. Herbicides ('Glins' 10 g ha^{-1} and 'Kemivets' 200 ml ha^{-1}) were used to control weeds and insecticides ('Fastac 50' 0.4 l ha^{-1}) sprayed against flax flea beetles as it is required by instruction. Tractor-drawn sprayer 'Pilmet 412' was used.

Evaluated flax varieties and lines

'S29-1', 'S29-2', 'S37-1', 'S37-2', 'T36-1', 'T36-2', 'T36-3', 'K9-1', 'K9-2', 'L26-1', 'I7-1', 'I7-2', 'I18-1' (Agricultural Scientific Centre of Latgale origin lines) and 'Vega 2'(ST) (Lithuania origin variety). Agriculturally important traits were determined such as flax total plant height, technical plant height, fibre contents, yield of stems and seeds. The genotypes were determined in phenological stages in each plot. The total and technical plant heights, fibre content were determined using randomly selected most typical 20 plants in each parcel area before the harvest. Plants were pulled manually at the stage of early yellow ripeness and then left on ground for air-drying for 5-8 days. The seedpods were removed by 'Eddi' device. Seeds were cleaned with 'MLN' sample cleaner. The yield of seed was weighed and then re-calculated to weight by 100% purity and 12% humidity. The yields of stem and seed were determined in each harvested parcel area (according by Cabinet Regulation No. 518/ 2012 Regulations for the Assessment of Value for Cultivation and Use of Plant Variety).

Meteorological conditions

Agro-meteorological conditions were determined by using ADCON – installed meteorological stations that were connected to the computer program Dacom Plant Plus. The facility provided information in direct nearby field trials. The amount of precipitation in 2013 growing period was by 22% lower and in 2015 by 6% lower in comparison to the long-term average of 311 mm (by 1. Fig.). However, precipitation in 2012 was by 50% and in 2014 by 14% higher than the long-term average. According to the air temperature,

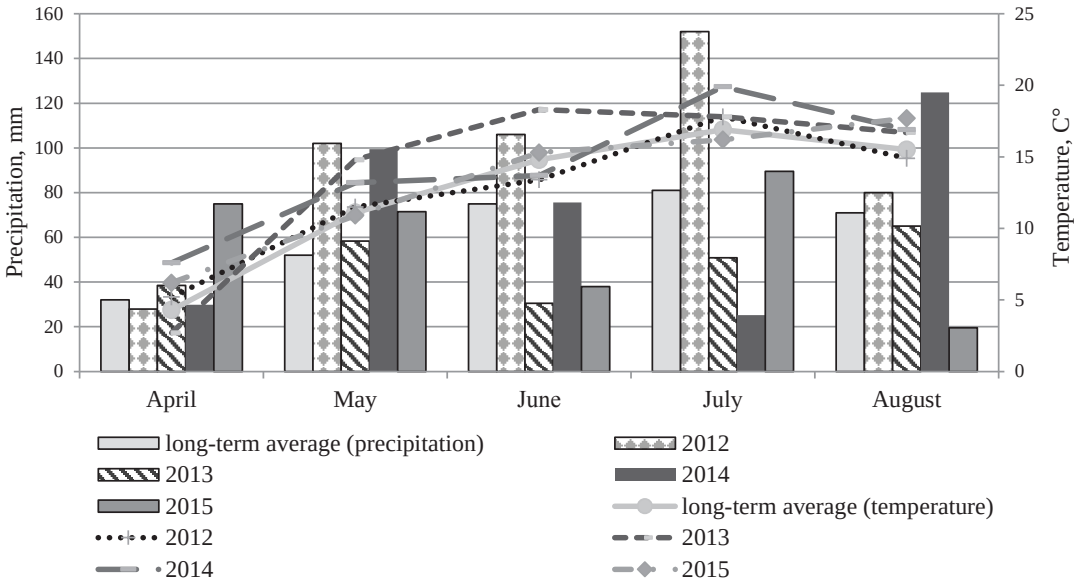

Figure 1. 2012 – 2015 sum of precipitation (mm) and average of air temperature (°C) value in vegetation period of flax.

four growing periods were warmer, than generally in long-term average. In 2012 average air temperature was 12.56 °C in 2013, it was 14.06 °C, in 2014 and 2015 it was 14.26 °C and 13.26 °C respectively, while the long-term average result is 12.52 °C.

Data analysis

MS-Excel and SPSS software were used for data statistical analysis (Arhipova & Bāliņa, 2006). Data analysis tools provide descriptive statistics, coefficient of variation (CV), regression, correlation and cluster analysis. Correlation analysis finds out significant or insignificant relationships between precipitation and yield of stem and seeds for each genotype. Regression analysis finds out significant or insignificant relationships between total plant height and sum of precipitation using linear regression for each flax variety and lines by MS-Excel software. Coefficient of variation of yield of stem was displayed against average yield of stem identifying yield stability of genotypes. Cluster analysis was used to construct a distance matrix using the Euclidian coefficient and based on the Ward method. Cluster analyses included flax yield of stem, fibre contents, total plant height and technical plant height. Before computing the distance between varieties, our data were standardized as recommended by Ward (1963).

Results and Discussion

According to the data, the amount of precipitation during the growing season plays a major role in flax yield of stem (Fig. 2.).

The largest yield of stem increase was observed in 2012. Evaluating the period in 2012 from germination until full flowering of flax, it was characterized by high moisture content (102 – 152 mm) from May to July that favorably increased flax stem growth. The drought in April 2012 did not have a significant negative impact on the germination and plant development. In 2014, the lowest stem yield increase was obtained.

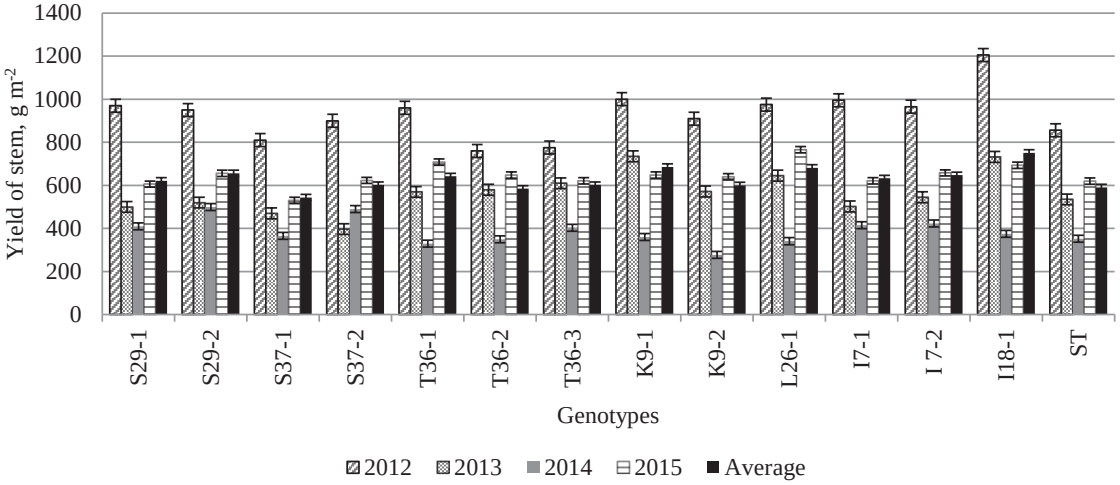

Figure 2. 2012 – 2015 yield of stem (g m^{-2}) of lines and variety of flax.

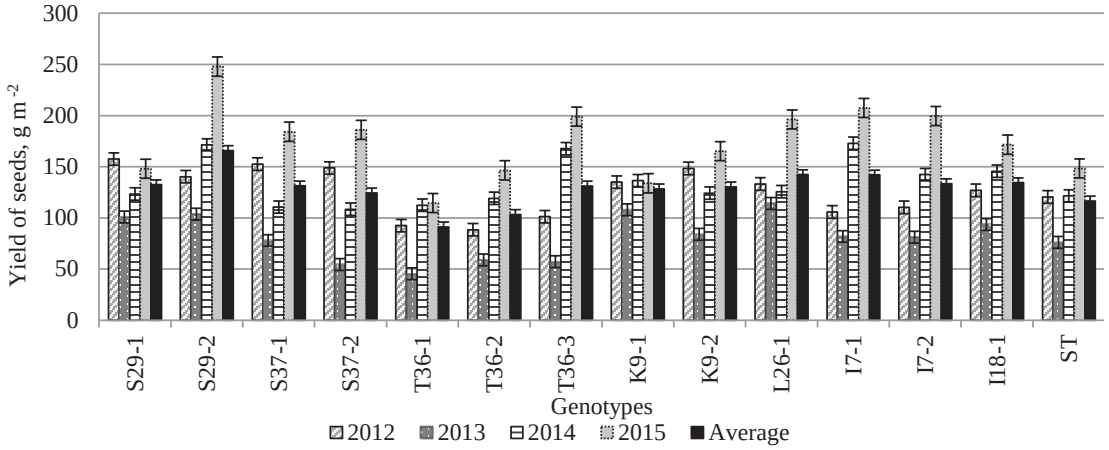

Figure 3. 2012 – 2015 yield of seeds (g m^{-2}) of lines and variety of flax.

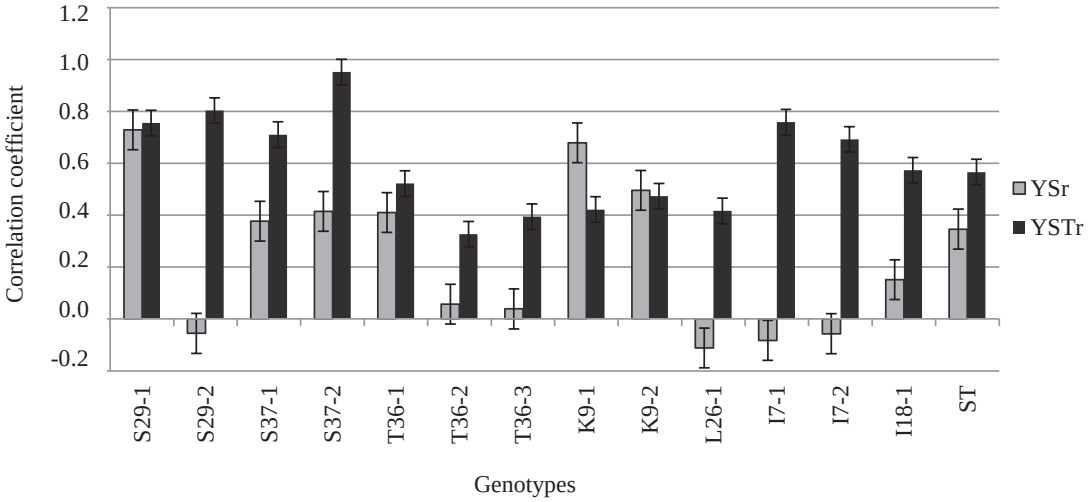

Figure 4. Correlation between yield of stem and sum of precipitation as well as between yield of seed and sum of precipitation for variety and lines of flax. (YS – yield of seeds; YST – yield of stem; r – correlation coefficient).

This year was characterized with a rapid drop of moisture from June to July (72.60 – 25.20 mm) and a rapid increase of moisture in August (124.80 mm) that created significant stress conditions for plants and stem development.

In the 1st and 2nd decade of May, a high (91% from long- term average) precipitation increase was observed and then a rapid drop in moisture (until 0 mm) that significantly affected plant emergence and development of flax stem occurred. In 2014, the line 'S29-2' (500 g m^{-2}) had the highest yield that was by 42% larger than the standard variety. According to the data, flax yield of stem could be majorly impacted by the amount of precipitation during the growing season and higher yield of stem results from lines of flax can be obtained in moist and cool weather. Berger (1969); Mankowski, Pudełko, & Kołodziej, (2013); Bakry *et al.,* (2014) also reported about similar results. Furthermore, by Nykter (2006) in order to obtain the best flax yield (fibre and seeds) the weather conditions should be stable from germination to the end of flowering. According to Bavec & Bavec, (2006), fibre flax belongs to hygrophytic plants with high transpiration coefficients between 400 and 780 as well as drought has a negative influence on plants from emergence to the flowering stage. In our case, genotypes had presented similar effect. Although results characterized the 2013 as the driest year, the two lines 'I18-1' and 'K9-1' exhibited higher yield of stem compared to 2014 and 2015 that had higher moisture content in vegetation period. These lines have the highest yield compared to other genotypes in moist as well as drought years. The higher average yield of stem has the line 'I18-1' (751.25 g m^{-2}) which is by 27% larger than the standard variety 'Vega 2'.

Comparing the data to a yield of stem, significantly higher yield of seeds was obtained in 2015 (by Fig. 3.). The year is characterized by high moisture content in May (about 38% higher than the long-time average) that has a positive impact on the smooth and good seed germination and plant development. In 2015, higher yield of seed has the line 'S29-2' (247.9 g m^{-2}) which is by 67% larger than the standard variety 'Vega 2'. Furthermore, the 2013 has the lowest yield of seed, which is characterized as the driest midst of the four investigational years. During this year, a significant negative impact on seed germination had drought in the 1st decade (0mm) of May. In 2013, higher yield of seed had the line 'L26-1' (114.2 g m^{-2}) which was by 50% larger than the standard variety 'Vega 2'. Comparing all years the most productive by average yield of seed was the flax line of 'S29-2' (165.85 g m^{-2}) which was by 42% larger than the standard variety 'Vega 2'.

Correlations are displayed between each flax variety and lines yield of seeds as well as stem and precipitations in Fig. 4. Positive relationships were found between the yield of stem and precipitation for all lines. In the analysis, significant positive relationships between the yield of stem and sum of precipitation of line 'S37-2', where r = 0.95 by significance of $p \leq 0.05$were identified were identified. The effects are related to the sum of precipitation level. Considering the relationships between the yield of seed and sum of precipitation - they are comparatively less sought by high moisture quantity, and presented analysis had a positive but no significant effect. Higher positive correlation for the yield of seeds has the line 'S29-1' (r = 0.73). Taking into account the productivity of yield rates and plasticity characteristics, the most

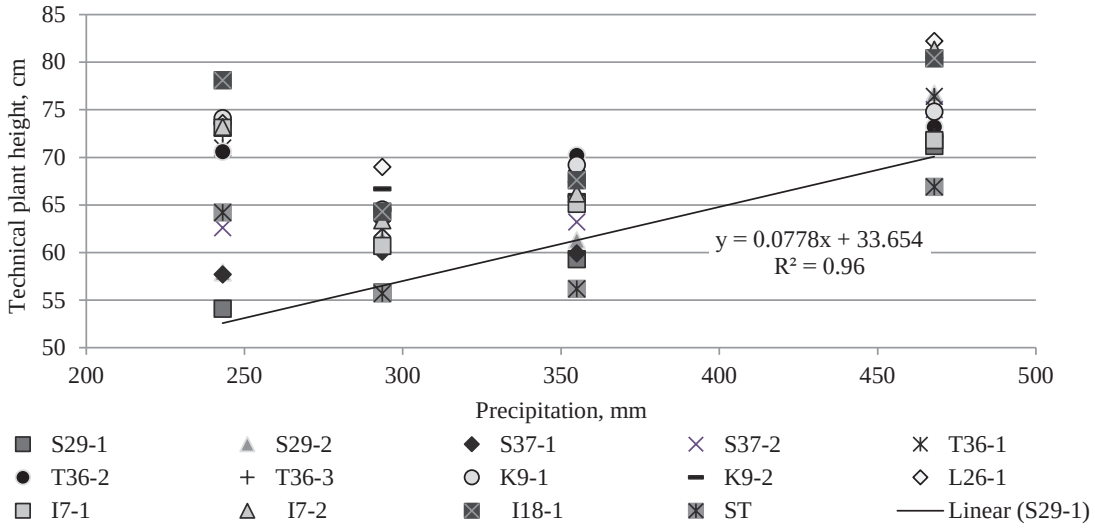

Figure 5. Relationships between technical plant height (cm) and sum of precipitation in four vegetation periods for each flax lines and variety. (2012 – 467.9 mm, 2013 – 243.1 mm, 2014 – 354.9 mm, 2015 – 293.5 mm).

valuable lines for fiber flax breeding were lines 'I18-1' and 'K9-1'. The line 'S29-2' that is more resistant to rapid changes precipitations during the growing season by the yield of stem and higher productivity of yield of seeds has good potential.

Results showed the regression line with positive relationship between the technical plant height and sum of precipitation during the growing season for all lines and variety (presented in Figure 5.). The results indicated that the technical plant of height increases against precipitation level. Results are confirmed by the results of Polonetskaya, Panifedova, & Sakovich, (2001). In case, statistical significant positive correlation has one line 'S29-1' $R^2 = 0.96$ and with $r = 0.98$ by significance of $p \leq 0.05$.

Evaluating the averages the highest technical plant height has the line 'L26-1' (73.05 cm) by 20% higher than the standard variety 'Vega 2'. Grauda, Stramkale, & Rashal (2004) proved that the most important trait for the fibre flax breeding is the technical plant height. This study presented similar results that the genotype with higher average yield of stem as the line 'I18-1' does not provide the highest technical plant length as the line 'L26-1'. In addition, the genotypes displayed different correlation in relation to sum of precipitation and statistical significance level presented for the yield of stem ('S37-2') as well as the technical plant height ('S29-1'). Result presents that yield formation was significantly influenced by the sum of precipitation and genotype.

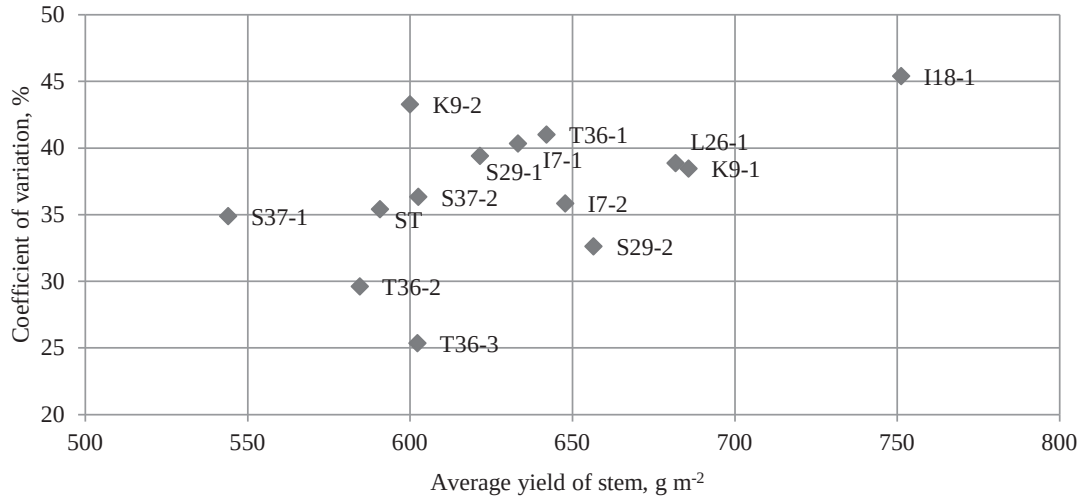

Figure 6. Coefficient of variation against average yield of stem for lines and variety of flax.

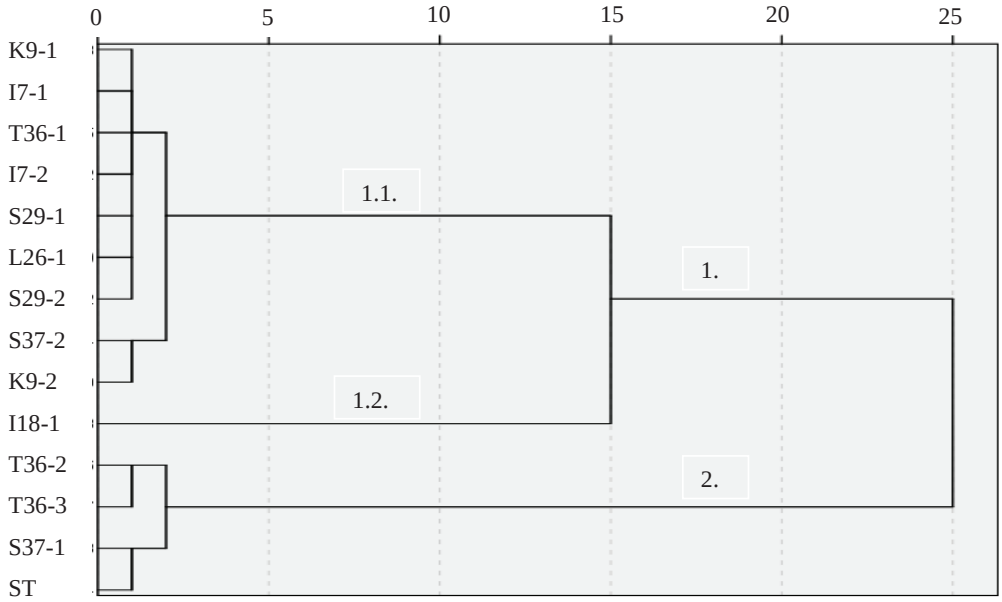

Figure 7. Dendrogram for 14 flax genotypes. (1 and 2 main group; 1.1 and 1.2 sub-group).

High yield stability usually refers to a genotype ability to perform consistently, whether at high or low yield levels by weather changes. In this case characterizing yield stability in a breeding program, an important criterion is heritability. According to Ortiz *et al*., (2001) coefficient of variation (CV) had the highest narrow-sense heritability (h^2 = 0.522) and analyzing grain yield results suggested that it may be possible to select simultaneously for high and stable yield by selecting out yielders that exhibit low CV. In our study coefficients of variation were not significantly correlated with average yields (by Fig. 6.). Some genotypes showed better stability than others. According to results, the higher yield of stem and higher CV has the line 'I18-1'from all genotypes. However, better potential has the lines 'L26-1', 'K9-1' or 'S29-1' that show high average yield of stem and more stable yield level to changing environmental conditions.

The cluster analysis of 14 genotypes was based on yield of stem and yield component (by Fig. 7.). According to the results, the genotypes were diverged in two main groups. The first main group was divided in two sub-groups. First sub-group of yield of stem and yield component in comparison to second main sub-group is more productive and contains 9 lines of flax ('K9-1', 'I7-1', '36-1', 'I7-2', 'S29-1', 'L26-1', 'S29-2', 'S37-2'and 'K9-2') . Second sub-group contains an independent line 'I18-1' that is characterized by the highest yield of stem and total plant height that is potentially different from other line after yield components and with largest distances 15. Dendrogram results indicated first main group with good potential for breeding program; consequently, it is a suitable group for producing fibre. Bakry *et al*., (2014) also found similar results: agronomic data of 49 flax varieties were evaluated, using cluster analysis that revealed the existence of variations among varieties. Therefore, cluster analysis is a suitable solution to group and select desirable genotypes for well-grounded selection as well for classifying the high yield genotypes with high component characters.

Conclusions

Overall, the higher yield of stem for all evaluated flax genotypes was obtained in the moisture and cool environmental conditions and suggesting that water stress was a major factor that influenced yield variation. Results showed that high-yielding cultivars can differ in yield stability, and suggested that yield stability and high yield of stem are not mutually exclusive. According to the results, it could be put forward flax line 'I18-1' (yield of stem 751.25 g m^{-2}) where higher yield of stem was obtained, but it was associated with low stability and specifically adapted to favorable environmental conditions. However, the line 'S29-2' (yield of stem 656.5 g m^{-2}) that showed higher yield productivity and resistance to stress factors (as rapid precipitation change) has higher stability. Most valuable by the average technical plant height was the line 'L26-1' (73.05 cm). Determination of correlation, regression, coefficient of variation and cluster analysis has provided effective selection criteria for creating new ecological plastic fiber flax varieties.

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References

1. Akin, D.E. (2013). Linen most useful: perspectives on structure, chemistry, and enzymes for retting flax. *Hindawi Publishing Corporation ISRN Biotechnology*, pp. 23.
2. Arhipova, I., & Bāliņa, S. (2006). *Statistika ekonomikā. Risinājumi ar SPSS un Microsoft Excel. (Statistics in the economy. The solutions with SPSS and Microsoft Excel.)* 2. iss. Rīga: Datorzinību Centrs, pp. 364. (in Latvian).
3. Bakry, A.B., Omar, M.I., Tarek, A.E.E., & Mohamed, F.E. (2014). Performance assessment of some flax (*Linum usitatissimum* L.) varieties using cluster analysis under sandy soil conditions. *Agricultural Sciences*, 5, 677-686.
4. Bavec, F., & Bavec, M. (2006). *Organic production and use of alternative crops*. CRC Press, Taylor& Francis Group, pp. 181-183.
5. Berger, J. (1969). In the world's major fiber crops their cultivation and manuring. *Part 1, Flax*, 209-213.
6. Booker, H., Bueckert, R., Duguid, S., Gavloski, J., Gulden, R., Dueck, R., … Ulrich, A. (2014). *Growing Flax Guide*. Retrieved March 8, 2016, from http://flaxcouncil.ca/growing-flax/growth-and-development/.
7. Booth, I., Harwood, R.J., Wyatt, J.L., & Grishanov, S. (2004). A comparative study of the characteristics of fibre-flax (*Linum usitatissimum* L.). *Ind. Crops Prod.* 20: 89-95. CrossRef.
8. Cabinet Regulation (LV) No. 518 Adopted 24 July 2012. 'Regulations for the Assessment of Value for Cultivation and Use of Plant Variety.' Latvijas vēstnesis. Nr. 120 (4723) Retrieved March 3, 2016, from https://www.vestnesis.lv/op/2012/120.3.
9. Diederichsen, A., & Ulrich, A. (2009). Variability in stem fibre content and its association with other characteristics in 1177 flax *(Linum usitatissimum* L.*)* genebank accessions. *Ind. Crops Prod*, 30, 33-39.
10. Fotokian, M.H., Agahi, K., Ahmadi, J., & Vaezi, B. (2014). Selection of barley advanced lines at rainfed conditions using regression and cluster analyses. *International Journal of Biosciences.* Vol. 4, No. 6, pp. 80-88. ISSN: 2220-6655.
11. Grashchenko, M.G. (1963). On flax fibre flexibility. Bulletin of applied botany, genetics and plant. Moscow Leningrad: Selkhozizdat 35 (3): pp. 99-105.
12. Grauda, D., Stramkale, V., & Rashal, I. (2004). Evaluation of Latvian flax varieties and hybrids. *Proceedings in Agronomy*, No. 6, pp. 159-165.
13. Ivanovs, S., & Stramkale, V. (2001). Linu audzēšanas un novākšanas tehnoloģijas (Growing and harvesting technology of flax), Jelgava, 191. lpp. (in Latvian).
14. Karpunin, B. (1995). The perspective flax line with good quality of fibre. *Breeding for fiber and oil quality in flax.* France, St. Valery en caux, pp. 57-63.
15. Kazmi, D.H., & Rasul, G. (2012). Agrometeorological wheat yield prediction in rained Potohar region of Pakistan. *Agricultural Sciences*. Vol. 3, No. 2, 170-177.
16. Mankowski, J., Pudełko, K., & Kołodziej, J. (2013). Cultivation of Fiber and Oil Flax (*Linum usitatissimum* L.) in No-tillage and Conventional Systems. Part I. Influence of No-tillage and Conventional System on Yield and Weed Infestation of Fiber Flax and the Physical and Biological Properties of the Soil. *Journal of Natural Fibers*, 10: pp. 326-340. DOI: 10.1080/15440478.2013.797949.
17. Mustăţea, P., Săulescu, N.N., Ittu, G., Păunescu, G., Voinea, L., Stere, I., ... Năstase, D. (2009). Grain yield and yield stability of winter wheat cultivars in contrasting weather conditions. *Romanian Agricultural Research.* No. 26, pp. 1-8.
18. Nykter, M. (2006). Microbial quality of hemp (*Cannabis sativa* L.) and flax (*Linum usitatissimum* L.) from plants to thermal insulation. Academic dissertation. Helsinki, Finland. Retrieved March 2, 2016, from http://ethesis.helsinki.fi/julkaisut/maa/maaja/vk/nykter/microbia.pdf.
19. Ortiz, R., Wagoire, W.W., Hill, J., Chandra, S., Madsen, S., & Stølen, O. (2001). Heritability of and correlations among genotype-by-environment stability statistics for grain yield in bread wheat. *Theor. Appl. Genet.*, 103, 469-474.
20. Polonetskaya, L.M., Panifedova, L.M., & Sakovich, V.I. (2001). *Analysis of gene effects controlling elements of productivity and fiber quality in fiber flax cultivars.* Bast Plants in the New Millennium (Proceedings of the 2nd Global Workshop, 3 – 6 June, 2001, Borovets, Bulgaria): pp. 180-182.

21. Rameeh, V. (2015). Heritability, genetic variability and correlation analysis of some important agronomic traits in rapeseed advanced lines. *Cercetări Agronomice în Moldova* Vol. XLVIII, No. 4 (164). DOI: 10.1515/cerce-2015-0054.
22. Rashal, I., & Stramkale, V. (1998). Conservation and use of the Latvian flax genetic resources. Proceedings of the Symposium „Bast fibrous plants today and tomorrow." Breeding, Molecular Biology and Biotechnology beyond 21th century", 28-30 September 1998 (Iss. 2, pp. 56-58.) St. Petersburg, Russia. Natural Fibres.
23. Ward, J.J.H. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association*, 58, 236-244. Retrieved March 4, 2016, from http://dx.doi.org/10.1080/01621459.1963.10500845.
24. Wretfors, C. (2005). *Cultivation, processing and quality analysis of fibres from flax and industrial hemp – an overview with emphasis on fibre quality.* Swedish University of Agricultural Biosystems and Technology (Report 139:1-37.).

FERTILISATION PLANNING AS EFFECTIVE TOOL FOR BALANCED ECONOMIC AND ENVIRONMENTAL BENEFITS IN CROP FARMING

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Abstract
Since the middle of the last century rapid intensification of agricultural production systems has resulted in dramatic increase in fertilizer consumption as fertilizer has been considered as one of the most important factors for increased yields. However, not all the nutrient ions in a fertilizer applied to soil are taken up by crops, thus certain amount of the applied fertilizer is lost from agricultural fields leading to increases in nitrogen surplus, nitrogen losses to the environment and harmful impacts on biodiversity, air and water quality. This study aims to focus on crop fertilisation planning which is based on the knowledge of physical and chemical properties of soil and involves performing soil tests, designing a fertilisation plan and its practical implementation as well as calculating the balance of N, and to evaluate crop fertilisation planning as a tool for achieving balanced economic and environmental benefits in crop farming, which play an important role in efficient farming. In this study, the authors have analysed current situation in Latvia regarding requirements for fertilization planning in crop farms and have assessed potential costs and benefits from fertilisation planning. The research finds out that total cost of introducing of fertilisation planning ranges from 34 to 22 EUR ha^{-1}, however, fertilisation planning is a neutral measure where costs are compensated by savings from N inputs which ranges from 10 to 40 kg N ha^{-1}.Fertilisation planning generates environmental benefits, i.e. – reduces direct N_2O emissions from agricultural soils by 47 – 187 kg CO_{2eq} ha^{-1} through reduced N fertilizer inputs.
Key words: fertilisation planning, nitrous oxide, GHG emissions, savings.

Introduction

Agricultural production fulfils important needs of human beings, most importantly the production of essential nutritional products, supplying raw materials for industrial purposes, producing bioenergy and environmental stewardship (Kirchmann & Thorvaldsson, 2000). However, agriculture faces with a range of challenges, like, weather, infestation, manpower and environmental problems, where environmental problems have been considered as topical once (Kirchmann & Thorvaldsson, 2000; Tilman *et al*., 2002). According to H. Kirchmann & G. Thorvaldsson (2000), some of environmental problems are caused by natural conditions (high native heavy metal content, drought, volcanic eruptions, etc.), others depend on agricultural practices (leaching of nutrients and pesticides, etc.), and some are related to human influence in other areas (air pollution).This means that in modern agriculture farmers should produce adequate amounts of a high-quality product, protect its resources and be both environmentally friendly and economically profitable (Valkama *et al*., 2013).However, according to D. Tilman and co-authors (2002) modern agricultural practices that have greatly increased global food supply have had inadvertent, detrimental impacts on the environment. The rapid intensification of agricultural production systems since 1950 has resulted in a dramatic increase in inputs in general, and in fertilisers in particular (Van Alphen & Stoorvogel, 2000). It has been even revealed that in order to ensure that the yield potential could be reached each year, farmers often applied quantities of nitrogen (N) fertiliser that were far greater than the amount actually required to achieve the yield potential (Lemaire, Jeuffroy, & Gastal, 2008). At the same time it has been also estimated that only 30–50% of applied nitrogen fertilizer (Smil, 1999) and approximately 45% of phosphorus fertilizer (Smil, 2000) are taken up by crops. Moreover, incorporation of excessive nitrogen fertilizer rates contributes to nitrate accumulation in soil (Līpenīte & Kārkliņš, 2015).It means that a significant amount of the applied nitrogen and a smaller portion of the applied phosphorus are lost from agricultural fields. In turn, excess fertilizer application leads to increases in nitrogen surplus, nitrogen losses to the environment and harmful impacts on biodiversity, air and water quality (Goulding, Jarvis, & Whitmore, 2008; Līpenīte & Kārkliņš, 2015). Such findings have highlighted the need for more sustainable agricultural methods and many scientific studies of different aspects of sustainable agricultural methods have been carried out. For example, many countries such as Belgium, Denmark, Germany, the Netherlands, Norway, Switzerland (OECD, 2008), and Finland (Valkama *et al*., 2013) show further potential to reduce agricultural N surpluses to levels that are not potentially environmentally damaging. Some findings reveal that in order to maintain high yields while reducing environmental impact, it appears necessary to increase N-use efficiency through the promotion of good farming practices (Dumont *et al*., 2015). Widespread approach in Europe and North America for adjusting the N fertilization is soil sampling at the start of the growing period in order to analyze the amount of NO_3^--N (and NH_4^+-N). However, such a

procedure is time-consuming and costly and fails to take into account additional N from mineralization during the coming season (Valkama *et al*., 2013).

Such situation analysis set the aim for this study – to evaluate crop fertilisation planning as a tool for achieving balanced economic and environmental benefits in crop farming. This aim goes in line with the key purpose of crop fertilisation planning which is focused on ensuring optimum crop fertilisation, as the lack of basic elements can reduce crop growth and yields, while the unabsorbed amount of N results in economic and environmental losses, as N_2O emissions are produced. In order to achieve the aim, two specific research tasks were set: 1) to analyse current situation in Latvia regarding requirements for fertilization planning in crop farms; 2) to assess potential costs and benefits from introducing fertilisation planning in farms.

Materials and Methods

This study is part of a broader research aiming to assess the agricultural sector greenhouse gas (further in text – GHG) emissions reduction potential and to make costbenefit analysis for GHG abatement measures and make recommendations for policy planning in the field of emission reduction. This study proceeds in two stages: 1) to analyse current situation in Latvia regarding requirements for fertilization planning in crop farms in order to examine the real situation concerning fertilisation planning; 2) to assess potential costs and benefits from fertilisation planning in order to estimate its effects on the economy of farms.

In order to analyse the current situation in Latvia regarding requirements for fertilization planning in crop farms, authors have used various sources of materials and data: the scientific literature, legislation, reports and recommendations, as well as websites.

In order to calculate potential gains and losses from fertilisation planning, the main costs related to implementation of fertilisation planning were made. Introduction of fertilisation planning consists of several processes:

1. Agrochemical soil testing;
2. Development of crop fertilization plan;
3. Calculation of nitrogen balance.

Agrochemical soil testing

Assessment of the agrochemical properties of the soil is the first step in the fertilisation planning process. Soil agrochemical composition is important information that should be considered when choosing crops to be grown and planning use of fertilizers. If farmers grow crops without knowing the soil agrochemical properties, then it may happen that the crop is unable to take full advantage of all the fertilizer inputs. Agrochemical test must be carried out every 6 years.

In Latvia, the official authority competent of soil and authority where agrochemical soil testing can be carried out is State Plant Protection Service. Soil agrochemical testing is set of measures which include:

- a professional soil sampling with specific probes, according to the Latvian State Land Service soils maps indicated soil type and particle size distribution;
- soil agrochemical measurement in accredited laboratory of soil analysis carried out methods approved by the Ministry of Agriculture;
- the data are entered and stored at Soil agrochemical research database;
- the analytical results developed by Latvian scientists are evaluated and groups of agrochemical indicators approved by the Ministry of Agriculture;
- agrochemical soil testing materials include chemical studies of soil maps, the preparation and issuance to the customer;

Taking into account the farmers' interest in precision agriculture and in receiving agrochemical soil test results in digital format, starting from 2013 State Plant Protection Service offers agrochemical soil testing with usage of geographical positioning device (GPS) to farmers.

Crop fertilization plan

The next step in the fertilisation planning is to estimate the amount of nutrients that the crop needs and to develop crop fertilization plan. In order to develop crop fertilization plan and to calculate the necessary amount of fertilizers, several important factors should be taken into account:

- crop specie planned to grow in the field, realistic yield potential;
- crop specie grown in the field in the previous season;
- soil properties of the field (using data from agrochemical soil tests).

In order to provide effective farming practice, crop fertilization plans should be developed for all farms that use fertilizers in crop cultivation. In Latvia, farmers have several options how they can develop crop fertilization plans:

1. farmers can use on-line fertiliser planning system offered by Rural Support Service Electronic Application System (further in text - E-service LDS EPS);
2. farmers can do calculations themselves by using specific normative tables (Kārkliņš &Ruža, 2013) drawn up on the basis of experimental data obtained or by using the software provided by different services;

3. farmers can use consulting services of Latvian Rural Advisory and Training Centre.

Calculation of nitrogen balance

Nitrogen balance is necessary for keeping track of the nitrogen flows on the farm, and the key for improved nitrogen use efficiency and reduced risk of nitrogen losses on the farm. Nitrogen balance informs farmers about their degree of nitrogen utilisation and helps to identify the risk of nitrogen leaching and other losses from the field and the whole farm. The work with nitrogen balance provides important information for improved fertiliser planning and improved farm finances.

To achieve the set aim and tasks of the research, the appropriate research methods have been used in the research study, mainly qualitative and also quantitative: monographic; analysis and synthesis, data grouping, abstract analysis, logical construction etc.

Results and Discussion

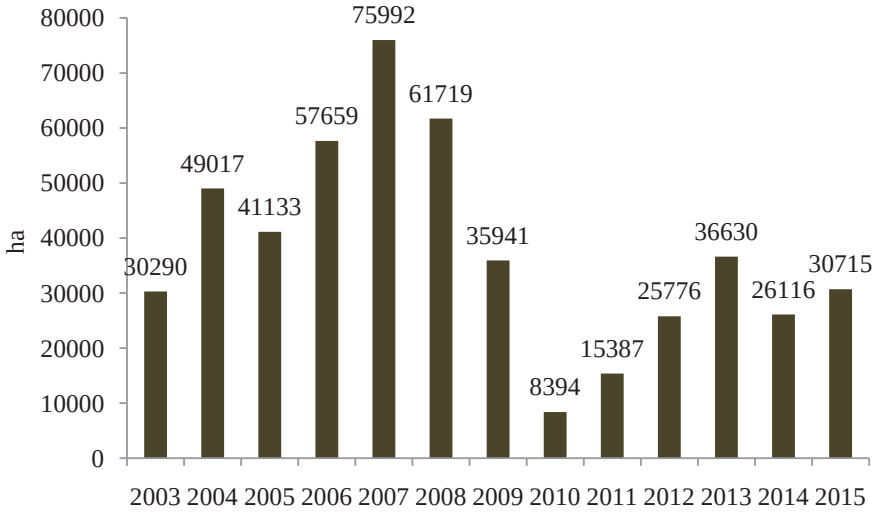
Current situation in Latvia regarding requirements for fertilization planning in crop farms

In the scientific literature (Goulding, 2000; Tilman *et al*., 2002; Valkama *et al*., 2013; Dumont *et al*., 2015) there can be found various examples of best management practices for N management, like choosing of the highestyielding variety appropriate to maximize the use of the available nutrients; maintaining a green cover as much as is practicable to retain N; making regular soil analyses for pH, P, K and Mg and possibly trace elements; using lime to maintain the appropriate pH for optimum nutrient supply; calculating fertilizer requirements using a recommendation system; avoiding unnecessary autumn and early spring applications of N; applying fertilizers and manures evenly, and well away from watercourses, with a properly calibrated spreader.

Thus, fertilization planning which in the frame of this study has been understood as set of three activities - agrochemical soil testing, development of crop fertilization plan, and calculation of nitrogen balance - is one of possibilities how to meet the best management practices for N management.

Soil agrochemical testing is a key to soil nutrient management or the first step in planning an economical and environmentally sound fertilization program. Information about soil properties provides a farmer with an estimate of the amount of fertilizer nutrients needed to supplement those in the soil (Baker, Ball, & Flyn, 2002). Applying the appropriate type and amount of needed fertilizer will give to agriculture farmer a more reasonable chance to obtain the desired crop yield. According to information provided by State Plant Protection Service (the official authority competent of Latvian soil and authority where agrochemical soil testing can be carried out), over the past six years agrochemical tests have been made only for 10% of agricultural land soil (Rulle, 2014). It means that a large part of Latvian farmers grows crops without knowing the soil agrochemical properties. In contrast, in the neighbouring country Estonia, where soil agrochemical testing is a condition of national and EU support system, farmers have information about 80% of agricultural land soil agrochemical properties (Astover & Rossner, 2013).

As regards development of crop fertilization plans, currently in Latvia crop fertilization plans are mandatory for two kinds of farmers:



Source: Rulle, 2016.

Figure 1. Dynamics of agricultural land (ha) in which agrochemical soil testing has been carried out in Latvia, 2003 – 2015.

- For those farmers whose farms are located in nitrate vulnerable zones and use 20 ha or more of agricultural land, but for horticulture and vegetable growing farms – 3 ha or more of agricultural land.
- For those farmers who are professional users of plant protection products of second registration class (about 17000 farms).

For the rest of farmers, this activity is voluntary and farmers don't receive any financial support. Similarly, it is with calculation of nitrogen balance; this is voluntary and depends on farmer's interests. Therefore, the dynamics of agricultural land area in which agrochemical soil testing has been carried out over the years is very uneven (see Fig. 1).

Information provided by State Plant Protection Service about changes in proportion of different agrochemical characteristics of the agricultural land in Latvia is summarized in Figure 2. This information should be considered as indicative because monitoring sites differ from year to year and do not reflect the situation in constant area. However, from the soil monitoring results summarized in Figure 2 can be concluded general observations: Latvian agricultural land has a tendency to acidification of soil; agricultural land is generally poorly served by phosphorus, where one of the most important reasons for the low phosphorus content could be unbalanced fertilizer use; potassium available for plants in soil tends to get worse.

In the context of fertilisation planning, these tendencies are very unwanted as nutrient imbalance and acid soil have negative impact on N uptake by crops.

As regards development of crop fertilization plans, then currently in Latvia crop fertilization plans are mandatory for two kinds of farmers:

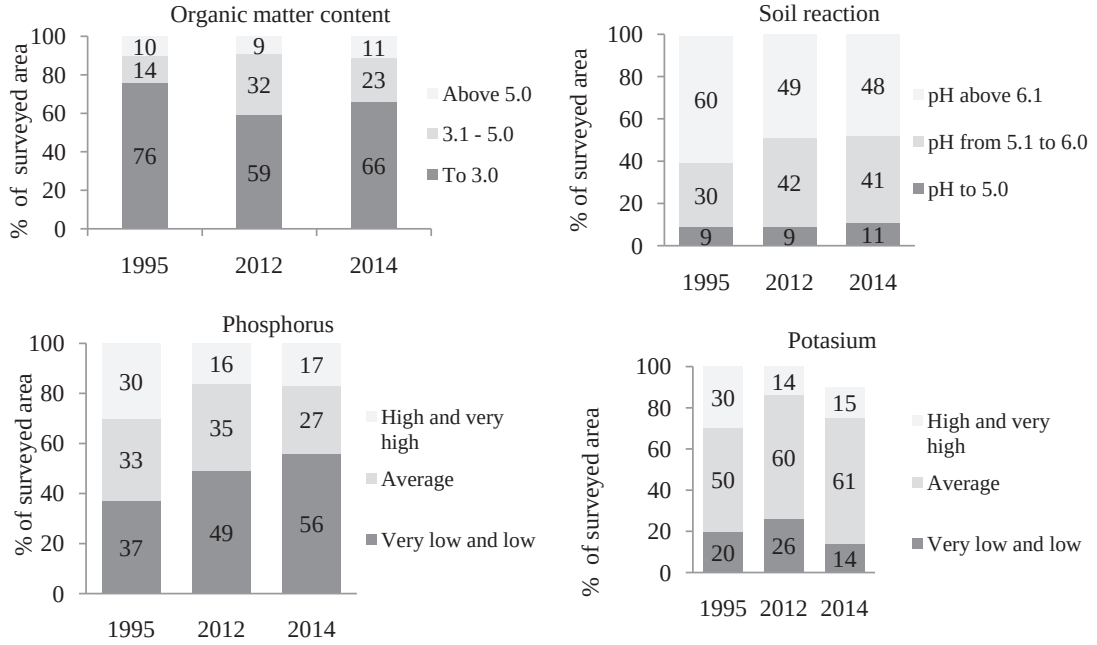
- those farmers whose farms are located in nitrate vulnerable zones and use20 ha or more of agricultural land, but for horticulture vegetable growing farms – 3 ha or more of agricultural land;
- farmers who are professional users of plant protection products of second registration class.

For rest of farmers this activity is voluntary. Similarly with calculation of nitrogen balance, this is voluntary and depends on farmer's interests.

Such situation in Latvia shows that fertilization planning has to be included on the list of national agricultural activities eligible for support, which would motivate farmers and contribute to maintaining the quality of soils, increasing yields, accumulating and updating information on the condition of soils, fertilization practice and nutrients balance.

Potential costs and benefits from introducing fertilisation planning in farms

Fertilisation planning is essential to obtain the best balance of economic and environmental benefits in each farm as lack of certain plant nutrients can reduce



Source: authors' calculations after Rulle, 2014; 2016.

Figure 2. Proportion of different agrochemical characteristics of the agricultural land in Latvia in 1995, 2012 and 2014.

Table 1

Potential costs and benefits from introducing fertilisation planning in farms

Fertilisation planning activities	Implementation costs, EUR ha^{-1}	Economic benefits	Environmental benefits
		Savings in N input rates, kg N ha^{-1}	GHG reduction potential, kg CO_{2eq} ha^{-1}
Agrochemical soil tests	From 28 to 16	X	X
Development of crop fertilization plan	3	X	X
Development of nitrogen balance	3	10 – 40	47 – 187
Total	34 – 22	10 – 40	47 – 187

Source: authors' calculations after Valkama *et al*., 2013; Domingo *et al*., 2014.

plant growth and lower yield, but surpluses can be costly both from an environmental and an economic perspective.

Nitrous oxide (N_2O) is a greenhouse gas with a global warming potential 298 times higher than carbon dioxide (CO_2) on a per mass basis, and is the largest stratospheric ozone-depleting substance (IPCC, 2015). Agricultural soils are the main anthropogenic source of N_2O emissions, primarily as a result of the addition of synthetic N fertilizers and animal manures to soil (Bouwman, Boumans, & Batjes, 2002). The potential for mitigation of N_2O emissions arising from fertilizer management practices has been scientifically assessed in recent decades. Given the strong association between fertilizer management and crop productivity, which to a large extent determines farmers' willingness to adopt such practices, it is essential to incorporate the impacts on yields before any mitigation practice can be recommended (Abalos *et al*., 2016). Yet, the potential consequences of N_2O mitigation practices on crop yield remain largely unexplored (Millar *et al*., 2010). Both positive and negative effects, depending on the practice, can be expected.

The optimum N fertilization is known to vary within the same field and with each growing season as a result of the heterogeneity of soil properties, as well as inter- and intra-annual climatic patterns (Basso *et al*., 2012). Furthermore, the decision-making process linked to N management remains complex because even if a spatial map of soil properties exists, the decision regarding the amount of N fertilizer to apply must be made without any prior knowledge of future weather conditions (Basso *et al*., 2011). In such a context, determining the optimum amount of and the most appropriate timing for N fertilizer is a challenge (Dumont *et al*., 2016).

Application of N fertilizer in Latvia has been determined by the Republic of Latvia Cabinet Regulation No. 834 'Regulation Regarding Protection of Water and Soil from Pollution with Nitrates Caused by Agricultural Activity' where maximum permissible amount of nitrogen, which may be used for crops in one harvest period depending on the planned yield level has been indicated. Current agricultural practice in Latvia shows that those farmers who don't implement fertilisation planning are usually guided by maximum permissible amount of nitrogen, which may be used for crops. However, it has been scientifically proved that in some cases current fertilizer recommendations, which are based on the grower's yield expectation, can lead to significant errors in N management practice. For example, current Finnish N-fertilizer recommendations are uneconomically high for poorly responsive fields, where N input can be reduced by 20 – 75 kg ha^{-1} without economic loss to agriculture. Such improved practices could reduce N balances by 10 – 40 kg ha^{-1} $year^{-1}$. In contrast, the current recommendations may be uneconomically low for highly responsive fields, thus leading to economic losses for the growers (Valkama *et al*., 2013).

Such situation analysis let authors conclude that introduction of such best management practice for N management as fertilisation planning should be associated not only with costs but also with economic and environmental benefits (see Table 1).

The main costs associated with introduction of fertilisation planning are as following:

1. Agrochemical research of soil: these costs depend on size of the farm and farmers choice regarding usage of GPS in research. Thus farmers' costs for agrochemical soil tests can vary from 16 EUR ha^{-1} to 28 EUR ha^{-1}.
2. Development of crop fertilization plan: farmers have several options - farmers can use on-line fertiliser planning system offered by E-service LAD EPS or farmers can do calculations themselves by using specific normative tables (Kārkliņš & Ruža, 2013) drawn up on the basis of experimental data obtained or by using the software provided by different services. In this

case these will be transaction costs. In the case if farmers use consulting services of Latvian Rural Advisory and Training Centre costs will be 3 EUR ha^{-1}.

3. Calculation of nitrogen balance: farmers can do calculations themselves by using specific normative tables (Kārkliņš & Ruža, 2013) drawn up on the basis of experimental data obtained or by using the software provided by different services. In this case these will be transaction costs.

The total cost of introducing of fertilisation planning range from 22 to 34 EUR ha^{-1}. However, according to scientific findings (Valkama *et al*., 2013; Domingo *et al*., 2014)the fertilisation planning would generate savings in N inputs – ranging from 10 to 40 kg N ha^{-1}, which can be considered as economic benefits. Thus fertilisation planning can be considered as a neutral measure where costs are compensated by savings. Fertilisation planning associates also with some environmental benefits – reduced N fertilizer inputs will positively affect GHG emissions through reduced direct N_2O emissions from agricultural soils.

Conclusions

1. Agrochemical soil testing is a key to soil nutrient management and provides a farmer with an estimate of the amount of fertilizer nutrients needed to supplement those in the soil. Situation analysis in Latvia shows that over the past six years only for 10% of agricultural land soil agrochemical research has been made. It means that a large part of Latvian farmers grow crops without knowing the soil agrochemical properties. Thus, fertilization planning has to be included on the list of national agricultural activities eligible for support, which would motivate farmers and contribute to maintaining the quality of soils, increasing yields, accumulating and updating information on the condition of soils, fertilization practice and nutrients balance.
2. The assessment of potential costs and benefits from fertilisation planning revealed that:
   - total cost of introducing of fertilisation planning range from 22 to 34 EUR ha^{-1}, however, fertilisation planning is a neutral measure where costs are compensated by savings from N inputs which range from 10 to 40 kg N $ha^{-1;}$
   - fertilisation planning generates environmental benefits, i.e. – reduces direct N_2O emissions from agricultural soils by 47 – 187 kg CO_{2eq} ha^{-1} through reduced N fertilizer inputs.

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References

1. Abalos, D., Jeffery, S., Drury, C.D., & Wagner-Riddle, C. (2016). Improving fertilizer management in the U.S. and Canada for N_2O mitigation: Understanding potential positive and negative side-effects on corn yields. *Agriculture, Ecosystems & Environment*, Volume 221, 214-221. DOI: 10.1016/j.agee.2016.01.044.
2. AlphenVan, B.J., & Stoorvogel, J.J. (2000). A methodology for precision nitrogen fertilization in high-input farming systems. *Precision Agriculture*, 2 (4), 319-332. DOI: 10.1023/A:1012338414284.
3. Astover, A., & Rossner, H. (2013). Phosphorus status of agricultural soils in Estonia. Retrieved March 2, 2016, from http://www.balticmanure.eu/download/Reports/status_report_estonia_revised_final_web.pdf.
4. Baker, R.D., Ball, S.T., & Flyn, R. (2002). Soil analysis: a key to soil nutrient management. Retrieved March 2, 2016, from http://aces.nmsu.edu/pubs/_a/A137.pdf.
5. Basso, B., Sartori, L., Cammarano, D., Fiorentino, C., Grace, P.R., Fountas, S., & Sorensen, C.A. (2012). Environmental and economic evaluation of N fertilizer rates in a maize crop in Italy: a spatial and temporal analysis using crop models. *Biosystem Engeneering*, 113, 103-111. DOI: 10.1016/j.biosystemseng.2012.06.012.
6. Basso, B., Sartori, L., Bertocco, M., Cammarano, D., Martin, E.C., & Grace, P.R. (2011). Economic and environmental evaluation of site-specific tillage in a maize crop in NE Italy. *European Journal of Agronomy*, 35 (2), 83-92. DOI: 10.1016/j.eja.2011.04.002.
7. Bouwman, A.F., Boumans, L.J.M., & Batjes, N.H. (2002). Modeling global annual N_2O and NO emissions from fertilized fields. *Global Biogeochemycal Cycles*, 16(4), 1080. DOI: 10.1029/2001GB001812.
8. Domingo, J., De Miguel, E., Hurtado, B., Metayer, N., Bochu, J.L., & Pointereau, P. (2014). Measures at farm level to reduce greenhouse gas emissions from EU agriculture. Retrieved March 6, 2016, from http://www.europarl.europa.eu/RegData/etudes/note/join/2014/513997/IPOLAGRI_NT%282014%295139_EN.pdf.

9. Dumont, B., Basso, B., Bodson, B., Destain, J.P., & Destain, M.F. (2015). Climatic risk assessment to improve nitrogen fertilisation recommendations: A strategic crop model-based approach. *European Journal of Agronomy*, Volume 65, 10-17. DOI: 10.1016/j.eja.2015.01.003.
10. Dumont, B., Basso, B., Bodson, B., Destain, J.P., & Destain, M.F. (2016). Assessing and modeling economic and environmental impact of wheat nitrogen management in Belgium. *Environmental Modelling & Software*, Volume 79, 184-196. DOI: 10.1016/j.envsoft.2016.02.015.
11. Goulding, K., Jarvis, S., & Whitmore, A. (2008). Optimizing nutrient management for farm systems. *Philosophical Transactions of the Royal Society*, B, 363, 667-680. DOI: 10.1098/rstb.2007.2177.
12. Goulding, K.W.T. (2000). Nitrate leaching from arable and horticultural land. *Soil Use Management*, 16, 145-151. DOI: 10.1111/j.1475-2743.2000.tb00218.x.
13. IPCC (2015). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, prepared by the National Greenhouse Gas Inventories Programme. Retrieved March 5, 2016, from http://www.ipcc-nggip.iges.or.jp/public/2006gl/.
14. Kārkliņš, A., & Ruža, A. (2013). Lauku kultūraugu mēslošanas normatīvi (Fertilizer regulations for crops). Jelgava: LLU. (in Latvian).
15. Kirchmann, H., & Thorvaldsson, G. (2000). Challenging targets for future agriculture. *European Journal of Agronomy*, 12, 145-161. DOI: 10.1016/S1161-0301(99)00053-2.
16. Lemaire, G., Jeuffroy, M.H., & Gastal, F. (2008). Diagnosis tool for plant and crop N status in vegetative stage. Theory and practices for crop N management. *European Journal of Agronomy*, 28 (4), 614-624. DOI: 10.1016/j.eja.2008.01.005.
17. Līpenīte, I., & Kārkliņš, A. (2015). Tauriņziežu audzēšanas vides riski (Cultivation of leguminous crops and environmental risks). *Proceedings of the Scientific and Practical Conference "Harmonious Agriculture"*, 24-37. lpp. (in Latvian).
18. Millar, N., Robertson, G.P., Grace, P.R., Gehl, R., & Hoben, J. (2010). Nitrogen fertilizer management for nitrous oxide (N_2O) mitigation in intensive corn (maize) production: an emissions reduction protocol for US Midwest agriculture. *Mitigation and Adaptation Strategies for Global Change*, 15 (2010), 185-204. DOI: 10.1007/s11027-010-9212-7.
19. OECD (2008). *Environmental Performance of Agriculture in OECD Countries since 1990*. Paris: Organization for Economic Co-operation and Development.
20. Rulle, S. (2014). Soil Fertility of the Agricultural Land in Latvia and Measures for Sustainable Land Management. Retrieved March 2, 2016, from http://www.ifc.uz/upload/iblock/a87/a8754113ac03d15729c48911590552ff.pdf.
21. Rulle, S. (2016). Soil Fertility and Fertiliser Plans. Retrieved July 27, 2016, from http://zemniekusaeima.lv/wp-content/uploads/2016/02/04_GreenAgri_S_Rulle.ppt.
22. Smil, V. (1999). Nitrogen in crop production: an account of global flows. *Global Biogeochemical Cycles*, 13, 647-662. DOI: 10.1029/1999GB900015.
23. Smil, V. (2000). Phosphorus in the environment: natural flows and human interferences. *Annual Review of Energy and the Environment*, 25, 53-88. DOI: 10.1146/annurev.energy.25.1.53.
24. Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature*, 418, 671-677. DOI: 10.1038/nature01014.
25. Valkama, E., Salo, T., Esala, M., & Turtola, E. (2013). Nitrogen balances and yields of spring cereals as affected by nitrogen fertilization in northern conditions: A meta-analysis. *Agriculture, Ecosystems and Environment*, 164, 1-13. DOI: 10.1016/j.agee.2012.09.010.

LIMING EFFECT ON NITROGEN USE EFFICIENCY AND NITROGEN OXIDE EMISSIONS IN CROP FARMING

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Abstract
Liming soils make both direct and indirect effects on greenhouse gas (GHG) emissions. If raising the pH of soil, the amount of N_2O emissions in the result of nitrification decreases; therefore, it is important to perform also maintenance liming if applying nitrogen fertilisers. Liming acidic soils contributes to the absorption of nutrients supplied by means of fertilisers by plants, limits the spread of plant diseases, forms better soil moisture and air regimes for plants, improves the structure of soil and activates microorganisms. The aim of this study was to assess liming effect on nitrogen use efficiency and nitrogen oxide emissions in crop farming. To achieve the aim, this study proceeds in two stages: 1) to analyse the scientific literature on the liming effect on nitrogen use efficiency and nitrogen oxide emissions in other countries, as a few such research studies are available in Latvia; 2) to calculate potential gains and losses from liming acid soils in order to examine the real situation concerning liming and its effects on the economy of farms. The research finds out that at the farm level in Latvia liming gives a positive economic effect (41.6 EUR ha^{-1}) however, it is essential for maintaining soil fertility, increasing yields, and presumably for more efficient circulation of nitrogen, which decreases nitric oxide emissions.
Key words: liming, pH, nitrogen efficiency, GHG emissions.

Introduction

Mineral fertilizers have a significant impact on greenhouse gas (GHG) emissions, but at the same time they also imply a big mitigation potential by contributing to better land productivity and to reducing the need for land use change. By improving nutrient use efficiency, highly productive farming systems contribute to GHG mitigation. The expected decrease in N inputs to soils in the future will also decrease soil acidification. The amount of limestone used in agriculture in several western and northern European countries has decreased substantially. (Velthof *et al*., 2011). Now in Latvia of the total agricultural land 40% has acidic soils; lime has to be applied to gain high yields of protein crops and other crops. Liming was extensively implemented in Latvia in the period 1986–1988, but even then the $CaCO_3$ balance was negative in Latvia's agricultural areas exploited intensively, as calcium and magnesium compounds were leached from the arable layer by rain waters, removed by crops and neutralised by acidity caused by fertilisers. In Latvia, according to G. Pakalns (2006), if liming 217 thou ha of acidic soils a year, on average, 1007 thou t $CaCO_3$ are brought into soil by means of agricultural lime and organic and synthetic fertilisers, while 1075 thou t are removed by crops, leached and used to neutralise acidic fertilisers; the deficit amounts to 68 thou t, i.e., on average, 34 kg ha^{-1} $CaCO_3$. According to A. Kārkliņš (1996), $CaCO_3$ leaches from clay soils at a rate of 200–250 kg ha^{-1} and from sandy soils at a rate of 60 kg ha^{-1}, while the quantity of $CaCO_3$ needed for the neutralisation of acidity caused by fertilisers depends on the kind of fertilisers and their application rates. Already since 1992 a too small agricultural area was limed, which began affecting the quality of soils. In 1990, an area limed reached 149.2 thou ha, while in 2000 it decreased to 2.5 thou ha. According to the Central Statistical Bureau, approximately 18 777 ha were limed in 2014; yet, the leaching of calcium and its removal by crops continued. In Latvia, 100 thou ha have to be limed in order to prevent soils from becoming more acidic. Liming an acid soil is the first step in creating favourable soil conditions for productive plant growth. Crops vary in their ability to tolerate an acidic (low pH) soil. In addition, evidence has shown that soil acidity may influence other crop management problems such as herbicide activity. Soil pH is a good indicator of the need for liming. A soil pH of 5.5 or lower will often result in significant negative impact on most crops. The general goal of liming agricultural soils continues to be a soil pH of 6.0 to 7.0.

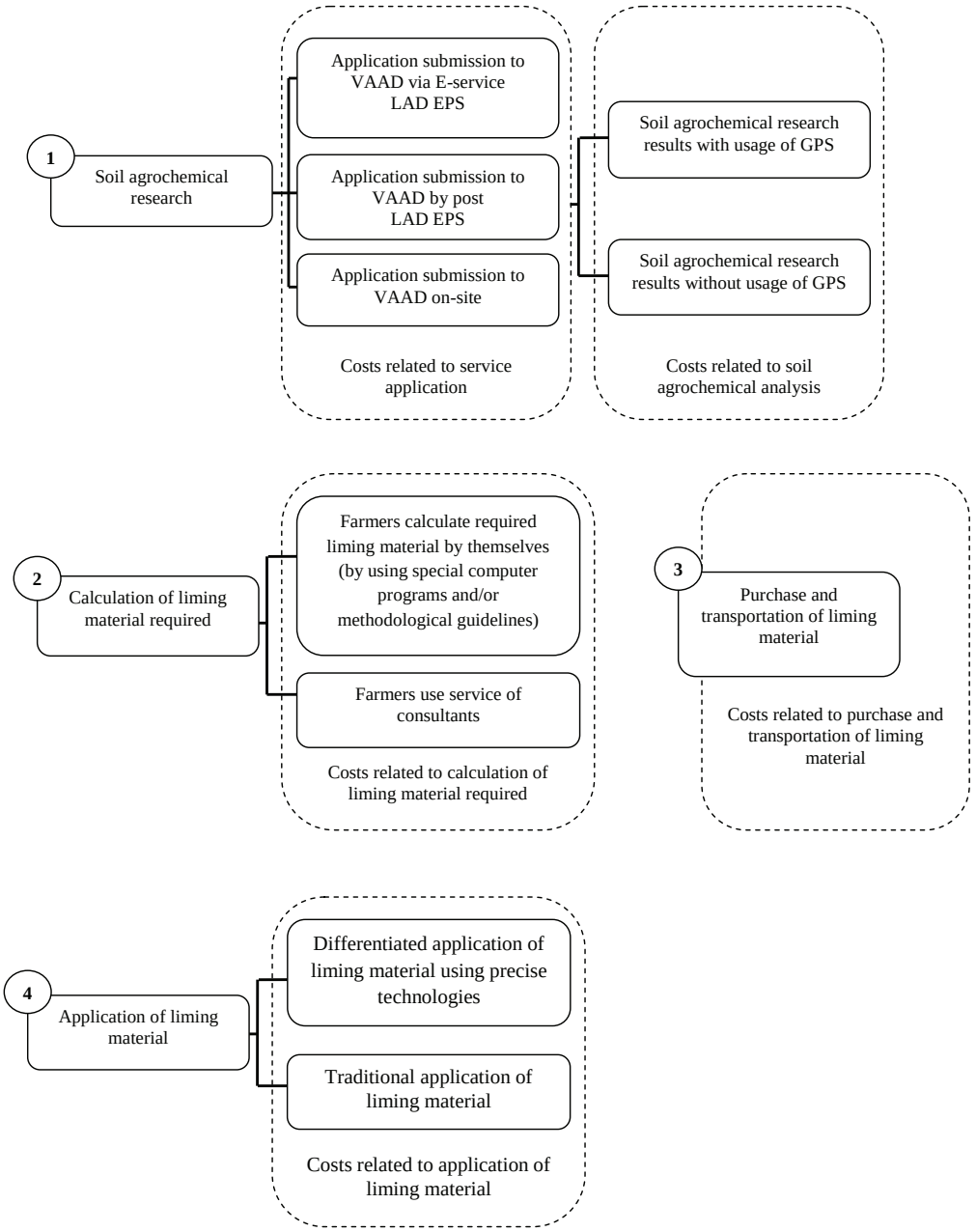
Such situation analysis set the aim for this study – to assess liming effect on nitrogen use efficiency and nitrogen oxide emissions in crop farming. To achieve the aim, two specific research tasks were set: 1) to analyse the scientific literature on the liming effect on nitrogen use efficiency and nitrogen oxide emissions; 2) to calculate potential gains and losses from liming acid soils. The object of this study is potential gains and losses from the liming acid soils.

Materials and Methods

This study is part of a broader research aiming to assess the agricultural sector GHG emissions reduction potential and to make costbenefit analysis for GHG abatement measures and make recommendations for policy planning in the field of emission reduction. This study proceeds in two stages: 1) to analyse the scientific literature on the liming effect on nitrogen

use efficiency and nitrogen oxide emissions in other countries, as a few such research studies are available in Latvia; 2) to calculate potential gains and losses from liming acid soils in order to examine the real situation concerning liming and its effects on the economy of farms.

According to scientific literature (Soon & Arshad, 2005; Valkama *et al*., 2013), liming acid soils can be used as one of the GHG mitigation measure. However, current situation in Latvia has showed that agrochemical research of soils was conducted only in less than 10% of the utilised agricultural area (UAA), mainly in very sensitive territories. Therefore, in order to estimate the real situation concerning liming and its effects on the economy of Latvian farms, calculations of potential gains and losses from liming were performed in this study. In order to understand the main costs, positions related



Abbreviations: LAD - Rural Support Service; EPS - electronic application system; VAAD – State Plant Protection Service.
Source: created by authors.

Figure 1. Mapping of costs related to implementation of liming.

to implementation of liming mapping of costs were made (see Figure 1).

To achieve the set aim and tasks of the research, the authors have used the publications and studies of foreign and Latvian scientists, legislation, reports and recommendations. The research authors have widely applied generally accepted research methods in economics, i.e. monographic descriptive method as well as analysis and synthesis methods to study the problem elements.

Results and Discussion

Analysis of the scientific literature on the liming effect on nitrogen use efficiency and nitrogen oxide emissions

It has been scientifically proved that soil N transformations and fluxes can be affected by soil pH (Soon & Arshad, 2005). According to P.W. Moody and co-authors (1995) and C.A. Rosolem and co-authors (1995), the flow of N through processes such as mineralization, nitrification and microbial immobilization influences N availability, and thus when acid soils are limed, crop uptake of N can increase through enhancement of soil N turnover and root and shoot growth. Some research findings (Barton, Murphy, & Butterbach-Bahl, 2013) show that the largest nitrous oxide (N_2O) emissions arise from soils lying fallow after a rain period, compared with the emissions from nitrogen fertilisers produced during the crop growing period. N_2O emissions from acidic soils increase during nitrification. Besides, N_2O emissions from dry soils reach 0, but with moisture increasing in soils, the emissions can increase up to 0.065 µg N_2O owing to both nitrification and denitrification. With the pH of soil increasing, N_2O emissions decrease. According to research studies, increasing the pH of soil decreases N_2O emissions from acidic soils during rainfall periods when the emissions are caused by nitrification (Barton, Murphy, & Butterbach-Bahl, 2013). Australian scientists, in their research on lupine-wheat and wheat-wheat rotations with using N fertilisers, have also proved that liming contributes to decreases in GHG emissions from farms, as the flow of N_2O declines and the absorption of CH_4 increases (Barton, Murphy, & Butterbach-Bahl, 2013).

Under the conditions in Latvia there can be performed two types of liming – correction liming and maintenance liming. Correction liming is aimed at radically raising soil reaction in the entire arable layer for a long period. It is performed if the reaction of mineral soils is below pH KCl 5.5, while for peat soils it is pH KCl 5.0. A lime fertiliser is brought into soil while doing correction liming functions only for a limited period; therefore, liming has to be periodically repeated. In order to compensate acidification processes caused by application of acid fertilisers, runoff of Ca and by acid rain a repeated liming operation is needed even if the soil was very acidic and the correction liming operation did not result in optimum soil reaction. Unfortunately, there are no recent researches about effect of liming on yield. However, experiment results from trials made in 1982–1983 showed that after performing liming in fields with pH 5.5, an increase in barley yield by 0.3 – 0.5 t ha^{-1} (Štikāns, 1992) was observed. Maintenance liming is performed to periodically offset the loss of Ca and Mg in the arable layer of soil and to maintain the pH of soil at optimum level. Maintenance liming is usually recommended to be done once in three years, spreading from 1.0 to 1.5 t of $CaCO_3$ per hectare. According to research studies by J. Vigovskis (2014) in Skriveri: in the area where a higher lime rate was applied, soil acidity decreased to a pH of 5.2, while in the area with a low lime rate the pH of soil decreased to a lower level (pH 4.6) than it was before (pH 4.8). In the area that was not limed the soil reaction also continued gradually declining (from pH 4.8 to pH 4.4.) The experimental results convincingly prove that without carrying out maintenance liming operations, soils became more acidic by pH 0.7 – 0.8.

The size of farms is not important for liming acidic soils, but the choice of a lime fertiliser, depending on the amounts of Ca and magnesium (Mg) available in soil, is essential. From the perspective of soil reaction, there are two types of soils in Latvia: soils that are formed on dolomites and soils that are formed on limestone. For example, along the rivers of Daugava and Lielupe and in some other areas – on dolomites – where soil acidity should be normal, it often lacks Ca, as the ratio of Ca to Mg is inappropriate. For example, near Saulkalne where Mg in soil is available in too large amounts, applying dolomite powder brings more Mg into soil, which is not necessary; the most appropriate substance in this case is limestone powder. In contrast, in Southern Kurzeme – in the vicinities of Saldus and Liepaja – the situation is opposite, as there is a lack of Mg in soil and dolomite powder is appropriate for liming. A very important indicator in the assessment and choice of lime fertilisers is their contents of Ca and Mg and the ratio of these elements. If an inappropriate lime fertiliser is chosen, the expected result will not be achieved neither on large nor small farms if the purpose is only to adjust the pH of soil by liming without taking into consideration the ratio of Ca to Mg in the soil (Nollendorfs, 2004).

Calcium together with humus forms the structure of soil and determines soil water and air capacities and soil reaction. Acidic soils do not have enough Ca, but it is the most essential nutrient for plant growth. If soils are not limed, their structure degrades, they become dense faster and unfavourable moisture and air regimes emerge in the soils; nitrification in acidic

soils is also hindered – the activity of microorganisms declines and plant diseases spread. Consequently, crop yields decrease as well. Plant nutrients brought into soil by means of fertilisers do not perform effectively in acidic soils, and the absorption of microelements is obstructed. For example, phosphorous forms compounds difficult to reach and absorb by plants. Molybdenum is actually unabsorbed too. If soils are acidic and lack calcium, even the contents of potassium and magnesium decrease in plants. In contrast, the absorption of radioactive substances and heavy metals (lead, zinc, cadmium, arsenic), which are dangerous for human health, increases. They can accumulate in plants to toxic rates. Accordingly, one can conclude that liming is a way of achieving higher yields and better product quality on any crop farm. On livestock farms, feed produced in limed soils has higher contents of Ca and protein; therefore, there is an opportunity to achieve greater agricultural output and higher product quality (Hylander, 1995; Mandai, Pal, & Mandai, 1998).

With acidity rising and the content of organic matter declining in soil, plants can absorb less nutrients, whereas the absorption of pollution by plants increases. Consequently, one can find that liming acidic soils is urgent for any kind of farms. It is of great importance to enterprises of intensive farming due to high rates of nitrogen fertiliser application and relatively high rates of Ca removal from soil, while the formation of organic matter in soil, which is hindered in an acidic environment, is important to organic farms. For example, liming soils in Scandinavia is very important; it is estimated that up to 300 kg calcium (Ca) per hectare have to be annually brought into soil. For this reason, crop yields in Sweden, where soils have formed mainly on rock, are higher than in Latvia (Fornara *et al*., 2011).

Under the conditions in Latvia due to denitrification, N_2O and N_2 turn into 10% of the mineral nitrogen present in soil. Soil affects GHG emissions and their absorption. Therefore, GHG monitoring, simulations of expected GHG changes and forecasts of the potential effects on climate change, vegetation, etc. are not possible without information on the most important soil properties (Kasparinskis, Nikodemus, & Kārkliņš, 2016). However, limited information is available on liming effects on crop production and nitrogen (N) cycling in acid soils in Latvia. Therefore, experience of other countries can be very relevant for estimating liming effect on nitrogen use efficiency and nitrogen oxide emissions.

In Northern Ireland liming has significantly increased perennial ryegrass (*Lolium perenne*) yield and N off take and affects N recovery by swards at both harvests in at least two different ways. During phases of net N mineralization liming stimulates biomass activity and increases the amount of organic N mineralized, but during phases of net N immobilization, liming by increasing Ca availability in the rhizosphere improves the ability of plants to absorb N. Thus, it helps plants to compete with the biomass for mineral N (Baileya, 1995) more effectively. In experiments in Canada, it has been proved that liming improves fertilizer efficiency and increases the activity of soil microorganisms to release organic nitrogen and other crop nutrients from manures and plant residues more rapidly and enhances nitrogen fixation by legumes. Liming improves soil aggregate stability, it is one of the best suppliers of calcium and magnesium to crops; it also reduces toxic aluminium levels, which is very important for alfalfa and other legumes yield performance and longevity (van Roestel, 2014). Lower uptake efficiency of nitrogen and other primary nutrients can be observed in acidic soils (pH 5.0), where the overall fertilizer uptake efficiency is 46%compared with 86% in neutral soils (see Table 1). In acidic soils primary nutrients are strongly attached to soil clay particles and therefore their uptake by crops is much slower; as the result of this the yield and protein content in such crops is lower than in crops grown in neutral soils.

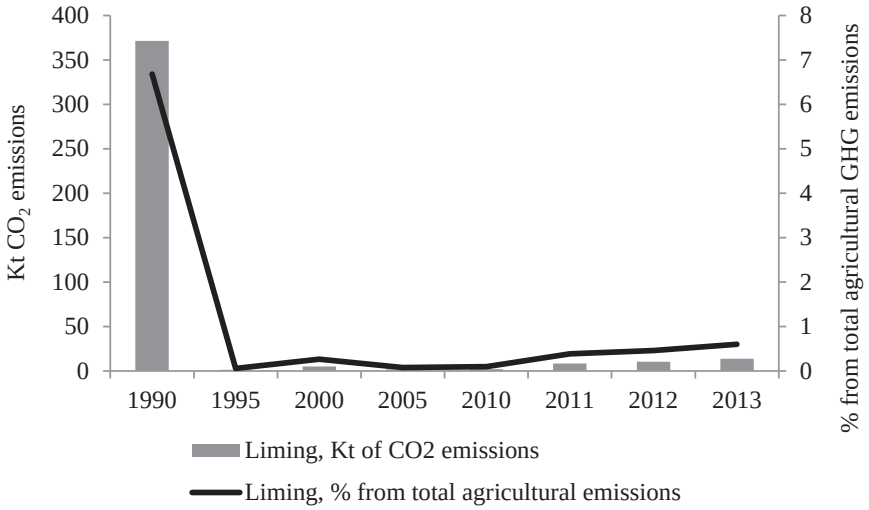
In experiments in Germany, it was concluded that application of nitrogen fertilizer may acidify soil, thus in the selection of liming material type of nitrogen

Table 1

Efficiency of primary nutrients uptake by crops at various soil pH values, %

Soil pH	Nitrogen efficiency, %	Phosphorous efficiency, %	Potash efficiency, %	Overall fertilizer efficiency, %
6.5	95	63	100	86
6.0	89	52	100	80
5.5	77	48	77	67
5.0	53	34	52	46

Source: van Roestel, 2014.



Source: authors' calculations complied with National Inventory Report, 2015.

Figure 2. Dynamics of CO_2 emissions removed from liming in Latvia, 1990 – 2013.

fertilizer should be taken into account. For example, in the case of application of ammonium nitrate, urea and liquid urea ammonium nitrate there will be a need for 1.8 kg $CaCO_3$ per kg N; in the case of application of calcium ammonium nitrate – 0.86 kg $CaCO_3$ per kg N; in the case of ammonium sulphate – 5.4 kg $CaCO_3$ per kg N; but in the case of application of calcium nitrate, there will be no need for liming (Brentrup & Pallière, 2008).

Considering the liming positive effect on nitrogen use efficiency and nitrogen oxide emissions, it should be taken into account that due to dissolution of lime in soils, liming results in release of CO_2 emission. The Intergovernmental Panel on Climate Change (IPCC) has recognised this source of CO_2 in methodology of calculating GHG emissions (IPCC, 2006). Countries are obliged to report the CO_2 emission from limestone and dolomite use in agriculture in the annual national GHG inventories to United Nations Framework Convention on Climate Change (UNFCCC). The use of lime in agriculture is only a minor source of CO_2, but at the same time it is much smaller than the N_2O emission from agriculture (Velthof *et al.*, 2011). Dynamics of CO_2 emissions removed from liming in Latvia during period 1990 – 2013 is summarized in Figure 2.

In Latvia, soil liming is voluntary and farmers do not receive any financial support. Therefore, the dynamics of CO_2 emissions removed from liming in Latvia has been very uneven with a growing tendency starting from 2013.

Potential gains and losses from liming acid soils in Latvia

The next step in this study was to examine the real situation concerning liming and its effects on the economy of farms. A problem situation was analysed to illustrate the costs of the activity based on the following assumptions: the analysis period is 8 years, soils are acidic and the corrective liming rate is 5.9 t ha^{-1} for Nordkalk. A repeated liming operation is performed every third year, and the maintenance liming rate is 1 t ha^{-1} every third year. Agrochemical soil test costs are changeable; therefore, it is assumed that the average cost is 18.76 EUR ha^{-1}. It is also assumed that machinery includes a fertiliser seeder; fuel consumption is 9.4 L ha^{-1}, the fuel price is EUR 0.80 per litre, time consumption is approximately 10 min per ha and the wage paid is EUR 850 a month or EUR 5.31 per hour. An annual increase in yields is 0.5 t ha^{-1}. A crop grown is wheat. The price of wheat is 160 EUR t^{-1}. The results obtained are summarised in Table 2.

Table 2

Potential gains and losses from liming acid soils

Activities and effects	Economic costs/gains per year, EUR ha^{-1}
Agrochemical soil tests	2.3
Transaction costs	0.4
Lime fertiliser cost	34.7
Spreading costs (fuel, wages)	1.0
Yield increase	80.0
Relative cost	- 41.6

Source: authors' calculation.

The results summarized in Table 2 show a negative relative costs which means that a farmer has positive

benefits from liming. However, liming is essential for maintaining soil fertility, increasing yields, and presumably for more efficient circulation of nitrogen, which affects GHG emissions. There are no data for unambiguous environmental effects, but it is possible to acquire the data from the present research studies. The effectiveness of liming soils remains for several years and is one of the most efficient ways of raising crop yields. According to research studies done by J. Vigovskis, a lime rate of 4 – 6 t ha^{-1} raises grain yields by 0.5 – 0.7 t ha^{-1} a year for a period of 6 – 8 years. However, not always production conditions allow to achieve such results. According to research results made by A. Zemīte, correction liming using 3 – 5 t ha^{-1} liming material resulted in an increased yield – by 0.46 t ha^{-1} for winter wheat and by 0.25 t ha^{-1} for summer wheat (Štikāns, 1992).

Liming has to be included in the list of national agricultural activities eligible for support, which would contribute to maintaining the quality of soils, increasing yields and (if agrochemical tests are eligible for support) accumulating and updating information on the condition of soils.

Conclusions

1. In the scientific literature it has been identified that soil N transformations and fluxes can be affected by soil pH, where increasing the pH of soil decreases N_2O emissions from acidic soils during rainfall periods when the emissions are caused by nitrification as well as liming acidic soils contributes to the absorption of nutrients supplied by means of fertilisers by plants. Lower uptake efficiency of nitrogen and other primary nutrients can be observed in acidic soils (pH 5.0), where the overall fertilizer uptake efficiency is 46% compared with 86% in neutral soils. It is of great importance to intensive agricultural farms due to high rates of nitrogen fertiliser application and relatively high rates of Ca removal from soil.
2. The assessment of potential gains and losses from liming acid soils in Latvia revealed that:
   - on the farm level liming gives a positive economic effect (41.6 EUR ha^{-1}); however, it is essential for maintaining soil fertility, increasing yields, and presumably for more efficient circulation of nitrogen, which decreases nitric oxide emissions;
   - liming has to be included in the list of national agricultural activities eligible for support, which would contribute to maintaining the quality of soils and increasing crop yields, as well as contribute to mitigation of N_2O emissions.

Acknowledgements

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References

1. Baileya, J.S. (1995). Liming and nitrogen efficiency: Some effects of increased calcium supply and increased soil pH on nitrogen recovery by perennial ryegrass. *Communications in Soil Science and Plant Analysis*. 26 (7-8)**,** 1233-1246. DOI: 10.1080/00103629509369366.
2. Barton, L., Gleeson, D.B., Maccarone, L.D., Zúñiga, L.P., & Murphy, D.V. (2013). Is liming soil a strategy for mitigating nitrous oxide emissions from semi-arid soils? *Soil Biology and Biochemistry*, 62(28-35). DOI: 10.1016/j.soilbio.2013.02.014.
3. Barton, L., Murphy, D.V., & Butterbach-Bahl, K. (2013). Influence of crop rotation and liming on greenhouse gas emissions from a semi-arid soil. *Agriculture, Ecosystems and Environment.*167(1), 23-32.
4. Brentrup, F., & Pallière, C. (2008). Energy efficiency and greenhouse gas emissions in European nitrogen fertilizer production and use. *Proceedings of the International Fertiliser Society, no.639.* Retrieved February 28, 2016, from http://www.fertilizerseurope.com/fileadmin/user_upload/publications/agriculture_publications/Energy_Efficiency__V9.pdf.
5. Fornara, D.A., Steinbeiss, S., McNamara, N.P., Gleixner, G., Oakley, S., Poulton, P.R., Macdonald, A.J., & Bardgett, R.D. (2011). Increases in soil organic carbon sequestration can reduce the global warming potential of long-term liming to permanent grassland. *Global Change Biology.* 17 (5), 1925-1934.
6. Hylander, L.D. (1995). Effects of lime, phosphorus, manganese, copper, and zinc on plant mineral composition, yield of itarley, and level of extractable nutrients for an acid Swedish mineral soil. *Communications in Soil Science and Plant Analysis*. 26(17-18), 2913-2928.
7. IPCC (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, prepared by the National Greenhouse Gas Inventories Programme. IGES, Japan. Retrieved February 25, 2016, from http://www.ipcc-ggip.iges.or.jp/public/2006gl/.
8. Kasparinskis, R., Nikodemus, O., & Kārkliņš A. (2016, March). Ilgtspējīgas zemes resursu pārvaldības veicināšana, izveidojot digitālu augšņu datubāzi (Promoting of sustainable land resource management

creating of a digital database of soils). Retrieved February 28, 2016, from https://www.zm.gov.lv/public/ck/files/ZM/lauku_attistiba/zinatne/EEZ_FI_projekti_Raimonds%20Kasparinskis_augsnu%20datubaze_FINAL.pdf. (in Latvian).

9. Kārkliņš, A. (1996). Agroķīmija *(*Agricultural chemistry). Lekciju konspekts, II daļa. Rīga: Ražība, XVII nodaļa. (in Latvian).
10. Mandai, B., Pal, S., & Mandai, L.N. (1998). Effect of molybdenum, phosphorus, and lime application to acid soils on dry matter yield and molybdenum nutrition of lentil. *Journal of Plant Nutrition*. 21 (1), 139-147.
11. Moody, P.W., Aitken, R.L., & Dickson, T. (1995). Diagnosis of maize yield response to lime in some weathered acidic soils. In Date, R.A., et al. (Eds.) (1995). *Plant Soil Interactions at Low pH: Principles and Management*. Dordrecht: Kluwer Academic Publishers.
12. Nollendorfs, V. (2004). Augsnes jākaļķo regulāri (Soil limed regularly). *Vides vēstis*, 3 (68), 38-41. (in Latvian).
13. Pakalns, G. (2006). Agroķīmija Latvijā (Agricultural chemistry in Latvia). Rīga: Agroķīmisko pētījumu centrs. (in Latvian).
14. Pāvule, A. (2009, March). Cik ilgi augsne spēj tikai dot? (How long is the soil able only to give?) *AgroPols.* Retrieved February 28, 2016, from http://www.agropols.lv/?menu=110&numurs=328&newsid=63393. (in Latvian).
15. vanRoestel, J. (2014, March). The Value of Maintaining a Good Soil pH. Retrieved February 28, 2016, from http://www.perennia.ca/Fact%20Sheets/Other/Soils/Lime%20value%20factsheet.pdf.
16. Rosolem, C.A., Bicudo, S.J., & Marubayashi, O.M. (1995). Soybean yield and root growth as affected by lime rate and quality. In Date, R.A., et al. (Eds.) (1995) Plant Soil Interactions at Low pH: Principles and Management. Dordrecht: Kluwer Academic Publishers.
17. Soon, Y.K., & Arshad, M.A. (2005). Tillage and liming effects on crop and labile soil nitrogen in an acid soil. *Soil & Tillage Research*, 80, 23-33.
18. Štikāns, J. (1992). Augšņu kaļķošana un tās efektivitāte (Soil Liming and Its Effectivity). Latvijas Valsts Zemkopības ZPI Agra, Skrīveri, 278 lpp. (in Latvian).
19. Valkama, E., Salo, T., Esala, M., & Turtola, E. (2013). Nitrogen balances and yields of spring cereals as affected by nitrogen fertilization in northern conditions: A meta-analysis. *Agriculture, Ecosystems and Environment*, 164, 1-13.
20. Velthof, G., Barot, S., Bloem, J., Butterbach-Bahl, K., de Vries, W., Kros, J., Lavelle, P., Olesen, J.E., & Oenema, O. (2011). Nitrogen as a threat to European soil quality. *The European Nitrogen Assessment.* Retrieved February 28, 2016, from http://www.nine-esf.org/sites/nine-esf.org/files/ena_doc/ENA_pdfs/ENA_c21.pdf.
21. Vigovskis, J. (2014). Augsnes kaļķošanas nozīme (Role of soil liming). *Demonstrējumi augkopībā un lopkopībā 2014*, SIA Latvijas Lauku konsultāciju un izglītības centrs, Ozolnieki: LLKC, 27-29. lpp. (in Latvian).

THE EFFECT OF AGROECOLOGICAL FACTORS ON YIELD AND FLAVONOIDS CONTENT OF GLOBE ARTICHOKE

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Abstract
Artichokes (*Cynara cardunculus* L.) contain many minerals, vitamins, fibres, polyphenols. Environmental conditions and climate change on a global scale affects the overall agriculture and food supply. Composition of biological active compounds in plants depends on the climate and growing conditions, cultivar properties, plant development stage, harvesting time and other factors. The aim of research was to evaluate the effect of agroecological factors on yield and flavonoids content of globe artichoke. An experiment was carried out under open field conditions in Institute of Horticulture, in Pūre investigation fields during the vegetation period of 2014 and 2015. The experiment was arranged in two different soils: brown soil with residual carbonates and the soil strongly altered by cultivation. The yield and its quality were analyzed during the whole vegetation period. Higher yield was observed in the soil strongly altered by cultivation. The results showed tendency that the higher flavonoids content in artichoke heads was observed in 2014 than in 2015. Significant differences between flavonoid content per harvest time are observed in both soils.
Key words: soil, flavonoids, biochemical composition, *Cynara cardunculus.*

Introduction

Artichoke has a long history, it has been used as a herbal medicine plant in traditional medicine since Roman times (Christaki, Bonos, & Florou-Paneri, 2012). The globe artichoke (*Cynara cardunculus* var. *scolymus* (L.) Fiori), (Fam. *Asteraceae*) is widely distributed all over the world and especially in the South Europe, Middle East, North Africa, South America, United States and also in China (Pandino *et al*., 2013). The production of artichokes in the world has a tendency to increase by years. In Europe, they are mainly grown in Italy, which had the production of 547 799 tonnes in 2013. In Baltic countries, artichokes are commercially grown in Lithuania with the production of 100 tonnes in 2013 (http://faostat3.fao.org/download/Q/QC/E). In Latvia, artichokes are not grown on commercial scale, but only in home gardens. Globe artichoke is a perennial herbaceous plant. In Latvia, artichoke is cultivated mostly as an annual plant because winter periods are characterized with low soil and air temperature damaging plants. Long periods without snow or thaws are typical in the wintering period. It has a negative influence on plant overwintering ability (Bratch, 2014).

The edible part of the plant is immature inflorescence, commonly called capitulum or head. Artichoke heads are characterized by low protein and fat, high content of minerals, vitamins, carbohydrates, inulin and polyphenolic compounds (Kolodziej & Winiarska, 2010; Pandino *et al*., 2013). All these compounds have strong antioxidant properties, although their content varies between different artichoke varieties and plant parts (Ciancolini *et al*., 2013). Caffeoylquinic acid derivatives, particulary chlorogenic acid and flavonoids are the most common and widely distributed group of plant phenolic compounds in artichokes (Lombardo *et al*., 2010). They have an important role in human diet due to their antioxidative activity (Yao *et al*., 2004; Kumar & Pandey, 2013).

The aim of research was to evaluate the effect of agroecological factors on artichoke yield and flavonoids content of globe artichoke in Latvia.

Materials and Methods

The investigation was carried out in Pūre village (Tukums district, Latvia 57°2′9″N 22°54′25″E) in vegetation seasons of 2014 and 2015. At the beginning of March, artichoke variety 'Green Globe' seeds were germinated in Petri dishes on filter paper saturated with water. After 10 days, sprouts were planted in trays and then after two weeks transplanted in 12 cm diameter plastic pods. Two different soils were compared for artichoke growing: strongly altered by cultivation soil (Ant), with high content of nitrogen and phosphorus, low content of potassium (total N 0.21%, P_2O_5 – 352.1 mg·kg^{-1}, K_2O – 133.5 mg·kg^{-1} and organic matter 5.4%) and brown soil with residual carbonates (BRk), with optimal content of nitrogen, phosphorus and potassium (total N 0.10%, P_2O_5 – 190.4 mg kg^{-1}, K_2O – 191.8 mg·kg^{-1} and organic matter 2.8%). In the middle of May, plants were planted on the field, in 4 replicates, with planting scheme 0.7 × 0.9 m. Plant vegetative parameters (plant diameter and height) were evaluated at the end of July. The first artichoke heads were harvested at the end of July in 2014 and beginning of August in 2015. Artichoke heads were harvested continuously every week until October both years.

Meteorological parameters used in the investigation (precipitation and average air temperature) were collected by an automatic meteorological station 'Lufft' located in Pūre (Fig. 1.).

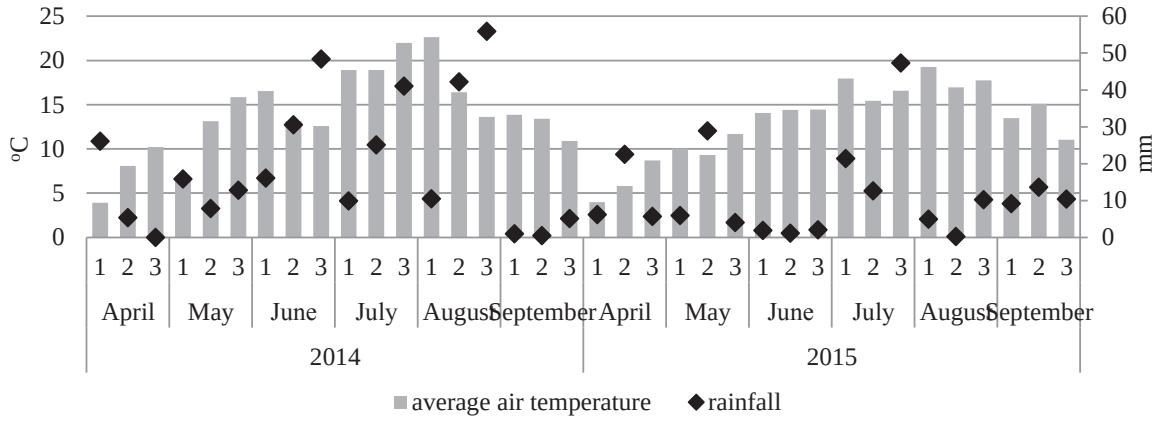


Figure 1. Meteorological parameters 2014/2015th season in decades.

Biochemical analyses were performed in Latvia University of Agriculture, Institute of Soil and Plant Sciences. The content of flavonoids was analysed spectrophotometrically (Shimadzu Spectrophotometer UV-18000) in three replicates (Kim *et al*., 2003). Average sample of artichoke heads from all replicates was blended and weighted 1 ± 0.01 g of sample. It was placed in a graduated tube filled up to 10 mL of ethanol and centrifuged (HermleZ383). 2 mL distilled water and 0.15 mL 5% sodium nitrite $NaNO_2$ were added to 0.5 mL aliquot of ethanolic artichoke extracts. After five minutes 0.15 mL 10% aluminium chloride $AlCl_3$ was added, again after five minutes 1 mL 1M sodium hydroxide NaOH was added and after fifteen minutes optical density of solution at 415 nm wavelength was determined. Results were expressed as mg catechin equivalent (CE) per 100 g of fresh mater (FM).

The results were analyzed using ANOVA at significance level of $\alpha = 0.05$.

Results and Discussion

Results show that yield per plant in both years ranged between 231 – 400 g (4 – 6 heads). Significant differences between years were not observed, but soils had a significant influence on artichoke yield ($p = 0.04$) (Fig. 2.).

Artichokes better grew and developed in strongly altered by cultivation soil than in brown soil with residual carbonates (Tab. 1.). This is in accordance to findings of others referring to the fact that artichokes better perform in the soils with higher concentrations of nutrients (Colla *et al*., 2013). Plants height and diameter were significantly higher ($p = 0.3 \times 10^{-2}$) in Ant than in BRk. In 2015, the plant developed much better than in 2014 (height difference – $p = 0.04$). For plant diameter, significant differences depending on soils and years were not observed.

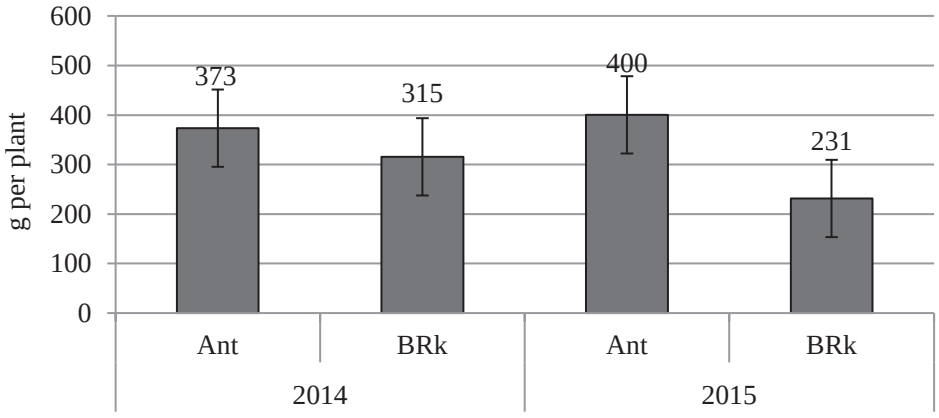


Figure 2. Yield of artichoke heads depending on soil, in 2014 and 2015.

Table 1

Plant vegetative parameters, 70 days after planting in 2014 and 2015

Year	Soil	Plant height, m	Plant diameter, m
2014	Ant	0.43	0.97
	BRk	0.29	0.82
2015	Ant	0.47	0.84
	BRk	0.38	0.74
$RS_{0.05}$		0.08	0.18

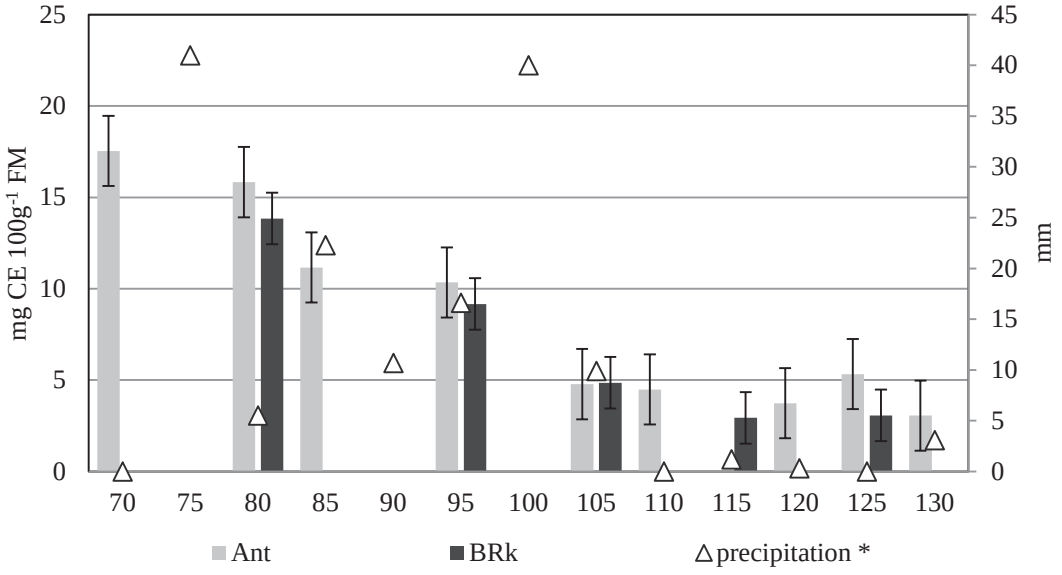
In the field located on strongly altered by cultivation soil organic matter was detected 5.4%. For many years different vegetables have been grown in this field, it was abundantly fertilized. In other field of brown soil with residual carbonates plants did not have so vigorous plant habit; plants also developed less heads.

In 2014, first artichoke heads were harvested in Ant soil on 28 July (70 days after planting). One week later first artichoke heads were harvested in BRk soil. Artichoke yield was harvested every week. The first decade of August characterized with low precipitation and high air temperature (22.7 °C). In this period heads developed faster and more intensively – heads were ready for cutting after 4 – 5 days.

The same tendency was in 2015 – first artichoke heads were harvested in Ant soil, on 3 August (67 days after planting). Similarly like in 2014, one week later first artichoke heads were harvested also in BRk soil. In the vegetation period of 2015, artichoke heads were harvested more rarely than in 2014. Although August and September also were dry, average air temperature was lower than in 2014 – heads were harvested once per week. Artichokes grow best at 25 °C daytime temperature (Bratch, 2014).

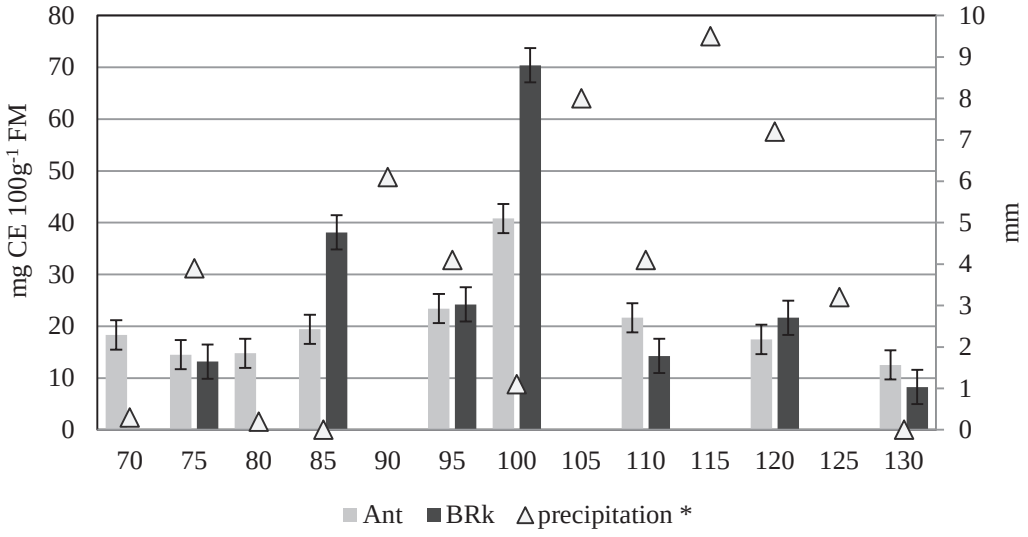
Abiotic factors (temperature, humidity, nutrients) have a significant influence on the nutritional quality of artichoke heads (Lombardo *et al*., 2010). They cause changes in the content of biochemically active compounds in the plants and following the artichoke heads. Results obtained in the trial show that flavonoids content in 2014 ranged between 3.1 – 17.5 mg catechin equivalent (CE) 100 g^{-1} fresh matter (FM) (Fig. 3.).

The content of flavonoids in the artichoke heads is fluctuating during the harvesting period in both soils – in Ant ($p = 4.89 \times 10^{-6}$) and in BRk ($p = 0.05 \times 10^{-2}$). There is an expressed tendency to decrease the flavonoid content in heads by the end of vegetation period almost by half. It should be stressed that 2014 was characterised with dry September. Probably it had some influence on the biochemical compounds of



* sum of precipitation of 5 previous days before of each harvest

Figure 3. The dynamic of flavonoids content in artichoke heads in relation to precipitation in 2014.



* sum of precipitation of 5 previous days before of each harvest

Figure 4. The dynamic of flavonoids content in artichoke heads in relation to precipitation in 2015.

artichoke. Drought is one of the main abiotic stresses limiting plant growth and development. Limited water supply is a major factor influencing physiological and metabolic processes in plant (Tahna, Ghasemnezhad, & Babaeizad, 2014). In Poland, researchers observed that irrigation positively influence flavonoids content in the plants (Kolodziej, & Winiarska, 2010).

According to our findings, air temperature had less influence on flavonoids content of artichoke heads. In both years of investigation, temperature regime was quite similar, although flavonoids content was different. In 2014, temperature was higher at the beginning of the vegetation period and gradually decreased by the end of harvesting period.

In 2015, the sharply expressed fluctuation of flavonoids content was detected for analysed artichoke heads in the trial. It ranged between 8.3 and 40.8 mg CE 100 g^{-1} FM (Fig. 4.)

Also, in 2015 similarly to 2014, differences between flavonoid content per harvest time were observed in both soils – in Ant ($p = 1.08 \times 10^{-6}$) and in BRk ($p = 6.83 \times 10^{-6}$). Although longer drought periods were registered in 2015 than in 2014, the content of flavonoids in the artichoke heads was notably higher, but more fluctuating. It is contrary to findings of others (Kolodziej and Winiarska, 2010). It can be assumed that fluctuating precipitation and less sum of precipitation in the whole vegetation period causes stress in plants which leads to increasing of physiologically active compounds in plants. Also Nakabayas et al., reported that synthesis of flavonoids increased in stress conditions (Nakabayashi *et al*., 2010). Obtained results do not show very clear relation of precipitation and flavonoids content, just some indications on possible positive influence of drought. There are also contrary reports of others on this topic (Salata, Gruszecki, & Dyducg, 2012).

In 2015, temperature was more fluctuation (Fig. 1), but in the same amplitude as in 2014 and with general tendency to decrease towards autumn. It is referred by others that air temperature and solar radiation influence accumulation of polyphenols in globe artichoke in different harvest times. Higher temperature positively influenced content of polyphenols (Pandino *et al*., 2013).

In California, artichoke plants were growing in the temperature amplitude from 13 to 24 °C in. Plants are tolerant of temperatures above 30 °C, but the quality of head reduced (Smith *et al*., 2008). In our conditions, temperature was much lower (mostly between +10 and +17 °C). It leads to the assumption that temperature conditions in our trial were under optimal; therefore, fluctuation in this amplitude has not significant influence on accumulation of flavonoids.

According to the findings of our trial performed in two years in Latvia agro-climatic conditions, we see that artichoke growing is possible and this region can be assumed as boundary of artichoke growing in Latvia, since yields are obtained much less than in Europe, but still there are some consumable heads harvested. Biochemical content also differs from artichoke grown in more southern locations. In Poland, it was observed that artichoke head weight was obtained between 150 – 350 grams and weather conditions influence the content of chemical compounds in artichoke heads (Salata, Gruszecki, & Dyducg, 2012). In Portugal, it was found that content of phenols in artichoke depends not only on growing conditions (Velez *et al*., 2012), but also on the physiological plant stage (Negro *et al*., 2012). This

is in line with our findings where common tendency to decrease the flavonoid content in artichoke heads with the plant age was found. We can assume that flavonoid content in artichoke head is detected not only by moisture availability in the soil, but also by other environmental and physiological factors.

Conclusions

Artichoke yield in strongly altered cultivation soil (Ant) was harvested one week earlier than in brown soil with residual carbonates (BRk) in both years. Higher artichoke head yield was obtained in Ant soil (373 and 400 g per plant) than in BRk (315 and 231 g per plant).

Our findings lead to the assumption that fluctuating precipitation and less sum of precipitation in the whole vegetation period causes stress in plants, which leads to increasing of flavonoids in plants. Temperature regime in Latvia agroecological conditions had no significant influence on the flavonoid content in artichoke plants. Flavonoid content in artichoke head is determined not only by precipitation, but also by other environmental and physiological factors.

Acknowledgement

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References

1. Bratch, A. (2014). *Specialty crop profile: globe artichoke*. Retrieved March 5, 2016, from http://pubs.ext.vt.edu/438/438-108/438-108_pdf.pdf.
2. Christaki, E., Bonos, E., & Florou-Paneri, P. (2012). Nutritional and functional properties of Cynara crops (globe artichoke and cardoon) and their potential application: a review. *International Journal of Applied Science and Technology*, 2 (2), 64-70.
3. Ciancolini, A., Alignan, M., Pagnotta, M.A., Miquel, J., Vilarem, G., & Crino, P. (2013). Morphological characterization, biomass and pharmaceutical compounds in Italian globe artichoke genotypes. *Industrial Crops and Products*, 49, 326-333. DOI: 10.1016/j.indcrop.2013.05.015.
4. Colla, G., Rouphael, Y., Cardarelli, M., Svecova, E., Rea, E., & Lucini, L. (2013). Effects of saline stress on mineral composition, phenolic acids and flavonoids in leaves of artichoke and cardoon genotypes grown in floating system. *Journal of the Science of Food and Agriculture*, 95(5), 1119-1127. DOI: 10.1002/jsfa.5861.
5. Kim, D., Chun, O., Kim, Y., Moon H., & Lee, C. (2003). Quantification of phenolics and their antioxidant capacity in fresh plums. *Journal of Agricultural. Food Chemistry*, 51(22), 6509-6515. DOI: 10.1021/jf0343074.
6. Kołodziej, B., & Winiarska, S. (2010). The effect of irrigation and fertigation in artichoke (*Cynara cardunculus* L . ssp. *flavescens* Wikl.) culture. *Kerva Polonica*, 56(3), 7-14.
7. Kumar, S., & Pandey, A.K. (2013). Chemistry and biological activities of flavonoids: an overview. *Scientific World Journal*, 39, 1-16.
8. Lombardo, S., Pandino, G., Mauromicale, G., Knodler, M., Carle, R., & Schieber, A. (2010). Influence of genotype, harvest time and plant part on polyphenolic composition of globe artichoke (*Cynara cardunculus* L. var. *scolymus* (L.) Fiori). *Food Chemistry*, 119(3), 1175-1181. DOI: 10.1016/j.foodchem.2009.08.033.
9. Nakabayashi, R., Yonekura-Sakakibara, K., Urano, K., Matsuda, F., Kojima, M., Shinozaki, K., Tohge, T., Yamazaki, M., & Saito, K. (2010). *A novel function of flavonoids for abiotic stress tolerance*. Retrieved March 5, 2016, from https://www.arabidopsis.org/servlets/TairObject?type=publication&id=501737777.
10. Negro, D., Montesano, V., Grieco, S., Crupi, P., Sarli, G., De Lisi, A., & Sonnante, G. (2012). Polyphenol compounds in artichoke plant tissues and varieties. *Journal of Food Science*, 77(2), 244-252. DOI: 10.1111/j.1750-3841.2011.02531.
11. Pandino, G., Lombardo, S., Monaco, A., & Mauromicale, G. (2013). Choice of time of harvest influences the polyphenol profile of globe artichoke. *Journal of Functional Foods*, 5(4), 1822-1828. DOI: 10.1016/j.jff.2013.09.001.
12. Salata, A., Gruszecki, R., & Dyducg, J. (2012). Morphological and qualitative characterization of globe artichoke (*Cynara scolymus* L.) cultivars ‘Symphony’ and ‘Madrigal’ on depending of the heads growth. *Acta Science Polonorum Hortorum Cultus*, 11(5), 67-80.
13. Smith, R., Baameur, A., Bari, M., Cahn, M., Giraud, D., Natwick, E., & Takele, E. (2008). *Artichoke production in California*. Retrieved March 5, 2016, from http://anrcatalog.ucanr.edu/.
14. Tanha, S.R., Ghasemnezhad, A., & Babaeizad, V. (2014). A study on the effect of endophyte fungus, Piriformospora indica, on the yield and phytochemical changes of globe artichoke (*Cynara scolymus* L.)

leaves under water stress. *International Journal of Advanced Biological and Biomedical Research*, 2(6), 1907-1921.

15. Velez, Z., Camphino, M.A., Guerra, A.R., Garcia, L., Ramos, P., Guerreiro, O., Felicio, L., Schmit, F., & Duarte, M. (2012). Biological characterization of *Cynara cardunculus* L. methanolic extracts: antioxidant, anti-proliferative, anti-migratory and anti-angiogenic activities. *Agriculture*, 2(4), 472-492. DOI: 10.3390/agriculture2040472.
16. Yao, L.H., Jiang, Y.M., Shi, J., Tomas-Barberan, F.A., Datta, N., Singanusong, R., & Chen, S.S. (2004). Flavonoids in food and their health benefits. *Plant Foods for Human Nutrition*, 59(3), 113-122.

EFFECT OF CONFORMATION TRAITS ON LONGEVITY OF DAIRY COWS IN LATVIA

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Abstract
Cow lifespan is one of most important economical traits in every dairy farm and is affected by different environmental factors. One of genetic factors that affects longevity is cow conformation traits, which varies within different breeds, farms and animals. The aim in this study was to determine how stature and linear conformation traits affect cow lifespan and lifetime milk productivity. In the study, data about 34806 crossbred Holstein Black and White and 38201 Red cow group breed cows, which ended at least one full lactation and was culled from 2002 – 2012 year were analyzed. Data about cow productivity and culling was obtained from Latvian Agricultural Data center. In the study, data about cow stature, udder depth, central ligament, teat length, and rear and front teat placement were analyzed. Conformation traits were distributed in 3 groups. The average lifespan of analyzed cows was 1869.9 days in which average 18550.8 kg energy corrected milk (ECM) was obtained. Holstein Black and White cows characterize with shorter lifespan (1833.7 days) than red breed group cows, but lifetime productivity is for 2339.1 kg ECM higher than for average red breed cow. Significantly longer ($p<0.05$) lifespan – 2031.6 days was in cow group with stature 100 – 135 cm, but in cow group with stature more than 146 cm there is significantly higher lifetime and life day productivity. There is a significant difference between lifetime milk productivity and rear and front teat placement. Significantly higher productivity was given by cows with teat placement inside of quarter (linear evaluation 6- 9 points).
Key words: conformation traits, longevity, milk productivity.

Introduction

The term 'longevity' is usually referred to lifespan which ends by natural causes in old age, but nowadays in our intensive farming systems cow lifespan is significantly shorter than its potential. There is a significant amount of costs that covers heifer rearing process, and there is a possibility to avoid them by increasing herd lifespan. Breeders in many countries have recognized the economic importance of longevity, have calculated genetic parameters of longevity and have included them in dairy cattle breeding programs. Cow longevity is mainly affected by different environmental factors – herd management, feeding conditions, housing conditions etc., but there are cow genetic factors that affect cow potential lifespan as well. One of genetically lifespan determined factors is cow conformation traits – mainly those affecting udder. The relationship between conformation traits and cow longevity were analyzed in different populations, authors have reported that some traits are significantly related to longevity (Short & Lawlor, 1992; Larroque & Ducrocq, 2001; Schneider *et al*., 2003; Sewalem *et al*., 2004). In Latvia, Holstein Black and White breed cattle constitute approximately half of all dairy cow population. Red breed cows are more resistant to different farm obstacles and they easier adjust to new conditions than Holstein Black and White breed cows. Holstein Black and White cows genetically are bigger than Latvian Brown breed or other red breed cows; the breeding goals in Latvian cow breeding program are: average stature – 145 cm for red breed group cows and 150 cm for Holstein Black and White cows. In Latvia, cow conformation traits are evaluated by linear evaluation method in a 9 point scale. For different udder traits, optimal evaluation value is determined 5 pints (for central ligament 6 points).

Different studies determined that udder conformation traits significantly affect somatic cell count in milk, and milk quality is one of factors that affects cow life length. (Dube *et al*., 2008; Dadpassand *et al*., 2013). In Ral and his collagues study, the higher somatic cell count was determined for cows with udder evaluation of 1 – 5 points (udder below hock), whereas Latvian Brown cow breed characterizes with low, pendulous udder and long teat (Ral *et al*., 1990). Holstein Black and White breed cows characterize with well-made udder, short teat, and strong central ligament; udder traits impair as cow gets older (Zavadilová, Němcová, & Stípková, 2011).

The main objective of this study was to determine how different conformation traits affect Holstein Black and White and Red cow breed cow longevity and lifetime productivity.

Materials and Methods

In the study, data about 73 007 dairy cows culled in time period from 2002 to 2012 and finished at least one full lactation were included. The data were obtained from Latvian Agricultural data center, which operates the national recording scheme. Cows were distributed in 2 different groups depending on breed – Holstein Black and White cows (purebred and crossbred, N = 38201) and Red breed group cows (N = 34806). In Red breed group, Latvian Brown (local breed), Latvian Brown crossbred cows with 60 to 95% LB ancestry, and Danish Red, Angeln,

Table 1

Summary statistics for conformation traits and its optimal values

Type trait	n		Min (1)	Optimal	Max (9)
Stature	73007	141.6 ± 0.02	×	×	×
Udder depth	73006	6.9 ± 0.01	Below hock	5	Shallow
Central ligament	73005	4.9 ± 0.01	Weak	6	Strong
Teat length	73003	6.0 ± 0.01	Short	5	Long
Front teat placement	73006	4.7 ± 0.01	Outside of quarter	5	Inside of quarter
Rear teat position	73005	5.6 ± 0.01	Outside of quarter	5	Inside of quarter

Table 2

Distribution of cows depending on linear evaluation score of conformation traits

Type trait	1 group	2 group	3 group
Udder depth	1 – 4	5	6 – 9
Central ligament	1 – 5	6	7 – 9
Teat length	1 – 4	5	6 – 9
Front teat placement	1 – 4	5	6 – 9
Rear teat position	1 – 4	5	6 – 9
Stature	100 – 135 cm	136 – 145 cm	>146 cm

Aishere, Swedish Red and White, Swiss, Holstein Red and White cows were included.

Means, standard errors, min and max values for conformation traits of dataset and conformation traits optimal values are shown in Table 1.

There is large variation between traits score, in each group linear score varies from 1 to 9 points independent from traits optimal value. The optimal value for practically all udder conformation traits is 5 points except udder ligament; there optimal value is 6 points.

To evaluate and compare cow productivity in the study, we used energy corrected milk (ECM), which was calculated by formula:

$$ECM = milk\ yield \times \times \frac{(0.383 \times fat\ content,\%) + (0.242 \times protein\ content,\%) + 0.7832}{3.14} \quad (1)$$

To evaluate cow lifespan and lifetime productivity, cows were distributed in 3 different groups depending on analyzed type trait. The second group always was the optimal value of type trait (Table 2).

For the statistical analyses of influence of conformation traits groups to the lifespan and lifetime milk productivity, analysis of variance (ANOVA) was performed. Bonferroni's pairwise comparisons test was used to analyse the differences between factors groups. Differences were considered statistically significant when $p<0.05$. Significant differences ($p<0.05$) in the tables were marked with different superscripted letters of alphabet (A, B, C, etc.). The mathematical processing was performed using the SPSS for Windows, version 15.

Results and Discussion

Cow longevity and lifetime productivity depend not only on different environmental factors, but also it is affected by cow breed. The Black and White breed cows have shorter lifespan than Red breed group cows, but the level of productivity not only in life, but as well in one life day is larger for Holstein Black and White cows. The average productivity for all in the study included dairy cows was 18550.8 kg energy corrected milk (ECM) in 1869.9 life days (5.12 years) (Table 3).

The lifespan of Red breed cows was 1903.0 days long, but for Holstein Black and White cows it was 70 days shorter. The difference between lifetime productivity of Red breed cows and Holstein breed cows was more than 2300 kg ECM. The same tendency occurred within life day productivity. There is a large variation between cow lifetime productivity traits, because cows are located in different farms and farms have different cows feeding and housing conditions, and different levels of productivity.

Table 3

Average longevity and milk productivity of cows

Traits		Min	Max	V, %
Total (N = 73007)				
Lifespan, days	1869.9 ± 2.06	786	4058	29
Lifetime productivity, kg	18550.8 ± 42.24	1488	98524	61
Life day productivity, kg	9.3 ± 0.01	0.6	29.9	40
Red cow breed (N = 34806)				
Lifespan, days	1903.0 ± 2.89	768	4050	29
Lifetime productivity, kg	17435.6 ± 54.1	1488	90132	60
Life day productivity, kg	8.5 ± 0.01	0.6	23.5	39
Holstein Black and White (N = 38201)				
Lifespan, days	1833.7 ± 2.93	845	4058	29
Lifetime productivity, kg	19774.7 ± 65.09	1560	98524	61
Life day productivity, kg	10.1 ± 0.02	1.0	29.9	40

The lifetime productivity range is from 1488 to 90132 kg ECM for Red cow breed and from 1560 to 98524 kg ECM for Holstein Black and White breed.

The stature is one of the conformation traits that shows cows' postnatal growth and is affected by cow's genetic potential. The longer lifespan (2031.6 days) had cows with stature 100 – 135 cm, and it was significantly ($p<0.05$) higher than in cows groups with stature 136 cm and higher (Table 4).

The lifetime productivity was obtained in cow group with stature 136 – 175 cm (18624.5 – 18826.1 kg ECM), but in one life day milk productivity significantly increased with cow stature. In different studies cow stature is a factor which significantly affects cow productivity (Short *et al*., 1992; DeGroot *et al*., 2002; Němcová *et al*., 2011). Udder conformation traits: udder depth and central ligament are associated with udder health problems, including different traumas as udder is unprotected and high somatic cell count in milk (Samoré *et al*., 2010). In our study, it was obtained for cows with drooping udder average lifespan (2041.8 days) and it is significantly longer than for cows with udder located close to the body (1865.7 days). The lifetime milk productivity was significantly lower for cows whose udder was evaluated with 1 – 5 points, but significantly higher lifetime milk productivity was for cows with udder located close to body (18612.0 kg in lifetime and 9.3 kg ECM in one life day). Central ligament is a trait that is responsible for the udder composition and teat

Table 4

Longevity and lifetime productivity depending on stature, udder depth and central ligament

Group**	N	Lifespan, days	Lifetime productivity, kg	Life day productivity, kg
Stature, cm				
100 – 135 cm	10163	2031.6 ± 6.04^{A}	17751.5 ± 108.16^{A}	8.1 ± 0.03^{A}
136 – 145 cm	45534	1869.6 ± 2.59^{B}	18624.5 ± 53.58^{B}	9.3 ± 0.02^{B}
146 – 175 cm	17310	1775.9 ± 3.88^{C}	18826.1 ± 88.41^{B}	9.9 ± 0.03^{C}
Udder depth				
1 – 4	584	2041.8 ± 25.61^{A}	16815.2 ± 440.77^{A}	7.6 ± 0.13^{A}
5	2256	1956.5 ± 12.60^{B}	17096.6 ± 228.98^{A}	8.1 ± 0.07^{B}
6 – 9	70167	1865.7 ± 2.09^{C}	18612.0 ± 43.16^{B}	9.3 ± 0.01^{C}
Central ligament				
1 – 5	61180	1873.7 ± 2.25^{A}	18592.9 ± 46.17^{A}	9.3 ± 0.01^{A}
6	9773	1861.2 ± 5.67^{A}	18567.0 ± 116.47^{A}	9.3 ± 0.03^{A}
7 – 9	2054	1799.8 ± 11.39^{B}	17223.6 ± 234.26^{B}	8.9 ± 0.08^{B}

**Cows divided by groups, depending on linear evaluation score of different type traits.

Table 5

Average longevity and lifetime productivity depending on different udder conformation traits

Group**	N	Lifespan, days	Lifetime productivity, kg	Life day productivity, kg
Teat length				
1 – 4	7078	1908.4 ± 7.00^{A}	17560.8 ± 132.28^{A}	8.6 ± 0.04^{A}
5	17348	1899.7 ± 4.36^{A}	18198.6 ± 85.12^{B}	9.0 ± 0.02^{B}
6 – 9	48581	1853.7 ± 2.45^{B}	18820.1 ± 52.24^{C}	9.5 ± 0.01^{C}
Front teat placement				
1 – 4	11589	1869.6 ± 5.46^{A}	16894.5 ± 100.16^{A}	8.5 ± 0.03^{A}
5	17118	1890.0 ± 9.32^{B}	18338.1 ± 85.99^{B}	9.1 ± 0.03^{B}
6 – 9	44300	1862.3 ± 2.59^{A}	19066.4 ± 55.07^{C}	9.6 ± 0.02^{C}
Rear teat position				
1 – 4	20792	1878.6 ± 3.88^{A}	18318.0 ± 72.70^{A}	9.1 ± 0.03^{A}
5	49378	1865.3 ± 2.50^{B}	18559.4 ± 51.53^{B}	9.3 ± 2.50^{B}
6 – 9	2837	1888.3 ± 10.35^{AB}	20107.7 ± 228.17^{C}	10.0 ± 0.07^{C}

**Cows divided by groups, depending on linear evaluation score of different type traits.

placement and angle towards ground. If the central ligament is optimally evaluated with 6 points, it means that teats are parallelly placed. The lifespan was longer for cows with average central ligament evaluation 1 – 6 points, but if ligament is too strong (evaluation 7 – 9 points), cow lifespan was shorter by 72 days. The

Table 6

Longevity and milk productivity of cows within different breeds depending on different conformation traits

Group**	Breed	N	Lifespan, days	Lifetime productivity, kg	Life day productivity, kg
Stature					
100 – 135 cm	HM*	1268	1989.5 ± 17.58^{A}	18230.3 ± 327.89^{A}	8.5 ± 0.10^{A}
136 – 145 cm	HM*	20474	1854.5 ± 3.88^{B}	19953.2 ± 85.48^{B}	10.0 ± 0.03^{B}
146 – 175 cm	HM*	13064	1786.0 ± 4.53^{C}	19644.9 ± 105.3^{B}	10.3 ± 0.03^{B}
100 – 135 cm	RB*	8895	2037.6 ± 6.43^{A}	17683.3 ± 114.39^{A}	8.1 ± 0.03^{A}
136 – 145 cm	RB*	25060	1882.0 ± 3.48^{B}	17538.9 ± 67.05^{A}	8.7 ± 0.03^{B}
146 – 175 cm	RB*	4246	1783.5 ± 4.35^{C}	16306.7 ± 151.46^{B}	10.3 ± 0.03^{C}
Udder depth					
1 – 4	HM*	153	1978.8 ± 48.29^{A}	16824.2 ± 873.92^{A}	7.8 ± 0.28^{A}
5	HM*	762	1940.3 ± 21.62^{A}	18450.4 ± 435.72^{B}	8.8 ± 0.14^{B}
6 – 9	HM*	33891	1830.6 ± 2.96^{B}	19818.0 ± 65.99^{C}	10.1 ± 0.02^{C}
1 – 4	RB*	431	2064.0 ± 30.13^{A}	16811.9 ± 10.20^{AB}	7.5 ± 0.15^{A}
5	RB*	1494	1964.8 ± 15.52^{B}	16406.1 ± 263.22^{A}	7.8 ± 0.08^{A}
6 – 9	RB*	36276	1898.5 ± 2.95^{C}	17485.4 ± 55.64^{B}	8.6 ± 0.02^{B}
Central ligament					
1 – 5	HM*	29054	1836.2 ± 3.20^{A}	19831.8 ± 71.37^{A}	10.1 ± 0.02^{A}
6	HM*	4746	1834.1 ± 8.10^{A}	19830.4 ± 177.28^{A}	10.1 ± 0.06^{A}
7 – 9	HM*	1006	1758.4 ± 15.99^{B}	17876.1 ± 346.84^{B}	9.5 ± 0.01^{B}
1 – 5	RB*	32126	1907.6 ± 3.16^{A}	17472.5 ± 59.02^{A}	8.5 ± 0.01
6	RB*	5027	1886.8 ± 7.93^{B}	17374.5 ± 150.59^{A}	8.6 ± 0.04
7 – 9	RB*	1048	1839.5 ± 16.11^{B}	16597.2 ± 315.05^{B}	8.4 ± 0.10

*HM – Holstein Black and White, RB – Red breed group cows
**Cows divided by groups, depending on linear evaluation score of different type traits.

same tendency was observed in lifetime productivity and one life day productivity. The significant effect of central ligament and udder depth on cow lifespan and lifetime productivity occurred in studies that covered different cow breeds (Moore *et al*., 1998).

The teat length and placement are traits which need to be corrected by breeders, because of new milking technologies that change every few years. Cows whose conformation traits do not comply with milking technology are culled from herds and more technology appropriate cows are kept for breeding purposes. (Mrode, Swanson, & Winters, 1998; Ptak *et al*., 2009) The Teat length negatively influences milking characteristics and potentially udder health and, as a result, influences the cows' longevity (Table 5).

The significantly longer productive life (1899.7 - 1908.4 days) occurred in a cow group with average teat length evaluation 1 – 5 points, but in those groups there were significantly lower lifetime milk production and life day milk production. Front and rear teat placement mainly affects milking process (Samoré *et al*., 2010). Significantly longer lifespan occurred within a cow group with optimal front teat placement, but productivity wise cows in this group characterized with second lowest lifetime milk productivity and life day milk productivity (18338.1 and 9.1 kg ECM). Significantly longer lifespan and higher life and life day milk productivity was for cows with rear teat evaluation 6 – 9 points. There are differences between longevity traits not only between type trait groups, but also between different breeds (Table 6).

Holstein Black and White cows characterize with shorter lifespan, but lifetime productivity and productivity in one life day shows that they are more productive than Red breed group cows. Latvia Holstein Black and White cows are usually bigger than Red breed group cows. In analyzed populations, the number of Holstein Black and White cows with stature more than 146 cm is around 25% larger than the number of Red breed cows.

The longer lifespan in Holstein Black and White cow group was for cows with stature at least 135 cm (1989.5 days), but in this group the lowest lifetime and life day productivities are detected. Average stature 136 – 145 cm ensure lifespan of 1854.5 days with

Table 7

Udder teat type trait effect on different breed cow lifespan and milk productivity

Group**	Breed	N	Lifespan, days	Lifetime productivity, kg	Life day productivity, kg
Teat length					
1 – 4	HM*	3216	1866.4 ± 10.08^{A}	18511.0 ± 203.64^{A}	9.2 ± 0.06^{A}
5	HM*	7838	1851.4 ± 6.31^{A}	19624.9 ± 135.39^{B}	9.9 ± 0.04^{B}
6 – 9	HM*	23752	1823.4 ± 3.49^{B}	19994.5 ± 79.57^{C}	10.2 ± 0.06^{C}
1 – 4	RB*	3862	1943.5 ± 9.67^{A}	16769.6 ± 172.25^{A}	8.0 ± 0.05^{A}
5	RB*	9510	1939.6 ± 5.99^{A}	17023.0 ± 106.48^{B}	8.2 ± 0.03^{AB}
6 – 9	RB*	24829	1882.6 ± 3.49^{B}	17696.5 ± 67.45^{C}	8.7 ± 0.02^{B}
Front teat placement					
1 – 4	HM*	4628	1788.9 ± 8.22^{A}	18128.5 ± 166.44^{A}	9.5 ± 0.06^{A}
5	HM*	7372	1835.6 ± 6.44^{B}	19449.4 ± 138.98^{B}	9.9 ± 0.04^{AB}
6 – 9	HM*	22806	1942.1 ± 3.58^{C}	20214.0 ± 81.70^{C}	10.3 ± 0.03^{B}
1 – 4	RB*	6961	1923.2 ± 7.20^{A}	16074.2 ± 123.76^{A}	7.7 ± 0.01^{A}
5	RB*	9746	1931.2 ± 5.79^{A}	17497.5 ± 107.68^{B}	8.5 ± 0.03^{AB}
6 – 9	RB*	21494	1883.6 ± 3.74^{B}	17848.7 ± 72.35^{C}	8.9 ± 0.02^{B}
Rear teat position					
1 – 4	HM*	9819	1832.9 ± 5.49	19574.2 ± 120.00^{A}	10.0 ± 0.04
5	HM*	23316	1832.8 ± 3.59	19755.8 ± 79.85^{A}	10.1 ± 0.02
6 – 9	HM*	1671	1850.8 ± 13.17	21212.9 ± 313.62^{B}	10.7 ± 0.10
1 – 4	RB*	10973	1919.5 ± 5.43^{A}	17193.2 ± 99.50^{A}	8.3 ± 0.03
5	RB*	26062	1844.3 ± 65.84^{B}	17489.1 ± 65.84^{A}	8.6 ± 0.02
6 – 9	RB*	1166	1941.8 ± 16.54^{A}	18523.8 ± 320.27^{B}	8.9 ± 0.10

*HM – Holstein Black and White, RB – red breed group cows
**Cows divided by groups, depending from linear evaluation score of different type traits.

significantly higher lifetime and life day productivity (19953.2 and 10.0 kg ECM). In Red cow breed group highest life day productivity occurred in the group with stature more than 146 cm, but in this cow group there is the shortest lifespan and lifetime productivity. Udder depth grow with the cows age and depend on cows productivity. The lifespan of Holstein Black and White and Red cow breed cows is longer when udder depth in first lactation is evaluated with 1 – 4 points (udder is deep), but in this group there is significantly lower lifetime and life day productivity. There are not significant differences between longevity traits within central ligaments groups with optimal evaluation point score and within cow group with ligament evaluation 1 – 5 points (udder central ligament is weak and little expressed), in those groups occurred longest lifespans and largest lifetime and life day productivities. The results of different studies show that udder depth and central ligament are factors that have statistically significant correlation with lifespan and cow lifetime productivity (DeGroot *et al*., 2002; Caraviello, Weigel, & Gianola, 2004; Němcová *et al*., 2007).

Red cow breed cows usually are characterized with longer teat in our study −7838 (22%) Holstein Black and White cow and 9510 (23%) and Red breed cow teats were evaluated with optimal 5 points (Table 7).

Average lifespan is significantly shorter in cow groups with teat length evaluation 6 – 9 points (teats are longer than in average population), but in those groups larger lifetime and life day productivity occurred. Front teat placement results differ between two breed groups. In Holstein Black and White cow group, longer lifespan with more productivity in one life day and in lifetime occurred in a cow group with front teat placement 6 – 9 points (teats located closer, into the quarter), but in Red cow breed group lifespan longer was in the group with front teat evaluation 1 – 4 points (teats are versed to outside, located outside quarter), but in this group, significantly lower lifetime and life day productivity occurred. Rear teat placement significantly affects cow lifetime productivity, the largest amount of ECM was obtained in the cow group with evaluation score 6 – 9 points.

Conclusions

1. Average lifespan of Holstein Black and White cows were 1903.0 days with average lifetime productivity 17435.6 kg ECM, but in Red breed group average lifespan was 1835.7 days with 19774.7 kg ECM.
2. Holstein cow lifespan was significantly affected by all analyzed udder type traits and cow stature ($p<0.05$). The longest lifespan in almost all type traits (except front and rear teat placement) was in cow groups with linear evaluation score less than optimal.
3. Lifetime and one life day productivity were significantly ($p<0.05$) affected by all analyzed traits and it was higher for cows with type trait linear evaluation scores above optimal.
4. Udder central ligament linear evaluation score showed less impact on cow lifespan and lifetime productivity traits within Holstein Black and White and Holstein Red and White breed groups.

References

1. Caraviello, D.Z., Weigel, K.A., & Gianola, D. (2004). Analysis of the relationship between conformation traits and functional survival in US Holstein cattle using a Weibull proportional hazards model. *Journal Dairy Science*, 87, 2677-2686. DOI: 10.3168/jds.S0022-0302(04)73394-9.
2. Dadpasand, M., Zamiri, M.J., Akhlaghi, A., & Atashi, H. (2013). Genetic relationship of conformation traits with average somatic cell score at 150 and 305 days in milk in Holstein cows of Iran. I*ranian Journal of Veterinary Research, Shiraz University*, 95(12), 7340-7345. DOI: 10.3168/jds.2011-5002.
3. DeGroot, B.J., Keown, J.F., Van Vleck, L.D., Marotz, E.L. (2002). Genetic parameters and responses of linear type, yield traits, and somatic cell scores to divergent selection for predicted transmitting ability for type in Holsteins. *Journal of Dairy Science*, 85, 1578-1585.
4. Dube, B., Dzama, K., & Banga, C.B. (2008). Genetic analysis of somatic cell score and udder conformation traits in South African Holstein cows. *South African Journal of Animal Science*, 38, 1-11. DOI: 10.4314/sajas.v38i1.4102.
5. Larroque, H., Ducrocq, V. (2001). Relationships between type and longevity in the Holstein breed. *Genetic Selection and Evolution*, 33, 39-59. DOI: 10.1186/1297-9686-33-1-39
6. Moore, R.K., Higgins, S., Kennedy, B.W., & Burnside, E.B. (1998). Relationships of teat conformation and udder height to milk flow rate and milk production in Holsteins. *Canadian Journal of Animal Science*, 61, 493-501. DOI: 10.4141/cjas81-059.
7. Mrode, R.A., Swanson, G.J.T., Winters, M.S. (1998). Genetic parameters and evaluations for somatic cell counts and its relationship with production and conformation traits in some dairy breeds in the United Kingdom. *Animal Science*, 66, 569-576. DOI: 10.3168/jds.2011-5002.
8. Němcová, E., Štípková, M., Zavadilová, L. (2011). Genetic parameters for linear conformation traits in Czech Holstein cattle. *Czech Journal of Animal Science*, 56, 157-162. DOI: 10.17221/8730-CJAS.

9. Němcová, E., Štípková, M., Zavadilová, L., Bouška, J., & Vacek, M. (2007). The relationship between somatic cell count, milk production and six linearly scored conformation traits in Holstein cows. *Czech Journal of Animal Science,* 52, 437-446. DOI: 10.3168/jds.2011-5002.
10. Ptak, E., Jagusiak, W., Żarnecki, A., & Otwinowska-Mindur, A. (2009). Relationship between somatic cell score and udder conformation traits in Polish Holstein-Friesian cows. *Annual Animal Science,* 9, 237-241. DOI: http://dx.doi.org/10.5713/ajas.13.0627.
11. Ral, G., Berglund, B., Philipsson, J., Emanuelson, U., Tengroth, G. (1990). Comprehensive experiments on traits affecting longevity in Swedish dairy cattle breeds. 3. Teat, udder and milkability traits effects of breed and age repeatabilities and correlations. *Swedish Journal of Agricultural Research,* 52, 89-95.
12. Samoré, A.B., Rizzi, R., Rossoni, A., & Bagnato, A. (2010). Genetic parameters for functional longevity, conformation traits, somatic cell scores, milk flow and production in the Italian Brown Swiss. *Italian Journal of Animal Science* 9, 145-151. DOI: 10.4081/ijas.2010.e28.
13. Schneider, M.P., Durr, J.W., Cue, R.I., & Monardes, H.G. (2003). Impact of conformation traits on functional herd life of Quebec Holsteins assessed by survival analysis. *Journal of Animal Science,* 86, 4083-4089. DOI: 10.3168/jds.S0022-0302(03)74021-1.
14. Sewalem, A., Kistemaker, G.J., Miglior, F., & Van Doormaal, B.J. (2004). Analysis of the relationship between conformation traits and functional survival in Canadian Holsteins using a Weibull proportional hazards model. *Journal of Dairy Science,* 87, 3938-3946. DOI: 10.3168/jds.S0022-0302(03)74021-1.
15. Short, T.H., & Lawlor, T.J. (1992). Genetic parameters of conformation traits, milk yield and herd life in Holsteins. *Journal of Dairy Science,* 75, 1987-1998. DOI: 10.3168/jds.S0022-0302(92)77958-2.
16. Zavadilová, L., Němcová, E., & Stípková, M. (2011). Effect of conformation traits on functional longevity of Czech Holstein cows estimated from a Cox proportional hazards model. *Journal of Dairy Science,* 94(8), 4090-4099. DOI: 10.3168/jds.2010-3684.

ANALYSIS OF HEIRERS REARING FROM DIFFERENT LACTATION DAIRY COWS

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Abstract
The research was conducted in Latvia University of Agriculture Research and Study Farm 'Vecauce' in 600 dairy cows herd, in the period from 2009 to 2013. Within the framework of the research, growth indicators (from birth till the first delivery) of 102 dairy cow calves were analysed. Live weight and hip height of the heifers were found out at birth, at the age of 6 and 12 months, at first insemination and first calving. Heifers born to primiparous cows in both breed groups had notably lower live weight (42.0 and 42.4 kg), as compared to the 4th group heifers born to mature cows ($p<0.05$). At the age of one year, the greatest weight among the red breed animals was recorded for the 4th group heifers born to mature cows (on average 354.8 ± 7.09 kg), while in Holstein breed those were heifers born to mothers calving on average for the 2nd time (on average 363.0 ± 6.47 kg). The 4th group heifers born to mature Holstein cows had notably greater hip height at birth – on average 78.1 ± 0.9 cm ($p<0.05$). Heifers of red and Holstein breeds on average were inseminated at the age of 14.6 – 14.8 months as they reached live weight 395 – 396.5 kg. Heifers of red breeds on average calved at the age of 25.8 months, whereas Holstein heifers - of 26.4 months. The research aimed at analysing growth rates of heifers born to dairy cows at different age.
Key words: heifers, weight, hip height, insemination age, calving age.

Introduction

Under intensive framing, dairy cows on average are used for 2 – 3 lactations (Maia *et al*., 2013; Jouzaitiene *et al*., 2015). As a result, one third of calves is born to primiparous cows, which are not grown-ups yet. Newborn calves born to primiparous cows often are smaller than calves born to older cows (Pietersma *et al*., 2006; Kamal *et al*., 2014). Several researches conducted prior show that live weight of calves at birth affects further growth and development thereof (Arthington *et al*., 2000), whereas live weight of newborn calves is influenced by several factors, e.g., breed, calving season, nutrition of mother, health status, etc. Suitable breeding of heifer is a precondition for healthy and highly-productive cattle used for herd restocking or expansion. Optimal breeding of calves reduces costs, by ensuring high productivity, reproduction, and long cattle life (Raguz *et al*., 2011). Development of calves at various rearing periods differs; it is influenced by calve's physiological characteristics, housing and nutrition conditions. Insufficiently nourished heifers lag behind in growth, thus first insemination thereof will be delayed, whereas overfed heifers have lower conception indicators, and they may have difficult delivery (Vacek *et al*., 2015). The research aimed at analysing breeding indicators (till the first delivery) of different breeds heifers born to dairy cows at different age.

Materials and Methods

The research was conducted in Research and Study Farm 'Vecauce' of Latvia University of Agriculture in a herd consisting of 600 dairy cows. Heifers were bred under the same conditions, by separating them till the age of three months and grouping afterwards. The research period covered the time period from 2009 to 2013. During the period, 147 heifers were born, 45 of them were excluded from the research due to various reasons. In the red breed group 53.3% of heifers were excluded, and in Holstein group – 46.7%. Out of the heifers excluded 27% were born to primiparous cows and cows in their 3rd lactation, 24% – to cows in their 4th lactation, and 22% – to cows in their 2nd lactation.

Dairy cows were grouped by the number of calving times, but newborn heifers – were grouped by a breed or breed group (Table 1).

Table 1

Research scheme

Group No	Calving time	Number of newborn calves	Breed or breed group of newborn calves			
			Red breeds, n	%	Holstein breed, n	%
1.	1st	27	9	19.6	18	32.1
2.	2nd	28	13	28.2	15	26.8
3.	3rd	26	12	26.1	14	25.0
4.	4th and up	21	12	26.1	9	16.1
Total:		102	46	100	56	100

Table 2

Factors influencing live weight of calves

Characteristics		Factors	
		mother calving time	heifer breed
		p – value	
Live weight, kg	at birth	***	***
	at age of 6 months	***	***
	at age of 12 months	***	***
	at first insemination	***	***
	at first calving	***	***
Hip height, cm	at birth	***	***
	at age of 6 months	***	***
	at age of 12 months	***	***
	at first insemination	***	***

*** $p<0.001$, factor has significant influence on live weight and hip height of calves.

The group of red breeds includes Latvian Brown and Danish Red heifers, while Holstein breed group – Holstein black and white and Holstein red and white cows. The research covered 46 heifers of red breed and 56 heifers of Holstein breed.

In several researches it has been pointed out that, live weight and growth indicators of red breeds and Holstein breed cattle differ (Pietersma *et al*., 2006; Kamal *et al*., 2014); therefore, the results acquired were analysed for each breed separately. With the help of verified measuring instruments heifer live weight and hip height at birth, at the age of six and twelve months, at first insemination and first calving was found out.

Analysis of the data acquired was based on the indicators of descriptive statistics: arithmetical mean and standard error. Analysis of the factors influencing the research data was performed by using univariate analysis of variance. Significant differences among factor gradation classes were found with the t-test; in tables they have been indicated with a superscripted letter and symbol (A; B – between breed groups, a; b – between research groups, * between rearing groups: to 6 months and after 6 months). Research correlations were characterised with linear correlation coefficient.

Results and Discussion

When initiating analysis of the data acquired, the influence left by mother calving time and heifer breed on live weight and hip height was found out (Table 2).

The results acquired show that live weight and hip height of calves at different rearing periods are influenced by calving time of a mother and breed or breed group of a heifer ($p<0.001$).

Other researches have shown that during the first twelve months of life, live weight of heifers increases rapidly (Cooke *et al*., 2013) – the same phenomenon was observed also in this research (Table 3).

Live weight of red breed heifers at birth was between 42.4 and 46.3 kg; for heifers of the 4th group it was notably greater – 46.3 ± 0.81 kg, while heifers of the 1st group were by 3.9 kg lighter than 4th group heifers. At the age of six months live weight of calves levelled up and did not differ significantly; however, greater live weight still was observed for 2nd and 4th group heifers – 187.5 ± 5.09 kg and 187.6 ± 5.08 kg, respectively. At the age of one year heifers of the 4th group were remarkably heavier (345.8 ± 7.09 kg) than heifers of the 1st and 3rd groups ($p<0.05$).

Similar indicators at birth may be observed for Holstein breed heifers. Notably greater live weight was recorded for the 4th group heifers – on average 46.6 ± 1.07 kg ($p < 0.05$). The results acquired within the research show that Holstein heifers at birth were heavier than it was stated in other researches (Spiegler *et al*., 2014; Passille, Rabeyrin, & Rushen 2014; Kamal *et al*., 2015), indicating that live weight of Holstein calves at birth on average comprised 39.8 – 41.4 kg. At the age of six months no significant differences were observed among groups of Holstein breed heifers, similarly as it was with the heifers of red breeds. However, heifers of 3rd and 4th groups were heavier – 193.1 ± 4.78 kg and 201.3 ± 8.63 kg, respectively. Data of a research conducted in the United Kingdom show that Holstein breed heifers born to primiparous cows at the age of six months weighted on average 183.3 kg (Cooke *et al*., 2013), but weight thereof in this research on average constituted 185.2 kg – it is 1.9 kg more. At the age of one year notably greater live weight was recorded for the 2nd group heifers – on average 363.0 ± 6.47 kg, and it is 30 kg more than live weight of the 1st group heifers ($p<0.05$).

Table 3

Changes in live weight of calves of red and Holstein breeds (kg)

Heifer age	Research group			
	1.	2.	3.	4.
	Red breeds group			
At birth	42.4 ± 1.13[a]	45.2 ± 1.03[a,b,A]	44.1 ± 1.41[a,b]	46.3 ± 0.81[b]
At the age of 6 months	178.9 ± 5.73	187.5 ± 5.09	183.0 ± 4.93[A]	187.6 ± 5.08
At the age of 12 months	331.1 ± 9.94[a]	341.6 ± 7.88[a,b]	324.3 ± 6.31[a]	345.8 ± 7.09[b]
	Holstein breeds group			
At birth	42.0 ± 0.78[a]	42.9 ± 0.72[a,B]	44.5 ± 1.09[b]	46.6 ± 1.07[b]
At the age of 6 months	185.2 ± 4.26	185.6 ± 4.59	193.1 ± 4.78[B]	201.3 ± 8.63
At the age of 12 months	332.9 ± 7.58[a]	363.0 ± 6.47[b]	335.9 ± 7.80[a,b]	338.1 ± 11.51[a,b]

[a,b,c] – characteristic feature notably differs among research groups; $p<0.05$
[A,B] – characteristic feature notably differs between breed groups; $p<0.05$

The results acquired meet the findings of other researchers and prove that heifers born to primiparous cows tend to have smaller calves (Kamal *et al*., 2014). Live weight was similar for the newborn calves born in the red breed group and ones born in the Holstein group, still red breed heifers of the 2nd group were by 2.3 kg heavier than Holstein heifers ($p<0.05$). At the age of six months Holstein heifers of the 3rd group were by 10.1 kg heavier than red breed heifers ($p<0.05$). At the age of one year live weight of calves evened out and did not differ significantly among breeds.

Heifer growth rate is characterised by the daily live weight gain (Table 4). Scientist Shamay and his colleagues (2005) believe that, desirable daily weight gain of dairy cows from birth till insemination on average accounts for 700 g.

Live weight gain of red breed heifers aged up to six months did not differ significantly, but at the age 6 – 12 months daily live weight gain of the 4th group heifers was by 94 g greater than one observed for the 3rd group heifers ($p<0.05$). Red breed heifers of the 1st, 2nd, and 3rd group gained weight evenly in both rearing periods, and no notable differences were recorded; however, the 4th group heifers aged 6–12 months grew by 100 g more than heifers in the age group 0 – 6 months ($p<0.05$).

Daily live weight gain of Holstein breed heifers aged up to six months on average constituted 818.3 g, while of heifers in the second age group – on average 825.3 g daily. Such results differ from the findings of other researchers (Cooke *et al*., 2013) showing that average daily live weight gain of Holstein-Freeze breed heifers aged up to six months comprises - 1094 g, while after the age of six months – 764 g. Differing results were published also by Kertz, Prewitt, & Ballam, (1987), pointing out that, in the research conducted

Table 4

Daily live weight gain of red and Holstein breed calves (g) by research period

Heifer age	Research group			
	1.	2.	3.	4.
	Red breed group			
0 – 6 months	758 ± 33.1	791 ± 28.1	772 ± 28.5	785 ± 27.8 *****
6 – 12 months	846 ± 47.5[a,b]	856 ± 53.4[a,b]	785 ± 35.2[a]	879 ± 30.4[A,b,*]
	Holstein breed			
0 – 6 months	795 ± 23.9	793 ± 24.9*****	825 ± 26.0	860 ± 45.1
6 – 12 months	821 ± 37.4[a]	930 ± 40.7[b*]	794 ± 46.4[a]	760 ± 46.2[B,a]

[a,b,c] – live weight gain differs notably among research groups; $p<0.05$
[A,B] – live weight gain differs notably among breeds; $p<0.05$
***** – daily live weight gain differs notably within the breed between rearing periods (to 6 month and after 6 month); $p<0.05$

Table 5

Changes in hip height of red and Holstein breed heifers (cm) by research period

Heifer age	Research group			
	1.	2.	3.	4.
	Red breed group			
At birth	78.2 ± 1.62	79.8 ± 1.76^{A}	77.5 ± 1.39	78.4 ± 1.63
At the age of 6 months	110.8 ± 1.62	110.7 ± 1.12	109.5 ± 0.50^{A}	110.3 ± 0.75
At the age of 12 months	126.3 ± 1.27^{ab}	127.3 ± 0.63^{a}	125.3 ± 0.68^{b}	126.0 ± 0.89^{ab}
	Holstein breed			
At birth	75.1 ± 0.82^{a}	75.1 ± 1.04^{a,B}	76.4 ± 0.60^{b,a}	78.1 ± 0.9^{b}
At the age of 6 months	109.8 ± 0.77	110.7 ± 0.99	111.1 ± 0.64^{B}	111.9 ± 1.42
At the age of 12 months	126.3 ± 0.75	127.5 ± 1.02	125.6 ± 0.80	125.8 ± 1.49

^{a,b} – characteristic feature differs notably among the research groups; $p<0.05$
^{A,B} – characteristic feature differs notably between the breed groups; $p<0.05$

thereof Holstein heifers aged up to six months gained on average 830 – 930 g daily, while heifers aged 6 – 12 months – on average 1000 g daily. In this research daily live weight gain of Holstein heifers aged up to six months did not differ significantly among groups and varied between 793 g and 860 g, while for heifers aged 6 – 12 months remarkably greater daily live weight gain was recorded for the 2nd group heifers – on average 930 ± 40.7 g ($p<0.05$). Comparison of daily live weight gain by rearing period shows notable increase in growth rate of the 2nd group heifers – on average by 137 g daily ($p<0.05$).

Between the breed groups significantly higher growth rates were recorded for red breed heifers of the 4th group – on average 879 ± 30.4 g daily, comprising 119 g daily more than weight gain of the 4th group Holstein heifers ($p<0.05$).

Size of an animal is characterised by wither and hip height thereof. Insufficient or unbalanced nutrition of heifers leads to lack in reaching desired size. Wither height of the research heifers closely correlated with hip height, r = 0.83; therefore, research covered only analysis of hip height (Table 5).

Within the framework of the research, it was found out that hip height of red breed heifers at birth on average constituted 78.5 cm and did not differ notably among the groups. However heifers of the 2nd group were of a greater height – on average 79.8 ± 1.76 cm. Also, at the age of six months hip height of heifers did not differ significantly; nevertheless, heifers born to primiparaous cows were of greater height – hip height thereof on average constituted 110.8 ± 1.62 cm. At the age of one year notable differences in hip height were recorded for the 2nd group heifers, hip height of which was by 2.0 cm greater than one of the 3rd group heifers ($p<0.05$).

Within the Holstein breed group, significantly greater hip height at birth was observed for the 4th group heifers – on average 78.1 ± 0.9 cm ($p<0.05$). The findings are confirmed also by results of other researches indicating that Holstein breed heifers from primiparous cows were born on average with 75.5 cm high hips, while hip height of older cows on average constituted 76.6 cm (Kamal *et al*., 2015). At the age of six months Holstein heifers in all groups had similar hip height; however, the indicator in the 4th group was higher – on average 111.9 ± 1.42 cm. Similarly as in the group of red breeds, also in the Holstein group at the age of one year heifers with higher hips were born in the 2nd group. Comparison of the results acquired between the breed groups shows that the 2nd group red breed heifers at birth had by 4.7 cm higher hips than the 2nd group Holstein heifers; moreover, live weight thereof at birth was greater as well. At the age of six months the 3rd group Holstein heifers were significantly higher – the hip height thereof on average comprised 111.1 ± 0.64 cm ($p<0.05$).

Age at the first insemination in all research group met the optimum indicators – from 14 to 15 months – suggested by foreign scientists (Cooke *et al*., 2013; Duplessis *et al*., 2015; Vacek *et al*., 2015) and animal breeding specialists in Latvia (Ciltsdarba programma..., 2012; Latvijas Holšteinas..., 2012).

In 2015, the average age of calves at the first insemination in Latvia was 15.8 months (Lauksaimniecības datu..., 2015); one of the research heifers of both breeds – on average 14.7 months.

Age at the first insemination is closely related to the live weight of heifer; optimally heifer has to reach 55% of the live weight of a mature cow (Duplessis *et al*., 2015). For heifers of the red breeds the age at the first insemination varied between 14.2 (3rd group) and 14.9 (1st group) months, while average live weight – from 380.5 kg (1st group) to 415.1 kg (4th group). Notably greater live weight at the age of 14.7 months was reached by the 4th group heifers –

Table 6

Age, live weight, and hip height of red breed calves at the first insemination and calving

Indicators	Research group			
	1.	2.	3.	4.
At first insemination				
Age, months	14.9 ± 0.33	14.4 ± 0.31	14.2 ± 0.25	14.7 ± 0.26
Live weight, kg	380.5 ± 11.01[a]	402.0 ± 7.66[b]	381.9 ± 9.38[ab]	415.1 ± 7.09[b]
Hip height, cm	130.1 ± 1.83	131.0 ± 1.14	128.9 ± 0.85	130.8 ± 1.34
At first calving				
Age, months	27.0 ± 1.18[a]	24.6 ± 0.43[b]	25.6 ± 1.28[ab]	25.8 ± 0.65[ab]
Live weight, kg	610.0 ± 31.96	615.5 ± 27.40	598.8 ± 26.32	576.0 ± 24.17
Hip height, cm	142.8 ± 1.06[a]	143.0 ± 0.8[a]	143.9 ± 1.35[ab]	146.7 ± 0.86[b]

[a,b] – characteristic feature differs notably among research groups; $p<0.0$

on average 415.1 ± 7.09 kg ($p<0.05$). In Canadian research conducted with Ayrshire breed heifers the first insemination was made at the age of 17.9 months, when live weight of the heifers comprised 400 kg (Pietersma *et al.*, 2006). In this research, red breed heifers for the first time were inseminated on average at the age of 14.6 months, as animal reached hip height 130.2 cm and 395 kg of live weight, that on average constitutes 66.9% of the live weight of mature red breed cow. The results acquired show that in this research heifers were inseminated by 3.3 months earlier than in the Canadian research.

Calving age is influenced not only by the heifer age at the first insemination, but also by the number of insemination times (Cooke *et al.*, 2013). Within the red breed group, remarkably later calving was observed for heifers born to primiparous cows – on average at the age of 27.0 ± 1.18 months. Insemination of these heifers was started at the age of 14.9 months and done on average 1.2 times that is the lowest number of inseminations among red breed groups. Based on the results acquired, a conclusion may be made that, within the primiparous cow heifer group problems are faced in respect to conception.

Live weight of red breed heifers at the first calving on average comprised 576 – 615.5 kg. No significant differences were observed among the groups; however, greater weight was recorded for the 2nd group heifers – on average 615.5 ± 27.40 kg. First calving of the heifers of this group took place at optimum age, i.e., on average at the age of 24.6 months; the interval between the first insemination and the first calving on average lasted for 10.2 months, whereas average number of inseminations constituted 1.4 ± 0.24. Suitable live weight is not the only indicator important at calving, cow size has to be taken into consideration as well. Red breed heifers calve with an average hip height 144.1 cm – 3.1 cm more than stated in the Breeding Programme (Ciltsdarba programma) for 2013 – 2017. Significantly greater hip height at

Table 7

Age, live weight, and hip height of Holstein breed calves at first insemination and calving

Indicators	Research group			
	1.	2.	3.	4.
At first insemination				
Age, months	14.6 ± 0.38	14.6 ± 0.39	14.6 ± 0.29	15.3 ± 0.37
Live weight, kg	401.7 ± 8.28	404.1 ± 5.55	397.7 ± 7.39	382.5 ± 14.08
Hip height, cm	132.4 ± 0.87	133.9 ± 1.34	131.7 ± 1.09	133.9 ± 148
At first calving				
Age, months	26.1 ± 0.82[a,b]	26.9 ± 0.84[a,]	24.9 ± 0.45[b]	27.6 ± 1.65[a,b]
Live weight, kg	610.0 ± 17.83	626.2 ± 19.76[a]	572.2 ± 14.03[b]	598.3 ± 34.82
Hip height, cm	145.7 ± 1.38	145.8 ± 1.25	143.7 ± 1.77	146.8 ± 1.89

[a,b] – characteristic feature differs notably among research groups; $p<0.05$

calving was recorded for the 4th group heifers – on average 146.7 ± 0.86 cm, exceeding the indicator desirable for the breed by 3.1 cm ($p<0.05$).

Canadian scientist Pietersma and others (2006) in their research on Ayrshire breed heifers found out that their first calving takes place at the age of 28 months, as cows have reached average live weight of 507 kg; while in this research heifers calved 2.2 months earlier and at that moment were by 93 kg heavier.

Holstein breed heifers for the first time were inseminated at the age of 14.8 months as they reached average live weight of 396.5 kg that is equal to 61.5% of live weight of mature Holstein cow and exceeds the indicators optimal for the breed by 6.5% (Table 7).

The greatest live weight at the age of 14.6 months was reached by the 2nd group heifers. In the Canadian research, Holstein heifers for the first time were inseminated on average at the age of 17.3 months as they reached average live weight of 464 kg (Pietersma *et al*., 2006). Czech scientists emphasize that an important role in further productivity of a heifer is fulfilled by age at insemination and live weight. In their opinion, it is advisable to inseminate Holstein breed heifers at the age of 14 months as they reach live weight comprising 400 kg (Vacek *et al*., 2015).

In this research, Holstein heifers calved on average at the age from 24.9 months (2nd group) to 27.6 months (4th group) and reaching live weight of 572.2 ± 14.03 kg and 598.3 ± 34.82 kg, respectively. Notable differences at the age of the first calving were recorded between the 2nd and 3rd group heifers – 2 month difference ($p<0.05$). Pietersma and other researchers (2006) in research conducted with Holstein heifers found out that they calved on average at the age of 26.9 months as they reached live weight of 587 kg. Kamal and other scientists within the researched carried in Belgium and Germany farms discovered that heifers, which calved at the age 23.5 – 25.5 months, had higher reproduction and productivity indicators, as compared to heifers calving earlier or later than at this age (Kamal *et al*., 2014). The findings are confirmed also by results obtained in other researches (Mohd Nor *et al*., 2013).

In this research, the hip height of Holstein heifers at calving on average comprised 145.5 cm that meets indicators characteristic to mature Holstein cows.

Comparison of the results by breed group allows concluding that the age of calve at the first insemination does not differ notably, while significantly greater live weight was recorded for Holstein heifers of the 1st group – difference of 21.2 kg ($p<0.05$). Significantly older age at the first calving was observed for Holstein heifers of the 2nd group (26.9 months) – difference of 2.3 months, as compared to the red breed 2nd group heifers ($p<0.05$). Generally it may be concluded that Holstein heifers had shorter time interval between the age at the first insemination and calving – on average 10.3 – 12.3 months.

Conclusions

1. Heifers born to primiparous cows in both groups had smaller live weight, while at the age of six months it levelled among all research groups. In red breed group one-year-old heifers of the 4th group were heavier, while in Holstein group – heifers, mothers of which calved for the second time.
2. Hip height at birth recorded for heifers in the red breed group did not differ notably among the research groups, while the 4th group heifers born to mature Holstein cows had significantly greater hip height ($p<0.05$). Comparison of the research group heifers by breed shows that red breed heifers, mothers of which calved for the second time, were born with a greater hip height ($p<0.05$).
3. Heifers in the red breed group on average calved at the age of 25.8 months, while Holstein heifers calved on average 0.6 months later – at the age of 26.4 months. The fact may be explained by higher average number of inseminations and gestations – on average 1.7 times that is 0.2 times more than for red breed heifers.
4. Hip height at calving observed for Holstein breed heifers was similar in all groups, while in red breed group it was significantly greater for mature cows of the 4th group – on average 146.7 cm, exceeding hip height of a mature cow by 5.7 cm.
5. At insemination, research cows had 66.9% of mature red cow live weight and 61.5% of mature Holstein cow live weight, indicating that cows may have been inseminated earlier.

References

1. Arthington, J.D., Cattell, M.B., Quigley, J.D., McCoy, G.C., & Hurley, W.L. (2000). Passive immunoglobulins transfer in newborn calves feed colostrum or spray dried alone or as a supplement to colostrum of varying quality. *Journal of Dairy Science*, 83, 2834-2838. DOI: 10.3168/jds.S0022-0302(00)75183-6.
2. Ciltsdarba programma sarkano šķirņu govju selekcijā 2013-2017. gadam un tuvākajā nākotnē (2012). (The breeding program of red breed cows selection 2013-2017 and the near future). Retrieved February 9, 2016, from https://www.google.lv/?gws_rd=ssl#q=ciltsdarba+programma. (in Latvian).

3. Cooke, J.S., Cheng, Z., Bourne, N.B., & Wathes, D.C. (2013). Association between growth rates, age at first calving and subsequent fertility, milk production and survival in Holstein-Friesian heifers. *Journal of Animal Sciences*. 3(1), 1-12. DOI: 10.4236/OJAS,2013.31001.
4. Duplessis, M., Cue, R., Lefebvre, D., & Lacroix, R. (2015). Weight, height, and relative-reliability indicators as a management tool for reducing age at first breeding and calving of dairy heifers. *Journal of Dairy Science*, 98 (3), 2063-2073. DOI: 10.3168/JDS.2014-8279.
5. Juozaitiene, V., Anskiene, L., Banys, A., Rekešiute, A., Šileika, A., Muzikevičius, A., Kantautaite, J., Žoštautiene, V., & Juozaitis, A. (2015). Investigation of exterior traits dependence on the genotype of Lithuanian Black and White cows according to the degree of Holstein genes. *Veterinarija ir zootechnika*, 69 (91), 26-33. DOI: 1392-2130.
6. Kamal, M., Van Eetvelde, M., Bogaert, H., Hostens, M., Vandaele, L., Shamsuddin, M., & Opsomer, G. (2015). Environmental factors and dam characreristics associated with insulin sensitivity and insulin secretion in newborn Holstein calves. *Animal Sciences*, 9 (9), 1490-1499. DOI: 10.1017/S17517311150000701.
7. Kamal, M., Van Eetvelde, M., Depreester, E., Hostens, M., Vandaele, L., & Opsomer, G. (2014). Age at calving in heifers and level of milk production during gestation in cows are associated with the birth size of Holstein calves. *Journal of Dairy Science*, 97 (9), 5448-5458. DOI: 10.3168/jds.2014-7898.
8. Kertz, A., Prewitt, L., & Ballam, J. (1987). Increased weight gain and effects on growth parameters of Holstein heifer calves from 3 to 12 months of age. *Journal of Dairy Science*, 70 (8), 1612-1622. DOI: 10.3168/jds.S0022-0302(87)80189-3.
9. Latvijas Holšteinas šķirnes govju citsdarba programma 2013-2017. (2012). (Latvian Holstein cow breeding program 2013-2017). Retrieved February 9, 2016, from https://www.google.lv/?gws_rd=ssl#q=Hol%C5%A1teinas+%C5%A1%C4%B7irnes+ciltsdarba+programma. (in Latvian).
10. Lauksaimniecības datu centrs (2015). Piena pārraudzības rezultāti 2015. (Agricultural Data Centre. Milk recording in 2015). Retrieved February 9, 2016, from http://www.ldc.gov.lv/upload/doc/republika_2015.pdf. (in Latvian).
11. Maia, R., Ask, B., Madsen, P., Pedersen, J., & Labouriau, R. (2013). Genetic determination of mortality rate in Danish dairy cows: A multivariate competing risk analysis based on the number of survived lactations. *Journal of Dairy Science*, 97 (3), 1753-1761. DOI: 10.3168/jds.2013-6959.
12. Mohd Nor, N., Mourits, M., Hogeveen, H., & Steeneveld, W. (2013). First-calving age and first-lactation milk production on Dutch dairy farms. *Journal of Dairy Science*, 96 (2), 981-992. DOI: 10.3168/jds.2012-5741.
13. Passille, A., Rabeyrin, M., & Rushen, J. (2014). Associations between milk intake and activity in the first days of a calfs life and later growth and health. *Animal Behaviour Science*, 10, 1-6. DOI: 10.1016/j.applanim.2014.10.002.
14. Pietersma, D., Lacroix, R., Lefebvre, D., Cue, R., & Wade, K.M. (2006). Trends in growth and age at first calving for Holstein and Ayrshire heifers in Quebec. *Canadian Journal of Animal Science*, 91, 325-336. DOI: 10.4141/A05-080.
15. Raguz, N., Jovanovac, S., & Gantner, V. (2011). Analysis of factors affecting the length of productive life in Croatian dairy cows. *Bulgarian Journal of Agricultural Science*, 17 (2), 232-240.
16. Shamay, A., Werner, D., Moallem, U., Barash, H., & Bruckental, I. (2005). Effect of nursing management and skeletal size at weaning on puberty, skeletal growth rate, and milk production during first lactation of dairy heifers. *Journal of Dairy Science*, 88 (4), 1460-1469. DOI: 10.3168/jds.S0022-0302(05)72814-9.
17. Spiegler, S., Kaske, M., Köhler, U., Meyer, H., Schwarzb, F., & Wiedemann, S. (2014). Effect of feeding level of pregnant dairy heifers sired by one bull on maternal metabolism, placental parameters and birthweight of their female calves. *Animal Reproduction Science*, 146 (3-4), 148-156. DOI: 1016/j.anireprosci.2014.03.007.
18. Vacek, M., Krpakova, L., Syruček, J., Štipkova, M., & Janecka, M. (2015). Relationships between growth and body condition development during the rearing period and performance in the first three lactations in Holstein cows. *Czech Journal of Animal Science*, 60 (9), 417-425. DOI: 10.17221/8460-CJAS.

DIFFERENT BEEF BREED CATTLE FATTENING RESULTS ANALYSIS

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Abstract
In Latvia, different breeds of beef cattle are grown; therefore, it is important to explain their suitability to organic farming systems, because most Latvian beef cattle breeders work with organic farming methods. The aim of this research was to compare fattening of different beef breed bulls (*Bos Taurus)* in organic farming system at similar housing and feeding conditions. In the research, there were included Blonde d'Aquitaine (BA), Hereford (HE), Simmental (SI) and crossbred (CB) bulls. Fattening period started after calf weaning from suckler cows at 7 – 8 months of age. Fattening results were significantly affected by factors like breed, live weight and age before fattening, but slaughter results were significantly affected by breed, live weight and age before slaughter. During the fattening period the biggest daily weight gain was showed for SI breed bulls (849 g), but the biggest live weight increase was recognized for BA breed bulls (295 kg). The required slaughter weight the fastest was reached for XG bulls, which average slaughter age was 532 days ($p<0.05$). The greatest slaughter weight – 342 kg ($p<0.05$) and dressing percentage (58% ($p<0.05$)) was recognized for BA breed bulls; also, carcass conformation score in muscle development was the highest for BA bulls (2.0 points ($p<0.05$)). The greatest economic benefit was from CB bulls, income calculated per one rearing day from CB bulls was - EUR 1.80.
Key words: beef cattle breeds, bulls, growth and fattening.

Introduction

The branch of cattle meet production takes a significant role in the structure of agriculture production in the developed countries of the world and EU countries. Similar development can also be seen in the new countries of the EU. During the last ten years a number of suckler cows has grown in Latvia. On 1st January 2006, 6955 of suckler cows were registered in the Agricultural data centre of the Republic of Latvia, but on 1st January 2016 – already 38878 suckler cows. This tendency shows that beef cattle branch has been developing, but still the main production of this branch is weaned calves which are sold for export. Only a small part of weaned calves has been left on the farms for further fattening. In Latvia, there is necessary to arrange an internal beef meat market and develop the payment system of fattened beef cattle according to the carcass classification of SEUROP, which is used in other EU countries in order to facilitate farmers' interest in young cattle fattening and sale in Latvia. Also, EU countries meat procesor and marketing company interest about Latvia farmed beef purchase options is growing every year. Considering of our country's potential to produce high qulity biological products which is equivalent to the production of other EU countries, Latvia has the objective to increase the competitiveness of local beef cattle breeders in the common market in all areas, in terms of the quality of the weaned calves and carcases (Gaļas šķirņu govju ciltsdarba programma, 2013).

In order to develop the branch of beef cattle successfully, it is very important to know, how to grow up high quality beef cattle, thus ensuring the high quality of the carcass assessment and meat. As researchers, Lujane, Oshmane, & Jansons (2013) have recognized the quality of beef at the present genetic material could be much higher in Latvia, but we have to improve the conditions of animal nutrition. It is important to take into account that in order to obtain high – quality meat, there should be adequate nutrition at all stages of animal development.

Intensive farming is not possible in many places of Latvia, but in the branch of beef cattle there is also possibility to farm extensively using natural pastures, bushes, overgrown places and so on. Comparing beef cattle with typical dairy cattle, beef cattle gives greater live weight, increases daily live weight, the outcome of the slaughter and gets higher class of a meat market (Lujane, Oshmane, & Jansons, 2013).

In Latvia, different breeds of beef cattle are grown. According to the information of Agricultural data centre of the Republic of Latvia the biggest populations are: Charolais (19570), Limousin (6424) and Hereford (5347). A smaller number of the beef cattle population are breeds: Angus (2867), Simmental (1941), Highland (885), Galloway (525) and Blonde d'Aquitaine (132). There is also a great number of different beef cattle crossbreed (18471). It is important to explain their suitability to organic farming systems because most of Latvian beef cattle breeders work with organic farming methods.

Up to now in Latvia, separate studies on beef cattle fattening have been carried out. Though there is a lack of studies on the appropriate choice of beef cattle breed for fattening and the most effective model for profitable fattening, so the beef cattle breeders who choose to fatten weaned calves, they often should carry out experiments by themselves (Lujane, Oshmane, & Jansons, 2013).

Many foreign authors researched differences between individual beef breeds in growth performance, fattening and carcass traits (Polach *et al*., 2004; Barton

et al., 2006; Hollo *et al*., 2012; Pesonen & Huuskonen, 2015), however these studies can not fully apply to the conditions of Latvia.

The aim of this research was to compare the breed of Blonde d'Aquitaine, Hereford, Simmental and crossbred bulls fattening in organic farming system at similar housing and feeding conditions.

Materials and Methods

The research was carried out in the certified organic cattle farm 'Bētas' (56.901566, 22.241868) during the period from November 2014 till December 2015 at similar housing and feeding conditions at the barn. During the whole fattening period rations contained hay, grass silage, grains (oats, barley, triticale) and mineral feed, in summer period also green forage. The winter period forage was with the following indicators: hay – dry matter 92.73%, protein 7.30%, *net energy* for l*actation* (NEL) 6.06 MJ kg^{-1}, *neutral detergent fiber (*NDF) 56.5%, acid *detergent fiber(*ADF) 32.0%; grass silage – dry matter 46.19%, protein 10.50%, NEL 5.67 MJ kg^{-1}, NDF 54.33, ADF 36.87%. Cereal meal mix dry matter content was 89.87%, protein content 13.22%, NEL content 7.86 MJ kg^{-1}, NDF content 20.11 MJ kg^{-1} un ADF content 9.36 MJ kg^{-1}.

Forage was fed *ad libitum*, but grain portion was 4 kg per day. At the beginning of fattening, bulls were partially adapted to grain portion until the portion reached maximum – 4 kg per day. Water was supplied with heated watering place. The specific type of fattening is considered as medium intensive because fattening was carried out in the organic farming system. To assess growth performance, each month starting from January 2015 all of the bulls were weighted with electronic cattle scales with accuracy of 0.100 kg.

The research included 21 fattening bulls and depended on their breed type. Four research groups were created:

1st group: Blonde d'Aquitaine (BA) – 4 bulls;
2nd group: Hereford (HE) – 6 bulls;
3rd group: Simmental (SI) – 6 bulls;
4th group: beef cattle crossbreed – 5 bulls.

Bull fattening started after calf weaning from suckler cows 7 – 8 months of age, but fattening finished when bulls reached live weight at least 500 kg.

Using the growth rates of the bulls, average daily gain during fattening period was calculated (1):

$$a = \frac{Wt - W0}{t} \quad (1)$$

where Wt - live weight before slaughter, kg
W0 – live weight before fattening, kg
t – fattening duration, days.

All bulls were slaughtered in certificated slaughterhouses where carcases were wheighed and the carcass SEUROP conformation score was determined (Classification of bovine animal carcasses). Conformation score was marked with the letters EUROP with the following meaning: E – excellent (the numeric designation – 1), U – very

Table 1

Bulls fattening results

Indice	Breed							
	BA (n=4)		HE (n=6)		SI (n=6)		XG (n=5)	
	x ±Sx	V,%	x ±Sx	V,%	x ±Sx	V,%	x ±Sx	V,%
Age before fattening	222±10.3[a]	9.3	226±4.9[a]	5.3	237±1.5[a]	1.6	237±11.9[a]	11.3
Live weight before fattening, kg	299±22.1[a]	14.8	269±8.2[a]	7.4	366±7.3[b]	4.9	376±12.5[b]	7.4
Live weight before slaughter, kg	594±32.6[ab]	11.0	558±14.3[a]	6.3	630±17.9[b]	7.0	626±23.5[b]	8.4
Fattening period lenght, days	352±20.4[ab]	11.6	389±8.0[a]	5.1	307±13.1[b]	10.4	296±19.8[b]	15.0
Live weight gain, g per day^{-1}	844±60.0[a]	14.2	745±57.9[a]	19.0	849±40.9[a]	11.8	828±70.5[a]	19.0

[a b] – indices is significantly different between groups, $p<0.05$.

Table 2

Bulls fattening affecting factors

Traits	Factors		
	breed	live weight before fattening, kg	age before fattening, days
	p-value		
Live weight before fattening, kg	***	...	***
Live weight increase during the fattening period, kg	***	***	***
Fattening period duration, days	***	...	***
Live weight gain, gper day^{-1}	***	***	***

***p<0.001.

good (2), R – good (3), O – medium (4), P – poor (5) developed muscularity.

For preparation income analysis, slaughter houses prices per carcass and bulls age at a slaughter moment were used.

MS Excel software was used for data mathematical processing. Average values, standard error and coefficient of variation results were calculated. T–test for average values was used for significance determination. Different letters (a, b, c) on figures and tables mark significant differences at p<0.05. To analyze factors influencing fattening and slaughter traits one–way analysis of variance (ANOVA) was performed. The following factors were analysed: breed, live weight and age before fatening and live weight and age before slaughter.

For traits relationship correlation analysis determination, which was established between the fattening and slaughter traits was used.

Results and Discussion

At the beginning of fattening bulls average age was from 222 to 237 days, among groups there were no significant differences (Table 1). The biggest live weight at the beginning of the fattening was for CB and SI breed bulls, respectively – 377 kg and 366 kg, whereas BA and HE breed bulls live weight was significantly lower – 299 kg and 269 kg (p<0.05) respectively.

Fattening period with the biggest live weight – 630 kg was completed by SI breed bulls which during the fattening period reached also the biggest live weight gain – 849 g. In several foreign studies (Chambaz *et al*., 2003; Barton *et al*., 2006; Hollo *et al*., 2012) the SI breed bulls live weight gains have been greater than in our study due to the fact that bulls were fattened with intensive methods. In the study, which was carried out by a Dannenberger *et al.* (2006) SI breed bulls were fattened in two different systems and it was established that with intensive fattening system bulls live weight gain was on average 1.40 kg, but in system where forage was used, but concentrates only in the finishing phase, live weight gain was on average 0.90 kg.

HE breed bulls live weight gain during the fattening period was on average 745 g what is lower than in a study carried out by the Barton*et al*., (2006) who found live weight gain for this breed bulls during the fattening period on average 1.315 kg. These diferences between live weight gain can be explained with the use of different feeding system because in Barton*et al.* (2006) study bulls were fattened with Total mixed ration (TMR) which consisted of maize (*Zea mays*) and lucerne (*Medicago*) silage, as well as concentrates.

The shortest fattening period in our study was for CB group bulls, which is 296 days, when they achieved average live weight 626 kg. These indicators were significantly different from HE breed bulls, which was 389 days and average live weight 558 kg (p<0.05).

Throughout the period of fattening the largest live weight increase was obtained for BA breed bulls –average 295 kg, but for CB group bulls live weight increase during the fattening period was the least – 250 kg, the diference was 45 kg, which can be explained not only with the shortest fattening period but also with the highest live weight before fattening. Live weight increase for HE breed bulls was 289 kg, but for SI breed bulls – 265 kg.

The bulls fattening affected factors results analysis show that all analyzed factors significantly affect traits of live weight and growth rate (Table 2).

CB group bulls were slaughtered younger than the other group bulls, average 532 days of age, which was 13 days earlier than SI breed bulls, 43 days earlier than BA breed bulls and 83 days earlier than HE breed bulls (p<0.05) (Table 3). Studies in Finland compared to our study show differences in age at slaughter. In these studies BA breed bulls were slaughtered in 570 days of age which is 5 days earlier, HE breed bulls at 561 – 572 days of age which is 43 – 45 days earlier, but SI breed bulls were slaughtered at 565 – 566 days of age which is 20 – 21 days later

Table 3

Bulls slaughter results

Indices	Breed							
	BA (n=4)		HE (n=6)		SI (n=6)		XG (n=5)	
	x ±Sx	V,%	x ±Sx	V,%	x ±Sx	V,%	x ±Sx	V,%
Age before slaughter, days	575±18.2^{ab}	6.4	615±10.5^{a}	4.2	545±13.3^{b}	6.0	532±14.3^{b}	6.0
Slaughter weight, kg	342±18.4^{ab}	10.8	298±8.4^{a}	6.9	323±7.5^{b}	5.7	319±3.4^{b}	2.4
Conformation score (1-5)	2.0±0.00^{a}	0.0	3.2±0.17^{bc}	12.9	2.3±0.21^{a}	22.1	2.6±0.24^{ac}	21.1
Income per carcass	1,048.81± 55.211^{a}	10.8	887.61± 33.657^{b}	9.3	963.09± 26.574^{ab}	6.8	957.73± 10.088^{ab}	2.4
Income in one breeding day	1.78±0.065^{a}	7.3	1.45±0.067^{b}	11.3	1.77± 0.021^{a}	3.0	1.80±0.032^{a}	3.9

$^{a\,b}$ – indices is significantly different between groups, $p<0.05$.

(Pesonen, Honkavaar, & Huuskonen, 2013; Pesonen & Huuskonen, 2015).

Slaughter age of HE breed bulls was significantly different from SI breed and CB bulls, but for BA breed bulls significant difference was not recognized.

The biggest slaughter weight was obtained from BA breed bulls – 342 kg, but slaughter weight indicator was not significantly different between the research groups. Conformation score was from 2.0 to 3.2 points. Muscularity was the best for BA breed bulls – 2.0 points. All breed group bulls carcases were scored as class U. HE breed bulls carcasses were scored in 83% of cases as class R, but 33% of cases as class O, whereas 67% of cases SI bred bulls carcasses were scored as class U, but 33% of cases as class R. CB bulls carcasses were scored in 33% of cases as class U, but in 67% – as class R. Several foreign scientific studies observed a similar trend conformation scoring for BA, HE and SI breed bulls, which found that BA breed bulls muscularity scoring is higher than other beef breeds (Pesonen & Huuskonen, 2015). In the study which included SI and HE breeds, bulls carcases score was not significantly different though (Urgakovic, Ivankovic, & Konjacic, 2013).

The comparison of income which was received from bulls sales shows that the greatest economic benefit was from BA breed bulls – EUR 1048.81 per carcass which was significantly more in comparison to the benefit from HE bulls carcases ($p<0.05$).

Income per carcass must be analyzed together with the number of days used for bulls rearing until the slaughter weight was achieved because each rearing day raises costs. The number of days for each research group was different; as a result, the biggest income calculated per one rearing day was from CB bulls – EUR 1.80, which was EUR 0.02 more than BA, EUR 0.03 more than SI and EUR 0.35 ($p<0.35$) more than HE breed bulls.

The highest dressing percentage – 57.6% showed BA breed bulls, whereas the smallest – 51.3% SI breed and 51.2% CB bulls. HE breed bulls dressing percentage was 53.5% which is by 2.5% lower than in Barton *et al*. (2006) study where HE breed bulls showed dressing percentage 56%. SI breed bulls dressing percentage in our study was lower than in other authors' studies where this breed bulls dressing percentage was from 54 to 58% (Chambaz *et al*., 2003; Barton *et al*., 2006; Link *et al*., 2007; Hollo *et al*., 2012). BA breed bulls dressing percentage results were significantly different from the other research groups' bulls dressing percentage results ($p<0.05$).

The factor analysis results allows concluding (Table 4) that breed, live weight before slaughter and age before slaughter are factors which have significant effect on slaughter results – age before slaughter, slaughter weight, dressing percentage and conformation score.

To find out relationship of the slaughter traits, correlation analysis was performed (Table 5). By analyzing the study groups, it was found that between traits age before slaughter and live weight before slaughter exists significant correlation for SI (0.99) and CB (0.90) groups, there was the same significant correlation between traits live weight before slaughter and slaughter weight for SI (0.94) and CB (0.93) groups.

Between traits age before slaughter and dressing percentage, a significant correlation for HE (0.83) and SI (-0.86) groups exists.

Table 4

Bulls slaughter results affecting factors

Trait	Factors		
	breed	live weight before slaughter, kg	age before slaughter, days
	p-value		
Age before slaughter, days	***	...	...
Slaughter weight, kg	***	***	***
Dressing percentage, %	***	***	***
Conformation score (1-5)	***	***	***

***p<0.001

Table 5

Slaughter traits correlation analysis

Traits BA (n=4)		Group			
		HE (n=6)	SI (n=6)	CB (n=5)	
Age before slaughter, days	live weight before slaughter, kg	0.55	-0.45	0.99*	0.90*
	slaughter weight, kg	0.79	0.30	0.94*	0.93*
	dressing percentage, %	0.56	0.83*	-0.86*	-0.78
Live weight before slaughter, kg	slaughter weight, kg	0.92	0.59	0.98*	0.69
	dressing percentage, %	-0.27	-0.34	-0.77	-0.97*
Slaughter weight, kg	dressing percentage, %	0.13	0.56	-0.62	-0.50

*p<0.05

For traits live weight before slaughter and slaughter weight a significant correlation for SI group (0.98) was observed, but for traits live weight before slaughter and dressing percentage significant correlation was for CB group (0.97).

For traits slaughter weight and dressing percentage correlation was not significant.

Conclusions

1. The shortest fattening period was for crossbreedgroup bulls – 296 days, which achieved average live weight gain 828 g. The fattening period with the biggest live weight finished Simmentalbreed bulls– 630 kg whose average live weight gain during the fattening period was 849 g.
2. The best slaughter results showed *Blonde* d'*Aquitaine* breed bulls whose slaughter weight was average 342 kg with dressing perecentage 58% (p<0.05). This breed bull's carcass conformation score was 2.0 points which was the highest among the groups.
3. Bulls fattening and slaughter results significantly affected breed, live weight and age start or end fattening.
4. Between traits age before slaughter and live weight before slaughter and traits age before slaughter and slaughter weight, a significant correlation for SI and CB groups exists, but between traits age before slaughter and dressing percentage a significant correlation for HE and SI groups exists.
5. For traits live weight before slaughter and slaughter weight, a significant correlation for SI group was observed, but for traits live weight before slaughter and dressing percentage a significant correlation was for CB group.

References

1. Barton, L., Rehak, D., Teslik, V., Bures, D., & Zahradkova, R. (2006). Effect of breed on growth performance and carcass composition of Aberdeen Angus, Charolais, Hereford and Simmental bulls. *Czech Journal of Animal Science*, 51 (2), 47-53. Retrieved January 27, 2016, from http://www.agriculturejournals.cz/publicFiles/52258.pdf.
2. Chambaz, A., Scheeder, M.R.L., Kreuzer, M., & Dufey, P.A. (2003). Meat quality of Angus, Simmental, Charolais and Limousin steers compared at the same intramuscular fat content. *Meat science*, 63 (4), 491-500. DOI: 10.1016/S0309-1740(02)00109-2.

3. Dannenberger, D., Nuernberg, K., Nuernberg, G., & Ender, K. (2006). Carcass - and meat quality of pasture vs concentrate fed German Simmental and German Holstein bulls. *Archiv Tierzucht*, 49 (4), 315-328. Retrieved January 27, 2016, from http://www.archanimbreed.com/pdf/2006/at06p315.pdf.
4. *Gaļas šķirņu govju ciltsdarba programma 2013. – 2017. gadam* (Breeding Programme of beef cows for the years 2013 – 2017). (2013). Retrieved February 15, 2016, from http://lgla.lv/wp-content/uploads/2013/03/LGLA.citsdarba.programma.2013-2017.pdf. (in Latvian).
5. Hollo, G., Nuernberg, K., Somgyi, T., Anton, I., & Hollo, I. (2012). Comparison of fattening performance and slaughter value of local Hungarian cattle breeds to international breeds. *Tierzucht*, 55 (1), 1-12. Retrieved January 27, 2016, from http://arch-anim-breed.fbn-dummerstorf.de/pdf/2012/at12p001.pdf.
6. *Liellopu liemeņu klasifikācija* (Classification of bovine animal carcasses) (n.d.). Retrieved January 27, 2016, from file:///C:/Users/User/AppData/Local/Temp/Liellopu_klasifikacija.pdf. (in Latvian).
7. Link, G., Willeke, H., Golze, M., & Bergfeld, U. (2007). Mast - und Schlachtleistung bei Bullen und Färsen von Fleisch - rinderrassen und der Kreuzung Deutsch Angus × Fleckvieh (Fattening - and slaughter performance of bulls and heifers of beef breeds and the cross breed German Angus × Simmental). *Archiv Tierzucht*, 50 (4), 356-362. Retrieved February 3, 2016, from http://www.archanimbreed.com/pdf/2007/at07p356.pdf. (in German).
8. Lujāne, B., Ošmane, B., & Jansons, I. (2013). Liellopu gaļas ražošana (Production of cattle meat). Latvijas iedzīvotāju pārtikā lietojamās gaļas raksturojums, 105-156. Retrieved February 24, 2016, from http://llufb.llu.lv/LLUgramatas/SIGRA/Latvijas_iedzivot_partik_galas_rakstur.pdf. (in Latvian).
9. Pesonen, M., Honkavaar, M., & Huuskonen, A. (2013). Production, carcass and meat quality traits of Hereford, Charolais and Hereford Charolais bulls offered grass silage-grain-based rations and slaughtered at high carcass weights. *Acta Agriculturae Scandinavica, Section A — Animal Science*, 63 (1), 28-38. DOI: 10.1080/09064702.2013.777091.
10. Pesonen, M., & Huuskonen, A. (2015). Production, carcass characteristics and valuable cuts of beef breed bulls and heifers in Finnish beef cattle population. *Agricultural and Food science*, 24 (3), 164-172. Retrieved January 29, 2016, from http://ojs.tsv.fi/index.php/AFS/article/viewFile/50930/16504.
11. Polach, P., Subrt, J., Bjelka, M., Uttendorfsky, K., & Filipcik, R. (2004). Carcass value of the progeny of tested beef bulls. *Czech Journal of Animal Science*, 49 (1), 315-322. Retrieved January 29, 2016, from http://www.agriculturejournals.cz/publicFiles/53254.pdf.
12. Urgakovic, N.K., Ivankovic, A., & Konjacic, M. (2013). Effect of breed and age on beef carcass quality, fatness and fatty acid composition. *Tierzucht*, 56 (97), 958-970. DOI: 10.7482/0003-9438-56-097.

COMPARISON OF CONFORMATION TRAIT SCORES OF DAMS AND DAUGHTERS IN LATVIAN WARMBLOOD HORSE BREED

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Abstract
The objective of the study was to detect the difference of the conformation scores between dams and daughters in Latvian Warmblood horse breed. For this purpose the correlations and regression coefficient between conformation traits of broodmares and the same traits of their daughters were estimated. Data of Latvian Warmblood horse breed broodmares were analyzed. The horse breeding organisations' evaluating data from 1995 till 2015 were analyzed. The data included conformation valuation of Latvian Warmblood horse breed dams (n = 423) and their daughters (n = 596) of different ages. An average in ten-point scale in the group of dams was 7.71 ± 0.04 for top line scoring, 7.33 ± 0.05 for forelimbs and 7.35 ± 0.05 points for hind limbs. An average of valuation points of their daughters was 7.51 ± 0.03 for top line scoring, 7.21 ± 0.04 for forelimbs and 7.21 ± 0.04 for hind limbs. A significant difference between valuations of dams and their daughters ($p<0.05$) was found for all three conformation traits. Positive and low correlation was calculated between groups of dams and daughters for all three conformation traits. The results show that the relationship between conformation traits of dams and daughters was weak. Further studies are needed in order to estimate influence of broodmare quality to daughters, analyzing the latest data of progeny.
Key words: Latvian Warmblood, broodmares, dams, daughters, conformation traits.

Introduction

The Latvian Warmblood horse breed is divided in a sport type and carriage type. The development of sport type is based on breeding of horses suitable for show jumping and dressage. A strong body conformation, suitability for tourism and driving are representative features of carriage type horses (Rozītis, Kļaviņa, & Juršāne, 2008). Breeding Programme of Latvian Warmblood Horse (2010) determines criteria for quality of broodmares of both types appropriate to breeding objective and registering in Stud Book. Mares are used for breeding purpose based on the owners' preference and knowledge without external control. Especially, selection of Latvian Warmblood sport type females is completely breeder dependant likewise in majority of warmblood breeds (Dubois, Manfredi, & Ricard, 2007). Consequently, export of the best broodmares led to production of large number of horses with a low conformation quality. The selection of stallions is important for the genetic progress in population although the mare contributes as much as the male to the individual foal (Viklund *et al*., 2011). The selection of females can contribute 1/4 of genetic response (Dubois, Manfredi, & Ricard, 2008). Currently, Latvian Horse Breeding Association with the help of a special prize and support payments promotes breeders to include the best mares in stud herd.

A methodology of horse valuation at Breeding programme of the Latvian Warmblood horses schedules seven conformation criteria. Conformation is determined as the most important, second or third major selection criteria in breeding programmes of almost all breeding organisations of warmblood horses (Koenen, Aldridge, & Philipsson, 2004). Conformation is a physical appearance of an animal due to the arrangement of muscles, bones and other tissue and quality, durability and efficiency of performance are closely related to conformation, especially to conformation of top line and limbs. The score of top line of horse combines the quality of several parts of body - head, neck, withers, shoulder, back, loins, croup. Close genetic correlations were found among separate traits of top line (Posta, Komlósi, & Mihók, 2010). Conformation influences reliability of horse limbs and quality of gaits and lameness frequently occur due to a less than ideal joint and limb angulation (Dyson, 2000; Laizans, 2012). The differences in conformation traits between younger and older groups of horses are not significant (Simcic, Mesaric, & Potocnik, 2012). Conformation valuation in Latvia included seven conformation criteria – a type, top line of horse (head, neck, withers, shoulder, back, loins, and croup), width of body, conformation of forelimbs, conformation of hind limbs, correctness of movement and temperament – evaluated in ten point scale.

The objective of the study was to detect the difference of the conformation scores between dams and daughters in Latvian Warmblood horse breed.

Materials and Methods

Data of Latvian Warmblood horse breed broodmares were analyzed. The data included conformation valuations of Latvian Warmblood horse breed dams (n = 423) and their daughters (n = 596) of different ages (several dams had more than one daughter). The horse breeding organisations' evaluating data from 1995 to 2015 were analyzed (from Latvian Horse Breeders Association, Latvian Horse Breeding Association). Such factors as

Table 1

The average scores of several conformation traits of Latvian Warmblood horse breed mares

Traits	Dams n=423		Daughters n=596		Difference
	$\bar{x} \pm s_{\bar{x}}$	V, %	$\bar{x} \pm s_{\bar{x}}$	V, %	
Top line	7.71 ± 0.041	11.8	7.51 ± 0.031	10.1	0.20*
Forelimbs	7.33 ± 0.038	13.2	7.21 ± 0.034	11.7	0.12*
Hind limbs	7.35 ± 0.042	13.3	7.20 ± 0.035	11.9	0.15*

* $p<0.05$

mares' age in evaluating time, type (sport or carriage), used sires and sires' breed, count of foals, place of evaluating and information about experts were not included in this research.

The Latvian Warmblood horse breed broodmares were evaluated in accordance with Breeding Programme of Latvian Warmblood Horse. Research was carried out using horse breeding organisation's data. The valuation of three conformation traits were analyzed - top line of horse (head-neck-body), conformation of forelimbs and conformation of hind limbs due to higher objectiveness in valuation of these traits, importance in horse selection, close relationship to horse productivity and less influence of age and other factors.

The information about pedigree of mares, their conformation valuation and conformation valuation of their progeny was found in public horse database of Latvian Horse Breeding Association, available at: www.lwhorse.lv.

The statistical analysis was performed using Microsoft Excel. The difference between average values of analysed traits of dams and daughters determined by the t – test; $p \leq 0.05$ means that difference is significant. The phenotypic correlation (r_p) between scores of analysed traits was calculated by the Pearson correlation coefficient.

Results and Discussion

The data analyses showed that dams had higher average valuation than a group of daughters. An average in ten-point scale in the group of dams was 7.73 ± 0.04 for top line scoring, 7.38 ± 0.04 for forelimbs and 7.40 ± 0.04 points for hind limbs (Table 1). An average of valuation points of their daughters was 7.51 ± 0.03 for top line scoring, 7.21 ± 0.03 for forelimbs and 7.20 ± 0.04 for hind limbs. A significant difference between valuations of dams and their daughters ($p<0.001$) was found for all three conformation traits. Results can be explained with different experts and date of birth of mares that would not be included in research. These differences in scores of conformation traits would be the result of more strict breeding criteria in horse selection and higher quality of broodmares also due to larger population. It would be recommended to analyze population of young mares and their dams to detect breeding progress in the last ten years.

The scores of dams were more unequal as it was shown by higher values of coefficient of variation (11.8 to 13.3%) as in the group of daughters (10.1 to 11.9%).

Although scores of daughters were significantly lower, results also showed that scores between daughters were more adjusted. Minimal scores in the group of daughters were not lower than 5 points whereas the 2 point score was registered in dams' group for forelimbs. Previous studies with a similar horse scoring system (scale from 1 to 10) showed that scores of hind limbs were from 5 to 8, scores of forelimbs – 4 to 8, on average – 6.4 points for both traits in the group of mares (Simcic, Mesaric, & Potocnik, 2012).

The grouping of dams and daughters basis to score points of top line showed that most frequent valuation for this trait was 7.00 to 8.99 points in both groups (Fig. 1). According to the frequency of scores, dams had higher quality of top line.

The analysis of forelimbs and hind limbs scores showed that the most frequent score was 7 points (7 to 7.99) that could be described as 'good' (Fig. 2, 3). It is not possible to detect the most common conformation traits (also faults) from this valuation system.

In valuation of hind limbs both groups had scoring under 6 points more frequently than for other conformation traits.

Positive and low correlation was calculated between groups of dams and daughters in all three conformation traits. The correlation between groups was significant.

Correlation between traits into each group ranged widely and the highest correlation was between forelimbs and hind limbs in the group of dams (r_p = 0.70). Limb quality was moderately correlated with top line in the group of dams. Lower correlations were detected in the group of daughters; it could be explicable with more consolidated and more

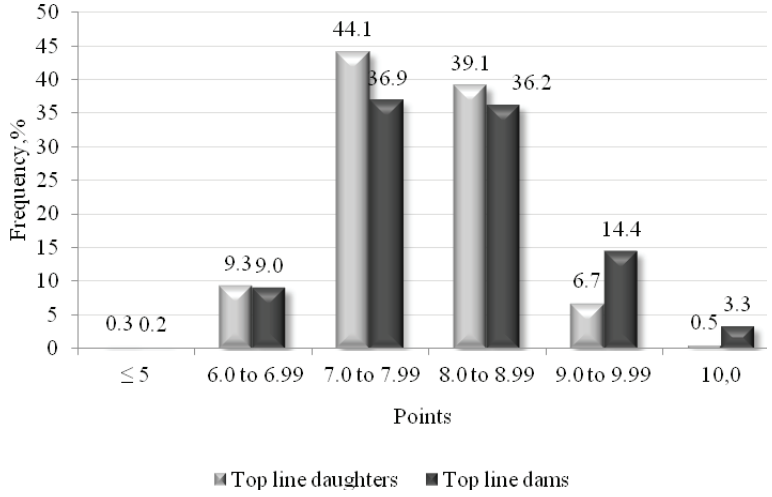

Figure 1. The grouping of Latvian Warmblood horse breed dams and daughters by top line scoring.

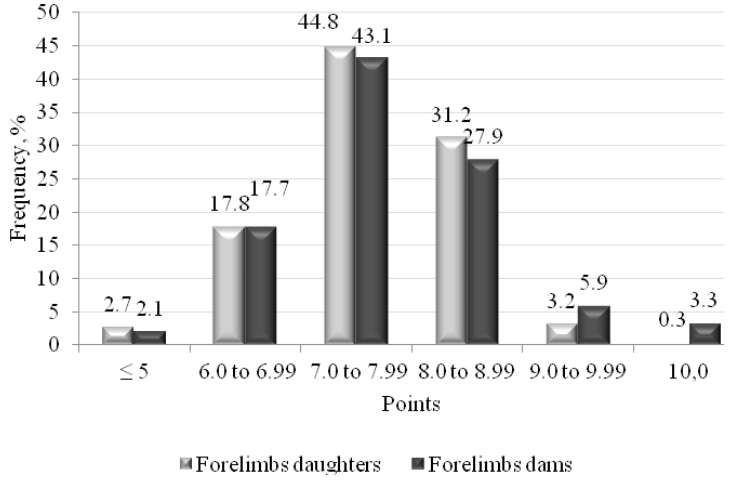

Figure 2. The grouping of Latvian Warmblood horse breeds dams and daughters by forelimbs scoring.

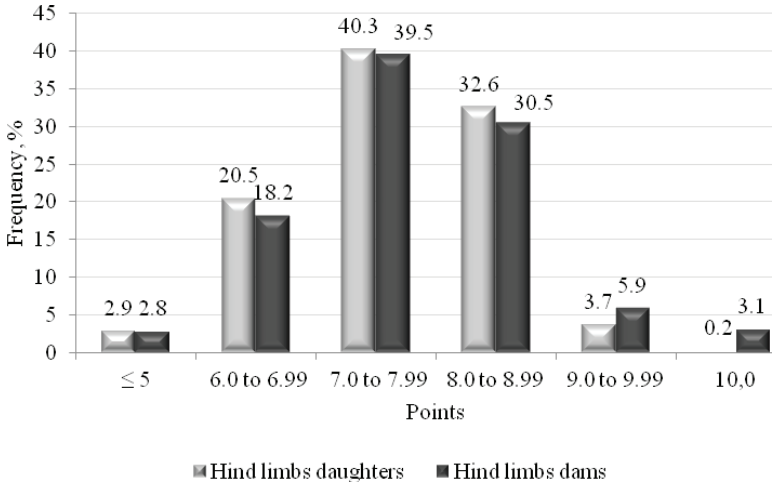

Figure 3. The grouping of Latvian Warmblood horse breeds dams and daughters by hind limbs scoring.

qualitative group of dams or specifics of horse evaluating by different experts, less from objective relation between traits.

To realise successful selection work, it is essential to find out what relationships exist between different selectional traits.

Figures 4, 5, 6 were showing scattering of valuation of conformation in groups of dams and their daughters.

Relationship between scores of dams and daughters in conformation trait 'top line' is positive however weak (r_p = 0.24). As it was shown in Figure 4, dams whose score was 10 points, no daughter has received equally high scoring. Also, the opposite situation – daughters from dams with scoring 9 and 8 points were evaluated with 10 points - was observed.

Relationship between scores of forelegs of dams and daughters was weaker than between scores of top line because r_p = 0.17. The lowest score of dams for this trait was 5 points, but for the daughter of this mare – only 2 points. As it was shown in Figure 5, dams with 10 point score have daughters whose scores were medium – from 5 to 7.

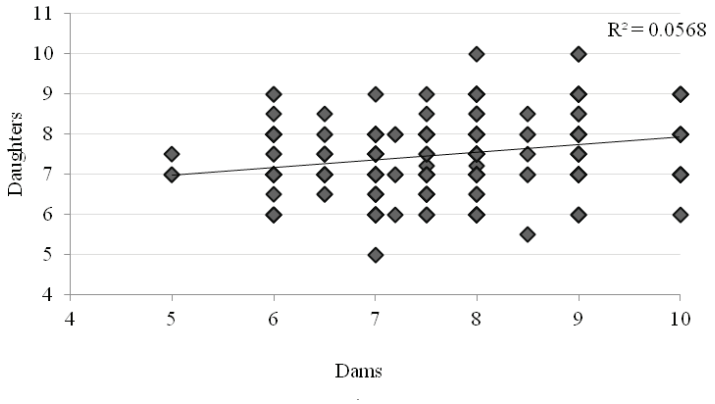

Figure 4. The relationship between dams and daughters of Latvian Warmblood horse breed in top line's valuation (in points).

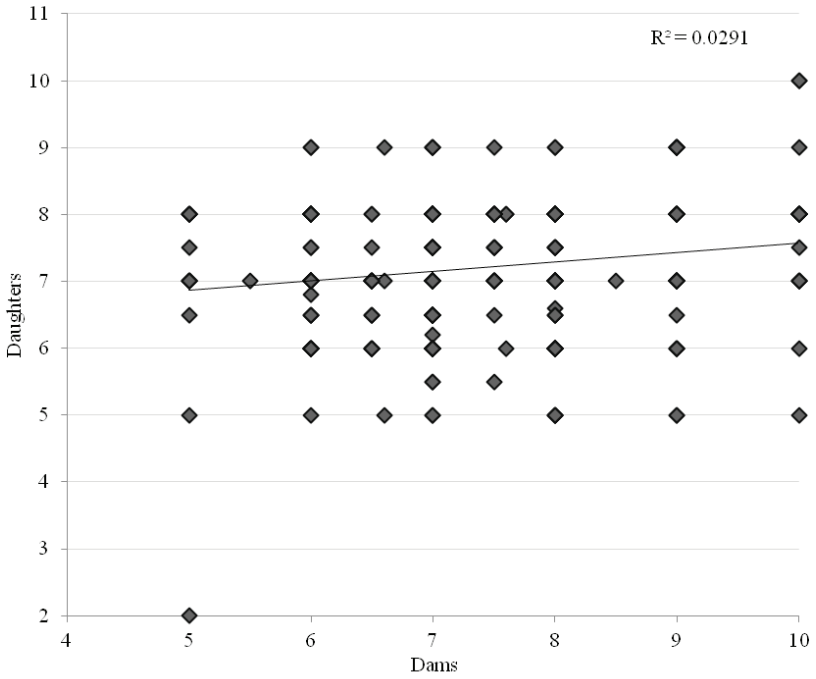

Figure 5. The relationship between dams and daughters of Latvian Warmblood horse breed in forelimbs' valuation (in points).

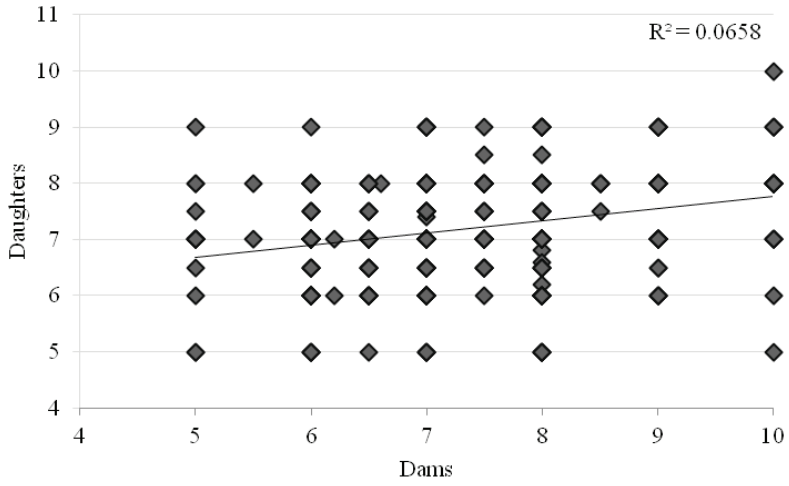

Figure 6. The relationship between dams and daughters of Latvian Warmblood horse breed in hind limbs' valuation (in points).

Closer relationships were observed between scores of hind limbs than between scores of forelimbs; however, it was also weak ($r_p = 0.26$). Also in valuation of hind limbs it is seen that dams with score 10 points have daughters whose scores were only 5 points (Fig. 6).

The results showed that the relationship between conformation traits of dams and daughters was weak, because the development of traits depends on the genetic information received from both parents. Therefore, the obtained results may indicate that successful pair selection was not carried out.

Heritabilities for analyzed conformation traits tended to be relatively low due to specifics of scoring. Previous studies verified that the lowest heritabilities were calculated directly for the limb score. It could be explicable with the large number of included limb traits (Jönsson *et al*., 2014). The evaluation of limbs in ten point scale hides many parameters as faults and advisable conformation traits, and it is also subjective due to various experts.

Conclusions

Comparison of conformation scores of dams and daughters in Latvian Warmblood horse breed showed that groups differed significantly ($p<0.05$) by analyzed traits – top of body, forelimbs and hind limbs. Dams had higher valuation than the group of daughters.

The close relation between conformation quality of dams and their daughters was not found.

The main recommendation is provident selection of high quality stallions of both types for breeding purpose to reproduce young broodmares with higher quality of conformation. It would be necessary to continue studies about broodmare quality, analyzing the latest data of progeny.

References

1. Breeding Programme of Latvian Warmblood Horse (2010). Retrieved February 18, 2016, from http://www.lszaa.lv/images/stories/Copy_of_Latvijas_zirgu_irnes_ciltsdarba_programma_2010-2015_A.pdf.
2. Dyson, S. (2000). Lameness and poor performance in the sports horse: dressage, show jumping and horse trials (eventing). Retrieved February 18, 2016, from http://www.ivis.org/proceedings/aaep/2000/308.pdf.
3. Dubois, C., Manfredi, E., & Ricard, A. (2007). Efficiency of past selection of the French Sport Horse: Selle Français breed and suggestions for the future. *Livestock Science*, 112, 161-171.
4. Dubois, C., Manfredi, E., & Ricard, A. (2008). Optimization of breeding schemes for sport horses. *Livestock Science*, 118, 99-112.
5. Jönsson, L., Näsholm, A., Roepstorff, L., Egenvall, A., Dalin, G., & Philipsson, J. (2014). Conformation traits and their genetic and phenotypic associations with health status in young Swedish warmblood riding horses. *Livestock Science*, 163, 12-25.
6. Koenen, E.P.C., Aldridge, L.I., & Philipsson, J. (2004). An owerview of breeding objectives for warmblood sport horses. *Livestock Production Science*, 88, 77-84.
7. Laizāns, N. (2012). Zirga kāju stāvotnes un to ietekme uz darba kvalitāti (The leg conformation in horses and its impact on the performance quality). Dzīvnieki. Veselība. Pārtikas higiēna: Veterinārmedicīnas zinātnes un prakses aktualitātes, Konference, Latvijas Lauksaimniecības universitāte, Jelgava, 191-195. lpp. (in Latvian).

8. Posta, J., Komlósi, I., & Mihók, S. (2010). Genetic Parameters of Hungarian Sporthorse mares. Retrieved February 18, 2016, from http://old.eaap.org/Previous_Annual_Meetings/2006Antalya/Papers/H25.3_Posta.pdf.
9. Rozītis, G., Kļaviņa, I., & Juršāne, V. (2008). Latvijas šķirnes zirgu ģenētiskie resursi (Latvian breed horse genetic resources). Agronomijas Vēstis, 10, 277-281. lpp. (in Latvian).
10. Simcic, M., Mesaric, M., & Potocnik, K. (2012). Analysis of conformation traits of the Posavje horse in Slovenia. *Slovenian Veterinary Research*, 49, 141-148.
11. Viklund, Å., Näsholm, A., Strandberg, E., & Philipsson, J. (2011). Genetic trends for performance of Swedish Warmblood horses. *Livestock Science*, 141, 113-122.

LIVEWEIGHT CHANGE OF RED DEER (*CERVUS ELAPHUS* L.) CALVES AFTER WEANING

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Abstract
The article analyses the data obtained while evaluating red deer calves on the red deer breeding farm 'Dumpji' during the herd's annual prophylactic check-up in December and April of the years 2013 and 2014. Farm is a private enterprise owned by a company located in Northern Latvia. The study comprises data for calves born in 2013 (n = 36) that were born from the same hinds, but from different stags in consecutive years. It was discovered that the calves' liveweight gain in 24 hours significantly decreases during wintering period. After the wintering smaller body mass was observed in calves of both sexes born in 2014; however, the body mass of bull calves born in both years of reference considerably exceeded that of the hind calves. In the group of hind calves born in both years of the study period the liveweight loss was observed during the wintering. Nevertheless, at the age of 1.5 years the lowest liveweight among hind calves was 82.4 kg (year 2013), and the highest 129.6 kg (year 2014). In the group of spikers, during the winter period liveweight loss was not observed. Analysis of the results revealed a close positive correlation between the liveweight in December and the liveweight in the spring among spikers and heifers alike. The conducted analysis of influencing factors attests to the fact that the liveweight at the age of six months has material impact on the animals' liveweight both in the spring and at the age of 1.5 years.
Key words: Red deer, cross breed calves, liveweight gain.

Introduction

Considering deer-breeding a profitable farming industry in Latvia there has been developed the Red deer breeding program. Its first stage commenced in 2005. After completion of the second stage in 2015, 17 farms were acknowledged as red deer breeding farms. Implementation of red deer breeding program in Latvia ensures production of quality breed, thus improving the existing animal population. The second stage of the program expired in 2015. Deer-breeding in Latvia is being coordinated by the society Organic Farmers and Wild Animal Breeders Association (OF&WABA) (Proškina, 2013; Staltbriežu ciltsdarba programma, 2010).

In Europe there are no red deer breeding programs similar to that developed in Latvia. There have been developed some guidelines for red deer breeders based on the demand in global markets and the newest scientific studies have been published in a handbook, such as Deer industry manual etc. (Beatson, Campbell, & Judson, 2000; Deer industry news, 2015).

Under the Red deer breeding program that was developed in Latvia in 2005 (Staltbriežu ciltsdarba programma, 2010), as a primary breeding feature was considered the precocity of calves. The precocity of calves is being assessed by measuring their liveweight prior or after their weaning from mothers and at the age of 100 days. When reaching the age of 1.5 years young animals are subjected to reassessment. Best animals are earmarked for the reproduction of breed, while others are realised for the meet production (Staltbriežu ciltsdarba programma, 2010). In Europe and New Zealand the calves' liveweight is taken upon their separation from mothers or fattening during the winter period (Bokor & Bokor, 2014; Beatson, Campbell, & Judson, 2000; Dan DeBaedemaecker, 2014). The weaning of farmed calves from their mothers takes place at the age of three to five months depending on the farming strategy, while wild animals suck for 5 to 8 months (Guinness, Hall, & Cockerill, 1979; Clutton-Brock, Guinness, & Albon, 1982; Pollard, Littlejohn, & Suttie, 1992). The body mass by the end of feeding period has a close correlation with the livestock output, and it is economically justified (Dusalijeva, 2006).

Elsewhere around the world for the needs of studies on red deer calves of various ages the calculations are based on the data about their time of birth, circumstances and liveweight upon birthing. In Latvia as of 2016 there is no appropriate methodology of acquiring such data. In literature sources as the calves' birth period is mentioned the turn of May and June (Clutton-Brock *et al*., 1987; Drabinska, 2006). In turn, the results acquired in New Zealand imply that, statistically, the frequency of parturition is concentrated within the 10-day period at the turn of November and December, which corresponds to May-June in Europe (Audige *et al*., 1999).

The objective of this study is to compare changes in liveweight of red deer calves born in 2013 and 2014 and the pace of growth from the age of 6 months to 1.5 years as well as the compliance of liveweight with the requirements specified in the breeding program for calves of both sexes. Similar studies have been performed in New Zealand, Australia, United Kingdom and Poland. Taking into account the climatic

differences of the current place of study, we believe that locally conducted researches will facilitate the goal set by WABA- breed both trophy and meat animals of local bloodline, which are suitable for the Latvian climatic conditions.

Materials and Methods

The research was conducted in red deer breeding farm 'Dumpji' which is located in Northern Latvia, Vidzeme region - Lat: 57.4552889, Lon: 26.6339798. According to the administrative division it is situated in Trapene rural parish of Ape region. In terms of geographic location - in Tālava lowland, Trapene plains, on the right bank of the Melnupe river, which is the tributary to the Mustjõgi river in Estonia. Total space of the farm comprises 164 ha, out of which the woods take some 70 ha and farming land - some 89 ha. Red deer breeding takes place in a fenced territory of 72 ha.

The conception date for more than 100 red deer hinds cannot be determined with absolute precision. As such is assumed the period from 1st through 20th October based on observations of similar studies (Beatson, Campbell, & Judson, 2000; Clutton-Brock, Guinness, & Albon, 1982). The length of gestation period that depends also on the calf's sex for red deer hinds comprises 234 ± 3 days (Clutton-Brock, Guinness, & Albon, 1982), or 34-35 weeks (Siliņš, 1984). Respectively, the parturition takes place from 25th May through 15th June.

During the prophylactic herd handling, the calves and young animals were weighted in a pen with installed scales 'Tru-Test Multipurpose MP800'. Scale producer specified an error of no more than ± 0.5 kg, readings taken by the electronic 'EziWeigh6' indicator were entered into Windows Excel software and prepared for processing. By several reasons the study was commenced on 8th December 2013 when the calves were separated from their mothers and weighted for the first time. Late separation is beneficial for calves, in particular for late borne animals, yet such practice may impair the next-year reproduction ratios and affect the herd's numerical growth (Beatson, Campbell, & Judson, 2000). Therefore, the farm's strategy discontinues such practice. Out of 36 separated calves in December 2013, 18 were female and 19 male. Initially, after taking the liveweight during the wintering period from the group of study were excluded three bull calves and two hind calves. After initial data processing for further research purposes, the number of young animals was n = 15 female and n = 16 male calves. Calves were 25% Polish and 75% UK blood born from two years old Polish/UK crossbreed hinds. Stags were 100% UK born. In the mating season of the year 2013 the same hinds were mated with pure Polish blood stag. As a result, calves born in the year 2014 were 75% Polish and 25% UK blood born from three years old Polish/UK crossbreed hinds. The number of new-born calves was 20 female and 22 male. Calves born in 2014 for the first time were weighted and separated from mothers as soon as by the end of October and weighted again in early December prior to the wintering period, in the spring and at the age of 1.5 years. As no comparison with liveweight of calves born in 2013 was possible in October, information for October was not taken in

Table 1

Supplementary feed quality indicators

Feed products	Detectable indicator, unit	Result
Oat grain	Crude protein, %	11.18
	NDF, %	32.75
	ADF, % NEI, MJ kg^{-1} of dry matter	16.08 7.33
	Digestibility	76.40
Silage	Crude protein, %	14.25
	NDF, %	53.81
	ADF, % NEI, MJ kg^{-1} of dry matter	38.64 5.53
	Digestibility	58.80
Hay	Crude protein, %	6.91
	NDF, %	64.30
	ADF, % NEI, MJ kg^{-1} of dry matter	38.04 5.57
	Digestibility	59.3

consideration regarding calves born in 2014. Within both years of study calves were weighted three times:

- calves born in 2013 – December 7 same year, April 13 and December 8 in the year 2014
- calves born in 2014 – December 7 same year, May 4 and November 26 in the year 2015.

At the beginning of wintering period the calves born in 2013 and 2014 were kept in a small enclosure that was connected to the shed. For supplementary feeding were used the oat grain, silage from sown grassland (mixture G1) and hay from natural pastures. Water as well as silage and hay were freely accessible to the animals - *Ad libitum.*

The forage ration was defined and fed according to the age and weather when calculating 1.0 – 1.5 kg per calf. For feed, chemical analysis were carried out and quality indicators identified in year 2014 (see Table 1). What should be taken in consideration is the fact that the mothers of calves born in 2013 were just 2 years old; however, as pointed out in the literature sources, red deer hinds at the age of two reach their rutting time by 17 days later and in the third year by some 5 days later than those of the age of 5 (Beatson, Campbell, & Judson, 2000).

The analysis was conducted by applying the statistical methods subject to calculating the minimum, maximum and mean values, standard error of mean, deviation and variance. Comparison of liveweight and liveweight gain is based on t-test, while the analysis of impact exerted by influencing factors - on One-way ANOVA. To determine the relationship between liveweight in different periods, the correlation analysis was used. Data analysis was performed on IBM SPSS Statistics 21 software.

To mark the importance of differences in results acquired over the years of study, lower-case letters are used, while those among sexes – with upper-case letters.

Results and Discussion

Analysis of the study results was commenced with the calves' liveweight in December. According to Table 2, the average liveweight of bull calves born in 2013 amounted to 64.9 kg, varying from 46 (worst result) to 79 kg (top result). At the same time, the weight of hind calves was lower by 4.6 kg on average, which corresponds to the data specified in the deer producers' handbook published in New Zealand. This manual states that the liveweight of red deer bull calf subject to weaning at the age of 3 months exceeds that of the hind calf by 4.8 ± 0.8 kg on average (Beatson, Campbell, & Judson, 2000). The highest liveweight for hind calves in 'Dumpji' farm amounted to 70 kg, while the lowest – to 45 kg.

Weighting of calves born in December of 2014 revealed similar differences in the average liveweight between bull and hind calves, i.e. some 4.9 kg ($p<0.05$). Dispersion of liveweight among bull calves was close to the mean, the coefficient pf variation being 10%, which was by 3.6% less than that among the bull calves born in 2013. The maximum liveweight among bull calves was by 1 kg less, yet the minimum - by 7 kg more than in 2013. As to the hind calves, their maximum liveweight remained the same, while the

Table 2

Liveweight of calves at the beginning of study in 2013 and 2014

Variable	Year	Sex	x±Sx	Min	Max	V, %
Liveweight in December, kg	2013	male (n = 16)	64.9 ± 2.20^{A}	46.0	79.5	13.6
		female (n = 15)	60.3 ± 1.40^{A}	45.0	70.0	9.10
	2014	male (n = 16)	66.4 ± 1.38^{A}	52.0	78.5	10.0
		female (n = 15)	61.5 ± 1.70^{B}	48.0	70.0	11.0

$^{A, B}$ – significant differences have been observed between sexes, $p<0.05$.

Table 3

Calves' liveweight by the end of wintering period, kg

Variable	Year	Sex	x±Sx	Min	Max	V, %
Liveweight in April/ May, kg	2013	male (n = 16)	72.4 ± 2.30^{A}	51.0	94.5	13.0
		female (n = 15)	64.3 ± 0.90^{B}	58.5	71.5	5.2
	2014	male (n = 22)	70.8 ± 1.70^{A}	53.0	84.5	11.0
		female (n = 17)	62.7 ± 1.50^{B}	49.0	73.5	11.0

$^{A, B}$ – signifficant differences have been observed between sexes, $p<0.05$.

Table 4

Liveweight of young animals at the age of 1.5 years, kg

Variable	Year	Sex	x±Sx	Min	Max	V, %
Liveweight at age 1.5 years, kg	2013	male (n = 16)	110.5 ± 3.00^{aA}	82.5	140.0	10.8
		female (n = 15)	92.4 ± 1.20^{aB}	82.5	103.5	4.8
	2014	male (n = 22)	97.8 ± 2.13^{bA}	77.0	114.0	10.0
		female (n = 10)	$96.3 \pm 2.20a^{A}$	87.5	110.0	7.0

$^{A, B}$ – significant differences have been observed between sexes, $p<0.05$.
^{a,b} – significant differences have been observed by years of observation, $p<0.05$.

minimum liveweight grew by 3.0 kg. The variation range has decreased, while the coefficient of variation - increased. The study reveals that in both years the sex has been a significant factor to affect the calves' liveweight in December.

By the end of wintering period, which in both years occurred to be late April - early May, red deer calves were weighted once again. The mean liveweight of young red deer spiker born in 2013 was 72.4 kg (Table 3).The heaviest spiker at the time weighted 94.5 kg, while the lightest - 51 kg.

The coefficient of variation for liveweight in the group remained within the borders of 13%. Among spikers born in 2014, the heaviest weighted 84.5 kg, which is by 10 kg less than the maximum liveweight among spikers born one year before, while the lightest - 53 kg, which, in turn, is by 2 kg more than one year before. The coefficient of variation as compared to the precedent year has decreased by 2%. The mean liveweight among bull calves in both years of study reveal no significant differences, $p>0.05$.

The average liveweight among hind calves born in 2014 as compared to those born in 2013 was by 1.6 kg less, i.e. 64.3 kg and 62.7 kg, respectively. Considerably lower was the weight of the lightest hind calf: mere 49 kg, which was by 9.5 kg less than that of the lightest hind calf in 2013. Moreover, for the liveweight of hind calves born in 2014 the coefficient of variation had grown by 5.8%, reaching that of spikers – 11%, thus pointing out to bigger dispersion of liveweight.

The mean liveweight of hind calves at the age of 1.5 years, i.e. 96.3 kg implies improved quality of animals. The weight of the heaviest hind calf born in 2014 amounted to110 kg, which was by 6.5 kg more than that of the one born in 2013 (see Table 4). Similar situation is with the minimum observed liveweight. The weight of the lightest hind calve born in 2014 by 5 kg exceeded that of the one born in 2013.

According to observations, the coefficient of variation regarding liveweight grew by 2.2%, while the mean value - by 3.9 kg, which may be explained by alternations within the group: in the summer/autumn period seven hinds with the lowest weight were sold to a farm abroad.

It should be noted that in breakdown by years negative liveweight variation trends were observed in the group of spikers, where the mean liveweight of those born in 2014 was by 12.7 kg less ($p<0.05$) as compared to those born in 2013, which only by 1.5 kg exceeded the calves' liveweight.

Analysis of the results revealed a close positive correlation for calves of both sexes between their liveweight in December and in spring: for males=0.9 and females r = 0.8, as well as between liveweight in December and at the age of 1.5 years r = 0.7. The critical value of the correlation coefficient has been taken into account and indicates that correlation is considered to be statistically significant.

By using the attained liveweight of calves and young animals, the liveweight gain per day over various rearing periods was computed (see Table 5). Bull calves born in 2013 produced the liveweight gain per day during the winter period by 72.2 g on average. Those males that were born one year later over the same period gained 35.88 g per day on average, which is by 49.7% less than one year before ($p<0.05$). The minimum liveweight gain per day for males born in 2013 amounted to 14.6 g, while for those born in 2014 - 6.76 g. In turn, the maximum liveweight gain per day for males of the above groups amounted to 145.6 g and 121.6 g, respectively. Liveweight gain for female calves per day during the winter period on average amounted to 25.0 g for those born in 2013 and to 1.79 g for those born in 2014 ($p<0.05$). It was observed that part of female calves that were born in 2013 and 2014 lost some liveweight during the winter period. The biggest liveweight loss for female calves of both groups was similar, 55.1 g and 50.7 g per day on average, thus resulting in material dispersion ratio of this feature. Material differences on liveweight gain from December through April/May were observed both between years and sexes.

From December till the age of 1.5 years the biggest liveweight gain per day was observed among hind calves born in 2014, i.e. 106.3 g, while among those

Table 5

Calves' liveweight gain per day over the observation periods, g day^{-1}

Variable	Year	Sex	x±Sx	Min	Max	V, %
Liveweight from December to spring April/ May, g day-1	2013	male (n = 16)	72.2 ± 8.10^{aA}	14.6	145.6	45.0
		female (n = 15)	25 ± 8.76^{aB}	-55.1	106.3	144.4
	2014	male (n = 21)	35.88 ± 6.62^{bB}	6.8	121.6	84.8
		female (n = 17)	1.79 ± 4.33^{bB}	-50.7	33.8	997.8
Liveweight from December to age 1.5 years, g day-1	2013	male (n = 16)	134.0 ± 5.80^{aA}	94.1	177.9	17.3
		female (n = 15)	94.4 ± 3.10^{B}	82.4	129.4	12.5
	2014	male (n = 21)	88.7 ± 7.74^{bA}	15.5	165.3	40.9
		female (n = 8)	106.2 ± 4.05^{B}	96.0	129.6	10.8

$^{A, B}$ – signifficant differences have been observed between sexes, $p<0.05$.
^{a,b} – significant differences have been observed by years of observation, $p<0.05$.

born in 2013 it amounted to 94.4 g. Liveweight loss among hind calves was observed during the wintering period only, while over the entire observation period the liveweight gain per day was positive. The fast growth of calves might be explained by the so-called compensatory growth during the spring period, when the vegetation recommences in pastures and animals stop receiving the fodder (Fletcher, 2006). One of the explanations why liveweight loss among hind calves was observed during wintering period could be the fact that male and female calves are kept together in one enclosure and female calves have limited access to forage due to their size and weight. Of particular importance is the liveweight gain for hind calves in summer-autumn period, taking into account their sooner maturity for breeding and liveweight at the age of 16 months when they reach the economic maturity for breeding and are ready for mating (Moore, Littlejohn, & Cowie, 1988).

In the group of bull calves the highest liveweight gain from December till the age of 1.5 years displayed those born in 2013 (134.0 g), which by 45.3 g ($p<0.05$) exceeded the daily liveweight gain among bull calves born in 2014 over the same period. During this time the growth of hind calves was faster, exceeding the daily liveweight gain of bull calves by 17.5 g ($p<0.05$).

Spikers born in 2014 at the age of 1.5 years reached the liveweight of 97.8 kg, which according to the Red deer breeding program gives them 4 points and is considered very poor.

Taking into consideration the accessible data from other studies (Beatson, Campbell, & Judson, 2000; Asher *et al*., 2011) one can conclude that the ratios in both groups are behind the optimum ones. There was a rather small share of animals which met and even surpassed the expectations. According to the Red deer breeding program, the optimum weight of hind calves at this age should be 70 – 90 kg and more, while that of spikers – 110 – 125 kg and more (Staltbriežu ciltsdarba programma, 2010).

After separation, the daily liveweight gain till the age of 5 months may be up to 236 g, while at the age of 5 to 6 months the liveweight gain decreases and may shrink below 138 g per day. In order to ensure such liveweight gain prior and after separation, the nursing hinds and their calves must be provided with quality feed, maintaining the energetic concentration of 11 MJ kg of dry contents, green weight of some 60% out of the total feed ration, limiting the content of proteins to 400 g per day (Beatson, Campbell, & Judson, 2000; Asher *et al*., 2011).

One may make a supposition that different climatic conditions in the southern hemisphere pose an important factor both in terms of the feed quality and the weather conditions.

The conducted analysis of influencing factors indicate that the liveweight at the age of six months has material impact both on the liveweight attained during the spring period and that at the age of 1.5 years. Similar evidence was already obtained in New Zealand where the researchers ascertained that the liveweight upon separation influences the liveweight at the age of six months and that at the age of 12 months (Beatson, Campbell, & Judson, 2000). It indicates that in order to breed a quality animal one should pay particular attention to receiving the utmost ratios during their first months of life. Material impact on liveweight at the age of 1.5 years had both the sex and the year of birth ($p<0.05$).

Under the Red deer breeding program (Staltbriežu ciltsdarba programma, 2010) that was effective until 2015, calves of both sexes at the age of 1.5 years passed evaluation (see Table 6). The obtained results confirmed that 11 of spikers out of 16 born in 2013 scored 7 points and more. In turn, all hind calves both in 2013 scored 9 and 10 points.

Table 6

Evaluated spikers and score according to the Breeding program, points

Score points	Number of spikers
10	1
9	2
8	2
7	6
6	3
5	1
4	-
3	1

The liveweight of spikers born in 2014 should be regarded critically at the age of 1.5 years. Only two out of 22 animals, according to the Red deer breeding program received the score of 7 points; other animals received 6 points and less. However, 9 out of 10 hinds that still were at the farm by the end of research received 10 points. To be ready for mating in the second year of life, the hind calves must have at least 60% of an adult hind's liveweight, i.e. some 85 kg (Kelly & Moore, 1977; Beatson, Campbell, & Judson, 2000). Such liveweight, according to the breeding program requirements should score 8 points (Staltbriežu ciltsdarba programma, 2010).

The low score of spikers' liveweight hypothetically could be explained by the fact that two-year old hinds last year were in heat on average by some 14 days later than those of three years (Beatson, Campbell, & Judson, 2000). It entails later parturition and lactation, which might affect the hind's bodily condition and the new generation. Observers in Rama Island concluded that every 10 liveweight kilos of the hind increase the calf's liveweight upon birth by 0.33 - 0.53 kg (Moore, Littlejohn, & Cowie, 1988). In turn, the liveweight upon birth has impact on further growth of the calves. It should be noted that during the entire research period the calves of both sexes were held, separated and fed under similar conditions.

Conclusions

1. Liveweight of calves of both sexes at the age of six months upon commencement of the research in December exceeded 60 kg, being considerably higher for bull calves born in 2014, i.e. 66.4 kg on average, which is by 4.9 kg more than that of hind calves born in the same year ($p<0.05$). The obtained results are similar to those acquired elsewhere around the world.
2. After wintering, calves of both sexes that were born in 2014 had a lower liveweight; however, in both years of observation the liveweight of bull calves considerably exceeded that of the hind calves, i.e. by 8.1 kg on average ($p<0.05$).
3. In the group of hind calves born in both years of research the liveweight loss was observed during the wintering period. The biggest calculated liveweight loss was 55.1 g day^{-1} (in 2013) and 50.7 g day^{-1} (in 2014), which was compensated over the spring and summer seasons, so that at the age of 1.5 years the lowest liveweight among hind calves was 82.4 kg (in 2013), and the highest 129.6 kg (in 2014). All reared hind calves under the breeding program requirements can be used for breeding and the obtained results may serve for the purpose of further studies.
4. In the group of spikers, over the wintering period the liveweight gain per day considerably decreased, down to 72.2 g (in 2013) and 35.9 g (in 2014), while no liveweight loss was detected. Yet, at the age of 1.5 years just 11 bull calves born in 2013 scored 7 points and more, while in 2014 the breeding animal requirements were met by mere 2 spikers only. The results may be explained by the influence of various factors. Additional research would be required in the future to assess the influence of such factors.

References

1. Asher, G.W., Stevens, D.R., Archer, J.A., Barrell, G.K., Scott, I.C., Ward, J.F., & Littlejohn, R.P. (2011). Energy and protein as nutritional drivers of lactation and calf growth of farmed red deer. *Livestock Science.* 140, (1-3), 8-16.
2. Audige, L.J.M., Wilson, P.R., Pfeiffer, D.U., & Morris, R.S. (1999). Reproductive performance of farmed red deer (*Cervus elaphus* L.) in New Zealand: II. Risk factors for adult hind conception. *Preventive Veterinary Medicine* 40, 33-51.
3. Bokor, A., & Bokor, J. (2014). *The Innovation in red deer (Cervus elaphus* L.*) farming in Hungary.* In: The international Scientific Conference on Deer genetics and Management. Proceedings and materials. Sigulda.
4. Beatson, N., Campbell, A., & Judson, G. (2000). *Deer Industry Manual*, Deer Master, New Zealand, South Canterbury &North Otago Branch NZDFA.
5. Clutton-Brock, T.H., Guinness, F.E., & Albon, S.D. (1982). *Red Deer: Behaviour and Ecology of Two Sexes*. The University of Chicago Press, Chicago.

6. Clutton-Brock, T.H., Major, M., Albon, S.D., & Guinness, F.E. (1987). Early Development and population Dynamics in Red Deer. I. Density-Dependent Effects on Juvenile Survival. *Journal of Animal Ecology*, 56, 53-67.
7. DeBaerdemaecker, D. (2014). *The simple secrets of successful deer management at Woburn deer farm.* In: The international Scientific Conference on Deer genetics and Management. Proceedings and materials. Sigulda.
8. Drabinska, A. (2006). *Efektiwnošč rozrodu i wyniki odchowu jeleni hodowanych w warunkach fermerowich (The efficiency of breeding and results in farm bred red deer rearing). Praca doktorska.* Uniwersytet Warmińsko-Mazurski w Olsztynie, *Katedra Hodowli Owiec i Kóz. Olsztyn. (in Polish).*
9. Dusalijeva, I. (2006). Briežkopības produkti. *Staltbriežu audzēšana un selekcija (Red deer breeding and selection).* (pp. 30-35). Riga: SDAA. (In Latvian).
10. Fletcher, J. (2006). Ievads briežkopībā. *Staltbriežu audzēšana un selekcija (Red deer breeding and selection),* (pp. 13-29). Riga: SDAA. (In Latvian),
11. Guinness, F.E., Hall, M.J., & Cockerill, R.A. (1979). Mother-offspring association in red deer (*Cervus elaphus* L.) on Rhum. *Animal Behaviour*. 27, 536-544.
12. Kelly, R.W., & Moore, G.H. (1977). Reproductive performance in farmed red deer. *New Zealand Agriculture Science*, 11(4), 179-181.
13. Moore, G.H., Littlejohn, R.P., & Cowie, G.M. (1988). Factors affecting liveweight gain in red deer calves from birth to weaning. *New Zealand Journal of Agricultural Research*.31, 279-283.
14. Pollard, J.C., Littlejohn, R.P., & Suttie, J.M. (1992). Behaviour and weight change of red deer calves during different weaning procedures. *Applied Animal Behaviour Science*, 35, 23-33.
15. Proškina, L. (2013). *Briežkopības attīstības iespējas Latvijā. (Deer farming possibilities in Latvia).* Summary of the doctoral dissertation for the scientific degree of Dr.eoc. Subdivision Ekonomikas: Agricultural Jelgava: LLU. (in Latvian).
16. Siliņš, A. (1984). *Medības Latvijas PSR (Hunting in the Latvia SSR).* Rīga: Avots (in Latvian).
17. *Staltbriežu ciltsdarba programma 2010–2015. gadam (Breeding program for Red deer 2010-2015).* Retrieved October 10, 2015, from http://www.ldc.gov.lv /lv/likumdosana/nacionala/. (in Latvian).
18. Deer industry news 73 (2015). Retrieved August/September, 2015, from http://www.deernz.org/sites/dinz/files/DINZ73-Optimised.pdf.

HIGH-PRESSURE PROCESSING AS NOVEL TECHNOLOGY IN DAIRY INDUSTRY: A REVIEW

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Abstract
The aim of this review was to summarize available bibliography on the possible applications of high pressure processing in dairy industry, the effect of this non-thermal treatment on bacterial microflora and milk constituents. Traditional thermal treatments applied to milk processing lower nutritional quality because many nutrients are heat labile. To overcome this problem, several non-thermal processing technologies including high hydrostatic pressure (HHP) processing have been developed. Pressures between 400 and 600 MPa inactivate microorganisms including food-borne pathogens; however, high pressure (HP) injured bacteria in milk during storage can recover. All enzymes are inactivated only at pressures of 800 MPa. During HHP the casein micelle size decreases, whey proteins are denaturated, the level of free fatty acids increases. These characteristics indicate that for better understanding and application of HPP in dairy industry research should be done to offer the numerous practical applications to produce microbially safe, minimally processed dairy products with improved performances, and to develop novel dairy products of high nutritional and sensory quality and increased shelf life.
Key words: high pressure, milk, microbial inactivation, functional properties.

Introduction

Nowadays, milk and dairy products are treated at high temperature (70 – 145 °C) to ensure product safety. Heat is by far the most widely used technology utilized to inactivate microbes in foods. Traditional treatments for dairy products include different temperature regimes. The most common milk treatment is pasteurization; it allows decreasing microorganisms counts in the product and ensuring approximately 7 to 20 days shelf-life. Higher thermal treatment temperatures ensure product quality for the longer time period, which is very important for food processing and distribution companies.

Long shelf life of milk is often achieved through ultra-high temperature (UHT) processing for a few seconds at or above 135 °C; however, canning of milk products at 120 °C up to 30 min is still practiced in the dairy industry (Fitria *et al*., 2015). Processing at high temperature lowers the nutritional quality of foods because many nutrients are heat labile. To overcome this problem, several non-thermal processing or `cold processing` techniques including high hydrostatic pressure technology have been developed.

High pressure processing combining high pressure (up to 1000 MPa) and sometimes heating (above 60 °C) has been considered equal to sterilisation, which extends shelf life of foodstuff due to its ability to inactivate bacterial spores at reduced heat and thereby preserving desirable functional properties of foods better than conventional thermal processing (Heinz & Buckow, 2009; Fitria *et al*., 2015).

The use of non-thermal methods for food preservation is due to consumer demands for microbiological safe products without changes in the sensory and nutritional quality of the product. The HHP has emerged as an alternative to traditional thermal processing methods for foods (Muñoz-Cuevas *et al*., 2013). The HHP can be used to process both liquid and solid (water-containing) foods and adds advantages to the foods such as: kills bacteria in the raw food, extends shelf-life, ponders additive free and fresh food, manipulates the texture and enhances desired attributes (digestibility) (Chawla, Patil, & Singh, 2011).

One of the first scientific reports on high pressure applications for food was written by Hite (1899) on shelf-life extension of milk, and HP effect on food-born microorganisms by subjecting milk to a pressure of 650 MPa (Chawla, Patil, & Singh, 2011). Since then the application of HP treatment has been broadened to other food products such as raw and cooked meats, fish and shellfish, fruit and vegetable products, cheeses, salads, dips, grains and grain products, and liquids including juices, sauces, and soups. The range of products now being considered for high pressure treatment continues to grow. At present, 167 industrial installations exist with volumes from 55 to 420 litres and a total annual production volume has increased from 200 000 t in 2009 (Heinz & Buckow, 2009) to 350 000 t in 2012 (Bello *et al*., 2014). Bello *et al*. (2014) reported that HP processed vegetable products account for 28%, meat products for 26%, seafood and fish for 15%, juices and beverages for 14%, and other products for 17% in 2012.

Studies addressing the effect of HP treatment on the quality of dairy products are still limited (Devi *et al*., 2013). It is known that HHP can lead to modifications in the structure of milk components, in particular protein, which may provide interesting possibilities for the development of high value nutritional and functional ingredients (Beresford & Lane, 1999). The development of food ingredients with novel functional

properties offers the dairy industry an opportunity to revitalise existing markets and develop new ones.

The aim of this review was to summarize available bibliography on the possible applications of high pressure processing in dairy industry, the effect of this non-thermal treatment on bacterial microflora and milk constituents.

Materials and Methods

Monographic method was used in this study. The review summarizes the available literature on principles of high pressure processing and its application in dairy industry to produce microbially safe, minimally processed dairy products with improved performances, and to develop novel dairy products of high nutritional and sensory quality and increased shelf life. Literature study aimed to cover broad spectrum of published research results on factors affecting microorganisms survival during HPP and impact of HPP treatment on separate milk constituents.

Results and Discussion

Principles of high pressure processing

Hydrostatic pressure is generated by increasing the free energy; this can be achieved by physical compression during pressure treatment in a closed system by the mechanical volume reduction. HP processing is usually accompanied by a moderate increase in temperature (adiabatic heating) which depends on the composition of the food product being processed (Knorr, 2002; Knorr, Heinz, & Buckow, 2006; Naik *et al*., 2013).

The operating principles behind high pressure technology are as follows:

Le Chatelier's principle: whenever stress is applied to a system in equilibrium, the system will react so as to counteract the applied stress, reactions that result in reduced volume will be promoted under high pressure, such reactions may result in inactivation of microorganisms or enzymes (Carlez *et al*., 1994).

Isostatic principle: when food products are compressed by uniform pressure from every direction and then returned to their original shape when the pressure is released. The products are compressed independently of the product size and geometry, because transmission of pressure to the core is not mass/time dependant (Carlez *et al*., 1994).

The high pressure process is characterised by three parameters: temperature (T), pressure (p) and exposure time (t) when compared heat preservation process which is based on only two parameters (T, t). The three processing parameters allow great flexibility in the design of the process (Heinz & Buckow, 2009; Naik *et al*., 2013).

Application of high pressure in dairy industry

HP technology can be used to increase the microbiological safety and quality of milk to produce high quality cheeses. In relationship to the structure formation of the cheese matrix, the applications of HP treatment can be classified into: improvement of rennet coagulation, assistance of curd formation, enhanced salting and/or ripening, and improvement of the microstructure/texture of cheese or fresh cheese (Devi *et al*., 2013). High hydrostatic pressure may modify parameters controlling proteolysis during cheese ripening and has already been found useful to shorten the maturation period (Butz *et al*., 2000; Iwanczak & Wisniewska, 2005). The HP-treated cheese have higher moisture, salt and total free amino acids contents than raw or pasteurised milk cheeses (Trujillo *et al*., 2002).

Two strategies have been used to improve yoghurt quality and preservation by means of HP: yoghurt making from HP-treated milk and pressurisation of yoghurt to inactivate microbiota (Trujillo *et al*., 2002).The application of the high pressure in preliminary treatment of milk used for yoghurt production improved firmness of the curd and limited its syneresis (Jankowska,Wiśniewska, & Reps, 2005). HP processing of milk before fermentation has been successfully used (Udabage *et al*., 2010) to manufacture low fat set-type yogurt (12% total solids) with a creamy consistency, requiring no addition of polysaccharides. The application of HHP to milk for yoghurt preparation could be an alternative to the use of food additives, which can affect the taste, flavour, aroma, and mouth feel of yoghurt (Sfakianakis & Tzia, 2014).

In order to produce low-fat ice cream with similar textural properties to full-fat samples, whey protein is often incorporated to the ice cream mix. Partially denatured whey protein is expected to give better foaming properties, which hinder excessive growth of ice crystals and hold air bubbles during the freezing process (Devi *et al*., 2013). Ice cream from pressure treated mixes showed a slower melting rate and improved sensory properties compared to the control ice cream, possibly because of the formation of pressure induced protein gels (Huppertz *et al*., 2011).

Effect of high pressure on bacterial flora in milk

A major function of high pressure processing of food is the destruction of microorganisms. HP inactivates most of spoilage and pathogenic bacteria present in milk. Most of the reported bacteria are inactivated in milk after treatment at 400 – 600 MPa (Shigehisa *et al*., 1991; Patterson, 2005; Rodriguez *et al*., 2005; Okpala, Piggott, & Schaschke, 2009; Rivalain, Roquain, & Demazeau, 2010; Udabage *et al*., 2010; Gustavo, Espejo, & Hern, 2014; Meirelles

et al., 2014; Pedras *et al*., 2014; Pedras, Tribst, & Cristianini, 2014; Sfakianakis & Tzia, 2014). The mechanisms of microbial inactivation by HP are not fully understood yet, but are thought to act in several ways. The viability of vegetative microorganisms may be affected by inducing structural changes at the cell membrane or by the inactivation of enzyme systems which are responsible for the control of the metabolic actions (Knorr & Heinz, 2001; Heinz & Buckow, 2009) and ribosome disintegration (Farkas & Hoover, 2001).

Survival of microorganisms depends on the extent of pressure, holding time and temperature, composition of the food and the condition and growth phase of microorganisms (Goyal *et al*., 2013). Pressures up to 150 MPa are not able to ensure more than 2 decimal reduction of different microorganisms, while pressure at 200, 300 and 400 MPa are required to reach high level of microbial inactivation (Pedras *et al*., 2012). Temperature and HP can cause considerable microbial inactivation when applied alone, but it has been observed that these two treatments combined can confer dramatically improved inactivation levels, particularly with regard to bacterial spores (Considine *et al*., 2008). The type of substrate and composition of the food can have a dramatic effect on the response of microorganisms during pressure treatment. Certain food constituents, like proteins, carbohydrates, lipids and vitamins, can have a protective effect on microbial inactivation (Erkmen, 2011). Water activity (a_w) of the food is also an important parameter determining the effectiveness of HP treatment (Bulut, 2012). The environment around the microorganism can significantly influence HP inactivation, e.g. low pH in a suspending medium can render pathogens more sensitive to the effects of HP treatment (Datta & Deeth, 1999; Alpas & Bozoglu, 2002).

Microorganisms in lag phase are more sensitive to HP than those in stationary phase (Bello *et al*., 2014). This behaviour could be explained by the fact that in the lag phase the microorganism is in the process of cellular division and the membrane is more sensitive to environmental stresses. Pressures between 300 and 600 MPa inactivate yeasts, moulds and most of the vegetative bacteria. In general, yeasts and moulds can be inactivated at 200 – 400 MPa, but when they are in the spore or ascospore state or in a food with a very high concentration of sugar, the pressure needed to inactivate them could be close to 600 MPa (Bello *et al*., 2014). Spores are more resistant than vegetative cells and can survive at pressure of 1000 MPa (Zhang & Mittal, 2008; Reineke, Mathys, & Knorr, 2011). Pressures between 50 and 300 MPa may even stimulate spore germination. Germination can be markedly increased (to 95 – 99%) when spores are treated in the presence of L-alanine. Gram-positive microorganisms are more resistant to pressure than Gram-negative (Patterson, 2005), e.g. Gram-positive organisms need an application of 500 – 600 MPa at 25 °C for 10 min to achieve inactivation while Gram-negative organisms can be inactivated with 300 – 400 MPa (Alpas & Bozoglu, 2002) with the same time-temperature combination. It has been suggested that the cell membrane structure is more complex in Gram-negative bacteria, making it more susceptible to environmental changes caused by pressure (Shigehisa *et al*., 1991).

However, some researchers have demonstrated recovery of HP-injured bacteria in milk during further storage (Bozoglu, Alpas, & Kaletunç, 2004; Patel *et al*., 2006; Bulut, 2012; Muñoz-Cuevas *et al*., 2013). The recovery phenomenon during storage is a critical issue from the viewpoint of food safety. Research on the effect of high pressure on milk showed that HP-injured cells could be restored within 1–15 days, indicating the potential for bacterial recovery on these food products (Bozoglu, Alpas, & Kaletunç, 2004). Koseki, Mizuno, & Yamamoto (2008) investigated the effect of mild-heat treatment (30–50 °C) following HP treatment (550 MPa) on the inhibition of recovery of *Listeria monocytogenes* in milk. The results of this study would contribute to safer production of high-pressure-processed food by controlling bacterial recovery.

The impact of high pressure treatment on constituents in milk

HP treatment affects many milk constituents, such as the proteins and the fat fraction. In contrast, small compounds such as vitamins, amino acids, simple sugars and flavour compounds remain unaffected by HHP treatment (Chawla, Patil, & Singh, 2011).

Effect of HP on casein and whey proteins. A large number of factors, e.g., temperature, time, micelle concentration, pH, additives and pre-treatment of casein micelles affect the disruption of casein micelles and reformation of casein particles under pressure. HP produces casein micelles disintegration into smaller diameter particles, with a decrease of turbidity and lightness and an increase of viscosity of the milk. Solubilisation of colloidal calcium phosphate leads to disruption of casein micelles with increasing pressure and time (Huppertz *et al*., 2006) and in milk, micelle disruption is complete at 400 MPa. At 250 and 300 MPa reformation of casein particles from disrupted micelles occurs, but this process does not occur at lower or higher pressures (Harte *et al*., 2003). Casein micelle disruption decreases with increasing temperature (Gebhardt, Doster, & Kulozik, 2005; Orlien, Boserup, & Olsen, 2010). Addition of whey

protein to casein isolates protected the micelles from high pressure induced disruption (Chawla, Patil, & Singh, 2011).

During pressure treatment, the whey proteins are denatured under conditions where hydrophobic interactions are reduced and the solubility of calcium phosphate is increased, so more calcium phosphate is moved to the serum phase (Datta & Deeth, 1999; Anema, 2008; Baier, Schmitt, & Knorr, 2015). A pressure treatment of 500 MPa at 25 °C denatures lactoglobulins (Chicón *et al*., 2006). Denaturation of immunoglobulins and lactalbumins occurs only at the highest pressure, particularly at temperature above 50 °C, which gives an idea of preservation of colostrum immunoglobulins which otherwise gets damaged during heat treatment (Chawla, Patil, & Singh, 2011).

Effect of HP on milk lipids. During milk processing, the membrane of milk fat globules (MFG) is altered, making the action of lipase to triglycerides possible and increasing the levels of the free fatty acids (FFA) in milk. This process (lipolysis) is a good index on the damage of the MFG membrane. When raw milk was pressurized at 200 MPa at 4 °C for 10 or 20 min, the short-chain FFA did not change, while treatment for 30 min increased the FFA content slightly (Kim *et al*., 2008). Studies carried out by Gervilla, Ferragut, & Guamis (2001) on free fatty acids (FFA) content (lipolysis of milk fat) in ewe's milk have showed that HP treatments between 100 – 500 MPa at 4, 25 and 50 °C did not increase FFA content, even some treatments at 50 °C showed lower FFA content than fresh raw milk. The difference between the results of the two studies could be explained by the difference in the applied pressure level.

Effect of HP on lactose. Lactose in milk and milk products may isomerise in lactulose by heating and then degrade to form acids and other sugars. No changes in these compounds are observed after pressurisation (100 – 400 MPa for 10 – 60 min at 25 °C), suggesting that no Maillard reaction or lactose isomerisation occur in milk during pressure treatment (López-Fandiño, 2006; Chawla, Patil, & Singh, 2011).

Effect of HP on minerals. HP does not affect minerals as such, but may affect the food matrix resulting in improved bioavailability and health benefits (Barba *et al*., 2015). HP treatment increases the level of ionised calcium in milk, as well as the level of total calcium in the serum phase of milk. HP-induced shifts in the mineral balance of milk result in an increase in milk pH, by around 0.1 unit. The shifts in salts and the increase in milk pH are rapidly reversible after HP treatment, particularly when the milk is stored at a temperature above 10 °C (Huppertz, Kelly, & Fox, 2002). An increasing concentration of Ca, P and Mg in serum upon increasing pressure to

Table 1

Impact of high pressure processing on milk quality parameters

Parameter	Treatment condition	Major findings	References
Bacterial flora	300 MPa/10 min/10 °C	inactivation of *E.coli* O157:H7	Rodriguez *et al*., 2005
	500 – 600 MPa/10 min/25 °C 300 – 400 MPa	inactivation of Gram-positive organisms inactivation of Gram-negative organisms	Alpas & Bozoglu, 2002
	200 – 400 Mpa close to 600 MPa	inactivation of yeasts and moulds inactivation of yeasts and moulds (in the spore or ascospore state) and most of vegetative bacteria	Bello *et al*., 2014
	50 – 300 MPa	stimulatation of spore germination	Gould & Sale, 1970
Casein and whey protein	400 MPa	casein micelle disruption	Huppertz *et al*., 2006
	500 MPa/ 25 °C	denaturation of lactoglobulin	Chawla, Patil, & Singh, 2011
Lipids	200 MPa/30 min/4 °C	increase in the FFA content	Kim *et al*., 2008
Lactose	100 – 400 MPa/ 10 – 60 min/25 °C	no Maillard reaction observed	Chawla, Patil, & Singh, 2011
Vitamins	400 MPa/30 min/ 25 °C	insignificant loss of vitamin B_1 and B_6	Sierra *et al*., 2000
Enzymes	400 MPa	lipase, xanthine, oxidase, lactoperoxidase are resistant	Naik *et al*., 2013
	550, 630 and 800 MPa	phosphohexose isomerase, γ-glutamil transferase anad alkaline phosphatase are completely inactivate respectively	Sakharam, Prajapati, & Jana, 2011

400 MPa was also reported (López-Fandiño, 2006; Barba *et al*., 2015) for bovine, caprine, and ovine milk immediately after HP treatment.

Effect of HP on vitamins in milk. Studies carried out by Sierra *et al*. (2000) did not find any losses either of B group vitamins in pressurised milk. HP treatment of milk at 400 MPa (2.5 MPa/sec for 30 min at 25 °C) results in non-significant loss of vitamin B_1 and B_6. However, any information on the behaviour of some vitamins during storage of pressurised milk is still lacking.

Effect of HP on enzymes in milk. Milk enzymes vary in their sensitivity to high pressure. Lipase, xanthine oxidase, and lactoperoxidase are resistant to pressures up to 400 MPa (Naik *et al*., 2013). Phosphohexose isomerase, γ-glutamyl transferase, and alkaline phosphatase (ALP) in milk are partially inactivated at pressures exceeding 350, 400 and 600 MPa respectively; they are completely inactivated at pressures of 550, 630 and 800 MPa respectively (Sakharam, Prajapati, & Jana, 2011). No inactivation of alkaline phosphatase (ALP) in milk has been reported after treatment up to 400 MPa for 60 min and complete inactivation of ALP has been observed only after treatment of milk at 800 MPa for 8 min (Naik *et al*., 2013).

Summary about HPP impact on milk and dairy product quality of various studies is given in the Table 1.

Conclusions

High pressure processing is currently of great interest and perspective in food research and industry, as a possible alternative to thermal processing. Literature study revealed that high hydrostatic pressure processing can be used in the dairy industry to increase the microbiological safety as well to modify functional properties of foods. However, it can affect a wide range of constituents in milk and dairy products: increasing level of the free fatty acids, decrease casein micelle size, denaturating whey proteins in milk. For better understanding and application of HP processing in dairy sector, research should be done to offer the dairy industry numerous practical applications to produce microbially safe, minimally processed dairy products with improved performances and to develop novel dairy products of high nutritional and sensory quality and increased shelf life.

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References

1. Alpas, H., & Bozoglu, F. (2002). Inactivation of *Staphylococcus Aureus* and *Listeria Monocytogenes* in Milk and Cream of Chicken Soup by High Hydrostatic Pressure and Bacteriocins. *High Pressure Research*, 22(3-4), 681-684. DOI: 10.1080/08957950212440.
2. Anema, S.G. (2008). Heat and/or high-pressure treatment of skim milk: Changes to the casein micelle size, whey proteins and the acid gelation properties of the milk. *International Journal of Dairy Technology*, 61(3), 245-252. DOI: 10.1111/j.1471-0307.2008.00418.x.
3. Baier, D., Schmitt, C., & Knorr, D. (2015). Changes in functionality of whey protein and micellar casein after high pressure – low temperature treatments. *Food Hydrocolloids*, 44, 416-423. DOI: 10.1016/j.foodhyd.2014.10.010.
4. Barba, F.J., Terefe, N.S., Buckow, R., Knorr, D., & Orlien, V. (2015). New opportunities and perspectives of high pressure treatment to improve health and safety attributes of foods. A review. *Food Research International*, 77(1), 725-742. DOI: 10.1016/j.foodres.2015.05.015.
5. Bello, E., Martínez, G., Ceberio, B., Rodrigo, D., & López, A. (2014). High Pressure Treatment in Foods. *Foods*, 3(3), 476-490. DOI: 10.3390/foods3030476.
6. Beresford, D.T., & Lane, C. (1999). High Pressure Processing of Dairy Foods. *Dairy Products Research Centre*, DPRC No.22, 1-17.
7. Bozoglu, F., Alpas, H., & Kaletunç, G. (2004). Injury recovery of foodborne pathogens in high hydrostatic pressure treated milk during storage. *FEMS Immunology and Medical Microbiology*, 40(3), 243-247. DOI: 10.1016/S0928-8244(04)00002-1.
8. Bulut, S. (2012). Survival of microorganisms in high pressure treated minced meat during chilled storage and at pH and temperature mimicking gastrointestinal tract. *African Journal of Microbiology Research*, 6(36), 6558-6564. DOI: 10.5897/AJMR12.757.
9. Butz, P., Fernández, A., Koller, W.-D., Messens, W., & Tauscher, B. (2000). Effects of high pressure treatment on fermentation processes during ripening of Gouda cheese. *High Pressure Research*, 19(1-6), 37-41. DOI: 10.1080/08957950008202533.

10. Carlez, A., Rosec, J.-P., Richard, N., & Cheftel, J.-C. (1994). Bacterial Growth During Chilled Storage of Pressure-Treated Minced Meat. *LWT - Food Science and Technology*, 27(1), 48-54. DOI: 10.1006/fstl.1994.1011.
11. Chawla, R., Patil, G., & Singh, A. (2011). High hydrostatic pressure technology in dairy processing: A review. *Journal of Food Science and Technology*, 48(3), 260-268. DOI: 10.1007/s13197-010-0180-4.
12. Chicón, R., López-Fandiño, R., Quirós, A., & Belloque, J. (2006). Changes in chymotrypsin hydrolysis of β-lactoglobulin A induced by high hydrostatic pressure. *Journal of Agricultural and Food Chemistry*, 54(6), 2333-2341. DOI: 10.1021/jf051983s.
13. Considine, K., Kelly, A., Fitzgerald, G., Hill, C., & Sleator, R. (2008). High-pressure processing - effects on microbial food safety and food quality, *FEMS Microbiology Letters*, 281(1), 1-9. DOI: 10.1111/j.1574-6968.2008.01084.x.
14. Datta, N., & Deeth, H.C. (1999). High pressure processing of milk and dairy products. *Australian Journal of Dairy Technology*, 54(February), 41-48. DOI: 10.1002/9781118448205.ch6.
15. Devi, A.F., Buckow, R., Hemar, Y., & Kasapis, S. (2013). Structuring dairy systems through high pressure processing. *Journal of Food Engineering*, 114(1), 106-122. DOI: 10.1016/j.jfoodeng.2012.07.032.
16. Erkmen, O. (2011). Effects of high hydrostatic pressure on *Salmonella typhimurium* and *aerobic* bacteria in milk and fruit juices, *Romanian Biotechnological Letters*, 16(5), 6540-6547. Retrieved January 16, 2016, from http://www.rombio.eu/rbl5vol16/10%20Osman%20Erkmen.pdf.
17. Farkas, D.F., & Hoover, D.G. (2001). High pressure processing. *Journal of Food Science*, 65(8), 47-64. DOI: 10.1111/j.1750-3841.2000.tb00618.x.
18. Fitria, A., Buckow, R., Singh, T., Hemar, Y., & Kasapis, S. (2015). Colour change and proteolysis of skim milk during high pressure thermal – processing. *Journal of food engineering*, 147, 102-110. DOI: 10.1016/j.jfoodeng.2014.09.017.
19. Gebhardt, R., Doster, W., & Kulozik, U. (2005). Pressure-induced dissociation of casein micelles: Size distribution and effect of temperature. *Brazilian Journal of Medical and Biological Research*, 38(8), 1209-1214. DOI: 10.1590/S0100-879X2005000800008.
20. Gervilla, R., Ferragut, V., & Guamis, B. (2001). High hydrostatic pressure effects on color and milk-fat globule of ewe's milk. *Journal of Food Science*, 66(6), 880-885. DOI: 10.1111/j.1365-2621.2001.tb15190.x.
21. Goyal, A., Sharma, V., Upadhyay, N., Sihag, M., & Kaushik, R. (2013). High Pressure Processing and Its Impact on Milk Proteins: A Review. *Journal of Dairy Science and Technology*, 2(1), 2319-3409. ISSN: 2319-3409.
22. Gustavo, G., Espejo, A., & Hern, M.M. (2014). Inactivation of *Bacillus spores* inoculated in milk by Ultra High Pressure Homogenization. *Food Microbiology*, 44, 204-210. DOI: 10.1016/j.fm.2014.06.010.
23. Harte, F., Luedecke, L., Swanson, B., & Barbosa-Cánovas, G.V. (2003). Low-fat set yogurt made from milk subjected to combinations of high hydrostatic pressure and thermal processing. *Journal of Dairy Science*, 86(4), 1074-1082. DOI: 10.3168/jds.S0022-0302(03)73690-X.
24. Heinz, V., Buckow, R. (2009). Food preservation by high pressure. *Journal of Consumer Protection and Food Safety*, 5(1), 73-81. DOI: 10.1007/s00003-009-0311-x.
25. Hite, B.H. (1899). The effect of pressure in the preservation of milk. West Virginia Agricultural Experimental Station Bulletin. 58: 15-35.
26. Huppertz, T., Fox, P.F., de Kruif, K.G., & Kelly, A.L. (2006). High pressure-induced changes in bovine milk proteins: a review. *Biochimica et Biophysica Acta*, 1764(3), 593-598. DOI: 10.1016/j.bbapap.2005.11.010.
27. Huppertz, T., Kelly, A.L., & Fox, P.F. (2002). Effects of high pressure on constituents and properties of milk. *International Dairy Journal*,12(7), 561-572. DOI: 10.1016/S0958-6946(02)00045-6.
28. Huppertz, T., Smiddy, M.A., Goff, H.D., & Kelly, A.L. (2011). Effects of high pressure treatment of mix on ice cream manufacture. *International Dairy Journal*, 21(9), 718-726. DOI: 10.1016/j.idairyj.2010.12.005.
29. Iwanczak, M., & Wisniewska, K. (2005). Effect of high pressures on the process of Edam cheese proteolysis. *High Pressure Research*, 25(1), 43-50. DOI: 10.1080/08957950500061884.
30. Jankowska, A., Wiśniewska, K., & Reps, A. (2005). Application of *Probiotic Bacteria* in production of yoghurt preserved under high pressure. *High Pressure Research*, 25(1), 57-62. DOI: 10.1080/08957950500062023.
31. Kim, H.Y., Kim, S.H., Choi, M.J., Min, S.G., & Kwak, H.S. (2008). The effect of high pressure-low temperature treatment on physicochemical properties in milk. *Journal of Dairy Science*, 91(11), 4176-82. DOI: 10.3168/jds.2007-0883.
32. Knorr, D. (2002). High Pressure Processing for Preservation, Modification and Transformation of Foods. *High Pressure Research*, 22(3-4), 595-599. DOI: 10.1080/08957950212411.

33. Knorr, D., & Heinz, V. (2001). Development of nonthermal methods for microbial control. In S.S. Block (ed) *Disinfection, sterilization and preservation*. Part IV (Physical sterilization and disinfection), 853-877. Lippincott Williams & Wilkins.
34. Knorr, D., Heinz, V., & Buckow, R. (2006). High pressure application for food biopolymers. *Biochimica et Biophysica Acta*, 1764(3), 619-31. DOI: 10.1016/j.bbapap.2006.01.017.
35. Koseki, S., Mizuno, Y., & Yamamoto, K. (2008). Use of mild-heat treatment following high-pressure processing to prevent recovery of pressure-injured *Listeria monocytogenes* in milk. *Food Microbiology*, 25(2), 288-93. DOI: 10.1016/j.fm.2007.10.009.
36. López-Fandiño, R. (2006). High pressure-induced changes in milk proteins and possible applications in dairy technology. *International Dairy Journal*, 16(10), 1119-1131. DOI: 10.1016/j.idairyj.2005.11.007.
37. Meirelles, M., Oliveira, D., Esteves, P., Augusto, D., Gomes, A., & Cristianini, M. (2014). Effect of dynamic high pressure on milk fermentation kinetics and rheological properties of probiotic fermented milk. *Innovative Food Science and Emerging Technologies*, 26, 67-75. DOI: 10.1016/j.ifset.2014.05.013.
38. Muñoz-Cuevas, M., Guevara, L., Aznar, A., Martínez, A., Periago, P.M., & Fernández, P.S. (2013). Characterisation of the resistance and the growth variability of *Listeria monocytogenes* after high hydrostatic pressure treatments. *Food Control*, 29(2), 409-415. DOI: 10.1016/j.foodcont.2012.05.047.
39. Naik, L., Sharma, R., Rajput, Y.S., & Manju, G. (2013). Application of High Pressure Processing Technology for Dairy Food Preservation - Future Perspective: A Review *Journal of Animal Production Advances*, 3(8), 232-241. DOI: 10.5455/japa.20120512104313.
40. Okpala, C.O.R., Piggott, J.R., & Schaschke, C.J. (2009). Effects of high-pressure processing (HPP) on the microbiological, physico-chemical and sensory properties of fresh cheeses: A review. *African Journal of Biotechnology*, 8(25), 7391-7398. DOI: 10.4314/ajb.v8i25.
41. Orlien, V., Boserup, L., & Olsen, K. (2010). Casein micelle dissociation in skim milk during high-pressure treatment: effects of pressure, pH, and temperature. *Journal of Dairy Science*, 93(1), 12-18. DOI: 10.3168/jds.2009-2244.
42. Patel, J.R., Bhagwat, A.A., Sanglay, G.C., & Solomon, M.B. (2006). Rapid detection of *Salmonella* from hydrodynamic pressure-treated poultry using molecular beacon real-time PCR. *Food Microbiology*, 23(1), 39-46. DOI: 10.1016/j.fm.2005.01.011.
43. Patterson, M.F. (2005). Microbiology of pressure-treated foods. *Journal of Applied Microbiology*, 98(6), 1400-1409. DOI: 10.1111/j.1365-2672.2005.02564.x.
44. Pedras, M.M., Tribst, A.A.L., & Cristianini, M. (2014). Effects of high-pressure homogenisation on physicochemical characteristics of partially skimmed milk, *International Journal of Food Science & Technology*, 49(3), 861-866. DOI: 10.1111/ijfs.12378.
45. Pedras, M.M., Pinho, C.R.G., Tribst, A.A.L., Franchi, M.A., & Cristianini, M. (2012). MiniReview The effect of high pressure homogenization on microorganisms in milk, *International Food Research Journal*, 19(1), 1-5. Retrieved January 14, 2016, from http://www.ifrj.upm.edu.my/19%20(01)%202011/(1)IFRJ-2011-088%20Alline.pdf.
46. Pedras, M.M., Pinho, C.R.G., Tribst, A.A.L., Franchi, M.A., Cristianini, M., Okpala, C.O.R., Piggott, J. R., Schaschke, C.J., Letters, R.B., & Sleator, R.D. (2014). Microbiological effects of high pressure processing on food. *Foods*, 4(2), 159-172. DOI: 10.3168/jds.2013-7245.
47. Reineke, K., Mathys, A., & Knorr, D. (2011). The impact of high pressure and temperature on bacterial spores: Inactivation mechanisms of *Bacillus subtilis* above 500 MPa. *Journal of Food Science*, *76*(3), 189-197. DOI: 10.1111/j.1750-3841.2011.02066.x.
48. Rivalain, N., Roquain, J., & Demazeau, G. (2010). Development of high hydrostatic pressure in biosciences: Pressure effect on biological structures and potential applications in Biotechnologies. *Biotechnology Advances*, 28(6), 659-672. DOI: 10.1016/j.biotechadv.2010.04.001.
49. Rodriguez, E., Arques, J.L., Nuñez, M., Gaya, P., Medina, M., & Nun, M. (2005). Combined Effect of High-Pressure Treatments and Bacteriocin-Producing *Lactic Acid Bacteria* on Inactivation of *Escherichia coli* O157 : H7 in Raw-Milk Cheese *Applied and Environmental Microbiology*, 71(7), 3399-3404. DOI: 10.1128/AEM.71.7.3399.
50. Sakharam, P., Prajapati, J.P., & Jana, A.H. (2011). High Hydrostatic Pressure Treatment for Dairy Applications. *National seminar `Indian Dairy Industry - Opportunities And Challenges`*, 2014. 176-180. Retrieved January 14, 2016, from http://dairyknowledge.in/sites/default/files/ch17_0.pdf.
51. Sfakianakis, P., & Tzia, C. (2014). Conventional and Innovative Processing of Milk for Yogurt Manufacture; Development of Texture and Flavor: A Review. *Foods*, 3(1), 176-193. DOI: 10.3390/foods3010176.

52. Sierra, I., Vidal-Valverde, C., & Lopez-Fandino, R. (2000). Effect of high pressure on the Vitamin B_1 and B_6 content in milk. *Milchwissenschaft*, 55, 365-367. ISSN: 0026-3788.
53. Shigehisa, T., Ohmori, T., Saito, A., Taji, S., & Hayashi, R. (1991). Effects of high hydrostatic pressure on characteristics of pork slurries and inactivation of microorganisms associated with meat and meat products. *International Journal of Food Microbiology*, 12(2-3), 207-215. DOI: 10.1016/0168-1605(91)90071-V.
54. Trujillo, A.J., Capellas, M., Saldo, J., Gervilla, R., & Guamis, B. (2002). Applications of high-hydrostatic pressure on milk and dairy products: A review. *Innovative Food Science and Emerging Technologies*, 3(4), 295-307. DOI: 10.1016/S1466-8564(02)00049-8.
55. Udabage, P., Augustin, M., Versteeg, C., Puvanenthiran, A., Yoo, J., Allen, N., & Kelly, A. (2010). Properties of low-fat stirred yoghurts made from high-pressure-processed skim milk. *Innovative Food Science & Emerging Technologies*, 11(1), 32-38. DOI: 10.1016/j.ifset.2009.08.001.
56. Zhang, H., & Mittal, G.S. (2008). Effects of High-Pressure Processing (HPP) on *Bacterial Spores*: An Overview. *Food Reviews International*, 24(3), 330-351. DOI: 10.1080/87559120802089290.

AMINO ACID AND DIETARY FIBRE CONTENT OF PEA AND BUCKWHEAT FLOURS

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Abstract
The aim of this study was to investigate amino acid content, biological value and dietary fibre content of conventional and organic pea (*Pisum sativum* L.) and buckwheat (*Fagopyrum esculentum* M.) flours.
Results showed that pea flours contained high amounts of aspartic acid, threonine, serine, glycine, alanine, valine, isoleucine, leucine, tyrosine, phenylalanine, histidine, lysine and arginine while glutamic acid, proline, methionine and tryptophan were found in similar or smaller amounts comparing with wheat flour. The differences of various amino acids between conventional and organic pea flours were insignificant. The content of aspartic acid, threonine, serine, glycine, alanine, valine, histidine, lysine and arginine was high in buckwheat flours in comparison with wheat flour. There were significant ($p<0.05$) differences in the individual amino acid contents across buckwheat flours. Significant ($p<0.05$) variation existed in the content of essential amino acids among samples, whereas the results concerning the proportion of essential amino acids in total amino acids showed insignificant ($p>0.05$) differences between pea flours and buckwheat flours (34.80 – 35.77% and 29.96 – 33.90% respectively). The highest content of lysine was found in pea flours, and it formed about 23% of essential amino acids content. For pea flours the total dietary fibre amount varied between 15.28 g 100 g^{-1} for conventional and 27.24 g 100 g^{-1} for organic pea flour.
Pea and buckwheat flours could be characterised as a good source of dietary fibre with significantly ($p<0.05$) higher content of total dietary fibre comparing to wheat flour.
Key words: pea, buckwheat, amino acids, dietary fibre.

Introduction

Buckwheat *(Fagopyrum esculentum* M.*)* is an old and alternative crop which belongs to *Polygonacea* family. Buckwheat protein has one of the highest amino acid scores of protein in plant food stuffs (Cai, Corke, & Lee, 2004; Qin *et al*., 2010), it is gluten-free (Ikeda, 2002) whereas the protein digestibility of buckwheat is relatively low (Ikeda & Kishida, 1993; Skrabanja, Nygaard, & Kreft, 2000).Due to high lysine content, buckwheat proteins have a higher biological value than cereal proteins (Ikeda, 2002). Buckwheat protein products have been associated with preventative nutrition (Bonafaccia, Marocchini, & Kreft, 2003). Li and Zhang (2001) reported that buckwheat proteins act similarly to dietary fibre by exhibiting cholesterol-lowering and antihy pertension effects and reducing constipation and obesity. A diet rich in dietary fibre decreases risk of cardiovascular diseases, metabolic disorder and type 2 diabetes (Barclay *et al*., 2008; Hopping *et al*., 2010). Health effects of dietary fibre can be substantiated when the intake is high enough – 25-38 g day^{-1} for healthy adults (Slavin *et al*., 2009). The positive health effect of buckwheat *in vivo* is associated especially with its fibre components (Rokka *et al*., 2013). Izydorczyk *et al.* (2014) reported that there are differences in the molecular composition of dietary fibre in buckwheat compared with cereal grains. A diet rich in buckwheat fibre reduced many overweight-related risk factors of cardiovascular diseases in rats (Son, Kim, & Lee, 2008).

Dry peas (*Pisum sativum* L.) have been recognised as nutritious due to their high quality proteins (Boye, Zare, & Pletch, 2010) and nutrient density (Azarpazhooh & Boye, 2012).Field pea is relatively high in protein and lysine and has been suggested as an alternative source to soybean in circumstances where it cannot be used due to intolerance or allergic reactions (Davidsson *et al*., 2001). Combination of pea proteins with low-lysine cereal proteins results in a more nutritionally complete protein (Hood-Niefer & Tyler, 2010). It is known that lysine is the most limited amino acid in the human diet. Less known is the fact that pea can be a valuable source of dietary fibre. The hypoglycaemic effects of legumes have been attributed to their high content of dietary fibre (Trinidad *et al*., 2010). The total dietary fibre measurements of dried peas range from 14 to 26% of dry weight basis (Brummer, Kaviani, & Tosh, 2015), peas are especially rich in insoluble fibre (Wang, Hatcher, & Gawalko, 2008). Dodevska *et al.* (2013) reported that cellulose was the major fibre component in pea samples comprising about 40% of total fibre. The dietary fibre fraction of field pea could be used as a nutritional supplement and functional food ingredient for novel food development (Stoughton-Ens *et al*., 2010).

The background of this study is to investigate the potential of pea and buckwheat flours, their blends in the manufacture of new functional products with increased nutritional value as the first step toward increasing their consumption. The specific aim of this study was to investigate amino acid content, biological value and dietary fibre content of conventional and organic pea (*Pisum sativum* L.) and buckwheat (*Fagopyrum esculentum* M.) flours.

Materials and Methods

Research was performed at the scientific laboratories of Faculty of Food Technology, LatviaUniversity of Agriculture and at the laboratoryof the Institute of Biology, University of Latvia, from September to December, 2015.

Materials

Two pea (*Pisum sativum* L.) flours: conventional (Company 'Fasma', Lithuania) and organic (Farm 'Kaņepītes', Latvia) and three buckwheat (*Fagopyrum esculentum* M.) flours obtained from conventional steamed (Company 'Fasma', Lithuania), organic steamed (Farm 'Kaņepītes', Latvia) and organic (Farm 'Bebri', Latvia) buckwheat seeds were analysed (Table 1). Fine wheat flour as control was purchased from the company 'Dobeles Dzirnavnieks', Latvia.

Table 1

Description of flours

Code	Sample
Control - WF	Wheat flour
CPF	Conventional pea flour
OPF	Organic pea flour
OBF	Organic buckwheat flour
OSBF	Flour of organic steamed buckwheat seeds
CSBF	Flour of conventional steamed buckwheat seeds

Determination of the amino acid content

The content of amino acids was determined the amino acid analyser '*Microtechna Praha AAA339*' according to the requirements of 'Amino acid standard solution for protein hidrolysates – 0.5 µmoles per mL'. The measurements were performed in triplicate.

Determination of the total content of dietary fibre

The total dietary fibre content was determined according to the AOAC Official Method 985.29 'Total dietary fibre in Foods' using equipment '*Fibertec system 1010 Heat Extractor*'. The measurements were performed in triplicate.

Statistical analysis

The results were analysed using the analysis of variance (ANOVA). T-test was applied to compare the mean values, and p-value at 0.05 was used to determine the significant differences. Mean ± standard deviation of three replicates was used.

Results and Discussion

Buckwheat proteins have a high biological value with well-balanced amino acid composition (Cai, Corke, & Lee, 2004) whereas field pea is relatively high in protein and lysine and low in cysteine and methionine (Hood-Niefer & Tyler, 2010). The combination of pea and buckwheat proteins could result in a more nutritionally complete protein. Iqbal *et al.* (2006) concluded that, in order to improve the protein quality of leguminous seeds, their consumption should be combined with cereals.

Pea flours contained high amounts of aspartic acid, threonine, serine, glycine, alanine, valine, isoleucine, leucine, tyrosine, phenylalanine, histidine, lysine and arginine while glutamic acid, proline, methionine and tryptophan were found in similar or smaller amounts comparing with the control sample (wheat flour) (Table 2). Iqbal *et al.* (2006) concluded that aspartic acid and glutamic acid were major unessential amino acids in legume, int.al. green pea. The same conclusions confirmed this research analyzing conventional and organic pea flours. The differences of various amino acids between conventional and organic pea flours were insignificant ($p>0.05$); however, the content of amino acids in organic pea flour was higher with the exception of proline, methionine, leucine, tyrosine, histidine and tryptophan. The first limited amino acid was methionine in conventional and organic pea flours. Similar results can be found in literature suggesting that all essential amino acids except methionine and tryptophan are present in excessive amounts in legume (Iqbal *et al*., 2006; Zia-Ul-Haq *et al*., 2013).

The content of aspartic acid, threonine, serine, glycine, alanine, valine, histidine, lysine and arginine was high in buckwheat flours comparing with wheat flour (Table 2). There were significant ($p<0.05$) differences in the individual amino acid contents, particularly for serine, glutamic acid, proline, alanine, isoleucine, leucine, phenylalanine and arginine across buckwheat flours. The differences in amino acid contents in various buckwheat flours may be due to the cultivars variability and growing conditions. Aspartic acid, glutamic acid and arginine were abundant in the buckwheat flours. Similar results were reported in Wei *et al.* (2003) for buckwheat kernels.

The sum of all amino acids was significantly ($p< 0.05$) different in the examined flour samples. The highest amount of total amino acids was found in pea flours, respectively in conventional (18.82 g 100 g^{-1}) and in organic (19.30 g 100 g^{-1}) flours. The total amino acids content in pea flours was close to the data given by Gómez, Doyagüe, & de la Hera (2012) about protein content in pea flour (22.23 g 100 g^{-1}). The total amino acids content of buckwheat flours ranged from 9.62 g 100 g^{-1} for OSBF to 11.09 g 100 g^{-1} for CSBF. The results are in a fair agreement with those reported by Qin *et al.* (2010) where the flour of common buckwheat cultivars contained 8.06-12.44% protein.

Table 2

Amino acids content of pea and buckwheat flours, g 100 g^{-1}

Amino acids	WF	CPF	OPF	OBF	OSBF	CSBF
Essential amino acids						
Histidine	0.38	0.83	0.78	0.64	0.62	0.52
Isoleucine	0.14	0.41	0.43	0.14	0.17	0.30
Leucine	0.61	1.53	1.51	0.66	0.86	0.64
Lysine	0.33	1.48	1.58	0.68	0.56	0.65
Methionine	0.12	0.16	0.15	0.16	0.12	0.19
Phenylalanine	0.50	1.01	1.14	0.52	0.35	0.70
Threonine	0.19	0.73	0.75	0.34	0.43	0.43
Tryptophan	0.19	0.23	0.17	0.16	0.11	0.20
Valine	0.23	0.42	0.53	0.42	0.33	0.33
Unessential amino acids						
Alanine	0.19	0.81	0.82	0.66	0.52	0.34
Arginine	0.14	1.67	1.67	0.72	0.38	1.03
Aspartic acid	0.61	2.60	2.83	1.31	1.24	1.27
Glutamic acid	3.28	2.99	3.09	2.43	2.30	2.02
Glycine	0.30	0.90	0.92	0.68	0.56	0.70
Prolamin	1,22	1.25	1.04	0.20	0.16	0.56
Serine	0.38	0.99	1.09	0.53	0.58	0.69
Tyrosine	0.37	0.81	0.80	0.36	0.33	0.52
Total	**9.18**	**18.82**	**19.30**	**10.61**	**9.62**	**11.09**

Literature (Biel & Maciorowski, 2013) reports that low lysine/arginine and methionine/arginine ratios may suggest that buckwheat products have blood cholesterol-lowering properties. Evaluating the results of this research it could be concluded that lysine/arginine ratio was low for CSBF and OBF and methionine/ arginine ratio was low for all buckwheat flour samples.

Both the quantity and quality of protein are very important in nutrition. The amino acid composition determines the nutritional value of protein and, more specifically, the amount of essential amino acids.

The amino acids composition of the pea and buckwheat flours showed significant ($p<0.05$) differences in the content of essential and unessential amino acids (Fig.1). The level of essential amino acids content was lower than the level of unessential amino acids in the tested samples. Similar conclusions were reported by Radu (2012) about pea and buckwheat flours. The highest total essential and unessential

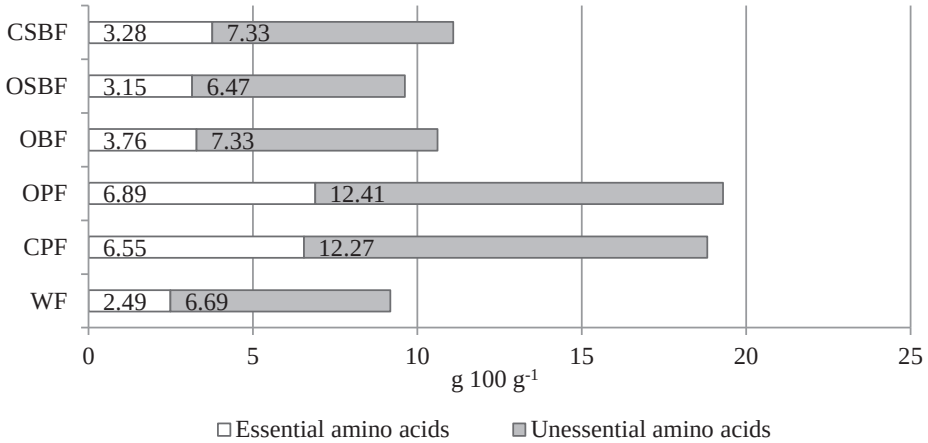

Figure 1. Comparison of essential and unessential amino acids content in pea and buckwheat flours.

Table 3

Essential amino acidsand lysine content of pea and buckwheat flours

Flours	Essential amino acids content, g $100g^{-1}$	Proportion of essential amino acids to total amino acids, %	Lysine content, g $100g^{-1}$	Lysine content of essential amino acids content, %
WF	2.49	27.12	0.33	13.25
CPF	6.55	34.80	1.48	22.60
OPF	6.89	35.77	1.58	22.93
OBF	3.28	30.91	0.68	20.73
OSBF	3.15	32.74	0.56	17.78
CSBF	3.76	33.90	0.65	17.30

amino acids was found in organic pea flour, although the differences of essential and unessential amino acids were insignificant ($p>0.05$) between organic and conventional pea flours. Buckwheat flour samples had higher essential and unessential amino acids content comparing with wheat flour, however, the differences were insignificant ($p>0.05$).

Many studies (Boye, Zare, & Pletch, 2010; Davidsson *et al*., 2001; Qin *et al*., 2010; Cai, Corke, & Lee, 2004) have shown that pea and buckwheat flours are a good source of protein and are rich in essential amino acid – lysine. Biel *et al.* (2009) reported that, as it concernsthe nutritional value, the amino acid composition of buckwheat is the most favourable among cereals due to the content of lysine, which can be found in limited amounts inmost cereals.

Significant ($p<0.05$) variation existed in the content of essential amino acids across flour samples (Table 3), whereas the results concerning the proportion of essential amino acids to total amino acids showed insignificant ($p>0.05$) differences for pea flours (34.80 – 35.77%) and for buckwheat flours (29.96 – 33.90%). It could be concluded that the amount of essential amino acids made one third of the total amino acid content in the tested pea and buckwheat flours (Table 3).The highest content of lysine was found in pea flours (1.48 g 100 g^{-1}in conventional and 1.58 g 100 g^{-1} in organic flours respectively), and it formed about 23% of the essential amino acids content. Results are comparable to those presented in the research papers by Zia-Ul-Haq *et al.* (2013) and Lisiewska *et al.* (2008).The content of lysine in OBF was more than double comparing with wheat flour and formed 20.73 % of the essential amino acids content. Similar results are confirmed by the data presented by Wei, Zhang, & Li (1995) and Bonafaccia, Marocchini, & Kreft (2003). The results of our research that pea and buckwheat flours are rich in lysine comparing with wheat flour confirmed the conclusions made in the literature.

Legumes are a rich source of dietary fibre having a hypoglycaemic effect (Trinidad *et al*., 2010), ie., consumption of legumes showed an improvement in fasting blood glucose concentration in both diabetic and non-diabetes subjects (Sievenpiper *et al*., 2009). However, Stoughton-Ens *et al.* (2010) reported that there were very strong genotypic and environment (location and year) effects on the dietary fibre content in field pea. Similar conclusions about the growing conditions and milling methods' effects on the dietary

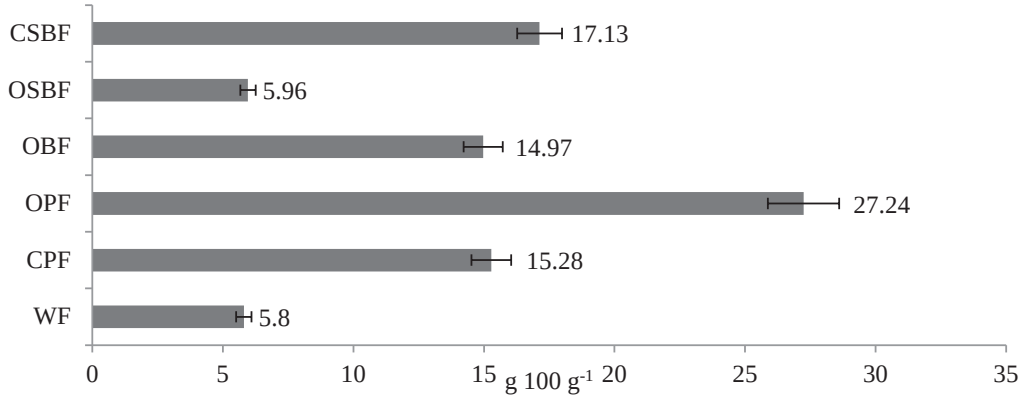

Figure 2. Total dietary fibre amount in pea and buckwheat flours.

fibre content in buckwheat were made by Bonafaccia, Marocchini, & Kreft (2003).

For pea flours the total dietary fibre amount varied between 15.28 g 100 g^{-1} for conventional and 27.24 g 100 g^{-1} for organic pea flour (Fig.2). The significant ($p<0.05$) difference of dietary fibre among pea flours could be associated with different stage of pea treatment for flour production. The appearance of conventional pea flour was daffodil without impurities whereas organic pea flour was light brown with black flecks. It indicated that organic pea flour could be potential high amount of dietary fibre. It was confirmed by obtained data. The research data differed from the results obtained by Stoughton-Ens *et al.* (2010) where the total dietary fibre content of the pea samples ranged from 10.7% to 14.8% of dry matter. It could be explained by the conclusion made by Aldwairji *et al.* (2014) that the fibre content is affected by both the processing method and the method of analysis. The total dietary fibre content of buckwheat flours ranged from 5.96 g 100 g^{-1} for OSBF to 17.13 g 100 g^{-1} for CSBF (Fig. 2).The significantly lower total dietary fibre content of OSBF comparing to OBF and CSBF could be associated with differences in the flour processing method and environment because the buckwheat flour samples were taken from various locations (Lithuania, Latvia) and producers. Comparing results with the data given by Bonafaccia, Marocchini, & Kreft (2003) where common buckwheat grain contained 22.17 g 100 g^{-1} of the total dietary fibre and buckwheat flour contained 5.87 g 100 $g^{-1,}$ it was possible to see similarities. Pea and buckwheat flours could be characterised as a good source of dietary fibre with significantly ($p<0.05$) higher content of the total dietary fibre comparing to wheat flour, except OSBF.

Conclusions

1. The highest amount of total amino acids was determined for pea flours (18.82 g 100 g^{-1} for conventional and 19.30 g 100 g^{-1} for organic flours respectively), whereas for buckwheat flours it ranged from 9.62 g 100 g^{-1} for OSBF to 11.09 g 100 g^{-1} for CSBF.
2. There were significant ($p<0.05$) differences in the individual amino acid contents, particularly as concerns serine, glutamic acid, proline, alanine, isoleucine, leucine, phenylalanine and arginine, across buckwheat flours.
3. The amount of essential amino acids made up one third of the total amino acid content in the tested pea and buckwheat flours which were rich in lysine (1.58 – 1.68 g 100 g^{-1} and 0.56 – 0.68 g 100 g^{-1} respectively) in comparison with wheat flour (0.33 g 100 g^{-1}).
4. Pea and buckwheat flours had a significantly ($p<0.05$) higher content of the total dietary fibre comparing to wheat flour, except OSBF.
5. Due to the biological value of buckwheat and pea flours, it is strongly recommendable to use these ingredients in the production of new functional products and to increase their consumption.

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References

1. Aldwairji, M.A., Chu, J., Burley, V.J., & Orfila, C. (2014). Analysis of dietary fibre of boiled and canned legumes commonly consumed in the United Kingdom. *Journal of Food Composition and Analysis*, 36, 111-116. DOI: 10.1016/j.jfca.2014.06.010.
2. Azarpazhooh, E., & Boye, J.I. (2010). Composition of processed beans and pulses. In M. Siddiq & M.A. Uebersax (Eds.), *Dry beans and pulses production, processing and nutrition* (pp. 101-128). Oxford, UK: Blackwell Publishing Ltd.
3. Barclay, A.W., Petocz, P., McMillan-Price, J., Flood, V.M., Prvan, T., Mitchell, P., & Brand-Miller, J.C. (2008). Glycemic index, glycemic load, and chronic disease risk – a meta-analysis of observational studies. *The American Journal of Clinical Nutrition*, 87, 627-637.
4. Biel, W., Bobko, K., & Maciorowski, R. (2009). Chemical composition and nutritive value of husked and naked oats grain. *Journal of Cereal Science*, 49, 413-418. DOI: 10.1016/j.jcs.2009.01.009.
5. Biel, W., & Maciorowski, R. (2013). Evaluation of chemical composition and nutritional quality of buckwheat groat, bran and hull (*Fagopyrum Esculentum* Möench L.). *Italian Journal of Food Science*, 25, 384-389.
6. Bonafaccia, G., Marocchini, M., & Kreft, I. (2003). Composition and technological properties of the flour and bran from common and tartary buckwheat. *Food Chemistry*, 80, 9-15. DOI: 10.1016/S0308-8146(02)00228-5.

7. Boye, J., Zare, F., & Pletch, A. (2010). Pulse proteins: Processing, characterization, functional properties and applications in food and feed. *Food Research International*, 43 (2), 414-431. DOI: 10.1016/j.foodres.2009.09.003.
8. Brummer, Y., Kaviani, M., & Tosh, S.M. (2015). Structural and functional characteristics of dietary fibre in beans, lentils, peas and chickpeas. *Food Research International*, 67, 117-125. DOI: 10.1016/j.foodres.2014.11.00.
9. Cai, Y.Z., Corke, H., & Lee, W.D. (2004). Buckwheat. In C. Wrigley, H. Corke & C.E. Walker (Eds.), *Encyclopedia of grain science* (pp. 120-128). Oxford, UK: Academic Press.
10. Davidsson, L., Dimitriou, T., Walczyk, T., & Hurrel, R.F. (2001). Iron absorption from experimental infant formulas based on pea (*Pisum sativum* L.) – protein isolate: the effect of phytic acid and ascorbin acid. *British Journal of Nutrition*, 85, 59-63. DOI: 10.1079/BJN2000232.
11. Dodevska, M.S., Djordjevic, B.I., Sobajic, S.S., Miletic, I.D., Djordjevic, P.B., & Dimitrijevic-Sreckovic, V.S. (2013). Characterisation of dietary fibre components in cereals and legumes used in Serbian diet. *Food Chemistry*, 141, 1624-1629. DOI: 10.1016/j.foodchem.2013.05.078.
12. Gómez, M., Doyagüe, M.J., & de la Hera, E. (2012). Addition of pin-milled pea flour and air-classified fractions in layer and sponge cakes. *LWT – Food Science and Technology*, 46, 142-147.
13. Hood-Niefer, Sh.D., & Tyler, R.T. (2010). Effect of protein, moisture content and barrel temperature on the physicochemical characteristics of pea flour extrudates. *Food Research International*, 43, 659-663.
14. Hopping, B.N., Etber, E., Grandinetti, A., Verheus, M., Kolonel, L.N., & Maskarinec, G. (2010). Dietary fiber, magnesium, and glycemic load alter risk of type 2 diabetes in a multiethnic cohort in Hawaii. *Journal of Nutrition*, 140, 68-74. DOI: 10.3945/jn.109.112441.
15. Ikeda, K. (2002). Buckwheat: Composition, chemistry and processing. *Advances in Food and Nutrition Research*, 44, 395-434.
16. Ikeda, K., & Kishida, M. (1993). Digestibility of proteins in buckwheat seed. *Fagopyrum*, 13, pp. 21-24.
17. Iqbal, A., Khalil, I.A., Ateeq, N., & Khan, M.S. (2006). Nutritional quality of important food legumes. *Food Chemistry*, 97, 331-335. DOI: 10.1016/j.foodchem.2005.05.011.
18. Izydorczyk, M.S., McMillan, T., Bazin, S., Kletke, J., Dushnicky, L., & Dexter, J. (2014). Canadian buckwheat: A unique, useful and under-utilized crop. *Canadian Journal of Plant Science*, 94, 509-524. DOI: 10.4141/cjps2013-075.
19. Li, S., & Zhang, Q.H. (2001). Advances in the development of functional foods from buckwheat. *Critical Reviews in Food Science and Nutrition*, 41, 451-464. DOI: 10.1080/20014091091887.
20. Lisiewska, Z., Słupski, J., Kmiecik, W., & Gębczyński, P. (2008). Effect of pre-freezing and culinary treatment on the content of amino acids of green pea. *ACTA Scientiarum Polonorum Technologia Alimentaria*, 7 (4), 5-14.
21. Qin, P., Wang, Q., Shan, F., Hou, Zh., & Ren, G. (2010). Nutritional composition and flavonoids content of flour from different buckwheat cultivars. *International Journal of Food Science & Technology*, 45, 951-958. DOI: 10.1111/j.1365-2621.2010.02231.x.
22. Radu, S. (2012). Optimizing the content of essential amino acids in edible flours obtained from cereals and leguminous green. *Agronomy Series of Scientific Research*, 55, 277-282.
23. Rokka, S., Ketoja, E., Järvenpää, E., & Tahvonen, R. (2013). The glycaemic and C-peptide responses of food rich in dietary fibre from oat, buckwheat and lingonberry. *International Journal of Food Sciences and Nutrition*, 64 (5), 528-534. DOI: 10.3109/09637486.2013.763914.
24. Sievenpiper, J.L., Kendall, C.W.C., Esfahani, A., Wong, J.M.W., Carleton, A.J., Jiang, H.Y., Bazinet, R.P., Vidgen, E., & Jenkins, D.J. (2009). Effect of non-oil-seed pulses on glycaemic control: a systematic review and meta-analysis of randomised controlled experimental trials in people with and without diabetes. *Diabetalogia*, 52, 1479-1495. DOI: 10.1007/s00125-009-1395-7.
25. Skrabanja, V., Nygaard, L.H., & Kreft, I. (2000). Protein-polyphenol interactions and in vivo digestibility of buckwheat groat proteins. *Pflügers Archiv – European Journal of Physiology*, 440, 129-131.
26. Slavin, J.L., Savarino, V., Paredes-Diaz, A., & Fotopoulos, G. (2009). A review of the role of soluble fibre in health with specific reference to wheat dextrin. *Journal of International Medical Research*, 37, 1-17.
27. Son, B.K., Kim, J.Y., & Lee, S.S. (2008). Effect of adlay, buckwheat and barley on lipid metabolism and aorta histopathology in rats fed an obesogenic diet. *Annals of Nutrition and Metabolism*, 52, 181-187. DOI: 10.1159/000138121.
28. Stoughton-Ens, M.D., Hatcher, D.W., Wang, N., & Warkentin, T.D. (2010). Influence of genotype and environment on the dietary fiber content of field pea (*Pisum sativum* L.) grown in Canada. *Food Research International*, 43, 547-552.

29. Trinidad, T.P., Mallillin, A.C., Loyola, A.S., Sagum, R.S., & Encabo, R.R. (2010). The potential health benefits of legumes as a good source of dietary fibre. *British Journal of Nutrition*, 103, 569-574.
30. Wang, N., Hatcher, D.W., & Gawalko, E.J. (2008). Effect of variety and processing on nutrients and certain anti-nutrients in field peas (*Pisum sativum*). *Food Chemistry*, 111, 132-138.
31. Wei, Y.M., Zhang, G.C., & Li, Z.X. (1995). Study on nutritive and physic-chemical properties of buckwheat flour. *Nahrung/Food*, 39, 48-54.
32. Zia-Ul-Haq, M., Ahmad, S., Amarowicz, R., & Ercisli, S. (2013). Compositional studies of some pea (*Pisum Sativum* L.) seed cultivars commonly consumed in Pakistan. *Italian Journal of Food Science*, 25, 295-302.

EFFECTS OF GERMINATION ON CHEMICAL COMPOSITION OF HULL-LESS SPRING CEREALS

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Abstract
The objective of the current research was to investigate effects of germination on chemical composition of hull-less barley (*Hordeum vulgare* L. *var. nudum Hook. f.*), hull-less oat (*Avena sativa*), rye (*Secale spp.*), and wheat (*Triticum spp.*) grains for comparison. All the grains were cleaned, washed, steeped and germinated at temperature 35 ± 2 °C and relative humidity 95 ± 2% for 12, 24, 36, and 48 hours. After germination grains were dried till moisture content 14 ± 2%. Main quality parameters such as starch, proteins, b-glucan (in hull-less barley) and individual sugars were determined in cereals during their steeping and germination. Non-germinated grains were used as a control sample. In the present experiments non-significant protein content increase was observed in the analysed hull-less barley, hull-less oat, rye, and wheat during their germination for 48 hours. Starch content in hull-less barley, wheat and rye grains decreased non-significantly during germination for 24 h; opposite results were obtained for hull-less oat grains, where content of starch decreased by 16.7% after steeping and by 26.4% after germination for 24 h. b-glucan content in hull-less barley grains after germination for 48 h decreased by 20.5%. Non-significant changes were obtained in fructose content in analysed cereal grains during germination for 48 h; it was significantly increased after germination for 24 h and in germination for 48 h. Non-significant sucrose content changes were observed in hull-less barley, rye and wheat grains during germination for 12 h and in hull-less oat grains – for 24 h significantly increasing in future germination for 48 h.
Key words: hull-less cereals, germination, sugars, starch, proteins.

Introduction

Cereal grains constitute a major source of energy and nutrients in the world. The benefits of cereals to human health are the subject of extensive research and epidemiological studies, which have linked whole grain intake to the prevention of metabolic syndrome, obesity, and associated chronic diseases such as cardiovascular disease and two types of diabetes. The health benefits of cereals are primarily caused by their phytochemicals including phenolic acids, flavonoids, vitamins, fibre, and minerals, which act together to combat oxidative stress, inflammation, hyperglycaemia, and carcinogenesis (Poutanen, 2012; Wang, Wu, & Shyu, 2013).

Of the various barley (*Hordeum vulgare*) cultivars, hull-less barley has recently been receiving considerable research attention concerning the development of functional food, as it is an excellent source of both soluble and insoluble fibre. Hull-less (or 'naked') barley (*Hordeum vulgare* L. var. *nudum* Hook. f.) is a form of domesticated barley, in which, unlike hulled barleys but similarly to wheat (*Triticum aestivum*), the lemma and palea (hull) are non-adherent to the caryopsis. The total β-glucan content of hull-less barley is higher than that of hulled barley genotypes; whereas the insoluble dietary fibre content is lower (Xue *et al.*, 1997; Blandino *et al.*, 2015). In comparison with other cereals, naked oat (*Avena sativa*) grain is characterised by a larger amount of total protein and crude fat and a smaller one of crude fibre. The characteristic feature of protein is its good amino acid composition with a high nutritive value. A high level of fat is a good source of essential unsaturated fatty acids (Brand & Merwe, 1996; Petkov *et al.*, 2001; Biel, Bobko, & Maciorowski, 2009). The main chemical constituents of the rye (*Secale cereale*) grain are starch, dietary fibre (DF), protein, and mineral matter (ash). The starch content is limited mainly to the endosperm, and contents between 57.1 and 65.6 g 100 g^{-1} of dry matter (DM) are reported in rye. The DF components are found as cell-wall constituents in all parts of the kernel, and the total content of DF reported in rye grain is between 14.7 and 20.9 g 100 g^{-1} of DM. Approximately 25% of the total DF components are water-extractable (Hansen *et al.*, 2004). Wheat is the primary cereal grain produced in the European Union, and bread wheat represents the most important wheat species worldwide to be used as food ingredient in human nutrition (Matsuo, 1994; Rosenfelder, Eklund, & Mosenthin, 2013). Wheat is mainly appreciated as a source of carbohydrates and proteins (albeit poor in some essential amino acids, especially lysine), but contributes also a significant proportion of fibre, minerals, and antioxidant compounds, such as phenolic acids and tocols, to the human diet (Ward *et al.*, 2008; Hidalgo, Scuppa, & Brandolini, 2016).

Germination, a complex process causing physical, chemical and structural changes in grains, has been identified as an inexpensive and effective technology for improving cereal quality. The germination process is characterized by the growth of the embryo of the grain, manifested by the rootlets growth and increase

in length of the shoot (acrospire), with the concomitant modification of the contents of the endosperm (de Pinho Ferreira Guine & dos Reis Correia, 2013). Germination of grain commences with the uptake of water. Once germination is initiated, the predominant endosperm reserves, starch, cell wall, and storage proteins, are mobilized by the action of hydrolytic enzymes, which are synthesized in the aleurone layer and in the scutellum and secreted into the starchy endosperm of germinating grains (Lu, Lim, & Yu, 1998; Shaik *et al*., 2014). During germination, endogenous enzymes of cereal grains are activated, and some major substances such as starch and protein undergo degradation to small molecules. For example, a significant decrease of starch content is found during germination of rice. Furthermore, some functional compounds can be enriched, meanwhile some anti-nutrition factors, such as phytic acid, is degraded during germination. Current studies indicated that germination enriched γ-aminobutyric acid in brown rice (*Oryza sativa* L.), wheat, and foxtail millet (*Setaria italica*). Germinated cereal grains also show higher total phenolic content and antioxidant activity than those of un-germinated rice, wheat and oat. The germination process improves the nutritional quality of cereal. During the process of germination, significant changes in the biochemical, nutritional, and sensory characteristics of cereals occur due to degradation of reserve materials as used for respiration and synthesis of new cell constituents for developing embryo in the seed (Danisova *et al*., 1995; Sharma, Saxena, & Riar, 2016). As compared to un-germinated seed, germinated seeds contain high protein, low unsaturated fatty acids, low carbohydrate, and mineral content (Narsih, 2012; Sharma, Saxena, & Riar, 2016). Alpha-amylase enzyme plays a primary role in native starch granule degradation, and its expression is controlled by both gibberellin and sugar demand/ starvation. Sugar or carbon starvation activates the α-amylase promoter (Lu, Lim, & Yu, 1998; Shaik *et al*., 2014). As a result, during germination amylases are produced and partial breakdown of starch into simple sugars occurs (Chesworth, Stuchbury, & Scaife, 1998). Intense biochemical processes occur during the grain activation (the first stage of germination); as a result, grain biological value increases – the content of vitamins B_2, E and niacin, total sugar, dietary fibre and glucosamine increase; vitamin C is synthesized, and the content of irreplaceable amino acids is increased during the process of protein hydrolysis (Rakcejeva, 2006).

The objective of the current research was to investigate effects of germination on chemical composition of hull-less barley, hull-less oat, and rye, and wheat grains for comparison.

Materials and Methods

The study was realised at the scientific laboratories of the Faculty of Food Technology at Latvia University of Agriculture.

Conventional hull-less barley (′Irbe′), hull-less oat (′Lizete′), rye (′Kaupo′), wheat (′Ellvis′) grains cultivated at State Priekuli Plant Breeding Institute (Latvia) in 2015 were used in the experiments.

All the grains were cleaned, washed and steeped in water in the ratio of 1 : 2 (seeds to water) for 24 ± 1 h at 22 ± 2 °C. After steeping, water was drained, and grains were allowed to germinate in the dark at controlled temperature (35 ± 2 °C) and 95 ± 2% relative humidity (RH) in a climatic chamber ICH110 (Memmert, Germany). Grains were germinated for 12, 24, 36, and 48 hours. After germination grains were dried till moisture content 14 ± 2%. For air drying experiments, a convective dryer 00-800 (Memmert, Germany) was used; drying parameters were as follows: temperature 50 ± 1 °C, air flow velocity 1.2 ± 0.1 m s^{-1}. Grains were placed on a perforated sieve (diameter − 0.185 m), with the diameter of the holes – 0.002 m.

Before testing of parameters grains were ground in laboratory mill 3100 (Perten, Sweden) obtaining fine whole grain flour.

An Infratec™ 1241 Grain Analyzer (Foss, Sweden) was used to analyse starch, protein, and b-glucan concentration in grains according to ISO 12099. The measurements are based on the fact that the main constituents in the grain such as starch and others absorb electromagnetic radiation in the near-infrared region of the spectrum. Sample preparation is not required and the measurements of starch concentration (% of fresh weight basis) are directly displayed after grains are inserted in a pre-calibrated auto-analyser (Singh, Mackill, & Ismai, 2009).

For the analysis of content of individual sugars 5 grams of milled samples were extracted with 20 mL deionized water and stirred for 1 hour. After 1h the extract solution was filtered through the filter paper. The obtained extract was filtered through a high-performance liquid chromatography (HPLC) syringe filter with pore size of 0.45 μm. The content of individual sugars in the grain sample extract filtrate was determined with high-performance liquid chromatography LC 20 Prominence (Shimadzu, Japan). Determination parameters were: detector – refractive index RID-10A; column – Alltech NH2, 4.6 mm × 250.0 mm, 5 μm; temperature 25 °C; isocratic elution regime, mobile phase –A – acetonitrile, B – deionized water (A70:B30); capacity of the injection sample – 10 μL; total time of the analysis – up to 15 min; rate of the flow – 1.0 mL min^{-1}. Acquired data were processed using Shimadzu LabSolutions software (LCsolution Version 1.21 SP1).

Table 1

Protein content changes in grains during steeping and germination, g 100 g^{-1} DM

Type of cereals	Control	Steeped	Germination time, h			
			12	24	36	48
Hull-less barley	10.5 ± 0.1	11.1 ± 0.1	10.7 ± 0.1	10.6 ± 0.1	10.9 ± 0.1	11.0 ± 0.1
Wheat	9.8 ± 0.1	10.3 ± 0.1	10.2 ± 0.1	10.1 ± 0.1	10.1 ± 0.1	10.0 ± 0.1
Hull-less oats	14.8 ± 0.1	14.9 ± 0.1	14.8 ± 0.1	14.8 ± 0.1	14.9 ± 0.1	15.0 ± 0.1
Rye	7.5 ± 0.1	7.7 ± 0.1	7.6 ± 0.1	7.8 ± 0.1	7.8 ± 0.1	7.8 ± 0.1

The results were processed by mathematical and statistical methods (mean, standard deviation, p-value). Data were subjected to one-way analysis of variance (ANOVA) by Microsoft Office Excel 2007; significance was defined at $p<0.05$. Analyses were completed in triplicate.

Results and Discussion

Non-significant ($p>0.05$) protein content changes were observed in analysed cereals during germination. During germination for 48 h content of proteins in hull-less barley grains increased by 4.5%, in wheat – by 2.0%, in hull-less oats – by 1.3% and in rye – by 3.8%. The increase of protein content (Table 1) in cereals mainly can be explained by the results of M. He *et al.* (2015) for wheat cereals, as during germination, the embryo and endosperm of wheat seeds possibly have a basic pattern of oxygen consumption. They consume plenty of oxygen at the beginning of germination; enter lag period, then oxygen consumption increases sharply when the radicles have broken through the episperm. When germination is completed, oxygen consumption increases continuously in the embryo but decreases in the endosperm. Reserve substances from the endosperm begin to be mobilized when the germination is finished, and more enzymes involved in these processes are synthesized in large quantities. The mobilization also possibly concerns the activation of enzymes and inactivation of inhibitors. Proteins produce amino acids, peptides, and their derivatives, which are used to synthesize new proteins, then transported to the seedling.

Barley has usually been grown for feed uses. However, nowadays, barley is becoming more interesting due to its high content of bioactive compounds. Among these biologically active components, β-glucans play an important role. They are soluble dietary fibres located in the cell wall of the endosperm of barley grains, and their content can reach up to 15%. They contribute to lower cholesterol levels; regulate blood glucose levels, control colon cancer, and increase mineral and vitamin bioavailability (Gómez-Caravaca *et al.*, 2015).

Total content of β-glucan in barley normally ranges from 2 to 8% and depends on both genetic and environmental factors. About 66% of the barley β-glucans are in soluble form (Lee & Bamforth, 2009). In the present research content of b-glucans in analysed hull-less barley was found 4.40 ± 0.08 g 100 g^{-1}. However, significant changes ($p=0.011$) in b-glucans' content were observed in barley during processing as steeping and germination. As results of our experiments demonstrate, content of b-glucans decreased during grain steeping by 6.8%. But after grain germination for 48 h content of glucans decreased by 20.5% comparing with non-germinated hull-less barley grains. More significant ($p=0.024$) b-glucan content decrease was observed in hull-less barley grains after germination for 24 h; as a result, content of analysed parameter decreased by 11.4%, comparing with control grain sample (Fig. 1). O. Marconi *et al.* (2014) indicates that in particular the total β-glucan content decreased during malting due to the action of β-glucanase while β-glucan solubility increased during malting and is positively affected by the germination time.

During the seed germination process, α-amylase is the major enzyme for initial degradation of starch granules and β-amylase is also involved in starch conversion into free simple sugars. A-amylase randomly attacks only the α- (1→4) bonds; the amyloglucosidase (also called glucoamylase) selectively attacks the last bond on the non-reducing terminals, which can act on both the α- (1→4) and the α- (1→6) glucosidic linkages. The patterns of enzyme digestion were to produce large pin holes at starch granule surface in corn and triticale (Li *et al.*, 2011). Figure 2 shows grain starch content changes during germination process.

Non-significant ($p>0.05$) starch content decreases were detected in wheat, hull-less barley, and rye grains after steeping (Fig. 2). However, after hull-less oat steeping content of starch decreased by 16.7% ($p<0.05$) comparing with non-processed cereals. Non-significant ($p>0.05$) starch content decrease was detected in hull-less barley, wheat and

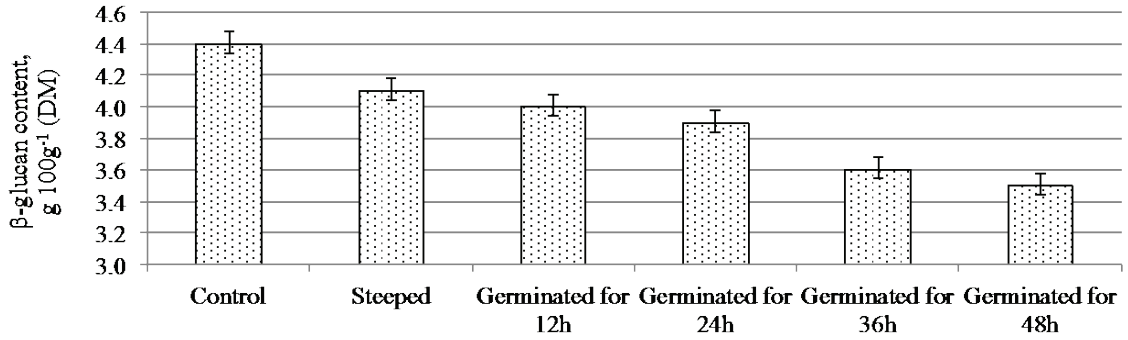

Figure 1. β-glucan content in hull-less barley during its germination.

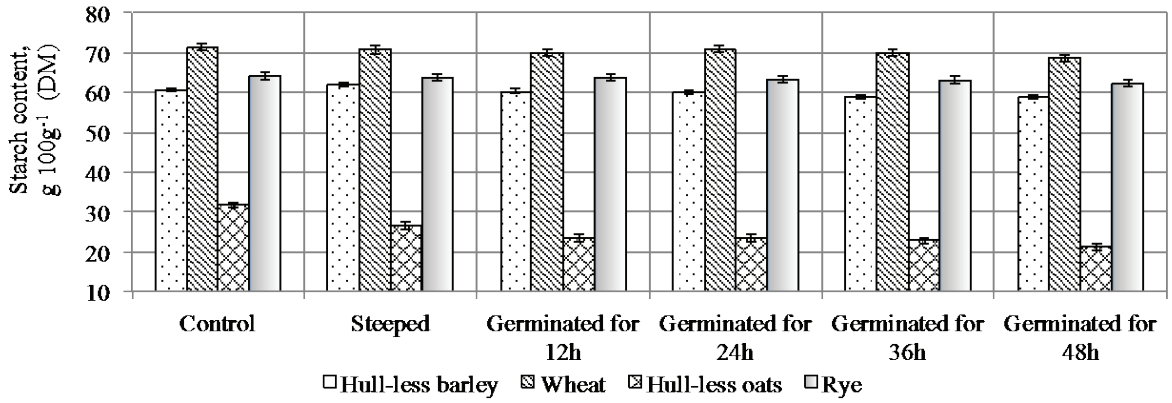

Figure 2. Grain starch content changes during germination.

rye grains after germination for 24 h, the content of starch in presented cereals decreased by 0.8%, 0.7% and 1.3% respectively. Starch content in hull-less oat grains decreased by 26.4% ($p=0.014$) after germination for 24 h, comparing with non-germinated hull-less oat. Non-significant ($p>0.05$) starch content decrease was detected in hull-less barley, wheat, and rye grains after germination for 48 h as follows by 3.5%, 3.9% and 2.7% respectively comparing with non-germinated grains. More pronounced ($p<0.05$) starch content decrease was detected in hull-less oat after germination for 48 h – by 33.6%, comparing with control hull-less oat sample. Similar results were observed in B. Tian *et al.* (2010) research, in oat seeds during germination the contents of protein, starch and phytate decreased significantly, the free amino acids, reducing sugars, free significant correlation among them was found. V. M. E. Andriotis *et al.* (2016) review recent advances in understanding the roles of carbohydrate-active enzymes in starch degradation in cereal grains through complementary chemical and molecular genetics. These approaches have allowed us to start dissecting aspects of starch degradation and the interplay with cell-wall polysaccharide hydrolysis during germination. With a view to improving and diversifying the properties and uses of cereal grains, it is possible that starch degradation may be amenable to manipulation through genetic or chemical intervention at the level of cell wall metabolism, rather than simply in the starch degradation.

During germination the activity of amylases increased progressively, but that of phosphorylase tended to increase during starch degradation (Fig. 3). A new α-amylase isoenzyme band appeared during germination. Glucose was the major product of starch degradations. Sucrose, maltose, maltotriose, raffinose and fructose were also detected. Protease activity reached a maximum on the fifth or sixth day and closely paralleled the increase in amino acids and soluble protein (Basuchaudhuri, 2014). In the present research non-significant changes ($p>0.05$) were obtained in fructose content in wheat, rye, hull-less barley and hull-less oat grains during germination for 48 h. Similar results were reported by D. Charalampopoulos *et al.* (2009), as interestingly the main sugars of the medium (fructose, maltotriose, etc.) and amino nitrogen were consumed in very low quantities during the fermentation – germination process. In the present experiments, non-significant ($p>0.05$) decrease of glucose content was observed

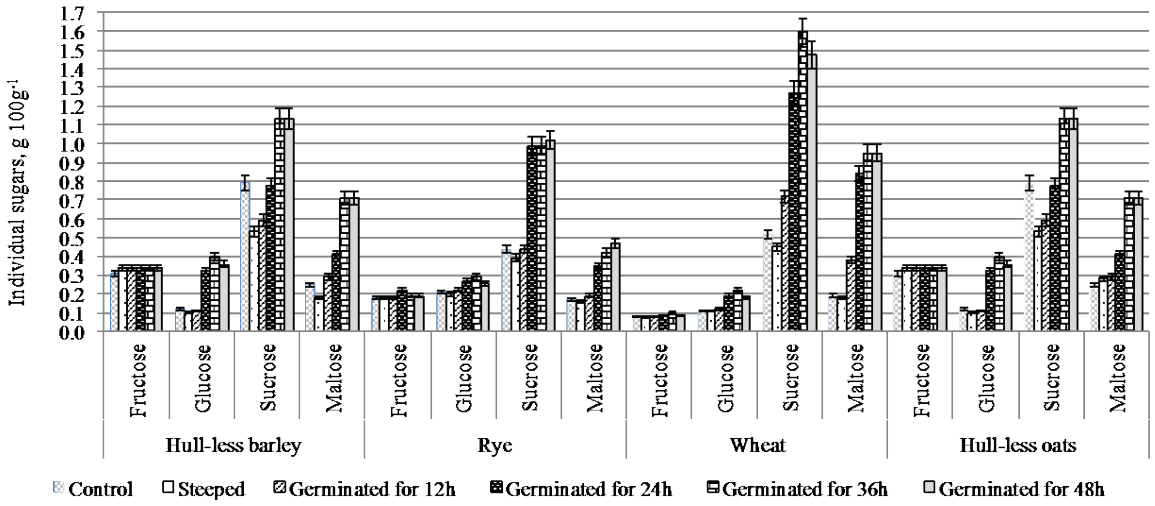

Figure 3. Individual sugars composition in grains.

in analysed cereals during germination for 12 h. However, glucose content significantly increased after germination for 24 h, accordingly, in hull-less barley and hull-less oats – by 62.5%, in rye – by 22.2%, in wheat – by 42.1% comparing with non-germinated cereals. In further germination for 48 h, glucose content changes were not significant ($p>0.05$). The obtained results could be explained with b-glucans breakdown, for example, in hull-less barley, (Fig. 1) into low molecular weight glucans and glucose by the endo-β-glucanases and β-glucosidases (de Pinho Ferreira Guine & dos Reis Correia, 2013). Non-significant ($p>0.05$) sucrose content changes were observed in hull-less barley, rye and wheat grains during germination for 12 h and in hull-less oat grains – for 24 h. On the contrary, sucrose content after 48 h germination in analysed grains increased significantly ($p<0.05$). After germination for 48 h sucrose content in hull-less barley grains increased by 30.1%, in rye – by 56.9%, in wheat – 64.4%, and in hull-less oats – by 46.3%

Significant ($p<0.05$) maltose content changes were detected in the analysed cereals after germination for 24 h; as a result, maltose content in hull-less barley and hull-less oats increased by 39.0%, in rye – by 51.4%, in wheat – by 77.4%. Similarly, the maltose content increased in cereals a further germination for 48 h.

Three enzymes are important for hydrolyzing starch to smaller molecules. They are α-amylase, β-amylase, and glucoamylase. Some of these enzymes (α-amylase and β-amylase) are naturally present in cereal grains and become active during germination. A-amylase displays an endoaction and can hydrolyze the α-1,4 linkage of starch internally and randomly, yielding low molecular weight dextrins. b-amylase is an enzyme having an exoaction. It can hydrolyze starch from the non-reducing chain end. The product removed through β-amylase action is maltose due to the hydrolysis of alternate α-1,4 linkages. β-amylase alone is basically inactive on granular starch but is capable of rapid action when the substrate is solubilized. β-amylase is found in sound, intact cereal grains and the level does not increase much as a result of germination (Liu & Rosentrater, 2011)

Conclusions

In the present research non-significant protein content increase was observed in the analysed hull-less barley, hull-less oat, rye, and wheat during their germination for 48 hours. Germination time has a significant effect on hull-less spring chemical composition resulting change in β -glucan and sugars content especially. Starch content in hull-less barley, wheat and rye grains decreased non-significantly during germination for 24 h. However, opposite results were obtained for hull-less oat grains, where content of starch decreased by 16.7% after steeping and by 26.4% after germination for 24 h. b-glucan content in hull-less barley grains after germination for 48 h decrease by 20.5% resulting starch breakdown. In the present research non-significant changes ($p>0.05$) were obtained in fructose content in analysed cereal grains during germination for 48 h. However, glucose content significantly increased after germination for 24 h, accordingly, in hull-less barley and hull-less oats – by 62.5%, in rye – by 22.2%, in wheat – by 42.1% comparing with non-germinated cereals and in germination for 48 h, glucose content changes were not significant ($p>0.05$). Non-significant ($p>0.05$) sucrose content changes were observed in hull-less barley, rye and wheat grains during germination for 12 h and in

hull-less oat grains – for 24 h significantly increasing in future germination for 48 h. However, maltose content in analysed cereals increase significantly after germination for 24 h – by 39.0% in oat, in rye – by 51.4%, in wheat – by 77.4%.

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References

1. Andriotis, V.M.E., Rejzek, M., Rugen, M.D., Svensson, B., Smith, A.M., & Field, R.A. (2016). Iminosugar inhibitors of carbohydrate-active enzymes that underpin cereal grain germination and endosperm metabolism. *Biochem Soc Trans*., 44(1), 159-165. DOI: 10.1042/BST20150222.
2. Basuchaudhuri, P. (2014). *Cold Tolerance in Rice Cultivation*. CRC Press, pp. 12-13.
3. Biel, W., Bobko, K., & Maciorowski, R. (2009). Chemical composition and nutritive value of husked and naked oats grain. *Journal of Cereal Science*, 49(3), 413-418. DOI: 10.1016/j.jcs.2009.01.009.
4. Blandino, M., Locatelli, M., Gazzola, A., Coïsson, D.-J., Giacosa, S., Travaglia, F., Bordiga, M., Reyneri, A., Rolle, L., & Arlorio, M. (2015). Hull-less barley pearling fractions: Nutritional properties and their effect on the functional and technological quality in bread-making. *Journal of Cereal Science*, 65, 48-56. DOI: 10.1016/j.jcs.2015.06.004.
5. Brand, T.S., Merwe, J.P. (1996). Naked oats (*Avena nuda*) as a substitute for maize in diets for weanling and grower-finisher pigs. *Journal of Animal Feed Science and Technology*, 57(1–2), 139-147. DOI: 10.1016/0377-8401(95)00827-6.
6. Charalampopoulos, D., Pandiella, S.S., & Webb, C. (2009). Uses of Whole Cereals and Cereal Components for the Development of Functional Foods. In *Innovation in Food Engineering*. CRC Press, pp. 638-639.
7. Chesworth, J.M., Stuchbury, T., & Scaife, J.R. (1998). *An Introduction to Agricultural Biochemistry*. Chapman & Hall, pp. 341-342.
8. Danisova, C., Holotnakova, E., Hozova, B., & Buchtova, V. (1995). Effect of germination on a range of nutrients of selected grains and legumes. *Acta Alimentaria*, Vol. 3, pp. 287-298.
9. De Pinho Ferreira Guine, R., & dos Reis Correia, P.M. (2013). Engineering Aspects of Cereal and Cereal-Based Products: *CRC Press*, pp. 53-55.
10. Gómez-Caravaca, A.M., Verardo, V., Candigliota, T., Marconi, E., Segura-Carretero, A., Fernandez-Gutierrez, A., & Fiorenza Caboni, M. (2015). Use of air classification technology as green process to produce functional barley flours naturally enriched of alkylresorcinols, β-glucans and phenolic compounds. *Food Research International*, 73, 88-96. DOI: 10.1016/j.foodres.2015.02.016.
11. Hansen, H.B., Moller, B., Andersen, S.B., Jorgensen, R.J., & Hansen, A.A. (2004). Grain Characteristics, Chemical Composition, and Functional Properties of Rye (*Secale cereale* L.) As Influenced by Genotype and Harvest Year. *Journal of Agricultural and Food Chemistry*, 52(8), 2282-2291.
12. He, M., Zhu, C., Dong, K., Zhang, T., Cheng, Z., Li, J., & Yan, Y. (2015). Comparative proteome analysis of embryo and endosperm reveals central differential expression proteins involved in wheat seed germination. *Journal of Plant Biology*, 15, 97-111. DOI: 10.1186/s12870-015-0471-z.
13. Hidalgo, A., Scuppa, S., & Brandolini, A. (2016). Technological quality and chemical composition of puffed grains from einkorn (*Triticum monococcum* L. subsp. *monococcum*) and bread wheat (*Triticum aestivum* L. subsp. *aestivum*). *LWT - Food Science and Technology*, 68, 541-548. DOI: 10.1016/j.lwt.2015.12.068.
14. Lee, Y.-T., & Bamforth, C.W. (2015). Variations in solubility of barley beta-glucan during malting and impact on levels of beta-glucan in wort and beer. *Journal of the American Society of Brewing Chemists*, 67(2), 67-71. DOI: 10.1094/ASBCJ-2009-0226-01.
15. Li, C.Y., Li, C., Lu, Z.X., Li, W.H., & Cao, L.P. (2012). Morphological changes of starch granules during grain filling and seed germination in wheat. *Starch*, 64, 166-170. DOI: 10.1002/star.201100093166.
16. Liu, K.S., & Rosentrater, K.A. (2016). Distillers Grains: Production, Properties, and Utilization. *CRC Press*, pp. 63-64.
17. Lu, C.A., Lim, E.K., & Yu, S.M. (1998). Sugar Response Sequence in the Promoter of a Rice Alpha-Amylase Gene Serves as a Transcriptional Enhancer. *Journal of Biological Chemistry*, 273(17), 10120-10131. PMID: 9553059.
18. Marconi, O., Tomasi, I., Dionisio, L., Perretti, G., & Fantozzi, P. (2014). Effects of malting on molecular weight distribution and content of water-extractable β-glucans in barley. *Food Research International*, 64, 677-682. DOI: 10.1016/j.foodres.2014.07.035.

19. Matsuo, R.R. (1994). Durum wheat: its unique pasta-making properties. W. Bushuk, V.F. Rasper (Eds.), *Wheat – Production, Properties and Quality, Blackie Academic & Professional.* An imprint of Chapman & Hall. Great Britain, pp. 169-178.
20. Narsih, H.Y. (2012). The study of germination and soaking time to improve nutritional quality of sorghum seed. *International Food Research Journal*, 19(4), 1429-1432.
21. Petkov, K., Biel, W., Kowieska, A., & Jaskowska, I. (2001). The composition and nutritive value of naked oat grain (*Avena sativa* var. *nuda*). *Journal of Animal and Feed Sciences*, 10(2), 303-307.
22. Poutanen, K. (2012). Past and future of cereal grains as food for health. *Trends in Food Science and Technology*, 25(2), 58-62. DOI: 10.1016/j.tifs.2012.02.003.
23. Rakcejeva, T. (2006). Biologically Activated Grain in Wheat Bread Technology. *Resume of the Ph.D. thesis*, Jelgava, Latvia: LLU, PTF. 18 p.
24. Rosenfelder, P., Eklund, M., & Mosenthin, R. (2013). Nutritive value of wheat and wheat by-products in pig nutrition: A review. *Animal Feed Science and Technology*, 185(3–4), 107-125. DOI: 10.1016/j.anifeedsci.2013.07.011.
25. Shaik, S.S., Carciofi, M., Martens, H.J., Hebelstrup, K.H., & Blennow, A. (2014). Starch Bioengineering Affects Cereal Grain Germination and Seedling Establishment. *Journal of Experimental Botany*, 65(9), 2257-2270. DOI: 10.1093/jxb/eru107.
26. Sharma, S., Saxena, D.C., & Riar, C.S. (2016). Analysing the effect of germination on phenolics, dietary fibres, minerals and γ-amino butyric acid contents of barnyard millet (*Echinochloa frumentaceae*). *Food Bioscience*, 13(1), 60-68. DOI: 10.1016/j.fbio.2015.12.007.
27. Singh, S., Mackill, D.J., & Ismai, A.M. (2009). Responses of SUB1 Rice Introgression Lines to Submergence in the Field: Yield and Grain Quality. *Field Crops Research*, 113(1), 12-23. DOI: 10.1016/j.fcr.2009.04.003.
28. Tian, B., Xie, B., Shi, J., Wu, J., Cai, Y., Xu, T., Xue, S., & Deng, Q. (2010). Physicochemical changes of oat seeds during germination. *Food Chemistry*, 119(3), 1195-1200. DOI: 10.1016/j.foodchem.2009.08.035.
29. Wang, C.-Y., Wu, S.-J., & Shyu, Y.-T. (2013). Antioxidant properties of certain cereals as affected by food-grade bacteria fermentation. *Journal of Bioscience and Bioengineering*, 117(4), 449-456. DOI: 10.1016/j.jbiosc.2013.10.002.
30. Ward, J.L., Poutanen, K., Gebruers, K., Piironen, V., Lampi, A.-M., & Nyström, L. (2008). The health grain cereal diversity screen: concept, results, and prospects. *Journal of Agricultural and Food Chemistry*, 56(21), 9699-9709. DOI: 10.1021/jf8009574.
31. Xue, Q., Wang, L., Newman, R.K., Newman, C.W., & Graham, H. (1997). Influence of the hulles, waxy starch and short-awn genes on the composition of barleys. *Journal of Cereal Science*, 26(2), 251-257. DOI: 10.1006/jcrs.1996.0114.

NON STARTER LACTIC ACID BACTERIA IN RAW MILK, THERMALLY TREATED MILK AND SWISS TYPE CHEESE

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Abstract
The diversity of non starter lactic acid bacteria in raw, pasteurised milk and maturated Swiss type cheese was tested. The aim of the present study was to analyse the concentrations and representatives of non-starter lactic acid bacteria in raw milk and to evaluate the changes of their concentrations and representatives during pasteurisation of cheesemilk and Swiss-type cheese production. The analysis carried out in the study showed a variation in the microbial composition and quantity of raw milk. The most frequently isolated lactobacilli were found at low level in raw milk (mean 27.5×10^4 CFU mL^{-1}) and the most frequently identified species were *Lactobacillus brevis* and *Lactobacillus paracasei.* The microflora of raw and pasteurised milk is similar analysing lactic acid bacteria representatives in the samples. *Lactobacillus brevis* and *Lactobacillus paracasei* were detected in the same samples in raw milk, pasteurised milk and maturated cheese. Our study showed that lactic acid bacteria concentration was quite low in pasteurised milk (1-12 CFU mL^{-1}), but they grow rapidly in cheese during ripening reaching $1.1\text{-}1.8*10^6$ CFU g^{-1}. The present study has shown that NSLAB in Swiss-type cheese mainly derive from raw milk, and only a few strains survive the processing conditions and grow during ripening.
Key words: lactic acid bacteria, lactobacilli, raw milk, pasteurised milk, cheese.

Introduction

The raw milk is a natural growth medium for microorganisms. An integral part of raw milk microflora is the non-starter lactic acid bacteria (NSLAB) - *L.casei subsp. paracasei, L.plantarum, L.rhamnosus, L.curvatus, L.brevis, L.fermentum; Leu. lactis, Leu.cremoris; E.faecium, E.faecalis, E.durans and Pediococcus spp.: P.pentosaceus, P.acidilactici.* It provides milk with its microflora and enriches the microflora of cheesemaking environment (Montel *et al*., 2014).

Pasteurization regimes selected in cheese manufacturing are able to destroy essential microflora (also lactic acid bacteria), enzymes and pathogens in milk. Inactivation level of microorganisms depends on the count of microorganisms, growth phase and other factors. Some NSLAB strains also withstand heat treatment, mainly resulting in damaged cells that recover and proliferate in the curd during ripening (De Angelis *et al*., 2004). According to R. Coppola and co-authors study (1997), mesophilic lactobacilli are present in relatively low numbers in pasteurised milk and our previous study (Bluma & Ciprovica, 2015) showed that it was from 0 to 76 CFU mL^{-1}, however, they grow rapidly in cheese during ripening.

A lot of reviews approve that the significance of non starter lactic acid bacteria is still controversial and several approaches have been used in attempts to elucidate the role of NSLAB in cheese production (Shakeel-Ur-Rehman *et al*., 2000; Beresford & Williams, 2004; Mikelsone, 2011; Gobbetti *et al*., 2015). Species and, particularly, biotypes of NSLAB may vary between dairy plants, within a dairy plant, depending on season and day of manufacture, and even vary between batches of cheese (Gobbetti *et al*., 2015; Østlie *et al*., 2016). The aim of the present study was to analyse the concentrations and representatives of non-starter lactic acid bacteria in raw milk and to evaluate the changes of their concentrations and representatives during pasteurisation of cheese milk and Swiss-type cheese production.

Materials and Methods

Research was performed from January 2015 to February 2016 at:

- ✓ the Laboratory of Microbiology of the Department of Food Technology of Latvia University of Agriculture;
- ✓ the Laboratories of the dairy processing company 'Latvijas piens' and 'Bauskas piens' Ltd.

Object of the research

In order to study the non-starter lactic acid bacteria representatives in raw milk (n = 15), pasteurised milk (n = 15) and cheese samples after maturation (n = 15) all samples were tested. The samples were taken from raw milk tanks in the dairy company. Bulk milk was kept at 2-4 °C prior treatment. Bulk milk samples were analysed in the dairy company 'Latvijas piens'.

For better understanding the proliferation of lactic acid bacteria representatives during thermal treatment, raw milk was pasteurized at +74 °C 30 s in the dairy company 'Latvijas piens'. Treated milk samples (n = 15) were taken from cheese vats before renneting. Ripened Swiss type cheese (ripening regimes: 8-12 °C, 20-25 °C, 8-12 °C temperature, 85-90% relative humidity and ripening period 6-8 weeks) was analysed at the end of maturation determining NSLAB representatives and their concentrations.

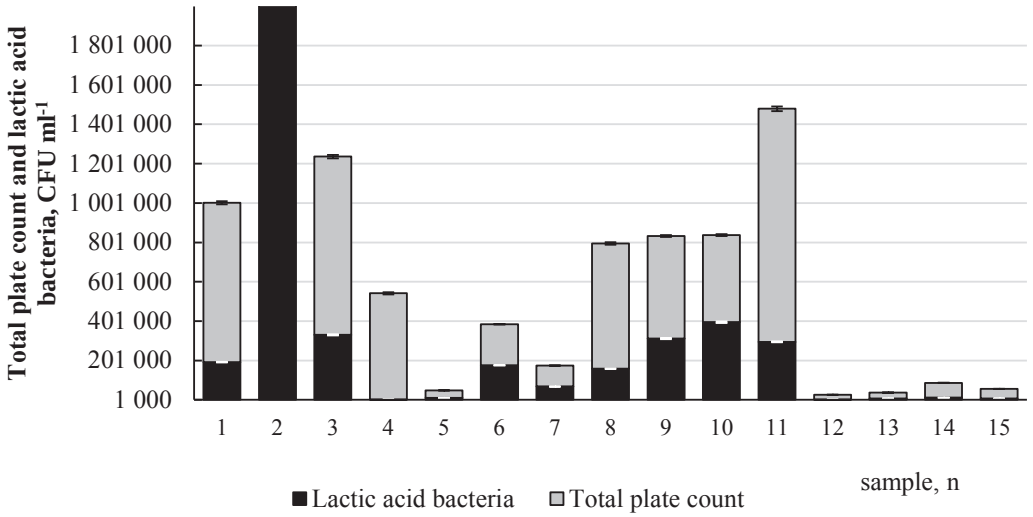

Figure 1. Total plate and lactic acid bacteria count (thous CFU mL^{-1}) in analysed bulk milk samples.

According to information given in literature (Demarigny *et al*., 1996), all studied cheese samples belong to young cheese group.

Methods of analyses

Determination of total plate count (TPC) was performed in all analyzed bulk milk samples according to LVS EN ISO 4833-1:2014 using PCA (plate count agar) (OXOID, UK). Sample dilutions were performed according to ISO 6887-5:2010 using salt-peptone solution. The chosen parameters for cultivation of bacteria in PCA agar were 72 hours at 30 °C.

Determination of *Lactobacillus* spp. was performed in all analyzed samples (raw milk, pasteurised milk, cheese) according to LVS ISO 15214:1998 using MRS agar (de Man Rogosa and Sharpe with Tween) media (OXOID, UK). Media were prepared according to LVS CEN ISO/TS 11133-1:2009. Sample dilutions were performed according to ISO 6887-5:2010 using salt-peptone solution.

The cultivation media were prepared according to LVS CEN ISO/TS 11133-1:2009.

The chosen parameters for cultivation of lactic acid bacteria in MRS agar were 72 hours at 37 °C, taking as a basis regimes recommended in Coeuret *et al*. (2003) work.

Identification of *Lactobacillus* spp. colonies was performed taking as a basis the fermentation of carbohydrates using API 50 CHL (BioMerieux, France). The program APILAB Plus version 4.0 (BioMerieux) was used for identification of the isolated colonies up to species.

Data mathematical treatment was performed by using Microsoft Excel program. The mean and the standard deviation of experimental data were determined.

Results and Discussion

In order to determine the origin of the facultatively heterofermentative lactobacilli we examined the bulk milk and pasteurised milk samples used for the manufacture of cheese for the presence of these bacteria.

The total plate and lactic acid bacteria count of bulk milk samples is summarized in Figure 1.

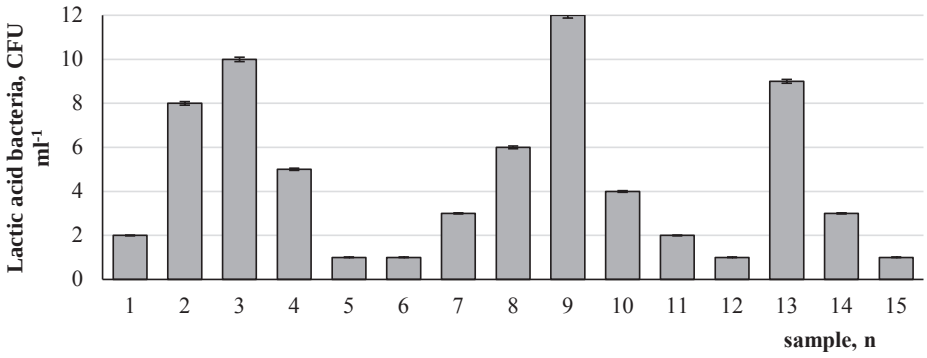

Figure 2. Lactic acid bacteria CFU in pasteurised milk samples (cheese milk).

The microbial quality of evaluated bulk milk samples is appropriate (except samples 3, 11), besides milk is usually pasteurised prior cheesemaking in Latvia, typically bulk milk used for cheese production contains 374 957 CFU mL^{-1} average.

Lactic acid bacteria in pasteurised milk samples are shown in Figure 2. Although pasteurisation reduces the flora of the raw milk to a large extent, small numbers of mesophilic lactobacilli may survive and subsequently grow in cheese made from pasteurised milk.

In cheese produced from pasteurised milk NSLAB typically grow from a few hundred per gram prior ripening to 10^7-10^8 g within 2-3 months of ripening. In analysed Swiss type cheese samples NSLAB vary from $1.10*10^6$ to $1.86*10^6$ CFU g^{-1}. The detected concentration is lower than previously mentioned statement that NSLAB slowly increase and reache a plateau at 10^7-10^9 CFU g^{-1} after a few to several months of cheese ripening (Fitzsimons *et al*., 2001). Our results we could explain with the findings of Gatti and co-authors (2014) when cheese aging is prolonged (Parmigiano Reggiano) the maximum of cell density decreases.

In the present study, microorganisms are identified based on phenotypical criteria and the obtained results also highlighted the absence of isolates in some analysed raw milk samples. The results of the identification are given in Figure 3.

The microflora of pasteurised milk is primarily of bacterial nature, and bacteria commonly isolated from pasteurised milk are of the same type that is found in raw milk (Fig. 3), as well as in cheese.

The bacteria were found at concentrations between 10^6 and 10^7 CFU g^{-1} and the large majority of isolates were *Lactobacillus brevis* and *Lactobacillus paracasei.* Three different species of NSLAB were found in raw milk, whereas 4 species were found in pasteurised milk. All species present in cheese (*Lactobacillus paracasei, Lactobacillus brevis, Lactobacillus curvatus* and *Lactobacillus plantarum*) as well as species in pasteurised milk (*Lactobacillus paracasei, Lactobacillus brevis, Lactobacillus curvatus* and *Lactobacillus plantarum*) were also found in the corresponding raw milk samples. Previously, Casey *et al*. (2006) described the diversity of mesophilic lactobacilli in Gruyère cheese (Swiss type cheese variety). The three genotypes found in the cheese were also found in raw milk, thus indicating that it is the raw milk flora and not the factory environment that principally determines the composition of the NSLAB in Gruyère cheese. It is interesting to note that in the cheese authors could not find the dominant genotype in raw milk, but genotypes were found at much lower concentrations. It can be assumed that some genotypes did not survive the temperatures applied during the cheesemaking process (Casey *et al*., 2006). The microflora of raw and pasteurised milk is similar to analysed lactic acid bacteria representatives in our study, too. Interestingly, we found *Lactobacillus brevis* and *Lactobacillus paracasei* in the same samples of raw milk, pasteurised milk and cheese.

The number of non-starter lactobacilli is higher in Swiss-type cheese made from raw milk than in cheese made from pasteurised milk, but the diversity of non-starter lactobacilli declines during ripening (Beuvier *et al*., 1997). The population of young cheese was comprised of *L.paracesei*, *L.plantarum* and *L.brevis* but as the cheese maturated *L.paracesei* dominated (Demarigny *et al*., 1996; Østlie *et al*., 2016). Species and, particularly, biotypes of NSLAB may vary between dairy plants, within a dairy plant, depending on season and day of manufacture, and even vary between batches of cheese, milk treatment and cheese ripening time (Gobbetti *et al*., 2015, Østlie *et al*., 2016). Although the different species have different growth characteristics (specific growth rate, acidification ability, and final cell number), they are

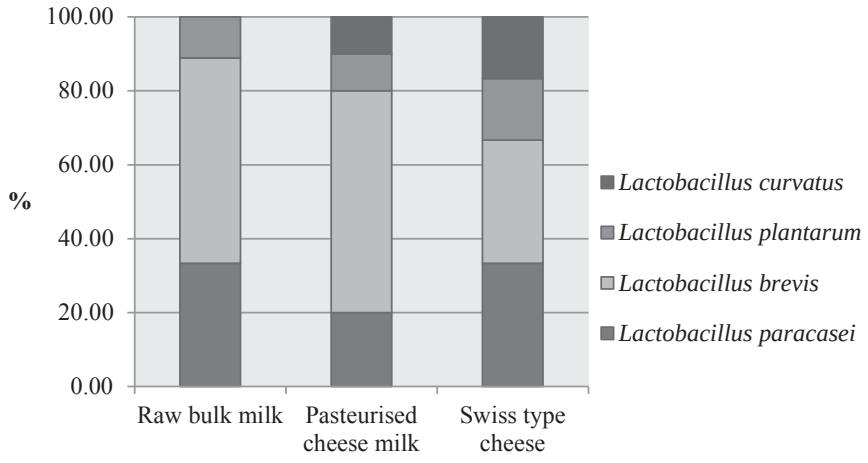

Figure 3. Lactic acid bacteria species isolated from raw, pasteurised milk and cheese samples.

well adapted in changing environmental parameters of ripening cheese (carbohydrate limitation, low temperatures and water activities). The present study has shown that NSLAB in Swiss-type cheese mainly derive from raw milk and generally only a few strains survive the processing conditions and grow during ripening.

Conclusions

In conclusion, the present study has shown that NSLAB in Swiss-type cheese mainly derive from raw milk and generally only a few strains survive the processing conditions and grow during ripening.

Lactic acid bacteria were found at low level in raw milk and the most frequently identified species were *Lactobacillus brevis* and *Lactobacillus paracasei.* Our study showed that lactic acid bacteria concentration was quite low in pasteurised milk (1-12 CFU mL^{-1}), but they grow rapidly in cheese during ripening reaching $1.1\text{-}1.8*10^6$ CFU g^{-1} at Swiss-type cheese samples.

References

1. Bereford, T.P., & Williams, A.G. (2004). The microbiology of cheese ripening. In: P.F.Fox, P.H.L.McSweeney, T.M.Cogan, T.P.Guinee (Eds.) *Cheese: Chemistry, physics and microbiology*, London, UK: Elsevier.
2. Beuvier, E., Berthaud, K., Cegarra, S., Dasen, A., Pochet, S., Buchin, S., & Duboz, G. (1997). Ripening and quality of Swiss-type cheese made from raw, pasteurised or microfiltered milk. *International Dairy Journal*, 7, pp. 311-323.
3. Bluma, A., & Ciprovica, I. (2015). Diversity of lactic acid bacteria in raw milk. Research for rural development 2015: Annual 21st International scientific conference proceedings, Jelgava, Latvia, 13-15 May, 2015 / Latvia University of Agriculture. - Jelgava, 2015. - Vol.1, pp. 157-161.
4. Casey, M.C., Hani, J.P., Gruskovnjak, J., Schaeren, W., & Wechsler, D. (2006). Characterisation of the non-starter lactic acid bacteria (NSLAB) of Gruyère PDO cheese. Lait 86, pp. 407-414.
5. Coeuret, V., Dubernet, S., Bernardieau, M., Gueguen, M., & Vernoux, J.P. (2003). Isolation, characterization and identification of lactobacilli focusing mainly on cheeses and other dairy products. *Lait*, 83, pp. 269-306.
6. Coppola, R., Nanni, M., Iorizzo, M., Sorrentino, A., Sorrentino, E., & Grazia, L. (1997). Survey of lactic acid bacteria isolated during the advanced stages of the ripening of Parmigiano Reggiano cheese. *Journal of Dairy Research*. 64(02), 305-310. DOI: 10.1017/S0022029996002038.
7. De Angelis, M., di Cagno, R., Huet, C., Crecchio, C., Fox, P.F., & Gobbetti, M. (2004). Heat shock response in *Lactobacillus plantarum*. *Applied and Environmental Microbiology*, 70, 1336-1346.
8. Demarigny, Y., Beivier, E., Dasen, A., & Duboz, G. (1996). Influence of raw milk microflora on the characteristics of Swiss-type cheese. 1. Evaluation of microflora during ripening and characterisation of facultatively heterofermentative lactobacilli. *Lait*, 76, pp. 371-387.
9. Fitzsimons, N.A., Cogan, T.M., Condon, S., & Beresford, T. (2001). Spatial and temporal distribution of non starter lactic acid bacteria in Cheddar cheese. *Journal of Applied Microbiology*.90(4), 600-608. DOI: 10.1046/j.1365-2672.2001.01285.x.
10. Gatti, M., Bottari, B., Lazzi, C., Neviani, E., & Mucchetti, G. (2014). Invited review: microbial evoluation in raw-milk, long-ripened cheeses produced using undefined natural whey starters. *Journal of Dairy Science*, 97(2), 573-591. DOI: 10.3168/jds.2013-7187.
11. Gobbetti, M., De Angelis, M., Di Cagno, R., Mancini, L., & Fox, P.F. (2015). Pros and cons for using non-starter lactic acid bacteria (NSLAB) as secondary/adjunct starters for cheese ripening. *Trends in Food Science & Technology*, 45, pp. 167-178.
12. Mikelsone, A. (2011). *Influence on non starter lactic acid bacteria on cheese ripening*: Summary of doctoral thesis for acquiring the doctor degree of engineering sciences in food science. LLU, Jelgava, 61p.
13. Montel, M.C., Buchin, S., Mallet, A., Delbes-Paus, C., Vuitton, D., & Desmasures, N. (2014). Traditional cheeses: rich and diverse microbiota with associated benefits. *International Journal of Food Microbiology*.177 (54). DOI: 136-154. DOI: 10.1016/j.ijfoodmicro.2014.02.019.
14. Østlie, H.M., Kraggerud, H., Longra, A.B., & Abrahamsen, R.K. (2016). Characterisation of the microflora during ripening of a Norwegian semi-hard cheese with adjunct culture of propionic acid bacteria. *International Dairy Journal*.54, 43-49. DOI:10.1016/j.idairyj.2015.10.005.
15. Shakel-Ur-Rehman, Fox, P.F., & McSweeney, P.L.H. (2000). Methods used to study non-starter microorganisms in cheese: a review. *International Journal of Dairy Technology*. 53 (3), 113-118. DOI: 10.1111/j.1471-0307.2000.tb02672.x.

INVESTIGATION OF IMMATURE WHEAT GRAIN CHEMICAL COMPOSITION

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Abstract
The present study provides research in content of protein, starch, sugars and concentration of B group vitamins (thiamine, riboflavin, pyridoxine and niacin) in immature wheat (*Triticum aestivum* L.) compared to mature wheat kernels.
The content of protein, starch was determined in kernels using Infratec1241 Grain Analyzer (Sweden), content of sugars was analysed by high- efficiency liquid chromatography HPLC (Shimadzu, Japan). The concentrations of vitamins were determined by high - efficiency liquid chromatography for vitamins B_1, B_2, B_3, B_6. Obtained results suggested that the immature wheat kernels obtained in milk stage showed higher contents of some compounds such as sugars and B group vitamins. The amount of all sugars presented in immature grains is higher and decreased uniformly during maturation. Therefore, immature grains are better sources of the B group vitamin that the mature grains, and therefore more nutritionally efficacious.
Key words: immature wheat grain, protein, starch, sugars, B group vitamins.

Introduction

The nutritional value of food is determined by the content of mainly following substances: fats, carbohydrates, proteins. For a long time it was considered, if human food includes all these nutrients, it fully meets the needs of biological organism. However, the practice does not always confirm the correctness of entrenched ideas about the biological value of food. Practical experience shows that there are diseases, directly related to food. Cereals are basic components of the human diet. Consumption of whole unrefined cereal products is known to contribute significantly to health and chronic disease prevention. Whole cereal grains contain nutritionally significant quantities of dietary fibre, as well as minerals and vitamins that are important for health. Therefore, the interest in cereals as a source of bioactive and functional ingredients has increased (Awika, 2011).

Wheat (*Triticum aestivum* L.) is one of the primary grains consumed by humans. The chemical composition and physical properties of wheat kernels changes during maturing process and depends on the degree of maturity. This is a complex process controlled by several factors. In recent studies it has been proven that wheat during maturation contains many valuable compounds which disappear or lose their unique properties in the mature kernels.

Therefore, the aims of this work are identified and theoretically justify the features of the chemical composition in immature wheat grain. Wheat grains harvested before maturity are a rich source of biologically active substances. Compared to wheat complete ripeness, immature wheat grains contain less starch, more vitamins, fibre and soluble sugars (Yang *et al*., 2012; Iametti *et al*., 2006). Kalnina *et al*. (2015) has informed on contents of vitamins B_1 (thiamine) and B_2 (riboflavin) in mature wheat 'Zentos' (*Triticum aestivum* L.). As reported by other scientists (Yang *et al*., 2012; Merendino *et al*., 2006), the immature grains and immature wholemeal showed higher contents of some important functional compounds such as vitamins C, niacin, dietary fibre, reducing sugars. Wheat kernels harvested during the milk stage suggested its use as an innovative material with interesting functional characteristics to prepare functional foods. Based on the above considerations our research focused in the study of various nutrients including protein, starch, sugars, and vitamins B in immature winter wheat kernels cultivars 'Zentos' compared with mature kernels.

Materials and Methods

Winter wheat (*Triticum aestivum* L.) bread cultivar 'Zentos' from the experimental farm 'Peterlauki' of Latvia University of Agriculture was harvested in immature conditions (milk stage) and mature conditions in 2015. Immature grains sample with initial moisture content 64% was dried in a microwave- vacuum dryer at 45 °C temperatures till moisture content 11.4%.

The content of protein and starch in grains was determined using Infratec1241 Grain Analyzer (Sweden). Content of sugars was analyzed by high-efficiency liquid chromatography. For the analysis of content of individual sugars 5 g of milled samples were extracted with 20 mL deionised water and stirred for 1 h. After one hour the extract solution was filtered through the filter paper. The obtained extract was filtered through a high-performance liquid chromatography (HPLC) syringe filter with pore size of 0.45 μm. The content of individual sugars in the grain sample extract filtrate was determined with high-performance liquid chromatography LC 20 Prominence (Shimadzu, Japan). Determination

parameters were: detector – refractive index RID-10A; column – Alltech NH2, 4.6 mm × 250.0 mm, 5 µm; temperature 25 °C; isocratic elution regime, mobile phase –A – acetonitrile, B – deionised water (A70:B30); capacity of the injection sample – 10 µL; total time of the analysis – up to 15 min; rate of the flow – 1.0 mL min^{-1}. Acquired data were processed using Shimadzu LabSolutions software (LCsolution Version 1.21 SP1).

The analysis of the content of vitamin group B was carried out at the Quality Department JSC 'Grindeks'. In the present study, the concentration of vitamins was determined by high- efficiency liquid chromatography for vitamins B_1, B_2, B_3 and B_6.

HPLC conditions

For simultaneous detection of vitamins, the liquid chromatography method described by Aslam *et al*., (2008), with a few changes was used. The mobile phase used trifluoroacetic acid water solution.

High-performance liquid chromatography (HPLC) analysis was performed with the following parameters: Column – Water Atlantis T3 4.6 × 150 mm, 3.0 µm; Column temperature at 30 °C; Sample temperature 10 °C; Mobile phase – A: 0.05% trifluoroacetic acid water solution (0.5 mL L^{-1}); B: acetonitrile. Flow rate 1.0 mL min^{-1}; Injection volume 10 µL; Injector wash solvent 10% solution of methanol in water for chromatography; Detection – 190 nm – 400 nm (use photodiode array detector) – for identification; 248 and 290 nm for assay; Integration-pyridoxine hydrochloride 248 nm, thiamine hydrochloride 290 nm (Table 1).

Table 1

Gradient cycle

Time, min	A, %*	B, %**	Curve
0.0	100	0	-
4.0	97	3	linear
6.0	90	10	linear
20.0	90	10	linear
30.0	60	40	linear
32.0	60	40	linear
33.0	100	0	linear
40.0	100	0	linear

*A - Mobile phase - A: 0.05% trifluoroacetic acid water solution (0.5 mL L^{-1}).
** - B: acetonitrile.

Statistical Analysis

Statistical analysis was performed with SPSS 23.0 package for Windows 10. Mean arithmetic value and standard deviation were calculated. ANOVA analysis was applied in order to see if there are significant differences between the mature and immature wheat kernels ($p<0.05$).

Results and Discussion

Protein content is one of the most important standards for measuring wheat quality. Proteins are synthesized and accumulated in developing grain at different times and different rates. Immature wheat grains contain 9.8% protein but mature wheat grains – 13.4%. The difference of protein content between immature and mature grains was 3.6%. Similar results have been obtained from other reports (Yang *et al*., 2012; Iametti *et al*., 2006). The protein content of whole wheat increases only very slightly during maturation. The pattern of the changes in total protein during the development of the endosperm resembles the pattern of relative changes in starch (Abou-Guendia & D'Appolonia, 1972.)

Starch content, in fact, increased from 63.7% to 67.6% because during ripening the monosaccharide, disaccharides are converted into storage polysaccharides, in starch. The group of sugars studied in immature and mature grains were the mono- and disaccharides which were extracted with 20 mL deionised water and included glucose, fructose, sucrose and maltose. The changes in individual free sugar content in immature and mature grains are shown in Figure 1. The amount of all sugars presented in immature grains is higher and decreased uniformly during maturation. The concentration of fructose decreased from 1.14 g 100 g^{-1} to 0.27 g 100 g^{-1}. Similar situation we have observed regarding glucose and sucrose. Maltose declined sharply from 2.16 g 100 g^{-1} to 0.59 g 100 g^{-1} in mature grains. The changes in sugars content can be explained that they are involved during maturity in starch and others non-starch oligosaccharides synthesis. Higher sugar content in immature wheat suggested favourable taste with sweetness. The results of present work agree with results of M. Abou-Guendia & B.L. D'Appolonia (1973) and suggest that the sugars in the kernel, which arise by both translocations from plant and by photosynthesis within kernel, are utilized in the rapid process of starch synthesis. The sugar content present in the kernel at any particular stage of maturity theoretically cannot account for the total amount of starch synthesized at the following stage, indicating that translocation and photosynthesis of sugars both are essential for starch accumulation in the kernel.

Vitamins – a group of low-molecular organic compounds are present in small amounts in the diet. Vitamins are essential nutrients that are required in many areas of biochemical metabolism, including deoxyribonucleic acid (DNA) synthesis, energy production and biosynthetic pathways (Ball, 2005).

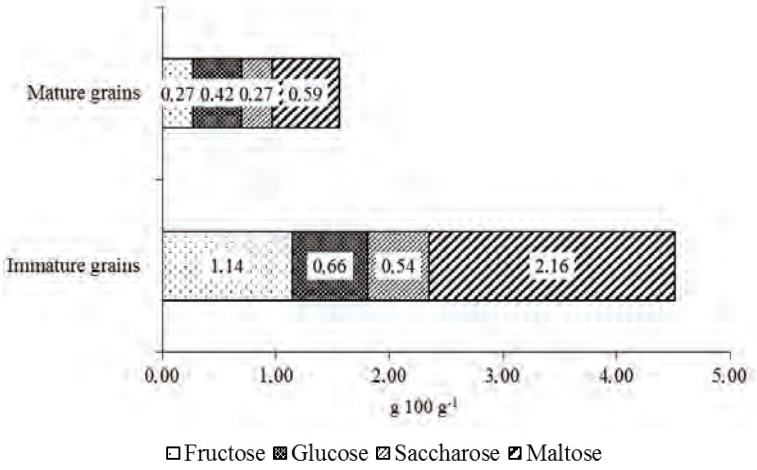

Figure 1. The sugar content in immature and mature wheat grains.

There are several B group vitamins in wheat such as vitamins B_1 (thiamine), B_2 (riboflavin), B_3 (niacin) and B_6 (pyridoxine). In cereal grains, the thiamine is unevenly distributed, being relatively low in the starch endosperm and high in germ. Cereal grains also contain relatively low concentration of flavins, but they are important sources in those parts of the world where cereals constitute the staple diet. In mature cereal grains most of the niacin is concentrated in the aleurone and germ layers. The whole-grain cereals are important source of pyridoxine, where over 90% of the vitamin B_6 is found in the bran and germ. They all, as well proteins and fats (riboflavin, pyridoxine) (Ball, 2005), play an important role in metabolism of carbohydrate (thiamine). B vitamins' concentrations indicate an important variability in wheat cultivars (Batifoulier *et al*., 2006). The contents of B group vitamins into the immature and mature wheat samples were measured and shown in Figure 2.

Niacin (4.45 ± 0.66 mg 100 g^{-1} in immature grains and 3.62 ± 0.15 mg 100 g^{-1} in mature grains) was an abundant component in B vitamins. The level of niacin decreased 20% during grain maturation. The same situation can be observed with content of riboflavin (0.34 ± 0.14) mg 100 g^{-1}) in immature wheat compared to mature (0.08 ± 0.01 mg 100 g^{-1}) wheat samples.

No significant change in thiamine and pyridoxine content was observed during maturation. Similar results were obtained by scientists while evaluating immature grains in two rice cultivars during maturation (Ji *et al*., 2013). The highest content of vitamin B_2, B_3, and B_6 was found in the mature rice grains. When the variability of B vitamin concentration in mature wheat grain cultivated in France was analysed, the concentration of thiamine, riboflavin, and pyridoxine represented cultivars with higher B vitamins concentration as cultivar 'Zentos' (Batifoulier *et al*.,

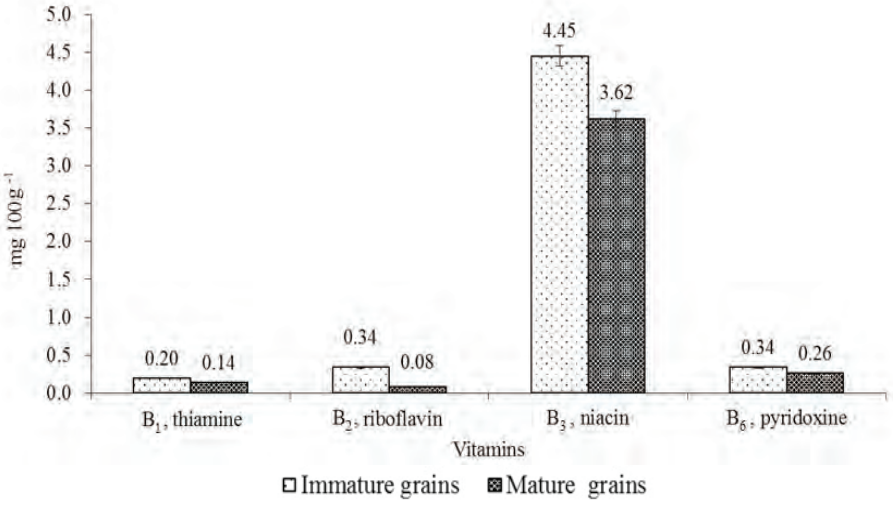

Figure 2. Vitamins in mature and immature wheat, mg 100 g^{-1}.

2006). It means that several factors promote vitamin variability such cultivar, year, growing location and conditions.

The results' interpretation of statistical programs SPSS by a single factor ANOVA showed significant differences between the value of B group vitamins in mature and immature wheat kernels ($p<0.05$).

The values are the means ±standard deviation of four independent experiments. All the differences between mature and immature wheat kernels were significantly different (T-test, $p<0.05$).

The results showed reduction of all group B vitamins during maturation.

Conclusion

In the present research concentrations of B group vitamins (thiamine, riboflavin, pyridoxine and niacin) in immature wheat compared to mature wheat were established. Obtained results suggested that the immature wheat kernels obtained in milk stage showed higher contents of some compounds such as sugars and vitamins B. The amount of investigated sugars presented in immature grains is higher compared with mature grains. Immature grains are better sources of the B group vitamins than the mature grains, and therefore more nutritionally efficacious.

Our results indicate that wheat kernels harvested at milk phase could be representing a valuable ingredient for production of functional foods.

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References

1. Abou-Guendia, M., & D'Appolonia, B.L. (1972). Changes in Carbohydrate Components during Wheat Maturation. I. Ghanges in Sugars, pentosans, and Starch. *Cereal Chemistry*, 49, 664-676.
2. Abou-Guendia, M., & D'Appolonia, B.L. (1973). Changes in Carbohydrate Components during Wheat Maturation. II. Ghanges in Free Sugars. *Cereal Chemistry*, 50, 723-734.
3. Aslam, J., Mohajir, M.S., Khan, S.A., & Khan, A.Q. (2008). HPLC analysis of water-soluble vitamins (B1, B2, B3, B5, B6) in invitro and ex vitro germinated chickpea (*Cicer arietinum L.*). *African Journal of Biotechnology* 43, 2310-2314.
4. Awika, J.M. (2011). Health promoting effects of cereals and cereal products. Tokusoglu, O., & Hall, Cl. III, Fruit and Cereals Bio actives. Sources, Chemistry, and Applications, (pp. 9-17). New York. Taylor&Francis Group.
5. Ball, G.F.M. (2005). Vitamins in foods: analysis, bioavailability, and stability (pp.149-205). New York. Taylor&Francis Group.
6. Batifoulier, F., Verny, M.A., Chanliaud, E., Remesy, C., & Demigne, C. (2006). Variability of B vitamin concentrations in wheat grain, milling fractions and bread products. *European Journal of Agronomy*, 25, 163-169.
7. Iametti, S., Bonomi, F., Paganini, M.A., Zardi, M., Cecchini, Cr., & D'Egidio, Gr. (2006). Properties of the protein and carbohydrate fractions in immature wheat kernels. *Journal of agricultural and food chemistry,* 54, 10239-10244.
8. Ji, Ch.-M., Shin, J.A., Cho, J.-W., & Lee, K.T. (2013). Nutritional evaluation of immature grains in two Korean rice cultivars during maturation. *Food Science and Biotechnology*, 22(4), 903-908.
9. Kalnina, S., Rakcejeva, T., Gramatina, I., Kunkulberga, D. (2014). Investigation of Total Dietary Fiber, Vitamin B1 and B2 Content in Whole-grain Pasta. *Baltic Conference on Food Science and Technology*, pp. 133-137.
10. Merendino, N., D'Aquino, M., Molinari, R., De Gara, L., D'Egidio, M.G., Paradiso, A., Cecchini, G., Corradini, C., & Tomassi, G. (2006). Chemical characterization and biological effects of immature durum wheat in rats. *Journal of Cerial Science*, Vol. 43, 129-136.
11. Yang, D., Shin, J.-A., Zhu, X.-M., Hong, S.T., Sung, Ch.-K., Cho, J.-W., Ku, J.-W., & Lee, K.T. (2012). Comparison of nutritional compounds in premature green and mature yellow whole wheat in Korea. *Cereal Chemistry*, 89(6), 284-289.

CHARACTERISTICS OF DRY NATURALLY FERMENTED KVASS OBTAINED BY SPRAY DRYING

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Abstract
Kvass is an aromatic soft drink which in a form of powder could be used in dairy or bakery products, or sugar confectionary to expand the diversity of flavours. Spray drying is one of the techniques used for producing powders; however, liquids with high sugar content become sticky during drying process and need additional drying aids to increase glass transition temperature and improve powder stability. The aim of this research was to evaluate the characteristics of dry naturally fermented kvass. Maltodextrin was used in 50, 40 and 25% quantity to kvass dry matter in order to aid the spray drying of naturally fermented non-pasteurised, non-filtered bread kvass. Spray drying of 8 l naturally fermented kvass returned approximately 500 g dry naturally fermented kvass powder with a light brown colour, a pronounced aroma of rye bread and moisture content of 7 ± 0.1%. Microstructure analysis of the spray dried naturally fermented kvass showed irregularly spherical shaped particles, having many shrinkages, breakages and dents on the surface in general. Total viable microorganism count in dry naturally fermented kvass powder was within the recommended levels, traces of lactic acid bacteria were found in all samples. The presence of *Bacillus amyloliquefaciens* was established in dry naturally fermented kvass powders, with possible contamination from spray dryer.
Key words: dry kvass, naturally fermented kvass, maltodextrin, spray drying, microbiological contamination, microstructure.

Introduction

Kvass is a soft drink produced by fermenting kvass mash with yeast, with alcohol content under 1.2% alc/vol and dry matter of 8 – 12%, mainly from sugars (Lidums *et al*., 2015). Kvass is an aromatic drink which in a form of powder could be used in dairy or bakery products, or sugar confectionary to expand the diversity of flavours.

Similar to juice powders which have many benefits and economic potentials over their liquid counterparts such as reduced volume or weight, reduced packaging, easier handling and transportation, and much longer shelf life, dry naturally fermented kvass could be a valuable contribution compared to liquid kvass. Besides, juice powder physical state provides a stable, natural, and easily dosable ingredient, which generally finds usage in many foods and pharmaceutical products such as flavouring and colouring agents (Shrestha *et al*., 2007; Goula & Adamopoulos, 2010).

Drying is widely used to extend the shelf life of food products; the decrease in moisture content causes the reduction of the mass, volume, enzymatic and microbial activity (Kaya *et al*., 2007). Spray drying is one of the techniques used for producing powders from liquid solutions and suspensions. The spray-drying technique is 30–50 times cheaper than freeze drying (Gharsallaoui *et al*., 2007). Spray drying is the transformation of feed from a liquid or slurry form to a dry powder. The feed is atomized into a chamber where the resulting spray mixes with hot gas, which evaporates the liquid component of the spray leaving dried particles (Goula & Adamopoulos, 2010). The products to be spray dried can be categorized into two major groups: non-sticky and sticky products. Sticky products are generally difficult to spray dry. During the drying process they may remain as syrup or stick on the dryer wall, or form unwanted agglomerates in the dryer chamber and conveying system (Bhandari & Howes, 2005). The problem of powder stickiness is mainly due to the low glass transition temperature of the low molecular weight sugars present in such products as sucrose, glucose and fructose (Roos *et al*., 1996; Oberoi & Sogi, 2015).

For example, more than 90% of solids in fruit juices are low molecular weight sugars and organic acids which attribute to the sticky behaviour. Sugar content in kvass is lower than in fruit juices; however, it is still too high to dry them under normal conditions (Goula & Adamopoulos, 2010; Oberoi & Sogi, 2015). To overcome the stickiness problem, various methods that are able to produce free-flowing fruit juice powder have been suggested: using an adjunct or a carrier agent (maltodextrin, gum, starch or gelatin) as an additive in the feed material during spray drying (Saénz *et al*., 2009). The addition of high molecular weight additives to the product before atomizing is a widely used alternative that increases glass transition temperature and improves product stability (Tonon *et al*., 2011). Maltodextrins are generally produced from starch by partial hydrolysis, consisting of β-D-glucose units linked mainly by glycosidic bonds (1 → 4) conneced in chains of variable length (Hobbs, 2009; Nurhadi *et al*., 2016). Maltodextrins are classified as a GRAS (generally recognised as safe) ingredient (Hobbs, 2009).

Microbiological criteria have been used internationally for many years as a means of assessing the safety and suitability of foods (CAC, 2013). Since

there are not microbiological criteria developed for dry naturally fermented kvass, it could be compared to juice powder. As juice powder has a low water activity that does not support growth of mesophilic aerobic microorganisms, expected levels of these microorganisms would be low in juice powder; they serve as an indicator of general contamination. Centre for Food Safety (2014) recommends maximum standard plate count at 10^4 CFU g^{-1} for satisfactory and 10^4 - $<10^6$ CFU g^{-1} for borderline quality of powdered foods (e.g., soup and drink powder, milk powder), also suggesting *Enterobacteriaceae* count below 10^2 CFU g^{-1} (10^2 - $<10^4$ for borderline quality). The aim of this research was to evaluate the characteristics of dry naturally fermented kvass.

Materials and Methods

Experimental design

Experiments were carried out at Institute of Process Engineering and Equipment, Faculty of Food Sciences, The University of Warmia and Mazury in Olsztyn, Poland during September to November 2015 and at the Department of Food Technology, Latvia University of Agriculture during December 2015. The object of the research was dry naturally fermented kvass. Ltd Liepkalni naturally fermented non-pasteurised, non-filtered bread kvass 'Liepzeme' was used to produce dry naturally fermented kvass at Institute of Process Engineering and Equipment, The University of Warmia and Mazury in Olsztyn, Poland. Dry naturally fermented kvass particle microstructure was analysed at Institute of Process Engineering and Equipment, while microbiological analyses were performed at the Department of Food Technology, Latvia University of Agriculture.

Spray drying conditions of dry naturally fermented kvass

Experiments were performed using a pilot plant spray dryer at a drying rate of 12.3 kg of water h^{-1}. Feeding solution of 1 litre was prepared by dissolving ~70 g maltodextrin in 100 ml kvass, and then it was mixed with the rest of kvass to dry matter content 14%. Kvass was atomized from a rotary atomizer (disk speed 11 000 rpm) into a vertical co-current drying chamber 1.8 m in diameter and with a height of 2.3 m. The inlet and outlet air temperatures were in 170 °C and 103 °C, respectively. Temperature inside the drying chamber was 75 – 80 °C, but the temperature of the feed mixture was 20 °C. The feed flow rate was fixed at 15 kg h^{-1}. Product flow rate and temperature inside the dryer were controlled throughout procedure, as temperature in the most important parameter in spray drying of kvass. Dried kvass samples were collected from the cyclone separator and after cooling to room temperature packaged in vacuum in laminated PE/PA pouches and stored in dark until further analysis.

Three dry naturally fermented kvass samples were investigated with drying aid (added as quantity to kvass dry matter):

- ✓ sample A (kvass 50% and maltodextrin 50%);
- ✓ sample B (kvass 60% and maltodextrin 40%);
- ✓ sample C (kvass 75% and maltodextrin 25%).

Dry naturally fermented kvass particle microstructure

Dry naturally fermented kvass particles were analysed by scanning electron microscope (XL-30, Philips, Amsterdam, The Netherlands). Dry naturally fermented kvass sample was attached to a double sided adhesive tape on SEM stubs, coated with 3 – 5 mA palladium under vacuum and examined with a scanning electron microscope at 3000 kV and magnification of 200× and 400×.

Microbiological analyses

Preparation of test samples, initial suspension and decimal dilutions for microbiological examination was carried out according to ISO 6887-1:1999. 90 ml 0.85% sterile saline was added to 10 g sample of dry naturally fermented kvass in a stomacher bag; then, the sample was homogenized with a stomacher BagMixer400 (Interscience, USA) for 10 seconds. Serial dilutions in 0.85% sterile saline were pour-plated in triplicate for determination of aerobic and facultative anaerobic, mesophilic bacteria (hereafter referred to as TPC – total plate count) on Plate Count agar (Ref. 01-161, Scharlau, incubation at 30 °C for 72 h, LVS EN ISO 4833-1:2014), for lactic acid bacteria on MRS agar (Ref. Ref. 01-135, Scharlau, incubation at 37 °C for 48 h, LVS ISO 15214:1998) and for *Enterobacteriaceae* on Violet Red Bile agar with Glucose (Ref. 01-295, Scharlau, incubation at 37 °C for 24 h, ISO 21528-2:2004 A).

After incubation, the colonies were counted using automated colony counter aCOLyte (Topac Inc., USA) and reported as colony forming units (CFU).

Identification of microorganisms in dry naturally fermented kvass was carried out by cultivating selected colonies on Plate Count agar using streak plate method. Gram staining was performed followed by catalase test. Identification of bacterial species was completed by the API (analytical profile index) biochemical test system using API 50 CHB kit (bioMérieux, France) which is intended for the identification of *Bacillus* and related genera.

Data analysis

The obtained data processing was performed with the Microsoft Excel 13 for Windows; mean values and standard deviations were calculated.

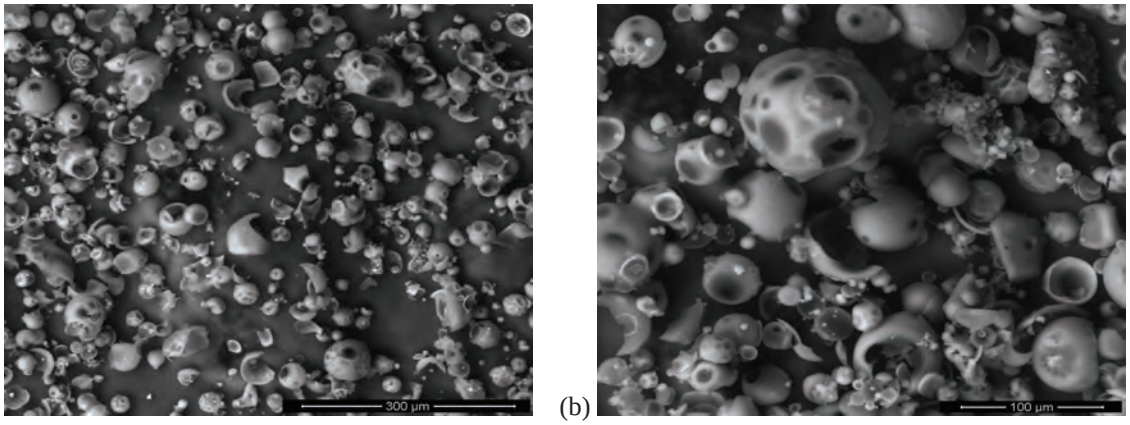

Figure 1. Micrographs of 50% dry naturally fermented kvass particles at magnifications of (a) 200×, (b) 400×. HFV: 746 µm (200×) and 373 µm (400×); det: DualBSD; temperature: 24.9 °C.

Results and Discussion

Spray drying process of dry naturally fermented kvass

Preliminary spray drying was carried out using 100% kvass from 30 l kegs. The resulting product was caramelised hard brown kvass crystals with a very pleasant and pronounced kvass aroma. Therefore, similar to juice spray drying, maltodextrin was used as a drying aid in order to obtain dry naturally fermented kvass. The first experiment was completed with 50% maltodextrin addition (quantity to kvass dry matter) according to Islam *et al*. (2016), where higher concentration of orange juice: maltodextrin (50:50) was investigated compared to Shrestha *et al*. (2007) and Goula and Adamopoulos (2010). Maltodextrin proportion was later reduced to 40% and 25%, in order to obtain dry naturally fermented kvass with less maltodextrin addition. Lower amount of maltodextrin (below 25%) gave a sticky syrup that started crystallising.

Spray drying of 8 L naturally fermented kvass returned approximately 500 g dry naturally fermented kvass. The resulting product was dry naturally fermented kvass with pronounced aroma of rye bread and light brown colour. Moisture content of dry naturally fermented kvass was 7 ± 0.1%.

Optimal technological parameters during spray drying, as well as the best drying method are still being researched, in order to reduce the added drying aid (or drying aid mixture) to minimum.

Dry naturally fermented kvass particle microstructure

Microstructure analysis showed that spray-dried naturally fermented kvass had irregularly spherical shaped particles, having many shrinkages, breakages and dents on the surface in general (Fig. 1). The results agree with Fazaeli *et al*. (2012), in which orange juice powder produced with 50% maltodextrin addition had dented surfaces with wrinkles and deformation. Powder with higher amounts of maltodextrin (70%) had the smoothest surface with smaller spherical shapes and no shrinkage. The particle size distribution showed that spray-dried naturally fermented kvass particles ranged up to 112.205 µm.

Microflora of dry naturally fermented kvass

TPC levels in dry naturally fermented kvass were within the recommended levels by Centre for Food Safety (2014), EU Regulation No 2073/2005 does not define TPC for juice powders and similar products. Significant differences were not found in TPC levels of dry naturally fermented kvass samples; total viable microorganism count in 50% dry naturally fermented kvass (sample A) was 7.58×10^4 CFU g^{-1}, in 60% dry naturally fermented kvass (sample B) 7.62×10^4 CFU g^{-1} and in 75% dry naturally fermented kvass (sample C) – 7.8×10^4 CFU g^{-1}. *Enterobacteriaceae* count in all samples was $<10^2$ CFU g^{-1}. Traces of lactic acid bacteria (<20 CFU g^{-1}) were found in all samples.

Bacteria found in all dry naturally fermented kvass samples with similar morphological characteristics were investigated further. Gram staining proved them to be gram positive and catalase positive sporeforming bacteria of *Bacillus* spp. API biochemical identification established the presence of *Bacillus amyloliquefaciens*, with possible contamination of dry naturally fermented kvass from spray dryer (or handling equipment).

B. amyloliquefaciens and its closely related species are particularly known to be involved in ropy bread spoilage that is characterized by an unpleasant fruity odour followed by enzymatic degradation yielding soft, sticky and stringy bread crumb making the bread inedible (Valerio *et al*., 2012).

The possibility of using dry naturally fermented kvass for flavour enrichment of different products depends on the product treatment process after dry naturally fermented kvass addition. Enterobacteria,

which were found in dry naturally fermented kvass, are non-spore-forming bacteria, therefore, if the products with added dry naturally fermented kvass are subjected to thermal treatment, vegetative cells of unfavourable bacteria will be destroyed and pose no harm to consumer health.

Conclusions

1. Spray drying of 8 L naturally fermented kvass returned approximately 500 g dry naturally fermented kvass. The resulting product was light brown dry naturally fermented kvass with pronounced aroma of rye bread and moisture content of 7 ± 0.1%.
2. Microstructure analysis of the spray dried naturally fermented kvass showed irregularly spherical shaped particles, having many shrinkages, breakages and dents on the surface in general.
3. Microbiological contamination of dry naturally fermented kvass samples was within the recommended levels for powdered foods (TPC $<10^5$ CFU g^{-1}). *Enterobacteriaceae* count in all samples was $<10^2$ CFU g^{-1}. Traces of lactic acid bacteria (<20 CFU g^{-1}) were found in all samples. Spores of *B. amyloliquefaciens* were found in all dry naturally fermented kvass samples; possible source of these bacteria was spray dryer.
4. Research should be continued to evaluate the obtained dry naturally fermented kvass for flavour enrichment of different products.

References

1. Bhandari, B., & Howes, T. (2005). Relating the stickiness property of foods undergoing drying and dried products to their surface energetics. *Drying Technology*, 23, pp. 781-797.
2. CAC (Codex Alimentarius Commission). (2013). Principles and guidelines for the establishment and application of microbiological criteria related to foods (CAC/GL 21-1997). Retrieved March 10, 2016, from http://www.codexalimentarius.org/standards/list-of-standards/.
3. Centre for Food Safety, Food and Environmental Hygiene Department. (2014). Microbiological Guidelines for Food (For ready-to-eat food in general and specific food items). Retrieved March 11, 2016, from http://www.cfs.gov.hk/english/food_leg/files/food_leg_Microbiological_Guidelines_for_Food_e.pdf.
4. Fazaeli, M., Emam-Djomeh, Z., Kalbasi Ashtari., A.K., & Omid, M. (2012). Effect of spray drying conditions and feed composition on the physical properties of black mulberry juice powder. *Food and Bioproducts Processing*, 90 (4), pp. 667-675.
5. Gharsallaoui, A., Roudaut, G., Chambin, O., Voilley, A., & Saurel, R. (2007). Applications of spray-drying in microencapsulation of food ingredients: an overview. *Food Research International*, 40 (9), pp. 1107-1121.
6. Goula, A.M., & Adamopoulos, G.K. (2010). A new technique for spray drying orange juice concentrate. *Innovative Food Science & Emerging Technologies*, 11 (2), pp. 342-351.
7. Hobbs, L. (2009). Sweeteners from starch. In J.B. Miller & R. Whistler (Eds.), *Starch. Chemistry and Technology* (pp. 797-829), Amsterdam: Academic Press.
8. Islam, M.Z., Kitamura, Y., Yamano, Y., & Kitamura, M. (2016). Effect of vacuum spray drying on the physicochemical properties, water sorption and glass transition phenomenon of orange juice powder. *Journal of Food Engineering*, 169, pp. 131-140.
9. Kaya, A., Aydin, O., & Dincer, I. (2007). Numerical modeling of forced-convection drying of cylindrical moist objects. *Numerical Heat Transfer, Part A: Applications*, 51, pp. 843-854.
10. Lidums, I., Karklina, D., Sabovics, M., & Kirse, A. (2015). Evaluation Of Aroma Volatiles In Naturally Fermented Kvass And Kvass Extract. Research for Rural Development 2014: Annual 20th International Scientific Conference Proceedings, Latvia University of Agriculture. Jelgava : LLU, Vol.1, pp. 143.-149.
11. Microbiology of food and animal feeding stuffs - Horizontal method for the enumeration of mesophilic lactic acid bacteria - Colony-count technique at 30° C: LVS ISO 15214:1998 (1998). Retrieved June 25, 2016, from https://www.lvs.lv/en/products/996.
12. Microbiology of food and animal feeding stuffs - Horizontal methods for the detection and enumeration of *Enterobacteriaceae*: LVS ISO 21528-2:2004 A (2004). Retrieved June 25, 2016, from https://www.lvs.lv/lv/products/15947.
13. Microbiology of food and animal feeding stuffs - Preparation of test samples, initial suspension and decimal dilutions for microbiological examination: ISO 6887-1:1999 (1999). Retrieved June 25, 2016, from https://www.lvs.lv/en/products/41944.
14. Microbiology of the food chain - Horizontal method for the enumeration of microorganisms: ISO 4833-1:2014 (2014). Retrieved June 25, 2016, from https://www.lvs.lv/lv/products/34560.

15. Nurhadi, B., Roos, Y.H., & Maidannyk, V. (2016). Physical properties of maltodextrin DE 10: Water sorption, water plasticization and enthalpy relaxation. *Journal of Food Engineering*, 174, pp. 68-74.
16. Oberoi, D.P.S., & Sogi, D.S. (2015). Effect of drying methods and maltodextrin concentration on pigment content of watermelon juice powder. *Journal of Food Engineering*, 165, pp. 172-178.
17. Roos, Y.H., Karel, M., & Kokini, J.L. (1996). Glass transitions in low moisture and frozen foods: effect on shelf life and quality. *Food Technology*, pp. 95-108.
18. Saénz, S.T., Chávez, J., & Robert, P. (2009). Microencapsulation by spray drying of bioactive compounds from cactus pear (*Opuntia ficus-indica*). *Food Chemistry*, 114, pp. 616-622.
19. Shrestha, A.K., Ua-arak, T., Adhikari, B.R., Howes, T., & Bhandari, B.R. (2007). Glass transition behavior of spray dried orange juice powder measured by differential scanning calorimetry (DSC) and thermal mechanical compression test (TMCT). *International Journal of Food Properties*, 10, pp. 661-673.
20. Tonon, R.V., Freitas, S.S., & Hubinger, M.D. (2011). Spray drying of acai (*Euterpe oleraceae mart*.) juice: effect of inlet air temperature and type of carrier agent. *Journal of Food Processing and Preservation*., 35 (5), pp. 691-700.
21. Valerio, F., De Bellis, P., Di Biase, M., Lonigro, S.L., Giussani, B., Visconti, A., Lavermicocca, P., & Sisto, A. (2012). Diversity of spore-forming bacteria and identification of *Bacillus amyloliquefaciens* as a species frequently associated with ropy spoilage of bread. *International Journal of Food Microbiology*, 156, pp. 278-285.

FORTIFIED CHOCOLATE SNACKS WITH INCREASED LEVEL OF IRON

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Abstract
Iron deficiency is a common problem especially among children, women of reproductive age and sportsmen. Addition of highly bioavailable iron to foods could be one possibility to enrich daily diet and increase iron absorption.
At present moment, there is a limited number of fortified products with iron in the market. Fortification of common food products is an effective strategy to prevent or overcome iron deficiency. The results show a significant increase of iron in products supplemented with bovine alimentary albumin. Comparing fortified products with non-fortified control samples of chocolate snacks the iron content increased from (1.17 – 2.61) to (10.15 − 11.53) mg 100 g^{-1} in products supplemented with bovine alimentary albumin. By developing a successful recipe of fortified food products, animal origin heme iron could be applicable component and satisfy sensory acceptability from consumers.
The aim of this work was to create an alternative sweet product as healthy snack with incorporated highly bioavailable heme iron which may be an addition to daily diet with nutritional properties and accepted by consumers.
Key words: fortified foods, iron deficiency, heme iron.

Introduction

Iron deficiency is the most common mineral deficiency affecting an estimated quarter of world's human population (WHO, 2015). It is one of the leading risk factors for disability and death worldwide (Zimmermann & Hurrell, 2007). Iron deficiency is especially widespread among children, women of reproductive age and sportsmen (Srdjan, Mukesh, & Agarwal, 2007). Iron deficiency or anaemia as its severe form develops after prolonged deficit of iron. If not for other reasons such as genetic illnesses or injuries, it is mainly due to insufficient iron absorption (Hurrell & Egli, 2010). There are two forms of dietary iron in the human diet: non-heme iron and heme iron. The first one is broadly present mostly in plants, whereas heme iron is found in foods derived from animal tissues (Sharp & Srai, 2007). Notwithstanding that there is an abundant amount of non-heme iron obtained from plant origin food products in our diet, only 2% – 15% of that is absorbed in human organism. It is due to phytates and polyphenols present in plants, which works as a strong inhibitor of non-heme iron (Hurrell & Egli, 2010). Poor absorbance is the main reason of iron deficiency. Whereas heme iron has high bioavailability of absorption (15%−35% absorbed) and is not affected of any other inhibitors except calcium which inhibits both types of iron (Abbaspour, Hurrell, & Kelishadi, 2014). Iron bioavailability can be enhanced when ingested in the presence of foods with high levels of ascorbic acid, fruit acids, fructose and muscle tissues (Pizarro *et al*., 2016; Christides & Sharp, 2013; Bæch *et al*., 2003). Based on studies, it is determined that heme iron absorption increases when ingested as haemoglobin. Several studies compare iron bioavailability of different food sources and describe effects (Eisenstadt *et al*., 2013). The major issue is to obtain a positive long term health effect from available food products. Fortified foods with high level of bioavailable iron may be used as one of tools (Alemán *et al*., 2016; Rebellato *et al.*, 2015).

Candies are popular and preferably consumed food items all over the world. There are many types of candies and each market differs with assortment depending on consumers' preferences, country's cultural and traditional factors, season of the year, etc. In traditional sweet manufacture, locally available products are used as classic ingredients. Fruits are considered healthy, and besides their pleasant flavour and taste there are numerous beneficial components they provide and enrich human diet. They are sources of essential vitamins, minerals, biologically active compounds and dietary fiber. What is more, heme iron absorption is not affected by fruit compounds and therefore may be consumed in the same meal. In many countries locally grown fresh fruits are available short period of the year due to their characteristic seasonality; therefore, there are adapted different methods and technologies for fruit preservation. As one of the common methods used is fruit dehydration. If drying method applied is delicate, fruits may preserve their vitamins, minerals and other bioactive compounds with smaller scale of losses (Sagar & Suresh, 2010).

Chocolate confectionery forms a great part of the sweet's market and incorporates diverse products. Continuous development of chocolate containing products is the result of manufacturers' creativity and market demand. In general, certain food products especially confectioneries have a negative reputation for their high calorific value what is the main reason for obesity and diverse health issues. Concerning this fact, market should provide more products with additional nutritional value which besides the good taste ensure functional properties.

Confectionery based food supplements are highly acceptable products providing good taste and necessary

compounds. Such products are easy to incorporate in daily diet for consumers of all ages. Regarding fortified sweets with iron, there is a very poor selection in the market. In Latvia such products available are toffees supplemented with bovine alimentary albumin (heme iron). The product traditionally is named 'Hematogen' and produced by companies in Lithuania, Belarus and Russia. The amount of iron in these products is around 70% of Recommended Daily Intake in 100 g of product. Recommended Daily Amount of Iron is 14 mg (Directive 2008/100/EC, 2008).

The aim of this work was to create an alternative sweet product as healthy snack with incorporated highly bioavailable heme iron which may be an addition to daily diet with nutritional properties and accepted by consumers.

Materials and Methods

For fruit snack production dried fruits, berries, nuts and seeds were chosen with focus on the use of locally cultivated products. Fruit seeds and nuts in packs were purchased from the wholesale store Ltd. 'Gemoss' in Latvia. Dry marc of pumpkins and red beetroots were obtained in the frame of AgroBioRes project. Extra dark chocolate with cocoa solids 70% (cocoa mass, sugar, low fat cocoa powder, cocoa butter, emulsifier ammonium phosphatide, flavouring) was chosen from the manufacturer Ltd. 'Laima' (Latvia). Spray-dried bovine blood alimentary albumin as a source of iron for products' supplementation was imported from Lithuania. The list of ingredients used in each recipe of snacks is shown in Table 1. The amount of ingredients was chosen to make suitable texture for shaping candies, as well as satisfy sensorial criteria.

All ingredients except chocolate and bovine alimentary albumin were prepared by grinding, crushing and cutting. Then, ingredients for each product shown in Table 1 were mixed together till uniform mass and from ready mixture by hands made the shape of small balls with weight of 7 ± 0.2 g each. The chocolate was melted in water bath at +43 ± 2°C. For bath of chocolate intended for use in

Table 1

Ingredients used in each recipe of snacks

Code of product	Ingredients	% of total product
1	Prunes (dry) Sunflower seeds (dry) Chocolate Blackcurrants (dry)	31 29 23 17
1F	Prunes (dry) Sunflower seeds (dry) Chocolate Blackcurrants (dry) Bovine alimentary albumin (iron)	31 29 19 17 4
2	Cranberries (dry) Hazelnuts (dry) Chocolate Redcurrants (dry)	38 23 23 16
2F	Cranberries (dry) Hazelnuts (dry) Chocolate Redcurrants (dry) Bovine alimentary albumin (iron)	38 23 19 16 4
3	Japanese quinces (candied) Pumpkin seeds (dry) Chocolate Pumpkin (dry marc)	46 23 23 8
3F	Japanese quinces (candied) Pumpkin seeds (dry) Chocolate Pumpkin (dry marc) Bovine alimentary albumin (iron)	46 23 19 8 4
4	Apples (dry) Chocolate Beetroots (dry marc)	65 23 12
4F	Apples (dry) Chocolate Beetroots (dry marc) Bovine alimentary albumin (iron)	65 19 12 4

iron supplemented products, the melted chocolate was chilled to +38 ± 0.5 °C and then bovine alimentary albumin was added. The temperature is crucial as to avoid protein denaturation and losses of iron of bovine alimentary albumin. Chocolate mixture was thoroughly stirred to ensure even incorporation of added ingredient. Ready fruit snacks were covered with chocolate to form a glaze and left to cool in refrigerator at +8 ± 0.5 °C.

Samples without added bovine alimentary albumin (1, 2, 3, and 4) were used as control to compare the differences between products. For the same products with incorporated bovine alimentary albumin the code includes 'F' (1F, 2F, 3F, and 4F) as shown in Table 1.

Atom-absorption-spectrometer Perkin Elmer Analyst 800 was used for iron determination in fortified chocolate snacks and control samples. Procedure was done according to LVS EN 14082 method.

pH was measured with pH-meter Jenway 3520 pH Meter (Jenway, AK). pH-meter calibration was done with pH standard solutions 4.01 and 7.00. 5.00 g of each sample was mixed with 50 ml of distilled water and mixed on magnetic stirrer 20 min. After that, pH was measured for five repeats of each product.

Moisture of products was determined using a moisture analyser Precisa XM 120. 2 g of product was used for each measure under 105 °C temperature.

Water activity was determined by LabSwift-aw (Novasina). 6 g of sample was put in a cup and placed in apparatus, then, results were recorded. Temperature during measurement was 22.2 °C.

The colour parameters of ready fruit snacks were measured in CIE L*a*b* colour system by direct reading using Colour Tec − PMC. For getting results, the following colour parameters were evaluated: brightness (L*) ranging from 0 (black) to 100 (perfect white); green-red saturation index (a*); and blue-yellow saturation index (b*) (Papadakis *et al*., 2000). Before measuring, snacks were cut in half and measures were taken from the core of product and from surface, to determine the colour parameters of chocolate glaze. Colour was measured more than ten times at randomly selected spots for five samples of each variety.

Colour difference (ΔE*) between chocolate glaze without and with added bovine alimentary albumin was calculated using the mathematical equation 1:

$$\Delta E^* = \sqrt{(L^* - L_0^*) + (a^* - a_0^*) + (b^* - b_0^*)}, \quad (1)$$

where ΔE* − colour difference;
L*, a*, b* − values for chocolate with bovine alimentary albumin;
L_0^*, a_0^*, b_0^* − values for chocolate without bovine alimentary albumin.

All obtained data were analysed with correlation, ANOVA, using Microsoft Excel 2014. Data Analysis, confidence level was 95% ($\alpha = 0.05$).

Results and Discussion

Iron content in products is shown in Figure 1.

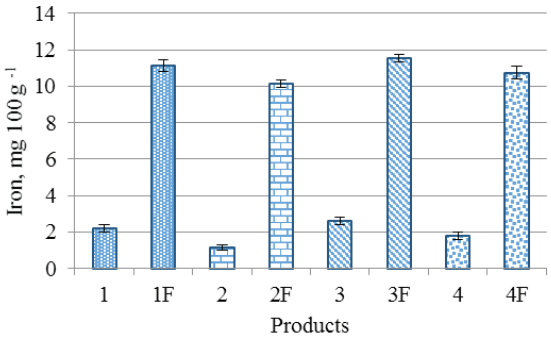

Figure 1. Iron content in products.

Comparing samples without added bovine alimentary albumin, there is no significant difference ($p>0.05$) between samples − the product 3 contains the highest amount of iron 2.6 ± 0.2 mg 100 g^{-1}. After that follows samples 1, 4 and 2 with 2.2 ± 0.2, 1.8 ± 0.2 and 1.2 ± 0.2 mg 100 g^{-1} respectively that could be explained with ingredients in products, as pumpkin and sunflower seeds contain higher amount of iron comparing to other products' ingredients used. Products with added bovine alimentary albumin follow the same order, as control samples. Addition of bovine alimentary albumin significantly ($p<0.05$) increases the content of iron in product reaching 11.6 ± 0.2 (sample 3), 11.1 ± 0.3 (sample 1), 10.8 ± 0.3 (sample 4) and 10.2 ± 0.2 (sample 2) mg 100 g^{-1} respectively was observed.

Figure 2 shows pH level of fortified chocolate snacks and control samples.

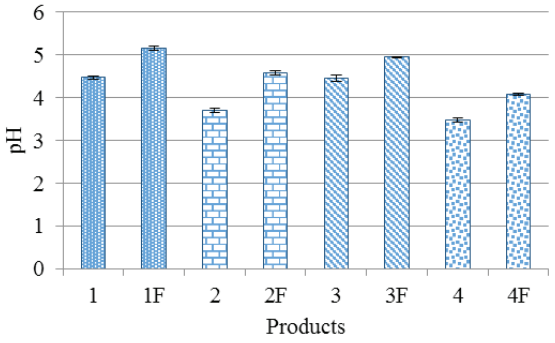

Figure 2. pH of products.

The most acidic product is of the 4th sample with pH 3.5 ± 0.02 which consists of apples, then follows the sample 2 made of cranberries and red currants.

Difference between the sample 1 and 3 is negligible ($p>0.05$). The results of pH reveals as significant ($p<0.05$) increase in value in all supplemented products and such a rise is likewise detected by other authors (Quintero-Gutiérrez, *et al*., 2012; Yousif, Cranston, & Deeth, 2003). That is due to bovine alimentary albumin additive which had been obtained from bovine blood and had pH 7.5 ± 0.02 what is usually detected pH level for dried bovine blood (Cingi *et al*., 2009).

In Figure 3, the obtained moisture level results of investigated products are shown. Samples of products were obtained after uniform mixing of the whole chocolate snack, so samples had parts of chocolate glaze and fruit filling.

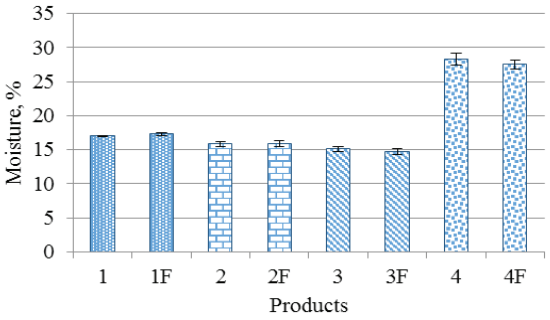

Figure 3. Moisture of products.

Comparing all results, the largest moisture content is in product 4, 4F samples (28.9 ± 0.5% and 27.52 ± 0.4%) which consist of apples and beet. The moisture content between 4, 4F samples and moisture of other products is significant ($p<0.05$). That is due to a high level of moisture of dried beet and apples which was suitable to make a sticky mixture suitable to form snack balls as more dried products failed in shaping. The moisture level comparing between products without and with bovine alimentary albumin is close; therefore, one can assert that composition of chocolate glaze does not influence total moisture of a whole product.

Water activity in products is moderately similar – the lowest result was determined in sample 2F (0.68 ± 0.02), but the highest – in sample 4 reaching 0.83 ± 0.04 (Fig. 4). In addition, no significant difference between samples without and with bovine alimentary albumin was observed.

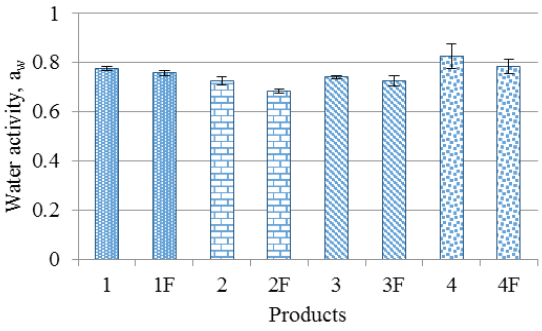

Figure 4. Water activity of products.

Colour is an important attribute in food as it gives the first impression about product and usually is critically evaluated by consumers. For colour evaluation, the surface of products as the iron supplement was incorporated only in chocolate glaze was used; therefore, the changes of colour of inside filling were not affected. The initial L*, a*, b* values describing colour differences of investigated samples' chocolate glaze with and without additional iron are shown in Table 2.

Chocolate glaze with bovine alimentary albumin was darker resulting in lower L^* values (20.6 ± 0.3). Similar results were reported by Yousif, Cranston, & Deeth (2003) using bovine blood components in food production. Addition of iron changes green-red and blue-yellow saturation in chocolate as obtained a* and b* values decrease. The calculated value for total colour change (Δ E*) in chocolate without and with iron supplement is 3.5.

Conclusion

The addition of bovine alimentary albumin is effective supplement for incorporating into foodstuff thus significantly increasing iron content. Products made in this project with additional bovine alimentary albumin have higher pH and darker colour, what is usually determined and reported properties using bovine blood components in food production. Further research is needed to determine sensory acceptability of product and other physical and chemical measurements. Additionally, shelf life and storage conditions for products must be observed.

Table 2

Colour components in chocolate glaze

Type of glaze	L*	a*	b*	Δ E*
Chocolate	27.8 ± 0.6	3.7 ± 0.5	6.6 ± 0.3	3.5
Chocolate with bovine alimentary albumin	20.6 ± 0.3	1.9 ± 0.3	3.3 ± 0.3	

Acknowledgements

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References

1. Abbaspour, N., Hurrell, R., & Kelishadi, R. (2014). Review on iron and its importance for human health. *Journal of Research in Medical Sciences.* 19, 164-172.
2. Alemán, M., Bou, R., Tres, A., Polo, J., Codony, R., & Guardiola, F. (2016). Oxidative stability of a heme iron-fortified bakery product: Effectiveness of ascorbyl palmitate and co-spray-drying of heme iron with calcium caseinate. *Food Chemistry*. 196, 567-576.
3. Bæch, S.B., Hansen, M., Bukhave, K., Jensen, M., Sørensen, S.S., Kristensen, L., Purslow, P.P., Skibsted, L.H., & Sandström, B. (2003). Nonheme-iron absorption from a phytate-rich meal is increased by the addition of small amounts of pork meat. *American Society for Clinical Nutrition*. 77, 173-177.
4. Christides, T., & Sharp, P. (2013). Sugars Increase Non-Heme Iron Bioavailability in Human Epithelial Intestinal and Liver Cells. *Plos one*. 8(12), 1-8. DOI: 10.1371/journal.pone.0083031.
5. Cingi, C.C., Civelek, T., Acar, A. & Eryilmaz, H. (2009). Changes in Blood Gas Composition and Acid-Base Equilibriums in Cattle Blood Samples Kept under Different Temperature Regimens and Times. *Journal of Animal and Veterinary Advances*. 8 (1), 103-107.
6. Commission of the European Communities. (2008). Directive 2008/100/EC amending Council Directive 90/496/EEC on nutrition labelling for foodstuffs as regards recommended daily allowances, energy conversion factors and definitions. *Official Journal of the European Union*. 285, 9-12.
7. Eisenstadt, A., Schäfer, U., Glei, M., & Jahreis, G. (2013). Iron metabolism and prevention of iron deficiency via iron fortification of foods. *Trace Elements and Electrolytes*. 30 (4), 156-166. DOI: 10.5414/TEX01303.
8. Hurrell, R., & Egli, I. (2010). Iron bioavailability and dietary reference values. *American Society for Nutrition*. 91, 1461-1465.
9. Papadakis, S.E., Abudal-Malek, S., Kamden, R.E., & Yam, K.L. (2000). Versatile and Inexpensive Techniques for Measuring Colour of Foods. *Food Technology*, 54 (12), 48-51.
10. Pizarro, F., Olivares, M., Valenzuela, C., Brito, A., Weinborn, V., Flores, S., & Arredondo, M. (2016). The effect of proteins from animal source foods on heme iron bioavailability in humans. *Food Chemistry*. 196, 733-738.
11. Quintero-Gutiérrez, A.G., Mariaca-Gaspar, G.I., Villanueva-Sánchez, J., Polo J., Rodríguez, C., & González-Rosendo, G. (2012). Acceptability and use of heme-iron concentrate product added to chocolate biscuit filling as an alternative source of a highly available form of iron. *Journal of Food*. 10 (2), 112-118.
12. Rebellato, A.P., Pacheco, B.C., Prado, J.P., & Pallone, J.A.L. (2015). Iron in fortified biscuits: A simple method for its quantification, bioaccessibility study and physicochemical quality. *Food Research International*. 77, 385-391.
13. Sagar, V.R., & Suresh, K.P. (2010). Recent advantages in drying and dehydration of fruits and vegetables: a review. *Journal of food science and technology*. 47 (1), 15-26.
14. Sharp, P., & Srai, S. (2007). Molecular mechanisms involved in intestinal iron absorption. *World Journal of Gastroenterology*. 13, 4716-4724.
15. Srdjan, D.M.D., Mukesh, M., & Agarwal, M.D. (2007). Nutritional iron deficiency: an evolutionary perspective. *Nutrition.* 23, 603-614. DOI: 10.1016/j.nut.2007.05.002.
16. WHO (2015). The global prevalence of anemia in 2011. Geneva: World Health Organisation.
17. Yousif, A.M., Cranston, P., & Deeth, H.C. (2003). Incorporation of bovine dry blood plasma into biscuit flour for the production of pasta. *Lebensm.-Wiss. U.-Technol.* 36, 295-302.
18. Zimmermann, M.B., & Hurrell, R.F. (2007). Nutritional iron deficiency. *Lancet*. 370, 511-520.

DIFFERENT DOSE INULIN FEEDING EFFECT ON CALF DIGESTION CANAL STATE AND DEVELOPMENT

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Abstract
The aim of this study was to determine the influence of Jerusalem artichoke flour feeding on the general health status of calves (*Bos Taurus*), the animal live weight gain and digestive canal morphological development in the first four months of life, as well as to find out the optimal of three inulin doses. Jeruslem artichoke (*Helianthus tuberosus)* concentrate produced in Latvia contains the prebiotic – inulin. The study was performed on four groups of animals - a control group of 10 animals and three prebiotic groups, 10 animals in each group. All groups were fed the whole milk, but the $PreG_6$ group animals were fed daily with 6 grams of prebiotic, calves $PreG_{12}$ group were fed with 12g of prebiotic, but each calf in $PreG_{24}$ group – 24g of prebiotic per day. CoG control animals did not receive feed supplement. Faecal mass consistence of $PreG_6$, $PreG_{12}$ groups of animals was more stable within the whole research period than CoG. We found that the control group animal weight gain on the 56th research day is statistically significantly ($p<0.05$) lower than of those calves that received inulin as a food supplement. The highest growth rates have shown $PreG_{12}$ and $PreG_{24}$ group of animals, significantly ($p<0.05$) being ahead of $PreG_6$ group of calves, the highest average daily live weight gain was observed in $PreG_{24}$ group (0.95 ± 0.093 kg).
Key words: calves, different doses, inulin, weight growth.

Introduction

In Europe they are trying to reduce the use of antibiotics in animal feed to achieve more rapid growth of the animal live weight, besides, since 2006 the use of antibiotics for productive animals is prohibited. Looking for alternative means which could contribute to a faster increase in live weight of calves and their healthier development, prebiotics are being studied as one of the alternatives. Interest in prebiotic feeding and their positive influence on the calf digestive canal and general state of health development increases more and more in recent years (Yutaka *et al*., 2015; Zábranský *et al*., 2015; Samanta, 2013; Masanetz *et al*., 2010).

A relatively large number of studies takes place shortly after the animal birth, the period when calves are fed with milk (Zábranský *et al*., 2015), but we would like to study the transition period from preruminant to ruminant when milk feeding decreases and fodder consumption increases. This is one of the periods when calves are re-located and re-grouped. At the same time the animal organism is exposed to very large changes due to changes in the proportion of feed materials, role of forestomach in feed digestion increases, the intestinal microflora changes take place - all that makes stressful situations more acute, most often displaying digestive channel impairment, diarrhea. It is researched that stress reduces immunity and increases the proliferation of pathogenic micro-organisms into the digestive canal and animal diseases (Salak-Johnson & McGlone, 2007).

It is known that the digestive canal is the largest immune organ that is equipped with a specific, complex immune cells in the mucous membrane, so the strengthening of this system and pathogenic micro-organism limitation by using feed supplement of natural origin is the direction, in which scientists are working to prevent stress-induced diarrhea, improve the organism's general immunity, accelerate the growth and development of calves in this difficult transition period from preruminant to ruminant.

As one of such influences for feed supplement may be prebiotics, which are not digested in the digestive canal, and digestive canal microflora uses them for its growth and development. They limit such pathogenic microorganism as *Salmonella sp.* or *Escherichia coli* spreading by improving the host organism's health (Gibson & Roberfroid, 1995; Patel *et al*., 2012; Ghosh & Mehla, 2012).

One of the more studied prebiotics is inulin, which is a classic oligo-saccharide and it contains many plants. Influence of inulin contained in the Jerusalem artichoke (*Helianthus tuberosus*) on the single-chamber stomach animals e.g. piglets (Flickinger *et al*., 2003) and birds (Kleessen, 2003; Valdovska *et al*., 2012) has been studied, but the data on whether and how it affects multi-chamber stomach of animal organism is lacking. Inulin can be able to modulate intestinal bacterial population towards a healthier flora (Gibson & Roberfroid, 1995).

The aim of this study was to determine the influence of Jerusalem artichoke flour feeding on the general health status of calves, the animal live weight gain and morphological development of the digestive canal in the first four months of life, as well as to find out the optimal inulin doses.

Materials and Methods

The research was carried out in one of the 420 cow farms of Latvia, in the district of Bauska.

At the beginning of research we formed four study groups, each group consisted of 10 randomly selectedclinically healthy 23 +/- 5 days old male calves with weight of 50 +/- 5 kg. During the study, animals were kept under the same conditions in groups of 10. The four-week-old calves were fed twice a day, each time for each animal feeding out on the average 3-3.5 l of whole milk. Animals had free access to drinking water and hay all day round. Two weeks after the start of the study or when the animals reached the age of 6 weeks, they were also offered fodder.

Feed of the research groups animals differed only in feed supplements - inulin doses. In this reasearch as prebiotic we used artichoke flour concentrate, produced in Latvia at the University of Latvia Institute of Microbiology and Biotechnology, where the inulin is 48.5 to 50.1% out of the dry weight. $PreG_6$ group (n = 10) animals were fed daily with 6 grams of prebiotic (it means 12 g of Jerusalem artichoke flour), calves $PreG_{12}$ group (n = 10) were fed with 12 g of prebiotic, but each calf in $PreG_{24}$ (n = 10) group - 24g of prebiotic per day. CoG control animals (n = 10) did not receive feed supplements. Artichoke powder for eating was added to milk for each animal individually. The study lasted 8 weeks or 56 days. A similar study framework has been used by other authors (Król, 2011).

Health state of the calves was evaluated daily during the whole research time period, with a particular focus on the stool consistency. Animal faeces were evaluated in points, where 0 points score was for solid faeces without diarrhea sign, 1 point was for soft faeces with maintained consistency, 2 points were for liquid ones with lost solidity, but 3 points – for watery faeces (Larson *et al*., 1977).

We fixed animal body weight at the study beginning (calves 4 weeks old) and after every two weeks (at the age of 6, 8, 10, 12 weeks). Every two weeks, during the weight checking, a general health check, in determining the physiological background characteristics, was also carried out.

A planned slaughter of calves at the age of 12 weeks was carried out, after slaughtering the cold carcass weight was determined. *MS Excel* 2008 and the *R-Studio* were used for the data processing.

Results and Discussions

Animal general health indicators corresponded to the physiological normal range in all groups animals. Calf faecal mass consistency was evaluated in points each day of the research. Faecal mass liquefaction on the seventh week of life was observed in all groups of animals, which could be due to the fact that the change in feed ration happened and calves began to eat the fodder. However, the data testified that faecal mass consistence of the prebiotic group $PreG_6$ and $PreG_{12}$ of animals was stable within the whole research period (Figure 1.).

As Figure 1 shows, after the seven weeks of life, when the calves were used to the new feed product, in all calf groups faecal mass consistency becomes firmer and more stable, there appear less and less animals with more soft species-appropriate faecal mass consistency than normal. It is interesting that the animals which were fed with 6g of prebiotic, had more stable faecal weight throughout the study than the groups that were fed with higher quantity of the feed supplement. This could indicate that the digestive canal needs a longer adaptation time to get used to such a high insulin dose and bacteria to breed at a sufficient level and adapt in digestive canal. Strong faecal mass liquefaction and diarrhea within a week was not observed in the studied animals. At about ten weeks of life, calves started receiving intensive fodder – hay, and animal faecal mass consistency began to stabilize. At the end of the research, steady faecal mass of about 0.5 points for all animals was observed.

B. Król (2011) study also showed that the faecal mass consistency of calves treated with prebiotic inulin (6g/day/head) and mannon-oligisaccharides

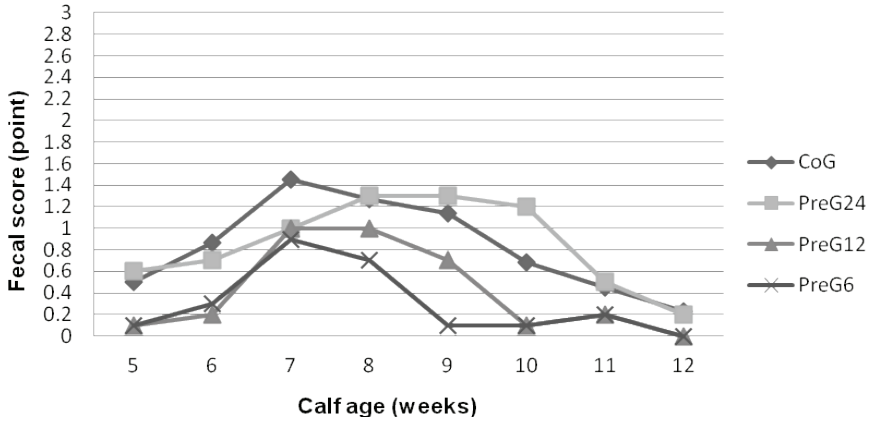

Figure 1. Various animal group faecal mass consistency comparisons.

Table 1

Calf weight gain and cold carcass weight

Group	Animal average live weight, kg at the research day			Average daily live weight gain, kg	Cold carcass weight, kg
	1	28	56		
CoG	50.8 ± 3.58	68.0 ± 6.63	87.6 ± 8.17	0.63 ± 0.13	42.6 ± 6.88
PreG6	49.8 ± 0.84	76.8 ± 3.11	93.2 ± 4.97	0.76 ± 0.99	44.8 ± 1.00
PreG12	54.0 ± 3.40	77.8 ± 5.63	101.6 ± 5.95	0.85 ± 0.10	54.0 ± 1.66
PreG24	49.8 ± 0.84	79.6 ± 3.11	102.8 ± 5.63	0.95 ± 0.09	50.2 ± 1.82

is more stable and steady (typical to animal species) than of the control animals, but significant differences between the control group and prebiotic animals were not found ($p>0.05$). Statistically significant differences between different prebiotic dose groups also were not found in this study.

Calf live weight was checked every second week. The live weight of all groups at the research start – on the first study day, in the mid-period – on the 28th study day and at the reasearch conclusion – on the 56th day are shown in Table 1. Daily live weight gain of calves and cold carcass weight average indexes also were calculated for each calf group.

Table 1 shows live weight gain average indices for different study groups of animals. We found that the control group animal weight gain on the 56th research day is statistically significantly ($p<0.05$) lower than of the calves that received inulin as a feed supplement. The highest growth rates were shown by $PreG_{12}$ and $PreG_{24}$ groups of animals, significantly ($p<0.05$) being ahead of $PreG_6$ group of calves, the highest average daily live weight gain was observed in $PreG_{24}$ group (0.95 ± 0.093 kg), but in comparison with the second largest growth rate of $PreG_{12}$ group calves (0.85 ± 0.10 kg), it is not statistically significantly higher. Both groups showed a very high daily live weight gain, which can be explained by the sustained action of the digestive canal. N. Stolić (2012), by feeding calves with prebiotic mannon-oligosaccharides, has also demonstrated that a statistically significantly greater increase of live weight can be gained in comparison with the control group.

When making animal cold carcass mutual comparison, we stated that cold carcass weight of the control group of animals and $PreG_6$ animal group was not statistically significantly higher, but having mutually compared $PreG_6$ against $PreG_{12;24}$ and CoG against $PreG_{12;24}$, we stated that the cold carcass weight was statistically significantly higher in $PreG_{12;24}$ than in $PreG_6$ and CoG ($p<0.01$).Having compared $PreG_{12}$ and $PreG_{24}$ we calculated that cold carcass weight of $PreG_{24}$ group animals was statistically significantly higher ($p<0.05$) than of $PreG_{12}$ one.

Conclusions

Feeding calf with inulin improves digestive channel functionality by reducing faecal mass liquefaction due to feed change or other stress influence. It makes animal gain live weight. Animals which were fed with inulin had higher cold carcass weight outcome. The animals included into our study indicated that the fed quantities of inulin statistically significantly increased the animal live weight gain, but not faecal mass consistency. We can conclude that when feeding an animal with a higher dose of inulin, digestive channel requires a longer adaptation and faecal consistency mass normalization period. In this research we found out that optimal inulin dose (for 4 – 12weeks old calves) is 6g/day/head or 12g/day/head of Jerusalem artichoke powder. In general, we can conclude that the increase of inulin quantity that is fed from the 4th – 12th week of calf life significantly influences the calf live weight gain and cold carcass weight, but does not statistically significantly affect the faecal mass consistency.

Acknowledgements

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References

1. Flickinger, E., Van Loo, J., & Fahey, G.Jr. (2003). Nutritional responses to the presence of inulin and oligofructose in the diets of domesticated animals: a review. *Critical Reviews in Food Science and Nutrition*, 43 (1), pp. 19-60.
2. Gibson, G.R., & Roberfroid, M.B. (1995). Dietary modulation of the human colonic microbiota: introducing the concept of prebiotic. *The Journal of Nutrition*, 125, pp. 1401-1412.
3. Ghosh, S., & Mehla, R.K. (2012). Influence of dietary supplementation of prebiotic (mannanoligosaccharide) on the performance of crossbred calves. Trop Anim Health Pro. 44, pp. 617-622. DOI: 10.1007/s11250-011-9944-8.
4. Kleessen, B., Elsayed, N.A., Loehren, U., Schroedl, W., & Krueger, M. (2003). Jerusalem artichokes stimulate growth of broiler chickens and protect them against cecal endotoxins and potential pathogens. *Journal of Food Protection*, 66 (11), pp. 2171-2175.
5. Król, B. (2011). Mannon-oligosaccharides, inulin and yeast nucleotides added to calf milkreplacers on rumen mikroflora, level of serum immunoglobulin and health condition of calves. *Electronic Journal of Polish Agricultural Universitas*, 14 (2), pp. 1-18.
6. Larson, L., Owen, F.G., Albright, J.L., Appleman, R.D., Lamb, R.C., & Muller, L.D. (1977). Guidelines Toward More Uniformity in Measuring and Reporting Calf Experimental Data. *Journal of Dairy Science*, 60, pp. 989-991. DOI: http://dx.doi.org/10.3168/jds.S0022-0302(77)83975-1.
7. Masanetz, S., Preißinger, W., Meyer, H.H.D., & Pfaffl, M.W. (2011). Effects of the prebiotic inulin and lactulose on intestinal immunology and hematology of preruminant calves. *Animal*, 5, pp. 1099-1106. DOI: 10.1017/S1751731110002521.
8. Patel, S., & Goyal, A. (2012). The current trends and future perspectives of prebiotic research: A review. *3 Biotech*, 2, pp. 115-125. DOI: 10.1007/s13205-012-0044-x.
9. Samanta, K., Jayapal, N., Senani, S., Kolte, A., & Sridhar, M. (2013). Prebiotic inulin: Useful dietary adjuncts to manipulate the livestock gut microflora. *Brazilian Journal of Microbiology*, 44, pp. 1-14. DOI: 10.1590/S1517-83822013005000023.
10. Salak-Johnson, J.L., & McGlone, J.J. (2007). Making sense of apparently conflicting data: stress and immunity in swine and cattle, *Journal of Animal Science*, 85 (13), 81-8. DOI: 10.2527/jas.2006-538.
11. Stolić, N., Milošević, B., Spasić, Z., Ilić, Z. (2012). Effects of prebiotic inclusion in the diet of weaned calves. *Macedonian Journal of Animal Science*, 2 (1), pp. 53-57.
12. Valdovska, A., Jemeļjanovs, A., Zītare, I., Krastiņa, V., Pilmane, M., & Proškina, L. (2012). Impact of prebiotic on chicken digestive tract morphofunctional status. In: Conference on *Current events in veterinary research and practice*, LLU, Jelgava, pp. 63-67.
13. Yutaka, U., Suguru, S., & Takeshi, S. (2015). Effects of Probiotics/Prebiotic on Cattle Health and Productivity. *Microbes and Enviroments*, 30 (2), 126-132. DOI: org/10.16/jsme2.ME14176.
14. Zábranský, L., Šoch, M., Novák, P., Brouček, J., Šimková, A., Švejdová, K., Čermák, B., Jirotková, D., & Pálka, V. (2015). Use of Natural Feed Supplements that Help to Improve Health Status of Calves, *Animal Science and Biotechnologies*, 48 (1), pp. 57-60.

THE EFFICACY OF PLATELET-RICH PLASMA USE AS A TREATMENT FOR THE OSTEOARTHRITIS

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Abstract
Platelet-rich plasma (PRP) is an autologous concentrated cocktail of growth factors and inflammatory mediators, and has been considered to be potentially effective for cartilage repair. Animal clinical studies suggest that PRP is a promising treatment for cartilage injuries and relieving symptoms due to its three biological properties: an anabolic effect, enhancement of cartilage regeneration and inhibitition of inflammation.The aim of this article is to analyze the available evidence on the clinical application of this biological approach to animals for the injective treatment of cartilage lesions and joint degeneration, and also to support the rationale for the use of platelet concentrates and to give indications on what to expect from intra-articular injections of platelet-rich plasma (PRP) in animals. This article is a summary of analytical research papers about the use of platelet-rich plasma as a treatment for the osteoarthritis. The intra-articular injections do not just target cartilage; instead, platelet-rich plasma might influence the entire joint environment, leading to clinical improvement. Many biological variables might influence the clinical outcome and have to be studied to optimize PRP injective treatment of cartilage degeneration and osteoarthritis.
Key words: platelet-rich plasma, osteoarthritis, cartilage.

Introduction

A healthy joint requires a fine-tuned balance between molecular signals regulating homeostasis, damage, restoration, and remodelling. This balance is determined both at the level of single cells and the whole tissue architecture, and it also involves interactions among different tissues such as cartilage, bone, synovium, ligaments, tendons, and menisci (Lores, 2008). Different factors are able to impair the maintenance of homeostasis in a joint that has been damaged or strained, and they may progressively lead to osteoarthritis (Heijink *et al*., 2012). Osteoarthritis (OA) is a progressively debilitating condition that is associated with pain and morbidity. It is associated with ageing, trauma or joint congenital development abnormalities (dysplasia) and most often affects the joints of the knees, elbows, hips. Several treatment modalities are available, involving both conservative and operative approaches. Non-operative management includes analgesics, non-steroidal anti-inflammatory drugs (NSAIDS), glucocorticoids, opioids, cartilage protective agents (glucosamine and chondroitin as well as physiotherapy). When these treatments fail, more invasive surgical approaches can be attempted to restore the mechanical balance and the regeneration of the articular surface, although results are still controversial (Fortier, Hackett, & Cole, 2011).

The search for a minimally invasive solution to improve the status of the joint surface and allow a fast return to full activity is therefore highly desirable. In this landscape, a novel promising injective treatment is platelet-rich plasma (PRP), a blood derivative that has a higher platelet concentrate than whole blood. When activated, platelets release a group of biologically active proteins that bind to the transmembrane receptors of their target cells, thus leading to the expression of gene sequences that ultimately promote cellular recruitment, growth, and morphogenesis, and modulating inflammation as well (Anitua, Sanchez, & Orive, 2010). Therefore, PRP represents an appealing biological approach to favour the healing of tissues with a low healing potential, such as cartilage. This led to the wide use of PRP, which shows promising results as a minimally invasive injective treatment of cartilage degeneration and OA, both in preclinical and clinical studies (Kon *et al*., 2013).

The aim of this paper is to analyze the available evidence on the clinical application of this biological approach to animals for the injective treatment of cartilage lesions and joint degeneration and as well as to support the rationale for the use of platelet concentrates and to give indications on what to expect from intra-articular injections of platelet-rich plasma (PRP) in animals.

Materials and Methods

Monographic method has been used for this article. As the research on use of platelet-rich plasma in veterinary medicine in Latvia is quite new, available scientific literature from other countries has been studied. All animal clinical trials on PRP injective treatment concerning the effect of PRP on cartilage, synovial tissue, and menisci were studied.

Results and Discussion

Concerning the animal clinical studies dealing with PRP injective treatment, we found 18 papers: 6 on rabbits, 4 on dogs, 3 on rats, 3 on sheeps, 1 on horses, and 1 on pigs, which showed heterogeneous results for heterogeneous indications.

Seven papers focused on OA treatment. Contrasting results have been reported in the small

animal model. In fact, Guner & Buyukbebeci (2012) did not find any immediate (2 weeks after the injection cycle) benefit of PRP on cartilage tissue in rat joints previously damaged with intra-articular formalin injection. Mifune *et al*. (2013) found in a rat OA model, induced by monosodium iodoacetate injection, that PRP had no marked effect by itself, but increased the cartilage repair effect of muscle derived stem cells, with a better histologic appearance, higher number of cells producing type II collagen, and lower levels of chondrocyte apoptosis at 4 weeks, although at 12 weeks its effects were lost. Kwon, Park, & Lee (2012) confirmed the benefit of PRP in a rabbit model of collagenase-induced OA: intra-articular injections influenced positively the cartilage regeneration in all OA severity degrees, with a more evident effect in moderate OA. Fahie *et al.* (2013) found that a single intra-articular injection of an autologous platelet rich-plasma concentrate significantly improves lameness, pain and peak vertical force scores at 12 weeks in 20 dogs with OA involving a single joint. Cook *et al*. (2015) performed five PRP injections in canine knee joint where the anterior cruciate ligament (ACL) was particularly transected and menisci was released. PRP-treated knees showed evidence of repair and less severe synovitis, also improved range of motion, decreased pain, and improved limb function for up to 6 months compared to saline-treated joints. Saito *et al.* (2009) used a rabbit OA model of anterior cruciate ligament resection for the treatment with gelatin hydrogel microspheres impregnated with PRP: injections markedly suppressed OA progression both morphologically and histologically (less significant results were obtained by the use of PRP only). Finally, Carmona *et al.* (2007) used a large animal model to analyze the effect of PRP injections: in a study on 4 horses with OA, 3 injections of PRP led to a significant improvement in both the degree of lameness and joint effusion. The most marked improvement was observed 2 months after treatment and persisted for 8 months with no adverse events.

Eleven studies focused on the injective treatment of chondral, osteochondral and ligament lesions. Also in this case, results were controversial. Serra *et al.* (2013) performed 7 PRP injections every other day in rabbit joints where a full-thickness osteochondral lesion was previously made surgically on the medial femoral condyle. A fibrous–cartilaginous tissue was found with no benefit from PRP. Smyth *et al.* (2015) performed one PRP injection in a rabbit knee where osteochondral lesion was previously made. There was no significant difference in macroscopic scores between the two groups, but histologic results were better and also greater glycosaminoglycan and type II collagen content in the repair tissue. Lee *et al.* (2016) performed a full-thickness circular defect on the menisci of rabbit filled with PRP. After eight weeks, the lesions in the control and PRP groups were occupied with fibrous tissue, but not with meniscal cells. PRP treatment of the meniscus results in an increase of catabolic molecules, especially those related to interleukin-1α induced inflammation. Hapa *et al*. (2013) evaluated PRP as augmentation in rat cartilage lesions after microfractures: at week 6, the microfracture group score was worse than that of the PRP microfracture group, which had an increased degree of type II collagen staining. Wei *et al.* (2007) found than chondrocytes/PRP composites injected subcutaneously in rabbits after 2 months form a new cartilage. In contrast, no tissue formed in the PRP-alone group. So results suggest the feasibility of using PRP as injectable scaffold seeded with chondrocytes to regenerate cartilage and showed the potential of using this method for the reconstruction of cartilage defects. Milano *et al.* (2010) used one PRP injection as augmentation procedure of microfracture in a sheep model. Although no hyaline cartilage was obtained, PRP offered better macroscopic, histologic, and biomechanical results. The PRP administration modality proved to be important for the final outcome, with better results when PRP was surgically applied as a gel over the treated lesion. However, this required a more invasive approach. Thus, in a further evaluation in sheep, Milano *et al*. (2011, 2012) focused on the injective approach: 5 weekly injections of PRP promoted a better spontaneous repair and also a better and more durable reparative response when applied after microfractures with respect to isolated microfractures, albeit without producing hyaline cartilage. Murray *et al.* (2006) used collagen-PRP scaffold to treat a central anterior cruciate ligament (ACL) defect in 10 dogs. Biomechanically, the treated ACL defects had a 40% increase in strength at 6 weeks, which was significantly higher than the 14% increase in strength of untreated defects. Xie *et al.* (2013) observed the increased expression of vascular endothelial growth factor, neurotrophin-3, thrombospondin-1 and nerve growth factor in canine ACL grafts treated with PRP at 2, 6 and 12 weeks after surgery.

Finally, only 1 paper focused on rheumatoid arthritis (RA). Lippross *et al.* (2011) reproduced RA in pigs: the animals were systemically immunized by bovine serum albumin (BSA) injections, and arthritis was induced by intra-articular BSA injection. The injection of PRP attenuated the arthritic changes on synovium and cartilage by modulating the activity of inflammation mediators. In particular, interleukin-6 (IL-6) and vascular endothelial growth factor (VEGF) staining was reduced, but concerning gene expression, only IL-6 levels were significantly lower after PRP application. Focusing on protein quantification, all

chondral protein concentrations returned to healthy tissue levels, and in synovial samples, besides the low levels of IL-6 and VEGF, the authors showed a reduction in insulin-like growth factor (IGF-1) and interleukin-1β (IL-1β) in PRP groups, whereas tumor necrosis factorα (TNFα) was not altered. So they conclude that treatment with PRP led to attenuation of these arthritic changes in the synovium and cartilage.

This systematic review confirmed the increasing interest in PRP as an injective treatment for cartilage degeneration and osteoarthritis, with an increasing number of published studies over time. PRP is a fashionable treatment, offering the possibility to deliver a high concentration of autologous growth factors and bioactive molecules in physiologic proportions, with low costs and in a minimally invasive way. This explains the wide application of this blood derivative to several tissues and heterogeneous pathologies in different fields of medicine (Kon *et al*., 2012). The rationale for using platelets for the treatment of different tissues is that they constitute a reservoir of growth factors that are critical for regulating the tissue healing process, which is quite similar in all kinds of tissues. However, even though the rationale for PRP use in other tissues is clear, since platelets represent the first response to a tissue damage where they participate in stopping the vessel bleeding and trigger the healing cascade (Cole *et al*., 2010), less intuitive is the rationale for PRP use in cartilage, which is a physiologically vessel-free tissue. 123 molecules such as transforming growth factor beta might justify its use in cartilage; PRP also contains other molecules such as vascular endothelial growth factor that do not take part or might even jeopardize cartilage homeostasis and regeneration (Mifune *et al*., 2013).

The systematic analysis of studies published up to now shows an overall positive effect of PRP on cartilage tissue. Besides some controversial results, most of the findings supported the role of PRP in increasing chondrocyte proliferation, without affecting chondrogenic phenotype and with an increase in the production of matrix molecules. Studies confirmed the usefulness of PRP treatment in different pathology models, with good results in cartilage regeneration after acute focal lesions, as well as in the more complex environment of joint osteoarthritic degeneration, and even in the challenging rheumatoid arthritis setting.

An intra-articular injection does not just target cartilage, instead, PRP might influence the entire joint environment, and some studies confirm the effects of PRP on other cell sources. Synoviocytes are affected by platelet releasate, as well as meniscal cells that seem to be induced by PRP and act synergically toward tissue healing. PRP has several potential effects by enhancing the cell signalling cascade in all joint tissues and inducing positive changes in the whole joint environment through a milieu of actions. Among these, tissue regeneration is actually not the only and maybe not the most important PRP mechanism of action, and increasing evidence supports the complex role of PRP in modulating inflammation. An overall down-modulation of the joint inflammation can explain the well-documented pain reduction, which is the most prominent and disabling symptom of cartilage lesions and OA. However, some findings suggest another intriguing aspect of PRP action mechanism, with a direct analgesic effect: Lee *et al*. (2016) showed the role of PRP in the augmentation of cannabinoid receptors CB1 and CB2, which might be involved in the analgesic effects. Further studies need to focus on understanding and possibly optimizing the analgesic and anti-inflammatory effects of PRP. PRP might not lead to hyaline cartilage regeneration and might not change the clinical history with significant disease-modifying properties, but it still might offer a clinical benefit with symptoms and function improvement and possibly a slowdown of the degenerative processes. The central feature in OA cartilage degeneration is the so-called apoptosis (programmed cell death); thus, chondrocytes apoptosis is a potential therapeutic target for OA interventions. The exact mechanism behind the PRP regulation of the apoptotic pathway is unclear, but it is likely that PRP might have an overall effect in slowing down the apoptosis cascade.

PRP injections seem to be safe, as we did not find adverse events reported in animal studies. Many studies have a small animal group or amount of cases, thereby they are not representative. Therefore, more high-quality trials are required.

Several aspects still need to be studied to understand the mechanism of action of PRP and give better treatment indications, and possibly to optimise the procedure and improve the potential of this biological minimally invasive approach for the treatment of cartilage.

Conclusions

Research findings derived from animal clinical studies suggest that PRP is a promising treatment for cartilage injuries and relieving symptoms due to its three biological properties. Firstly, PRP has an anabolic effect on chondrocytes and synoviocytes with resultant increases in cell proliferation and secretion of hyaluronic acid. Secondly, PRP may act as a bioactive cell scaffold to fill defects and enhance cartilage regeneration. Thirdly, PRP has the potential to inhibit inflammation and alleviate OA symptoms. Many biological variables might influence the clinical outcome and have to be studied to optimize PRP injective treatment of cartilage degeneration and osteoarthritis.

References

1. Anitua, E., Sanchez, M., & Orive, G. (2010). Potential of endogenous regenerative technology for in situ regenerative medicine. *Advanced Drug Delivery Reviews*, 62 (7-8), 741-752. DOI: 10.1016/j.addr.2010.01.001.
2. Carmona, J.U., Arguelles, D., Climent, F., & Prades, M. (2007). Autologous platelet concentrates as a treatment of horses with osteoarthritis: a preliminary pilot clinical study. J*ournal of Equine Veterinary Science*, 27(4), 167-170. DOI: 10.1016/j.jevs.2007.02.007.
3. Cole, B.J., Seroyer, S.T., Filardo, G., Bajaj, S., & Fortier, L.A. (2010). Platelet-rich plasma: where are we now and where are we going? *Sports Health*, 2(3), 203-210. DOI: 10.1177/1941738110366385.
4. Cook, J.L., Smith, P.A., Bozynski, C.C., Kuroki, K., Cook, C.R., Stoker, A.M., & Pfeiffer, F.M. (2015). Multiple injections of leukoreduced platelet rich plasma reduce pain and functional impairment in a canine model of ACL and meniscal deficiency. *Journal of Orthopaedic Research*, 24(4), 820-830. DOI: 10.1002/jor.23054.
5. Fahie, M.A., Ortolano, G.A., Guercio, V., Schaffer, J.A., Johnston, G., Au, J., Hettlich, B.A., Phillips, T., Allen, M.J., & Bertone, A.L. (2013). A randomized controlled trial of the efficacy of autologous platelet therapy for the treatment of osteoarthritis in dogs. *Journal of the American Veterinary Medical Association*, 243(9), 1291-1297. DOI: 10.2460/javma.243.9.1291.
6. Fortier, L.A., Hackett, C.H., & Cole, B.J. (2011). The Effects of Platelet-Rich Plasma on Cartilage: Basic Science and Clinical Application. *Operative Techniques in Sports Medicine*, 19(3), 154-159. DOI: 10.1053/j.otsm.2011.03.004.
7. Guner, S., & Buyukbebeci, O. (2012). Analyzing the effects of platelet gel on knee osteoarthritis in the rat model. *Clinical and Applied Thrombosis/ Hemostasis*, 19(5), 494-498. DOI: 10.1177/1076029612452117.
8. Hapa, O., Cakici, H., Yuksel, H.Y., Fırat, T., Kukner, A., & Aygun, H. (2013). Does platelet-rich plasma enhance microfracture treatment for chronic focal chondral defects? An in vivo study performed in a rat model. *Acta Orthopaedica et Traumatologica Turcica*, 47(3), 201-207. DOI: 10.3944/AOTT.2013.2928.
9. Heijink, A., Gomoll, A.H., Madry, H., Drobnic, M., Filardo, G., Espregueira-Mendes, J., & Van Dijk, C.N. (2012). Biomechanical considerations in the pathogenesis of osteoarthritis of the knee. *Knee Surgery, Sports Traumatology, Arthroscopy*, 20(3), 423-435. DOI: 10.1007/s00167-011-1818-0.
10. Kon, E., Filardo, G., Matteo, B.D., & Marcacci, M. (2013). PRP for the treatment of cartilage pathology. *Open Orthopedic Journal*, 3(7), 120-128. DOI: 10.2174/1874325001307010120.
11. Kon, E., Filardo, G., Drobnic, M., Madry, H., Jelic, M., van Dijk, N., & Della Villa, S. (2012). Non-surgical management of early knee osteoarthritis. *Knee Surgery, Sports Traumatololy, Arthroscopy*, 20(3), 436-449. DOI: 10.1007/s0016701117138.
12. Kwon, D.R., Park, G.Y., & Lee, S.U. (2012). The effects of intra-articular platelet-rich plasma injection according to the severity of collagenase-induced knee osteoarthritis in a rabbit model. *Annals of Rehabilitation Medicine*, 36, 458-465. DOI: 10.5535/arm.2012.36.4.458.
13. Lee, H.R., Shon, O.J., Park, S.I., Kim, H.J., Kim, S., Ahn, M.W., & Do, S.H. (2016). Platelet-rich plasma increases the levels of catabolic molecules and cellular dedifferentiation in the meniscus of a rabbit model. *International Journal of Molecular Sciences*, 17(1), 120. DOI: 10.3390/ijms17010120.
14. Lippross, S., Moeller, B., Haas, H., Tohidnezhad, M., Steubesand, N., Wruck, C.J., Kurz, B., Seekamp, A., Pufe, T., & Varoga, D. (2011). Intraarticular injection of platelet-rich plasma reduces inflammation in a pig model of rheumatoid arthritis of the knee joint. *Arthritis & Rheumatology*, 63(11), 3344-3353. DOI: 10.1002/art.30547.
15. Lories, R.J. (2008). Joint homeostasis, restoration, and remodeling in osteoarthritis. *Best Practice & Research Clinical Rheumatology*, 22(2), 209-220. DOI: 10.1016/j.berh.2007.12.001.
16. Mifune, Y., Matsumoto, T., Takayama, K., Ota, S., Li, H., Meszaros, L.B., Usas, A., Nagamune, K., Gharaibeh, B., Fu, F.H., & Huard, J. (2013). The effect of platelet-rich plasma on the regenerative therapy of muscle derived stem cells for articular cartilage repair. *Osteoarthritis and Cartilage*, 21, 175-185. DOI: 10.1016/j.joca.2012.09.018.
17. Milano, G., Deriu, L., Sanna Passino, E., Masala, G., Manunta, A., Postacchini, R., Saccomanno, M.F., & Fabbriciani, C. (2012). Repeated platelet concentrate injections enhance reparative response of microfractures in the treatment of chondral defects of the knee: an experimental study in an animal model. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, 28(5), 688-701. DOI: 10.1016/j.arthro.2011.09.016.
18. Milano, G., Deriu, L., Sanna Passino, E., Masala, G., Saccomanno, M.F., Postacchini, R., & Fabbriciani, C. (2011). The effect of autologous conditioned plasma on the treatment of focal chondral defects of the

knee. An experimental study. *International Journal of Immunopathology & Pharmacology*, 24, 117-124. DOI: 10.1177/03946320110241S222.

19. Milano, G., Sanna Passino, E., Deriu, L., Careddu, G., Manunta, L., Manunta, A., Saccomanno, M.F., & Fabbriciani, C. (2010). The effect of platelet rich plazma combined with microfractures on the treatment of chondral defects: an experimental study in a sheep model. *Osteoarthritis and Cartilage*, 18(7), 971-980. DOI: 10.1016/j.joca.2010.03.013.
20. Murray, M.M., Spindler, K.P., Devin, C., Snyder, B.S., Muller, J., Takahashi, M., Ballard, P., Nanney, L.B., & Zurakowski, D. (2006). Use of a collagen-platelet rich plasma scaffold to stimulate healing of a central defect in the canine ACL. *Journal of Orthopaedic Research*, 24(4), 820-830. DOI: 10.1002/jor.20073.
21. Saito, M., Takahashi, K.A., Arai, Y., Inoue, A., Sakao, K., Tonomura, H., Honjo, K., Nakagawa, S., Inoue, H., Tabata, Y., & Kubo, T. (2009). Intraarticular administration of platelet-rich plasma with biodegradable gelatin hydrogel microspheres prevents osteoarthritis progression in the rabbit knee. *Clinical and Experimental Rheumatology*, 27 (2), 201-207.
22. Serra, C.I., Soler, C., Carillo, J.M., Sopena, J.J., Redondo, J.I., & Cugat, R. (2013). Effect of autologous platelet-rich plasma on the repair of full-thickness articular defects in rabbits. *Knee Surgery, Sports Traumatology, Arthroscopy*, 21(8), 1730-1736. DOI: 10.1007/s0016701221410.
23. Smyth, N.A., Haleem, A.M., Ross, K.A., Hannon, C.P., Murawski, C.D., Do, H.T., & Kennedy, J.G. (2015). Platelet-rich plasma may improve osteochondral donor site healing in a rabbit model. *Cartilage*, 7(1), 104-111. DOI: 10.1177/1947603515599190.
24. Wei, W., Fulin, C., Yanpu, L., Qui, M., & Tianqiu, M. (2007). Autologous injectable tissue engineered cartilage by using platelet-rich plasma: experimental study in a rabbit model. *Journal of Oral Maxillofacial Surgery*, 65(10), 1951-1957. DOI: 10.1016/j.joms.2006.11.044.
25. Xie, X., Zhao, S., Wu, H., Xie, G., Huangfu, X., He, Y., & Zhao, J. (2013). Platelet-rich plasma enhances autograft revascularization and reinnervation in a dog model of anterior cruciate ligament reconstruction. *Journal of Surgical Research*, 183(1), 214-222. DOI: 10.1016/j.jss.2013.01.020.

INTERRELATIONS BETWEEN THE MILK UREA CONCENTRATION AND PRODUCTION AND REPRODUCTION PERFORMANCE OF DAIRY COWS

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Abstract
The objective of the study was to investigate the correlation between the milk urea (MU), milk yield and reproductive performance using milk recording tests and the health check results. Weak to average negative correlation was found between MU and the milk yield ($r = -0.44$ and $r = -0.34$; $p>0.05$), milk protein ($r = -0.22$; $p<0.05$) and milk freezing point ($r = -0.33$; $p<0.01$). Higher milk fat was found in cow milk with MU below 30 mg dL^{-1} in comparison with cow milk which had MU above 30 mg dL^{-1}, $4.0 \pm 0.77\%$ and $3.9 \pm 0.75\%$, respectively. High MU fluctuations within a cow group can be observed if cows of different productivity levels are grouped together or if there are too many animals in one group. Correlations between MU and times of artificial insemination or the service period were not established, possibly due to successful veterinary measures. In conclusion we emphasize the necessity on large dairy farms to analyse MU concentration in relation to milk protein and fat concentration for individual animals and in each feeding group separately. The study was the part of the State Research Project (*AgroBioRes*) No. 2014.10-4/VPP-7/5; subproject VP29.
Key words: cow, productivity, milk urea, freezing point.

Introduction

With increasing productivity of dairy cows special attention should be paid to properly balanced feeding so, that achieving of a high milk yield would also allow to avoid diseases and promote longevity of cows. In large-scale dairy operations, frequent re-grouping and feeding of cows in line both with their productivity and the physiological period, each time ensuring a different energy and protein level sometimes can be highly cumbersome. One of the feeding quality testing methods is evaluation of the chemical milk ingredients: fat and protein levels, their interrelations, as well as the urea concentration assay. Milk urea (MU) or milk urea nitrogen (MUN) can be established in the laboratory. In Latvia, MU is tested at Dairy Laboratory Ltd; its optimum level in milk is prescribed at 12 − 16 mg dL^{-1} (Young, 2001), 15 − 30 mg dL^{-1} (Bijgaart, 2003), or 20 − 30 mg dL^{-1} (Noordhuizen, 2012).

Urea is a decomposition side-product of amino acids or nitrogen substances (NH_3): a substance of low molecular weight that is formed in liver and distributed with blood stream over the whole body system reaching the uterus cavity, ovarian follicular fluid, as well as secreted with milk and urine (Hammon, Holyoak, & Dhiman, 2005; Latimer, Mahaffey, & Prasse, 2003). MU describes the amount of rumen protein and its balance with highly digestible carbohydrates. This indicator and its compensation is easily influenced also by the quality of feed materials, the nitrogen amount they contain, rumen-degradable protein (Noordhuizen, 2012; Godden, Lissemore, & Kelton, 1984), as well as the dry matter content of the feed ingested (Husband & Vecqueray, 2012) and genetic traits (Rzewuska & Strabel, 2015). An excess urea level in cow's organism has an adverse impact on reproductive performance (Nourozi *et al*., 2010; Butler, 2005; Melendez, Donovan, & Hernandez, 2000) and the body condition score (Kessell, 2015). It has been established that at low milk protein concentration related to elevated or lowered MU concentration, cows would have silent heats, breeding problems and early embryonic mortality (Noordhuizen, 2012).

Freezing point of milk is one of the milk quality indicators. Despite the fact that the milk composition is subject to certain fluctuations within the physiological range, this parameter is relatively constant and its physiological boundaries are set between − 0.468 and − 0.531 °C (Buchberger, 2000) or between − 0.527 °C and − 0.535 °C (Jonkus *et al*., 2008). In Latvia Dairy Laboratory Ltd. according to the European Cooperation for Accreditation has prescribed that the freezing point of milk should not be higher than − 0.520 °C. This parameter is actually fixed for practical purposes to enable the detection of water in milk as the latter is known to materially decrease the value of this temperature approximating it to zero degrees. Freezing point of milk could be influenced by the particular breed of the cows, lactation period, feeding, geographic area where the cows are located, season of the year, as well as the composition of milk (Ruska, 2014; Kedzierska-Matysek *et al*., 2011; Hanuš *et al*., 2011; Jonkus *et al*., 2008). The cows with a higher urea level in milk have also a higher freezing point of milk which is explained by higher milk protein concentration (Kedzierska-Matysek *et al*., 2011; Hanuš *et al*., 2011). Other authors in their turn (Jonkus *et al*., 2008) draw a conclusion that neither MU nor milk yield has any impact on freezing temperature of milk nor these factors have any correlation.

The aim of the study was to investigate the correlation between the MU and the milk yield and

reproductive performance using milk recording tests obtainable in the herd health check visits on productive dairy farms.

Materials and Methods

The study was performed on the basis of the milk recording data and herd health visit results on two dairy farms: X and Y. The correlation between the MU and the milk yield and reproductive performance was analysed for cows in early lactation period in the herd X, but in the herd Y only MU and productivity interrelations were evaluated.

The milk yield in the herd X was 8500 kg per cow in a year, but in the herd Y it was 8000 kg per cow in a year. On both farms, cows were kept in free stall barns and fed with the total mixed ration (TMR) calculated with software. On both farms, TMR consisted of grass silage, rape cakes, wheat grain and mineral additives. The cows were grouped according to their physiological period. On farm X with 350 lactating cows, data analysis was carried out for early lactating cow group from December of 2014 to December of 2015. The overall number of lactating cows in this group was 123 ± 4 cows each month despite the fact that 70 cows were planned in project sites. Within the study, quantitative, qualitative and biochemical data of milk were analysed: milk yield, freezing point of milk, concentration of fat, protein, lactose and MU as well as the amount of energetically corrected milk (ECM) were calculated. On the farm Y, the average quantitative data of the entire lactating herd of 250 cows were calculated over the period of 10 months.

The milk tests were performed at Dairy Laboratory Ltd., ISO 9622 / IDF 141:2013. Laboratory registration number LATAK-T-283-11-2003, accreditation standard: LVS EN ISO/IEC 17025:2005. ECM was calculated according to the formula prescribed by Agricultural Data Centre:

$$ECM = milk(kg)x\frac{(0.383xMF)+(0.242xMP)+0.7832}{3.140} \quad (1),$$

where ECM - energetically corrected milk, MF- milk fat and MP-milk protein. Reproductive data of cows were obtained from the computerised archives of the Farm X and analysed across the period of 12 months: service period and number of artificial inseminations. On farm Y, data were obtained just to evaluate the tendencies of milk yield and urea correlations in the herd with similar productivity and nutrition. On both farms, different was only the feeding management: on the farm X, TMR was given two times per day – every time more than two hours cows were without feed, but on the farm Y, TMR was given one time per day – cows were less than 2 hours without feed every day. The feed secondary fermentation was established organoleptically during the farm visits. Data statistical analyses were performed with *SPSS17* software (to calculate independent samples t-test, average, standard deviation, bivariate Pearson's correlation as well as to establish p-value) and graphic figures were prepared with *Excel* program.

Results and Discussion

In 2015, on farm X, the monthly average milk yield for cows on the upward lactation curve varied within the limits from 31.0 ± 5.8 kg to 38.0 ± 7.6 kg reaching the peak in December, while the MU average concentration was from 24.8 ± 5.8 mg dL^{-1} up to 38.3 ± 5.8 mg dL^{-1}, respectively, peaking in May (Figure1). It should be noted that the milk yield increase stabilised when the MU level had decreased below 35 mg dL^{-1}.

In farm Y in 2015, the average monthly milk yield varied within the limits of 29.1 ± 7.8 kg to 32.7 ± 8.40 kg while the MU level in monthly yield ranged from 20.0 ± 9.2 mg dL^{-1} to 31.3 ± 5.9 mg dL^{-1} (Figure 2). The MU level and the milk yield maximum did not coincide in this test version between farms

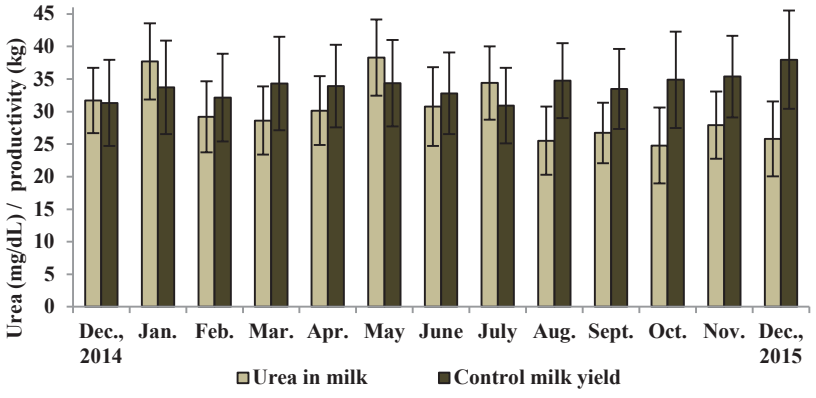

Figure 1. Dynamics of MU and milk yield on Farm X on lactation day 5-60, (n = 123), (r = -0.44; p>0.05).

X and Y. In both herds, a weak negative correlation was established between the milk yield and MU: on Farm X, r = -0.44, while on farm Y was r = -0.34. It is known that high amounts of nitrogen substances in feed increase the formation of ammonia in the rumen. In its transformation to urea, liver uses up more energy which is also required for the synthesis of milk in the udder. This results in less milk and more MU in milk than in a situation when the amount of nitrogen substances in feed ration stays on an optimum level (Noordhuizen, 2012). It is possible that the MU level was increased due to secondary fermentation of silage in poorly sealed silos. Furthermore, over lengthy storage period in the second half of winter, the material has been exposed to air after opening of the bulky storage bunker, in the process of daily removal of the silage or due to excessively long use of silage from the same bunker silo.

Analysing data of the farm X in greater detail, it has been established that in the course of one year for 16.4% of cows (n = 219) in the early lactation period, the protein level in milk was below 2.9%. The MU level for these cows was 32.8 ± 7.8 mg dL^{-1}, while the ECM amount was 38.2 ± 8.6 kg. For 12% of cows in their turn (n = 160), the protein level in milk was above 3.5% with MU in milk 25.7 ± 6.3 mg $dL^{-1}$and ECM 40.7 ± 9.9 kg. Concerning cows with low milk protein, the urea level stays higher 30 mg dL^{-1} and the milk yield is lower, and it should be concluded that the amount of rumen-digestible proteins in their feed has been insufficient. Cows with high milk protein however had optimum MU level suggesting that they were fed with a well-balanced ration. If, over early lactation curve period the milk protein level is low for more than 20% of cows, it suggests that feed energy deficient exist (Noordhuizen, 2012). On Farm X, a trend was observed that cows with varied MU level have different milk protein level, as well as the calculated ECM. For animals with MU below 20 mg dL^{-1}, the milk protein was 3.3 ± 0.0.41% and ECM 39.8 ± 8.97 kg, respectively, while for cows with an optimum MU (20-30 mg dL^{-1}), it was 3.2 ± 0.31% and 40.4 ± 8.72 kg, respectively. For cows with MU exceeding 30 mg dL^{-1}, it was 3.1 ± 0.27% and 39.8 ± 7.90 kg, respectively. Thus, the highest ECM was obtained from cows with optimum MU amount. The present study established a weak negative but significant correlation between MU and the milk protein level (r = -0.17, $p<0.001$).

On farm X over the whole period of study, the group of early lactation cows had received feeding ration not appropriate to all animals because of highly varied daily milk yield: from below 20 kg to above 50 kg (Figure 3). For low-producing cows, the urea level was elevated indicating ineffective use of nitrogen in the animal system. The feed ration was the most effective for cows with the milk yield above 50 kg, the MU of which was lower than for other cows in the same group. To avoid over-conditioning of low productivity cows or their falling sick with metabolic or reproductive tract diseases, it is advisable to group animals not only on the basis of their days in lactation but also the production level. Besides, wasteful consumption of protein feeds for low producers would increase the leakage of nitrogen in the surrounding environment through faeces.

The conclusion drawn from the data obtained in 2015 is that the first calf heifers on farm X had lower productivity than mature cows − 33.8 ± 6.6 kg and 39.7 ± 8.7 kg per cow per day ($p<0.001$), respectively,

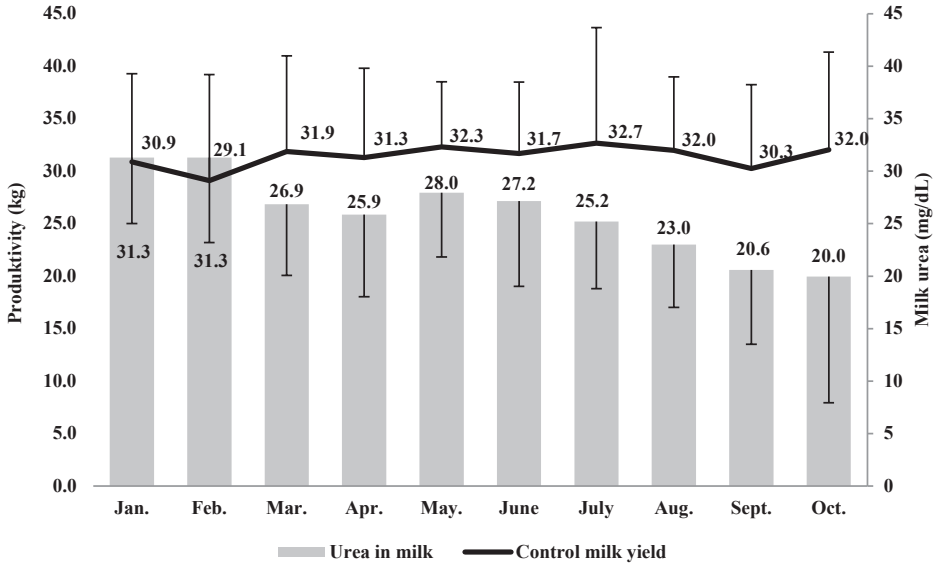

Figure 2. Dynamics of MU and milk yield on Farm Y. (n = 250), (r = -0.34, $p>0.05$).

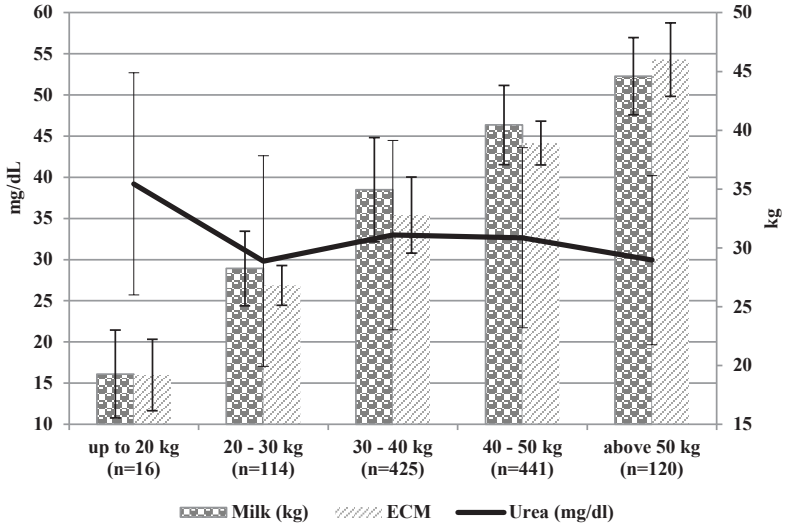

Figure 3. Milk yield and MU in relation to productivity of cows in the early lactation group over one year period on the farm X.

their fat content in milk was also lower: 3.8 ± 6.7% versus 4.1 ± 4.1% ($p<0.001$), milk protein was found to be 3.2 ± 0.3% versus 3.3 ± 0.4% ($p<0.05$) and they had a trend towards higher MU: 31.4 ± 7.6 mg dL^{-1} and 30.8 ± 7.7 mg dL^{-1} respectively ($p = 0.06$). Recalculating the daily milk yield to ECM, the differences in productivity are even more evident, the daily average ECM for first calf heifers was 32.2 ± 5.7 kg, while for mature cows it was 39.4 ± 8.0 kg per cow per day ($p<0.001$).

In the early lactation group of farm X the monthly average number of cows were 123 ± 4, while the feeding table allowed access to only 70 animals at one time. In the herd hierarchy, if kept in one and the same group, the first half heifers usually find themselves lower than mature cows. Consequently, the first calf heifers gain access to the feed table only after the stronger cows have already eaten. In one of the herd X health check visits it was established that TMR had been excessively dry. This gives an opportunity for cows to sort feed eating up the tastier bits, i.e. concentrates, first. Possibly, the first calf heifers mostly get just silage. It means that the feed ration for the first lactation cows is richer in nitrous substances and poorer in less highly digestible carbohydrates than for older cows. The conclusion to be drawn is that cows consuming more concentrates produce a higher milk yield with the higher milk protein level due to less ammonia found in their liver which has to be transformed into urea. Consequently, the high producing cows use up nitrogen substances more completely and the latter are less excreted into environment.

On Farm X, a statistically significant negative weak correlation was established between MU and the freezing point of milk ($r = -0.33$; $p<0.01$) as well as between MU and milk protein level ($r = -0.22$; $p<0.05$). The results of our study differ from findings published by other authors (Kedzierska-Matysek *et al*., 2011; Hanuš *et al*., 2011) who had found that cows with higher MU would demonstrate also a higher freezing point of milk, explained by higher milk protein concentration. Distinctive conclusions have been drawn also by other Latvian scientists (Jonkus *et al*., 2008): MU and the milk yield have no relation to freezing point of milk and these factors do not exert influence on one another.

Within the research period, on farm X, a weak positive correlation between MU and the number of artificial insemination was established for all cows ($r = 0.12$; $p<0.001$) despite the earlier findings in research literature which assert a significant negative impact of high urea in the cow's body system on their reproductive performance especially among the first calf heifers (Nourozi *et al*., 2010). Another veterinary medical science publication points out that reproductive problems in cows are observed only if at increased MU, the milk protein remains in norm or below it (Noordhuizen, 2012). In farm X, cows with MU concentration of up to 35 mg dL^{-1} have had 1.63 ± 0.99 artificial inseminations (AI) per pregnancy on average, while cows with MU level above 40 mg dL^{-1}, have had 1.71 ± 1.10 AI per pregnancy ($p>0.05$). The impact of other factors on reproductive performance of animals in research herds cannot be excluded either, e.g. the subacute rumen acidosis or ketosis which appears due to irrelevant grouping of animals or the heat stimulation with hormones practiced by veterinarians on cows with reproductive problems. As the result, within the present research study, an

insignificantly shorter service period was established for the cows with higher MU than ones with lower MU: for cows with MU above 40 mg dL^{-1} the service period was 96 ± 36.8 days on average, for cows with MU 35 − 40 mg dL^{-1} it was 98 ± 38.4, while for cows with MU below 30 mg dL^{-1}, the service period established was 108 ± 54.4 days. High urea level in milk correlates with its higher concentration in follicular liquid and intrauterine environment. High urea content in cows' body system hinders their fertility (Butler, 2005; Melendez *et al*., 2000). It should be noted that on farm X, the average productive life of cows is just 2.2 ± 1.20 lactations. In 2015, the first and second lactation cows made up 67.4% of the herd, while there were only 26.9% of third lactation cows and 5.7% cows of later lactations in the herd. These are economically alarming results calling for more in-depth future analysis of cow culling and involuntary slaughtering reasons with an aim of increasing the productive life of dairy animals.

Conclusions

In both herds**,** a weak negative correlation was established between the MU concentration and the milk yield, and MU and milk protein level on farm X. MU is a good indicator to control the optimum use of rumen degradable protein by the cow's body system and decrease the nitrogen excretion into environment. Deviations of MU from the norm may testify not only to the need to correct the rumen degradable protein (nitrogen substances) amount in the feed ration or the adjustment thereof with highly digestible carbohydrates but also point to substantial mistakes in the grouping of cows or preparing of feed. Essential changes in reproductive indicators of cows (number of AI per pregnancy, the length of service period) for cows with increased MU concentration influenced by hormones induced heat practiced on the farm X has not been established by the present research. The statistical analysis of data obtained on research farms is continued in order to establish the relation between biochemical components of milk, including MU with metabolic diseases of cows.

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References

1. Bijgaart, H. (2003). Urea: New applications of mid-infra-red spectrometry. *Bulletin of the IDF*, Volume 383, pp. 5-15. DOI: 1725, 35400011321537.0010.
2. Buchberger, J. (2000). Umweltfactoren und Rohmilch - ZumEinfluss sogenanten Umweltfaktoren auf den Gefrierpunkt (Environmental factors and raw milk - the influence so-called environmental factors on the freezing point). *Dmz Dtsch. Molkereien Ztg*. 121(25), 1054-1059. (in Germany).
3. Butler, W.R. (2005). Relationships of Dietary Protein and Fertility. *Advances in Dairy Technology*. Volume 17, pp. 159-168.
4. Godden, S.M., Lissemore, K.D., & Kelton, D.F. (1984). Relationships Between Milk Urea Concentrations and Nutritional Management, Production, and Economic Variables in Ontario Dairy Herds. *J. Dairy Sci.* 84(5), 1128-1139. DOI: 10.3168/jds.S0022-0302(01)74573-0.
5. Hammon, D.S., Holyoak, G.R. & Dhiman, T.R. (2005). Association between blood plasma urea nitrogen levels and reproductive fluid urea nitrogen and ammonia concentrations in early lactation dairy cows. *Animal Reproduction Science*. 86(3-4), 195-204. DOI: 10.1016/j.anireprosci.2004.08.003.
6. Hanuš, O., Zhang, Y., Bjelka, M., Kučera, J., Roubal, P., & Jedelská, R. (2011). Chosen biotic factors influencing raw cow milk freezing point. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*. Volume 59, Issue 5, pp. 65-82. DOI: 10.11118/actaun201159050065.
7. Husband, H.A., & Vecqueray, R.J. (2012). Nutritional Management of Herd Health. Edited by M. Green. *Dairy Herd Health*. (pp. 227-278). Wallingford, UK: CAB International.
8. Jonkus, D., & Rivža, P. (2009). Freezing point and investigation of influencing factors for milk obtained in Latvia// Latvijā iegūtā govju piena sasalšanas punkts, to ietekmējošo faktoru izpēte. The draft contract No: 140708/S-293. Retrieved December 12, 2015, from http://www.llu.lv/getfile.php?hash=090a28a4da3e706f547246d72c97c2b3.
9. Kedzierska-Matysek, M., Litwinczuk, Z., Florek, M., & Barlowska, J. (2011). The effects of breed and other factors on the compositionand freezing point of cow's milk in Poland. *International Journal of Dairy Technology*. 64 (3), 336-342.
10. Kessell, A. (2015). The Practice Laboratory. In Peter Cockcroft (Eds). *Bovine medicine*. Third edition by JohnWiley & Sons, Ltd., UK. pp. 100-105.

11. Latimer, K.S., Mahaffey, E.A., & Prasse, K.W. (2003). *Clinical Pathology*. Fourth Edition. USA: Iowa State University Press, pp. 250-255.
12. Melendez, P., Donovan, A., & Hernandez, J. (2000). Milk Urea Nitrogen and Infertility in Florida Holstein Cows. *Journal of Dairy Science*. Volume 83, Issue 3, pp. 459-463. DOI: 10.3168/jds.S0022-0302(00)74903-4.
13. Noordhuizen, J. (2012). *The Dairy Herd Health And Management Book*. A guide for veterinarians and dairy professionals. UK: Context Products Ltd., pp. 350-355.
14. Nourozi, M., Moussavi, A.H., Abazari, M., & Zadeh, M.R. (2010). Milk Urea Nitrogen and Fertility in Dairy Farms. *Journal of Animal and Veterinary Advances*. Volume 9, Issue 10, pp. 1519-1525.
15. Rzewuska, K., & Strabel, T. (2015). The genetic relationship between reproduction traits and milk urea concentration. *Animal Science Papers and Reports.* Volume 33, Issue 3, pp. 243-256.
16. Ruska, D. (2014). Dynamics of crude protein and urea content in milk from dairy cows. Doctoral thesis. Retrieved March 20, 2016, from http://llufb.llu.lv/dissertation-summary/animal_husbandry/Diana_Ruska_promoc_darba_kopsavilk_2014_LLU_LF.pdf.
17. Young, A. (2001). Milk urea nitrogen test (MUN). AG/Dairy-01, Utah State University, Logan, Utah. Retrieved December 12, 2015, from http://extension.usu.edu/files/publications/publication/AG_Dairy-01.pdf.

EFFECTS OF ANTIBIOTIC GROWTH PROMOTERS ON BIOCHEMICAL AND HAEMATOLOGICAL PARAMETERS OF BROILER CHICKENS' BLOOD

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Abstract
This study was designed with the aim to determine the impact of residual antibiotics on haematological and biochemical constituents of broiler chickens' blood. For this, one-day-old chickens were randomly divided into four equal groups with 10 individuals in each group (n = 40). All groups of chickens fed with commercial basal diet; the first group considered as control, fed only with basal ration; the feed of the second, third and fourth groups of chicken were supplemented with amoxystin, tetracycline and chloramphenicol, respectively. Antibiotics were given daily, individually, in sub-therapeutic concentrations: amoxystin at the dosage 10 mg kg^{-1}, tetracycline and chloramphenicol – 20 mg kg^{-1} of the chicken's weight for 41 days. The blood parameters were measured at the end of experiment on the 42nd day. In comparison with the control group, decreasing of leukocytes was observed in the 2nd and 4th groups, and increasing in the 3rd group of broilers. The concentration of erythrocytes and hemoglobin was reduced in the 2nd group and hematocrit was higher in the 3rd and 4th groups ($p \leq 0.01$). The total protein was decreased by 22% in the 2nd group, 16% – in the 3rd and 4th groups as compared to the control group ($p \leq 0.01$) in blood serum. The concentration of glucose was decreased by 45.8, 46.5 and 51.5% in the second, third and fourth groups of treated birds, respectively, compared to those of birds in the control group ($p \leq 0.01$). Based on the results it could be concluded that antibiotics influence the dynamics of haematopoiesis and biochemical indices of broilers.
Key words: Amoxystin, Tetracycline, Chloramphenicol, Broiler, Blood Parameters.

Introduction

Large amounts of antimicrobial agents are widely used in veterinary medicine for the prevention and treatment of diseases caused by microorganisms (Singer *et al*., 2003; Dantas *et al*., 2008), and more controversially, antimicrobial agents used and managed as feed additives or with drinking water for therapeutic, prophylactic purposes (Blasco, Torres, & Pico, 2007; Fabrega *et al*., 2008; Morales-Gutierrez, Barbosa, & Barron, 2015) as well as to improve the ability of animals to convert feed into body weight (Turnidge, 2004; Aarestrup, 2005; da Costa *et al*., 2010).

The theoretical possibility of stimulating action of some microbial agents on the growth of animals was shown in the forties of the XX century. Animal growth acceleration was explained by the presence of stimulants in the culture of used bacteria (Fedorov, 1974). It was found that the daily feed supplement for piglets and chickens contains small portions of definite soil bacterial species associated to the interaction with intestinal microbial population that accelerated growth and increased the weight gain of animals compared with the controls (Dibner & Richards, 2005; Niewold, 2007).

Antibiotic growth promoters are used to destroy or inhibit bacteria and are administered at a low, sub-therapeutic dose (Hao *et al*., 2014). Lee, *et al.* established that antibiotics promote improving the body weight through more efficient digestion of feed in growing animals (Lee *et al*., 2011). These promoters are now recognized in broiler industry as additives to shorten the period for attaining the market weight by stimulating growth: to improve feed efficiency and survivability of broilers (Hossain, Khairunnesa, & Das, 2015).

Although antimicrobial therapy chemicals and their use as growth promoters are of essential importance in maintaining animal health (Bywater, 2004; Prescott, 2008; Persoons *et al*., 2012), the use of antibiotics, along with a positive effect, leads to the emergence and widespread resistance of pathogens to antibiotics. This situation complicates the treatment of animal infectious diseases (Navashin & Fomina, 1982), as well as they adversely affect the immunegenesis and contribute to the sensitization of the human body (Abdullaev, 2006).

As the same classes of antimicrobials are used both in humans and animals, the emergence and spread of antimicrobial resistance in bacteria poses a threat to human health and presents a major financial burden. Moreover, few new antibiotics are being developed to replace those becoming ineffective through resistance (World Health Organization, 2007).

In the last few years, the concern about the use of veterinary drugs such as antibiotics in food-producing animals and their possible negative consequences for the health of consumers has made the control of these

residues in edible animal tissues mandatory at the EU. Maximum residue limits (MRLs) of antibiotics in foodstuffs of animal origin such as multiple animal tissues were established by the Commission Regulation (EC) № 37/2010 (EU Commission, 2010) for safe human consumption.

In 2007, the World Health Organization recommended stopping intensive routine use of antimicrobials for productive animals (Collignon *et al*., 2009), however, antibiotics, except for the prevention and treatment of animals, are still used as growth promoters in the world.

The consequences of the use of antibiotics are very diverse and appear as a failure of individual organs and systems in general. One of the most sensitive systems is the haematopoietic system. The process of haematopoiesis in the body is carried out continuously, and the young dividing cells are very sensitive to the action of drugs (Stolker & Brinkman, 2005).

Toxic effects of drugs on the process of haematopoiesis cause a change of blood parameters. For example, the toxic effect of chloramphenicol on the process of haematopoiesis is manifested by leucopenia. And using of amoxicillin, which is a part of the synthetic antibiotic 'Amoxystin', showed neutropenia and eosinophilia. When tetracycline was applied, there was observed an increase in blood transaminases and alkaline phosphatase (Stolker & Brinkman, 2005).

The aim of this study was to assess the impact of antibiotics used as growth promoters on the haematological and biochemical blood parameters of broiler chickens.

Materials and Methods

The experiment was carried out on 40 broiler chickens of 'Smena-7' cross from 'Allele-Agro' poultry farm's hatchery in the vivarium of the Kazakh National Agrarian University. As objects of research four groups of one-day broiler chickens were randomly formed by 10 birds in each group. The feeding of broilers was performed according to the instructions on the industrial poultry farm scheme 'Allele-Agro' with commercial basal diet. The chickens were allowed to have free access to feed and water.

The first control group of chickens received a basal diet without treatment. Other chicken groups were daily treated with antibiotics individually in aqueous solution, orally in sub-therapeutic concentrations of antibiotics as growth promoters from the first to day 41. So the second group of broilers was medicated with synthetic antibiotic amoxystin at the dosage 10 mg kg^{-1} of the chicken's weight. The third group of broilers was given tetracycline, and the fourth group – chloramphenicol at the dosage 20 mg kg^{-1} of the chicken's weight. Blood in the amount of 9 cm^3 for haematological and 3 cm^3 for biochemical study was collected from the jugular vein of each chicken on the 42nd day of slaughter.

Study of whole blood, stabilized with lithium-heparin, was performed at the Laboratory of Food Safety in the Kazakh Research Veterinary Institute. The following haematological parameters as leukocytes (lymphocytes, monocytes, granulocytes), erythrocytes, hematocrit, hemoglobin concentration, platelet and trombocrit were determined by the haematology analyzer Melet Schloesing MS4-3 with veterinary dial (France). In the separated serum the total protein, triglycerides, alkaline phosphatase (ALP), cholesterol, glucose, urea, alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were established by BioChem FC-360 (US) analyzer at the Digestion Physiology Laboratory in the Human and Animal Physiology Institute. The used laboratory equipment has been annually standardized according to the Kazakhstan state rules.

Basic data entry and handling were done using MS Excel 2007. The significance of difference among the groups was determined by one-way analysis of variance (ANOVA) and t-test. Differences were considered significant at $p<0.01$ levels.

The study was approved by the Local Ethical Committee of the Kazakh National Agrarian University, in accordance with the ethical standards of Principles of Animal Care.

Results and Discussion

Throughout the experiment broiler mortality was not observed. Visual physiological state and behavioral response of broiler chickens of experimental groups did not differ from the control group.

Analysis of haematological parameters showed that under a prolonged exposure to sub-therapeutic concentrations of antibiotics the quantitative and qualitative changes in some blood indices of broilers were observed (Table 1). There was established a marked change in the number of leukocytes towards reduction in the case of amoxystin ($p\leq0.01$) and chloramphenicol ($p\leq0.01$) and an increase in the tetracycline group compared to the control group of broilers. Antibiotics exert a significant impact on leukogram: under the influence of amoxystin and tetracycline ($p\leq0.01$) the relative proportion of granulocytes and lymphocytes increased but monocytes ($p\leq0.01$) decreased. Analogue leukocytosis and limphocytopenia had shown after intramuscular using of therapeutic doses of tetracycline in broiler chickens (Donkova, 2004).

The number of erythrocytes and the amount of hemoglobin were reduced after amoxystin application. In the groups that were given tetracycline ($p\leq0.01$) and chloramphenicol ($p\leq0.01$), an increase of hematocrit

Table 1

Haematological parameters of broilers blood

Parameters		Leukocytes (m/mm³)	Lymphocytes (%)	Monocytes (%)	Granulocytes (%)	Erythrocytes (m/mm³)	Hematocrit (%)	Hemoglobin concentration (g/dL)	Platelet (m/mm³)	Trombocrit (%)
Control, n = 10	M	23.14	41.62	11.49	46.89	2.50	19.98	9.28	573.1	0.53
	SEM	0.34	2.10	0.05	1.06	0.04	0.27	0.09	43.28	0.04
	σ	1.07	6.64	0.17	3.35	0.13	0.87	0.28	136.85	0.14
	C_v	4.61	15.95	1.45	7.15	5.37	4.34	3.00	23.88	25.46
Amoxystin, n = 10	M	18.55*	37.28	8.26*	51.24	2.25	19.34	8.44	475.3	0.40
	SEM	0.87	0.86	0.19	1.64	0.11	0.60	0.27	21.25	0.02
	σ	2.26	2.73	0.61	5.18	0.35	1.90	0.86	67.19	0.06
	C_v	14.88	14.60	7.40	10.11	15.74	9.83	10.18	14.14	15.53
Tetracycline, n = 10	M	24.72	35.71	8.24*	56.05*	2.64	23.52*	9.31	395.3*	0.32*
	SEM	0.55	1.34	0.21	1.57	0.05	0.68	0.19	32.53	0.03
	σ	1.73	4.23	0.67	4.97	0.16	2.15	0.62	102.87	0.10
	C_v	7.00	11.83	8.13	8.87	6.24	9.13	6.61	26.02	32.53
Chloram-phenicol, n = 10	M	19.85*	42.86	11.03	46.15	2.85	23.9*	9.7	432.0*	0.43
	SEM	0.71	0.30	0.33	0.73	0.16	0.54	0.08	10.22	0.01
	σ	2.26	0.95	1.06	2.31	0.51	1.70	0.24	32.31	0.02
	C_v	11.37	2.22	9.60	5.01	17.85	7.08	2.53	7.48	5.18

*Value with common superscript differed significantly from the control group ($p \leq 0.01$).
M – mean, SEM – standard error of sample means, σ – standard deviation, C_v – coefficient of variation.

was observed. A more significant decrease in platelet count and trombocrit was observed in all experimental groups of chickens, than in the control.

These results allow to suggest that a prolonged use of antibiotics in stimulating doses contributed to changes in the blood system and reduced the overall resistance of broiler chickens.

Biochemical study revealed the changes in blood indices of broiler chickens which were given antibiotics (Table 2). An important parameter for the diagnosis of diseases associated with the metabolic disorder is the total protein content. By results of research, it was observed that the amount of total protein in the control group was significantly higher – by 22% – than in the group of broilers which received amoxystin ($p \leq 0.01$), by 16% – in the groups with diet supplemented with tetracycline ($p \leq 0.01$) and chloramphenicol ($p \leq 0.01$). These changes could indicate a protein metabolism disturbance.

Activity of alkaline phosphatase in the control group was higher than 23.9% in comparison with the group where tetracycline ($p \leq 0.01$) was used and by 12.3% than in the group of chloramphenicol.

The level of carbohydrate metabolism was determined by the glucose content. Blood glucose of chickens in the control group was also significantly higher ($p \leq 0.01$) – by 45.8% – than in the group of amoxystin, by 46.5% – of tetracycline and by 51.5% – in the group of chloramphenicol. The same change processes of gluconeogenesis and decreasing of total protein were described when the broilers were treated by tetracycline (Donkova, 2004).

In assessing the activity of transaminases, it was established that the activity of ALT in the blood of chickens which received antibiotics was significantly reduced: by 30.7% in the group treated with amoxystin, by 34.6% in the tetracycline group and by 37% in the group of chloramphenicol ($p \leq 0.01$). The activity of AST in the group that was given amoxystin was inferior to the control by 14.1%, in the group of tetracycline – by 11.1% and chloramphenicol – by 13.6%. Perhaps it was caused by the major toxic effect mechanism of antibiotics which included their potential to cause lipid peroxidation, which is primarily responsible for toxication and tissue damage (Farombi, 2001).

Table 2

Biochemical parameters of broilers blood serum

Parameters		Total protein (g/l)	Triglycerides (mmol/l)	ALP (U/l)	Cholesterol (mmol/l)	Glucose (mmol/l)	Urea (mmol/l)	ALT (U/l)	AST (U/l)
Control, n = 10	M	35	2.49	1057	3.15	15.05	1.26	12.7	245.3
	SEM	0.77	0.01	33.28	0.12	0.78	0.16	1.07	8.94
	σ	2.45	0.02	105.25	0.37	2.47	0.49	3.37	28.26
	C_v	7.00	0.83	9.96	11.73	16.41	39.10	26.52	11.52
Amoxystin, n = 10	M	27.3*	2.50	1134.3	2.97	8.15*	1.15	8.8*	210.8
	SEM	0.95	0.002	55.25	0.05	0.76	0.14	0.70	4.62
	σ	3.02	0.005	174.71	0.15	2.40	0.45	2.20	14.61
	C_v	11.06	0.19	15.40	5.06	29.46	38.94	25.01	6.93
Tetracycline, n = 10	M	29.3*	2.45	804*	2.95	8.05*	0.54*	8.3*	218
	SEM	1.28	0.02	27.43	0.13	1.77	0.07	0.3	2.35
	σ	4.06	0.05	86.74	0.42	5.60	0.23	0.95	7.42
	C_v	13.84	2.00	10.79	14.10	69.56	42.05	11.43	3.41
Chloramphenicol, n = 10	M	29.5*	2.55*	928.5	3.03	7.3*	1.54	8.0*	212.0
	SEM	0.31	0.02	14.33	0.03	0.22	0.02	0.26	1.11
	σ	0.97	0.07	45.33	0.08	0.70	0.05	0.82	3.50
	C_v	3.29	2.64	4.88	2.77	9.50	3.35	10.21	1.65

*Value with common superscript differed significantly from the control group ($p \leq 0.01$).
M – mean, SEM – standard error of sample means, σ – standard deviation, C_v – coefficient of variation.

In our study, the level of triglycerides, cholesterol and urea in the control and experimental groups of broiler chickens did not deviate from indices of the control group chickens.

The analysis of the data show that all tested antibiotics adversely affect the biochemical parameters of blood, which is apparently connected with the negative impact of these xenobiotics on the liver and other internal organs of broiler chickens.

Conclusion

The use of growth stimulating doses of amoxystin, tetracycline and chloramphenicol during feeding of chicken promotes changes in haematological and biochemical parameters of broiler chickens' blood, which causes decrease of immune status and results in the violation of the haematopoietic system and liver function and, ultimately, affects the overall quality of the slaughter poultry products.

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References

1. Aarestrup, F.M. (2005). Veterinary drug usage and antimicrobial resistance in bacterial of animal origin. *Basic and Clinical Pharmacology and Toxicology*, 96(4), 271-281. DOI: 10.1111/j.1742-7843.2005.pto960401.x.
2. Abdullaev, A.M. (2006). *Влияние биологически активных соединений (L-лизин и лактобифадол) на естественную резистентность и продуктивность цыплят-бройлеров (Influence of biologically active compounds (L-lysine and laktobifadol) on natural resistance and efficiency of broiler chickens).*

Published candidate dissertation, Moscow State Academy of Veterinary Medicine and Biotechnology by K.I. Skryabin, Moscow, Russian Federation. (in Russian).
3. Blasco, C., Torres, C.M., & Pico, Y. (2007). Progress in analysis of residual antibacterials in food. *Trac-Trends in Analytical Chemistry*, 26(9), 895-913. DOI: 10.1016/j.trac.2007.08.001.
4. Bywater, R.J. (2004). Veterinary use of antimicrobials and emergence of resistance in zoonotic and sentinel bacteria in the EU. *Journal of Veterinary Medicine. B: Infectious Diseases and Veterinary Public Health*, 51(8-9), 361-363. DOI: 10.1111/j.1439-0450.2004.00791.x.
5. Collignon, P., Powers, J.H., Chiller, T.M., Aidara-Kane, A., & Aarestrup, F.M. (2009). World Health Organization ranking of antimicrobials according to their importance in human medicine: A critical step for developing risk management strategies for the use of antimicrobials in food production animals. *Clinical Infectious Diseases*, 49(1), 132-141. DOI: 10.1086/599374.
6. da Costa, P.M., Bica, A., Vaz-Pires, P., & Bernardo, F. (2010). Changes in antimicrobial resistance among faecal enterococci isolated from growing broilers prophylactically medicated with three commercial antimicrobials. *Preventive Veterinary Medicine*, *93*(1), 71-76. DOI: 10.1016/j.prevetmed.2009.09.012.
7. Dantas, G., Sommer, M.O.A., Oluwasegun, R.D., & Church, G.M. (2008). Bacteria Subsisting on Antibiotics. *Science*, 320(5872), 100-103. DOI: 10.1126/science.1155157.
8. Dibner, J.J., & Richards, J.D. (2005). Antibiotic growth promoters in agriculture: history and mode of action. *Poultry Science*, 84(4), 634-643. DOI: 10.1093/ps/84.4.634.
9. Donkova, N.V. (2004). *Морфофункциональные изменения органов гомеостатического обеспечения у кур в постнатальном онтогенезе и при воздействии лекарственных ксенобиотиков (Morphological changes of homeostatic maintenance of hens in a postnatal ontogenesis under the influence of drugs and xenobiotics)*. Published doctoral dissertation, Krasnoyarsk state agrarian university, Krasnoyarsk, Russian Federation. (in Russian).
10. EU Commission. (2010). Commission regulation (EU) No 37/2010 of 22 December 2009 on pharmacologically active substances and their classification regarding maximum residue limits in foodstuffs of animal origin. *Off J Eur Union. L*, *15*(1).
11. Fabrega, A., Sanchez-Cespedes, J., Soto, S., & Vila, J. (2008). Quinolone resistance in the food chain. *International Journal of Antimicrobial Agents*, 31(4), 307-315. DOI: 10.1016/j.ijantimicag.2007.12.010.
12. Farombi, E.O. (2001). Antioxidant status and hepatic lipid peroxidation in Chloramphenicol-treated rats. *The Tohoku Journal of Experimental Medicine*, 194(2), 91-98. DOI: 10.1620/tjem.194.91.
13. Fedorov, A.A. (1974). *Жизнь растений (Plant Life).* Moscow: Prosveschenie, Volume 1, pp. 428-429. (in Russian).
14. Hao, H., Cheng, G., Iqbal, Z., Ai, X., Hussain, H., & Huang, L. et al. (2014). Benefits and risks of antimicrobial use in food-producing animals. *Front. Microbiol.* 5, 87-97. DOI: 10.3389/fmicb.2014.00288.
15. Hossain, M.F., Khairunnesa, M., & Das, S.C. (2015). Use of non-antibiotic growth promoter "Grow Power" in commercial broiler diet. *Bangladesh Journal of Animal Science*, 44(1), 33-39. DOI: 10.3329/bjas.v44i1.23139.
16. Lee, D.N., Lyu, S.R., Wang, R.C., Weng, C.F., & Chen, B.J. (2011). Exhibit differential functions of various antibiotic growth promoters in broiler growth, immune response and gastrointestinal physiology. *International Journal of Poultry Science*, 10(3), 216-220. DOI: 10.3923/ijps.2011.216.220.
17. Morales-Gutierrez, F.J., Barbosa, J., & Barron, D. (2015). Metabolic study of enrofloxacin and metabolic profile modifications in broiler chicken tissues after drug administration. *Food Chemistry*, 172, 30-39. DOI: 10.1016/j.foodchem.2014.09.025.
18. Navashin, S.M., & Fomina, I.P. (1982). *Рациональная антибиотикотерапия (Rational antibiotic therapy)*. Moscow: Medicina, pp. 421-427. (in Russian).
19. Niewold, T.A. (2007). The nonantibiotic anti-inflammatory effect of antimicrobial growth promoters, the real mode of action? A hypothesis. *Poultry Science*, 86(4), 605-609. DOI: 10.1093/ps/86.4.605.
20. Persoons, D., Dewulf, J., Smet, A., Herman, L., Heyndrickx, M., & Martel, A. et al. (2012). Antimicrobial use in Belgian broiler production. *Preventive Veterinary Medicine*, 105(4), 320-325. DOI: 10.1016/j.prevetmed.2012.02.020.
21. Prescott, J.F. (2008). Antimicrobial use in food and companion animals. *Animal Health Research Reviews*, *9*(02), 127-133. DOI: 10.1017/S1466252308001473.
22. Singer, R.S., Finch, R., Wegener, H.C., Bywater, R., Walters, J., & Lipsitch, M. (2003). Antibiotic resistance – the interplay between antibiotic use in animals and human beings. *The Lancet Infectious Diseases*, 3(1), 47-51. DOI: 10.1016/S1473-3099(03)00490-0.

23. Stolker, A.A.M., & Brinkman, U.T. (2005). Analytical strategies for residue analysis of veterinary drugs and growth-promoting agents in food-producing animals-a review. *Journal of Chromatography A, 1067*(1), 15-53. DOI: 10.1016/j.chroma.2005.02.037.
24. Turnidge, J. (2004). Antibiotic use in animals – prejudices, perceptions and realities. *Journal of Antimicrobial Chemotherapy*, 53(1), 26-27. DOI: 10.1093/jac/dkg493.
25. World Health Organization. (2007). Critically important antimicrobials for human medicine: categorization for the development of risk management strategies to contain antimicrobial resistance due to non-human antimicrobial use: report of the second WHO Expert Meeting, Copenhagen, 29-31 May 2007.

COMPUTED TOMOGRAPHY FINDINGS OF DOGS WITH MEDIAL CORONOID DISEASE

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Abstract
Canine elbow dysplasia is an heritable orthopaedic disease which includes medial coronoid disease, osteochondritis dissecans and ununited anconeal process, as well as, elbow incongruity. Medial coronoid disease (MCD) is one of the most frequent part of elbow dysplasia syndrome. The aim of the study was to describe medial coronoid process CT findings in dogs with thoracic limb lameness. In cases where there is suspicion of medial coronoid disease for dogs with lameness, an orthopaedic examination and CT were performed. CT examination was done with Philips MX-16 – slice CT scanner. The study represents data from a time frame between September 2014 and December 2015. Examinations were done at The Faculty of Veterinary Medicine, Latvia University of Agriculture. The study included 20 large breed dogs, 14 males and 6 females, ages ranging from 6 to 60 months, with a median age of 21.7 ± 13.7 months. Results showed that, in most cases, the dogs had subtrochlear sclerosis of the ulna and fragmentation of medial coronoid. Computed tomography revealed 12 dogs with medial coronoid disease in both elbows, whereas 8 dogs only in one of the elbow joints.
Key words: canine elbow dysplasia, joints, orthopaedic disease, congenital disease, biceps muscle.

Introduction

Canine elbow dysplasia (ED) is a disease of elbow joints in dogs (*Canis lupus familiaris*). According to the International elbow working group (IEWG) definition, elbow dysplasia includes – medial coronoid disease, osteochondritis dissecans, ununited anconeal process, elbow incongruity (Kirberger & Fourie, 1998) and secondary arthrosis caused by these pathologies (Lang *et al*., 1998).

Medial coronoid disease (MCD) is the most frequently diagnosed component of the elbow dysplasia syndrome (Lau *et al*., 2015). Medial coronoid disease is a common debilitating condition of large and giant breed dogs (German Shepheard dogs, Rottweilers, Bernese Mountain dogs), however, medial coronoid disease has also been described in small-breed dogs (French Bulldog, English Cocker Spaniel) (Bakker *et al*., 2013).

MCD includes different pathologies, however, in the most cases, the diagnose is ulnar subtrochlear sclerosis (STS), blurring of the cranial edge of the medial coronoid process (MCP), MCP fragmentation and displaced fragment (Temwichitr, Leegwater, & Hazewinkel, 2010; Lau *et al*., 2015). Medial coronoid disease can be caused by multiple factors and etiology is still unclear. It is considered that environmental factors and genetic heritability play a role in predisposing dogs to this syndrome (Kirberger & Fourie, 1998; Micheflsen, 2013). Although causes of this disease are not entirely clear, however the latest research studies show that the disturbance of endochondral ossification and osteonecrosis play a major role in the development of this disease (Mariee, Gröne, & Theyse, 2014). In some cases, medial coronoid disease can be considered together with flexor enthesopathy (Bakker *et al*., 2013).

Radiography, computed tomography (CT), magnetic resonance imaging (MRI), arthroscopy, nuclear scintigraphy and micro-single photon emission tomography have been suggested for the diagnosis of pathologies in the elbow joints (Kirberger & Fourie, 1998; Villamonte-Chevalier *et al*., 2015). These techniques are representative, but some of them are very expensive and not always are available (Villamonte-Chevalier *et al*., 2015). Computed tomography is more sensitive than radiographs and is very often used in veterinary clinics to diagnose elbow dysplasia (Kunst *et al*., 2014; Villamonte-Chevalier *et al*., 2015).

Until now, no studies have been performed in Latvia on canine elbow dysplasia, although this syndrome has been spread among dogs of various breeds.

The aim of the study was to describe medial coronoid process CT findings in dogs with thoracic limb lameness. We hypothesized that dogs with medial coronoid disease often have ulnar subtrochlear sclerosis and fragmentation of medial coronoid.

It is important to describe and study the cause of elbow dysplasia syndrome, because the breed dog reproduction in Latvia is increasing and if the dogs are diagnosed with elbow dysplasia, one of the main tasks should be the elimination of reproduction of these dogs.

Materials and Methods

The study represents data from a time frame between September 2014 and December 2015. All examinations were done at the Faculty of Veterinary Medicine, Latvia University of Agriculture.

The study included 20 dogs, 14 males (70%) and 6 females (30%); ages ranging from 6 to 60 months,

with a median age of 21.7 ± 13.7 months. The median body weight was 35.4 ± 7.6 kg (range 22 – 40 kg). The study included nine breeds – German Sheheard dog (6), Labrador retriever (5), Golden retriever (2), Burmese Mountain dog (2), Rottweiler (1), Cane Corso (1), Pyrenees Mountain dog (1), King Charles spaniel (1), Weimaraner (1).

A general clinical and orthopaedic examination was performed for all dogs. Afterwards, if a medial coronoid disease was suspected, then a computed tomography of elbow joints was performed. All dogs had a history of intermittent or persistent lameness and pain reaction on joint extension and flexion. Blood creatinine and carbamide (Urea) values were obtained prior to the computed tomography and if results formed part of the reference intervals (Meyer & Harvey, 2008), then dogs were included in our research.

Dogs were anaesthetized with propofol 5 mg kg^{-1} of body weight administered intravenously and after that endotracheal intubation carried out. During the CT examination, anaesthesia was maintained with Isofluran and 100% oxygen. Patient heartbeat, blood pressure, breathing, oxygen saturation and body temperature were monitored using 'Bionet BM3 Vet ' veterinary monitor.

Computed tomography examination was done using Philips MX – 16- slice CT scanner. At the time of CT scanning, dogs were positioned in dorsal recumbency on the scanner table with the front limbs extended cranially and the antebrachial parallel to each other.

The first scan from the carpus up to the collum of the scapula was done using the soft tissue and bone reconstructions, with the technical parameter – 120 kVp (kilovoltage peak) and 2 mm slice thickness and scan for elbow joints using 120 kVp and 0.7 mm slice thickness.

Before the second CT scan, non-ionic contrast media ('Ultravist 300', 2 mL kg^{-1}) was administered intravenously. The second scan was from the carpus up to the collum of the scapula with 2 mm slice thickness and scan for both elbow joints using high resolution scans (0.7 mm slice thickness) in a bone reconstruction has been done two minutes after giving the contrast media. High-resolution CT is faster, less invasive, and more accurate than other scans.

Data were analysed using Horos medical image viewer and descriptive statistics were used.

Results and Discussion

Most of the included dogs were large and fast growing breeds, however, one King Charles spaniel was included in the study with the fragmentation of medial coronoid and it coincides with the literature, that MCD has also been described in the small-breed dogs (Bakker *et al*., 2013). Of the 20 dogs, 14 were male and this coincides with some authors' view, that MCD often occurs in male dogs (Hazewinkel & Voorhout, 1986; sVillamonte-Chevalier *et al*., 2015).

Usually for canine elbow dysplasia CT examination using of contrast media is not necessary, but in our cases it was important for further research to do muscle morphometric measurements. Blood analysis has been done before the contrast media accumulation, to figure out the kidney functional condition, because the contrast media excrets through kidneys. The included dogs' blood creatinine and Urea values formed part of the reference intervals.

Computed tomography revealed that 12 (60%) dogs had the medial coronoid disease in both elbows, but 8 dogs (40%) in one of the elbow joints. A total of 40 elbow joints were analysed during the study.

Computed tomography results showed that 34 (85%) joints had ulnar subtrochlear sclerosis, 24 (60%) fragmented medial coronoid disease (FMCD) and 14 (35%) joints had arthritic changes. Incongruity of the elbow joints was not found. High resolution computed tomography scans were used in this study and reconstructed data were reconstracte using a sharp bone algorithm, and it provided an opportunity to assess more accurately the elbow joints and describe pathological changes (Baker *et al*., 1988).

Our research results showed, that STS was diagnosed in 34 of 40 elbow joints, but 14 joints had fragmented medial coronoid and 11 dogs were male with a majority of German Shepherd dogs, Labradors, Golden Retrievers and Barnese Mountain dogs. Considering that, one of the most common findings of MCD is the fragmentation of medial coronoid disease (Fitzpatrick *et al*., 2009). In most of the cases, the joints with fragmented medial coronoid also had subtrochlear sclerosis of ulna, which may indicate that STS is an early change and other pathologies develop later. STS can be used as an indicator of medial coronoid disease (Fitzpatrick *et al*., 2009).

CT findings in our study show similar results as previous research and support the hypothesis that dogs with MCD often have ulnar subtrochlear sclerosis and fragmentation of medial coronoid.

Although the findings of medial coronoid disease have been already described in several studies in other countries, so far there have been studies on elbow dysplasia in dogs in Latvia. On the first stage of our study results, it is important to make further measurements of developing the medial coronoid disease causes and to determine the correlation between biceps muscle conformation and MCD. These measurements are important because there is a perception, that biceps/brachialis muscle forces could play a role in the development of MCD (Michelsen, 2013).

Conclusions

1. Subtrochlear sclerosis of the ulna is an early indicator of canine medial coronoid disease and might be diagnosed before the development of other pathological changes in elbow joints.
2. Medial coronoid disease is a common orthopaedic pathology with a prevalence mainly among fast growing large breeds and more often affects young male dogs with a majority of them being German Shepherd dogs and Labrador retrievers.
3. High resolution computed tomography scans with 0.7 mm slice thickness, provide a greater information about elbow joints and facilitate medial coronoid disease diagnostics, which is important in particular when the disease is at an early stage.

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References

1. Baker, M.E., Martinez, S., Kier, R., & Wain, S. (1988). High resolution computed tomography of the cadaveric sternoclavicular joint: Findings in degenerative joint disease. *Journal of Computed Tomography*, 12(1), 13-18. DOI: 10.1016/0149-936X(88)90022-7.
2. Bakker, E., Gielen, I., Caelenberg, A., Bree, H., & Ryssen, B. (2013). Computed tomography of canine elbow joints affected by primary and concomitant flexor enthesopathy. *Veterinary Radiology & Ultrasound: The Official Journal of the American College of Veterinary Radiology and the International Veterinary Radiology Association*, 55(1), 45-55. DOI: 10.1111/vru.12091.
3. Fitzpatrick, N., Smith, T.J., Evans, R.B., & Yeadon, R. (2009). Radiographic and arthroscopic findings in the elbow joints of 263 dogs with medial coronoid disease. *Veterinary Surgery: VS*, 38(2), 213-23. DOI: 10.1111/j.1532-950X.2008.00489.
4. Hazewinkel, H.A., & Voorhout, G. (1986). Examination and treatment of a loose medial coronoid process in dogs. *Tijdschrift Voor Diergeneeskunde*, 111(24), 1234-1245. Retrieved February 20, 2016, from http://www.ncbi.nlm.nih.gov/pubmed/3824323.
5. Kirberger, R.M., & Fourie, S.L. (1998). Elbow dysplasia in the dog : pathophysiology, diagnosis and control: review article. *Journal of the South African Veterinary Association*, 69(2), 43-54. DOI: 10.4102/jsava.v69i2.814.
6. Kunst, C.M., Pease, A.P., Nelson, N.C., Habing, G., & Ballegeer, E.A. (2014). Computed tomographic identification of dysplasia and progression of osteoarthritis in dog elbows previously assigned OFA grades 0 and 1. *Veterinary Radiology & Ultrasound: The Official Journal of the American College of Veterinary Radiology and the International Veterinary Radiology Association*, 55(5), 511-20. DOI: 10.1111/vru.12171.
7. Lang, J., Busato, A., Baumgartner, D., Flückiger, M., & Weber, U.T. (1998). Comparison of two classification protocols in the evaluation of elbow dysplasia in the dog. *Journal of Small Animal Practice*, 39(4), 169-174. DOI: 10.1111/j.1748-5827.1998.tb03625..
8. Lau, S.F., Theyse, L.F.H., Voorhout, G., & Hazewinkel, H.A.W. (2015). Radiographic, Computed Tomographic, and Arthroscopic Findings in Labrador Retrievers With Medial Coronoid Disease. *Veterinary Surgery*, 44(4), 511-520. DOI: 10.1111/j.1532-950X.2014.12291.
9. Mariee, I.C., Gröne, A., & Theyse, L.F.H. (2014). The role of osteonecrosis in canine coronoid dysplasia: arthroscopic and histopathological findings. *Veterinary Journal (London, England: 1997)*, 200(3), 382-6. DOI: 10.1016/j.tvjl.2014.04.009.
10. Meyer, D.J., & Harvey, J.W. (2004). *Veterinary Laboratory Medicine Interpretation and Diagnosis*. USA: Saunders.
11. Michelsen, J. (2013). Canine elbow dysplasia: Aetiopathogenesis and current treatment recommendations. *The Veterinary Journal*, 196(1), 12-19. DOI: 10.1016/j.tvjl.2012.11.009.
12. Temwichitr, J., Leegwater, P.A.J., & Hazewinkel, H.A.W. (2010). Fragmented coronoid process in the dog: a heritable disease. *Veterinary Journal (London, England: 1997)*, 185(2), 123-9. DOI: 10.1016/j.tvjl.2009.06.022.
13. Villamonte-Chevalier, A., van Bree, H., Broeckx, B., Dingemanse, W., Soler, M., Van Ryssen, B., & Gielen, I. (2015). Assessment of medial coronoid disease in 180 canine lame elbow joints: a sensitivity and specificity comparison of radiographic, computed tomographic and arthroscopic findings. *BMC Veterinary Research*, 11(1), 243. DOI: 10.1186/s12917-015-0556-9.

THE EFFECT OF SEA BUCKTHORN (*HIPPOPHAE RHAMNOIDES*) EXTRACT ON *CRYPTOSPORIDIUM* SPP. INVASION IN CALVES

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Abstract
The present work aimed to evaluate the effect of sea buckthorn (*Hippophae rhamnoides*) extract on *Cryptosporidium* spp. invasion in calves. Sea buckthorn is a good source of vitamins, carotenoids, organic acids and tannins. It has been reported that it possesses anti-inflammatory effect, as well as anthelmintic and antibacterial activity. Research was conducted in a dairy cattle farm 'Mežacīruļi' during April and July 2015. Experimental (n = 10) and control (n = 10) groups of calves were used. The experimental group received a mix of aqueous alcohol sea buckthorn leaf and berry pomace extract, administered with milk, at dose of 5 – 8 mL twice a day for 20 days. The control group received only milk. Samples were analysed with the concentration McMaster technique. The results showed that there is no significant ($p>0.05$) difference in the number of oocysts per gram of feces between the experimental and control groups. It was concluded that the administration of sea buckthorn leaf and berry pomace extract had no effect on *Cryptosporidium* spp. invasion in calves. Studies will be continued with a higher dose of extract.
Key words: sea buckthorn, tannins, Cryptosporidium, calves, Latvia.

Introduction

Cryptosporidiosis is recognized worldwide, primarily in neonatal calves but also in lambs, kids, foals, and piglets. There are currently 19 species and 40 genotypes of *Cryptosporidium* spp. *C. parvum* is a common cause of calf diarrhea (mild to moderate), and cryptosporidium oocysts have been detected in the feces of 70% of 1- to 3-week-old dairy calves. Calves with persistent diarrhea have villous atrophy in the small intestine (O'Donoghue, 1995). Infection can be detected as early as 5 days of age, with the greatest proportion of calves excreting organisms between days 9 and 14 (Current, 1985).

The berries of sea buckthorn have been reported to be a good source of vitamins (A, C, E and K), carotenoids, flavonoids and organic acids (Gutzeit *et al*., 2008). Epigallocatechin and ursolic acid isolated from the branches of sea buckthorn exhibited anti-inflammatory effects (Kallio, Yang, & Peippo, 2002). Sea buckthorn fruits produced in Latvia are used as additives in acidified milk products (Segliņa, 2007). The shoots and green berries of female sea buckthorn plant contained the highest concentrations of condensed tannins, reaching 22.47 and 23.29 mg g^{-1} dry weight, respectively, which was about 20 times higher than in leaves of both genders (Šnē *et al*., 2013). However, it is mentioned, that the level of tannins in sea buckthorn can reach 13 mg g^{-1} condensed tannins (Michel *et al*., 2012).

Tannins are widely distributed in the plant kingdom (Mole, 1993). The ability of tannins to bind with proteins in the guts of mammals can have beneficial effects, depending on tannin concentration and nutrient levels. In cattle and other ruminants, moderate concentrations of condensed tannins (2 – 4% dry weight) reduce foaming of protein rich forage in the rumen and improve amino acid availability (McSweeney *et al*., 2001). Some tannin-rich forage has been evaluated for its anthelmintic and antibacterial activity (Mueller-Harvey, 2006). Tannins provided anthelmintic activity in many *in vitro* tests, adult nematodes exposed to commercial tannin extracts, from 25 mg mL^{-1} to 100 mg mL^{-1}, showed no motility inhibition after different exposure times. The authors suggested that adult worms may be more resilient to tannins compared to the larval stages (Iqbal *et al*., 2007).

There are no studies about anthelmintic effect of sea buckthorn on ruminants, but it is reported to possess unique health benefits. The main aim of the present study was to evaluate the effect of a mix of aqueous alcohol sea buckthorn *Hippophae rhamnoides* leaf and berry pomace extract on *Cryptosporidium* spp. invasion in calves.

Materials and Methods

Between April and July 2015, we collected fresh fecal specimens from newborn calves in the dairy cattle farm 'Mežacīruļi'. Animals were divided into two groups (n = 10 in each group). Starting with the second feeding the experimental group orally received a mix of aqueous alcohol sea buckthorn (*Hippophae rhamnoides*) leaf and berry pomace extract, which contains 3.2 g tannins in 100 mL. The starting dose was 5 – 8 ml, administered with milk, twice a day for 20 days. The control group received only milk. No other food supplements, drugs or vitamin injections were given or made. Rectal fecal samples were collected separately from each calf every day for 31 days, collected into plastic bags and kept in a refrigerator at 4 °C prior to examination. If the amount of feces was too small (especially in the first days of calves' life), native smears were made.

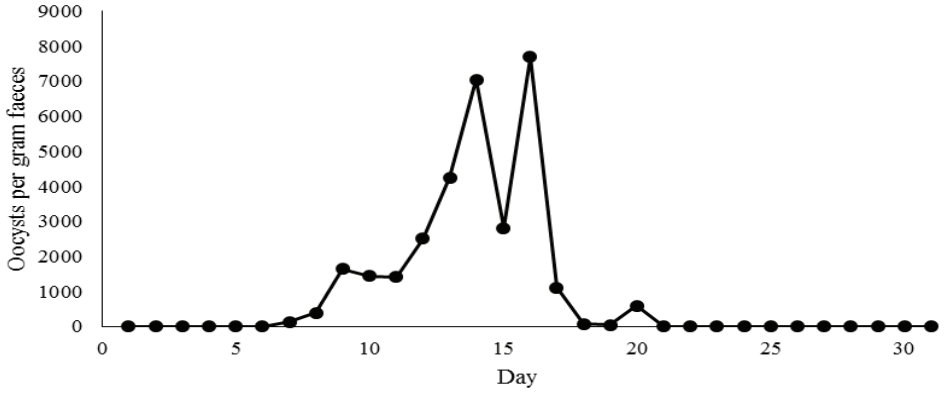

Figure 1. Shedding of oocysts in experimental group.

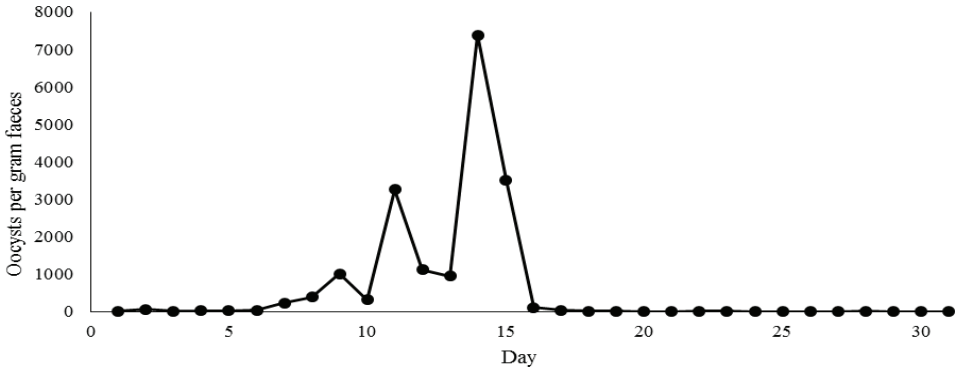

Figure 2. Shedding of oocysts in control group.

Laboratory tests were made in the Laboratory of parasitology, Institute of Food and Environmental Hygiene, Faculty of Veterinary Medicine, Latvia University of Agriculture. Samples were analyzed both with the concentration McMaster technique (Novan *et al*., 2006) and modified Ziehl-Neelsen method (Henriksen & Pohlenz, 1981). The difference in number of oocysts in the experiment and control groups was calculated using the t-test function in Microsoft Excel 2013 program.

Results and Discussion

Our research showed that calves in both groups were positive for oocysts of *Cryptosporidium* spp.

The main difference between two groups was in the number of bacteria in the stains. No identification of the bacterium was made. There were no bacteria in samples from the experimental group and a lot of bacteria in samples from control group during the first eleven days. After the eleventh day, no bacteria were matched. It could be explained with antibacterial activity of tannins (Funatogawa *et al*., 2004).

Shedding of oocysts in the experimental group is shown in Figure 1.

In the experimental group, the first *Cryptosporidium* spp. oocysts were detected in the feces starting with the seventh day. The highest oocysts count per gram of feces was on the fourteenth and sixteenth day (7050 and 7700 oocysts, respectively). After the twentieth day the number of oocysts was sharply reduced - from 585 oocysts on the twentieth day to 2.5 oocysts on the twenty first day. There are few reports on effects of tannins on new-born calves' digestive system. *In vitro* experiments (Khiaosa-Ard *et al*., 2009; Vasta *et al*., 2009) show positive effects on rumen, *in vivo* studies seem to suggest no significant or even negative effects (Benchaar & Chouinard, 2009).

Shedding of oocysts in the control group is shown in Figure 2.

In samples from the control group *Cryptosporidium* spp. oocysts were found starting with the first day. At the same time the number of oocysts per gram of feces on the fourteenth day was almost the same as in the experimental group – 7385 and 7050 oocysts, respectively. After the sixteenth day shedding of oocysts decrea sed and completely stopped after the nineteenth day. These findings are similar to the previous studies which report that *Cryptosporidium*

spp. infection in calves occurs at 5 – 15 days of age (Constable, 2014).

Our research showed that the administering of sea buckthorn leaf and berry pomace extract, containing 3.2 g tannins in 100 mL did not change *Cryptosporidium* spp. invasion ($p>0.05$). Therefore, we will continue studies to determine the effect of a higher dose of sea buckthorn extract on *Cryptosporidium* spp. invasion.

Conclusion

1. In the experimental group first *Cryptosporidium* spp. oocysts were detected in the feces starting with the seventh day. In the control group *Cryptosporidium* spp. oocysts were found in fecal samples starting with the first day.
2. The highest number of oocysts per gram of feces in both groups was on the fourteenth and sixteenth day in the experimental group and on the fourteenth day in the control group.
3. The administering of sea buckthorn leaf and berry pomace extract, containing 3.2 g tannins in 100 mL, did not change *Cryptosporidium* spp. invasion in calves ($p>0.05$). Studies will be continued with a higher dose of extract.

Acknowledgment

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References

1. Benchaar, C., & Chouinard, P.Y. (2009). Assessment of the potential of cinnamaldehyde, condensed tannins, and saponins to modify milk fatty acid composition of dairy cows. *Journal of Dairy Sciences* 92, 3392-3396. DOI: http://dx.doi.org/10.3168/jds.2009-2111.
2. Constable, P.D. (Last full review/revision May 2014). *Overview of Cryptosporidiosis*. Retrieved March 4, 2016, from http://www.merckvetmanual.com/mvm/digestive_system/cryptosporidiosis/overview_of_cryptosporidiosis.html.
3. Current, W.L. (1985). Cryptosporidiosis. *Journal of American Veterinary Medicine Association*. 187, 1334-1338.
4. Funatogawa, K., Hayashi, S., Shimomura, H., Yoshida, T., Hatano, T., Ito, H., & Iria, Y. (2004). Antibacterial activity of hydrolysable tannins derived from medicinal plants against *Helicobacter pylori*. *Microbiology and Immunology*, 48, 251-260. DOI: 10.1111/j.1348-0421.2004.tb03521.
5. Gutzeit, D., Baleanu, G., Winterhalter, P., & Jerz, G. (2008). Vitamin C content in sea buckthorn berries (*Hippophae rhamnoides L. ssp.*) and related products: a kinetic study on storage stability and the determination of processing effects. *Journal of Food Science*, 73, 615-620. DOI: 10.1111/j.1750-3841.2008.00957.
6. Henriksen, S.A., & Pohlenz, J.F.L. (1981). Staining of cryptosporidia by a modified Ziehl-Neelsen. *Acta Veterinaria Scandinavica* 22: 594-596. Retrieved March 16, 2016, from http://garfield.library.upenn.edu/classics1991/A1991GA09700001.pdf.
7. Iqbal, Z., Sarwar, M., Jabbar, A., Ahmed, S., Nisa, M., Sajid, M.S., Khan, M.N., Mufti, K.A., & Yaseen, M. (2007). Direct and indirect anthelmintic effects of condensed tannins in sheep. *Veterinary Parasitology*, 144, 125-131. DOI: 10.1016/j.vetpar.2006.09.035.
8. Kallio, H., Yang, B., & Peippo, P. (2002). Effects of different origins and harvesting time on vitamin D, tocopherols and tocotrienols in seabuckthorn (*Hippophae rhamnoides L.*) berries. *Journal of Agricultural and Food Chemistry*, 50, 6136-6142. DOI: 10.1021/jf020421v.
9. Khiaosa-Ard, R., Bryner, S.F., Scheeder, M.R.L., Wettstein, H.R., Leiber, F., Kreuzer, M., & Soliva, C.R. (2009). Evidence for the inhibition of the terminal step of ruminal alpha-linolenic acid biohydrogenation by condensed tannins. *Journal of Dairy Science* 92, 177-188. DOI: http://dx.doi.org/10.3168/jds.2008-1117.
10. Michel, T., Destandau, E., Le Floch, G., Lucchesi, M.E., & Elfakir, C. (2012). Antimicrobial, antioxidant and phytochemical investigations of sea buckthorn (*Hippophae rhamnoides L.*) leaf, stem, root and seed. *Food Chemistry*, 131, 754-760. DOI: 10.1016/j.foodchem.2011.09.029.
11. McSweeney, C.S., Palmer, B., McNeill, D.M., & Krause, D.O. (2001). Microbial interactions with tannins: nutritional consequences for ruminants. *Animal Feed Science Technology Journal*. 91, 83-93. DOI: 10.1016/S0377-8401(01)00232-2.
12. Mole, S. (1993). The systematic distribution of tannins in the leaves of angiosperms: a tool for ecological studies. *Biochemical Systematic and Ecology*. 21, 833-846. DOI: 10.1016/0305-1978(93)90096-A.
13. Mueller-Harvey, I. (2006). Unravelling the conundrum of tannins in animal nutrition and health. *Journal of the Science of Food and Agriculture*, 86, 2010-2037. DOI: 10.1002/jsfa.2577.

14. Novan, T., Church, M., Knight, D., Gilson, D., Dykhouse, C., & Mah, K. (2006) University of Pennsylvania School of Veterinary Medicine. *McMaster Egg Counting Technique*. Retrieved March 03, 2016, from http://cal.vet.upenn.edu/projects/parasit06/website/mcmaster.htm.
15. O'Donoghue, P.J. (1995). *Cryptosporidium* and cryptosporidiosis in man and animals. *Journal of Parasitol*ogy, 25: 139-195. DOI: 10.1016/0020-7519(94)E0059-V.
16. Segliņa, D. (2007). *Sea buckthorn fruits and their processing products.* PhD theses in Food Science. Latvia University of Agriculture, Jelgava.
17. Šnē, E., Segliņa, D., Galoburda, R., & Krasnova I. (2013). Content of phenolic compounds in various sea buckthorn parts. *Proceedings of the Latvian Academy of Sciences. Section B*, Vol. 67, No 4/5 (685/686), 411-415. DOI: 10.2478/prolas-2013-0073.
18. Vasta, V., Makkar, H.P.S., Mele, M., & Priolo, A. (2009). Ruminal biohydrogenation as affected by tannins in vitro. *British Journal of Nutrition*, 102, 82-92. DOI: http://dx.doi.org/10.1017/S0007114508137898.

THE CHANGES IN KAUNAS URBAN LANDSCAPE DURING THE PERIOD BETWEEN 2010 AND 2015

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Abstract
The paper presents the comparative analysis of the Kaunas city landscape change during the period between 2010 and 2015. For this analysis, the land fund statistics of the Republic of Lithuania, which had been grouped into a relatively natural and anthropogenic landscape, were used. Landscape change is graphically shown in the figures. Lithuanian and foreign scientific literature and legal acts as well as planning documents were analyzed for the fulfillment of the work. The Kaunas city landscape analysis of the current situation was done. During the analysis the Kaunas city statistics were compared with the data of Kaunas County and the Republic of Lithuania.
The analysis showed that during the analyzed period the Kaunas city natural landscape area relatively increased by 1115.34 ha or 20.42 percent. The largest part of relatively natural landscape consisted of forests – 51.12 percent. During the period between 2010 and 2015, the anthropogenic environmental area increased by 47.33 hectares (2.80 percent.). In the period between the years 2010 and 2015, the Kaunas city anthropogenic landscape decreased by 1.189.41 hectares or 12.23 percent. This phenomenon was affected by the decrease of built-up areas of 1,233.36 hectares, or 14.10 percent. Built-up areas cover the largest part of the Kaunas city anthropogenic landscape – 88.09 percent. The analysis of the planning documents showed that after their implementation the built-up areas would increase, the aesthetic image of recreational environment would improve, the environmental condition would become of a higher quality.
Key words: landscape, anthropogenic landscape, the landscape change.

Introduction

Article relevance. Landscape structure maintenance is the subject important and relevant to this day, as the landscape shapes the country's culture and is the component of natural and cultural heritage contributing to the quality of life and it consolidates Lithuanian identity, uniqueness in Europe and the world.

Over the last century Lithuanian cities have experienced several fundamental transformations of their urban form. From historical compact towns they became large cities with distinct characteristics of late-soviet era (Cirtautas, 2014).

In Lithuania, as well as throughout Central and Eastern Europe, territorial economic organizations, the territorial management system are radically changing, population migration is intensifying, urbanization is developing, other intensive public geographical processes are going on. Studies of those processes, with emphasis on the state and change of landscape structure are absolutely necessary in order to support and implement the principles of sustainable development, to form the optimal landscape that meets the needs of modern society.

The landscape structure optimality concept and its changes depend on public awareness, information and technical volatility (Skorpskas, 2001).

European Landscape Convention (European, 2000) describes the landscape as people perceived area, as determined by the nature and (or) the factors of human action and interaction.

It is noted that the landscape evolved and changed over time, exposed to nature and people.

In the convention, the concept of landscape differs from the concept contained in some documents in which the landscape is considered as 'property' (landscape concept of heritage sense) and evaluated (as 'cultural', 'natural' landscape and the like) as part of physical space (Recommendation, 2008).

Scientific opinion on the subjective dimension and the relevance of related sociological studies, while evaluating and developing the environment, is different. For example, professor P. Kavaliauskas criticizes the European Landscape Convention. According to him, of all the environmental concepts it stands out in terms of the dominant populist approach and even in the concept of landscape itself it emphasizes not the objective scientific understanding but the subjective one of the local population, which is focused on quality objective as the aspirations of the wording in relation to their surroundings landscape features, understanding. Meanwhile, scientists J. Stephenson, G. Swensen and G. B. Jerpasen emphasize the social dimension of the landscape and the local communities, planners and other specialists poll importance in the exploration and evaluation of landscapes (Gražulevičiūtė-Vileniškė, 2014).

According to the degree of anthropogenic impact, the two following basic types of landscape are being singled out (Bučas, 2010): natural and cultural. Professor Bučas says that the natural landscape is designated as human economic or other activities

intact or only slightly touched natural landscape, as such in Lithuania, as well as in many other countries, with the exception of reserves, does not exist. G. Kisielienė agrees with the professor, arguing that the natural landscape can be seen only in Lithuanian reserves (Kiselienė, 2012).

The Environmental Protection Agency in the publication 'Lithuanian natural environment, state, processes and development' (Aplinkos, 2008) stated that in general, the current Lithuanian cultural landscape of the territorial structure of the main features led to purposeful planning, experienced in strong centralized management.

Therefore, rural (agrarian) and urban (urbanized) landscape structures reinforce prints clearly defined by coded planning purposes and sought to benchmarks and a variety of the mentioned prints shape the structural diversity of cultural landscape of these days.

However, the landscape spatial structure diversity of the Republic of Lithuania and the types of identification study state (Lietuvos, 2005) that the cultural landscape consists of 15 percent of the Earth surface, 5 percent consist of incomplete, weak and marginalized anthropogenic structured nature landscape, 80 percent of the Earth consist of natural landscapes, from which 65 percent - marine, terrestrial nature covers 15 percent of the Earth's surface, or 38 percent of the entire planet's land.

Natural frame in Lithuania amounts to 61.4 percent of the whole territory of the country and it represents a large proportion of natural and semi-natural areas (Mieliauskas & Palaima, 2012).

According to the National landscape plan, the cultured agrarian nature landscape model should dominate in Lithuanian landscape formation. By one-fifth of the territory cover a mixture of forested little cultured and natural forested landscapes (Lietuvos, 2012).

In Lithuania, cities and other residential areas are spread evenly throughout the country and are well enough to reach, which makes it rational to distribute economic and social potential, to more rapidly expand regions lagging behind, to reduce the disparities in development (Nacionalinė darnaus, 2011).

However, anthropogenisation affects the natural environment, so the expansion of cities, its areas are decreasing and components are vulnerable. Thus, the landscape changes are connected with urban sprawl, the change in urban and natural areas ratio, landscape condition (from psychoecological point of view).

The modern city is faced with new forms and functions (Loureiro, 2014). Cities are experiencing prosperity and decline phases. With the change of policy and external environment, social processes, that influence urban change, are changing as well (Wekel & Koriakina, 2014).

The changes in the landscape caused by global urbanization, form territories distingiuished for new, unusual characteristics or their combinations. In order to better understand processes going on in the area of city's influence, scientists are developing theoretical models of urban and rural environmental interactions (Brinkytė & Gražulevičiūtė - Vileniškė, 2013).

Lithuanian landscape studies show that these issues are highly relevant and should be carried out continuously (Balevičiūtė & Veteikis, 2012).

The biggest gap is targeted studies of cities and towns involving long-term historical perspective. Lithuania is in exceptional situation – the country is at the intersection of Western and Eastern cultures, so a lot of its significant historical events are related to changing regimes and ideologies. This uniqueness determines imbalances and strains of specific urban structures characteristic to the development of cities and towns, eclectics and change of architectural styles, sporadity of cultural layer (Rubavičius, 2013).

The object of the research – Kaunas city landscape.

The aim of the research is to carry out the analysis of the changes in Kaunas City landscape during the period between 2010 and 2015.

Goals of the research:

1. To describe and analyze the current situation of natural and urban landscape elements of Kaunas city.
2. To analyse the changes in Kaunas city landscape during the period between 2010 and 2015.
3. To anticipate trends in landscape change.

Materials and Methods

Comparative, analytical as well as statistical and logical analysis methods were used for the research.

The article analyzed Lithuanian and foreign scientific literature and legal acts.

The analysis of the scientific literature revealed conflicting opinions on the issues of the term of landscape and naturalness of landscape. Also, the following planning documents were analysed in the work: the general plan of the Republic of Lithuania, the National landscaping plan, the general plan for Kaunas city territory and so on. The collected material was analyzed, systematized and generalized.

The land fund statistics of the Republic of Lithuania (Nacionalinė žemės, 2010 – 2015), graphically depicted in figures, were used for the fulfilment of the research of the Kaunas city landscape change for the years 2010 – 2015. During the study, Kaunas city landscape was divided into relatively natural landscape, anthropogenic and anthropogenized landscapes. Each type was analyzed, a five-year change was set.

During the analysis the Kaunas city statistics were compared with the data of Kaunas County and the Republic of Lithuania.

The paper presents the Kaunas city landscape change causes, problems and trends of the planned change.

Results and Discussion

The current situation of Kaunas city landscape

Kaunas – the second metropolitan city in Lithuania, a large centre of industrial, cultural, technological and scientific potential. The city is located at the intersection of the main Lithuanian roads and national and international integration axes; it is crossed by two international transport corridors, existing and planned European gauge railway tracks, potential river corridors, not far away – the airport and a free economic zone (Zaleckis, Kaimičaitytė – Virbašienė, & Ramanauskas, 2013).

Kaunas city has a municipal status; it is divided into 11 subdistricts. The city covers an area of 15,688.47 hectares, i.e. 1.94 percent of Kaunas County and 0.24 percent of the area of the Republic of Lithuania.

Landscape structure of the city of Kaunas consists of both natural and anthropogenic components that intertwine with each other and form the urban landscape. Kaunas city is situated on the plain, which has risen over the sea level averagely by 70-80 meters.

According to Lithuanian physical-geographical classification, the territory of Kaunas city belongs to Baltic lowlands area, the Nemunas midland and the Neris lower reach plateau zone, which includes the central lowlands and highlands Baltic contact zone. According to biogeographical classification, according to wildlife Kaunas city falls to the east of the Baltic province, Nemunas Valley unit. In urban areas, coherent and strong moderate as well as bulk moderate primers are spread fully (Kaunas, 2011). The prevailing are heavy loam and clay soil types.

Nemunas and Neris river valleys and their slopes – the main axes of the Kaunas city natural frame.

In the Republic of Lithuania, protected areas consist of 15.71 percent of the country's area (Saugomų, 2016). In Kaunas municipality, there are 1,822.42 hectares of protected areas (excluding 'Natura 2000'), i.e. 11.60 percent of the analyzed municipal area. Kaunas city parks and squares occupy 731.91 hectares and consist of 4.66 percent of the Kaunas city area. Central greeneries occupy 218.42 hectares (1.39 percent), regional greeneries – 406.02 ha (2.59 percent.), cultural, historical parks – 122.84 ha (0.78 percent.), i.e. 11.60 percent of the analyzed municipal area.

The natural situation and historical circumstances determined the Kaunas city urban-architectural structure. Nemunas and Neris rivers, relief formed by small streams, green areas created peculiarities of the territory urbanization. There are 1,232 objects of cultural heritage in Kaunas city, of which 1,043 objects include immovable and 189 – movable cultural heritage.

The Kaunas city urban structure was formed over a long period of time and is a result of the urban development of many centuries. The future urban development will depend on the economic, social and political processes taking place in Lithuania.

Kaunas city landscape change

Natural conditions within the designed Kaunas city have uniqueness and until the beginning of the twentieth century had a huge impact on the territorial development, spatial structure and landscape identity of the city. Therefore, in order to continue to build a distinctive Kaunas city landscape, it is necessary to maximize the value of the natural conditions of the city, its distinctive character during the formation of urban structures.

The naturalness of landscape structure in the city can be classified into the following groups: relatively natural areas, anthropogenic impact areas, anthropogenic areas.

The relatively natural landscape in this article is understood as a landscape, which has preserved the greater part of the natural components, with the experience of transforming human influence though. Anthropogenic environment is perceived as favourable for life environment, slightly changed by human activity, which preserves the natural and cultural coexistence options. Anthropogenic areas – the environment transformed by human activity.

Lithuanian natural frame consists of over 60 percent of the area of the country, its territorial management and planning is complex. The Kaunas city natural frame consists of about 45 percent of the municipal area and is a natural part of of the country's natural frame.

The relatively natural landscape of the city of Kaunas. In 2010, natural landscape covered 4,346.28 ha, i.e. 27.66 percent of the Kaunas city area, in 2015 – 5,461.60 hectares, or 34.81 percent. Within five years, relatively natural landscape area increased by 1115.34 ha (Fig. 1). This was influenced by the development of the areas of forests and meadows as well as natural grasslands. During the period between the years 2010 and 2015 the forest area in Kaunas city increased by 5.16 percent, in Lithuania – by 4.27 percent, in Kaunas County – 2.77 percent. In Kaunas city, meadows and natural grassland areas increased by 82.31 percent, while in the country and county the decline in these areas was set, as appropriate: 41.57 percent and 11.13 percent.

In 2015, the largest part of the relatively natural landscape consisted of forests – 51.12 percent and water bodies – 24.39 percent, the smallest part – wetlands (0.03 percent.).

Forests assigned to the subgroup of urban forest have integrated both recreational and ecological functions and under Kaunas city conditions, in which most of these forests are located on the slopes of little-used recreation, their ecological function is even more important. Urban natural landscape, greenery play an important ecological, aesthetic and recreational role, but attention and resources for their maintenance are insufficient.

Kaunas city anthropogenized landscape. In 2010, Kaunas city anthropogenized environmental area totaled 1,644.17 hectares and amounted to 10.46 percent. Kaunas city area, in 2015 was 1,691.50 hectares (10.78 percent.).

After analyzing the data obtained, one can see that the area of anthropogenized environment during the period between the years 2010 and 2015 increased by 47.33 ha (2.80 percent) (Fig. 2). The increase of trees and shrubs plantations resulted in the development of this landscape, which increased by 463.06 ha or 82.03 percent during this period. Tree and shrub plantings in 2015 occupied 564.53 hectares or 33.36 percent of the Kaunas city anthropogenized landscape area. Trees and shrub plantation development was influenced by the development and expansion of recreational areas, arrangement of green paths, etc.

In Lithuania and Kaunas county, during the period between the years 2010 and 2015 the increase of these areas was identified as well: in the country – 23.56 percent, in the county – 11.25 percent.

Greeneries and plantations growing there make up an aesthetic environment of the city, connect buildings and facilities with urban or natural landscape.

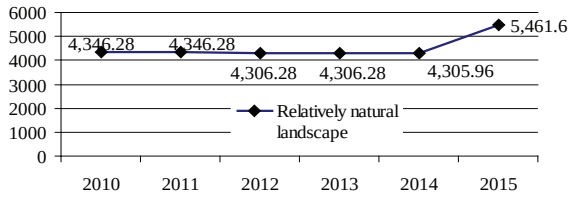

Figure 1. Relatively natural landscape change in Kaunas city in hectares during the period between the years 2010 and 2015.

Anthropogenic Kaunas city landscape. Anthropogenic areas include: built-up areas, roads, damaged land. In 2010, anthropogenic landscape covered 9,724.78 hectares and amounted to 61.88 percent of the Kaunas city area, in 2015 – 8,535.37 hectares (54.40 percent.). During the period between the years 2010 and 2015 the anthropogenic landscape of Kaunas city decreased by 1,189.41 hectares or 12.23 percent (Fig. 3). This was affected by the decrease of built-up areas by 1,233.36 hectares or 14.10 percent. The decrease resulted in the development of individual and tied green plantations, afforestation of public spaces and recreational areas, management of abandoned areas, conversion of old, unused stadiums into the natural environment, as well as the integration of green areas into residential, public, commercial and industrial areas.

Meanwhile, in the Republic of Lithuania and Kaunas county the built-up areas during the analysed period have increased: in the country – 25.35 percent, in the county – 15.66 percent.

Built up areas occupy the largest part of anthropogenic landscape of Kaunas city – 88.09 percent.

Road area is gradually increasing every year, and in 2015 it ranked 1,004.38 ha. The area increased by 38.69 hectares or 3.85 percent. Transportation need is rising constantly, thus increasing the number of cars on roads, which has a significant impact on road and street network load. With the growing number of cars, road and street network development is being installed, the gradual reconstruction of the existing network goes on, the permanent surveillance is being improved.

During the analyzed period, the affected land area has increased by 47.32 percent and in 2015 it covered 11.96 hectares and made up the smallest part of anthropogenic landscape – 0.14 percent. However, both in Lithuania and the county violated land area decreased: in the country – 0.95 percent, in Kaunas County – 3.90 percent.

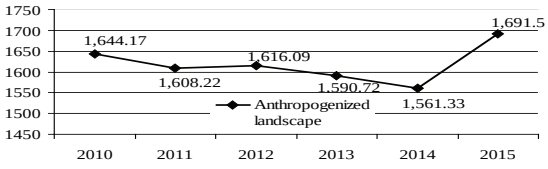

Figure 2. Anthropogenized landscape change of Kaunas city in hectares during the period between the years 2010 and 2015.

Summarizing the relatively natural, anthropogenized and anthropogenic spatial data of the city of Kaunas, it was found that relatively natural areas increased by 1115.34 ha, anthropogenized areas also increased by 47.33 ha and anthropogenic areas decreased by 1,189.41 hectares (Fig. 4).

While analyzing percentage distribution, it was determined that anthropogenic landscape in 2010 accounted for the most part of the city of Kaunas (61.88 percent.), in 2015 – 54.41 percent. It was found that the reduction of anthropogenic landscape was influenced by the decline of built-up areas caused by the development of individual and tied green plantations and recreation areas. Anthropogenic landscape occupied the smallest part of Kaunas city:

in 2010 – 10.46 percent, in 2015 – 10.78 percent.

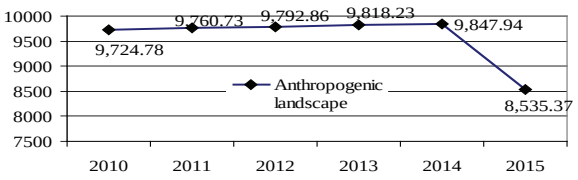

Figure 3. Anthropogenic landscape change in Kaunas city in hectares during the years 2010 and 2015.

The structure of urban areas is influenced by the natural environment in which the city was established and was expanding. Therefore, the city landscape – an important factor of the city's farming lands structure affects the distribution of natural farming lands (Milius & Ribokas, 2004).

The main factors influencing the quality of the living environment of the city are *urban natural and semi-natural and built-up areas ratio (rate of naturalness)*, which in the city of Kaunas in 2015 was 34.81 / 10.78 / 54.41. The optimal ratio of relatively natural and anthropogenized areas and anthropogenic territories in European cities makes up 1/3 of the city area. The above analysis shows that the ratio of the mentioned areas in Kaunas city corresponds to the European urban planning guidance.

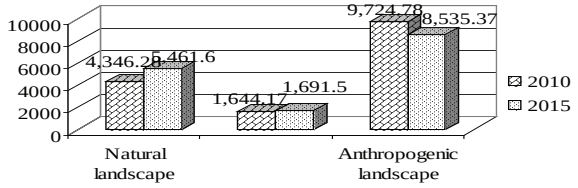

Figure 4. Kaunas city landscape change during the period between the years 2010 and 2015.

Territorial-urban problems of Kaunas city. Kaunas is situated in the center of Lithuania and is surrounded by demographically, structurally and ethnically balanced districts without greater economic and social contrasts.

Kaunas city has many advantages, but there are unresolved territorial-urban problems as well: Kaunas city asymmetric configuration, unevenly developed area, insufficiently balanced architecture of workplaces, housing, recreation areas, urban physical and urban environment features, communications of the urban parts passing through the center, the lack of attention to the natural environment, neglected and therefore unattended green areas of riversides and slopes, the lack of the functional quality in the central part and its adjacencies, deteriorated urban environment.

Expected future changes. The accuracy of the projection of the city landscape condition depends on the chosen method. The only source on which it is possible to accurately predict the landscape change is – the planning documents. The analysis of the general plan of Lithuanian territory (Lietuvos, 2002), the National Landscape Management Plan (Lietuvos, 2012), Kaunas Metropolitan Area General Plan (Kauno, 2013) showed that one of the goals is not to reduce green space, as well as to develop recreational infrastructure, to upgrade and expand recreational small architectural objects, to update and expand pedestrian and cycling systems, to equip 6 beaches, to renovate apartments and their environment. The plan provides for the development of apartments in the areas of multi-high intensity and mixed construction, construction of individual houses in undeveloped areas on the periphery of the city. 13 undeveloped business and industrial areas are being projected. It is also intended to deal with the parking and traffic problems of Old and New Town and other microdistricts.

It can be argued that after the implementation of Kaunas city master plan, built-up areas would increase, aesthetic view of the recreational ambient would improve, visual status of living environment would become of higher quality.

Sustainable urban development is inseparable from the public welfare, vibrant economy, healthy environment as well as from active and constructive community.

Conclusions

1. According to Lithuanian physical-geographical classification, the Kaunas city territory belongs to the Baltic lowlands area, the plateau region of the lower reaches of the river Neris and Nemunas midland, the composition of the soil type - heavy loams and clays; terrain – smooth. Protected areas constitute 11.60 percent of the entire Kaunas Municipality area.
2. During the period between the years 2010 and 2015, the relatively natural landscape area increased by 1115.34 ha or 20.42 percent. This was influenced by the development of areas of forests, the area of which increased by 5.16 percent as well as the increase of meadows and natural grassland areas, which increased even by 82.31 percent. In 2015, the largest part of the relatively natural landscape consisted of forests – 51.12 percent and water – 24.39 percent, the smallest part consisted of wetlands (0.03 percent).
3. Anthropogenized environmental area during the period between the years 2010 and 2015 increased by 47.33 hectares (2.80 percent). The reason – the tree and shrub plantations increase of 82.03 percent.

4. During the period between the years 2010 and 2015 the Kaunas city anthropogenic landscape decreased by 1,189.41 hectares, or 12.23 percent. This was affected by the decrease of built-up areas by 1,233.36 hectares or by 14.10 percent. It was found that the reduction of anthropogenic landscape was influenced by the decline of built-up areas caused by the development of individual and tied green plantations and recreation areas. Built up areas cover the largest part of the Kaunas city anthropogenic landscape – 88.09 percent.
5. In 2015, the Kaunas city naturalness index was 34.81 /10.78/54.41, which corresponds to the European urban planning guidance.
6. The main problems of the city of Kaunas are as follows: asymmetric configuration; unevenly developed area; insufficiently balanced structure of housing and recreation areas; physical and urban environment peculiarities of the city parts communications going through the center of the city; lack of functional quality of the central part and its adjacencies.
7. The analysis of the planning documents showed that the implementation of the solutions of the general plan of Kaunas city, built-up areas would increase, the aesthetic appearance of the recreational environment would improve, the visual status of living environment would become of a higher quality.

References

1. Aplinkos apsaugos politikos centras. (2013). 2014 – 2020 m. ES struktūrinės paramos veiksmų programos strateginio pasekmių aplinkai vertinimo ataskaita (Report on EU structural support for the action program of the strategic environmental impact assessment for the years 2014 – 2020). Vilnius, 187 p. (in Lithuanian).
2. Balevičiūtė, A., & Veteikis, D. (2012). Renatūralizacijos pokyčiai Lietuvos kraštovaizdyje 1995 – 2010 metais (The Changes of Renaturalisation in Landscape of Lithuania during the period between 1995 and 2010). Geografija. T. 48. Nr. 2. pp. 132-144. (in Lithuanian).
3. Brinkytė, E., & Gražulevičiūtė - Vileniškė, I. (2013). Urbanizuoto ir kaimiškojo kraštovaizdžių sąveikos raiška ir panaudojimas formuojant miestų želdynus (Urbanized and rural landscapes interaction resolution and use when forming urban green areas). *Miestų želdynų formavimas* 1 (10), pp. 30-40. (in Lithuanian).
4. Bučas, J. (2010). Miesto drieka kaime: socialinis ir aplinkosauginis aspektai (City development in rural areas: social and environmental aspects). IV Lietuvos urbanistinis forumas. Urbanistinė drieka: miesto ir kaimo sandūra. Mokslo straipsnių rinkinys. pp. 5-11. (in Lithuanian).
5. Cirtautas, M. (2014). Changing form of the Baltic cities: resurrection of the suburbs. *Our Common Future in Urban Morphology*. FEUP, Porto. Vol. 1, 79 p.
6. European Landscape Convention, Florence. (2000). 9 p.
7. Gražulevičiūtė-Vileniškė, I. (2014). Sociologiniai urbanizuotos aplinkos tyrimai: patirtis ir kryptys (Sociological studies of the urban environment: experience and directions). *Tiltai*, 2014 (3). pp. 35-52. (in Lithuanian).
8. Kauno miesto įvaizdžio strategija (Kaunas city image strategy). (2011). Kaunas, 140 p. (in Lithuanian).
9. Kauno miesto savivaldybės teritorijos Bendrasis planas (General Plan of Kaunas Municipality area). (2013). Aiškinamasis raštas. 5 tomas. Sprendiniai. Kaunas, 2013. 125 p. (in Lithuanian).
10. Kisielienė, G. (2012). Gamtinių išteklių, kraštovaizdžio ir bioįvairovės apsauga (Protection of natural resources, landscape and biodiversity). *Jaunųjų mokslininkų darbai.* Šiaulių universiteto leidykla. 2012, Nr, 5 (38) pp. 130-135. (in Lithuanian).
11. Lietuvos Respublikos kraštovaizdžio erdvinės struktūros įvairovės ir jos tipų identifikavimo studija. Kraštotvarkos supratimo ir jo erdvinės struktūros pažinimo nuostatos. I dalis (2005). (The Ministry of Environment of the Republic of Lithuania. Part I. The study of the identification of landscape spatial structure diversity and its types in the Republic of Lithuania. Provisions of the landscape understanding and its spatial structure knowledge). Vilnius, 124 p. (in Lithuanian).
12. Lietuvos Respublikos aplinkos ministro įsakymas 'Dėl Nacionalinio kraštovaizdžio tvarkymo plano parengimo' (2012 05 28, Nr. 446) (Decree of the Lithuanian Minister of the Environment On the national landscape management plan preparation). Iš Valstybės žinios: 2012, Nr. 60-3028. (in Lithuanian).
13. Lietuvos Respublikos aplinkos ministro pakeitimo įsakymas 'Dėl atskirųjų rekreacinės paskirties želdynų plotų normų ir priklausomųjų želdynų normų (plotų) nustatymo tvarkos aprašo patvirtinimo' (Amending Order of the Minister of Environment of the Republic of Lithuania 'On the Approval of the Procedure for the determination of the separate recreational green space norms and standards of tied green spaces (areas)'. (2007 12 21, Nr. D1-694; 2014 01 14, Nr. D1 – 36). Iš Teisės aktų registras: 2014, Nr. 2014-00298. (in Lithuanian).

14. Lietuvos Respublikos Seimo nutarimas 'Dėl Lietuvos Respublikos teritorijos bendrojo plano patvirtinimo' (Resolution of Lithuanian Seimas 'On the approval of the general plan of the territory of the Republic of Lithuania'). (2002 10 29, Nr. IX-1154). Iš Valstybės žinios: 2002, Nr. 110-4852. (in Lithuanian).
15. Loureiro, V. (2014). Favela: informality leading spontaneity into contemporary city. *Our Common Future in Urban Morphology*. FEUP, Porto. Vol. 1, 199 p.
16. Mieliauskas, P., & Palaima, A. (2012). Ekologinis tinklas Lietuvoje: kūrimo principai gamtinio karkaso pagrindu (Organic net in Lithuania: the principles of the development on the natural frame basis). *Darnaus vystimosi strategija ir praktika / Mokslo darbai.* Vilnius, pp. 58-77. (in Lithuanian).
17. Milius, J., & Ribokas, G. (2004). Žemėveikslių apskaitos statistinės ypatybės: kaita ir dabarties problemos (Land accounting statistical characteristics: change and present problems) *Geografijos metraštis,* Nr. 37 (1-2) t. pp. 175-183. (in Lithuanian).
18. Nacionalinė darnaus vystymosi strategija. (2011). (The National Strategy for Sustainable Development). Lututė: Vilnius, 2011. 100 p. (in Lithuanian).
19. Nacionalinė žemės tarnyba prie Žemės ūkio ministerijos. Lietuvos Respublikos žemės fondas (The Land Fund of the Republic of Lithuania).Vilnius. 2010 – 2015. 144 p. (in Lithuanian).
20. Saugomų teritorijų statistika (Statistics of the Protected Areas). Retrieved January 15, 2016, from http://www.vstt.lt/VI/index.php#r/188. (in Lithuanian).
21. Skorupskas, R. (2001). Optimalaus kraštovaizdžio sampratos problema (The problem of the optimal landscape concept). *Geografija* 37 (2), 2001, ISSN 1392-1096, pp. 58-64. (in Lithuanian).
22. Recommendation CM/Rec (2008). 3 of the Committee of Ministers to member states on the guidelines for the implementation of the European Landscape Convention, 25 p.
23. Rubavičius, V. (2013). The visuality of cultural memory: urban aspect. *Sovijus,* 1(1), pp. 60-67.
24. Wekel, J., & Koriakina, P. (2014). Changing features of the urban structure in a transitional city. *Our Common Future in Urban Morphology*. FEUP, Porto. Vol. 1, 210 p.
25. Zaleckis, K., Kaimičaitytė - Virbašienė, J., & Ramanauskas, E. (2013). Kauno miesto identiteto formantų išsaugojimo galimybės planuojant miesto vystimąsi (Kaunas city identity formants conservation opportunities in planning urban development). *VII Urbanistinis forumas. Miestas ir vanduo.* 2013. pp. 43-47. (in Lithuanian).

ANALYSIS OF PURPOSES OF USE OF REAL PROPERTY IN MUNICIPALITIES OF LATVIA

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Abstract
One of the cornerstones of sustainable use of land resources is the use of land resources for the identified needs. In every country it is needed to list the land according to the type of land use. Such function of land classification in Latvia is maintained by the classification of purpose of real property use. In a certain period of time needs of the specific purposes for which the land resources are used are changing, so the aim of this study is to research changes of areas of purpose of real property use in municipalities of Latvia. The analysis of purpose of use of real property in Latvia municipalities demonstrates the trend of decrease of agricultural land resource areas in proportion to the increase of forest land resource areas, excluding the region around Riga, where areas of agricultural land and forest land resources are decreasing, but residential land resource area for needs of development of capital is increasing.
Key words: Land use, real property, purpose of real property use, municipality.

Introduction

Land is a basis of a development of every sector of national economy. The requirements regarding the land are different for various sectors of national economy. There are many options of how to use land. It can be cultivated in agriculture or processed in forestry. It can be processed in order to obtain minerals, to produce building and construction materials or to create energy. It can be used as a location of city institutions, buildings, structures, transport communications, resting places, enterprises (Zeme: mana, tava …, b.g.). Therefore, in every country it is needed to list the land according to the type of land use. Such function of land classification in Latvia is maintained by the classification of purpose of use of real property. In the regulation No.496 of Minister Cabinet (Nekustamā īpašuma lietošanas …, b.g.) it is defined that the purpose of use of real property is determined to a land unit or a part of land unit for purposes of cadastral evaluation according to a detail plan, to a territorial planning of municipality or to a current use of land or building initiated within the procedures specified in regulatory. Groups of purpose of use of real property, considering the factors forming the value, are classified in the following classes of purpose of use:

- Land on which the building is not for the primary use of land – building is permitted only in cases when it is necessary in order to ensure the permitted use of land;
- Building land.

The municipality in whose administrative territory the land unit or part of land unit is located determines its purpose of real property use. Administrative territory is a territorial unit in Latvia, where within its competence a corresponding local government implements an administration (Administratīvo teritoriju un …, b.g.). Currently, there are 9 cities of the Republic and 110 municipalities.

The main resources of nature in municipalities are a land and a forest growing on it. Besides, the land is not eternal, we received it from our ancestors and eventually we will pass it over to our children and their children – and the laws of Universe require us to maintain this land and to pass it over not worse than we received (Boruks, 2004). We need information about available resources of every location on the land and how they divide into renewable and non-renewable resources, as well as options of a rational use of resources and their preservation for the future. Overall, the humans are not short-term users of the land, but they are also rational users of resources of nature – humans are creating, building and maintaining many of them in order to pass them over to next generations, so they could have a basis for living and existing.

Therefore, the main aim of this publication is to research changes of areas of purpose of real property use in municipalities of Latvia. In order to achieve the aim, the following tasks have been set:

- To analyse the changes of areas of purpose of real property use separately in the country, in historical regions and in current municipalities;
- To analyse the biggest two groups of purposes of real property use – agricultural land and land of forestry – the changes of land areas.

Materials and Methods

The Overview of Land of administrative territories of LR provides information about a state of an apportionment of land of country on purposes of real property use and types of land use considering statuses of ownership and owners on date 01.01. each year.

The data used in the research is a publicly available data about purposes of real property use and types of land use in the country in total and in municipalities from the Overview of Land made by State Land Service. The time period used in the research is the years from 2009 to 2014.

The method used for a data processing was an analysis method of time series, which allows paying attention on a detection of changes of things and phenomena from a dynamic point of view, which happening during the flow of time, on a clarification of specific procedure and on a detection of regularities during the process of changes (Krastiņš & Ciemiņa, 2003).

The indicators of changes of time series are obtained by a comparison of two levels of time series. It follows that it is possible to calculate indicators of chain increase and base increase for each time series.

An absolute increase of chain $\Delta_{m(k)}$ can be found by subtracting a previous level y_{m-1} from an ordinary level y_m (1):

$$\Delta_{m(k)} = y_m - y_{m-1} \quad (1)$$

An absolute increase of base $\Delta_{m(b)}$ can be found by subtracting an original or base level of the series y_1 from an ordinary level of the row y_m (2):

$$\Delta_{m(b)} = y_m - y_1 \quad (2)$$

Absolute increases are expressed in same units as units in row levels, in this research it is ha (hectares).

Chain increase rate $T_{m(k)}$ can be found by dividing an ordinary level y_m with a previous level y_{m-1}, but base increase rate $T_{m(b)}$ – by dividing an ordinary level y_m with an original level y_1. Increase rates are expressed as fractions of number one. The percentage of increase rates is obtained by multiplying the results with 100 (3, 4):

$$T_{m(k)} = \frac{y_m}{y_{m-1}} \times 100 \quad (3)$$

$$T_{m(b)} = \frac{y_m}{y_1} \times 100 \quad (4)$$

Chain increase rate and base increase rate $t_{m(k)}$ can $t_{m(b)}$ be obtained by subtracting 1, respectively 100%, from the relevant chain and base increase (5, 6).

$$t_{m(k)} = T_{m(k)} - 100 \quad (5)$$

$$t_{m(b)} = T_{m(b)} - 100 \quad (6)$$

Since a time series in the economics mostly reflects increasing objects and phenomena, the indicators of changes traditionally are called as indicators of increase. If the time series reflects a descending process, then absolute increases are negative, but increase rates are less than 1, respectively 100%. It is very easy to detect simple mathematical correlations between the indicators of dynamic changes. Absolute base increases are obtained by summing up absolute chain increases. Base increase rate is obtained by multiplying chain increase rates in fractions of 1. With rounding the results, a minor accumulation of errors is possible.

The means of time series characterizes qualities of time series of analysed time period. Each mean average is only one number characterizing whole time series. Middle level of each time series expresses the size of typical phenomena contained in analysed time period. The arithmetic mean level of interval time series $\bar{y}$ calculates by dividing a sum of series levels with a number of levels (7):

$$\bar{y} = \frac{\sum_{m=1}^{n} y_m}{n}, \quad (7)$$

where y_m – level of period m;
n – indication of time of the last member of the series.

Absolute average increase expresses the average change per unit of time of researched phenomena during a time period of analysed series. The result of formula is obtained by dividing a sum of absolute chain increase with a number of chain increases $n_\Delta = n_{-1}$ (8):

$$\bar{\Delta} = \frac{\sum_{m=1}^{n} \Delta_{m(k)}}{n_\Delta} \quad (8)$$

Mean increase rate $\bar{T}$ expresses the mean intensity of changes of phenomena in fractions or percentage. It can be calculated (9):

$$\bar{T} = \sqrt[n_\Delta]{T_{n(b)}} \quad (9)$$

Mean increase rate is calculated by subtracting number 1 from mean increase rate.

Results and Discussions

According to the regulations of Minister Cabinet No 496 (Nekustamā īpašuma lietošanas …, b.g.), 12 groups of purposes of use of real property are defined. According to the data from the Overview of Land, the apportionment of land areas in groups of purposes of use of real property on 1st of January, 2015 shows that the largest land areas are covered by two groups – Agricultural land and Forestry land and specially protected nature territories, where any economic activity is prohibited by the laws and regulations. First of both groups covers 59.0% and the

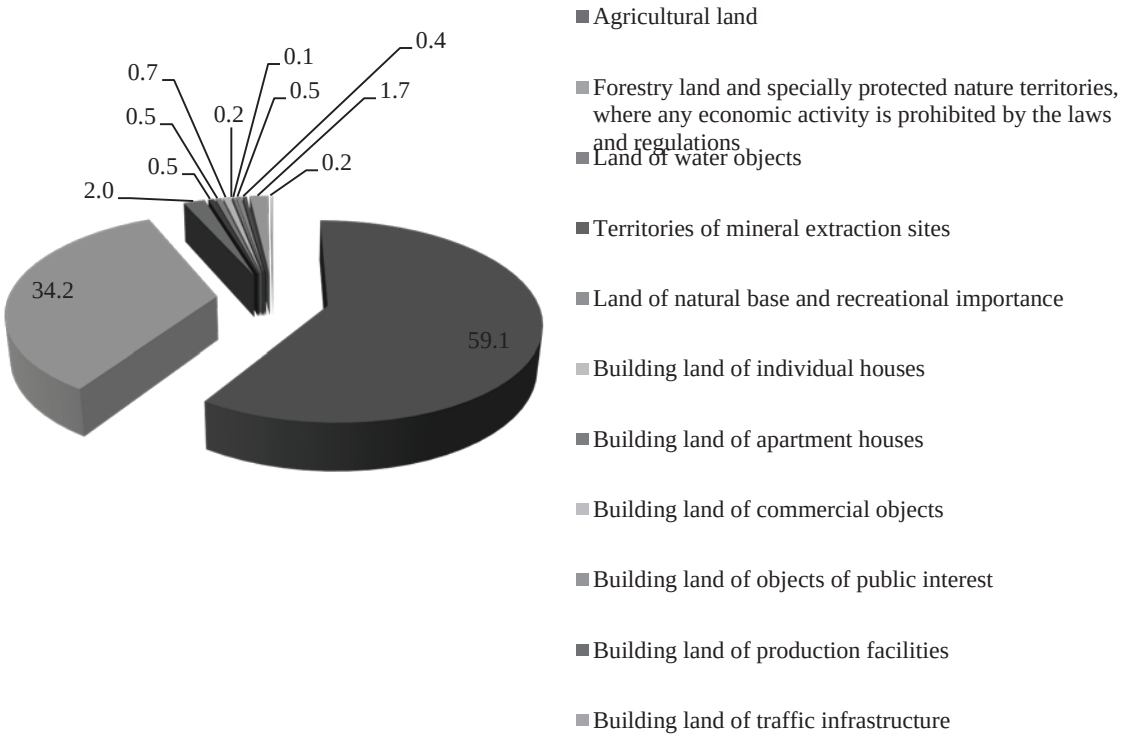

Figure 1. Land areas in groups of purpose of use of real property in Latvia (by State Land Service data on 01.01.2015).

other one covers 34.1% from the territory of Latvia (Figure 1).

Analysis on changes of land areas in groups of purposes of use of real property between the years 2015 and 2009 (Table 1) shows that there are some major changes, because the area of the group of Agricultural land has reduced by 67,734.8 ha, which is 1.8%, but the area of group of Forestry land has increased by 52,499.3 ha, which is 2.3%.

In groups of Land of natural base and recreational importance and Territories of mineral extraction sites are even greater changes, which have appeared as an increase of areas by 16.3% and 15.8%. Generally, these changes were affected by the changes in laws and regulations in Latvia, as well as the requirements regarding a sustainable use of land defined by The European Union (EU).

In order to obtain more precise explanation on these changes, a more detailed research further will be made on the largest two groups of purpose of use of real property – Agricultural land and Forestry land.

In the group of Agricultural land, a land where the main economic activity is agriculture, and a land, which is being used for sowing fields, grass mowing, grazing, cultivating forage grasses, orchards and other perennial plantations, vegetable gardening, mushroom gardening and cultivation of crops under glass are classified. In this group farms, backyard holdings, specialized state farms (state training and experimental farms, as well as other specialized state farms), agricultural enterprises, which specialize in a particular sector of agriculture and with an agricultural land according to the business specifics it uses appropriate buildings and other necessary structures in order to serve as providers in the production process are also classified. Types of land use that describe Agricultural land are arable land, meadows, pastures, as well as land under farm buildings and residential courtyards. Also, land with forests if they are not covering major part of land unit and not classified as a land with main economic activity of forestry, can be classified as agricultural land.

Whereas, in a group of Forestry land and specially protected nature territories, where any economic activity is prohibited by the laws and regulations, a land with main economic activity of forestry and specially protected nature territories, where any economic activity is prohibited by the laws and regulations, are classified. Land, where main economic activity is forestry, an economic, preserved and protected forests (with an exception of special areas of protected territories in which all natural resources are completely excluded from economic and other activities), land under the forest infrastructure, overflowing clearing adjacent to forest and within it, as well as marshes and glades, can be classified in this group. Also agricultural land, if it is not covering major part of land unit and not classified as a land with main economic

Table1

The changes of land areas in groups of purpose of real property use (2009-2014) in Latvia

Purpose of real property use	on 01.01.2010 (2009)	on 01.01.2015 (2014)	Changes of land areas regarding land areas of 2009
Agricultural land	3,876,363.1	3,808,628.3	-67,734.8
Forestry land and specially protected nature territories, where any economic activity is prohibited by the laws and regulations	2,152,822.4	2,205,321.7	+52,499.3
Land of water objects	126,466.6	126,060.8	-405.8
Territories of mineral extraction sites	29,002.0	34,460.5	+5,458.5
Land of natural base and recreational importance	29,185.4	34,859.3	+5,673.9
Building land of individual houses	43,886.4	43,635.9	-250.5
Building land of apartment houses	10,932.4	10,879.2	-53.2
Building land of commercial objects	6,316.2	6,054.0	-262.2
Building land of objects of public interest	32,433.1	31,205.0	-1,228.1
Building land of production facilities	23,731.8	24,699.7	+967.9
Building land of traffic infrastructure	106,461.1	108,621.8	+2,160.7
Building land of engineering supply networks and facilities	12,049.7	10,317.6	-1,732.1

activity of agriculture, can be classified as a Forestry land. In specially protected nature territories, where any economic activity is prohibited by the laws and regulations, all specially protected nature territories, where all resources of nature are completely excluded from economic and other activities can be classified.

In order to obtain a more precise explanation to previously mentioned changes, the analysis of relative and absolute indicators of time series of areas of Agricultural land and Forestry land in 110 municipalities about the time period of 2009 to 2014 was made (Table 2, Table 3).

The absolute mean increase of area of land of a group of Agricultural land has a negative tendency, -13213.8 ha, but mean increase rate is 99.7 ha, whereas the absolute mean increase of area of land of a group of forestry land has a positive tendency, + 10483.7 ha, but mean increase rate is 100.5 ha.

With the indicators of mean increase rate it can be concluded that the reducing of areas of Agricultural land has gradually happened, an average of 0.3% per year, but the increase of areas of Forestry land has been an average of 0.5% per year.

The results of analysis of land area of Agricultural land and Forestry Land in municipalities of historical regions have same tendency as in the country overall (Table 4). Land area of Agricultural land has reduced, but land area of Forestry land has increased.

Area of Agriculture land group in municipalities of Latvia has reduced, but area of Forestry land group in municipalities in Latvia has increased. In historical region of Kurzeme, the largest reduction of area of Agriculture land group is in Talsi municipality, -6,810.8 ha; the next largest decrease is in Kuldīga municipality, -1,594.8 ha. The smaller reductions of the area in this group of purpose are in Alsunga and Vaiņode municipalities, -99.3 ha and -165.9 ha respectively. In historical region of Latgale, the largest reduction of area of Agruculture land group is in Ludza municipality, -2814.0 ha and in Rēzekne municipality, -2,069.8 ha, but only -36.4 ha in Cibla municipality and -36.2 ha in Krāslava municipality. In historical region of Vidzeme, the largest reduction of area is in Limbaži municipality, -2,537.8 ha and in Gulbene municipality -1,715.6 ha, but the smallest reduction is in Carnikava municipality -27.1 ha and in Saulkrasti municipality -29.8 ha. In historical region of Zemgale, which is characterized by the richest soils, but as well there are observed reductions in area of agricultural land group, in Vecumnieki municipality -1,811.7 ha and in Tukums municipality -1,337.9 ha. The smallest decrease is in Rundāle municipality, -26.3 ha. But in Tērvete municipality, the only one in Latvia, a slight increase in the area of Agricultural land group has been observed, i.e., +2.4 ha. In areas of municipalities of Latvia in Forestry land group, increases as well as reductions are observed. For example, in historical region of Kurzeme, increases in purpose of use of real property – Forestry land are observed. The largest increases are in Talsi municipality, +4,961.5 ha and in Kuldīga municipality, +1,447.5 ha, smaller increases of area are in Alsunga municipality +67.3 ha and in Jaunpils municipality, +68.1 ha. In all municipalities in historical region of Vidzeme, increases of area of

Table 2

Relative and absolute indicators of time series of areas of Agricultural land

Indicators/ ha	2009	2010	2011	2012	2013	2014
	3,873,726.4	3,864,367.1	3,850,597.0	3,838,637.1	3,824,798.1	3,807,657.4
Chain increase,	-	-9,359.3	-13,770.1	-11,959.9	-13,839.0	-17,140.7
Base increase,	-	-9,359.3	-23,129.4	-35,089.3	-48,928.3	-66,069.0
Chain growth rate,	100	99.8	99.6	99.7	99.6	99.6
Base growth rate,	100	99.8	99.4	99.1	98.7	98.3
Chain increase rate,	-	-0.2	-0.4	-0.3	-0.4	-0.4
Base increase rate,	-	-0.2	-0.6	-0.9	-1.3	-1.7

Table 3

Relative and absolute indicators of time series of areas of Forestry land

Indicators/ ha	2009	2010	2011	2012	2013	2014
	2,143,780.0	2,148,850.4	2,159,498.5	2,167,718.6	2,179,541.8	2,196,198.7
Chain increase,	-	5,070.4	10,648.1	8,220.1	11,823.2	16,656.9
Base increase,	-	5,070.4	15,718.5	23,938.6	35,761.8	52,418.7
Chain growth rate,	100	100.2	100.5	100.4	100.5	100.8
Base growth rate,	100	100.2	100.7	101.1	101.7	102.4
Chain increase rate,	-	0.2	0.5	0.4	0.5	0.8
Base increase rate,	-	0.2	0.7	1.1	1.7	2.4

Table 4

The changes of land area in groups of Agricultural land and Forestry land

Historical regions	Agricultural land			Forestry land		
	on 01.01.2010 (2009)	on 01.01.2015 (2014)	Changes of land areas regarding land areas in 2009	on 01.01.2010 (2009)	on 01.01.2015 (2014)	Changes of land areas regarding land areas in 2009
Kurzeme	735,597.7	716,706.1	-18,891.6	630,319.3	644,452.9	+14,133.6
Latgale	1,003,865.3	991,600.0	-12,265.3	345,061.1	355,245.0	+10,183.9
Vidzeme	1,352,409.4	1,328,701.7	-23,707.7	778,930.4	797,272.9	+18,342.5
Zemgale	781,854.0	770,649.6	-11,204.4	389,469.2	399,227.9	+9,758.7

Forestry land group, are observed, except in Viļāni municipality, where reductions of area, -17.7 ha are observed, but greater increases of areas are in Ludza municipality, +2,633.5 ha and in Rēzekne municipality, +1,782.3 ha, lower ones – in Cibla municipality, +18.7ha. A situation with indicators of area changes in Forestry land group located in municipalities of historical region of Vidzeme is very interesting. In municipalities that are bordering with Riga – Olaine, Mārupe, Inčukalns, Ikšķile, Baldone, Ropaži un Stopiņi municipalities, Forestry land areas have reduced in the amplitude from – 1,163.1 ha (in Olaine municipality) to -3.1 ha (in Stopiņi municipality). That can definitely be explained with a change of purpose of land of real property in these municipalities. Owners had changed group of purpose of land to Building land of individual houses, which is very popular in municipalities that are bordering Riga. However, in municipalities that are further away from Riga a change of area of Forestry land group has increased; for example, in Gulbene municipality it is +1,607.0 ha, in Limbaži municipality +2,148.8 ha, in Mazsalaca municipality +1,351.1 ha. The situation in historical region of Zemgale is very similar to one in historical region of Latgale, mainly a change of land area has increased, for example in Vecumnieki municipality,

it is +1,819.8 ha, in Tukums municipality +1,267.0 ha. But in Jelgava municipality area of Forestry land group has reduced by -71.2 ha. This analysis revealed the tendency that if area of Agricultural land group in municipality or other researched territory has reduced, there is an approximate increase of area of Forest land group in the same territory.

Conclusions

1. According to purpose of use of real property, the areas of agricultural land and forestry land occupy the largest territory of Latvia – 59% and 34%, as well as their changes of size during the period from 2009 to 2014, respectively -1.8% and + 2.3%, show that these natural resources are used for the identified needs and retained as far as possible for future generations.
2. By the indicators of growth rate, it can be concluded that agricultural land area reduction has occurred gradually, during the analysed period – the average of 0.3% per year, while the forestry land areas are increasing – average 0.5% per year.
3. According to analysis of agricultural land by the purpose of real property use, in perspective of municipalities, can be concluded that in all municipalities over the research period the range of areas of land – from -6,810.8 ha (in Talsi municipality) to -26.3 ha (in Rundale municipality) decreased, except Tervete municipality where the area of agriculture land increased by +2.4 ha.
4. According to analysis of forest land by the purpose of real property use, in perspective of municipalities, it can be concluded that changes are in a range from +4,961.5 ha (Talsi municipality) to -1,163.1 ha (Olaine municipality).
5. The analysis of purpose of real property use in Latvia municipalities demonstrate the trend of decrease of agricultural land resource areas in proportion to the increase of forest land resource areas, excluding the region around Riga, where areas of agricultural land and forest land resources are decreasing, but residential land resource area for needs of development of capital is increasing.

References

1. *Nekustamā īpašuma lietošanas mērķu klasifikācija un nekustamā īpašuma lietošanas mērķu noteikšanas un maiņas kārtība (Classification of Real Estate Exploitation Purpose and Order of Real Estate Exploitation Purpose Determination and Change)* Ministru kabineta noteikumi Nr.496, Rīgā, 2006. gada 20. jūnijā Retrieved February 23, 2016, from http://likumi.lv/doc.php?id=139503. (in Latvian).
2. *Zeme: mana, tava, mūsu.... (Land: my, your, our...)* (2002). Rīga: VZD, 324 lpp. (in Latvian).
3. *Administratīvo teritoriju un apdzīvotu vietu likums. (Law On Administrative Territories and Populated Areas)* (2008, December). Retrieved February 18, 2016, from http://likumi.lv/doc.php?id=185993. (in Latvian).
4. Boruks, A. (2004). *Dabas apstākļi un to ietekme uz agrovidi Latvijā (Natural conditions and their impact on the agro-environment in Latvia.)* Rīga. 166 lpp (in Latvian).
5. Krastiņš, O, & Ciemiņa, I. (2003). *Statistika (Statistics).* Rīga. 267 lpp. (in Latvian).

POSSIBILITIES OF APPLICATION OF ORTHOPHOTO MAPS IN DETERMINATION OF LAND DEGRADATION

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Abstract
Aim of the paper is to explore the possibilities of application of orthophoto maps in determination of land degradation. One of the forms of remote sensing is aerial photography. Orthophoto maps are made from aerial photography with specialized software orthophoto maps were analysed in perspective for several years – from 2005 to 2011.The results are based on the expert. With each year possibilities of application of orthophoto maps are expanding. During the research, data of survey and SWOT analysis of determination of land degradation by orthophoto maps. The study results prove that based on orthophoto maps mainly, it can be detected the following land degradation processes – agricultural land overgrowing with bushes and abandonment of built-up areas.
Key words: remote sensing, orthophoto, land degradation.

Introduction

In recent years, increasing attention is being paid to sustainable land use issues. Not only in the world, but also in Latvia the land degradation processes – water and wind erosion, coastal erosion, bogging of ameliorate areas, agricultural land overgrown with bushes and landscape depletion is taking place.

In Latvia, according to the State Land Service data, 19.2% of agricultural land, including ameliorate lands, currently is not used, and they are gradually overgrown with weeds and bushes; therefore, the process of land degradation has already begun.

The solution of land degradation detection and reduction is to take a set of several important activities in order to successfully combat land degradation, which is already starting to develop or have already developed. It is very important to identify the type of land degradation and provide the appropriate solution for a particular type of degradation. Since each type of land degradation manifests its own specificities, it is important to choose the most appropriate way to determine which one would be more effective in a given situation.

This article highlights the remote sensing method – research of orthophoto maps, which is the best way to determine agricultural land overgrowing with bushes.

Application of remote sensing data for determination of land degradation can be divided into 4 stages (Lapina & Baumane, 2015):

- collection of remote sensing data;
- processing of obtained orthophoto maps;
- data accumulation and storage;
- use of data.

Aim of the paper is to explore the possibilities of application of orthophoto maps in determination of land degradation. To achieve the aim, the following tasks were set:

- to analyse data of orthophoto maps in perspective for several years;
- perform SWOT analysis of determination of land degradation by orthophoto maps;
- to carry out the expert survey analysis

Materials and Methods

One of the forms of remote sensing is aerial photography. Aerial photography can be performed, for example, from aircraft, a remotely controlled model aircraft, helicopter and others. Most appropriate time for aerial photography is usually spring, between snow melting and leaf unfolding, and when the sun is high enough, there are no clouds; the ground surface is transparent (Baumane, Cintina, & Tabynbaeva, 2014).

Orthophoto maps are made from aerial photography with specialized software.

For the research, the Latvian Geospatial Information Agency orthophoto, scale of 1:10 000, which is freely available at the website of Latvian Geospatial Information Agency was used.

In Latvia, orthophoto maps are prepared in Latvia Coordinate System LKS-92 TM in accordance with the TKS-93 division of map sheets (scale 1:10 000 map sheet complies with the 5x5 kilometers in nature). For the entire territory of Latvia the orthophoto maps are completed in TIFF format, scale 1:10 000 (Aerofotografēšana un ortofotokartes, b.g.).

Photogrammetry is often used in the context of remote sensing and the world has known the following definition (adopted in ISPRS conference in 1996) – photogrammetry is art, science and technology of obtaining reliable information about the Earth, its environment and other physical objects and processes, making data acquisition with a non-contact images and other sensor systems, their measurement analysis and representation.

In many countries, as well as in Latvia, since 1960 photogrammetry, which makes it possible to obtain visual and geometric information, has been very effectively used. Nowadays, due to evolving

technology and surface acquisition algorithms, there is an opportunity to work with acquisition of the surface geometry by the surface scanning and acquisition of point group from photographs. This method makes it possible to build a three dimensional object model and visualize objects with images, distinguishing surface from a few millimeters to microns.

Experience has shown that the use of GIS and analysis of aerial photographs and large-scale topographic maps obtained in different years can determine the changes of land use configuration; thus, it is possible to calculate their size and trends over time. Based on the facts, development of land-use path can be predicted. Furthermore, recommendations for spatial management (Barkāns, Lazdāns, & Orols, 2008) can be developed.

Researching the possibilities of application of orthophoto maps in determination of land degradation, Latvian Geospatial Information Agency overview map orthophoto images from 2005 to 2008 with orthophoto images from 2010 to 2011 were compared.

This study was conducted by using remote sensing method for determination of degraded lands.

Results and Discussion

Smarde municipality rural territory, which is located in Engure municipality (Figure 1), was selected as the research area. Engure municipality, on the coast of the Baltic Sea, is a local government in Zemgale, which was established at the time of the administrative and territorial reform. Engure municipality is characterized by one of the longest sea borders among all regions of Latvia – 56km.

Figure 1. Geographic location of Engure municipality.

For determination of land degradation in Smarde municipality rural territory, the Latvian Geospatial Information Agency's Map Browser (LĢIA karšu pārlūks, b.g.) was used. Orthophoto maps are in scale 1:10 000 (0.5 m/pix, colourful).

In Smarde municipality rural territory, three degraded territories (research objects) in which clearly visible degradation – agricultural land overgrowing with bushes and abandonment of built-up areas in Tukums airport territory is clearly visible, were assessed.

Figure 2. First research object orthophoto image, years 2005 – 2008.

Figure 3. First research object orthophoto image, years 2010 – 2011.

Comparing the first research object orthophoto images (Figure 2, Figure 3) from 2005 – 2008 and 2010 – 2011, land degradation in the form of agricultural land overgrowing with bushes can be observed.

Figure 4. Second research object orthophoto image, years 2005 – 2008.

Figure 5. Second research object orthophoto image, years 2010 – 2011.

Comparing the second research object orthophoto images (Figure 4, Figure 5) from 2005 – 2008 and 2010 – 2011, land degradation in the form of agricultural land overgrowing with bushes and cutting of forest land can be observed.

Comparing the third research object orthophoto images from 2005 – 2008 and 2010 – 2011, land degradation in the form of abandonment of built-up areas in Tukums airport territory can be observed.

Figure 6. Third research object orthophoto image, years 2005 – 2008.

Figure 7. Third research object orthophoto image, years 2010 – 2011.

Comparing these three degraded territories in Smarde municipality rural territory in the period from 2005 to 2011, it can be seen that land degradation had already taken place in such a short period of time. Using the following definition and scale (Scale 1:10000) orthophoto can already determine the impact of degradation in a relatively easy way, of course, the accuracy of such a scale and resolution orthophoto is not high, it could be said it is even low. However, such resolution orthophoto fulfils its function in the prevention of land degradation and using smaller scale, such as: 1:5000 or 1:2000 could achieve quite acceptable accuracy – up to 20 cm ('Metrum' veicis apbūves..., b.g.).

In Latvia, the company 'Metrum' has produced orthophoto with such a high resolution. Land surveying and territorial planning company 'Metrum', by using the company's aircraft and special aerial photography equipment, has made flights over the Gulf of Riga and the Baltic Sea coastal zone in territory of Latvia, identifying volumes of shoreline erosion and housing development in 300 meters dune protection zone.

Within the frame of the project, aerophoto images of coastline in length of 500 km and width from 500 to 1000 meters, from Lithuanian border to Estonian border have been obtained. By using aerophoto images, the orthophoto map of coastal areas in scale 1:2000 with a spatial resolution – 20 cm in nature was created. These are the most accurately obtained cartographic data by scale and quality up to this date about coastal area of Latvia. Previous orthophoto maps were in scale 1:10000 ('Metrum' veicis apbūves..., b.g.).

Newly acquired orthophoto materials were compared with the Latvian Geospatial Information Agency 2003–2005 orthophoto data. These data suggests that during last years around 65% of the total length of the Baltic Sea coastal zone in the territory of Latvia is affected by erosion in varying degrees. The main coastal erosion risk areas are in Limbazi, Tukums, Talsi, Ventspils and Liepaja municipality as well as Jurmala. There are places where coastal zone erosion in 3-4 years has washed away about 20 to 30 meters.

Coastal area orthophoto materials developed by 'Metrum' are applicable for development of spatial plan, for clarification of real property boundaries and protection zones, for economic activities, for example, construction or road infrastructure development monitoring. These data are applicable also for management of protected areas, monitoring of economic activity in the coastal zone, port development planning.

At the same time, also the laser scanning data in the form of point cloud are acquired that characterize the measured territory – land, trees, buildings. This information could be used to determine the amount of erosion, as well as for 3D modelling of territory. Obtained cartographic information could be used for the development of tourism and planning of infrastructure in the areas where there is an active vacationers flow (such as dune strip along the Talsi highway), as well as for control of the impact of

Table 1

SWOT analysis of application of orthophoto maps in determination of land degradation

Strengths	Weaknesses
• possibility to make observations over wide areas; • possibility to assess quickly the degraded territories; • available high-definition photo scenes; • no need to be located in area; • regular monitoring of degraded territories	• lack of experts; • changing situation in nature; • expensive hardware; • short period of time to carry out aerophotography; • impact of bad weather
Opportunities	**Threats**
• studies could promote exploration of degraded territories; • qualitative data extraction; • technological development; • could reduce the generation of degradation; • public funding for land degradation monitoring	• impact of national policy; • legislative changes; • impact of the economic situation; • innovations of information technology; • variable funding

human activity on coastal nature (‘Metrum’ veicis apbūves..., b.g.).

Services – aerial images, orthophoto maps, topographical plans and 3D models using the company’s specially equipped airplane PC-6, have been offered by ‘Metrum’ since 2007.

Currently, using aerial photography and laser scanning, ‘Metrum’ develops appropriate materials for specific needs, which could be applied for geospatial task solving in planning of territorial development, in research and development of communications, infrastructure and building solutions, as well as in disaster forecasting and liquidation, and other areas.

Researching the application of orthophoto maps in determination of land degradation, the Latvian Geospatial Information Agency orthophoto images from 2005 – 2008 and 2010 – 2011 were compared and SWOT analysis for application of orthophoto maps in determination of land degradation was carried out.

SWOT analysis is a method by which strengths and weaknesses are identified, as well as the existing opportunities or future threats for application of orthophoto maps in determination of land degradation (Table 1).

When all four critical elements of information are identified, based on them, application of orthophoto maps in determination of land degradation – the planned strategy for achieving the objectives can be implemented.

The main task of SWOT analysis is to split the available information to internal (strengths and weaknesses) and external (opportunities and threats) factors. When this work is done, the results of SWOT analysis show which factors (strengths and opportunities) can contribute to achieving the strategic objectives and which factors (weaknesses and threats) is an obstacle and which effects should be overcome or reduced (SVID analīze, b.g.).

Table 1 summarizes the SWOT analysis factors – strengths, weaknesses, opportunities and threats. In each section, there are five factors that affect every section.

After the creation of SWOT analysis, survey, which was performed experts from Latvia University of Agriculture was developed. In the survey, assessment of the importance of each factor (1 – insignificant, 5 – very important) was asked. The compiled survey data are shown in the diagrams.

Figure 8 featuring the results of SWOT analysis survey on the strengths. As it can be seen, the most significant factors of application of orthophoto maps in determination of land degradation is regular monitoring of degraded territories, possible to make observations over wide areas and available high-definition photo scenes; rating by experts – 4. While the factors – possibility to quickly assess the degraded territories, and it does not need to be located in area were evaluated on a scale from 1 to 5 with 3. None of the factors has been evaluated with 5.

Figure 9 features the results of SWOT analysis survey on the weaknesses. As it can be seen, the most significant weakness is lack of experts in the industry, which according to experts rating is rated 4.

While the factors – a short period of time to carry out aerophotography, expensive hardware and impact of bad weather – were rated with mark – 3. Factor – changing situation in nature was rated with mark 2. None of the factors has been evaluated with 5.

Figure 10 features the results of SWOT analysis survey on the opportunities. The most significant factor is that studies could promote exploration of degraded territories – this factor is rated with the mark 5, according to experts. Factors – could reduce the generation of degradation and qualitative data extraction is rated with the mark 4, but factor – technological development is rated with the mark 3.

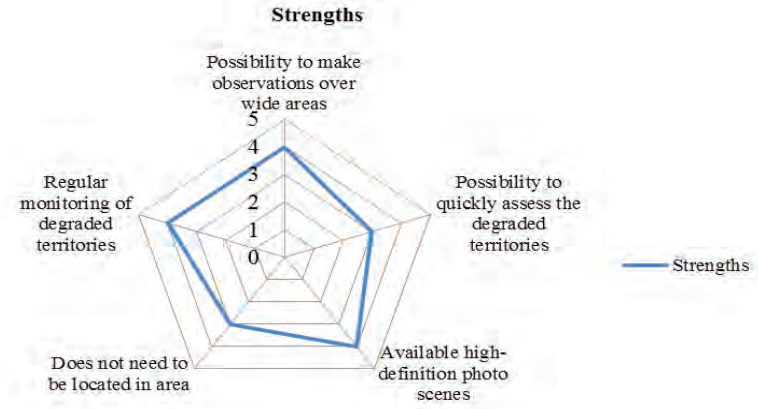

Figure 8. Results of SWOT analysis survey on the strengths.

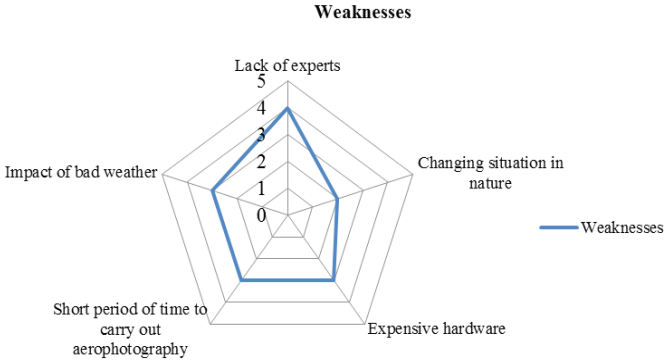

Figure 9. Results of SWOT analysis survey on the weaknesses.

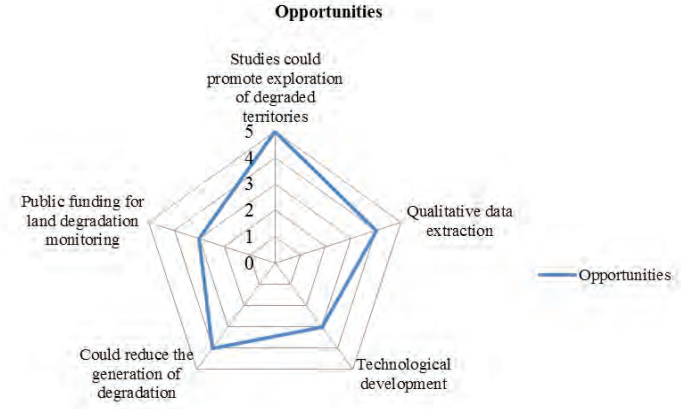

Figure 10. Results of SWOT analysis survey on the opportunities.

Impact of national policy, legislative changes and innovations of information technologies are assessed with the mark 4. Factors – variable funding and impact of the economic situation are assessed with the mark 3. None of the factors has been evaluated with 5.

Application of orthophoto maps in determination of land degradation is an effective method for monitoring of land degradation, and in Latvia it is also possible to use Latvian Geospatial Information Agency's Map Browser high-resolution Orthophoto maps from 1994 to 2015 which allows comparing the changes of degraded territories in 20 years. Of course, the situation changes in nature take place very rapidly and orthophoto materials are required for

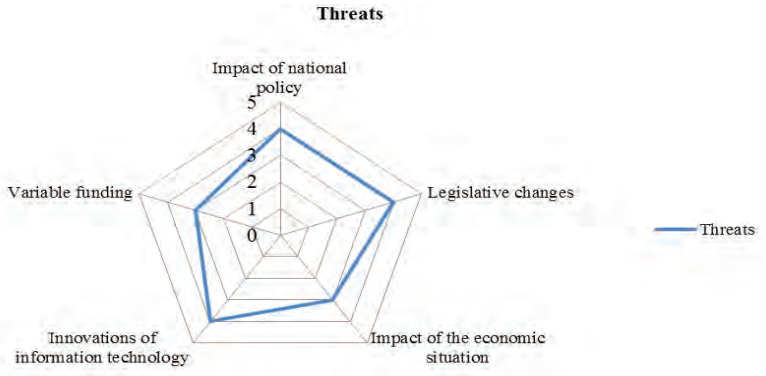

Figure 11. Results of SWOT analysis survey on the threats.

shorter periods of time; therefore, there is a need to take aerophotos in shorter period of time rather than rely on freely available orthophoto maps that can be outdated and no longer entirely fulfil its task – to successfully determine the land degradation.

As the results of SWOT analysis and survey show, orthophoto maps must have high resolution in order to successfully identify land degradation impacts and where it is likely to bring the greatest risks, because sometimes there is a need to book aerophotographs for certain areas with certain requirements and accuracy criteria that increase the costs of this process.

During the study, about 3,000 ha of degraded territories were inspected. For such an area, it is not required to use the aircraft that is designed for taking aerophotos, but it is fully sufficient to use the drone, which fully meets the criteria of orthophoto material definition.

Conclusions

1. To determine the land degradation and its occupied area, as well as to determine how the degraded land has changed over the years, it is possible to use publicly available orthophoto with high level of detail.
2. The study results proved that, based on orthophoto maps of Engure municipality from 2005 to 2011, mainly the following land degradation processes – agricultural land overgrowing with bushes and abandonment of built-up areas can be detected.
3. SWOT analysis proves that application of orthophoto maps in determination of land degradation is an effective method for monitoring land degradation process.

References

1. Barkāns, A., Lazdāns, D., & Orols, A. (2008). Rāznas Nacionālā Parka zemes lietojumu veidu analīze, izmantojot Ģis. (Analysis of Razna National Park types of land use applying GIS.) *LU 66. Zinātniskā konference. Ģeogrāfija. Ģeoloģija. Vides zinātne: Referātu tēzes*. Rīga: Latvijas Universitāte, 2008, 26-27. (in Latvian).
2. Baumane, V., Cintina, V., & Tabynbaeva, L. (2014). World experience in use of remote sensing data for determination of land degradation for conditions of Latvia. *Proceedings of international scientific - methodical conference "Baltic Surveying'14", Jelgava, Latvia, 7-9 of May, 2014* / Aleksandras Stulginskis University. Estonian University of Life Sciences. Latvia University of Agriculture. - Jelgava, 2014. - Vol. 2014, pp. 37-41. ISSN 2243-5999, ISSN 2243-6944 (online).
3. Latvijas Ģeotelpiskās Informācijas aģentūra. (2016). LĢIA karšu pārlūks. (Latvian Geospatial Information Agency Map Browser). Retrieved February 8, 2016, from http://kartes.lgia.gov.lv/.
4. Latvijas Ģeotelpiskās informācijas aģentūra (2008 – 2016). *Aerofotografēšana un ortofotokartes (Aerial photography).* Retrieved January 27, 2016, from http://map.lgia.gov.lv/index.php?lang=0&cPath=4_16&txt_id=23. (in Latvian).
5. Metrum (2010). *'Metrum' veicis apbūves izmaiņu un erozijas apjoma konstatāciju Latvijas teritorijas jūras krasta kāpu aizsargjoslā. ('Metrum' carries out findings of building change and volume of erosion in Latvian territorial sea protected coastal zone)* (in Latvian). Retrieved February 12, 2016, from http://www.metrum.lv/lv/jaunumi---publikacijas/publikacijas/?id=51. (in Latvian).
6. *SVID analīze. (SWOT analysis).* Retrieved February 15, 2016, from http://www.ltp.lv/cd/LV/lv/wso/index.cfm@fuseactionlearnl_id5318pl_id5310.htm. (in Latvian).

7. Лапина, А.С., & Баумане, В.З. (2015). Определение деградации земли в Латвии в муниципалитете Энгуре (Determination of land degradation in Latvia in Engure municipality) /Проблемы геологии и освоения недр*:* труды *XIX* Международного научного симпозиума имени академика М.А. Усова студентов и молодых ученых, Томск, Россия, 6-10 апреля 2015 г./ Министерство образования и науки РФ. Национальный исследовательский Томский политехнический университет. Томск, 2015. Том 1, с. 527-529. (in Russian).

LATVIAN NORMAL HEIGHT SYSTEM TESTING USING GNSS MEASUREMENTS

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Abstract
After height system replacement in Latvia, there is a transformation formula for point height difference theoretical value in any place of Latvia. Performing practical Global Navigation Satellite System (GNSS) measurements and obtained data mathematical processing, there is also a possibility to calculate point height difference, in this case – practical values. There were thirteen 1st class levelling network points selected in territory of Latvia and got the theoretical and practical values of them. As the result, it is possible to compare height differences between Baltic Normal Height System 1977 and Latvian Normal Height System 2000,5. The practical and theoretical values should coincide, but just 3 of selected geodetic points the height difference comparing practical and theoretical values is close to zero and point height difference of all measured points differs in 17 cm amplitudes indicating problems with transformation formula or need to improve geoid model.
Key words: Latvian Normal Height System, GNSS, elevation.

Introduction

Since 1st December 2014 in Latvia Cabinet of Ministers and state laws as a national height system finds the European Vertical Reference System realization in Latvia – Latvian Normal Height System 2000,5 (LHS-2000,5) (Celms, Bimane, & Reke, 2014). Prior to this, the Baltic Normal Height System 1977 (BHS1977) (Celms, Helfrica, & Kronbergs, 2007) was used as the national height system.

Nowadays the Global Navigation Satellite System (GNSS) offers more and more advantages. So to test LHS-2000,5 authors using GNSS measurements of 13 first class levelling points in the territory of Latvia obtained data compared with data calculated using the transformation formula for height difference calculation between two height systems (*Latvijas kvaziģeoīda modelis*, 2015). The global positioning for obtaining practical values was chosen because of their simplicity – using global positioning and calculating ellipsoidal coordinates it is possible to see the height difference control in height system datum point and regional main geodetic points (Lazdans *et al*., 2009). On these points where direct GNSS observations are not possible to do there is still need for precise levelling works (Celms *et al*., 2013).

The levelling network is a national height system forming element. Levelling network ensures the realization of various functions in the national economy (Celms, Kronbergs, & Cintina, 2013).

For precise GNSS measuring, it is necessary to have a precise quasigeoid model. Since 1st December 2014 Latvian specialists have developed a new quasigeoid model LV'14 with 4 cm accuracies (*Latvijas kvaziģeoīda modelis*, 2015).

The study aim is to figure theoretical and practical measurements obtained differences between BHS1977 and LHS-2000,5. To achieve the goal, the following tasks are set: 1) to do global positioning measurements in the national 1st class levelling network obtaining practical values of point height difference in two height systems; 2) to get point height difference theoretical values using height transformation formula; 3) to compare the obtained practical and theoretical values.

Materials and Methods

To do GNSS measurements to see practical values of point height difference in two height systems – BHS1977 and LHS-2000,5 – first of all, there was the national geodetic network point inspection done. There were some points selected and then visited on site to detect for each point the horizon above point and possibility to use GNSS methods for its height determination, the point location conformity to point abris. Also, global positioning real time measurements were done to detect the location of satellites above point. After inspection there were thirteen1stclass levelling network points chosen as an appropriate geodetic point for GNSS measurements – ground marks 1415, 1001, 37, 1155, 1537, 1636, 1676, 1727, 8248 and fundamental marks 1484, 0608, 3389 and 1463 (Fig. 1).

There are 3 measurement sessions performed – 14th December 2012, 22th November 2013 and 27th November 2014 in the territory of Latvia at the same time using global positioning in post-processing mode. The measurement has taken 4 hours long in the morning about 10 to 14 o'clock in Latvia Positioning System Base Station (LatPOS) network. LatPos is GNSS continuously operating the network of Latvia (Celms, Ratkevics, & Rusins, 2014). On each point was installed GNSS receiver – Leica, Trimble, Topcon or GeoMax receiver – and 4 hours long collected GNSS data.

For precise data processing and adjustment after measuring, there were collected data from 3 nearest LatPOS base stations from LatPOS home page

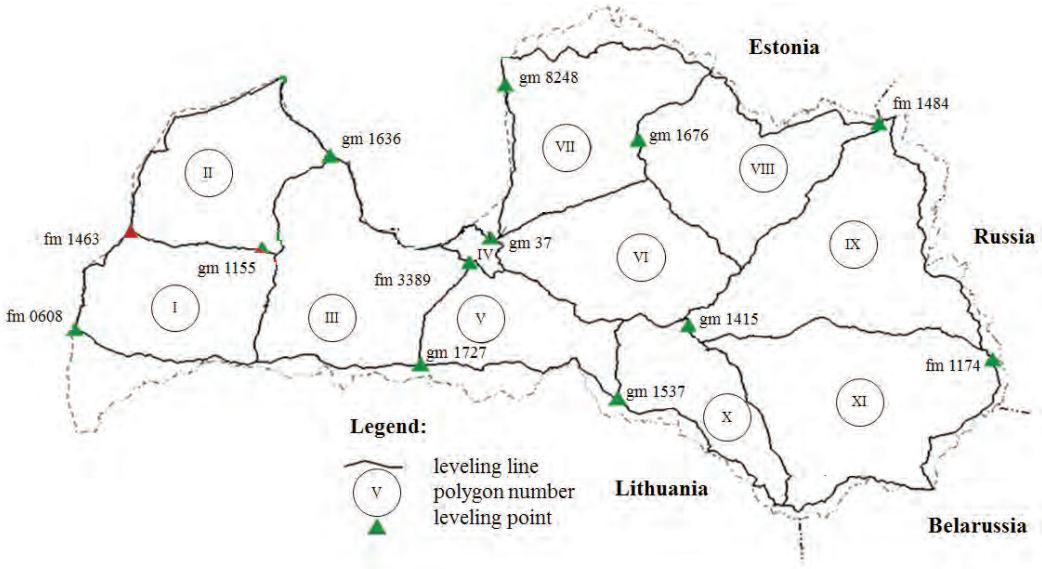

Figure 1. Performed GNSS measurements in 1st class levelling network.

choosing respective base stations. The data from GNSS receivers and LatPOS stations were used for data adjustment and point height determination (Reiniks, Lazdans, & Ratkus, 2010). Fig. 2. shows the location of measured points and LatPOS base stations.

Setting relevant parameters during data processing the point height can be adjusted in both height systems – BHS1977 and LHS2000,5. The difference between both height systems is the practical value – using GNSS method measured height difference (Celms, Eglaja, & Ratkevics, 2015). For getting more precise results, an average value of point height from all 3 measuring sessions was calculated.

Theoretical values of point height difference – the height difference between BHS1977 and LHS-2000,5 – has been determined by Cabinet Regulation No. 879 (adopted on 15 November 2011.) 'Regulations Regarding the Geodetic Reference System and the Topographic Map System'. The regulation defines the height transformation formula from BHS 1977 to LHS-2000,5:

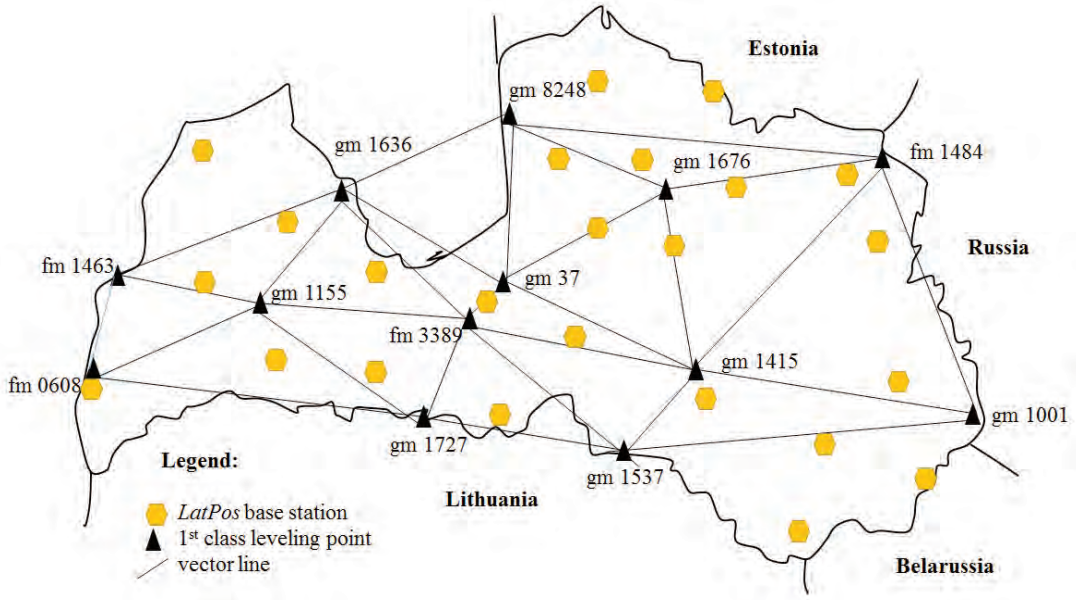

Figure 2. Vector lines between measured 1st class levelling network points and location of LatPOS base stations.

$$H_{(II)} = H_{(I)} + a_1 + a_2 \cdot M_0 \cdot (LAT - LAT_0) + \\ + a_3 \cdot N_0 \cdot (LON - LON_0) \cdot \cos(LAT) \quad (1)$$

Where $H_{(I)}$: height in BHS1977 (m);
$H_{(II)}$: height in LHS-2000,5 (m);
M_o: radius of curvature in the meridian of GRS80 (m) in P_o,63840416.7 m;
N_o: radius of curvature perpendicular to the meridian of GRS80 (m) in P_o,6393195.1 m;
LAT: latitude in ETRS89 (radian);
LON: longitude in ETRS89 (radian);
$P_o(LAT_o,LON_o)$: Reference point of the transformation $LAT_o = 56°58' = 0.994255897$ radian; $LON_o = 24°53' = 0.434296096$ radian;
a_1: vertical translation 1.49392900367864 E-0001 m;
a_2: slope in the direction of the meridian 7.99066182789555 E-0008 m;
a_3: slope in the direction perpendicular to the meridian 9.48289473646151 E-0008 m.

For unknown reasons, the regulation defines two parameters – slope in the direction of the meridian a_2 and slope in the direction perpendicular to the meridian a_3 – in meters, but it must be a mistake because parameters a_2 and a_3 can be determined only in radians or seconds. For the height difference calculations the authors of research adopted these values of both parameters in radians (Celms, Reke, & Ratkevics, 2015).

Calculating results with the transformation formula a height difference between BHS1977 and LHS-2000,5 is not a constant value of a whole territory of Latvia but differs from 125 mm in the south-east part of the country to 173 mm in the north-west part of the country (Fig. 3.) and depends on point location in the territory (coordinates). The amplitude between south-east and the north-west part of the country is 48 mm.

Using the transformation formula, the authors of research calculated point height difference between both height systems of the same 1st class levelling network points measured with GNSS. As point height in BHS 1977 $H_{(I)}$ was used with GNSS measured point height in BHS1977 average value from all 3 sessions.

Results and Discussion

Adjusted results from performed GNSS measurements of all 3 sessions are listed in Table 1. The measured data can be adjusted both in BHS1977 using geoid model LV 98 and in LHS-2000,5 using new geoid model LV'14. Next column shows the difference between both values and for more precise data there are calculated an average value of point height difference between BHS1977 and LHS-2000,5 – practical values of point height difference in two height systems.

Unfortunately, sometimes, there were not possible to do GNSS measurements of the point in all 3 sessions. Some points have changed their locations because of road construction works and in some cases, there was a problem with data adjustment.

Point No. 1636 – 0.268 m has the biggest average height difference, but point No. 1415 has the smallest average height difference – 0.058 m. Based on further results, these values are not comparable to each other, but they will be compared with theoretical values of point height difference in two height systems.

The theoretical values of point height difference in two height systems authors of research calculated using the transformation formula and as point height in

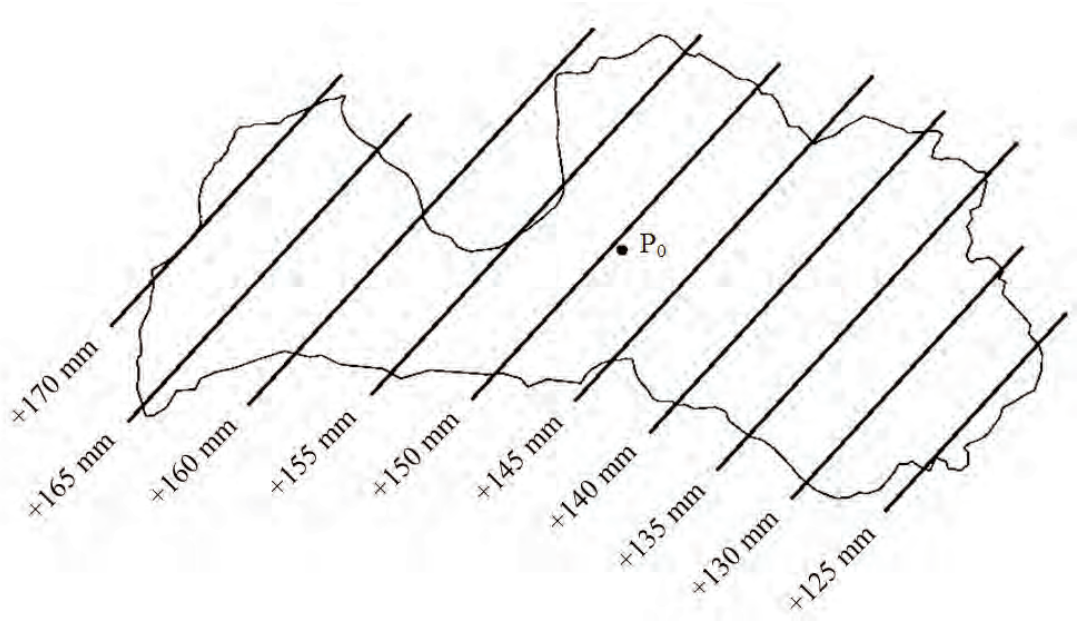

Figure 3. Height difference between BHS 1977 and LHS-2000,5.

Table 1

Point heights and height difference between BHS1977 and LHS-2000,5 of measured points

Session year	Point	Measured height in BHS1977, m	Measured height in LHS-2000,5, m	Height difference between BHS1977 and LHS-2000,5, m	Point average height difference, m
2012	1001	138.649	138.820	+ 0.171	+ 0.175
2013		138.662	138.846	+ 0.184	
2014		138.677	138.848	+ 0.171	
2012	1155	94.520	94.731	+ 0.211	+ 0.175
2013		82.026	82.188	+ 0.162	
2014		82.016	82.169	+ 0.153	
2012	1415	76.842	76.900	+ 0.058	+ 0.058
2013		76.853	76.911	+ 0.058	
2014		76.861	76.918	+ 0.057	
2012	1484	156.812	156.946	+ 0.134	+ 0.101
2013		156.739	156.755	+ 0.016	
2014		156.731	156.783	+ 0.152	
2012	1537	80.589	80.661	+ 0.072	+ 0.075
2013		80.458	80.538	+ 0.080	
2014		80.381	80.454	+ 0.073	
2012	1636	6.857	7.124	+ 0.267	+ 0.268
2013		6.852	7.120	+ 0.268	
2014		-	-	-	
2012	1676	58.536	58.650	+ 0.114	+ 0.111
2013		58.531	58.633	+ 0.102	
2014		58.509	58.625	+ 0.116	
2012	1727	32.393	32.575	+ 0.182	+ 0.182
2013		32.381	32.568	+ 0.187	
2014		32.387	32.565	+ 0.178	
2012	37	7.383	7.533	+ 0.150	+ 0.151
2013		7.357	7.509	+ 0.152	
2014		-	-	-	
2012	8248	4.723	4.829	+ 0.106	+ 0.161
2013		4.722	4.935	+ 0.213	
2014		4.694	4.858	+ 0.164	
2012	0608	-	-	-	+ 0.112
2013		5.727	5.838	+ 0.111	
2014		5.641	5.754	+ 0.113	
2012	3389	-	-	-	+ 0.126
2013		12.474	12.633	+ 0.159	
2014		12.394	12.488	+ 0.094	
2012	1463	-	-	-	+ 0.151
2013		-	-	-	
2014		13.476	13.627	+ 0.151	

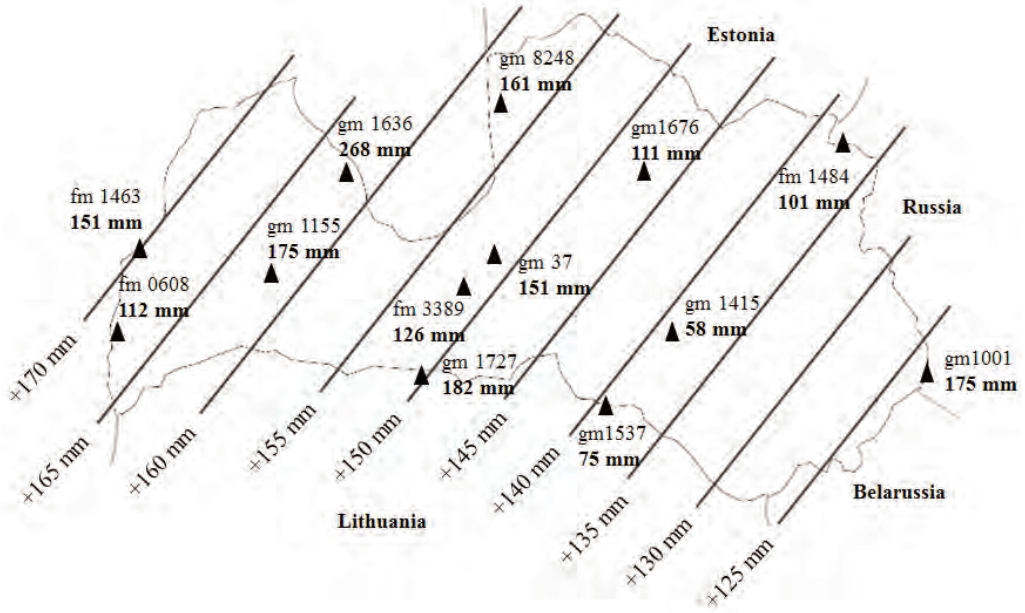

Figure 4. Height difference between BHS1977 and LHS-2000,5 comparing practical and theoretical data.

BHS1977 $H_{(I)}$ using with GNSS measured point height in BHS1977 average value from all 3 sessions. The results are showed in Fig. 4. – the height difference in the territory of Latvia and the height difference of each measured point. No one of the measured point height differences coincides with the height differences from transformation formula except point No. 37 which is quite close to calculated height difference (Fig. 4.).

The exact values of point height difference between BHS-1977 and LHS-2000,5 using GNSS measurements (practical values) and transformation formula (theoretical values) are shown in Table 2.

The last column of Table 2 shows the difference between practical and theoretical values. The difference varies from -0.066 to 0.104 m compiling 17 cm amplitude. Point No. 8248 has the smallest difference between practical and theoretical values – the height difference using GNSS measurements differs from height difference using transformation formula just about 0.002 m. Point No. 37 has next closest difference – 0.007 m. Points No. 1415; 1484; 1537; 1676; 608 and 3389 have negative height difference. The negative aspect is that difference between practical and theoretical values has also

Table 2

Calculated point height difference between BHS-1977 and LHS-2000,5

Point	Calculated point height difference between BHS1977 and LHS-2000,5 from GNSS measurements, m	Calculated point height difference between BHS1977 and LHS-2000,5 from transformation formula, m	Difference
1001	0.175	0.125	0.050
1155	0.175	0.163	0.012
1415	0.058	0.141	-0.083
1484	0.101	0.140	-0.039
1537	0.075	0.141	-0.066
1636	0.268	0.164	0.104
1676	0.111	0.150	-0.039
1727	0.182	0.151	0.031
37	0.151	0.144	0.007
8248	0.161	0.159	0.002
608	0.112	0.168	-0.056
3389	0.126	0.153	-0.027

negative values, because the transformation formula shows homogeneity of height difference. The possible reason could be that the transformation formula does not work correctly or geoid model is not developed sufficiently precise. Consequently, this study requires a further research.

Conclusions

GNSS measured data can be adjusted both in BHS1977 and in LHS-2000,5 using different geoid models – LV 98 and LV'14 – so giving an opportunity to calculate point height difference between BHS1977 and in LHS-2000,5. The calculated height difference of thirteen 1st class levelling points in the territory of Latvia comparing with using transformation formula calculated point height difference differs from each other in 17 cm amplitudes indicating problems with transformation formula or need to improve geoid model.

References

1. Celms, A., Bimane, I., & Reke, I. (2014). European Vertical Reference System in Baltic Countries. *Baltic Surveying*. 1 (8), 49-55. ISSN 2255–999X.
2. Celms, A., Eglaja, E., & Ratkevics, A. (2015). Latvia positioning system base station installation in Valka. Сучасні досягнення геодезичної науки та виробництва.1(29), 39-43.
3. Celms, A., Helfrica, B., & Kronbergs, M. (2007). Результаты нивелирования I класса в западной части Латвии (1st class levelling works in west part of Latvia). *Baltic Surveying*. 1, 14-18. (in Russian).
4. Celms, A., Kronbergs, M., & Cintina, V. (2012). Accuracy Estimation of the Latvia First Order levelling Network. *GEOFORUM*. 1, 44-47.
5. Celms, A., Kronbergs, M., Cintina, V., & Baumane, V. (2013). Precision of Latvia Levelling Network Nodal Point Height. *CIVIL ENGINEERING*. 4, 310-317.
6. Celms, A., Ratkevics, A., & Rusins, J. (2014). Research of National Geodetic Network Elevations in Eastern Part of Latvia. *Baltic Surveying*. 1, 84-91.
7. Celms, A, Reke, I., & Ratkevics, A. (2015). European Vertical Reference System Influence in Latvia. In 2nd International Conference Innovative Materials, Structures and Technologies, 30 September – 2 October 2015 (pp. 30-37). Riga: Riga Technical University.
8. *Latvijas kvaziģeoīda modelis* (Latvian quasigeoid model) (2015). Retrieved March, 11, 2015, from http://map.lgia.gov.lv/index.php?lang=0&cPath=2&txt_id=130 (in Latvian).
9. Lazdans, J., Aleksejenko, I., Kaminskis, J., Celms, A., Kalinka, M., Klive, J., & Reiniks, M. (2009). Aktualitāte Latvijas sasaistē ar Eiropas augstumu sistēmu (Current Events Latvia Connecting with European Height System). In Latvia University Scientific conference No.67, 12 February 2009. Riga: Latvia University. (in Latvian).
10. Reiniks, M., Lazdans, J., & Ratkus, B. (2010).Valsts augstuma izejas līmeņa noteikšana (Determination of state height datum level). *Riga Technical University scientific articles.* Nr.7, 7-13. *lpp.* (in Latvian).

SIGNIFICANCE OF FACTORS AFFECTING CREEP DEVELOPMENT IN TIMBER BEAMS

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Abstract
This study is a part of an extensive research of creep development in softwood (*Pinus sylvestris*) timber beams under natural environmental conditions. Large size test data sample obtained during long-term (approximately one and half year) static loading of timber beams in a four-point bending simulating the real service conditions of roof structures for winter and non-snow period has been processed and results presented. The correlation between creep deformation and its affecting factors, such as span to height ratio of beam, percent of latewood and width of year ring (a growth ring formed during a single year), orientation of year ring segments against main axis of cross section, number of year rings in 1 cm of wood, and density of wood have been analyzed and corresponding coefficients of correlation presented. It is concluded that the most significant creep development affecting factor is density of wood. Strong relationship between creep development and width of year ring, number of year rings in 1 cm of wood and density of wood was observed during test. Orientation of year ring segments against the main axis of cross section, amount of latewood and span/depth ratio do not have noteworthy direct influence on creep development in terms of this study. Temperature can be neglected as creep affecting factor in terms of this study but in the moments of sharp raise or fall of temperature, almost immediate effect on creep development was recorded.
Key words: Duration of load (DOL), creep, bending, softwood lumber.

Introduction

Serviceability limit state of timber structures is seriously influenced by increase of deformation due to creep of material. Creep process is affected by many physical and mechanical factors that leads to time-dependent increase of deformation of structural elements that can cause inadmissible deformations and even collapse of all construction.

According to the Burger body concept on physical model of deformation of wood, the mathematical model of total strain to be expected occurring in side fibers of timber beam has been proposed and proved in previous study by Ozola and Brokans (2013). Also, it has been revealed that the changes of relative humidity of air and sub sequential variation of the moisture content of wood in long-term performance do not affect the rate of creep significantly. The increase and decrease stages of creep taking place due to moisture cycling lead to some compensation of total deformation and do not result in a significant increase of total deformation at the inspected moisture content level (Ozola & Brokans, 2014).

Materials and Methods

The aim of this study is to evaluate the significance of all other factors disclosed in this study as affecting the creep development of timber beams subjected to approximately the same stress level during 478 days when moisture content of wood varied from 8 to 14%. Correlation analysis between creep rate (CRU) and creep development affecting factors is provided as the main task to reach the aim of this study.

Data processed in this study have been selected from measurements of static tests of timber beams under long-term load in four-point bending for approximately two years limiting deflection data sample corresponding to moisture content of wood from 8 to 14%. Test samples were cut out from tree trunk so they are free from knots and damages. Two groups of timber beams were selected: sample 'KS-4' which consists of four timber beams with span L = 1500 mm and span/depth ratio 25 – 26, and sample 'KS-3' which consists of eight beams, span L = 1320 mm with span/depth ratio of 22. The bending stresses varied between 8.2 to 11.1 MPa. Timber specie is

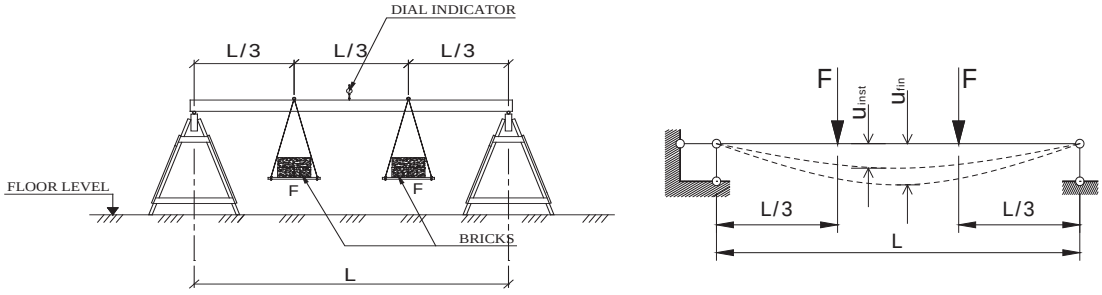

Figure 1. Long-term bending test setup and static model.

Scandinavian Pine (*Pinus Sylvestris*). Long-term test models loading schedule was described in previous publications by Ozola and Brokans (2013, 2014). Tests were carried out in an unheated building under uncontrolled climate conditions. The timber beam cross section nominal dimensions (height and width) were 60 mm and 30 mm respectively. The bending test setup and static model are given in Figure 1.

Concentrated forces were represented by clay and silicate bricks which were suspended on timber beams. The deflection measurements were made with dial indicators. Measuring precision of indicators is 0.01 mm while measuring diapason of indicators – 50 mm. The dial indicators were placed in the middle of the span on the compressed side of the beam. The environmental climatic condition parameters were recorded once during the day. Temperature (T, °C) in the room and outdoors was fixed with mercury-in-glass (Hg) type thermometers.

Results and Discussion

In the correlation analysis the relative increment of deflection, here named as creep rate (CRU) and estimated according deflection measurements of beams during time periods of relatively constant moisture content of wood (8%-14%), was defined as dependent variable:

$$CRU = \frac{u_{fin,t} - u_{init,t}}{u_{init,t}} \cdot 100\%, \quad (1)$$

where $u_{fin,t}$ is the final deflection of a beam, unit is the deflection value at the beginning of the dry period. The affecting factors measured, such as density of wood, amount of latewood, width of year ring, orientation of year ring segments against main axis of cross section, span/depth ratio and number of year rings in 1 cm of wood were defined as independent variables.

Quantity R (coefficient of linear correlation) for each relationship measures the strength and the direction of a linear relationship between CRU and affecting factors.

Results of correlation analysis present variable levels of relationships between CRU and affecting factors.

An assumption was made during test that CRU is significantly influenced by orientation of year ring segments against main axis of cross section of timber beam. This assumption was not proved and weak negative relationship with value rCRU, or = -0.245 was recorded between CRU and orientation of year ring segments against main axis of cross section. Significance level (α) for this and all other relationships in this study is defined as α=0.05. In this study moderate positive relationship between relative increment of deflection (CRU) and orientation of year ring segments against main axis of cross section has been characterized by Pearson's coefficient of linear correlation. See Figure 2. Sections of all test beams and main characteristics are showed in Figure 3. This relationship showed that orientation of year ring segments against main axis of cross section can be neglected as significant affecting factor.

It is found by Panshin and Zeeuw (1980), as well as by Cown (1992) and Dinwoodie (2000) that density is a general indicator of cell size, and it is a good predictor for strength and stiffness properties of wood. In this study moderate positive relationship between relative increment of deflection (CRU) and density of wood (r) has been found characterized by Pearson's coefficient of linear correlation rCRU, r = 0.67. See Figure 4.

Kubo and Jyodo (1996) stated that density of the wood increases directly with an amount of latewood in the growth ring, and density affects wood strength and stiffness significantly. Correlation analysis of current

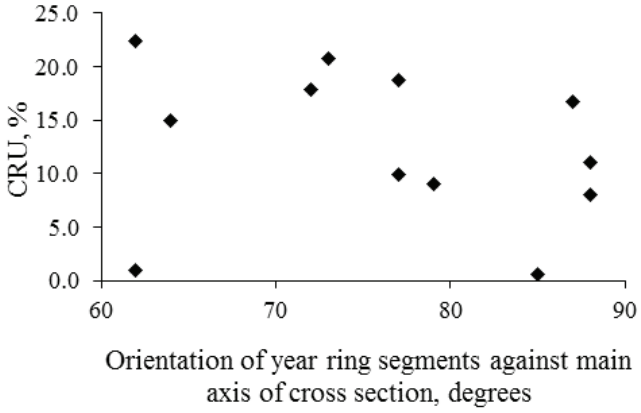

Figure 2. Relationship between CRU and orientation of year ring segments.

CRU= 18.8%
σ = 10.1 MPa
LW=45%; RW=1.3

CRU= 22.4%
σ = 9.8 MPa
LW=44%; RW=1.4

CRU= 11.1%
σ = 11.1 MPa
LW=44%; RW=2.3

CRU= 0.92%
σ = 9.7 MPa
LW=42%; RW=3.7

CRU= 20.8%
σ = 11.0 MPa
LW=50%; RW=2.0

CRU= 9.1%
σ = 9.6 MPa
LW=45%; RW=2.9

CRU= 15%
σ = 10.1 MPa
LW=52%; RW=1.4

CRU= 17.9%
σ = 9.7 MPa
LW=28%; RW=2.2

CRU= 16.7%
σ = 9.1 MPa
LW=50%; RW=1.7

CRU= 0.63%
σ = 8.9 MPa
LW=41%; RW=2.1

CRU= 9.9%
σ = 8.2 MPa
LW=57%; RW=2.9

CRU= 8.0%
σ = 9.1 MPa
LW=48%; RW=1.7

Figure 3. Sections of test beams: orientation of year ring segments and main characteristics.

data samples does not approve this relationship – there is no meaningful effect of amount of latewood in year ring (LW, %) to the relative increment of deflection CRU; moreover, dependence is negligible as revealed by coefficient of correlation rCRU, LW = 0.029. See Figure 5.

The assumption before study was made that the more year rings are in 1 cm of wood the higher is strength and stiffness of wood that leads to better behavior under long-term loading. This assumption was proved in this study by moderately good relationship (rCRU, n = 0.622) between relative

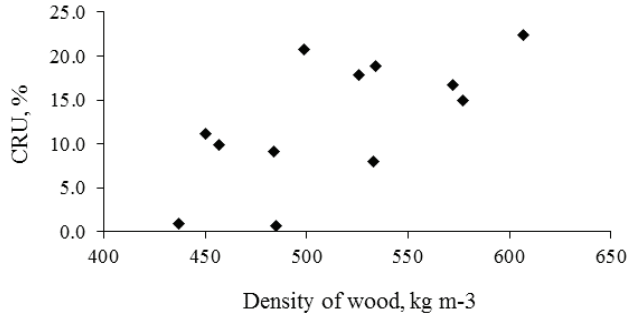

Figure 4. Relationship between relative increment of deflection and density of wood.

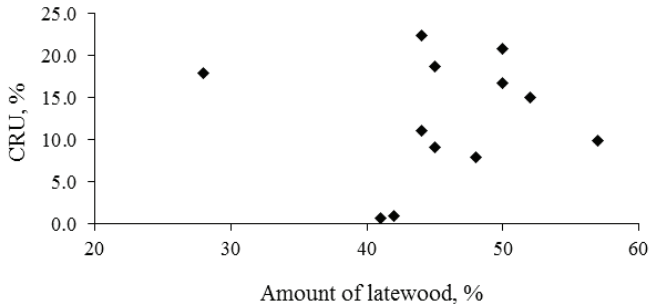

Figure 5. Relationship between relative increment of deflection and amount of latewood.

increment of deflection and number of year rings in 1 cm of wood (n). See Figure 6.

Early conjecture was made before test that span/ depth ratio could be assessed as one of the most important affecting factor in terms of this test, but this statement was rejected by results of test. Span/ depth ratio showed low negative relationship rCRU, s d^{-1} = -0.38 with relative increment of deflection. See Figure 7.

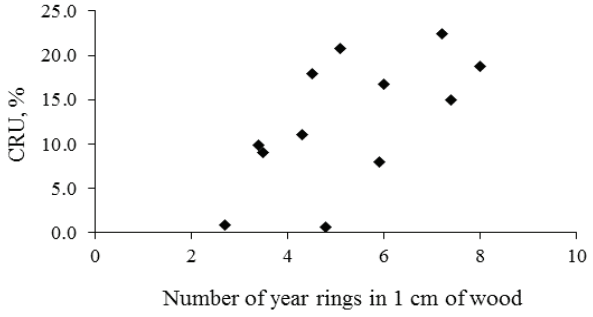

Figure 6. Relationship between relative increment of deflection and number of year rings in 1 cm of wood.

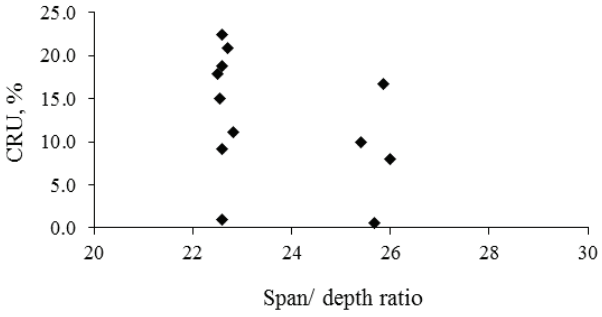

Figure 7. Relationship between relative increment of deflection and span-depth ratio.

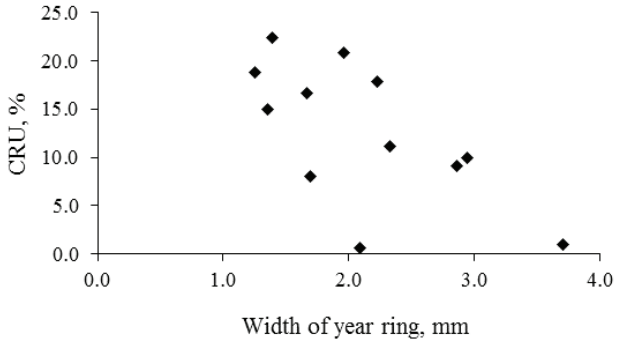

Figure 8. Relationship between relative increment of deflection and width of year ring.

Width of year rings can be used as an indicator of growth rate and good predictor of wood density which is one of the best indicators of wood quality, but there is no direct correlation witnessed. Results of this study confirm that there is moderate negative relationship (rCRU, w = -0.65) between width of year rings and relative increment of deflection. See Figure 8.

Conclusions

It was recognized during this study that width of year ring, the number of year rings in 1 cm of wood and density of wood are considered as the most significant factors affecting creep development in timber beams.

Correlation analysis present strong relationship between creep development and density of wood, width of year ring and number of year rings in 1 cm of wood. Most significant affecting factor in terms of this study is density of wood with coefficient of correlation R = 0.67.

Other above stated factors such as orientation of year ring segments against main axis of cross section, amount of latewood and span/depth ratio do not have noteworthy direct influence on creep development in terms of this study.

Temperature can be neglected as affecting factor in terms of this study with low total effect on creep development during sharp rise or fall of temperature.

References

1. Brokans, A., & Ozola, L. (2014). Behaviour of creep of timber beams under natural environmental conditions, WIT Transactions on the Built Environment, Volume 137, pp. 479-489. (International Conference on High Performance and Optimum Design of Structures and Materials, HPSM/OPTI 2014), Ostend, Belgium.
2. Cown, D.J. (1992). Corewood (Juvenile Wood) in *Pinusradiata* – should we be concerned? *New Zealand Journal of Forestry Science*, 22(1), pp. 87-95.
3. Dinwoodie, J.M. (2000). *Timber - its nature and behaviour.* E&FN Spon, London, 257 p.
4. Kubo, T., & Jyodo, S. (1996). Characteristics of the annual ring structure related to wood density variation in sugi (*Cryptomeria japonica*). *Mokuzai Gakkaishi* 42, pp. 1156-1162.
5. Ozola, L., & Brokans, A. (2013). Relationships in Creep Development of Timber Beams Under Natural Environmental Conditions, New Developments in Structural Engineering and Construction, Siamak Yazdani and Amarjit Singh (Eds.), Volume I, pp. 773-777. Research Publishing, Singapore.
6. Ozola, L., & Brokans, A. (2014). Development of mathematical model proposed for prediction of final deformation in bending of timber beams. Report Book of IABSE Symposium MADRID 2014: Engineering for Progress, Nature and People, 1650-1657. IABSE C/o ETH Hönggerberg CH-8093 Zurich, Switzerland.
7. Panshin, A.J., & Zeeuw, C. (1980). *Textbook of wood technology.* 4th edition. McGraw-Hill, NewYork, 722 p.

GENERATION OF A TEST REFERENCE YEAR FOR LIEPĀJA, LATVIA

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Abstract
Actual and reliable meteorological data are necessary for building performance analysis. Since meteorological conditions vary significantly from year to year, there is a need to create a test reference year (TRY), to represent the long-term weather conditions over a year. In this paper TRY data model was generated by analyzing every 3-hour weather data for a 30-year period (1984 – 2013) in Liepāja, Latvia, provided by the Latvian Environment Geology and Meteorology Centre (LEGMC). TRY model was generated according to standard LVS EN ISO 15927-4. The generated TRY contains from typical months that are included in TRY from a number of different years. The data gathered from TRY was compared with the climate data from the Latvian Cabinet of Ministers regulation No. 379, Regulations Regarding Latvian Building Code LBN 003-15. Average monthly temperature values in LBN 003-15 were lower than the TRY values that indicate on climate changes in this location. The results of this study may be used in building energy simulations and heating-cooling load calculations for selected region. TRY selection process should include the latest meteorological observations and should be periodically renewed to reflect the long-term climate change.
Key words: test reference year; climate analysis, climate change.

Introduction

In Latvian legislation long-term climate data is reflected in the Latvian Building Code (LBN) 003-15 'Būvklimatoloģija' (Construction climatology), Cabinet of Ministers, 2015 (Ministru kabinets, 2015), where various climatic indicators that represent the climatic situation in the territory of Latvia, providing information about the average monthly and yearly meteorological parameters are shown. But this information is not enough to fully describe the region's climatic conditions, because there is a necessity to define every day and every hour meteorological data values.

The need of such meteorological data worldwide led to the development of methodologies for generating the typical reference year (TRY) in the USA known as a typical meteorological year (TMY) (Hall *et al*., 1978). TRY is a data set that contains a sequence of 8760 hourly values of chosen meteorological quantities. The requirement of TRY is that it has to correspond to an average year (Skeiker, 2004). TRY provides hourly climatic parameter values, enabling to use these parameters for heating, ventilation and air conditioning (HVAC) device management and capacity optimization. One of the most important tasks to optimize these devices is to choose correct and precise outdoor air temperature that can be determined with TRY model (Gaujēna *et al*., 2015).

Creation of TRY was introduced in 1978 by Hall *et al*. (Hall *et al*., 1978). For a network of stations in the United States, a representative database consisting of weather data was created. Hall's method has been used to successfully generate TRYs for a number of locations across the globe (Chan *et al*., 2006; Guggenberger, Elemore, & Crow, 2013; Hall *et al*., 1978; Jiang, 2010; Kalogirou, 2003; Lee, Yoo, & Levermore, 2010; Skeiker, 2004; Skeiker, 2007; Yang, Lam, & Liu, 2007; Zang, Hu, & Biang, 2012; Zariņš, 2001).

LBN 003-15 describes climate parameters for ten cities of Latvia. These parameters have been calculated using data from 1961 – 1990 (Ministru kabinets, 2015). The aim of this research was to generate a representative climate database for one of these cities – Liepāja, by employing the method according to standard LVS EN ISO 15927-4 (Latvijas Valsts Standarts, 2005). Generation of TRY of Liepāja would provide hourly climate data that LBN 003-15 does not provide.

Geographical data for Liepāja: latitude 56°28'31,35" N; longitude 21°01'14,36" E; on relatively flat surface, elevated 3,71 m (LAS-2000,5) above sea level. It is located 195 km from the capital city of Latvia – Rīga (Figure 1). Average year temperature is 6.7 °C.

Figure 1. Location of Liepāja in Latvia.

The TRY is generated using the available weather data obtained from the station of Liepāja by the

Latvian Environment Geology and Meteorology Centre (LEGMC), covering the period from 1984 – 2013. LEGMAC database provides 3-hour weather data values for the temperature and relative humidity. As TRY consists of every hour values, the necessary values are interpolated.

In the region, there are only two studies that use LVS EN ISO 15927-4 standard with 30-year weather data: it is Estonian TRY (Kalamees & Kurnitski, 2006) and TRY for Alūksne (Ruduks & Lešinskis, 2015). The aim of this research is to generate TRY for Liepāja with most recent 30-year (1984 – 2013) climate data.

Materials and Methods

In this study, the ISO 15927-4 (Latvia State Standard, 2005) (Latvijas Valsts Standarts, 2005) method was used to construct the TRY. The primary selection was made on the basis of dry-bulb air temperature, cloud coverage (ISO 15927-4 suggested using direct normal solar irradiance, but this parameter is not available for this station, so it was replaced with cloud coverage), and relative humidity. The wind speed was used for secondary selection. To guarantee that the selected year represents the Liepāja climate as completely as possible, 30-year weather data were applied.

Climate data for TRY creation were obtained from LEGMC database from 1984 – 2013. LEGMC provides climate data with 3 hour interval, but TRY needs an hourly climate data. The necessary data for TRY were calculated by linear interpolation.

In February, there may be 28 or 29 days, and it is not possible to compare years with different count of days; thus, 29 February was excluded from TMY creation. The rest of the days were rearranged in ascending order starting with the first hour of January till the last hour of December (8760 values).

For each climatic parameter p (dry-bulb temperature, cloud coverage and relative humidity), daily means $\overline{p}$ are calculated. For each calendar month m, the cumulative distribution function $\Phi_{p,m,i}$ of daily means over all the years in the data set is calculated using equation (1):

$$\Phi_{p,m,i} = \frac{K_i}{N+1} \quad (1)$$

where K_i – rank order of the i-th value of the daily means within that calendar month in the whole data set;
N – number of days in any calendar month in the whole data set.

For each year y of the data set, the cumulative distribution function $F_{p,y,m,i}$ of the daily means within each calendar month is calculated using equation (2):

$$F_{p,y,m,i} = \frac{J_i}{n+1} \quad (2)$$

where J_i – rank order of the i-th value of the daily means within that calendar month and that year;
n – number of days in an individual month.

For each calendar month m the Finkelstein–Schafer statistic for parameter p, $FS_{p,y,m}$ for each year y of the data set is calculated using equation (3):

$$FS_{p,y,m} = \sum_{i=1}^{n} \left| F_{p,y,m,i} - \Phi_{p,m,i} \right|. \quad (3)$$

To normalize $FS_{p,y,m}$ for months of varying lengths, the results of equation (3) are divided by the number of days of the month (28, 30 or 31). For each calendar month individual months are ranked from the multiyear record in order of increasing value of $FS_{p,y,m}$. Monthly average $FS_{p,y,m}$ values of climate parameters dry-bulb air temperature, cloud coverage and relative humidity are added together and the same months of all years are ranked in the order of the increasing value of $FS_{p,y,m}$. From each calendar month, three candidate months with the lowest total ranking are selected. The monthly deviation of the wind speed of the three months is compared with the corresponding multi-year mean of calendar months. The month with the lowest deviation in wind speed is selected as the best month for inclusion in the TRY.

After the selection of the twelve calendar months for TRY, the months should be joined together. The first and the last eight hours of each month are adjusted by interpolation to ensure a smooth transition when months are joined to form a TRY. The adjustment also includes the last eight hours of December and the first eight hours of January, so that the test reference year can be used repeatedly in simulations (Latvia State Standard, 2005) (Latvijas Valsts Standarts, 2005).

Heating degree days (HDD)

HDD is a parameter used in the HVAC industry to estimate heating and cooling energy requirements. HDD can be calculated using equation (4) (Buyukalaca, Bulut, & Yilmaz, 2001):

$$HDD = \sum_{days} (T_b - T_m) \quad (4)$$

where T_b - base temperature (18 °C);
T_m - outdoor temperature (at duration of heating period);
$\sum_{days}$ - duration of heating period.

Results and Discussion

TRY was created combining months from different years based on their ability to follow the criteria described in materials and methods. Selected month/year combinations from which the TRY was created are shown in Figure 2. Two months (June and November) were selected from the year 2005, and two months (April and August) from 2011, but other months were selected from different years. That displays that months were selected from all range of the observed period.

After selected months (Figure 2) were connected and TRY was created, temperature fluctuation (Figure 3), temperature distribution (Figure 5), relative humidity fluctuation (Figure 4) and wind speed distribution (Figure 6) were displayed. Results show similar tendencies with data from Estonian TRY (Kalamees & Kurnitski, 2006) and TRY for Alūksne (Ruduks & Lešinskis, 2015).

Figures 3 and 4 show how temperature and relative humidity values change in TRY model starting from the beginning of January until the end of December.

When TRY model temperature distribution values are compared with 30-year average data (long term data) (Figure 5), TRY model shows a good agreement with the long-term data. TRY model's maximum temperature value deviation from long-term data is 151 hours per year at 5 °C. The total TRY model's temperature deviation from 30-year average data is 1384 hours. TRY for Alūksne deviation from 30-year average data was 1044 hours (Ruduks & Lešinskis, 2015).

Most typical wind speed value in TRY model is 3 m s^{-1}, it is observed for 1749 hours. TRY model's maximum wind speed value deviation from long-term data is 162 hours per year at 4 m s^{-1}. The total TRY model's wind speed deviation from 30-year average data is 826 hours. (Figure 6).

One of the most important results that can be obtained from TRY models is shown in Figure 7. This figure show how many hours per year each temperature and content of moisture combination can be observed. Most typical content of moisture and temperature combination in TRY model is 4 g kg^{-1} at

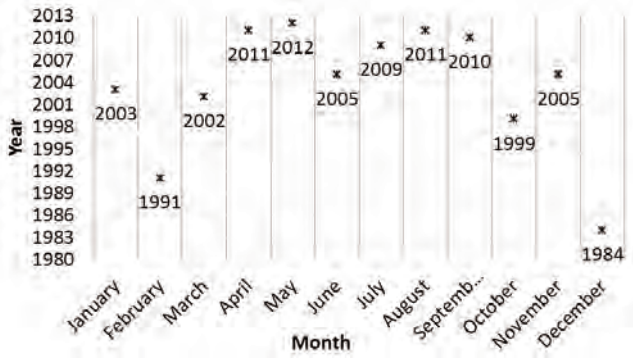

Figure 2. The month/year combinations for the composition of TRY.

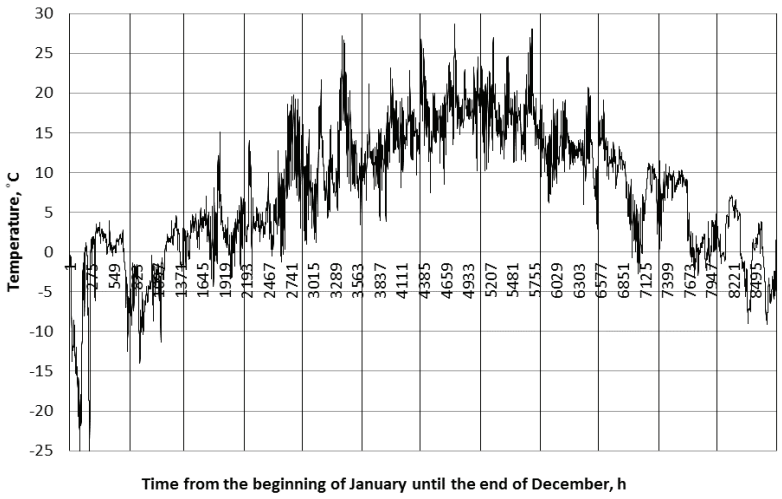

Figure 3. Temperature fluctuation in TRY.

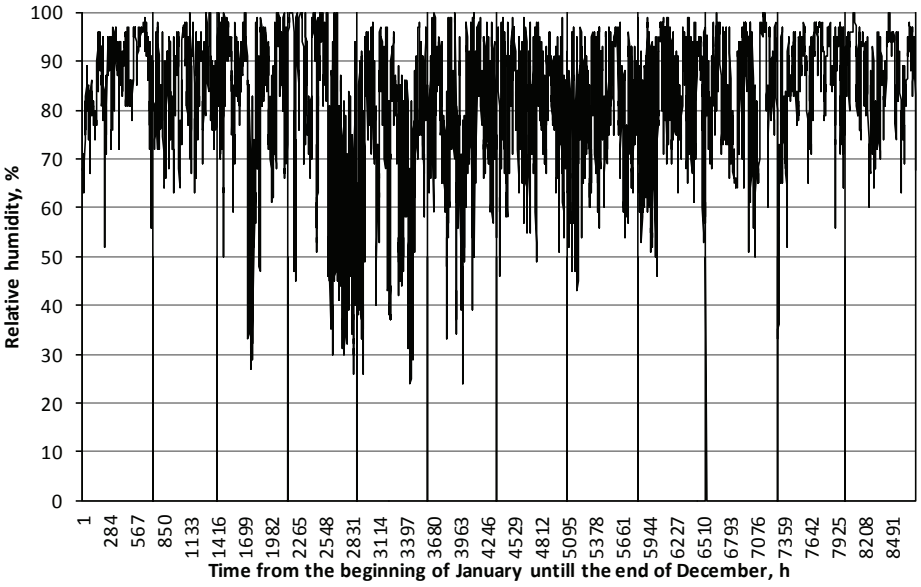

Figure 4. Relative humidity fluctuation in TRY.

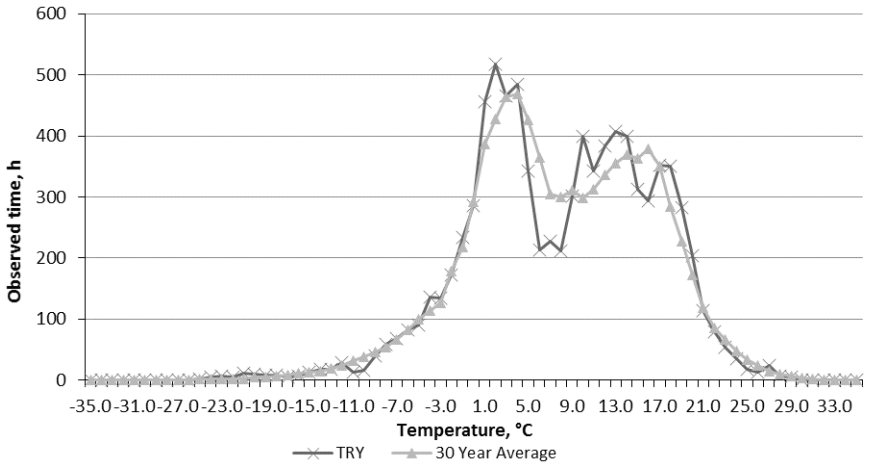

Figure 5. Hourly temperature distribution for TRY and 30-year average data.

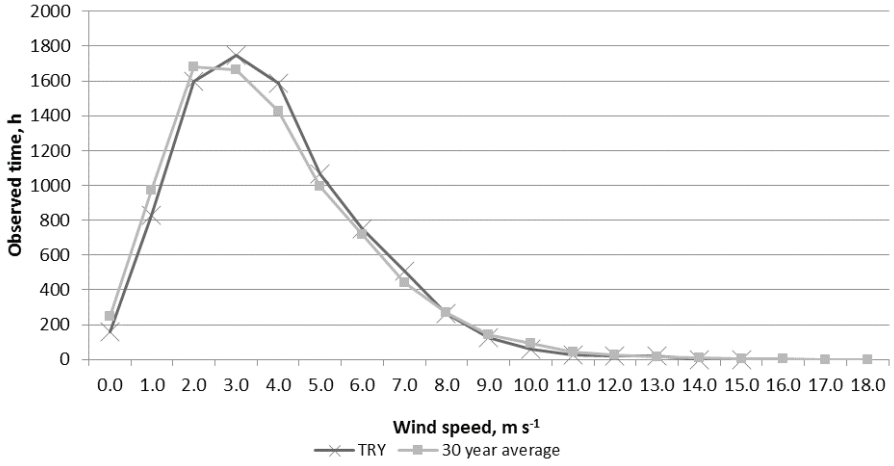

Figure 6. Wind speed distribution for TRY and 30-year average data.

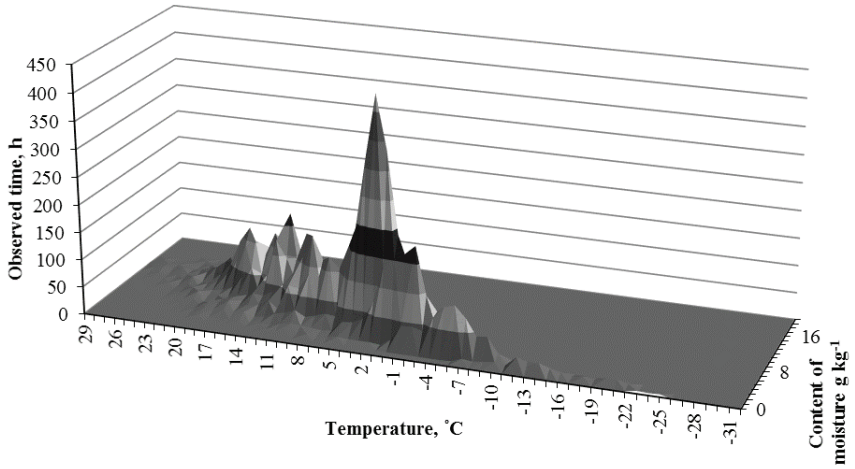

Figure 7. Combination of temperature and content of moisture for TRY.

2 °C. This combination can be observed for 432 hours (Figure 7). Most typical content of moisture value of TRY for Alūksne is also 4 g kg^{-1}, but most typical temperature is two degrees lower – 0 °C (Ruduks & Lešinskis, 2015). These results can be used for HVAC system analysis and building energy simulations. Data from Figure 7 gives an ability to calculate how long it will be necesary to use heating and cooling devices for buildings in this region, and choose optimal capacity for these devices.

Average year temperature value for TRY is 7.5 °C, but for 30-year average data it is 7.5 °C. Comparing results with LBN 003-15 values the difference is 0.8 and 1.1 °C respectively (Table 1). The difference with LBN 003-15 value can be explained by the fact that they have been obtained from 1961 – 1990, but TRY values were obtained from 1984 – 2013. The climate change can be the factor for the difference. Average relative humidity value for TRY and LBN 003-15 data is identical – 82%, but difference with 30-year average value is 1% (Table 2).

Table 1

Average monthly temperature values (°C)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul
30 year average	-1.0	-1.6	1.1	6.3	11.4	14.9	17.9
TRY	-3.3	-2.8	2.7	6.7	11.2	13.7	17.9
LBN 003-15	-3.0	-3.0	-0.2	4.6	10.3	14.3	16.4
Month	Aug	Sep	Oct	Nov	Dec	Average	
30 year average	17.6	13.4	8.8	3.9	0.6	7.8	
TRY	17.4	12.7	8.7	4.5	–0.1	7.5	
LBN 003-15	16.4	12.9	8.5	3.7	–0.3	6.7	

Table 2

Average monthly relative humidity value (%) comparison from January to December

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
30 year average	87	85	82	77	75	79	79	79	80	83	86	84	81
TRY	87	86	83	77	73	80	81	79	83	83	87	87	82
LBN 003-15	85	84	83	79	76	78	80	80	80	83	85	86	82

Table 3

Average monthly wind speed values (m s^{-1})

Month	Jan	Feb	Mar	Apr	May	Jun	Jul
30 year average	4.5	4.1	3.8	3.5	3.2	3.3	3.2
TRY	4.1	4.2	4.5	3.3	3.2	3.3	3.1
LBN 003-15	5.9	5.3	5.4	5.1	4.6	4.5	4.6
Month	Aug	Sep	Oct	Nov	Dec	Average	
30 year average	3.2	3.6	4.0	4.1	4.3	3.7	
TRY	3.3	3.8	4.2	3.9	4.5	3.8	
LBN 003-15	4.7	5.3	5.7	6.3	6.0	5.3	

Table 4

Summary of climate parameters

Parameter	TRY	LBN 003-15
Maximum temperature, °C	28.7	31.5
Minimum temperature, °C	-25.1	-26.1
Duration of heating period, days	189	193
Average temperature in heating period, °C	1.2	0.6
Number of heating degree days (HDD)	3175	3358

Average year wind speed value for TRY and 30-year average data are similar, the difference is 0.1 m s^{-1}, but difference with LBN 003-01 value is 1.5 and 1.6 m s^{-1} respectively (Table 3). The difference can be explained by the fact that LBN 003-01 values have been obtained from 1961 – 1990, but TRY values were obtained from 1984 – 2013, and latest studies show that wind speed values decrease (Green *et al*., 2012).

Comparing TRY and LBN 003-15 values (Table 4), LBN 003-15 has the longest duration of heating period, the lowest average temperature in heating period, and it also has the greatest number of degree days. All these parameters show the impact of increased average temperature value (Table 1) that can be explained with global changes. This tendency has also been observed in TRY for Alūksne (Ruduks, Lešinskis, 2015).

Conclusions

The aim of this research was to generate TRY for Liepāja, and it was generated based on the most recent 30-year (1984 – 2013) climate data. The generation of a TRY is very useful for optimal HVAC system design and building energy simulations. With hourly climate data, provided by TRY, it is possible to make building energy simulations and make calculations to determine necessary power for HVAC devices that was not possible with data from LBN 003-15.

Comparing TRY model values with LBN 003-15 ones, LBN003-15 has the longest duration of heating period, lower average temperature in heating period and has more HDD. All that can be explained with climate changes. These differences show that there is a need for TRY creation and the latest possible climate data should be used. In this paper, TRY is created for one city of Latvia, but results suggest that the research needs to be continued, and TRY models need to be generated for all 10 cities that are described in LBN 003-15.

References

1. Buyukalaca, O., Bulut, H., & Yilmaz, T. (2001). Analysis of variable-base heating and cooling degree-days for Turkey. *Applied Energy.* 69(4), 269-283. DOI: 10.1016/S0306-2619(01)00017-4.
2. Chan, A.L.S., Chow, T.T., Fong, S.K.F., & Lin, J.Z. (2006). Generation of a typical meteorological year for Hong Kong. *Energy Conversion and Management*. 47(1), 87-96. DOI: 10.1016/j.enconman.2005.02.010.

3. Gaujēna, B., Borodiņecs, A., Zemītis, J., & Prozuments, A. (2015). Influence of Building Envelope Thermal Mass on Heating Design Temperature. *IOP Conference Series: Materials Science and Engineering*. 96(1), 1-8. DOI:10.1088/1757-899X/96/1/012031.
4. Green, J.S., Chatelain, M., Morrissey, M., & Stadler, S. (2012). Estimated changes in wind speed and wind power density over the western High Plains, 1971 – 2000. *Theoretical and Applied Climatology.* 109(3-4), 507-518. DOI: 10.1007/s00704-012-0596-z.
5. Guggwnbwrger, J.D., Elemore, A.C., & Crow, M.L. (2013). Predicting performance of a renewable energy-powered microgrid throughout the United States using typical meteorological year 3 data. *Renewable Energy.* 55, 189-195. DOI: 10.1016/j.renene.2012.12.001.
6. Hall, I.J., Prairie, R.R., Anderson, H.E., & Boes, E.C. (1978). Generation of a typical meteorological year. In Annual Meeting of the American Section of the International Solar Energy Society, 28 – 31 August (pp. 669-671). Denver, Colorado, USA: American Section of the International Solar Energy Society.
7. Jiang, Y. (2010). Generation of typical meteorological year for different climates of China. *Energy*. 35(5), 1946 – 1953. DOI: 10.1016/j.energy.2010.01.009.
8. Kalamees, T., & Kurnitski, J. (2006). Estonian Test Reference Year for Energy Calculations. In proceedings of the Estonian Academy of Science, Engineering, March 2006 (pp. 40-58). Tallina, Estonia: Estonian Academy of Sciences.
9. Kalogirou, S.A. (2003). Generation of typical meteorological year (TMY-2) for Nicosia, Cyprus. *Renewable Energy*. 28(15), 2317-2334. DOI: 10.1016/S0960-1481(03)00131-9.
10. Latvijas Valsts Standarts. (Latvia State Standard). (2005). Ēku hidrotermiskie raksturlielumi. Klimatisko raksturlielumu aprēķināšana un izteikšana. 4. daļa: Ikstundas dati apkures un dzesēšanas ikgadējā enerģijas patēriņa novērtēšanai. (Hydrothermal performance of buildings - Calculation and presentation of climatic - Part 4: Hourly data for assessing the annual energy use for heating and cooling). LVS EN ISO 15927-4. Rīga (in Latvian).
11. Lee, K., Yoo, H., & Levermore, G.J. (2010). Generation of typical weather data using the ISO Test Reference Year (TRY) method for major cities of South Korea. *Building and Environment.* 45(4), 956-963. DOI: 10.1016/j.buildenv.2009.10.002.
12. Ministru kabinets (30.06.2015). *Noteikumi par Latvijas būvnormatīvu 003-15 "Būvklimatoģija" (Latvian Building Code 003-15 "Construction climatology")*. Retrieved November 05, 2015, from http://likumi.lv/ta/id/275013-noteikumi-par-latvijas-buvnormativu-lbn-003-15-buvklimatologija- (in Latvian).
13. Ruduks, M., & Lešinskis, A. (2015). Generation of a Test Reference Year for Alūksne, Latvia. *Proceedings of the Latvia University of Agriculture.* 33(1), (46-54). DOI: 10.1515/plua-2015-0006.
14. Skeiker, K. (2004). Generation of a typical meteorological year for Damascus zone using the Filkenstein–Schafer statistical method. *Energy Conversion and Management.* 45(1), 99-112. DOI: 10.1016/S0196-8904(03)00106-7.
15. Skeiker, K. (2007). Comparison of methodologies for TMY generation using 10 years data for Damascus, Syria. *Energy Conversion and Management.* 48(7), 2090-2102. DOI: 10.1016/j.enconman.2006.12.014.
16. Yang, L., Lam, J.C., & Liu, J. (2007). Analysis of typical meteorological years in different climates of China. *Energy Conversion and Management.* 48(2), 654-668. DOI: 10.1016/j.enconman.2006.05.016.
17. Zang, H., Xu, Q., & Biang, H. (2012). Generation of typical solar radiation data for different climates of China. *Energy.* 38(1), 236-248. DOI: 10.1016/j.energy.2011.12.008.
18. Zariņš, M. (2001). *Klimata datu izvēle gaisa kondicionēšanas jaudas aprēķinam. (Climate Data Choice to Calculate Air Conditioning Capacity)* Master thesis, Latvia University of Agriculture, Jelgava, Latvia. (in Latvian).

SCENIC ROADS IN LATVIA

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Abstract
United States of America and European countries like Great Britain, Germany, Norway have long traditions in the development of scenic roads, special scenic routes for tourists, National Scenic Byway Programs. They have set criteria for road landscape planning and design, discussed the economic value of scenic roads. Scenic roads are also important for tourism, as well as visual and cultural countryside development in Latvia. Planning regions and regional communities in Latvia have strategic development plans and spatial plans. All of them include high value landscapes and protected, scenic territories. Some scenic roads are defined in these documents, but criteria for scenic road designation are set in every region individually. There are unlisted roads with high aesthetic value which could be protected. Common methods, criteria for the assessment of road landscapes and scenic road designation in Latvia are not developed. The aim of the research was to evaluate and understand the present situation of scenic roads in Latvia. An online questionnaire was carried out in order to find out peoples' opinion about the road landscape quality. Spatial plans of regional communities and planning regions were examined. A field study of two sections of scenic roads was carried out. The research project was carried out from December 2014 to December 2015. Results show that current road landscape has a potential for development, and it needs improvements. The study gives a general insight into the scenic road situation in Latvia and provides basis for further research on scenic road planning and management.
Key words: road landscape, scenic road designation, scenic byway.

Introduction

Roads give access to the landscape and give us first impression of the place we are visiting. United States of America and European countries such as Great Britain, Germany, Norway have long traditions in the development of scenic roads, special scenic routes for tourists (Draper & Petty, 2001). The United States have National Scenic Byway Program which provides a formal way to identify, conserve, and promote roads that have special scenic, historic and recreational qualities. State byway designation process consisting of a basic description of the road, an inventory of each of the intrinsic qualities and a plan for how the road will be managed for promotion and resource protection is developed (Vermont Scenery …, 2000).

Researchers from Norway have elaborated theoretical framework for assessing the visual quality of roads (Blumentrath & Tveit, 2014), scenic road assessment methods are developed in the United States of America (DeWan &Terrence, 2008) and Spanish researchers have set the criteria for road landscape planning and design (Junta da Andalucia, 2009). Views of the road users about the scenic beauty of roadside vegetation (Akbar, Hale, & Headley, 2003), perceived quality of scenic tourism routes (Eby & Molnar, 2002; Denstadli & Jacobsen, 2011) and the economic impact of scenic byway designation is discussed (Timothy, Devitt, & Pizam, 1999).

In Latvia, the term scenic road is used by planning regions and regional communities in their strategic development plans and spatial plans. All of the plans include high value landscapes and protected, scenic territories. Some roads are defined as scenic in these documents. Tourism development plans of certain territories include information about scenic roads. The term is defined and explained in Landscape Policy Guidelines (Vides un …, 2013). Looking back in history, several roads in Latvia have been built as tourist roads or tourist demands have been considered in the road planning like the road from Sigulda to Turaida, from Riga to Saulkrasti (Dripe, 1940). Spatial development perspective 'Latvia 2030' sets areas of outstanding natural landscapes and historic sites in Latvia (Latvijas Republikas …, 2010). The objective is to save the diverse natural and cultural heritage, typical and unique landscapes. The road landscape is not marked out, but scenic roads are important for tourism, visual and cultural countryside development in Latvia.

Some research has been done on the Latvian road landscapes (Vugule, 2013; Vugule, Bell, & Stokmane, 2014); however, there is no overall information about the planned and existing scenic roads, and this field needs more attention.

The aim of the study was to understand and evaluate the present situation of scenic roads in Latvia. Three tasks were set in order to achieve the aim. The first task was to find out public opinion about the Latvian road landscape quality in the countryside. The second task was to examine how scenic roads are displayed in planning documents of planning regions and regional communities and the third – to carry out a field study, check the landscape features and quality of roads nominated as scenic roads as well as test the inventory method adopted from the United States for scenic road assessment and see if it is suitable for Latvian

conditions and for further research. Results from all three tasks were compared to see either results from document analyses conform with public opinion and real life situation.

Materials and Methods

An online questionnaire was carried out in December 2014. Information about the questionnaire was spread out through social networks and e-mail. A questionnaire form was open online for five weeks. The questionnaire consisted of nine questions. Eight of the questions were closed and one question was open, asking the respondents to name which features come into a person's mind when he/she thinks about the Latvian road landscape. The closed questions were about the age, gender, place of residence – city, village or countryside, region. The questions concerning landscape were about the level of management, how interesting or uninteresting it is. The survey was targeted both to drivers and passengers. Results of the survey were processed in SPSS (Statistical Package for the Social Sciences) software. Quantitative structure of respondents is analysed in the results section.

To obtain an overview of scenic roads named in planning documents spatial plans of 5 planning regions Kurzeme, Vidzeme, Zemgale, Latgale, Riga and 110 regional communities have been reviewed and compared. The authors looked for information about scenic roads in the community planning documents, checked which the most frequently used elements characterising scenic road landscape were.

Inventory of 2 road sections Ķipari - Nirmuži (V83) and Vējupīte-Jūdaži in Gauja National Park was carried out. The chosen road sections are situated in Sigulda region, one of the most visited regions by tourists in Latvia. The inventory took place on October 6, 2014. Evaluation method developed by the American Vermont Landscape Road Program was used (Vermont Agency …, 2000).

The surveyed roads were 4 km long each, and they were divided into 1 km long sections. Each section was evaluated using an inventory form consisting of two blocks with the list of positive and negative landscape features. Positive features are, for example, vegetation, road surface and functionality, presence of water bodies, manmade artificial objects like farmsteads, historic and cultural objects. Negative landscape features are, for example, landscape scars like lumbering scars, heavy erosion, disturbance, utility lines, buildings and manmade structures - unattractive, dilapidated buildings, structures out of context. The inventory led to the total amount of positive and negative landscape elements. This method allowed us to carry out the road assessment, to compare results of various road landscapes.

GoPro Hero 3 camera, mounted in front of the car at 1.1 m height from the ground was used for filming the road landscape. The driving speed was 60 km h^{-1} due to the uneven road surface. Photos were taken by Canon Power Shot A3300IS digital camera at the height of 1.3 m after each kilometre on both sides of the road. Panorama pictures were processed in Adobe Photoshop software.

Results and Discussion

Results of the questionnaire

The number of survey respondents was 114. Distribution of genders was 84% female and 16% male. It shows that women are more active and more interested in what is happening to the society and the environment where they live.

Average age of the respondents was 29 years. Forty seven percent of all respondents travel by car as drivers more often and 53% – more often as passengers. It was determined to find out whether drivers and car passengers perceive the landscape differently.

Results of the survey mainly represent the view of city residents while 75% of respondents live in cities, 15% in villages and 10% in the countryside.

The largest number of respondents was from Zemgale (39%) and the most common answer describing the landscape was – fields, meadows and open views are the most characteristic of the region.

Results of the questionnaire show that current countryside road landscape has a potential for development, and it needs improvements – 30% of respondents described the Latvian road landscape as interesting, 57% as medium interesting and 13% of the respondents as uninteresting. The majority of respondents, 86% believe that the Latvian countryside road landscape needs to be improved, 3% have an opinion that it does not need improvements and 11% of all respondents do not have a clear point of view on this issue. Female and male respondents have a similar opinion on this.

Respondents were asked to name the most characteristic elements of the road landscape in general. Landscapes consisting of fields, meadows, open views were mentioned most frequently (54.4%), the second most common response was the forest (45.6%) and the third – individual trees, groups of trees and shrubs, alleys (39.5%) (see Figure 1). Presence of these elements was checked in planning documents and is described further.

The answer 'other' includes the landscape characteristics and feelings expressed by people. For example, poor visibility, grey and gloomy overall picture, landscape enjoyment, visual landscape qualities - picturesque, colourful, diverse, calming, open, chaotic. Respondents who have an opinion that

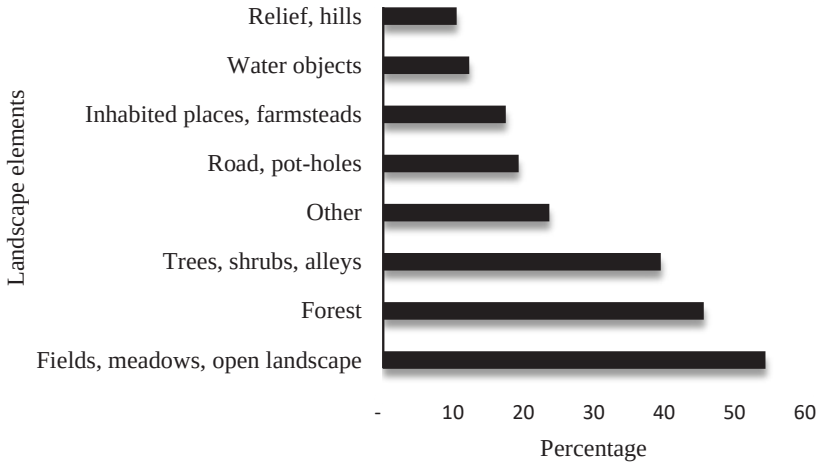


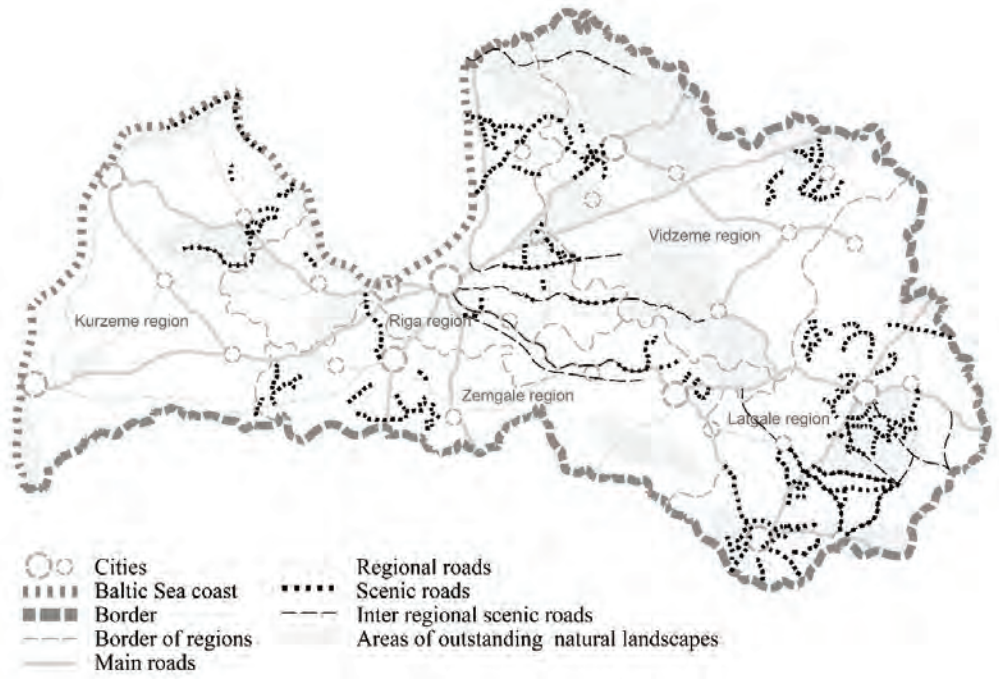
Figure 1. Characteristic elements of the road landscape named by respondents.

the Latvian road landscape is not interesting named such features like overgrown road sides, long grass, ditches, pot holes, pour quality of the road, garbage on road sides, forest clear-cuttings close to the road, trees, forests, abandoned buildings, no resting places along the road, fields, meadows. Research of S. Bell *et al.* and Z. Peneze on peoples' perception of countryside landscape changes has proved that Latvian people are concerned about field abandonment and see overgrowing as a negative trend (Bell *et al*., 2007; Peneze, 2009). Lack of management has been detected in previous research in the road landscape today (Vugule, 2013).

Evaluation results of planning documents

All regional communities in Latvia have spatial plans, which include high value landscapes and protected, scenic territories. The map in Figure 2 shows scenic roads listed in the spatial plans of regional communities, interregional scenic roads listed in the spatial plans of planning regions and outstanding nature areas marked in the Latvian spatial development perspective 'Latvia 2030'.

There are 110 regional communities in Latvia (Vides aizsardzības ..., 2016). Thirty nine of them mention scenic roads, landscape roads or sections of scenic roads in their spatial plans or sustainable



Source: author's marks on the map of the Latvian State Roads (Valsts akciju..., 2016).

Figure 2. Map of scenic roads in Latvia.

development strategies. Some communities have information about scenic roads both in spatial planning and sustainable development strategies. Sustainable development strategies describe the potential scenic roads. Twelve regional community planning documents mention road landscape elements that are present along the scenic roads.

The most frequently noted scenic road elements are cultural and historical objects and buildings (mounds, castles, manors, churches), forests and tree alleys, significant trees. Less frequently mentioned are farmsteads, agriculture land, open glades, lakes and rivers, and protected nature areas (swamps, bogs). Plains and hilly areas are mentioned least often.

There are 5 planning regions in Latvia. Each region has its spatial plan or regional strategy for sustainable development. They include information about scenic road development.

The Spatial Plan of Riga Planning Region foresees development of interregional scenic roads connecting larger and smaller cities and regional scenic roads in several road sections (Rīgas reģiona…, 2007).

Twelve from 28 regional communities from Riga Planning Region have defined scenic roads in their planning documents. Only a few regional communities have included scenic roads defined by Riga planning region in their planning documents. And not all of interregional scenic roads are included community planning documents.

The Spatial Plan of Latgale Planning Region foresees development of scenic roads in order to maintain cultural landscapes of Latgale and promote tourism there. It is stated that road reconstruction and improvement of road surface is necessary, and it should be done taking into account the landscape character (Latgales reģiona..., 2006). Scenic road sections should be defined more precisely in the spatial plans of regional communities and local municipalities (Latgales reģiona ..., 2006a). Currently several of Latgale planning documents foresee the development of various scenic road sections.

Eleven out of 19 regional communities in Latgale Planning Region have defined scenic roads in their planning documents. Some regional communities like Aglona, Dagda, Rezekne foresee to develop scenic roads defined in regional spatial plans as interregional scenic roads and develop some local scenic roads (Aglonas novada..., 2013; Reģionālie projekti ..., 2012; Rēzeknes novada …, 2013). The interregional scenic road along the Daugava River has been taken into account only in the Daugavpils Regional Community, but not in other municipalities through which it is passing (Rīgas reģiona …, 2007). Sustainable development strategy of the Vidzeme Planning Region sets out a long-term plan to develop the region's scenic roads (Vidzemes plānošanas …, 2014). Six out of 25 regional communities have defined scenic roads or sections of scenic roads in their planning documents. One community defines the criteria for high value landscape views.

The Kurzeme Planning Region Spatial Plan mentions that local municipalities should foresee development of scenic and tourism roads in their spatial plans (Kurzemes reģiona…, 2007). Four out of 18 regional communities have mentioned scenic roads planning documents. Two communities – Dundaga and Talsi – have defined precise scenic roads and some of the municipalities have mentioned reconstruction of scenic roads.

Scenic roads are not mentioned in any of Zemgale Region planning documents. There are 20 regional communities in Zemgale and 6 of them have defined scenic roads or sections of scenic roads.

The results of document analyses show that regional communities of the Latgale Planning Region are most active. Next comes Riga Region, followed by Zemgale, Vidzeme and then Kurzeme as the last one. Table 1 features the overview of regional communities mentioning scenic roads in their planning documents.

Table1

Overview of scenic roads in planning documents of regional communities

Planning region	Number of regional communities in planning region	Number of regional communities mentioning scenic roads in planning documents
Latgale	19	11
Riga	28	12
Zemgale	20	6
Vidzeme	25	6
Kurzeme	18	4

Some spatial plans include guidelines in the form of recommendations and compulsory requirements for landscapes with outstanding value along the roads and viewing points. The most frequent requirements are: road character and landscape vividness should be preserved; afforestation, large buildings or other structures blocking valuable views from the road are not allowed; road surface quality needs to be improved; resting places and tourist infrastructure should be provided.These requirements are essential for the scenic road development (Vermont Agency …, 2000) and should be considered for all scenic roads.

The distribution of scenic roads listed in the planning documents is uneven. There are unlisted roads with high aesthetic value and potential to be designated as scenic, for example, roads along the Baltic sea coast in Kurzeme and Baltic Sea gulf, roads

Source: author's photo (2014).

Figure 3. Vējupīte-Jūdaži. Positive landscape features - field and forest edge, agricultural pattern, significant tree, distant view, view with a dominant, wide panorama, gravel road surface.

Source: author's photo (2014).

Figure 4. Ķipari - Nirmuži. Positive landscape features - field and forest edge in the distance, agricultural pattern, gravel road surface. Negative features – overgrown unmanaged road ditches and edges of the road.

in areas of outstanding natural landscapes and historic sites which are set in Spatial development perspective 'Latvia 2030'.

Comparison of questionnaire results and documents of planning regions and regional communities show that most frequently mentioned landscape elements by respondents like fields, forests, trees are mentioned in the planning documents as well. Cultural and historical objects are more often mentioned in the planning documents, while respondents do not mention them as characteristic. The reason could be that such elements do not stand out in the landscape, for instance, churches often are hidden behind old trees which are in the protection zone of historic monuments. Visibility of such landscape elements is a problem as noted by other researchers (Markova, 2014). Planners and road designers should pay special attention how to show the presence of cultural and historical features in the landscape for road users.

Problems like bad road surface and poor visibility are recognized by people. Previous research shows that territories close to the road have maintenance problems (Vugule, 2013). Planning documents reflect it by foreseeing road reconstruction and management actions. Both people and planning documents name water bodies, farmsteads and buildings as important landscape elements. Road character and vividness is more stressed in the planning documents. Respondents and planning documents pay the least attention to the relief – hills and plains.

Definition from Latvian Landscape Policy Guidelines explains that scenic roads are those with significant landscape value for the identity of the territory, and they should be set in spatial planning documents on the bases of evaluation carried out by the society and might need specific management and planning (Vides aizsardzības …, 2013). Theoretically, the public should be involved in the process of scenic road designation process. The US Vermont Byways Program requires a nominating committee which seeks to represent the interests of a wide range of people and organizations along the road (Vermont Agency …, 2000). Meanwhile in Latvia, the scenic roads in the planning documents are mostly defined by experts.

Development and management plans of protected nature territories include information on scenic roads. No survey of these documents was included in this study. It is the next step to get a complete overview of present state of scenic roads in Latvia.

Results of field study

Results of the inventory of two road sections Ķipari - Nirmuži (V83) and Vējupīte-Jūdaži in Gauja National Park give insight about the scenic road landscape in Vidzeme Region (See Fig. 3 and 4).

Agricultural landscape dominates in both sections of the road. Other visible features are forests, field and forest edges, solitary trees, alleys and farmsteads, the road conforming to landscape.

Negative features are neglected overgrown unmanaged edges of the road, power lines. Previous research on road landscape (Vugule, 2013) shows that overgrowing of agricultural land is a problem in mosaic landscape. Results of the field study conform the public opinion detecting the negative aspects of road landscape, like unmanaged road side territories causing visibility problems. Values and features noticed by public like fields, open view to landscape, forests are present along the surveyed sections of scenic roads.

The total number of positive landscape elements in the section Vējupīte – Jūdaži is 29, total number of negative elements is 7. The average value of the landscape by kilometre after taking off negative features from positive features and dividing by number of kilometres is 5.5. The total number of positive landscape elements in the section Ķipari – Nurmiži is 21, total number of negative elements is 9. The average value of the landscape in the second section is 3. The difference is mainly from the number of positive elements.

Conclusions

Results of the public survey show that current Latvian road landscape has a potential for development, and it needs improvements.

Scenic roads are mentioned in planning documents of planning regions and regional communities. Two terms – scenic road and landscape road are used in Latvian planning documents. The term 'landscape road' appears mostly in planning region documents, the term 'scenic road' is used more often in regional community plans. The terms have the same meaning and this should be discussed further, which of the two should be used in planning documents.

There is no consistency between different planning levels. Regional communities do not follow regional plans regarding scenic road designation. One of the reasons could be lack of information and communication between the planning levels. The criteria for scenic road nomination and landscape assessment methods are set individually in every region. A comprehensive approach for assessing aesthetic road qualities and classification of scenic roads is missing. It is necessary to examine what kind of methodology is used in regional communities for scenic road designation and see how public can be involved in this process. Experience from other countries show that initiatives about scenic road designation should come from local municipalities, but the process of road designation should be developed and regulated by one institution, which should provide common methodology for road landscape assessment and scenic road designation.

The field study gives insight in the scenic road landscape qualities and highlights that negative features like overgrown and unmanaged road sides are present in a road landscape which is defined as scenic.

The adapted inventory method is suitable for scenic road evaluation. Further research with more sample territories is necessary in order to draw up general conclusions about the state of scenic roads in Latvia.

References

1. Akbar, K.F., Hale, W.H.G., & Headley, A.D. (2003). Assessment of scenic beauty of the roadside vegetation in northern England. *Landscape and Urban Planning.* 63(3), 139-144. DOI: 10.1016/S0169-2046(02)00185-8.
2. Aglonas novada dome (2013). *Aglonas novada teritorijas plānojums 2013 – 2025. gadam I daļa* (Spatial plan of Aglona regional municipality 2013 – 2025, part I). Retrieved March 1, 2016, from http://www.aglona.lv/wp-content/uploads/2013/08/I-dala-paskaidrojuma-raksts.pdf. (in Latvian).
3. Bell, S., Penēze, Z., Nikodemus, O., & Montarzino, A., & Grīne, I. (2007). The value of Latvian rural landscape. In European Landscapes and Lifestyles. The Mediterranean and beyond, (pp. 347-362). Lisbon, Lusofonas: Edicoed Universitarias.
4. Blumentrath, C., & Tveit, M. (2014). Visual characteristics of roads: A literature review of people's perception and Norwegian design practice. *Transportation Research Part A: Policy and Practice*. 59, 58-71. DOI: 10.1016/j.tra.2013.10.024.
5. Denstadli, J.M., & Jacobsen, S.Kr.J. (2011). The long and winding roads: Perceived quality of scenic tourism routes. *Tourism Management*. 32(4), 780-789. DOI: 10.1016/j.tourman.2010.06.014,
6. DeWan, T., & Terrence, J. (2008). *Scenic assessment Handbook.* Maine: Maine State Planning Office
7. Draper, R., & Petty, K. (2001). The National Scenic Byways Program: On the Road to Recreation. *Journal of Physical Education, Recreation & Dance*. 72(1), 27-31. DOI: 10.1080/07303084.2001.10605816.
8. Dripe, J. (1940). Latvijas zemes ceļi un tūrisms (Latvian gravel roads and tourism). *Ceļš un satiksme*, 13. (in Latvian).

9. Junta da Andalucia (2009). *Roads in the Landscape: criteria for their planning, layout and project design.* Sevilla: Conserjeria de ObrasPublicas y Transportes.
10. Eby, D.W., & Molnar, L.J. (2002). Importance of Scenic byways in route choice: a survey of driving tourists in the United States. *Transportation Research Part A: Policy and Practice*. 36(2), 95-106. DOI: 10.1016/S0965-8564(00)00039-2.
11. Kurzemes reģiona attīstības aģentūra (2007). *Kurzemes plānošanas reģiona teritorijas plānojums. II daļa. Telpiskās attīstības perspektīva 2006 – 2026* (Spatial development plan of Kurzeme planning region 2006 – 2026). Retrieved March 3, 2016, from http://www.kurzemesregions.lv/jomas/Teritorijas_attistibas_planosana/KPR_teritorijas_planojums/. (in Latvian).
12. Latgales reģiona attīstības aģentūra (2006). *Latgales plānošanas reģiona teritorijas plānojums. Vides pārskats* (Spatial plan of Latgale planning region. Environmental report). Latgales reģiona attīstības aģentūra. (in Latvian).
13. Latgales reģiona attīstības aģentūra (2006a). *Latgales plānošanas reģiona teritorijas plānojums. Telpiskās attīstības perspektīva II daļa* (Latgale planning region territory plan. Spatial development perspective, part II). Retrieved March 1, 2016, from http://www.latgale.lv/lv/padome/planosana. (in Latvian).
14. Latvijas Republikas Saeima (2010). *Latvijas ilgtspējīgas attīstības stratēģija līdz 2030. gadam* (Sustainable development strategy for Latvia ill the year 2030). Retrieved March 3, 2016, from http://www.latvija2030.lv/upload/latvija2030_saeima.pdf. (in Latvian).
15. Markova, M. (2014). Latgales dievnamu ainava (Church landscape of Latgale). Summary of doctoral dissertation, Latvia University of agriculture, Jelgava (in Latvian).
16. Penēze, Z. (2009). *Latvijas lauku ainavas izmaiņas 20. un 21. gadsimtā: cēloņi, procesi un tendencies* (Changes in Latvian rural landscape in 20th and 21st century: reasons, processes and tendencies). Summary of doctoral dissertation, Latvia Universitty, Riga. (in Latvian).
17. Reģionālie projekti (2012). *Dagdas novada ilgtspējīgas attīstības stratēģija 2030* (Sustainable development strategy of Dagda regional community 2030). Retrieved March 1, 2016, from http://www.dagda.lv/uploads/media/Dagdas_novada_Ilgtspejigas_attistibas_strategija_2030-mod.pdf. (in Latvian).
18. Rēzeknes novada dome (2013). *Rēzeknes novada teritorijas plānojums 2013 – 2024* (Spatial plan of Rezekne regional municipality 2013 – 2024). Retrieved March 1, 2016, from http://rezeknesnovads.lv/wp-content/uploads/2014/05/teritorijasizmantosanasapbuvesnoteikumi.pdf. (in Latvian).
19. Rīgas reģiona attīstības aģentūra (2007). *Rīgas plānošanas reģiona telpiskais (teritorijas) plānojums. II daļa* (Spatial plan of Riga planning region. Part II). Rīga: Rīgas reģiona attīstības aģentūra. (in Latvian).
20. Timothy, J., & Devitt, M. (1999). Valuing Changes to Scenic Byways. In Pizam, A., Mansfeld, Y. *Consumer Behaviour in Travel and Tourism* (pp. 227-244). New York: The Haworth Hospitality Press
21. Vermont Agency of Transportation. (2000). *The Vermont byways program Program manual*, Vermont: Vermont Agency of Transportation.
22. Valsts akciju sabiedrība Latvijas Valsts ceļi (2014). *Valsts autoceļu tīkla statistika* (Statistics of state road network). Retrieved March 1, 2016, from http://lvceli.lv/wp-content/uploads/2015/08/Latvijas_Valsts_Celi_2014_A4_LAT_ENG_20150617.pdf. (in Latvian).
23. Vides aizsardzības un reģionālās attīstības ministrija (2013). *Ainavu politikas pamatnostādnes 2013.–2019.gadam* (Guidelines of landscape politics 2013 – 2019). Retrieved March 1, 2016, from http://polsis.mk.gov.lv/documents/4427. (in Latvian).
24. Vides aizsardzības un reģionaālās attīstības ministrija (2016). *Republikas pilsētas un novadi* (Cities and regional communities). Retrieved March 1, 2016, from http://www.varam.gov.lv/lat/darbibas_veidi/pasv/?doc=13065. (in Latvian).
25. Vidzemes plānošanas regions (2014). *Vidzemes plānošanas reģiona ilgtspējīgas attīstības stratēģija 2014 – 2030* (Sustainable development strategy of Vidzeme planning region 2014 – 2030). Retrieved March 4, 2016, from http://www.vidzeme.lv/upload/VPR_IAS_10112014_labots.pdf. (in Latvian).
26. Vugule, K. (2013). The Latvian landscape as seen from the road. In Research for rural development 2013: annual 19th international scientific conference proceedings, 15 – 17 May 2013 (pp. 120-127). Jelgava, Latvia: Latvia University of agriculture.
27. Vugule, K., Bell, S., & Stokmane, I. (2014). Road landscape development in Latvia up to the 21st century. *Landscape Architecture and Art*. 4(4), 10-16.

LANDSCAPE ARCHITECTURE STUDIES BY USING SERVICE LEARNING METHOD

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Abstract
This article deals with the use of the service learning method in the study courses of landscape architecture bachelor studies outcomes from a student's perspective. This kind of research is unique with combining service learning method research and involvement of student's perspective. The service learning method, which includes both theoretical studies and practical work in the planning of actual territories and communication with the customer, is important for the development of professional competences in the field of landscape architecture. The aim of the research was to state the benefits of students' professional growth from using this method in the study process. The article summarises the evaluation of the experience of Latvia University of Agriculture landscape architecture studies in cooperation with 3 non-governmental organisations, 8 municipalities and governmental organisations and 4 associations from 2013 to 2016. The research was based on the students' survey. The students had to answer close-ended questions about the knowledge they had acquired from the projects of different scales. As a result of the survey, it was concluded that the students' main benefits of professional knowledge are mainly associated with a better understanding of specific features of particular places, which is not always possible within the framework of theoretical studies. The possibility of presenting projects to a real customer, thus improving one's presentation skills was also positively evaluated.
Key words: service learning, work-based studies, landscape architecture, study projects.

Introduction

An important stage in landscape architecture education is the territory planning of different types and scales, which, already in the study process, develops the future specialists' understanding of the scale of the territory in selecting an appropriate research and planning approach (McGarigal, s.a.; Benson, & Mackenzie, 1995; Saura & Martínez-Millán, 2001; Wu, Shen, & Sun, 2002; Wu, 2004). However, modern scientific publications are showing a trend that landscape architecture studies are becoming increasingly theoretical and comprehensive, focusing more on global issues such as climate change and urbanization. This approach does not allow a student to find a suitable solution in specific situations (Horrigan & Oles, 2015). Developing a project for an actual place with a real customer being interested in developing the territory, encourages the students to think systematically, sometimes even in inter-disciplinary perspective, including critical analysis of previously acquired theoretical knowledge and the use of this knowledge. Students take an active part in the project development process not only in communication with the customer, but also in affecting the progress of the course and project development on the whole (Grandin *et al*., 2010). Thus, landscape architecture studies are becoming even more effective.

Different types of teaching and learning aiming at practical use of theoretical knowledge

Most often the practice-oriented studies are implemented within the framework of work-based and project-based learning (Marcia, 2008; Deming & Swaffield, 2011; Genca, 2015) service learning (Nelsona *et al*., 2010; Angotti, Doble, & Horrigan, 2012; Grabbatina & Fickeya, 2012) and practice work (Wenger-Trayner *et al*., 2014). The advantage of these methods has been emphasized in several scientific articles.

The project-based study process involves an active participation of students in it. The lectures which are conducted in a traditional way make up the basis of students' theoretical knowledge, while the project-based study activities provide an opportunity to apply this basic knowledge to solving existing problem issues in the development of real territories. Thus, a linkage between theory and practice is created and understanding of how to use various types of basic knowledge in life is reached (Amstrong, 1999; Chinowsky *et al*., 2006). Although the project-based studies are useful in improving the students' knowledge, this approach involves an active participation of lecturers in developing cooperation and selection of the territories to be developed in the course projects.

The students' work in their respective field during the study course is a kind of work-based studies (Freestone, Thompson, & Williams, 2006). This approach is important for the development of professional competences. An integral part of the study process which is based on the development of practical skills are discussions, exchange of opinions, as well as defending the chosen concepts, being aware of their pros and cons (Baum, 1997). The practical experience of the academic staff plays a great role here, not only in sharing the experience, but also in being able to most effectively organise the study

process and include theory and practice in a balanced way, so that these two parts could be linked. As a limiting factor of this approach, one should mention the professional competence of the academic staff required for work-based learning, to be able to ensure the quality monitoring of the study process.

Service learning has become a widely used approach in higher education in different fields. It is considered to be an effective tool in increasing the importance of the studies not only for students, but also for people not related to the study process but who are participating in the project development (Eyler *et al*., 2001). Consequently, by using the service learning approach in territory planning, the community is also involved and educated. Service learning has several potential limitations. One of them can be the problem for the faculty workloads and rewards that directly relate to the motivation mentioned before, the lack of which may be a limiting factor. Another limiting factor can be differing traditions of planning and design. The quality of the design solution is undoubtedly evaluated as a risk factor, since the students are not professional designers yet. In general, it is believed that service learning can offer very useful services to neighborhoods while offering students vital skills for working with multiple publices (Forsyth, Lu, & McGirr, 2000). Regarding the practice, it has been assessed that the major winners are the students. The most important benefit for the young professionals is that of working in a team, cooperating with customers; they have a chance to see how the project is being implemented, feel responsible, develop the culture of work (Burton, 2015).

The research of different scientists present the analysis of not only various teaching methods and approaches, but also the benefits the students have, the students' understanding of the usefulness of these methods as well as the emotional experience in the study process (Deming & Swaffield, 2011). An emotional load is created by the study process which includes working in groups, discussions, defending the ideas, working under the guidance of a mentor, communication with the third party (municipality, association and organisation), communication with lecturers, research of theoretical materials. Defence and discussion process during the project elaboration stage are issues to be dealt with separately, but it definitely involves gaining experience (Smith & Boyer, 2015). Quite often the research papers include the discussions about the landscape architecture students' different experiences in the study subjects and with regard to the problem issues to be solved, not only compared with the lecturers' or other professionals' experience, but also compared to that of other students when acquiring (in the process of acquiring) similar subjects or themes (Swaffield, 2002). The similarity in the diference of viewpoints can be found also among the professionals of different fields. Consequently, different approaches and viewpoints of studies can be explained by the chosen profession and specifics of the sector. Landscape, due to its multidisciplinary and all-inclusive nature, puts a burden on landscape agriculture students already from their early studies to look at things and issues in a broader sense.

Different ways of cooperation universities use in study process

Nowadays, more often society's participation in territory planning is being emphasized (Bloemers, 2010). In several articles the importance of participation of local governments and communities in the planning process (Healey, 1997), associated with a direct interest in the development of a certain territory has been cooperation in territory planning at different levels is becoming more and more important and the cooperation in territorial planning at various levels, embracing both academic and scientific environment, businesses and municipalities.

Cooperation between university and municipalities can be organised according to different models. In Latvia, service learning is quite widely used by universities engaging in project development in various sectors of the economy. In the Latgale region, tourism development is very important, and the local regional university is actively engaged in it (Silinevica, 2015). Also, Dutch universities actively use the university knowledge in development planning, in this case the transfer of knowledge in the social sector (Postma, 2013).

Cooperation projects between universities and local governments have been described in several publications, where the main emphasis is on the study process and the benefits for the students from this cooperation. It mainly reflects the development of better understanding about the future profession and necessary knowledge and skills. Overall, the service learning approach is useful for the universities, since it provides the possibility for cooperation. Moreover, the academic staff involved bears responsibility for implementing cooperation and its quality, thus offering students the opportunity to be responsible as well (Forsyth, Lu, & McGirr, 1999).

The main aim of the research was to summarise and analyse the information about the benefits of students' professional knowledge in the study courses which have been implemented by using the service learning method as well as to summarise problem issues they have addressed within the territories of different scales within the framework of landscape architecture studies from the year 2013 to 2016. The focus is on landscape architecture studies that

are carried out by trilateral cooperation 'university, student, municipality'.

Materials and Methods

The Landscape architecture 5-year professional bachelor's programme of Latvia University of Agriculture is composed of study courses which help improve the basic knowledge required for the profession, e.g.: drawing skills, sense of space, analysis, planning, etc. To improve this basic knowledge in practice, the study courses in Landscape architecture and design are elaborated, within the framework of which, cooperating with a real customer, the development projects of real territories are carried out. Prior to developing the diploma thesis the students strengthen the acquired knowledge by having practice in landscape designing companies or municipalities.

The service learning method according to which the cooperation between the local governments, faculty/university and students takes place during the course project analysed in research is schematically shown in Figure 1. One party is the university – the academic staff and students but the other one - the local government – city or municipality council, unions and organisations. This is a horizontal cooperation, since it is formed between two autonomous organisations.

From the experience and knowledge roles of each participant are defined in trilateral cooperation. The aim of the local government is to develop a specific territory through project development in cooperation with the speciality of landscape architecture, while the aim of the study programme and study course is to provide students – the future specialists with the knowledge and skills required in the specific field. The knowledge and skills are different within each study course, so that the students are able to acquire and strengthen the professional competences required for each subsequent level or task.

The faculty/local government cooperation was implemented in certain course project within the framework of research. The local government is the contracting authority, which defines its needs, sets tasks and results to be achieved, providing the necessary cartographic, photographic, archive materials, thematic lectures and other related materials. Taking into account the customer's interests as well as the theoretical knowledge to be strengthened and the competencies to be acquired during the course, the lecturers prepare the tasks to be completed by the students in a more detailed way. The tasks can be connected with the research of landscape spatial structure and value, heritage studies, design solutions, planning at different levels of detail and taking into account the specifics of the territory. In the course of 8 weeks (1 semester at LLU) the lecturers introduced theoretical material to the students. This material was related to the type of a specific area and the problem to be solved, such as forming the identity and image of a populated area.

The students have field trips to the territory once or twice. During these trips, based on the previously prepared cartographic material (topographic and other types of maps), they carry out deeper research of the site and make markings on maps; they also take photos and attend lectures prepared by municipalities. Then, alongside with the acquisition of the theoretical material, the work on the sketch of ideas and the development project of the territory takes place. During the designing period there are several interim reports in which the lecturers evaluate the progress of each student or each group if the work is done in groups. If necessary, the issues, which need to be addressed more thoroughly are pointed out. Students are also trained to use questionnaires, landscape analysis, the techniques of presenting their ideas and communication with the customer, organising

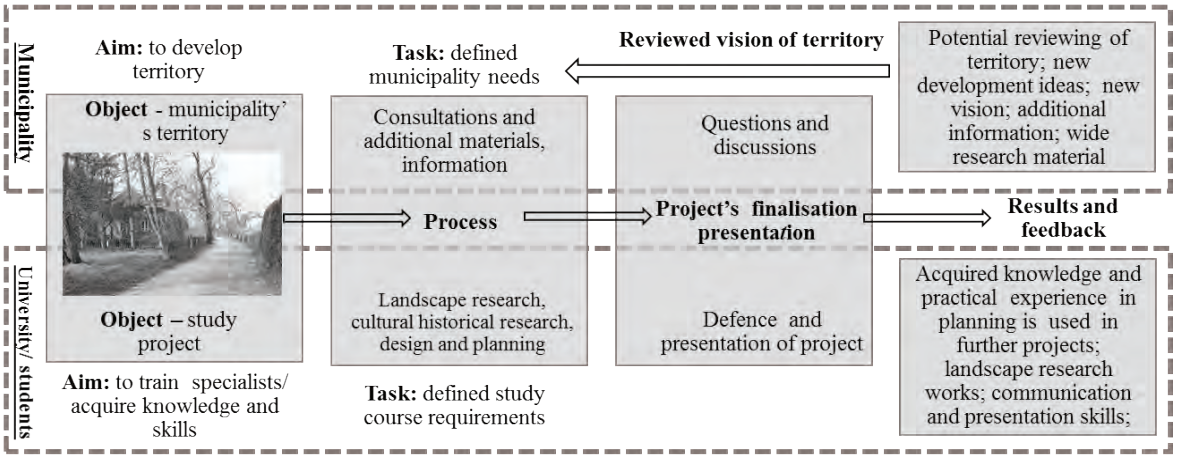

Figure 1. Trilateral cooperation through service learning (modified by authors).

discussions in interim reports and working on the design of visual material.

The project's final presentation to the customer is an integral part of service learning, because in this way the students have an opportunity to observe how the knowledge acquired during the study course, presentation skills and project execution skills work in practice. Customer's representatives attend the final presentation, participate in discussions, ask questions and comment on the students' results. After the final presentation the customer has an opportunity to review the development potential of the territory, find new ideas and obtain a wide range of research material.

Students` survey. In this research the experience of using service learning method in 18 course projects was analysed. Those were: Aldaris park (Riga); vicinity of Anniņmuiža (Riga) Reņķis garden (Ventspils); Sarkanmuiža park (Ventspils); Swedish rampant (Ventspils); courtyards of Jelgava's multi-storey residential buildings; Oskars Kalpaks square and Strūve park (Jēkabpils); the state social care centre 'Allaži', Šlokenbeka manor ensemble; greenery territories (Bauska); 'Raganu park' (Krimulda municipality); Greenery territory in the vicinity of Turaida; Brukna manor house; central part of Ranka village; Central part of Slampe village; Coastal nature park in Saulkrasti; Courtyard of 2, Daugava Street, Salaspils and the territory next to Griva boulevard in Ogre. These 18 projects were carried out in the framework of cooperation with 3 non-governmental organisations, 8 municipalities and governmental organisations and 4 associations.

The students' survey was carried out after the stucturing and analysis of the objects in order to ensure a transparent comparison of the tasks set, the students' opinions about the experience gained in conjunction with the scale of the design areas. Course project territories were divided into 3 groups – territories of up to 5 ha (small-scale), 6 to 30 ha (medium-scale) and over 30 ha (large-scale). Survey results were converted in percents and rounded to full figures.

Evaluating the territory development course projects, the lecturers involved in them indicated that addressing the territories with an area of up to 5 hectares, the students were given tasks mainly aiming to obtain the skills and knowledge of the composition of the territory planning, functional zone, the road network and parking lot development, lighting, greenery and design elements planning, as well as a detailed 3D visualization development. This can be explained by the high degree of course project details elaboration for this planning scale (most often M/S1: 200). In some thematic projects the tasks about specific issues were given, such as the location of the territory in the overall structure of the populated area, cultural and historical research, relief and environmental accessibility solutions. Tasks according to acquiring public interviewing skills have been only within the framework of one project, which is explained by the seclusion of the territory and limited public access to most of the designed territories.

Tasks aiming to obtain the most comprehensive knowledge and professional skills were in the design of the territories with an area of 6 to 30 ha, since the planning scale requires both conceptual and general solutions for M/S 1:500 or M/S 1:1000, as well as a separate place detailing M/S1: 200. Consequently, the given tasks in the planning of these territories are related to both conceptual solutions of territory development - spatial structure, the common infrastructure of the territory and links with the surrounding landscape, the blue-green networks, visual and physical access, as well as with detailed solutions - roads, lighting, greenery, terrain and water and design elements. In the design process students were working on landscape analysis and different methods of analyses. Public interviewing was also used in the designing of these territories, so that the students could develop the ability to analyse the needs of the population in the context of landscape architecture technologies.

In the territory group, having an area of over 30 hectares, the students were given tasks aiming to obtain knowledge and professional skills related to the design of large-scale territories (M/S 1:1000, M/S 1:10000). These territories are characterized by design tasks and issues more appropriate to a large scale. Consequently, the given tasks were related to the elaboration of the vision of territory development, planning of spatial structure and the blue-green networking, infrastructure solutions, in-depth analysis of the landscape, including the research of heritage, ecological, etc. landscapes. In dealing with these territories wider use of public interviewing is approved, since in the developing of such scale projects questionnaires play an important role, because the territory included in the project affects a large part of society. In the planning of these territories, fewer tasks were given relating to the project detail, such as environmental availability solutions, detailed elaboration of greenery, solutions of design elements, etc.

The students` survey was conducted in the winter of 2016, involving 41 respondents – students who had participated in the elaboration of course projects of different scales. The students had to explain what knowledge they had acquired in each of the project groups. The survey was based on four close-ended questions. Three questions of the survey were made based on the results obtained from the first part of the research that the course project territories have to be divided according to the scale of those areas. Those were: 'Was it possible to acquire the following skills and benefits from small-scale / medium-scale

/ large-scale projects?'. The students could choose several answer options from 15 given. Those were the following: 1.elaborating development vision; 2. developing the blue–green network; 3. developing spatial structure; 4. infrastructure solutions; 5. analysis of landscape and its elements; 6. heritage research; 7. developing and using surveys and interviews; 8. planning of road network and parking lots; 9. terrain solutions; 10. environment accessibility;11. planning of lighting; 12. planning of greenery; 13. planning of design elements; 14. developing visualisation; 15. elaborating project details of project parts. They were given a chance to add their own answer as well. The fourth question was adressed to the evaluation of cooperation with the local governments. The question was formulated as follows: 'Is cooperation with local governments important within the framework of the study course projects?'.

Results and Discussion

The students' survey was conducted after the first part of research was completed, thus the questions were formulated according to the course project parts and the defined scales. Answering the first question – 'Was it possible to acquire the following skills and benefits from small-scale projects (the state social care centre 'Allaži', Šlokenbeka manor ensemble, Courtyard of 2, Daugava Street (Salaspils), greenery territories (in the centre of Bauska), Oskars Kalpaks square and Strūve park (Jekabpils), 'Raganu park' (Krimulda municipality), Greenery territory in the vicinity of Turaida)?' more than 75% of the respondents consider that within the framework of the projects they have acquired knowledge in the following fields - elaborating development vision, planning of road network and parking lots, environment accessibility, planning of greenery, planning of design elements, developing visualisation. It should be mentioned that the lecturers never assign the task of elaborating development vision to small-scale territories, since the solutions for these territories do not affect a large part of public or development at a larger scale. More than a half of the respondents consider that they have acquired knowledge in such fields as developing spatial structure, infrastructure solutions, analysis of landscape and its elements, heritage research, terrain solutions, planning of lighting, elaborating project details of project parts. From the tasks mentioned above the lecturers have never given the tasks dealing with developing spatial structure in any of the projects. The respondents also mentioned that they had dealt with developing the blue–green network and planning of design elements. In addition, the students also mentioned that overall it could be considered that all the questions listed in the survey had been addressed. When dealing with small-scale territories, the students consider that they had also dealt with larger scale issues in both social and territorial context.

Responding to the second question – 'Was it possible for the students to gain the following skills and benefits from medium-scale projects (Brukna manor house, Aldaris park (Riga), vicinity of Anniņmuiža (Riga), Reņķis garden (Ventspils);

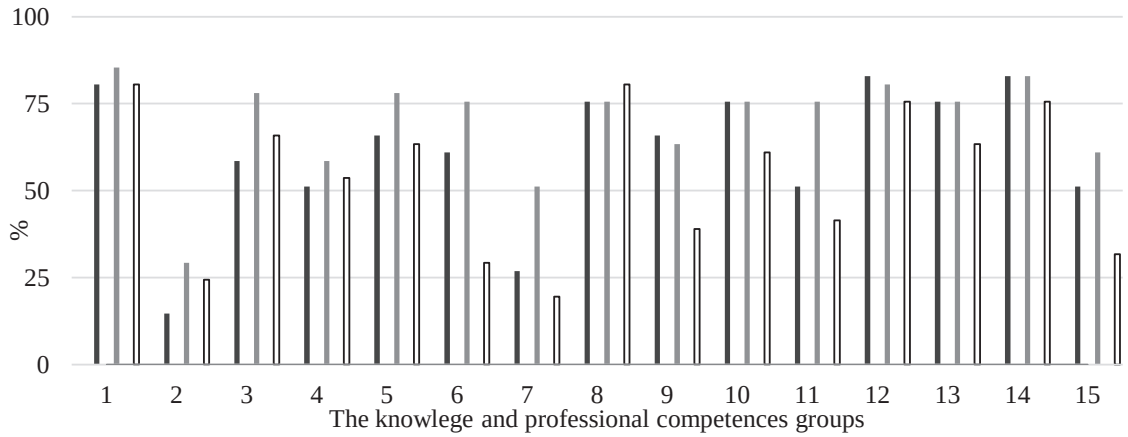

Figure 2. Summary of students` evaluation of acquired knowledge in: ■ small-scale projects (first question); ■ medium-scale projects (second question); □ large-scale projects (third question); 1. elaborating development vision, 2. developing the blue–green network; 3. developing spatial structure; 4. infrastructure solutions; 5. analysis of landscape and its elements; 6. heritage research; 7. developing and using surveys and interviews; 8. planning of road network and parking lots; 9 terrain solutions; 10. environment accessibility; 11. planning of lighting; 12. planning of greenery; 13. planning of design elements; 14. developing visualisation; 15. elaborating project details of project parts.

Sarkanmuiža park (Ventspils); Swedish rampant (Ventspils); central part of Ranka village, Central part of Slampe village)?' - more than 75% of the respondents consider that within the framework of the projects they have acquired knowledge in the following fields - elaborating development vision, developing spatial structure, analysis of landscape and its elements, heritage research, planning of road network and parking lots, environment accessibility, planning of lighting, planning of greenery, planning of design elements, developing visualisation. More than half of the respondents consider that they have acquired knowledge in such fields as - infrastructure solutions, developing and using surveys and interviews, terrain solutions and in elaborating details of project parts. The respondents have also mentioned that they had been dealing with such tasks as developing the blue-green network as well as mentioning (in the open section) that the acquired knowledge and competencies depend on each student's abilities and desires. The tasks for the medium-scale territories differ from the aim set in the project, but in total, all the 15 tasks defined were dealt with. The differences occur based on the public acessibility of the territory, or, on the contrary – on its seclusion. Likewise, when doing their project, work, the students have also tried to find the balance, dealing with the territory in different perspectives.

Responding to the third question – 'Was it possible to obtain the following skills and benefits from the large-scale projects (the coastal nature park in Saulkrasti, the territory next to Griva boulevard in Ogre, courtyards of Jelgava's multi-storey residential buildings)?' - more than 75% of the respondents consider that within the framework of the projects they have acquired knowledge in the following fields: elaborating development vision, planning of road network and parking lots, planning of greenery, developing visualisation. More than half of the respondents consider that they have acquired knowledge in the fields of developing spatial structure, infrastructure solutions, analysis of landscape and its elements, environment accessibility, planning of design elements. The respondents have also stated that they have dealt with such tasks as developing the blue–green network, heritage research, developing and using surveys and interviews, terrain solutions, planning of lighting, elaborating details of project parts. From the tasks mentioned here, the lecturers have not asked the students to deal with the following tasks: planning of road network and parking lots, planning of greenery, developing visualisation, planning of design elements, planning of lighting, elaborating details of project parts. These differences could be explained by the fact that quite often the large-size territories are dealt with in later years of studies after different kinds of detailed plans are solved. Although it was not required to submit a detailed plan for the territory, the students had thought about it and they had presented their ideas on that. In the open part of the questionnaire the students had mentioned that they had improved their presentation skills, acquired knowledge about the influence of the limited resources on the scope of the project design in Latvia.

In addition, in the fourth question the students were asked how they evaluated the cooperation with the local governments. Most respondents acknowledged that this cooperation was important. This positive evaluation indicates the attractivenes of the service learning method and its effectiveness not only from the lecturers' but also from the students' point of view.

Overall, it should be noted that the results of the survey reflect the different issues dealt with in the course projects of different scales, reflecting the tendency that the issues pertaining to large-scale territories are more general, whereas in medium-scale and small-scale territories the issues to be addressed are more detailed. It was quite surprising to learn that at all the levels the respondents consider that they acquire knowledge in a wide range of issues. The students consider that they have managed to deal with a wider range of tasks and acquired more than the lecturers had asked them to do. It is explained by a holistic nature of landscape. This holism (a complex whole) of landscape does not allow to unequivocally approve of any of landscape research or modeling theories, unless multidisciplinary approach is used. Therefore, understanding starts with the concept of landscape, the connections and interactions present in landscape and only then the analysis of separate constituent parts of landscape follows (European Council, 2002; Stewart, Liebert, & Larkin, 2004; Stephenson, 2010). The students have perceived this characteristic feature of landscape as something commonly known, that is reflected in their work within the context of their course projects. The results obtained from the research on the use of the service learning should be evaluated in the context of the particular field – landscape architecture, where it has been applied.

Conclusions

Service learning has a positive influence on the study process, since both lecturers and students are thus able to solve topical problem issues for real territories. For lecturers this trilateral cooperation has provided the opportunity to build a very broad theoretical basis, pertaining to territories of different scales with examples dealt with in the form of cooperation. For students, the course projects implemented with the service learning method provide an opportunity to improve their knowledge with a wide range of issues to be addressed. In developing the course projects, students become more convinced about the

comprehensive nature of landscape, as evidenced by their desire to solve not only the required tasks, but also to reflect on different aspects of the project solutions and scales. The results of the research should be researched and explained in more detail, by conducting a wider students' survey focusing more on the emotional experience in the development of course projects by applying the service learning method.

References

1. Amstrong, H. (1999). Design studios as research: an emerging paradigm for landscape architecture. *Landscape Review*, 5(2), 5-25.
2. Angotti, T., Doble, C., & Horrigan, P. (2012). *Service-Learning in Design and Planning: Educating at the Boundaries*. New Village Press.
3. Baum, H. (1997). Teaching practice. *Journal of Planning Education and Research*, 17, 21-29. DOI: 10.1177/0739456X9701700103.
4. Benson, B.J., & Mackenzie, M.D. (1995). Effects of sensor spatial-resolution on landscape structure parameters. *Landscape Ecology*, 10(2), 113-120. DOI: 10.1007/BF00153828.
5. Bloemers, T. (2010). Landscape in a Changing World: Bridging Divides, Integrating Disciplines, Serving Society. *European Science Foundation Policy Briefing*, 41.
6. Burton, M. (2015). How was your work experience? Students` perspectives of the year in practice. In ECLAS conference: 21 – 24 September 2015, Tartu, Estonia.
7. Chinowsky, P.S., Brown, H., Szajnman, A., & Realph, A. (2006). Developing knowledge landscapes through project-based learning. *Journal of Professional Issues in Engineering Education and Practice*, 132(2), 118-124.
8. Deming, M.E., & Swaffield, S. (2011). *Landscape Architectural Research: Inquiry, Strategy, Design*. John Wiley & Sons.
9. European Council. (2002). Concerning the implementation of Integrated Coastal Zone Management in Europe. *Official Journal of the European Communities*. 148, 24-27.
10. Eyler, J., Giles, D., E.Jr., Stenson, C.M., & Grey, C.J. (2001). *At A Glance: What We Know about The Effects of Service-Learning on College Students, Faculty, Institutions and Communities*. Retrieved January 15, 2016, from http://digitalcommons.unomaha.edu/slcehighered/139.
11. Forsyth, A., Lu, H., & McGirr, P. (1999). Inside the service learning studio in urban design. *Landscape Journal*, 18(2), 166-78. DOI: 10.3368/lj.18.2.166.
12. Forsyth, A., Lu, H., & McGirr, P. (2000). Service learning in an urban context: Implications for planning and design education. *Journal of Architectural and Planning Research*, 17(3), 236-260.
13. Freestone, R., Thompson, S., & Williams, P. (2006). Student experiences of work-based learning in planning education. *Journal of Planning Education and Research*, 26(2): 237-249. DOI: 10.1177/0739456X06295027.
14. Genca, M. (2015). The project-based learning approach in environmental education. *International Research in Geographical and Environmental Education*, 24(2). DOI: 10.1080/10382046.2014.993169.
15. Grabbatina, B., & Fickeya, A. (2012). Service-Learning: Critical Traditions and Geographic Pedagogy. *Journal of Geography*, 111(6), 54-260. DOI: 10.1080/00221341.2012.694465.
16. Grandin, J., Apine, L., Kovbasko, O., & Zhuk, Y. (2010). Student's role in sustainable development: to create attractive and sustainable future. Environment and sustainable development. Klavins, M., Leal, W.F., Filho & Zaloksnis, J., Riga: University of Latvia. ISBN: 978-9984-45-234-0.
17. Healey, P. (1997). *Collaborative Planning: Shaping Places in Fragmented Societies*. UBC Press. ISBN 10: 0774805986
18. Horrigan, P.H., & Oles, T. (2015). Learning to land, landing to learn: On fieldwork in landscape architecture education. Proceedings of: Landscapes in flux: Conference of the Council of European Landscape Architecture Schools (ECLAS), Proceedings of: Landscapes in flux: Conference of the Council of European Landscape Architecture Schools (ECLAS).
19. Marcia, L. (2008). Project-Based Learning for Sustainable Development. *Journal of Geography*, 107(3). DOI: 10.1080/00221340802470685.
20. McGarigal, K. (2016). *What is a Landscape?* Retrieved February 5, 2016, from http://www.umass.edu/landeco/teaching/landscape_ecology/schedule/chapter3_landscape.pdf
21. Nelsona, C., Antayá-Mooreb, D., Badleyc, K., & Colemand, W. (2010). The sustaining possibilities of service-learning engagements. *Teachers and Teaching: theory and practice. Sustaining Teachers in Teaching*, 16(3), 353-371. DOI: 10.1080/13540601003634529.
22. Postma, J. (2013). *The ability to work together: municipal cooperation for effective social sector policy implementation*. Retrieved February 10, 2016, from http://essay.utwente.nl/63657/.

23. Saura, S., & Martínez-Millán, J. (2001). Sensitivity of landscape pattern metrics to map spatial extent. *Photogrammetric Engineering & Remote Sensing*. 67(9), 1027-1036.
24. Silinevica, I. (2015). The role of collaboration municipality – regional university in sustainable tourism development: Case study of Dagda county. In Revelling in Reference: 10th International Scientific and Practical Conference, 2015, Rezekne, Latvia.
25. Smith, C.A., & Boyer, M.E. (2015). Adapted Verbal Feedback, Instructor Interaction and Student Emotions in the Landscape Architecture Studio. *International Journal of Art & Design Education*, 34(2), 260-278. DOI: 10.1111/jade.12006.
26. Stephenson, J. (2010). The Cultural Values Model: An integrated approach to values in landscapes. *Landscape and Urban Planning*, 84, 27-139. DOI: 10.1016/j.landurbplan.2007.07.003.
27. Stewart, W.P., Liebert, D., & Larkin, K.W. (2004). Community identities as visions for landscape change. *Landscape and Urban Planning*, 69, 315-334. DOI: 10.1016/j.landurbplan.2003.07.005.
28. Swaffield, S. (2002). Theory in Landscape Architecture: A Reader. University of Pennsylvania Press. 265.p.
29. Wenger-Trayner, E., Mark Fenton-O'Creevy, M., Hutchinson, S., Kubiak, C., & Wenger-Trayner, B. (2014). Learning in Landscapes of Practice: Boundaries, identity, and knowledgeability in practice-based learning. *Routledge*, 182.
30. Wu, J.G. (2004). Effects of changing scale on landscape pattern analysis: scaling relations. *Landscape Ecology*, 19(2), 125-138.
31. Wu, J.G., Shen, W.J., & Sun, W.Z. (2002). Empirical patterns of the effects of changing scale on landscape metrics. *Landscape Ecology*, 17(8), 761-782.

THE COMPOSITIONAL SOLUTIONS OF THE HISTORICAL PARKS IN LATVIA

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Abstract
The information about gardens of the Duchy of Courland in the 17th century is scarce and fragmentary, as part of documents is lost or exported abroad during the war. The time of the Duchy and its baroque gardens is attributed to reign of E. J. Biron in the first half of the 18th century, when impressive palace ensembles were created the help of architects F. B. Rastrelli and S. Jensen, building of summer residences in Rundāle, Vircava, Svēte, Luste. They served as summer amusement gardens or parks. In their arrangement, a compositional connection with the palace, the front courtyard, outbuildings and the garden was sought. These summer residences were located in rural plain areas, thus, the features of natural area - water, floodplains, terrain, nature of plantations and materials were used. The choice of planting materials was influenced by the climatic conditions - harsh winters, short summers, late spring frosts or early autumn frosts. Therefore, in the Duke's time gardens, there are no delicate plants such as jews, boxwood plants, peach and mandarin fruit trees imported from the Western Europe. The local trees and shrubs, fruit trees, spice plants were used, vegetable beds made. The study examines two of the Duchy's summer residences at Vircava (*Wūrzau*) and Svēte (*Swethof*), the study of which, as already mentioned, is made difficult due to the relatively scarce information.
Key words: landscape protection zones, central axis, compositional structure, cultural heritage, historical landscape.

Introduction

Like at Rundāle, in the construction of the Vircava palace in the 70s – 80s of the 18th century, the architect S. Jensen and the sculptor J. M. Graff were also invited by the Duke of Courland E. J. Biron (1690 – 1772). The Svēte palace was built under the control of his son Peter Biron in the period from 1774 to 1775. The style of S. Jensen and J. M. Graff is also felt here. After 1775, J. M. Graff leaves the Duchy of Courland. The creative cooperation of both has been admired to the present day, that is, for more than 250 years. In addition, the masterful and highly artistic level that has been achieved in the visually appealing external image of the palace never ceases to astonish us. It is also attributed to the architectural form of the Vircava and Svēte palaces, as well as to the emerging park's space, and, of course, to the natural elements that are already in front of us. There is the scale, proportion and harmony of the form of the language, maintaining style trends of that time. Undeniably, it is based on talent. The study includes the aim, which is linked to a detailed research of the cultural heritage, evaluating the compositional structure of the outdoor space and transformation processes. The examples of the landscape space of the Vircava and Svēte palaces are used.

The main assignments of the study are related to

- The mutual connection searches of the compositional structure of historical building, park and natural area;
- The assessment of the impact of the anthropogenic load on the historical values of the landscape space;
- The possibilities of the planning areas to regulate the landscape protection zones, not defined in the municipal planning tasks.

Materials and Methods

The methodology of the study includes the description of the historical archives, the comparison of engravings and photographic materials from the beginning of the 18th century to the present day, where under the effect of the economic and political conditions the values of the historical landscape space have been transformed. Over the last century, both ensembles of the palace have been severely affected by political battles. Partly, it is due to the proximity of the Svēte and Vircava palaces to Jelgava, which easily served for military purposes. Three other Duchy's summer residences are built far from cities, and they are not affected by political passions. They are positioned at Rundāle that is near to Bauska, Zaļenieki which is not far from Jelgava, and Luste that is close to Dobele. Today, the landscape is well shaped by the old tree planting sites and recognized by the compositional concept in the construction of the garden. It also allows to assess the impact of the transformation processes on cultural values. For further progress of the study, it is required to recover the historical paths, the pond line, the foundations of the park's tea house in nature. According to the basic principles of the compositional structure of the space, both the Vircava and Svēte buildings have an expressed longitudinal axis and transverse axis, which connect the palace to the park and natural area.The establishment of the Vircava park was mentioned in 1721, when E.J. Biron wrote to the chamberlain P. Bestuzhev-Ryumin to the Court of Duchess Anna Ivanovna, ". .. with this I report that during my absence the gardener has planted 300 linden trees. On Saturday and Monday, there are planted 700 more linden trees and 200 cherry trees ... I have ordered the folks to bring another 500 linden seedlings here, as without

Figure 1. The location of the Vircava palace is restored at present park (author's sheme).

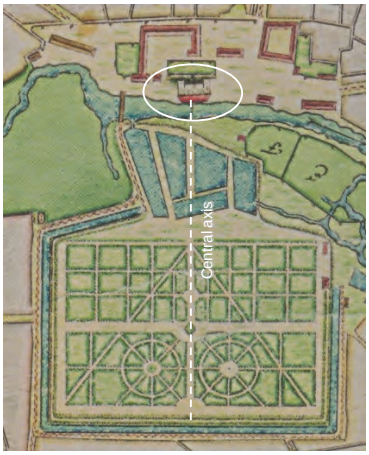

Figure 2. The central longitudinal axis as a view line across the river from Vircava palace to the (Janelis, 2010).

the mentioned ones we need much more. I mercifully beg you to deliver 1000 seedlings from the rest of the manors". During the inventory in 1793, this park was named "Duke's great amusement park and orchard" (Rundale palace museum, 1991).

Opposite the building of the Vircava manor, 250 m in length, the river Vircava forms a clear linearity, which is confirmed by the left bank slope. Here one might say-a bluff, if such a comparison could be attributed to the Zemgale plain. The flow of the river is slow and alongside with the manor garden forms a romantically expressive landscape space both upstream and downstream. The garden of the palace was often ruined by spring floods, as the right bank of the river was much lower and formed a floodplain.

The map drawn in 1779 by J. G. Schulz shows the compositional structure of the palace's ensemble (Janelis, 2010), where the symmetry of the common structure of the ensemble is readable, consisting of the palace building and the baroque garden (Fig.1). The map shows the intersection of the two main axes: one of them connects the palace and the park, where the expressiveness of the axis is intensified by a tree alley (Fig. 2). The second axis of the composition is the riverbed, as well as the linden transverse alley, which is perpendicular to the first one. The longitudinal axis and the intersection point of the river is a dominant, where the palace was positined. The culmination was complemented by a tower built in the central part of the palace by S. Jensen, as well as the side blocks of the palace. The expressiveness of the park and the palace is intensified by the linden alley, without reaching 100 meters in length (Fig. 3). On both sides of it there are ponds, and the alley forms a kind of a green bridge, leading across the pond system. In the sight line from the palace through the alley, one of the five park ponds serves as a culmination. Behind it – a wide regular garden, which adds expression to the central axis. The other summer residence belonging to the Duchy – the Svēte palace, which is about 7 km away from the winter residence, located alongside the river Svēte, which is winding and rapid, and in springs and rainy

Figure 3. The historical tree alley on the longitudinal axis of palace Vircava (author's photo, 2015).

Figure 4. The alley with a rampart along the western side of the canal of parks Vircava (author's photo, 2015).

Figure 5. The location of the old Vircava bridge and the road (author's photo, 2015).

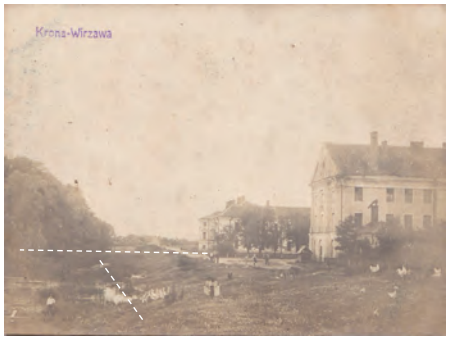

Figure 6. The intersection of two compositional axes: one axis – the Vircava palace and the park, the other axis – the riverbed (author's sheme).

summers forms extensive flood areas. Therefore, the river Svēte is characterized by huge floodplain meadows, but the building on its banks is distanced. Possibly, that is why the location of the old palace was chosen there, as the natural picturesqueness and the view from the right bank is really impressive. In spring, when the river turns into a huge lake at this place, tremendous amounts of migratory birds can be seen here.

Results and Discussions

By studying the spatial structure of the Vircava ensemble, it is concluded that its central axis had several depth plans, which formed an overall composition, counting from the northern part of the axis -

- The inner courtyard part of the palace;
- The palace and the left bank slope of the river, which is characterized by the Southern exposure to the sunlight;
- The picturesqueness of the river flow and shading on the right bank from the park trees, thus, creating a contrast game for both banks; the aspect should be taken into account that the right bank is lower and more inclined, thus emphasizing the greatness of the palace;
- The part of the alley, which is shady and mysterious, and during the summer sultriness pleasant, is located between the ponds. The plantations of tree rows bring a rhythmic dynamics to the park;
- A pond closing the alley, which is full of sunlight and forms a contrast with the shadowy alley. There is also the shift of the scale of the space from a closely-dense tree line parallelism and the tree canopy coverage – to a widely open and light, and exhilarating part of the park that should be mentioned.
- The northern part of the garden with a front square, where the paths of the two garden diagonals meet, coming from the corners of the perimetral rampart. The Baroque garden design is based on a strict regular path layout with plantings. On both sides of the promenade in the southeastern edge of the park there were two salons (intersection points of the alley), where in one of which there was a round pond, visible even now. In the second garden salon, there was a hillock, which was destroyed, when a new highway was constructed. Initially, in the garden alleys (17^{th} – 18^{th} centuries) cherries, currants, gooseberries, birch trees were planted. All this, except the birch trees, had low enough height, so as the garden would be well seen from the left, the high bank of the river Vircava (Janelis, 2010).

The park around the perimeter was concluded by a ditch, the ground was piled inside of the park to create a rampart, dividing the park. Along the sides of the rampart, rows of trees were planted to form an alley with a walking path (Fig. 4). The Vircava neighborhood is typical of fertile clay soils that provide a good tree and shrub root development. In the park's western and northern sides, ramparts, the steep edges of the ditches, rows of tree plantations along the rampart and the walking path on the top of the rampart are well readable. On the opposite side of the ditch, on the west side of the park – the old highway and bridge (Fig. 5). It was the most direct way of communication between the Salgale and Vircava churches. From the old bridge site, a view opens along the river up to the floodplain meadows, in turn, from the bridge to the east - a view to the palace building ensemble and the river downstream. The sight line from the former bridge location marks the above mentioned compositional axis, which is parallel to the river. No matter how weird it would sound, but there has never been a bridge opposite the palace that would connect it to the park. The river Vircava close to the palace is as a unique parterre (Fig. 6). Today, the park's northwest part, like the entire park as a whole, has lost much of the historic tree plantings, the path network, the pond banks, creating a sports ground in this place. The southwestern part of the park is crossed by a road and a bridge. The road bed was built (1931) through the park's diagonal path location. Only

Figure 7. Sight line towards the location of the old road Svete (author's photo, 2012).

Figure 8. Stage bank of the Svēte river in front of the Svete palace. Taking away of the tree overgrowth in order to expose the distant sight lines (author's photo, 2012).

individual 100-years old larch trees still tell about the plantations of the historical park. In the northeastern side of the park, the pond sites are bogged up, but the park is overgrown, and it is hard to pass it through. The ditch surrounding the eastern part of the park and the rampart have survived, as well as the old road along the outer edge of the park. Between the river and the northern part of the park, there is a floodplain meadow, giving the possibility of distant sight lines from the left bank of the river to the northeastern part of the park. The Vircava palace is built close to the driveway that ran along the left bank slope of the river, creating approximately 5 m distancing between the slope and the building. Researching the riverbed of the river Vircava upstream and downstream of the palace, it is evident that the flow of the river in this historic place is expressly straight. In turn, the upstream and downstream at the palace is winded. Until today, the Vircava park retains its historical scale that allows to recover its compositional structure. In 1870, the Duke's summer residence was transferred to the military department (Lancmanis, 1991). The palace was burned down in 1919 during the attack of the army of Bermont, and only a fragment of the eastern passage of the palace has survived. There is an intention to initiate the restoration of the palace, but it will be partly prevented by the distribution of land ownership. The Baroque garden of the palace was begun to be built (but, maybe, renewed) around 1736, which by its magnitude is charged to small gardens (Janelis, 2010). There is no cartographic material of the 17th, 18th centuries about Svēte; therefore, it is not known where the palace was located, which was probably pulled down in the 18th century before the last construction of the palace. And, perhaps, it had a closer connection with the compositional longitudinal axis of the garden (Janelis, 2010). Like the ensemble of the Vircava palace, the Svēte palace and the park also have two compositional axis. The central axis or the main sight line from the driveway to the place is formed by the landscape space. It is like the foreground – in the view from the historic road in the northern part of the palace, which consists of a broad floodplain. The depth plan is concluded by the palace, which is well readable in the K. J. R. Minckelde's engraving (the beginning of the 19th century, Fig. 9). This broad sight line is preserved even today. The second axis connects the park part with the palace's longitudinal facade in the part of the inner courtyard, where the driveway to the palace is located. The connection of the parts of the park has been formed in the eastern part of the palace with its regular planning. Like the park of the Vircava palace, the Svēte park was also delimited by a ditch around the perimeter and a rampart with tree plantation lines, creating walking paths. Compared to Vircava, the delimiting ditch of the Svēte park is shallower and the rampart is more inclined. In the southeastern part, this axis winds in the direction of the Vircava palace, over the so-called Ruļļu kalni (Reel hills), where even today the old road through the Lapu krogs (Lapu pub) is apparent. In the beginning of the 20th century, from the palace's garden side the road had a linden alley (Janelis, 2010).The Swethof palace was built from 1774 to 1775 (architect S. Jensen). In 1799 – 1800, barracks and stables were built in the manor, but in 1875 the palace was rebuilt, completely destroying the interiors and facades (Fig. 10). A rough idea of the palace's park is given by the survey of 1876, showing a square four boskets created by cruciform alleys. J. Bernoulli, who saw the palace in 1778, wrote: "Near this amusement palace, there is ... a great, with waters rich garden which the Duke ordered to look more beautiful with pleasing English-style formations" (Rundale palace museum, 1991).). There was also a stone pavilion with 6 columns and a small gallery above the roof in the park.

Figure 9. Svēte palace Gravure K.J.R. Mincelde 20th of the 19th century (Rundale palace museum, 1991).

Figure10. Places unclosed with walls of the historical window of Svēte palace (author's photo, 2004).

A serious transformation of the historical area of the Svēte palace dates back to the middle of the 19th century, when a new road between the palace and the park was built, as well as in the central part of the park horsemen cavalry barracks and stable buildings were built for the Imperial Army needs. The opulent conservatory was rebuilt, minimizing the window, door and floor height. This also applies to the central hall, which disappeared after the rebuilding. In the second part of the 19th century, solid long barracks were built in the courtyard side of the palace. The length of the perimetrally located building volumes is competing with the palace building. Their position is symmetrical against the palace and its courtyard, in the center creating the green area of a stretched form with a detour road. Following the above, it is apparent that the ensemble of the Svēte palace consists of three main compositional spaces – the floodplain grasslands in the northern part of the palace, the park in the southeastern part and the palace's courtyard in the west. Each of them has a different nature and scale of the construction. Here, another aspect should be mentioned. 1 km away from the park, the Vilce road is located in the southern direction, where in the far sight lines across the pasture, the park of the palace is readable, since the mentioned road is positioned in the terrain's elevation or the so-called neighborhood of of the Ruļļu kalni with the level difference against the position of the palace - about 12 m. In the perception of the historical landscape space, it plays a big role. Over the centuries, with the transformation of the functional meaning of the buildings, the composition structure of the historical building is broken. The park's northern, eastern and southern side edge with the line of the historic trees. Part of the park has survived and may be renewed. In turn,

in the park's western edge, both the ditch and the tree plantation line have disappeared. The central part of the park has been transformed into a housing area. Industrial buildings with a wide hard coverage area and a residential building are situated here. The military function of the palace remained until the 90s of the 20th century. As a result of the above conditions, the historic area of the park is away from the palace, so it is impossible to connect both cultural spaces. The unity of the palace and the park is recoverable only to the condition if the preserved historical road along the left bank of the river Svēte is renewed, thus bypassing the historic landscape space. These stable buildings (the second half of the 19th century) are positioned transversely to the longitudinal axis of the park, thus breaking the historical structure of the park. The rest of the industrial buildings (90s of the 20th century) have a standard metal frame that is easily dismantled and removed from the park (Fig. 11). The northern end of the palace is located very closely to the right bluff of the river. Here, the similarity is found both with the location of the Vircava palace near the river and the nature of the river bluff. It is a rare feature of the natural area, which can be found in rivers of the Zemgale Plain. For the area of the ensemble of the Svēte palace, 5 cultural room transformation periods of time are readable:

- The end of the 18th century – the time of the construction of the palace and the park (architect S. Jensen);
- The mid-19th century – rebuilding of the palace for military needs;
- 60s of the 20th century – high-rise residential building;
- 90s of the 20th century – establishment of industrial areas;
- The beginning of the 21st century – privatization of the northeastern part of the park and building of a mansion.

When studying the protection zones of the palace and the park's landscape, we can see that the eastern part of the park is surrounded by mansion building, but on the southern side there is a small agricultural area, which is possible to transform into a building area in a perspective. It would not be permissible, as then the sight line from the Vilce road would be hidden. The

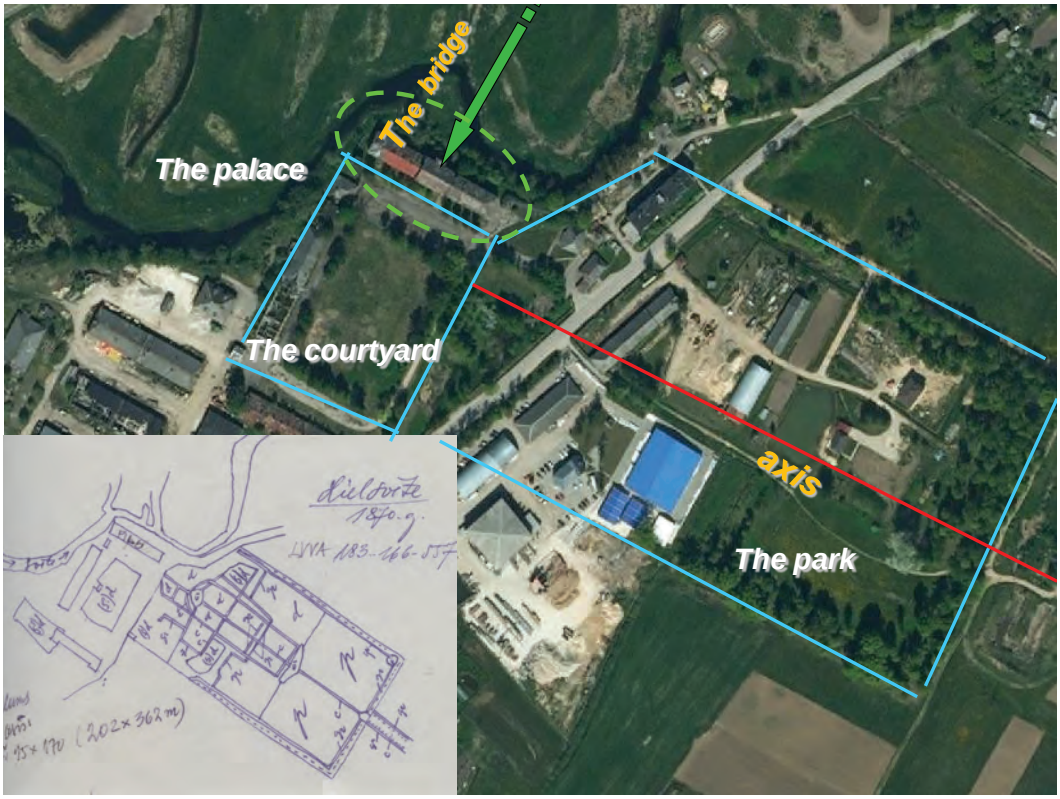

Figure 11. The comparison of the plan of the historic manor lands (1870) and today's situation (author's sheme, 2015).

current industrial area in the park is on lease, which is harmonized with the monument inspection. Thanks to the large areas of the floodplain of the river

Svēte, the landscape space of the northern part of the palace is not threatened by the load of the wave of the building intensity in Jelgava, which would block the silhouette of the palace. This is only possible on the right bank of the river, where the mansion building of the Svēte village tends to merge with the city's building areas. Like the ensemble of the Vircava palace, the ensemble of the Svēte palace consists of two compositions axes. The longitudinal axis of the park unites the longitudinal facade of the palace, touching the palace's entrance zone. The second axis is positioned perpendicularly, and within the inner courtyard of the palace. It forms the nature of the longitudinal axis of the courtyard. The courtyard has a form of a stretched rectangle, where the stables are positioned in the northern and western edges. In the middle of the courtyard, there is a wide, green area. Both axes do not unite the park and the part of the courtyard of the palace, as each of them is shifted. The northern end of the palace is located very closely to the right bluff of the river. Here the similarity is found both with the location of the Vircava palace near the river and the nature of the river bluff. It is a rare feature of the natural area, which can be found in rivers of the Zemgale plain. The building of the Svēte palace was rebuilt several times, but not destroyed, and its restoration is possible. However, the park has vanished. In its place, there is a huge industrial zone. The old trees have only survived along the historic canal, so giving the opportunity to read in the park's volume in nature. The palace was rebuilt several times and adjusted to military purposes. This sight point should be a landscape protection area. In the spatial development plan, the construction is not permissible, as it would block the sight lines. The Svēte valley is readable here as from a unique platform. The difference in the terrain is most accurately readable from the old burial mound located in Ruļļu kalni (Reel hills).

Conclusions

Given the current situation of the landscape space of the Svēte and Vircava manors, it is noted by two different visual sides of quality.

1. The landscape space of the Swethof palace retains its historical expression in the northern part, which for centuries has been protected by the character of the natural site or the flood plain of the river Svēte, which fills with water in springs. It has allowed to retain the historical sight points to the palace, which are not obstructed by building construction

and tree plantations. Consequently, the character of the historical engravings of K.J.R. Mincelde is readable in nature even today.

2. The southeastern part of the Swethof palace ensemble or the area of the historical park is almost gone as it is exposed to a strong industrial building construction. The sight points of the landscape space on the plain from the Vilce road are not interrupted by tree groups; therefore, the production area is readable in the silhouette.
3. The character of the bank line, the volume of the old Vircava park, the park's ditch and pond system have remained in the landscape space of the Vircava manor ensemble. The palace is lost, but its location is not built over and in the sight points from the palace's historical location, the upstream and downstream of the river Vircava are well readable. New building volumes have not interrupted these sight angles. Naturally enough, this is not true for the road through the park built in the 30s of the 20th century.
4. In the case of the reconstruction of the landscape space Vircava, it is possible to restore the historical bridge and the lost road bed that are now clearly readable in nature.
5. The restoration of the Vircava manor park is realistic with the recovery of the historical sight points of the tree alleys, rows and groups of individual tree plantations, as well as cleaning up ditches and old ponds.
6. The building and construction of the Vircava and Svēte manors once again prove that the expressive compositional solution of the two ensembles is based on the architect Jensen's masterly understanding of the expression of the existing natural site, connecting the architectural spatial form of the buildings to it. It should be mentioned that the natural site at the Svēte palace has an expressed form of plastic lines, where a regular garden form is brought in. In the compositional overall image of the landscape space, S. Jensen has intoduced the turning angles of sight points, view line lengths, side wings and the depth cue, thus increasing the expressiveness of the overall landscape space.

References

1. Briņķis, J., & Buka, O. (2006). Pilsētu un lauku apdzīvoto vietu kompleksu arhitektoniski telpiskā plānošana (Architecturally spatial planning of complexes of urban and rural settlements) *RTU*, 80-139. lpp. (in Latvian).
2. Briņķis, J., & Buka, O. (2008). Reģionālā attīstība un prognostika pilsētplānošanas kontekstā. (Regional development and prognostics in the context of urban planning) *RTU*, 27, 108. lpp. (in Latvian).
3. Grosmane, E. (2011). Senā Jelgava (Old Jelgava), *Neputns*, 31-45. lpp. (in Latvian).
4. Janelis, I.M. (2010). Latvijas muižu parki un dārzi (Parks and Gardens in Latvia). *Neputns*, (in Latvian).
5. Lancmanis, I. (2015). Rundāles pils (The Palace Rundale). *Rundāles pils muzejs* (in Latvian).
6. Rundāles pils muzejs. (1991). Ernsts Johans Birons. (*Rundale Palace Museum*). 67-70, 115. lpp. (in Latvian).
7. Schlau, K.O. (1995). Mitau im19.Jahrhundert. (Mitau in 19th century). *H. Hirschheydt (*in German).
8. Thomson, E., & Manteuffel-Szoege, G. (1959). Schlosser und Herrensitze im Baltikum. (Castles and Manor Houses in the Baltic States). *Frankfurt* p. 104. (in German).
9. Tomašuns, A. (2015). Mana Jelgava (My Jelgava) *Jelgavas tipogrāfija* 239. lpp. (in Latvian).

THE RESEARCH OF HYDRODYNAMIC PROCESSES IN REHABILITATING RIVERS OF LITHUANIA

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Abstract
From the 1920s through the 90s, most streams in Lithuania were channelized. Channelization is the deepening, clearing and straightening of meandering streambeds resulting increase of water flow velocity and the rate at which water drained away from agricultural land. Channelized and straightened streams have better hydrodynamic parameters and different morphological properties, but at the same time that caused more unfavourable conditions for natural biodiversity along stream beds and banks reducing the amount of vegetation which means less food and cover for wildlife. Most of West European countries have a good practice for restoring of channelized rivers. This experience is quite new in Lithuania and starting with pilot projects. The most important purpose of these projects is to choose the appropriate restoration measures and evaluate their effectiveness under conditions of dense channel network and tile drainage systems in Lithuania. Two channelized streams, selected for a pilot project are discussed in this paper. The main purpose is to restore stream meandering with minimal efforts allocating artificial obstructions at a right place and reach the necessary stream velocities to initiate the stream bed deformation. For this purpose detailed channel geometry data were collected and 1D hydrodynamic model applied. The results of different scenarios revealed that installed obstructions can accelerate deformations processes initiate the meandering process and at the same time it will not have any significant effect on the agricultural land along restored stream.
Key words: regulated streams, current velocity, discharge and streams restoration means.

Introduction

Land reclamation was the most frequent reason for channelizing of streams in Lithuania. Over 46 000 km stretches of streams were straightened and over 17 000 km the new ditches excavated during the intensive reclamation period in Lithuania (Gailiusis e*t al*., 2001). That caused alterations in streams morphometry including changes of furrow line, forms of the shoreline, the bottom substrate and changes of flow hydrodynamic. The riverbed straightening increased flow velocity, sediment transport and longitudinal gradients. More intensive erosion processes in appeared the upper reaches caused by increased stream power what lead to broadening and shallowing of straightened streams beds. Meanwhile, the sediment accumulation processes dominate in downstream reaches of straightened streams. Therefore, straightened streams with monotonous, fast currents and silty bed caused water ecosystems with poor conditions for fishes and invertebrates. Due to these modifications, the regulation of the rivers was named as one of the greatest threats to wildlife biodiversity and ecosystems (Rosenberg *et al*., 2000; Nakamura & Yamada, 2005; Horsák *et al*., 2009).

In order to restore morphometric, hydraulic and especially ecological conditions close to the natural ones the straightened reaches should be restored. This can return conditions close to previous (natural) which is much more favourable for the natural flora and fauna. Therefore, restoration of channelized streams is a prerequisite for more favourable water ecosystems. A good practice of stream restoration already exists in many countries and restoration projects are very popular over some decades in Europe and other continents (The river..., 1998; Coops & Geest, 2007; Morten e*t al*., 2007; Aulaskari, 2008; Pavils, 2003, 2006, 2007; Living..., 2006; Jormola e*t al*., 2007). In many cases restoration or self-restoration of channelized streams covers the measures which can be defined as full or partial recovery of morphological parameters and ecological functions in rivers almost completely destroyed by channelization. The main purpose of river restoration projects is to restore the disturbed natural balance, increase natural biodiversity and improve water quality in the channelized streams.

The aim of river and stream restoration is achieved using different methods and tools. Restoration tools directly modify hydraulic and morphometric parameters of flow. To evaluate the direct and indirect effects on the bed processes the hydrodynamic modelling can be used (Guidelines..., 2005; Paškauskas e*t al*., 2000; Vaikasas, 2007). It enables to predict the impact of the implemented measures on river morphometric and hydrodynamic characteristics, and the living conditions for ichtiofauna (Ward, 1998; Ward e*t al*., 2002; Dave, 2003).

The aim of the article is to assess the effect of river restoration tools on flow hydrodynamics and stream bed changes consequently.

Materials and Methods

Identification of channelized and natural stream parts was carried out on the basis of GIS database – 'GDB10LT' employing data layer 'Hidro_L' and database of orthorectified images 'ORT10LT' for controlled process. The recognition was done using

Table 1

The main characteristics of streams Viešinta and Vašuoka (Gailiušis *et al*., 2001)

Stream name	Main river name	Length of stream L, km	Stream catch-ment area A, km^2	Average dischar-ge Q, m^3 s^{-1}	Total natural length of stream L_n, km	Total regulated length of stream L_r, km	Average flow velocity v, m s^{-1}	The gradient of section i, m km^{-1}
Viešinta	Lėvuo	24	235.5	1.16	8.5	15.5	0.6	0.87
Vašuoka	Viešinta	34	128	0.66	0	30	0.46	2.25

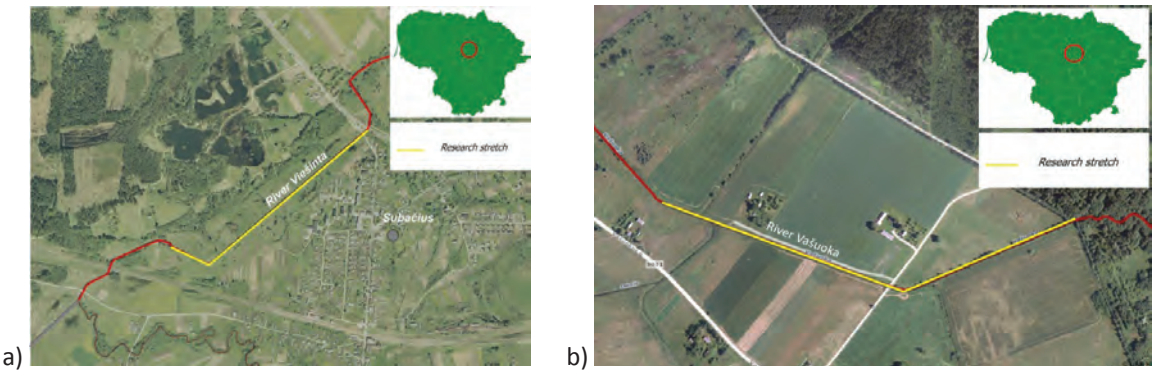

Figure 1. The fragments of Viešinta and Vašuoka streams.
(In yellow – parts of streams selected for restoration).

automated data processing by standard tools of ArcGIS and visual image analysis. Finally, all streams were separated into natural and channelized/straightened reaches and straightened stream sections divided into 7 groups, which were identified by stream catchment area, bed slope and river surrounding areas (forest, urban area or arable land).

For this study two streams - Viešinta and Vašuoka were selected. These streams belong to the fifth group of identified streams. The main characteristics of selected streams are presented in Table 1.

The location of Viešinta and Vašuoka rivers straightened stretches are presented in Figure 1.

In both selected stream parts by restoration project are foreseen to install artificial obstacles and is expected to achieve the start of stream meandering. The purpose was to verify that the threshold velocity will be reached. For that purpose 1D numeric model was developed using HEC-RAS software. The simulation of obstructions was performed modelling steady state flow for selected stream section. Geometrical characteristics for the model were obtained by field surveying. Using ArcGIS tools digital terrain model was created. Latter the by user interface Hec-GeoRas all data transferred to HEC-RAS. Model was calibrated under natural channel conditions for boundary conditions using measured flow rate, water level etc. An acoustic device 'Stream-Pro ADCP' was used for discharge, bed depth and velocity measurements. Topography was surveyed with the Trimble GPS/RTK. The shear stress coefficients were estimated visually in the field and latter corrected by calibration procedure. After calibration procedure, the channel geometry was corrected allocating artificial barriers along the stream. Model with modified channel geometry is continuously used simulating different stream flow and analysing distribution of velocities along the stream.

The differences of velocities with natural channel geometry and modified one enable to estimate the effect of obstructions for initiating stream bed erosion of the opposite side and the starting of meandering process. Threshold velocities depend on type of soil that is in a particular place. Composition of soil particles was found in each of the relevant section using data of 4 geological wells.

Results and Discussion

Water bodies differ in their natural characteristics, so there are differences between the aquatic communities that live there. According to the fact that Lithuanian water bodies are divided into separate types, each type is described by such natural factors that have the greatest impact on the aquatic communities structure (Nemuno..., 2010). Three main factors that describe the types of rivers and lead to the major differences in aquatic communities are: the absolute height, the catchment area and the river bed slope. According

Table 2

Groups of straightened streams' sections in Lithuania

Group	The type of river	The environment of biodiversity	Gradient m km^{-1}	Area of catchment A, km^2	The absolute height, m
1	1	-	-	<100	<200
2	2	forest	<0.7	100-1000	<200
3	2	field	<0.7	100-1000	<200
4	2	outskirts	<0.7	100-1000	<200
5	3	field	<0.7	100-1000	<200
6	3	forest	<0.7	100-1000	<200
7	3	outskirts	<0.7	100-1000	<200

to Lithuania's accepted river typology, the selected objects - Viešinta and Vašuoka belong to the third type of streams.

Regulated streams are divided into 7 groups according to the natural environment. The allocation of straightened sections into groups takes into account the fact that restoration of streams (basin area < 100 km^2) with regulated segments are associated with the emission-cleaning function along the way to larger bodies of water. It was decided that regulated streams with catchments area less than 100 km^2 can be restored without engineering tools to achieve good ecological status (Nemuno..., 2010). Natural instability, periodic drying, light vulnerability and a very high percentage of straightening are the main factors to leave regulated streams and their ecosystems for self-naturalisation with the proper protective bands. So all streams' sections of the first type are assigned to the first group.

For better ecological conditions, restoration engineering tools are suggested to be used only in water bodies with catchments area bigger than 100 km^2. Table 2 presents the groups of regulated streams considering different microclimatic and natural biodiversity conditions.

These groups include all straightened streams and rivers in Lithuania. The first group of streams (basin area < 100 km^2) consists of the majority of regulated streams. Due to this large group amount of regulated streams (24 371.6 km), ecological instability and other reasons, this group was not analysed. Groups of river stretch from No. 2 to No. 7 cover river basins area – 100-1000 km^2. River group No. 2 flows through a forest area, No. 3 flows through the fields, No. 4 flows through the outskirts. The slope of these three groups does not exceed 0.7 m km^{-1}. Meanwhile, rivers of groups No. 5 – 7 flow through the appropriate fields, forest and outskirts, and the slope is greater than 0.7 m km^{-1}. The summary table of straightened streams sections in Lithuania is presented in Table 3.

Channelized stream segments were explored and grouped. Two straightened streams – Viešinta and Vašuoka – have been selected as the fifth stream group for the pilot project. The investigated segments of streams are located in agricultural lands. Channel bed slope of along selected segments are greater than 0.7 m km^{-1}. That makes it possible to expect more rapid and effective impact of applicable restoration tools.

The numerical simulation using 1D model was performed for two scenarios: with obstacles and without obstacles. The purpose was to find out the difference of flow velocities in the absence of obstacles and install them. The differences of velocities enabled

Table 3

Summary table of straightened streams' sections in Lithuania

River basin	Group					
	Length L, km					
	2	3	4	5	6	7
Venta	1.163	16.153	2.997	6.325	0.821	0.143
Lielupė	10.236	82.276	23.481	24.723	2.776	2.620
Dauguva	-	15.785	-	-	-	-
Nemunas	14.355	228.892	15.273	-	-	-
Total:	25.754	343.106	41.751	31.048	3.597	2.907

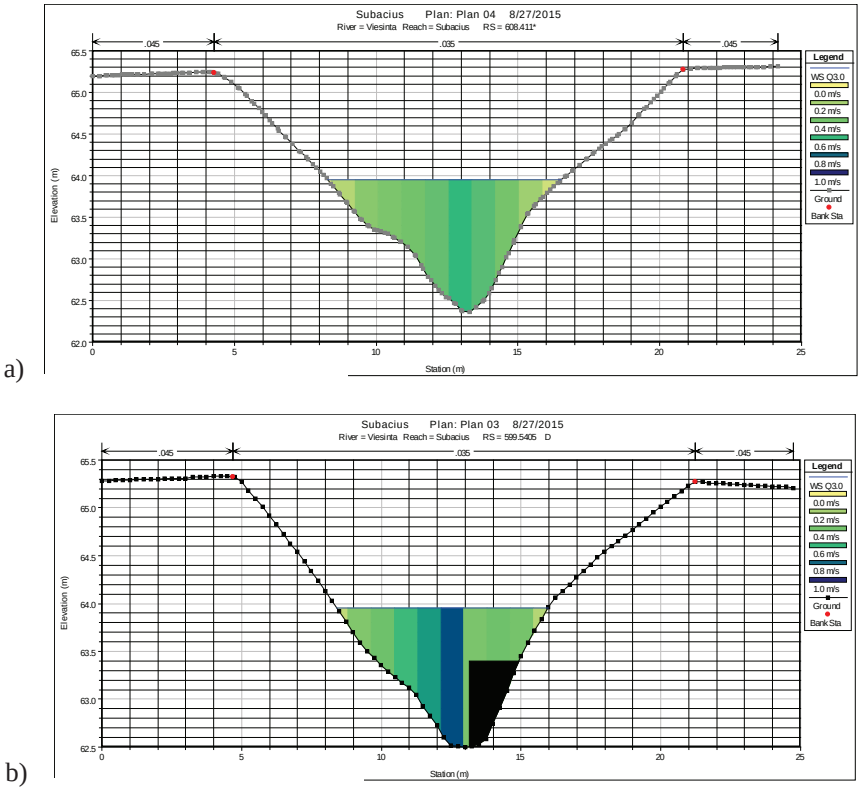

Figure 2. The distribution of velocity in profiles No. 608 (no barrier) (a) and No. 599 (installed barrier) (b), when the flow rate 0.65 $m^3 s^{-1}$.

to estimate the effect of obstructions for channel bed erosion and the beginning of meanders formation. Threshold velocities depend on a type of ground in a particular place. The distribution of velocity in cross sections is presented in Figure 2.

After installation of obstructions the highest differences of velocities in these cross-sections are at the flow rate, when water level reaches the height of obstructions. The average flow rate when water level becomes equal to top of obstruction was 0.65 $m^3 s^{-1}$. The changes of velocity vary in the range from 15 to 50%. Increasing flow rate over 0.65 $m^3 s^{-1}$ water level is overtopping the barriers. The average flow velocity in cross-section increases, but the difference between velocities with obstructions and without them decreases. It means that overall effect of obstructions on channel erodibility gradually decreases. To avoid large distribution of velocities along the channel bed, the parameters of barriers should be similar and any cross-sectional configuration should be taken into account.

Each implemented barrier must be designed in such a way as to reduce one-third of the flow cross-section. However, if it is not reached, barriers should have the same dimensions. At this case the efficiency can be insignificant in the deeper and wider areas of stream bed. The changes of velocity occur not only in places where obstacles were installed. This takes place in intermediate cross sections, because hydrodynamic changes take place throughout the flow after installation of barriers. The changes of water level due to installed obstructions are insignificant and fluctuate in the range of 3-7 cm. This means that implemented measures will not have significant impact on flood risk. The highlights of the flow velocity distribution in the river bed with barriers and without it at 1.5 $m^3 s^{-1}$ flow are presented in Figure 3.

Figure 3 shows that the effect of barriers is significant. High-speed curve peaks indicate changes of the flow velocity around them. Velocities between the barriers slightly reduce after the installation of barriers and this enables to accumulate washed silt.

The impact of the installed barriers to the channel bed formation can be assessed by the flow rates and prevailing soils. According to the soils of Viešinta river (gravel sand, fine sand with gravel impurities, and dust) and the table of threshold velocities, it was found that gravel sand is washed when stream velocity is 0.70-0.75 m s^{-1} and fine sand is washed when stream velocity is 0.35- 0.45 m s^{-1} (flow velocities are taken at 1-2 m water depth of the bed). Figure 3 shows that some barriers are ineffective and do not reach the threshold velocities. If the velocities are ineffective, the settings of barrier parameters are changed until the desired velocity is obtained. In order to determine the long-term impact of the barriers, it is necessary

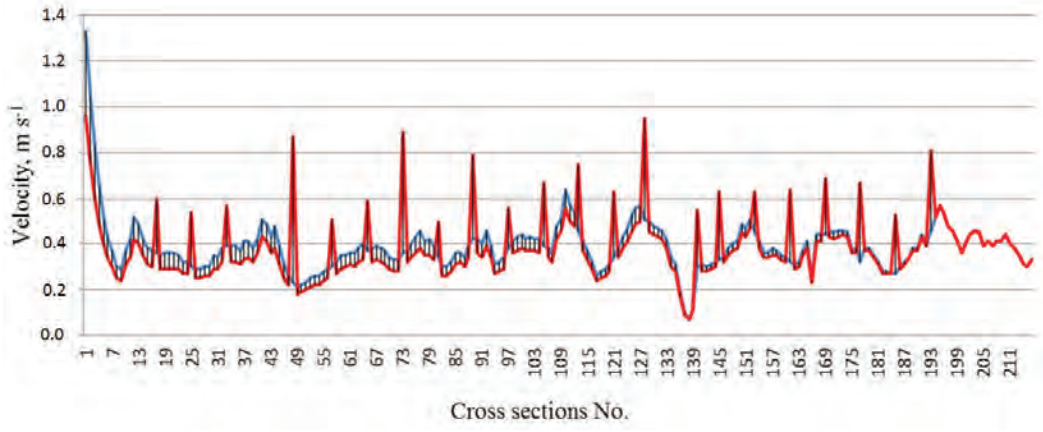

Figure 3. Comparison of velocities with barriers and without at flow rate 1.5 $m^3 s^{-1}$ (In red – with barriers, in blue – without barriers).

to carry out the hydrological calculations and to determine the selected flow pattern within a year. This remains an actual topic of future research.

The obtained geological data from straightened part of Vašuoka stream showed that the loam dominates with threshold velocities from 1.30 to 1.40 m s^{-1}. Flow velocities may exceed 1 m s^{-1} in the selected stream after removing the existed thresholds and implementing restoration tools. The results show that only a theoretical possibility of the bed erosion processes remains. However, only minimal washouts are expected due to the loam soil with grass and bushes along the riversides.

In conclusion, it can be noted that it is possible to achieve such a flow velocity variation that causes the primary deformations of channel and initiates the stream meandering if the proposed methodology of artificial barriers is properly implemented along the riverbed. One dimensional model of steady flow cannot evaluate the future development of the process, but the results show that this methodology proposes fast and low cost for streams' restorations.

Conclusions

1. The analysis of straightened streams' databases shows that straightened streams cover 1-3 type of rivers in Lithuania.
2. The stretches of straightened streams were divided into 7 groups depending on river type, bed gradient and type of environment (forest, outskirts and field).
3. The first type of river sections assigned to the first group of straightened streams (A <100 km^2). Self-naturalization is proposed to the first group of streams.
4. Good ecological status (biological, chemical) could be achieved by artificial tools. Depending on the different microclimatic conditions and biodiversity, large straightened streams (> 100 km^2) were divided into 2-7 groups. The partial and full restoration by using bioengineered means can be used for mentioned groups.
5. The largest distribution of velocities appears during the minimum flow discharge (0.65 $m^3 s^{-1}$). In this case water level stays beside of obstruction top level and cross sections of flow change in the biggest level. In these cases the distribution of velocities varies from 15 to 50%.
6. The changes of water level due to installed obstructions are insignificant and fluctuate in the range of 3-7 cm. This means that implemented measures will not have significant impact on flood risk.
7. The fluctuation of flow velocities will increase the initial bed deformations depending on the dominated types of soil, which initiate the formation of meanders. According to the calculations and visual assessment of the current situation, it is very likely that the riverbed meanders will form in the area of river floodplain.

References

1. Aulaskari, H. (2008). Restoration of small urban streams in Finland. In 4th ECRR Conference on River Restoration, 16-21 June 2008 (pp. 909-914). Venice, Italy. Retrieved March 6, 2016, from http://documents.mx/documents/proceed-15.html.
2. Coops, H., & van Geest, G. (2007). Ecological restoration of wetlands in Europe. Significance for implementing the Water Framework Directive in the Netherlands. The Netherlands, WL Delft Hydraulics. (Report No. Q4481).

3. Dave, B., Arscott, D.B., Tockner, K., & Ward, J.V. (2003). Spatio-temporal patterns of benthic invertebrates along the continuum of a braided Alpine river. *Arch. Hydrobiol*. 158(4), 431-460. DOI: 10.1127/0003-9136/2003/0158-0431.
4. Gailiušis B., Jablonskis, J., & Kovalenkovienė, M. (2001). *Lietuvos upės: hidrografija ir nuotėkis. (Lithuanian rivers: hydrography and runoff).* Kaunas: Lietuvos energetikos institutas. 796 p. (in Lithuanian).
5. Guidelines on Environmental Considerations for River Channel Design. Drainage Services Department. Practice Note No.1/2005.
6. Horsák, M., Bojková, J., Zahrádková, S., Omesová, M., & Heleśic, J. (2009). Impact of reservoirs and channelization on lowland river macroinvertebrates: a case study from central Europe. *Limnologica,* 39, pp. 140-151. DOI: 10.1016/j.limno.2008.03.004.
7. Jormola, J., Laitinen, L., & Sarvilinna, A. (2008). Environmentally friendly drainage practices. In 10th International drainage workshop proceedings of icid working group on drainage, 6-11 July 2008. Helsinki/ Tallinn, Estonia: Helsinki University of Technology.
8. Living river Liesing - demonstrative ecological reconstruction of a heavily modified waterbody in an urban environment. Life environment project LIFE02 ENV/A/000282, 2006. Retrieved March 1, 2016, from http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=2118.
9. Morten, L.P., Jens, M.A., Kurt, N., & Marianne, L. (2007). Restoration of Skjern River and its valley: Project description and general ecological changes in the project area. *Ecological engineering* 30, 131-144. DOI: 10.1016/j.ecoleng.2006.06.009.
10. Nakamura, F., & Yamada, H. (2005). The effects of pasture development on the ecological functions of riparian forests in Hokkaido in Northern Japan. *Ecological Engineering*, 24, 539-550. DOI: 10.1016/j.ecoleng.2005.01.010.
11. Nemuno upių baseinų rajono priemonių programa (A program of Nemunas river basin region measures) (2000). Aplinkos apsaugos agentūra (Environmental Protection Agency). Vilnius, Aplinkos apsaugos agentūra, 184 p. (in Lithuanian).
12. Paškauskas, S., Baubinienė, A., Dilys, K., & Vekeriotienė I. Reguliuotų upių vagų deformacijos besikeičiančios žemėnaudos sąlygomis (Regulate river beds deformation of changing land use conditions). *Geografijos metraštis* 33, 256 (in Lithuanian).
13. Pavils, G. (2003). Conservation of wetlands in Ķemeri National Park, Latvia. Latvia, Ķemeri National Park (Project Nr. LIFE2002/NAT/LV/8496).
14. Pavils, G. (2006). Conservation of wetlands in Ķemeri National Park, Latvia. (Project Nr. LIFE2002/NAT/LV/8496).
15. Pavils, G. (2007). Conservation of wetlands in Ķemeri National Park, Latvia. Latvia, Ķemeri National Park. (Project LIFE2002/NAT/LV/8496).
16. Rosenberg, D.M., Mccully, P., & Pringle, C.M. (2000). Global-scale environmental effects of hydrological alternations: introduction. *Bioscience,* 50(9), 746-752. DOI: http://dx.doi.org/10.1641/0006-3568(2000)050[0746:GSEEOH]2.0.CO;2.
17. The river Brede – enriching our countryside (1998). Committee for Technical and Environmental matters. Denmark, County of Sonderllyland.
18. Vaikasas, S. (2007). Ekologinė hidraulika (Hydraulic of ecology). Vilnius: Technika. (in Lithuanian).
19. Ward, J.V. (1998). Riverine landscapes: biodiversity paterns, disturbance regimes, and aquatic conservation. *Biological conservation* 83 (3), 269-278. DOI: 10.1016/S0006-3207(97)00083-9.
20. Ward, J.V., Florian, M.F., & Tockner, K. (2002). Landscape ecology: a framework for integrating pattern and process in river corridors. *Landscape Ecology* 17, 35-45. DOI: 10.1023/A:1015277626224.

QUATERNARY GROUNDWATER VULNERABILITY ASSESSMENT IN LATVIA USING MULTIVARIATE STATISTICAL ANALYSIS

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Abstract
Groundwater is the main drinking water source in Latvia, and Quaternary groundwater is widely used in households due to shallow occurrence. The identification of vulnerable areas is important for better water management and protection of deeper, more intensively used aquifers. The existing groundwater vulnerability map of Latvia does not take into account land use which can be an important factor affecting natural groundwater quality. Multivariate statistical methods - principal component analysis (PCA) and hierarchical cluster analysis (HCA) - were applied to identify groundwater groups with distinct water quality in Quaternary sediments in Latvia. On the basis of major ion concentrations and nitrogen compounds four distinct groundwater groups were identified. First group represents natural and most common calcium- magnesium bicarbonate water type in Latvia with low nitrate and ammonium concentrations. Samples from second and third group both reflect anthropogenic influence: diffuse agricultural contamination mostly with nitrates and/or contamination derived from artificial surfaces. Fourth group belongs to calcium bicarbonate water type and is characterised as a very young groundwater formed in sandy deposits. The results show that the highest concentrations of nitrogen compounds can be found in areas with agricultural land use or in artificial surfaces which are often classified as medium low or low vulnerability areas (mostly samples from group two and three). Meanwhile the lowest values of nitrogen compounds are present in areas where dominant land covers are forests and semi-natural areas or wetlands, and groundwater vulnerability classes are medium to high (samples from the first and fourth group).
Key words: Groundwater chemistry, principal component analysis, hierarchical cluster analysis, land use.

Introduction

The thickness of Quaternary deposits in Latvia varies from a few to 200 m and can reach even more in the areas where buried valleys occur. Due to shallow occurrence and ease of access Quaternary groundwater is widely used for small household needs in the whole territory of Latvia (Dēliņa, 2007).

Groundwater vulnerability reflects the ability of groundwater system to maintain natural condition and its sensitivity to contamination. Various parameters can be used as vulnerability indicators (for instance, site lithology, hydraulic conductivity, surface/ groundwater interaction, groundwater flow directions) and there are many approaches to evaluate aquifer vulnerability (Saidi *et al*., 2010; Valle Junior *et al*., 2014). Such factors as land use, type of contamination and groundwater exploitation are important factors affecting natural groundwater quality and should be taken into account.

Groundwater vulnerability map (Dēliņa & Prols, 2008) of Latvia outlines five vulnerability classes of water table aquifer based on lithological composition, hydraulic conductivity of the sediments, specific yield and recharge. It was made on the basis of Quaternary sediments map. As a result, five groups according to five vulnerability classes (starting from lowest) were outlined: 1) glaciolacustrine clay, 2) glacial till loam and sandy loam, 3) water saturated peat, 4) sand of different origin, 5) sand- gravel- pebbles sediments, mainly of glaciofluvial origin. The map of groundwater recharge modulus was used to adjust the contours of areas of different vulnerability classes. The map shows intrinsic vulnerability of water table aquifer, but it does not take into account land use or presence of sporadic shallow groundwater and its quality.

There have been several extensive studies on Quaternary groundwater in Latvia (Dēliņa, 2007; Levins & Gosk, 2007; Retike *et al*., 2016); however, there is a lack of research dealing with land use and groundwater vulnerability. The identification of vulnerable areas is necessary for sustainable groundwater management, in particular to meet the requirements of the Water Framework Directive. **The aim** of the study is to identify groundwater groups with distinct water quality in Quaternary sediments in Latvia using multivariate statistical analysis (principal component analysis (PCA) and hierarchical cluster analysis (HCA)) and compare the results with existing groundwater vulnerability map and land use data. This research demonstrates the validity of applying multivariate statistical methods (PCA and HCA) on groundwater chemistry to assess the compliance of the existing groundwater vulnerability map with observation data.

Materials and Methods

In this research, available data about Quaternary groundwater chemistry from previous studies (Levins & Gosk, 2007; Retike *et al.*, 2016) and new data from national groundwater monitoring programme

Table 1

Principal component loadings and explained variance for three components with Varimax rotation

Parameter	PC1	PC2	PC3
Ca^{2+}	**0.89**	0.19	0.07
Mg^{2+}	**0.88**	0.28	0.08
Na^{+}	0.40	**0.74**	-0.08
K^{+}	0.20	**0.68**	0.22
HCO_3^{-}	**0.89**	0.09	0.07
Cl^{-}	0.40	**0.69**	0.11
SO_4^{2-}	0.32	0.49	0.23
NH_4^{+}	-0.19	**0.70**	-0.11
NO_2^{-}	-0.12	0.19	**0.82**
NO_3^{-}	0.29	-0.08	**0.82**
Eigenvalue	4.03	1.46	1.34
Explained variance (%)	40.32	14.63	13.36
Cumulative % of variance	40.32	54.95	68.30

Variables with principal component loadings greater than 0.5 are considered to be significant and are marked in bold.

carried out by the Latvian Environment, Geology and Meteorology Centre in years 2014 and 2015 were analysed.

In the beginning, samples having incomplete records of major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}) were excluded from further analysis. Then samples having an ionic balance error greater that ± 10% were rejected from further analysis (Güler, Thyne, & McCray, 2002). For multiple samples from the same location median values were calculated. Data preparation for multivariate statistical analysis consisted of two steps: firstly data were log-transformed (except HCO_3^{-}) to achieve close to normal distribution, then data were standardized (Cloutier *et al*., 2008; Güler, Thyne, & McCray, 2002). In total, a data set of 650 samples collected from monitoring springs and wells, springs, project wells, drainage, and water supply wells was used for further multivariate analysis. Hierarchical cluster analysis was made using Squared Euclidean distance as a similarity measure and Ward's method as a linkage method. The number of principal components was extracted based on the Kaiser criterion (Kaiser, 1958), and Varimax rotation was used (Cloutier *et al*., 2008; Güler, Thyne, & McCray, 2002). Multivariate statistical analysis was performed on the basis of major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3-) and nitrogen compounds (NO_3^{-}, NO_2^{-} and NH_4^{+}). Data pre-treatment and multivariate statistical analysis were performed using SPSS Statistics 22 and MS Excel 2013. CORINE land cover (2012) data were used to analyse the distribution of first level land use classes within clusters.

Results and Discussion

Based on Kaiser criterion (Kaiser, 1958), three principal components (PC) having eigenvalues greater than 1 were retained explaining 68% of the total variance in the data set (Table 1). PC1 explains the greatest amount of the variance and groups the high positive loadings of Ca^{2+}, Mg^{2+} and HCO_3^{-}. This component reflects the most common Ca-Mg-HCO_3 water type in Quaternary sediments in Latvia (Dēliņa, 2007). Highest positive loadings of parameters Na^{+}, K^{+}, Cl^{-} and NH_4^{+} suggest that PC2 outline groundwater samples affected by mixing with Na-Cl dominated water (Retike *et al*., 2016). PC3 groups highest positive loadings of NO_2^{-} and NO_3^{-}. Probably the PC3 indicate active nitrification process (Valle Junior *et al*., 2014).

Dendrogram is the main result of hierarchical cluster analysis and the number of clusters was visually selected by moving the Phenon line (Güler, Thyne, & McCray, 2002). As a result, all samples were divided into four groups based on their geochemical similarities and dissimilarities, distribution of clusters can be seen in Figure 1. Median major ion and nitrogen compound concentrations as well as pH, total dissolved solids (TDS) and PC loadings in each of the distributed clusters are summarised in Table 2.

It can be observed that the highest median values of major ions (except HCO_3^{-}) can be found in C2. The highest median positive loading of PC2 and highest median TDS confirm the hypothesis of groundwater mixing with NaCl dominated water. Similar results were obtained in previous studies (Levins & Gosk, 2007; Retike *et al*., 2016), although they were mostly

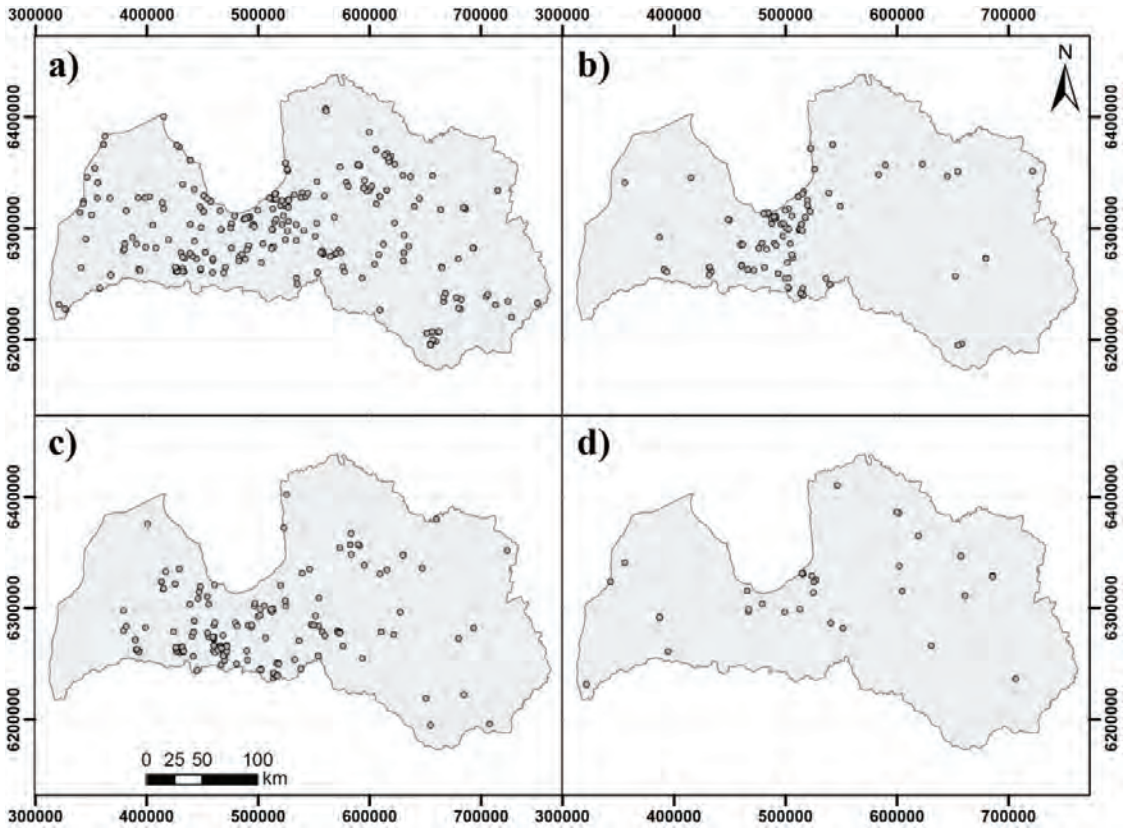

Figure 1. Distribution of sampling sites for four clusters obtained using hierarchical cluster analysis a) cluster 1; b) cluster 2; c) cluster 3; d) cluster 4.

from aquifers of greater depth. In some cases very high Na^+ and Cl^- values and Na/Cl ratio close to 1 were found in Quaternary groundwater as well (Retike *et al*., 2016) and can be explained as a result of halite dissolution delivered by roads de-icing (Cloutier *et al*., 2008). According to Dēliņa (2007), higher Na^+, Cl^- and K^+ values in Quaternary groundwater were found only in sandy deposits near the coastline and the distribution of sampling sites for C2 often match the previous observations (Figure 1). However, majority of the sampling sites in C2 are placed in the area near the capital city Riga and in Lielupe river basin, which is the most intensively used area for agricultural needs.

C4 shows the lowest median concentrations of all major ions, TDS and pH, as well as lowest median PC1 loading compared with other clusters (Table 2). All listed parameters in C4 have concentrations much lower than in slightly altered precipitation water found in earliest study (Retike *et al*., 2016). It can be seen (Figure 2) that C4 reflects Ca-HCO_3 water type and there are relatively low Mg^{2+} concentrations compared to Ca^{2+} concentrations (Table 2). For this reason C4 can be interpreted as very young groundwater formed in sandy deposits. C1 groups Ca-Mg-HCO_3 type groundwater with most typical chemical characteristic for Quaternary sediments in Latvia (Dēliņa, 2007) and sampling sites are distributed widely (Figure 1). Groundwater samples from C3 also belong to Ca-Mg-HCO_3 water type and C3 has highest median Ca^{2+}, HCO_3^- and NO_3^- values, highest positive PC1 and high positive PC3 loading. Moreover, very similar results were obtained in previous study (Retike *et al*., 2016) suggesting that such high median values of Ca^{2+}, HCO_3^- and NO_3^- as well as highlighted SO_4^{2-} and Cl^- values are not typical for groundwater and may indicate to diffuse agricultural influence. For example, Valle Junior *et al*. (2014) suggest that ploughing may promote the dissolution of carbonate and gypsum in the soils and increase the value of TDS in groundwater. Likewise, the placement of sampling points for C3 (Figure 1) in most intensively used area for agricultural needs- Lielupe river basin- supports the theory.

As it can be seen in Table 2, the highest NO_3^- concentrations can be found in C2 and C3. According to CORINE land cover data (Figure 3), C3 mostly represents agricultural areas and then artificial surfaces, but C2- artificial surfaces and then agricultural areas. Consequently, this explains the highest Na^+ and Cl^- concentrations in C2 and supports the theory of possible road de-icing influence. Likewise, the C3 shows the highest NO_3^- concentrations most likely produced via

Table 2

Chemical characteristics of four clusters and whole data set (median values)

Parameter	C1 (N = 298)	C2 (N = 121)	C3 (N = 194)	C4 (N = 37)	All samples (N = 650)
Ca^{2+} (mg l^{-1})	65.5	**105.0**	**105.0**	18.0	81.0
Mg^{2+} (mg l^{-1})	16.0	**34.0**	30.0	3.1	22.6
Na^{+} (mg l^{-1})	4.1	**20.0**	7.2	2.2	5.7
K^{+} (mg l^{-1})	1.5	**9.9**	2.5	1.4	2.2
HCO_3^{-} (mg l^{-1})	252.5	360.0	**412.5**	60.0	315.0
Cl^{-} (mg l^{-1})	6.0	**33.0**	15.0	4.0	11.0
SO_4^{2-} (mg l^{-1})	13.0	**52.0**	26.5	8.2	20.0
NH_4^{+} (mg l^{-1})	0.18	**0.48**	0.14	0.19	0.18
NO_2^{-} (mg l^{-1})	0.01	0.01	0.01	0.01	0.01
NO_3^{-} (mg l^{-1})	1.20	10.23	**11.60**	1.68	3.19
pH	**7.4**	7.3	**7.4**	6.5	**7.4**
TDS[1] (mg l^{-1})	383.8	**776.1**	630.5	100.9	495.7
PC1	-0.29	0.37	**0.78**	-2.27	0.10
PC2	-0.50	**1.46**	-0.16	-0.33	-0.16
PC3	-0.41	**0.57**	0.34	0.38	0.02

The highest values are marked in bold and the lowest are underlined; N- number of samples; [1]TDS calculated as the sum of major ions Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-}, SO_4^{2-} and NO_3^{-}; PC- principal component loading.

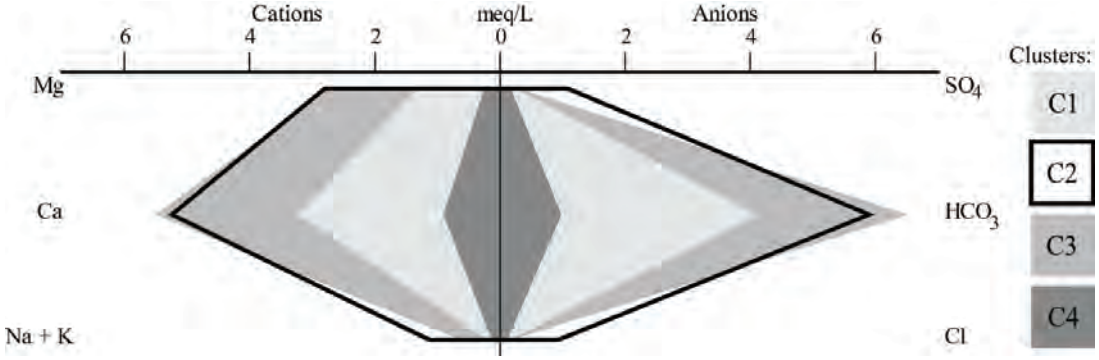

Figure 2. Median values of four clusters on Stiff diagram (meq/L).

the nitrification of N-fertilizers (Valle Junior *et al*., 2014). The lowest median NO_3^{-} concentrations are found in C1 and C4. In both clusters dominant land covers are forests and semi-natural areas or wetlands.

However, the distribution of existing vulnerability classes within four clusters shows unexpected results. For example, groundwater from C1 and C4, which are considered to be of good quality and non-affected by pollution are placed in the areas with high to medium groundwater vulnerability (Figure 3). Unlike the samples in C3 and C4, which have the highest nitrate concentration and indicate anthropogenic influence, they are placed in areas with medium to low vulnerability, especially for C3. In conclusion, the existing vulnerability classes at this point are useless as a tool for water management. More research should be carried out to improve the methodology how groundwater vulnerability classes are defined and the first step should be taking into account the pressures from diverse land use.

Conclusions

1. Four distinct groundwater groups were identified using multivariate statistical analysis. All groups belong to bicarbonate water type. The first group represents natural and most common calcium-magnesium bicarbonate water type in Latvia with low nitrate and ammonium concentrations that can be found in the whole territory of Latvia. Samples from second and third group both reflect anthropogenic influence: diffuse agricultural contamination mostly with nitrates produced

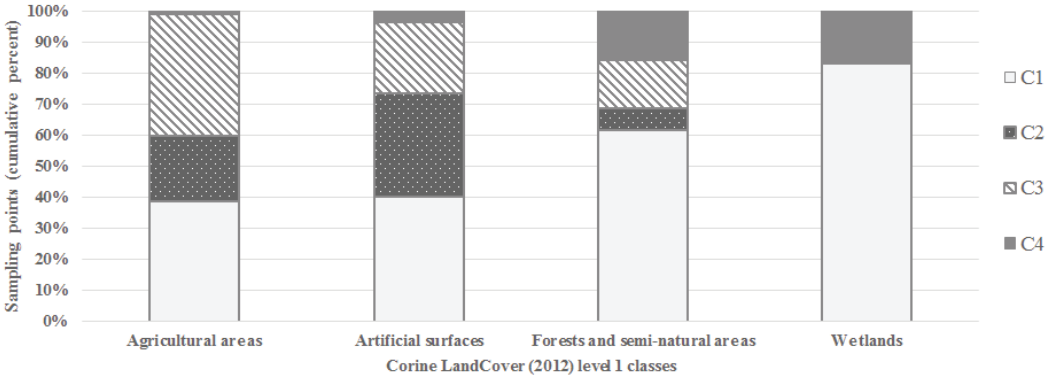

Figure 3. CORINE land cover (2012) level 1 classes within distributed four clusters.

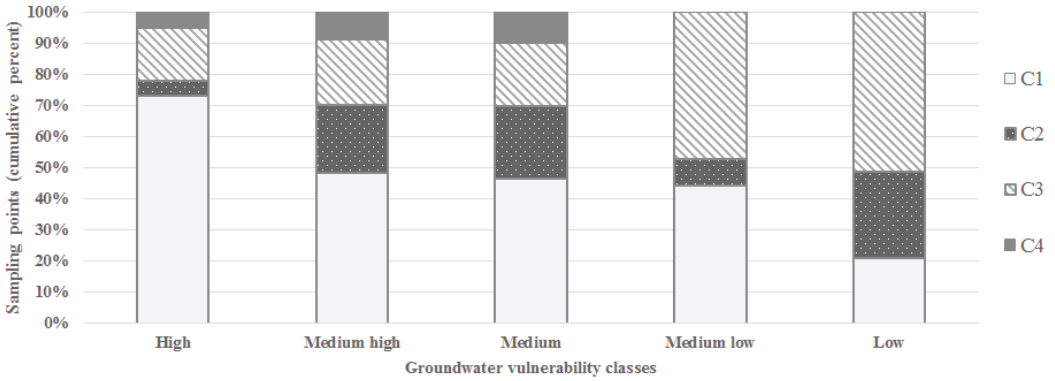

Figure 4. Groundwater vulnerability classes within distributed four clusters.

via the nitrification of N-fertilizers and / or contamination derived from artificial surfaces, for example, high Na^+ and Cl^- concentrations from road de-icing. Fourth group belongs to calcium bicarbonate water type and is characterised as very young groundwater located mostly in sandy deposits.

2. The results show that the highest concentrations of nitrogen compounds can be found in areas with agricultural land use or artificial surfaces which mostly are classified as medium low or low vulnerability areas. Meanwhile, the lowest values are present where dominant land covers are forests and semi-natural areas or wetlands and groundwater vulnerability classes are medium to high.
3. Fertility of the soil depends on the amount of clay minerals in it; therefore, areas with the highest clay content are mostly used in agriculture. Likewise, areas with more clay in soil are considered to be of lower vulnerability. As a result, areas with lowest groundwater vulnerability are mostly used in agriculture and have the highest anthropogenic pressure on groundwater.
4. The results show that all Quaternary groundwater in Latvia becomes vulnerable at a certain level of pressure and that the existing knowledge on groundwater vulnerability assessment in Latvia is insufficient; therefore, further researches are encouraged.

Acknowledgements

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References

1. Cloutier, V., Lefebvre, R., Therriern, R., & Savard, M.M. (2008). Multivariate statistical analysis of geochemical data as indicative of the hydrogeochemical evolution of groundwater in a sedimentary rock aquifer system. *J. Hydrol.* 353(3–4), 294-313. DOI: 10.1016/j.jhydrol.2008.02.015.

2. Dēliņa, A., & Prols, J. (1998). Latvijas pazemes ūdeņu aizsargātības karte (*Groundwater vulnerability map of Latvia*). SIA Geo Consultants, Rīga, 34. lpp. (in Latvian).
3. Dēliņa, A. (2007). *Kvartārsegas pazemes ūdeņi Latvijā (Quaternary groundwater in Latvia).* Summary of doctoral thesis, University of Latvia, Riga. (in Latvian).
4. Güler, C., Thyne, G.D., & McCray, J.E. (2002). Evaluation of graphical and multivariate statistical methods for classification of water chemistry data. *Hydrogeol. J.* 10(4), 455-474. DOI: 10.1007/s10040-002-0196-6.
5. Kaiser, H.F. (1958). The Varimax criteria for analytical rotation in factor analysis. *Psychometrika*. 23(3), 187-200. DOI: 10.1007/BF02289233.
6. Levins, I., & Gosk, E. (2007). Trace elements in groundwater as indicators of anthropogenic impact. *Environ. Geol.* 55(2), 285-290. DOI: 10.1007/s00254-007-1003-4.
7. Retike, I., Kalvans, A., Popovs, K., Bikse, J., Babre, A., & Delina, A. (2016). Geochemical classification of groundwater using multivariate statistical analysis in Latvia. *Hydrology Research*. In Print. DOI: 10.2166/nh.2016.020.
8. Saidi, S., Bouri, S., & Ben Dhia, H. (2010). Groundwater vulnerability and risk mapping of the Hajeb–Jelma aquifer (Central Tunisia) using a GIS-based DRASTIC model. *Environ Earth Sci.* 59(7), 1579-88. DOI: 10.1007/s12665-009-0143-0.
9. Valle Junior, R.F., Varandas, S.G.P., Sanches Fernandes, L.F., & Pacheco, F.A.L. (2014). Groundwater quality in rural watersheds with environmental land use conflicts. *Sci. Total Environ.* 493, 812-827. DOI: 10.1016/j.scitotenv.2014.06.068.

SURFACE WATER - GROUNDWATER INTERACTION IN THE SALACA DRAINAGE BASIN USING STABLE ISOTOPE ANALYSIS

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Abstract
This paper presents first results of monthly water stable isotope monitoring programme covering the most important surface and groundwater types in the Salaca River basin. The aim is to characterise the isotopic values of different water types in the Salaca River basin, and test if their contribution can be identified in the Salaca river runoff. A monthly groundwater and surface water stable isotope monitoring programme was initiated in August 2015 covering the most of the important surface and groundwater types in the study region – groundwater and surface water in the raised bogs, free-surface groundwater including artificially drained agricultural lands, water emerging from the Lake Burtnieks as well as Burtnieks and Arulika confined aquifers. Preliminary results show that stable isotopes are useful tool to identify distinct water components and their evolution. However, it is needed to continue monitoring programme to draw significant conclusions.
Key words: surface-groundwater interaction, stable isotopes, monitoring, Salaca river basin.

Introduction

The ratios of the stable isotopes in the water ($^{18}O/^{16}O$ and $^{2}H/^{1}H$) routinely presented as the delta value ($\delta^{18}O$ and δD) are a natural conservative tracer of the hydrological cycle with the exception when condensation of water vapour or evaporation from open water surface takes place (Mook, 2001). Terrestrial part of the hydrological cycle is dominated by the precipitation water input that is channelled back to the world ocean as surface and groundwater runoff if not returned to the atmosphere by evapotranspiration. Precipitation water has a characteristic isotopic composition controlled by the air temperature, the source of the water vapour and distance for the vapour transport. Around the world the isotopic composition of the precipitation water can be described by the global meteoric water line (Craig, 1961) that is found to be valid in the Baltic region as well. The precipitation water has a strong seasonality with more depleted values during the winter and more enriched values during the summer (IAEA/WMO 2014). During evaporation remaining liquid water is enriched in heavy isotopes and values of the $\delta^{18}O$ and δD are shifted away from the meteoric water line. In contrast, due to unidirectional transport of the water transpiration from plants and evaporation from soil surface, the isotopic composition of the remaining soil water does not change noticeably.

The aim of this research is to characterise the isotopic values of different water types in the Salaca River basin and test if their contribution can be identified in the Salaca river runoff. A monthly monitoring programme is initiated to observe the primary inputs postulated to be precipitation water and discharge from the Lake Burtnieks and compare their isotopic signature to the water sampled from Rivers Salaca and groundwater discharging into it. Here the first results are reported.

Study Area

The study region is the drainage basin of the Salaca River between its source from Lake Burtnieks and bridge near Vīķi in northern Latvia (Figure 1). The discharge of the Salaca River in the study region is dominated by the Lake Burtnieks that given its large surface area (40.06 km^2; Apsīte *et al*., 2012) has a moderating effect on the discharge fluctuations. The total drainage area of the lake is 2215 km^2; while the rest of the drainage area in the study region is 684 km^2. The largest tributaries of the Salaca in the studied section are Ramata and Iģe.

Lake Burtnieks is a shallow lake located in the North-Eastern part of Latvia. It is a flow lake: the water turnover time is 6 to 7 times a year, 2-3 weeks during the spring and 3 months during the summer (Apsīte *et al*., 2012). The lake surface area is 40 km^2. Long term mean water level of the Lake Burtnieks is 40.07 m a.s.l. The agricultural lands in the studied catchment cover 30 to 40%, bogs are 10% and forests are around 50% (Apsīte *et al*., 2012).

Glacial deposits of the Pleistocene glaciations form the upper part of the geological section within the study area. The thickness varies from a few meters up to 40 meters in elevated territories (Brangulis *et al*., 2000). The predominantly plain terrain is dominated by glacial (*gQ3*), glaciolimnic (*lgQ3*), glaciofluvial (*fQ3*), and peat deposits (*bQ4*) and numerous raised bogs are found. Water abstraction wells are usually installed in aquifers formed by the terrigenous Burtnieks and Arukila formations underlying the Quaternary deposits in the study region. The undulating plain is intersected with the valley of the Salaca river cutting Quaternary and Devonian deposits.

Materials and Methods

A monthly groundwater and surface water stable isotope monitoring programme was initiated in August

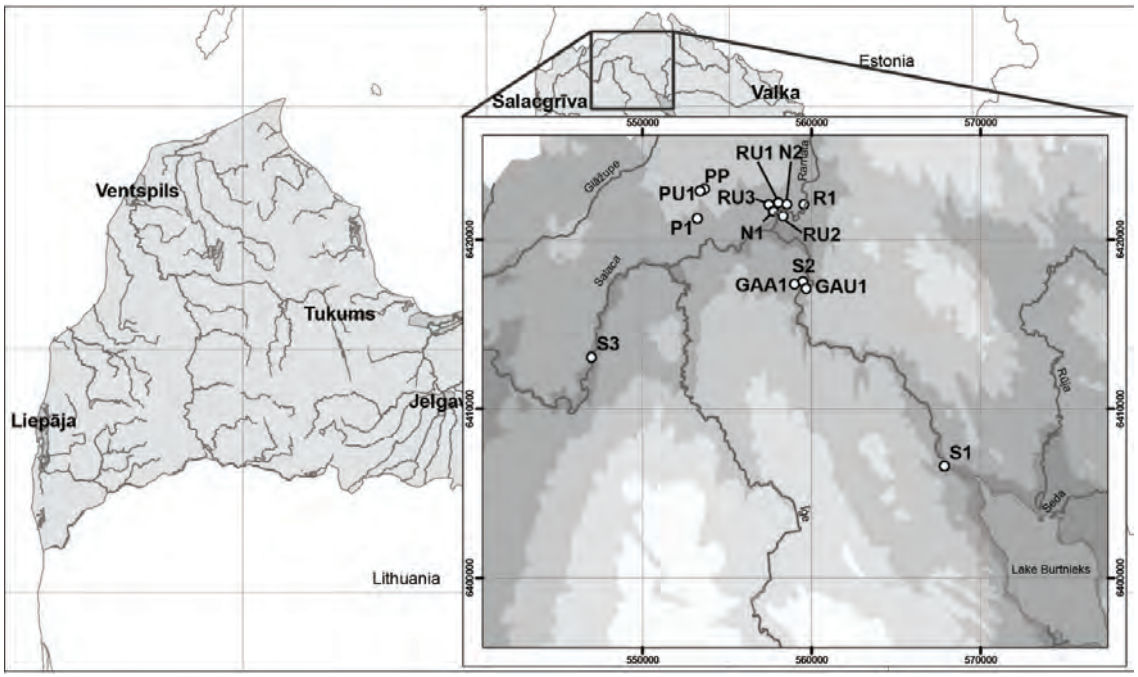

Figure 1. Study area and location of sampling points.

2015. The programme is designed to cover most of the important surface and groundwater types in the study region:

- Groundwater and surface water in the raised bogs: a weighted mean of the precipitation water to some extent modified by the evaporation from open surface (PP, P1 and PU1)
- Free-surface groundwater in sandy soils that might be biased towards the recharge of the depleted autumn-winter precipitation (GAA1)
- Free-surface groundwater in loam (till) soils, including artificially drained agricultural lands that is likely to be closer to the weighted mean of the yearly precipitation in comparison to the groundwater in the sandy soils (RU1, RU2 and RU3)
- water emerging from the Lake Burtnieks that is fed by a mix of groundwater and precipitation water and seasonally modified by the evaporation from free surface (S1)
- Burtnieks and Arukila confined aquifers: an integral value controlled by the local recharge conditions, likely more closely related to groundwater in the sandy-soil (GAU1).

Water samples were collected in 25 ml HDPE double-cap bottles and stored refrigerated until analysis. $\boldsymbol{\delta}^{18}O$ and $\boldsymbol{\delta}^{2}H$ were measured in all samples. Analysis was performed in Environment Dating Laboratory at the University of Latvia on Picarro laser cavity ring down spectrometer. Each sample was measured five times, but to prevent memory effect from previous sample, only average of the last 3 measurements were used to calculate mean value. Standards were placed between every 3 samples as well as at the beginning and at the end of each set of measurements. The repetitiveness of particular data set is ± 0.07‰ for $\delta^{18}O$ and ± 0.5‰ for $\delta^{2}H$ respectively; however, it is suggested to use result error ± 0.2‰ for $\delta^{18}O$ and ± 1‰ for $\boldsymbol{\delta}^{2}H$ (Clark & Fritz, 1997). All samples were measured against internal laboratory standard calibrated against international standard i.e., VSMOW (Vienna standard mean ocean water); accordingly, results can be compared internationally (Aggrwal *et al*., 2007).

Results and Discussion

During the five month observation period, 57 monthly samples were collected from 15 sampling points. Due to unusually low groundwater level in case of shallow wells near Ramata (RU1, RU2 and RU3) or technical problems in case of precipitation traps some sampling points have discontinuous observations. During the first sampling campaign, it was conducted that two sampling points for the river Salaca are insufficient, which explains missing SV3 sample during September 2015.

The slope of precipitation line at Ramata station between $\boldsymbol{\delta}^{18}O$ and $\delta^{2}H$ is 7.50 that is similar to long term Riga meteoric water line (RMWL) with slope of 7.45 (IAEA/WMO, 2014). Evaporation probably did not affect the results as all precipitation samples fit on the calculated line with determination coefficient 0.99.

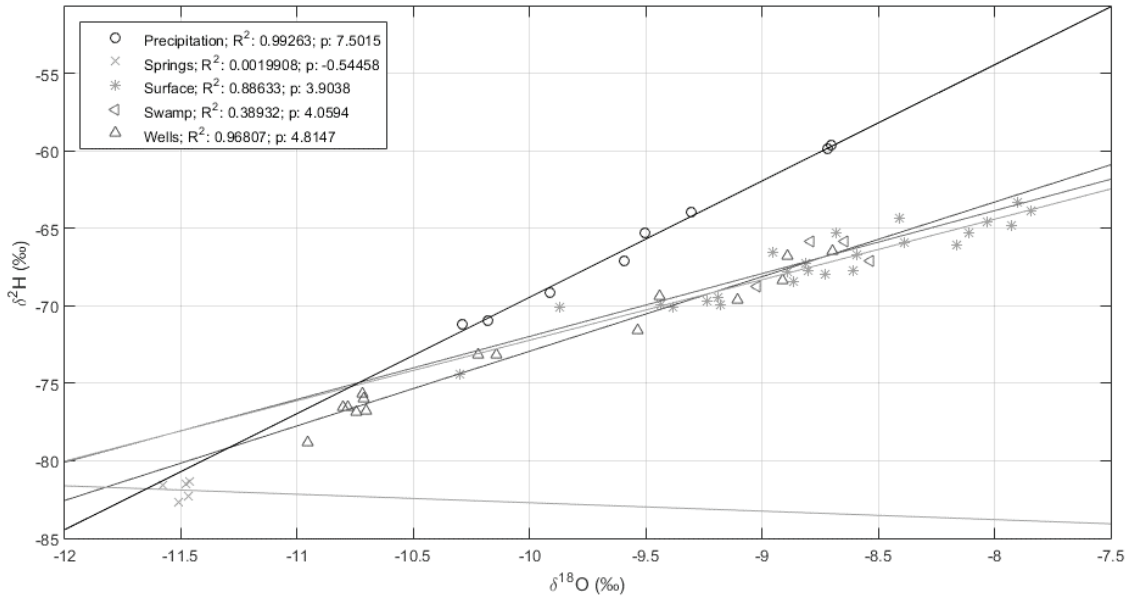

Figure 2. $\delta^{18}O$ versus $\delta^{2}H$ values by sampling groups.

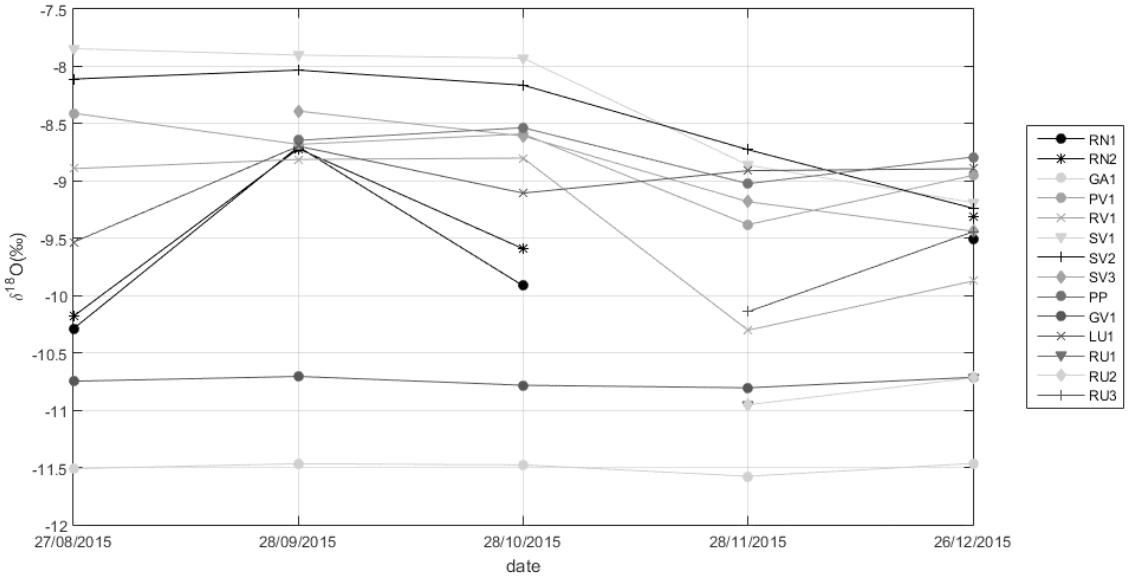

Figure 3. Five month time series of $\delta^{18}O$ at all sampling locations.

Isotope values of surface samples are spread within a wider range if compared to precipitation (Fig. 2) even though correlation between surface samples is significant i.e., 0.89. Observed values in rivers form essentially different regression slope 3.9. Such shift can be explained by evaporation of river or the source of river. In case of rivers Ramata and Piģele, the impact of raised bog discharge can be the case. In case of the river Salaca, evaporation comes from Lake Burtnieks. It is found that downstream form the Salaca source (SV1 observation point) the evaporation signal is diluted by admixture of more depleted water (Fig. 5).

Govs spring (GAA1) shows constant values in time i.e., range is 0.1 ‰ for $\delta^{18}O$ and 0.2‰ for δD, even narrower than receptiveness of measurements. Observed temperature and electric conductivity are also constant indicating longterm recharge. Isotope values of Govs spring plot on precipitation line; therefore, we suggest a direct meteoric recharge for Govsala spring.

Wells are within the widest range of isotope values compared to other groups and show more depleted values than surface samples. The most depleted well samples represent samples from the shallow Govsala (GAU1) well in the Burtnieks formation.

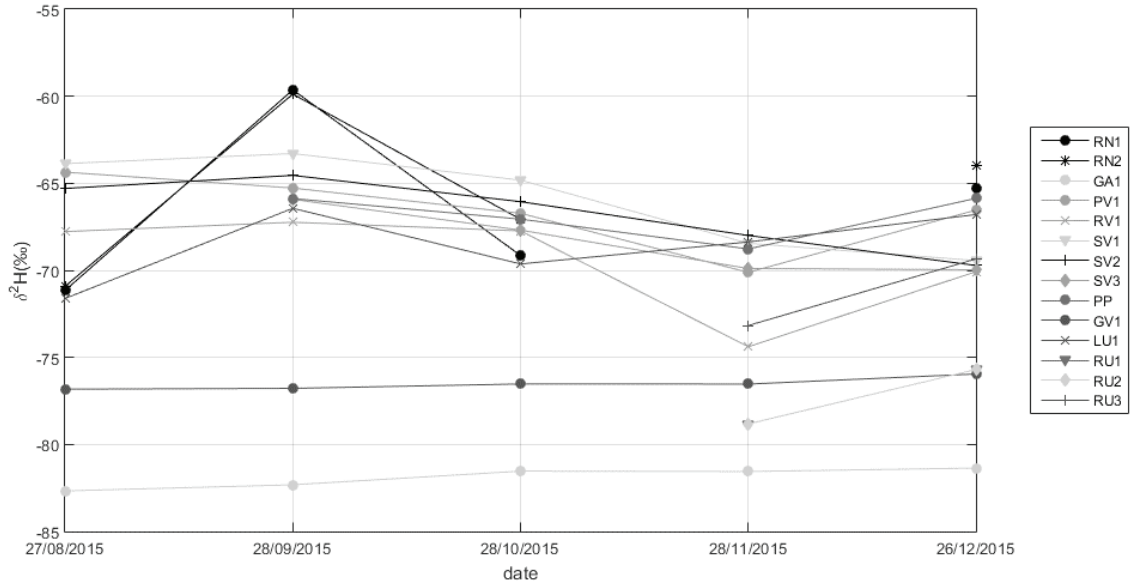

Figure 4. Five month time series of δ^2H at all sampling locations.

The evaporation signal also appears in samples from raised bog (PP, PU1) (Fig. 2) Bog samples change insignificantly during last months (Fig. 3 and Fig. 4) and have somewhat similar character of time series to the river Piģele (PV1). The river Piģele is an outflow from Saklauru raised bog; therefore, similar results were predicted.

Difference between the spring and well at Govsala station (GAA1 and GAU1) is almost 1 ‰ for $\boldsymbol{\delta^{18}O}$ and 5 ‰ for **δD**, although both the well and the spring show constant values during the observation period. The isotopic signal, as well as different electrical conductivity (518 and 118 µS/cm respectively) clearly points to different groundwater sources. Probably the Govsala spring (GAA1) emerging from Devonian sandstones represent locally recharge unconfined groundwater. The Govsala well (GAU1), on the other hand, more likely represent the regionally recharged confined groundwater.

Every subsequent month the river Salaca depicts more depleted isotope values (Fig. 5). A significant change in values between October and November corresponds to the end of the dry period in November and air temperature drop limiting the evaporation.

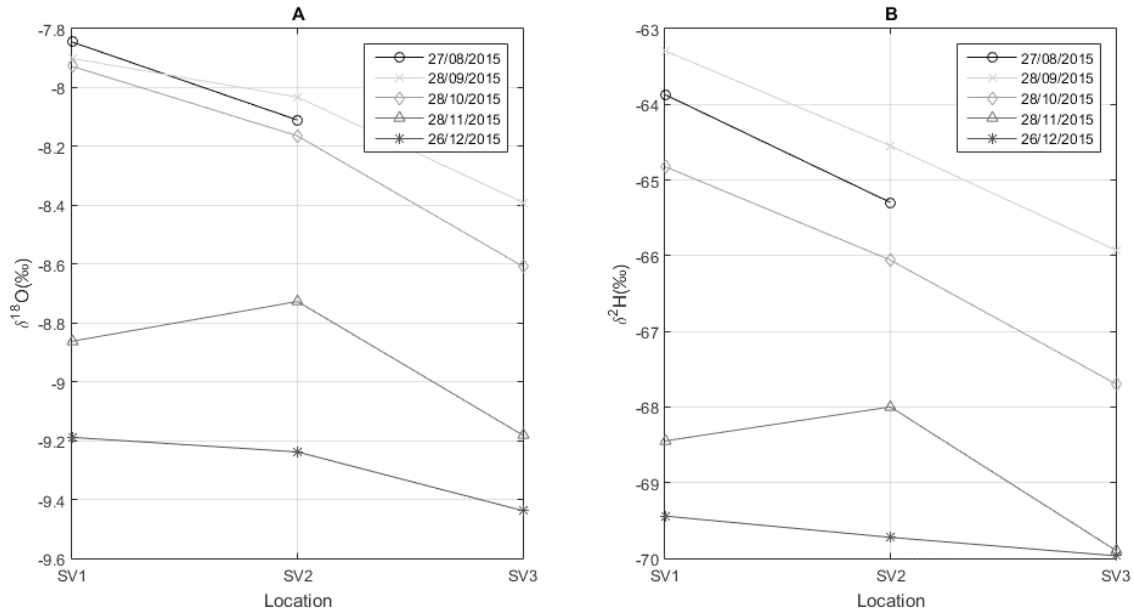

Figure 5. Change of $\delta^{18}O$ (A) and δD (B) along the flow path of the river Salaca.

Nevertheless, all months depict depletion of stable isotope values between Salaca observation points along the flow path.

Conclusions

During this study, stable isotopes are found to be a useful tool to identify distinct water components and their evolution, although a longer observation period is needed to draw robust conclusions.

We have found that:

1. Spring Govsala shows stable isotopic values, temperature and electric conductivity during the observation period; therefore, it portrays stable local recharge conditions with water source distinct from that found just a few meters deeper in the Burtnieki aquifer.
2. The water emerging from Lake Burtnieks at the source of the river Salaca in late summer and autumn has a strong evaporation signal, which is gradually diluted downstream.
3. Precipitation trend of Ramata observation station shows an equal slope as observed in Riga weather station 7.41 and 7.45 respectively.

Acknowledgements

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References

1. Apsite, E., Krikitis, M., Latkovska, I., & Zubanics, A. (2012). Long-Term Changes in Hydrological Regime of the Lakes Usma, Burtnieks and Rāzna. Proceedings of the Latvian Academy of Sciences. *Section B. Natural, Exact, and Applied Sciences*, 66(6), 261-270. DOI: 10.2478/v10046-012-0019-7.
2. Brangulis, A.J., Juskevics, V., Kondratjeva, S., Gavena, I., & Pomeranceva, R. (2000). Latvijas ģeoloģiskā karte, M 1: 200000 (Geological Map of Latvia, Scale 1:200000). Valsts ģeoloģijas dienests, Rīga (in Latvian).
3. Clark, I.D., & Fritz, P., (1997). Environmental isotopes in hydrogeology, CRC Press/Lewis Publishers, Boca Raton, FL.
4. Craig, H. (1961). Isotopic Variations in Meteoric Waters. *Science* 133:1702-3. DOI: 10.1126/science.133.3465.1702.
5. IAEA/WMO (2014). Global Network of Isotopes in Precipitation. The GNIP Database. RIGA (2642200, Latvia, 56° 58' 12'' / 24° 4' 12'' / 3m).
6. Mook, W.G. (2001). Environmental Isotopes in the Hydrological Cycle Vol. 1:- Introduction - Theory, methods, review. Atoms for Peace and United Nations Educational, Scientific and Cultural Organization.

ANALYSIS OF THE MAIN INDICATORS OF POLLUTION IN THE DOTNUVELE AND SMILGA STREAMS

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Abstract
Due to intensive agricultural activities being developed in Middle Lithuania, the water quality of rivers in this region significantly decreases. Rivers, flowing through the town territory, should provide aesthetic delight to the residents, however, because of pollution, especially at the end of summer, they are usually covered in duckweed and algae layer. The paper presents the change of the main water pollution indicators (BOD_7, N_{total}, NH_4-N, NO_3-N, P_{total}, PO_4-P and O_2) in Dotnuvele and Smilga streams during 2013 – 2015. The aim of research is to determine the change of the main surface water pollution factors in Dotnuvele and Smilga streams, depending on the meteorological conditions. Data analysis showed that dissolved oxygen, nitrate and total nitrogen concentrations are affected by air temperature: the lower the air temperature, the more of these elements were found in the water of the streams, (r = -0.61), (r = -0.83) and (r = -0.64) respectively. An increasing precipitation was also increasing the amount of O_2 and NO_3-N in streams' water, (r = 0.44), (r = 0.49) respectively. Meteorological conditions did not have a significant impact on concentrations of other chemical elements, however, correlation analysis showed that concentrations of BOD_7 in streams' water were increasing as precipitation level was falling (r = 0.41), and PO_4-P – when air temperature was increasing (r = 0.46). It was determined that in every spring the streams' water quality according to the concentrations of N_{total} and N-NO_3 was in a bad or average ecological condition. This was caused by the farming fields from which these streams are collecting drainage water during the spring melt.
Key words: ecologial status, concentration, surface water.

Introduction

In 2013, European Commission prepared a report to the Council and the European Parliment, where, according to the 2008 – 2011 yr. data from all EU27 states river observation stations, it can be claimed that 16.3% and 6.3% of rivers respectively were in eutrophic and hypertrophic condition, while 35.4% and 20.6% of rivers were in oligotrophic and ultra-oligotrophic condition. The biggest percentage of stations in rivers with ultra-oligotropic condition were in Spain, Bulgaria, and Slovenia, while the biggest percentage of stations in rivers with hipertrophic condition were in Belgium and the Netherlands, also in the Check Republic and Finland. A high eutrophication level was also observed in Lithuania and Luxembourgh (Report..., 2013).

In order to accomplish the goals set in the water framework directive (2000/60EB), both surface and ground water monitoring is being undertaken in Lithuania. Even though there is a lot of effort put into reducing the water pollution, according to the national monitoring data, the ecological condition of Lithuanian water bodies is not good. From 822 researched water bodies in river category, 75 of them were in a very good (9%), 327 – good (40%), 291 – average (35%), 85 – bad (11%) and 42 – very bad (5%) ecological condition (Mereškevičienė, 2015).

Nevezis basin lies in the Middle Lithuania lowland, where there are the most fertile soils. Due to intensive agricultural activities, the water quality in rivers of this region significantly deteriorates. Nowadays water bodies' ecological condition in Kedainiai town is not good: in summer, water surface very often becomes covered in algae and duckweed layer, slowing down the self-cleaning process and deteriorating the aesthetic view of the town.

There are 4 inflows of Nevezis in Kedainiai town, the biggest of these are Smilga and Dotnuvele. These streams are waterless, therefore, due to low debit, the streams' condition is bad during the dry season. Point pollution sources in basins of Dotnuvele and Smilga streams are municipal wastewater treatment plants, storm water treatment plants, and JSC ‚Kedainiai Canning Factory'. Not all residential houses are connected to the central sewer system, and part of the surface water from the town territory flows into the river. Wastewater accesses Dotnuvele and Smilga from various villages that are in their basins.

During 2009 – 2012 an environmental cleaning and restoration of these streams took place. Streams' water and shores were cleaned from pollutants. After this type of project, it is important to ensure a 5-year annual maintenance of cleaned water bodies and carry out streams' water monitoring. The aim of the research is to determine the change of the main surface water pollution factors in Dotnuvele and Smilga streams, depending on the meteorological conditions.

Materials and Methods

Dotnuvele and Smilga streams, flowing through Kedainiai town, are the right inflows of Nevezis river (Figure 1).

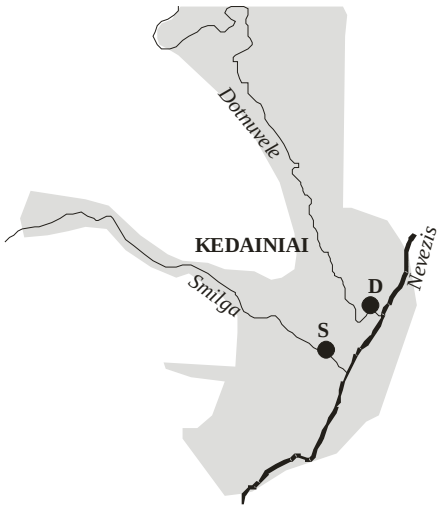

Figure. 1. The scheme of research object.
D – Dotnuvele stream's water sampling location,
S – Smilga stream's water sampling location.

Even though Smilga stream is almost twice shorter (32 km) than Dotnuvele (60.9 km), its basin is almost the same (208.8 km^2) compared to Dotnuvele's (192.7 km^2).

The cleaning of 1.95 km length of Dotnuvele stream (measured from the estuary of the stream) as well as restoration of 10 m width of coastal strip was completed in 2012. In 2013, 1.98 km length of Smilga stream and 2 ha of coastal land was cleaned, and 5157 m^3 of sludge removed.

Water samples were taken from the source of Dotnuvele (D) and Smilga (S) streams four times a year – in March, May, August, and November. Chemical analysis, was done by ASU Chemical Analytical Laboratory of Water Resources Engineering Institute.

In the samples total nitrogen (N_{total}) was determined by applying the spectrometric method, by mineralizing with potassium persulphate (LAND 59:2003), P_{total} was determined by spectrometric method after mineralization with potassium persulphate (LAND 59:2003), ammonium nitrogen (NH_4-N) – by spectrometric method, with Nessler's reagent (LAND 38:2000), nitrate nitrogen (NO_3-N) – by spectrometric with phenol sulfonic acid (LAND 65:2005), phosphorus residue (PO_4-P) – by spectrometric with ammonium molibdate and ascorbic acid. (LAND 59:2003)

BOD_7 was determined by estimating the difference in oxygen level after seven days of incubation (LAND 47-2:2007). Dissolved O_2 amount in water was determined using the electrochemical probe method (LST EN ISO 5814-2012).

According to this methodology, the ecological state of rivers is divided into 5 classes from a very good state, when N_{total} <2, P_{total} <0.1 to a poor state, when N_{total} >12, P_{total} >0.47 mg l^{-1} (Paviršinių..., 2011).

Statistical analysis of the data was performed using the computer program Excel and STATISTICA.

Results and Discussion

Average concentrations of researched chemical elements in the streams were changing unevenly: some of them were determined to be higher in Dotnuvele, others – in Smilga (Table 1).

Statistical data analysis showed that there is no significant difference between all researched chemical elements in both streams' water, because the calculated Student's t-test was lower than the 95% confidence level. The probability of confidence was also higher than the 0.05 level.

Oxygen amount in water is its pollution indicator. Therefore, the more oxygen is in water, the cleaner it is.

It was determined that water in both streams, according to the amount of dissolved oxygen, corresponded to a good and very good ecological condition (Figure 2). Data showed a tendency that there

Table 1

Average concentrations of researched chemical elements in streams' water

Indicator	Concentration, mg l^{-1}		$t_{fact.}$	$t_{theror.95\%}$	p
	In Dotnuvele	In Smilga			
BOD_7	2.54	2.94	-0.74	2.23	0.48
O_2	6.40	6.76	-0.14	2.18	0.89
NH_4-N	0.05	0.03	1.52	2.18	0.15
NO_3-N	3.60	4.38	-0.50	2.14	0.62
N_{total}	0.09	0.03	1.90	2.36	0.099
P_{total}	0.06	0.009	1.89	2.36	0.100
PO_4-P	9.64	11.14	-1.74	2.14	0.104

Note: $t_{fact.}$ – calculated Student's t-test, $t_{theor.95\%}$ – 95% Student's t-test probability; the difference between streams' water concentrations is significant when $t_{theor.95\%}<t_{fact.}$, p – confidence probability; when $p<0.05$ the relationship is significant.

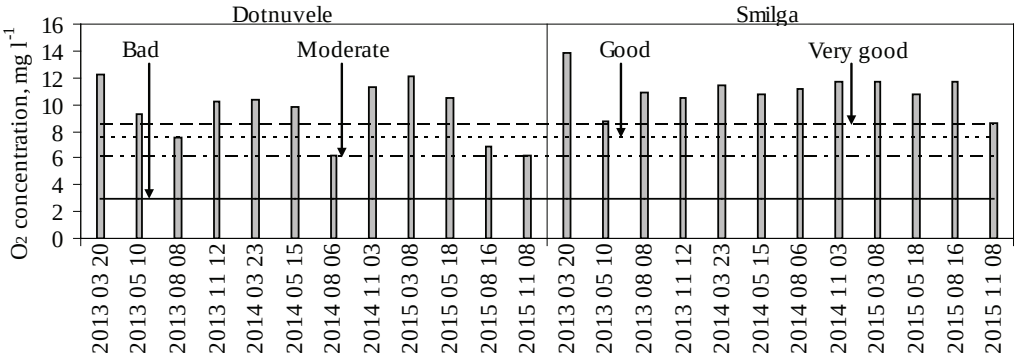

Figure 2. The change in dissolved oxygen concentrations in streams‘ water.

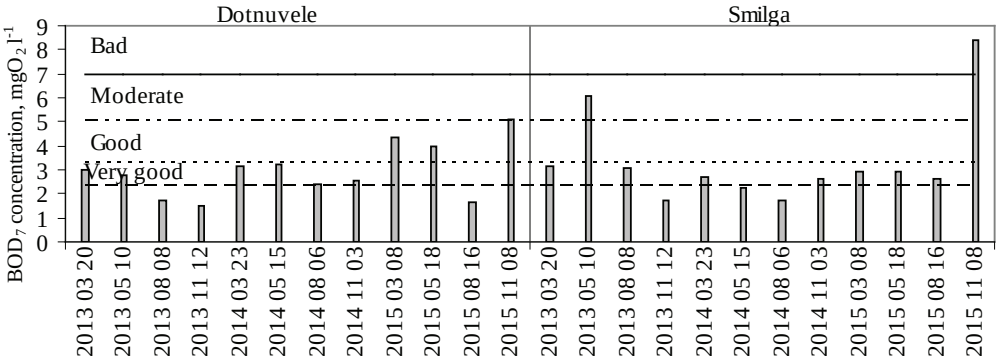

Figure 3. The change in BOD_7 concentrations in streams‘ water.

was less oxygen dissolved in Dotnuvele (6.22 – 12.3 mg l^{-1}) than in Smilga (8.7 – 13.9 mg l^{-1}), however, as literature states, open flow aeration directly depends on rivers‘ flow speed (Tilickis, 2005). The measured dry period lowest debits of Smilga (0.028 m^3 s^{-1}) are twice as big as those of Dotnuvele (0.015 m^3 s^{-1}) (Vaikasas & Poškus, 2004). The lowest oxygen concentrations in Dotnuvele were observed in August 2013, 2014, and November 2015, as there was the longest dry up period and water speed was the lowest. As there is a dam on Dotnuvele stream, its water speed has reduced even more, and this had an impact on the reduction of oxygen amount in water as well.

Organic matters reach rivers with industrial and household waste water, also large amounts of these materials accummulate in eutrophic river waters during vegetation degradation processes. A bigger organic matter amount essentially shows the pollution of that water body (Tilickis, 2005; Jouanneau *et al*., 2014; Simon *et al*., 2011; Gustavsson & Engwall, 2012; Chen *et al*., 2012). An increase in organic pollution was observed in Smilga stream in May 2013, when BOD_7 concentration had increased to 6.08 mg l^{-1}, and it corresponded to a bad ecological sream water condition (Figure 3).

In November 2015, organic pollution in both Dotnuvele and Smilga was the highest compared to the whole research period and was 5.13 and 8.37 mg O_2 l^{-1} respectively, and corresponded to a very bad ecological water condition. This was affected by precipitation that had fallen after a long and dry period, which washed town‘s streets from pollutants and increased organic pollution in the streams. According to Mallin *et al*. (2009), higher BOD concentrations can be found in rain water from urbanised territories, because town territories with impermeable coating increase surface wastewater and have an impact on hydrology and geomorphology of the streams (Paul & Meyer, 2008). During other seasons, Dotnuvele and Smilga streams‘ water was in a very good and good ecological condition.

In surface water bodies, even not affected by anthropogenic pollution, nitrogen and its compounds can be found all the time. According to literature, the most of total nitrogen can be found in rivers in Middle Lithuania, however, this is affected not only by human activity, but also by natural factors (Tumas, 2003; Šileika, 2012).

Ammonium nitrogen in both streams was observed to be very low; therefore, their water quality

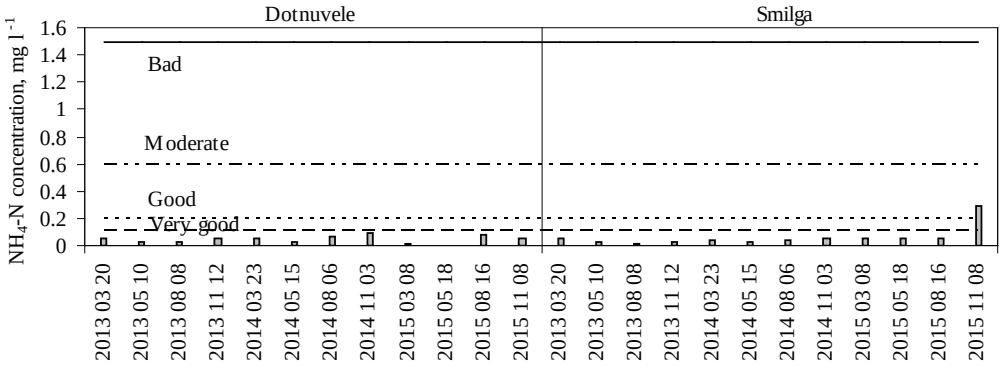

Figure 4. The change in NH_4-N concentrations in streams‘ water.

corresponded to a very good ecological condition, except November 2015, when NH_4-N concentration in Smilga stream was determined to be 0.287 mg l^{-1} and according to this element water quality was average (Figure 4).

This was probably affected by a large amount of precipitation (8.5 mm) that fell after a long dry period, as rain water dischargers from the town streets are installed on Smilga stream.

The analysis has shown that nitrate concentration in summer is lower: in August 2013, 2014, and 2015 it was 0.369, 0.651 and 0.814 mg l^{-1} respectively in Dotnuvele, and 1.08, 0.846 and 0.85 mg l^{-1} respectively in Smilga (Figure 5). This can occur due to water vegetation intensive assimilation.

In autumn, intensive rain washes a lot of organic and inorganic pollutants from the soil, which flow into streams and rivers. Besides, vegetation and algae start to decompose; therefore, nitrate concentration in water increases: it was determined to be 2.87, 0.973 and 1.17 mg l^{-1} in Dotnuvele, and 9.57, 2.09 ir 0.922 mg l^{-1} in Smilga. At the end of the cold period nitrate concentration in ecosystems was the highest and corrersponded to a bad ecological streams‘ condition:

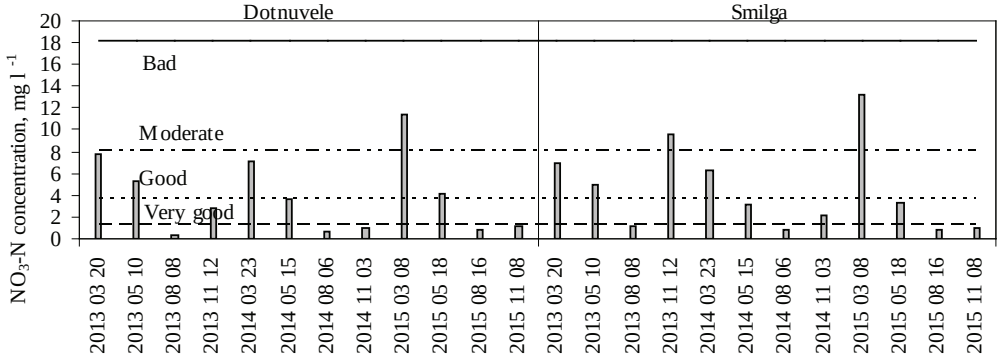

Figure 5. The change in NO_3-N concentrations in streams‘ water.

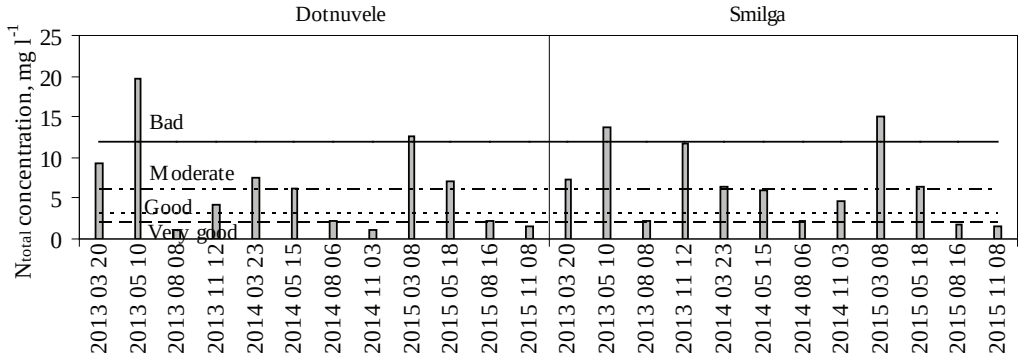

Figure 6. The change in N_{total} concentrations in streams‘ water.

in Dotnuvele it was 7.78, 7.15 and 11.4 mg l^{-1}, while in Smilga it was 7.01, 6.35 and 13.2 mg l^{-1}.

Due to human activity, nitrate nitrogen inflow into water bodies increases a lot; however, it depends on the season of the year (Gustavsson & Engwall, 2012; Stankevičienė, 2012; Kutra & Berankienė, 2006). There can be times when nitrate concentrations can depend not only on river's runoff, but also on other factors, such as plant vegetation, winter conditions, soil freezing depth, and snow cover (Tilickis, 2005).

In order to determine eutrophication tendencies of rivers, it is very important to analyse the fluctuation in total nitrogen in their water. Figure 6 shows that higher concentrations of this element as well as nitrate nitrogen were observed during the cold season or at the start of vegetation – at this time water condition in both streams was in a bad or very bad ecological condition. Dotnuvele and Smilga streams' water receives biogenic matters from agricultural lands, as higher concentrations of these elements were observed most often in spring, when, during the snow melt, water with dissloved nutrients reaches these streams by drainage.

PO_4-P concentrations in Dotnuvele and Smilga streams were observed to be very low and fluctuated between 0.006 and 0.061 mg l^{-1} in Dotnuvele and between 0.0049 and 0.038 mg l^{-1} in Smilga (Figure 7).

Only in August 2014 and 2015, phosphates and total phosphorus concentrations in Dotnuvele stream increased significantly (up to 0.235 and 0.237 as well as 0.32 and 0.298 mg l^{-1} respectively) and the water quality was in a bad ecological condition (Figures 7, 8). This was possibly affected by secondary pollution from algae accummulated in the stream.

Considering the ratio of total nitrogen and total phosphorus in the streams' water, it was determined that the most nitrogen in the streams was observed in the first, second, and fourth quarters of the year, while more phosphorus was observed in the third. This means that the third quarter provides good conditions for water vegetation to develop and thus streams become covered in duckweed.

The statistical data analysis has revealed a relationship of between concentrations of some chemical elements in streams' water and meteorological conditions (Table 2).

The data analysis has shown that dissolved oxygen, nitrate and total nitrogen concentrations are largely affected by air temperature: the lower the temperature, the higher is the concentration of

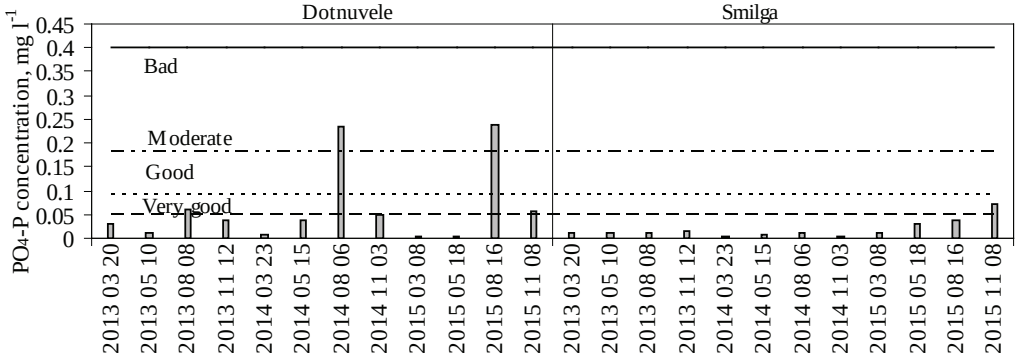

Figure 7. The change in PO_4 – P concentrations in streams' water.

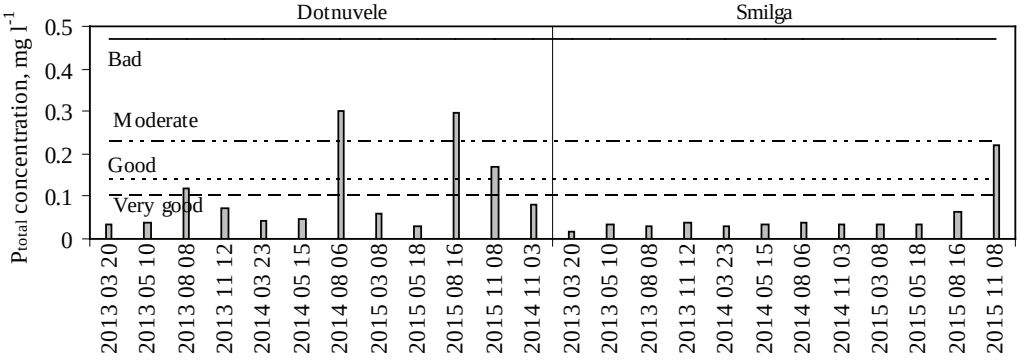

Figure 8. The change in P_{total} concentrations in streams' water.

Table 2

The influence of meteorological factors to the change in concentrations of chemical elements in streams‘ water

Indicator	Equation	n	r	Coefficient of partial correlation		$F_{fact.}$	p
				r_1	r_2		
BOD_7	$z=5.1-0.037x_1-0.013x_2$	24	0.44	-0.19	-0.39	2.52	0.10456
O_2	$z=9.6-0.162x_1-0.016x_2$	24	**0.65**	**-0.61**	**0.44**	**7.79**	**0.0294**
NH_4-N	$z=0.07+0.001x_1-0.0002x_2$	24	0.19	0.13	-0.15	0.38	0.68587
NO_3-N	$z=4.65-0.42x_1-0.024x_2$	24	**0.84**	**-0.83**	**0.49**	**24.65**	**0.0000**
N_{total}	$z=11.45-0.45x_1-0.009x_2$	24	**0.65**	**-0.64**	**-0.11**	**7.86**	**0.00282**
P_{total}	$z=0.09+0.005x_1-0.0004x_2$	24	0.43	0.41	-0.23	2.41	0.11388
PO_4-P	$z=0.03-0.004x_1-0.0002x_2$	24	0.49	0.49	-0.18	3.36	0.05409

Note: z – concentration of chemical element; x_1 – air temperature ºC; x_2 – precipitation amount mm; n – sample data points, r – sample correlation coefficient, coefficients of partial correlation: r_1 – air temperature, r_2 – precipitation, $F_{fact.}$ – calculated Fisher criterion, $F_{theor.95\%}$ – theoretical 95% probability of Fisher criterion = 3.44; relationship is significant when $F_{theor.95\%} < F_{fact.}$, p – confidence probability; relationship is significant when $p<0.05$.

these elements in streams‘ water (r = -0.61), (r = -0.83) and (r = -0.64), respectively. An increase in precipitation also increased O_2 and NO_3-N amount in streams‘ water, (r = 0.44), (r = 0.49) respectively. Meteorological conditions did not have a significant impact on concentrations of other chemical elements, except BOD_7 and PO_4-P. Correlation analysis was used to determine what effect precipitation and air temperature had on BOD_7, NH_4-N, P_{total} and PO_4-P concentrations in streams’ water individually. It showed that concentrations of BOD_7 in streams’ water were increasing as precipitation level was falling (r = 0.41) ($t_{theor.95\%} = 2.07<2.10$), and PO_4-P – when air temperature was increasing (r = 0.46) ($t_{theor.95\%} = 2.07<2.44$).

Conclusions

1. There was enough dissolved oxygen in streams‘ water – this corresponded to a good and very good ecological water condition. More oxygen was found when the water temperature was low (r = -0.6) and after more precipitation (r = 0.44).
2. It was determined that the quality of Dotnuvele and Smilga streams‘ water is mostly diminished by total and nitrate nitrogen. At the end of the cold period the concentations of these elements in the streams were found to be the highest and were 19.6 and 15.1 mg l^{-1} as well as 7.78 and 13.2 mg l^{-1} respectively. This corresponded to a very bad and bad streams‘ ecological water condition. This was influenced by the fact that these streams collect water from farming fields, which are fertilised and during the spring melt water containing the mentioned elements reaches the streams through drainage. It was determined that an increase in NO_3-N and N_{total} concentrations in streams‘ water were affected by meteorological conditions (r = 0.84 and r = 0.65) respectively. As air temperature fell, the amount of both these elements was observed to be higher in the water of both of the streams (r = -0.83) and (r = -0.64) respectively: NO_3-N when there was higher precipitation (r = 0.49), while N_{total} – when precipitation was lower (r = -0.11).
3. Ammonium nitrogen concentrations in streams‘ water corresponded to a very good ecological water condition, except in Smilga on the 11th November 2015, when 0,287 mg l^{-1} was observed and according to this element water quality was average. This was influenced by accidental pollution. Meteorological conditions had no effect on the concentration of streams‘ water (r = 0.19).
4. BOD_7 concentrations in the streams were found to be low, except in Dotnuvele in May 2013 (5.13 mg O_2 mg l^{-1}) as well as in May 2013 and November 2015 in Smilga streams when the pollution with organic matters was determined to be 6.08 and 8.37 mg O_2 l^{-1}. Meteorological conditions had a minor effect on it (r = 0.44): however correlation analysis showed that as there is less precipitation, organic pollution increases (r = 0.41).
5. According to the concentrations of phosphates and total phosphorus, streams‘ water was clean, except three samples from Dotnuvele stream in August 2014 as well as in August and November 2015, and Smilga stream in November 2015, when the amounts of these elements corresponded to a bad ecological condition. It was determined that meteorological factors had weak impact on the increase of these chemical elements (r = 0.49 and r = 0.43) respectively. Correlation analysis showed that as air temperature increases, phosphates concentrations in streams’ water increase statistically significantly (r = 0.46).

References

1. Chen, C-H., Lung, W-S., Li, S-W., & Lin, C-F. (2012). Technical challenges with BOD/DO modeling river in Taiwan. *Hydro environ Res.* 6, 3-8. DOI: 10.1016/j.jher.2011.08.001.
2. Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy. Retrieved February 18, 2016, from http://www.europa.eu.
3. Jouanneau, S., Recoules, L., Durand, M.J., Boukabache, A., Picot, V., Primault, Y., Lakel, A., Sengelin, M., Barillon, B., & Thouand, G. (2014). Methods for assessing biochemical oxygen demand (BOD): A review. *Water Res.* 49(1), 62-82. DOI: 10.1016/j.watres.2013.10.066.
4. Gustavsson, L., & Engwall, M. (2012). Treatment of sludge containing nitro-aromatic compounds in reed-bed mesocoms – Water, BOD, carbon, nutrient removal, *Waste Manage.* 32:104-109. DOI: org/10.1016/j.wasman.2011.08.016.
5. Report from Commission to the Council and the European Parliament. COM (2013). 683 final. Brussels. Retrieved February 18, 2016, from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0683:FIN:EN:PDF.
6. Kutra, S., & Berankienė, L. (2006). Azoto koncentracijos vidutinio dydžio upių vandenyje priklausomybė nuo nuotėkio modulio (Mid-sized river specific water runoff influence on nitrate nitrogen concentration). *Water Manage Eng.* 30(50), 57-66. (in Lithuanian).
7. Mallin, M.A., Johnson, V.L., & Ensing, S.H. (2009). Comparative impacts of stormwater runoff on water quality of an urban, a suburban, and a rural stream. *Environ Monit Assess.* 159(1–4), 475-491. DOI: 10.1007/s10661-008-0644-4.
8. Mereškevičienė, I. (2015). *Aplinkos būklė 2014. Tik faktai.* (Environment condition 2014. Only facts.) Vilnius: Lututė. (in Lithuanian).
9. Paul, M.J., & Meyer, J.L. (2008). Streams in the Urban Landscape. Marzluff, J.M., Shulenberger, E., Endlicher, W., Alberti, M., Bradley, G., Ryan, C., Simon, U., ZumBrunnen, C. (Eds.), *Urban Ecology*, (207-231), US: Springer. DOI: 10.1007/978-0-387-73412-5.
10. *Paviršinių vandens telkinių būklės nustatymo metodika.* (Surface water bodies' state evaluation methodology). (2011). Valstybės Žinios, No. 109-5146. (in Lithuanian).
11. Simon, F.X., Penru, Y., Guastalli, A.R., Llorens, J., & Baig, S. (2011). Improvement of the analysis of the biochemical oxygen demand (BOD) of Mediterranean seawater by seeding control. *Talanta,* 85:527-532. DOI: 10.1016/j.talanta.2011.04.032.
12. Stankevičienė, R. (2012). Mūšos baseino upių metinės ir sezoninės vandens taršos bendruoju azotu taikant fyris modelį (FYRIS model application for analysis annual and seasonal total nitrogen pollution in the Mūša catchment) *Water Manage Eng.* 40(60), 54-63. (in Lithuanian).
13. Šileika, A.S. (2012). Bendrojo azoto ir bendrojo fosforo tendencijos Nevėžio upėje (Tendencies of the total nitrogen and total phosphorus changes in the Nevėžis river) *Water Manage Eng.* 40(60), 14-21. (in Lithuanian).
14. Tilickis, B. (2005). *Vandens cheminės sudėties kaita Lietuvos baseinuose* (Water chemical composition alternation in Lihuanian cathments) Klaipėda: Klaipėdos universiteto leidykla. (in Lithuanian).
15. Tumas, R. (2003). *Vandens ekologija* (Water ecology). Kaunas: Naujasis lankas. (in Lithuanian).
16. Vaikasas, S., & Poškus, V. (2004). Dotnuvėlės ir Smilgos upelių vagų Kėdainiuose nuosėdų užterštumo tyrimai (Investigations on sediment pollution in the stresams Dotnuvele and Smilga in Kedainiai) *Water Manage Eng.* 26(46), 31-39. (in Lithuanian).

GROUND-PENETRATING RADAR (GPR) SCREENING IN SHALLOW ENGURE AND PAPE LAGOON LAKES

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Abstract
Geophysical studies in mapping and screening applications are widely applied for archaeological, environmental, geological, hydrological and many other applications. Ground-penetrating radar (GPR) is one of methods from geophysical toolbox that is also called a ground-probing radar, subsurface radar, surface-penetrating radar and 'georadar' or impulse radar – it is a non-invasive and non-destructive technique. Pulsed electromagnetic signal is recording the reflected energy and scattering from subsurface objects. Studies were performed in former Littorina Sea lagoons that became lakes after the further Limnea Sea stage in the Baltic Sea established with comparatively lower absolute sea level that is close to present day situation. Characterization of sediments as well as full sediment core description for comparison with GPR signals were performed. Major results show that GPR as non-destructive method in combination with geological coring followed by laboratory analysis of sediment properties can be successfully used to describe layering conditions, topography and depth of shallow lakes. Although there are some limitations regarding the electromagnetic (EM) noise and similar EM properties of analysed sediments, proper treatment of data gives complementary insight thus diminishing the necessity of dense coring network establishments in analysed areas of lakes. The aim of this screening study is to analyse potential advantages of GPR use for mapping sediments and topography of sandy bottom in shallow lagoon lakes as well as pinpoint problems during field and cameral works considering electromagnetic, geological and topographical disturbances.
Key words: ground-penetrating radar (GPR), benthic sediments, lagoon lakes, geophysics.

Introduction

Characterization of various environments (e.g., glacial, fluvial, aeolian or lacustrine) is influenced by obstacles of previous geological environment such as accumulation and erosion processes. The influence of these processes is mostly recorded in sedimentary architecture (Slowik, 2014). Geophysical methods might be useful tools for studies of internal structures as well as obtaining information about relief forms and their historical evolution. Nowadays geophysical data is becoming a primary source for such information versus traditional methods (e.g., coring and trenching) (van Dam, 2000; van Dam, 2012). In a variety of archaeological, environmental, engineering, geological, and hydrological applications, ground-penetrating radar (GPR) has become a popular geophysical tool with which to image the shallow subsurface (Bristow & Jol, 2003; Daniels, 2004; Jol, 2009).

In principle, GPR emits a pulsed electromagnetic signal and records the energy reflected and scattered at subsurface structures and objects. Data can be processed in a similar way to reflection seismic studies for obtaining a relatively structural image of the subsurface. GPR is a non-invasive and non-destructive geophysical technique that detects electromagnetic discontinuities in the shallow subsurface (< 50 m) (Neal, 2004). Despite some difficulties, GPR surveys are widely used in different scientific and applied fields: geosciences, structural and health monitoring, archaeology, forensic, exploration and mining, sedimentology (Ansellmetti *et al*., 2004). A key step in processing acquired data sets is the use of an appropriate migration scheme moving dipping reflections to their real position, eliminating electromagnetic (EM) noise, crossing and diffraction events resulting from point reflectors (Yilmaz & Doherty, 2001). During complex structural settings, the migration itself becomes an essential processing step for imaging subsurface structures and, thus, is a prerequisite for a relevant interpretation of GPR information. Despite all positive applications provided by GPR and diminishing technological weaknesses, it is still a research technique that can be called as the 'state-of-the-practice' rather than 'state-of-the-art' - it is developing and geophysicists are still elaborating the organisation of the multitude of parameters to enhance data quality and elaborating interpretation by improving technological tools (Parker *et al*., 2010). The shallow water environment creates operational problems with geophysical surveying in general matter as was pinpointed already by Dobinson *et al*., 1990. Case studies onshore as well as offshore by using GPR methods in combination with offshore high-resolution reflection seismic methods have been used for sedimentological analysis, e.g., Geneva Bay area (Switzerland) (Ansellmetti *et al*., 2004; Beres *et al*., 2006). GPR allows the imaging of sedimentary structures with some exceptions in the shallow sub-surface. It provides a near-continuous record both

above and beneath the groundwater sometimes even impossible by using conventional techniques. Therefore, it is used in a variety of depositional environments: wetland (Comas *et al*., 2004; Sass *et al*., 2010), glaciofluvial (Asprion & Aigner, 1999), fluvial (Leclerc & Hickin, 1997; Vandenberghe & van Overmeeren, 1999; Hickin *et al*., 2009; Słowik, 2012), aeolian (Tatum & Francke, 2012), glacial (Sadura *et al*., 2006), and finally technogenic (Blumberg *et al*., 2004; Słowik, 2011). Fluvial and wetland environments are most challenging for geophysical surveys in general due to high groundwater level standings and presence of clay and organic. These have properties of relatively low EM wave (Neal, 2004). Groundwater saturation and porosity are important factors causing GPR reflections. By the increase of moisture, the effect of free water in sediments affects GPR reflections (van Dam & Schlager, 2000; Koh, 2012). Sediments with significant admixture of clay give attenuation of the GPR signal (van Heteren *et al*., 1998; Bano *et al*., 2000). EM wave propagation has been detected also in Sass *et al*., 2010. Studies reveal that 2 m penetration in clayey sediments might be doable (Barone *et al*., 2013) hence are marked significantly lower than in unsaturated sands and gravels (Jol & Smith, 1995). Depth range and resolution of GPR surveys are dependent on antennae frequency (Neal 2004), hydrogeology (Boll *et al*., 1996; Steelman & Endres, 2010; Koh, 2012; Barone *et al*., 2013), climate conditions (Lunt *et al*., 2005; Tran *et al*., 2012).

In Latvia, scientific studies by using GPR have been performed mostly for peat properties and mapping studies as well as hydrological applications (Karuss & Berzins, 2014; Karuss, 2015).

The aim of this screening study is to analyse potential advantages of GPR use for mapping sediments and topography of sandy bottom in shallow lagoon lakes as well as pinpoint problems during field and cameral works considering electromagnetic, geological and topographical disturbances. GPR data in joint analysis with coring and laboratory information from experimental screening case studies in Engure and Pape lakes elaborate understanding of geophysical screening potential for mapping applications in shallow partly overgrown lagoon lakes.

Materials and Methods

Screening case study lakes and their geological description

Engure and Pape Lakes (Fig. 1) are relatively large and shallow lakes in Coastal Lowland developed during Littorina Sea stage and are separated (from the Gulf of Riga and Baltic Sea, respectively) by 1.5 to 2.5 km wide dune strips. At present, the Engure Lake depth

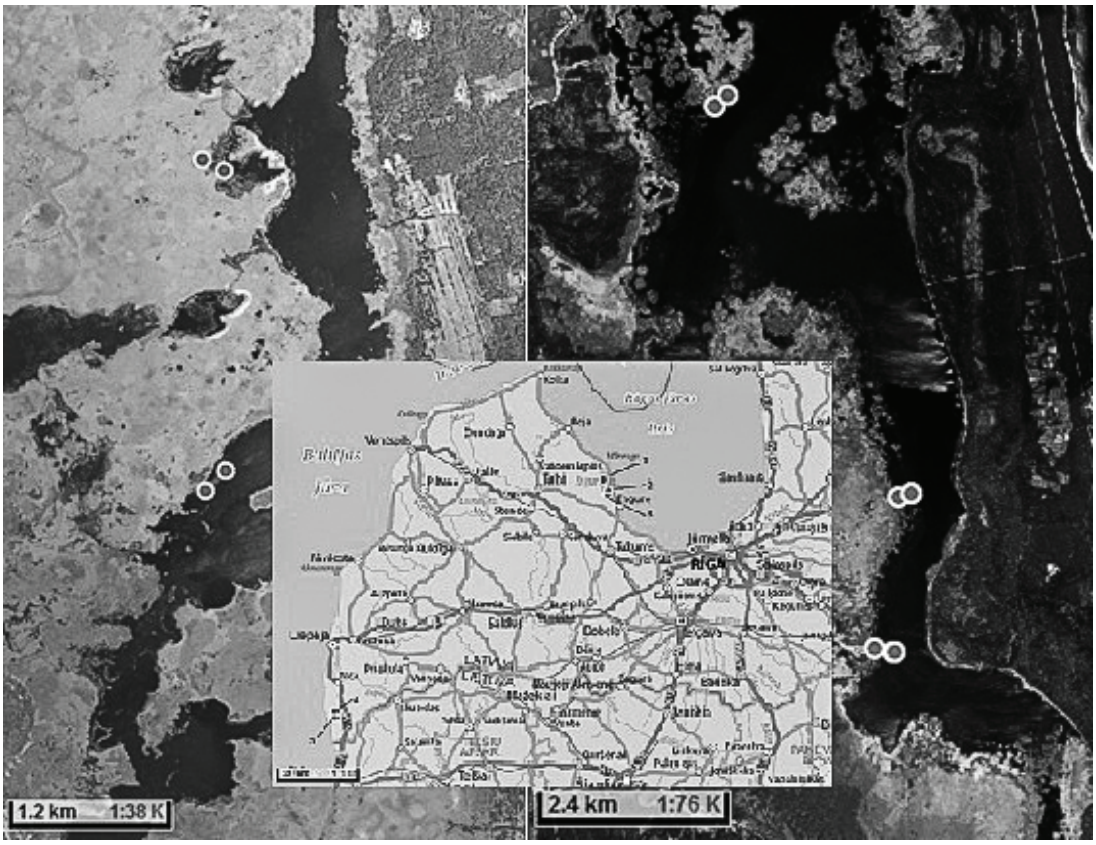

Figure 1. Location of sediment sampling and geophysical profiling sites in Pape (A) and Engure Lakes (B).

does not exceed 2 m and the Pape - 1 m (Eberhards *et al*., 2000), with an average depth of only 0.40 m for Engure and even less for Pape where depending on season the lake almost disappears (Prieditis, 2002). Banks of flat, open coastal landscape dominate, coasts of both lakes in several places are grazed and are severely overgrown. Sediment samples of various types were derived from both shallow overgrowing freshwater lakes containing rich organic sediment layers, located in Engure and Rucava Districts, in Latvia (Figure 1).

Sediment sampling cores in lakes were carried out in certain points selected according to the established network and coupled with geophysical study profiles (Fig. 2-5). Texture analysis, elemental and moisture content, loss of ignition, pH, conductivity were determined and are given in Table 1-3. Mostly organic material, mud and gyttja (sapropel) are covering mineral soil layer which is mostly sand, gravelly sand and rarely glacial till.

Coring of sediments was done using a Russian-type peat sampler equipped with a 1.0 m long (d=5 cm) camera. Every cored sample was put into a non-transparent air-tight plastic bucket with a lid and stored at constant temperature (+4 ºC) to achieve *in situ* conditions during the storage. Sediment core was

Table 1

Description of sediment profiles pH, ash, dry matter content in studied lakes (Engure, Pape)

Sample No.	Depth, m	pH	Content of organic matter, %	Content of carbonates, %	Ash, %	Moisture, %	Content of dry matter, %
Engure Lake							
1	1.33-1.50	6.74	17.08	1.65	84.58	78.99	21.01
	2.00-2.10	6.84	26.98	0.69	73.71	80.04	19.96
	2.35-2.50	8.5	10.53	8.53	98.00	76.42	23.58
2	1.50-1.60	7.15	34.06	0.19	66.14	91.76	8.24
3	2.60-2.70	6.65	3.61	0.12	96.51	45.16	54.84
Pape Lake							
4	1.50-1.60	6.65	15.58	0.14	84.56	82.68	17.32
	2.80-2.90	6.81	12.94	0.10	87.17	73.46	26.54
5	1.50-1.65	6.45	14.95	0.08	85.13	83.38	16.62
	2.50-2.60	6.91	17.02	0.20	83.18	82.58	17.42

Table 2

Lithology of Engure Lake sediments

Engure Lake								
	Coring coordinates	57°27’39,49” N 23°09’19,16” E			57°22’56,55” N 23°13’10,55” E			57°21’07,24” N 23°12’31,40” E
No.	**Depth, m**	**Lithology of sediments**	**No.**	**Depth, m**	**Lithology of sediments**	**No.**	**Depth, m**	**Lithology of sediments**
1	0-0.7	Water	2	0-0.9	Water	3	0-2.2	Water
	0.7-0.95	Mud		0.9-1.2	Mud		2.2-2.25	Mud
	0.95-1.85	Sapropel		1.2-1.8	Mud/sapropel		2.25-2.45	Peat
	1.85-2.1	Peat		1.8-2.3	Sapropel		2.45-2.5	Sapropel
	2.1-2.20	Sandy sapropel		2.3-2.6	Sand		2.5-2.6	Sapropel
	2.20-2.25	Sand with shells		2.6-2.75	Sand with shells		2.6-2.7	Sand
	2.25-2.30	Peat		2.75-2.85	Sand			
	2.30-2.35	Sand						

Table 3

Lithology of Pape lake sediments

Pape lake					
	Coring coordinates	56°20'56,20" N 21°04'28,11" E			56°18'55,26" N 21°04'45,17" E
No.	**Depth, m**	**Lithology of sediments**	**No.**	**Depth, m**	**Lithology of sediments**
4	0-0.73	Water	5	0-0.6	Water
	0.73-1.15	Reed roots with partly decomposed mud		0.6-1.25	Reed roots with partly decomposed mud
	1.15-1.35	Mud		1.25-1.62	Mud with reed roots
	1.35-3.00	Sapropel		1.62-2.5	Mud/sapropel with reed roots
	3.00-3.25	Sapropel with organic material		2.5-3.3	Sapropel
	3.25-3.5	Sandy sapropel		3.3-3.45	Sandy sapropel

characterised by type of sediments. Loss on ignition (LOI), pH and metal content analyses has been done for samples of sediments (Heiri *et al*., 2001)

GPR studies

The theoretical background to the GPR technique and the practical methodology of data collection are comprehensively described in the current literature (Davis & Annan, 1989; Reynolds, 1997; Neal & Roberts, 2000). The Zond-12e GPR Advanced equipped with shielded 500 MHz antenna, manufactured in Latvia by Radar Systems was used for the measurements. In Engure Lake, transects with length ~200 m were scanned, but in Pape Lake ~500 m. After test runs for better results there was decided to use dielectric permittivity – 81 with scanning rate – 512 samples per trace. Sounding (time) range was used 300 ns, which is equally 5.00 m in nature with used dielectric permittivity. Also, strong high-pass filter was applied for soundings.

Results and Discussion

GPR like other geophysical method characterises the subsurface and can identify inhomogeneous features or objects that differ from homogenous material. Identification of these anomalies is often the objective of a geophysical survey or buried target identification (Robinson *et al*., 2008; Kearey *et al*., 2002). The use of geophysical methods on water bodies is slightly different to terrestrial as the freshwater is chemically less variable in axial and planar directions than soil. Water bodies and their chemical composition are changing faster over shorter periods of time in comparison to soil (Parker *et al*., 2010). Objects can be identified when a contrast is sufficiently large to alter the geophysical signals of the subsurface. GPR survey success is dependent on complexity of soil or water body and differences of physical and chemical properties of material; also complexity of structures and textures influences interpretation quality (Parker *et al*., 2010). Lagoon lakes in this case can provide even more complexities, e.g., conductivity and suspended matter in water masses have certain EM noise effects creating additional wave propagation and reflection that leads to difficulties within interpretation works. The main reason is that fresh and saltwater have similar dielectric properties (about 80 each) and radar velocities (freshwater has 0.033m ns^{-1}, saltwater – 0.01m ns^{-1}); however, both mentioned have very incompatible conductivity parameters (freshwater has

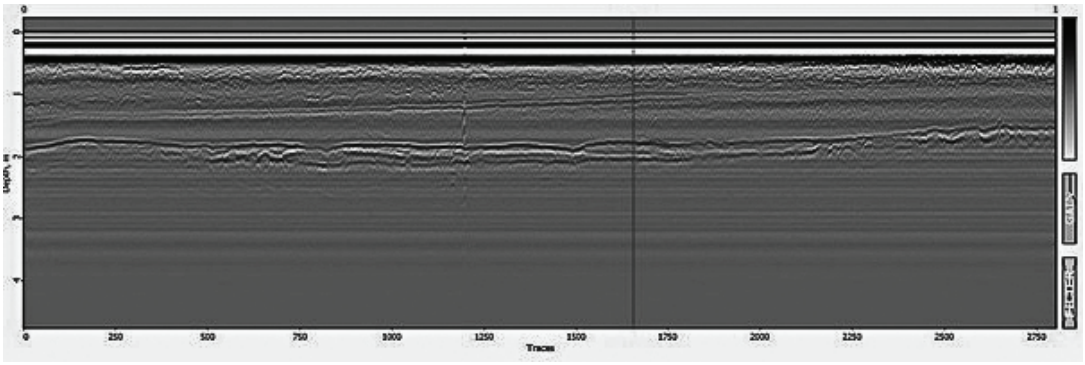

Figure 2. Scanned transect with GPR in Engure Lake (No.1).

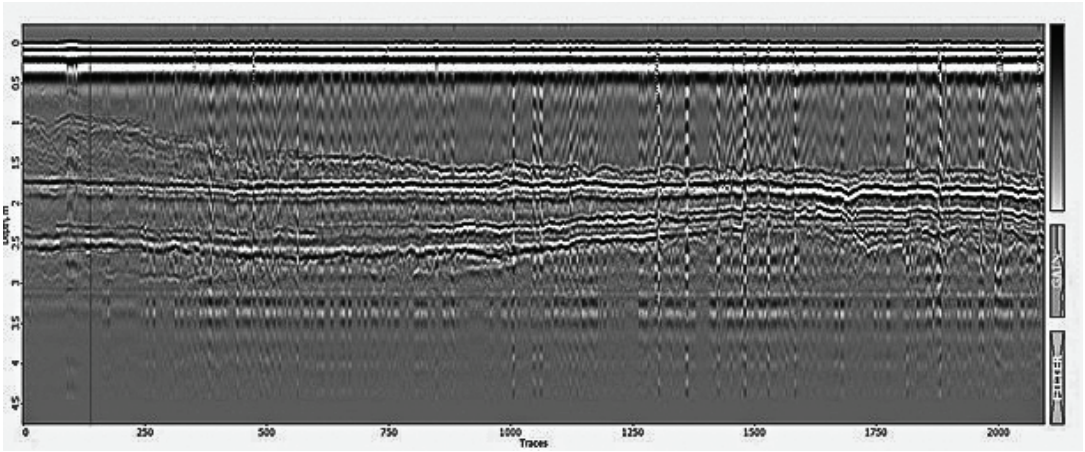

Figure 3. Scanned transect with GPR in Engure Lake (No.2).

0.5 mS m^{-1}, saltwater even up to 30 000 mS m^{-1}). All radar signals in such water bodies are simply soaked up. Nevertheless, in majority of freshwaters GPR response is good enough to operate with radar signal and discover layers and buried objects (Ruffell, 2006).

Studied lagoon lakes are shallow with several sediment layers with slight differences between Engure and Pape Lakes (Table 2, 3). High content of mineral compounds (also clays) and minor differences among layers in Pape Lake (Table 1) causes problem to analyse and even see the GPR signal. Most of the signal dissipates in sediments and deeper layers cannot be seen (Fig. 5, 6). Problems of permittivity in that kind of material correspond to results in literature, where is suggested that GPR is not a viable choice for surveying in clay rich areas where 5 – 10% clay content can reduce penetration depth to less than 1m (Parker *et al*., 2010; Karušs *et al*., 2012).

In GPR profiles with horizontal lines, sub-surfaces of sediments detected with GPR and confirmed by coring (vertical line) simultaneously are marked. For example, in Engure Lake (Fig. 2, 3, 4) easily can be

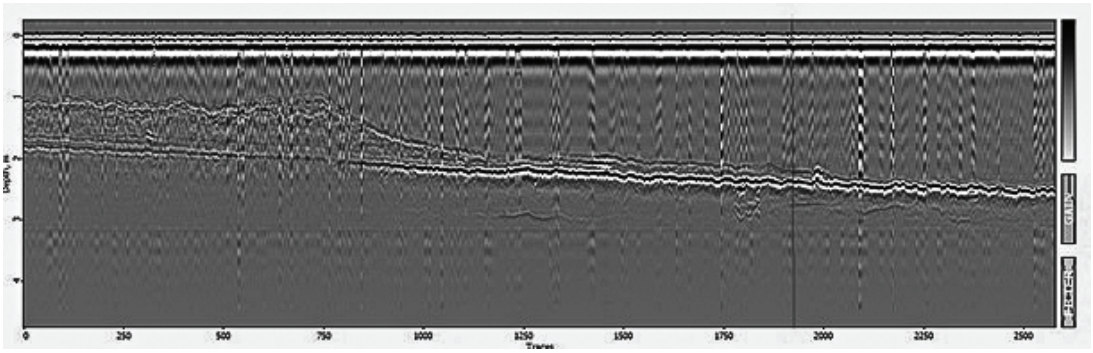

Figure 4. Scanned transect with GPR in Engure Lake (No.3).

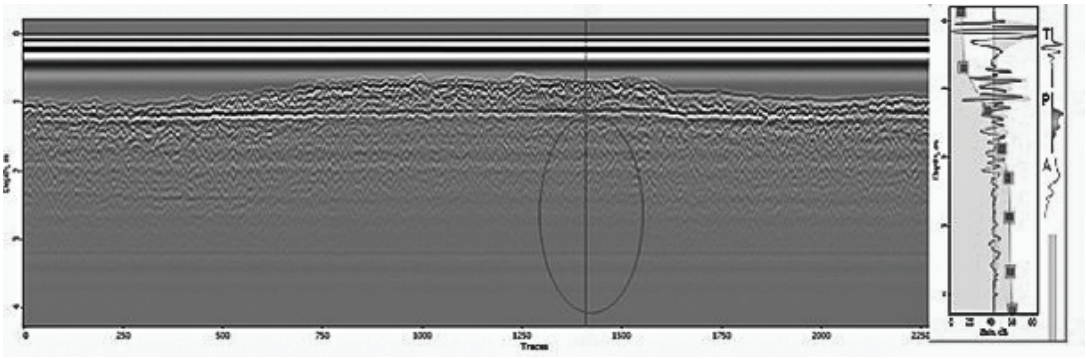

Figure 5. Scanned transect with GPR in Pape Lake (No.4).

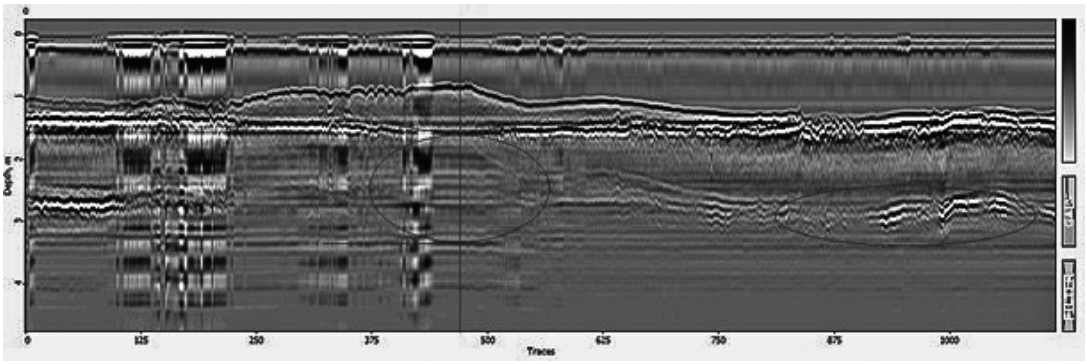

Figure 6. Scanned transect with GPR in Pape Lake (No.5).

distinguished upper sedimentary layers, but problems appear with detection of deeper layers. One of key problems is too slight difference among sediments (high homogeneity) of metal content as well as relatively uniform sediment composition. Sandy bottom clearly can be identified only in GPR profile 3 (Fig. 4) in Engure Lake where noticeable differences between sub-surface and upper (Holocene) sediments are detected. Other factor are differences of EM wave propagation among sediment layers, respectively, propagation speed in peat is significantly faster than in gyttja (sapropel) with high clay content above the peat layer. In the theory of EM wave propagation it is known that if bottom layer dielectric permeability is greater than the divisional layer complex dielectric permeability of the environment, the reflected GPR signal will have the opposite phase of the emitted signal (Reynolds, 1997). Due to differences of sediment permittivity ε in comparison to water, there can be slight offset of total depth of deeper sediment layers which can be corrected with adjusted ε or by linking with coring data.

In studied GPR profiles, there are different kinds of disturbances and reflections. For example, noise level and several disturbances can originate from air bubbles in water (boat engine, waves) (Fig. 2, 3, 6). In edges of GPR profile 5 (ellipse in right side) (Fig. 6), there is a strong reflection from upper layers bothering analysis of bottom layers. On the one hand, it is possible to partly identify the bottom layer with sand, but on the other hand, the middle part of sediments (homogenous sapropel layers with high content of reed roots) cannot be analysed even with inequalities of raw data straight form radar. There are differences in GPR profile 4 (Fig. 5.), where slight transition (high homogeneity) of sediments allow us to identify only the upper layer of sediments (marked with lines), but the gain profile (right side of Fig. 5) shows small differences of EM wave reflection in deeper layers (with ellipse marked deeper layers), regarding to composition of sandy sapropel (3.25-3.5 m).

Conclusions

The screening studies in Engure and Pape Lakes have shown that despite technical difficulties of GPR use in field environment on water bodies and complicated procedures of EM noise reduction, the research work can be performed in optimized mode if coupled with coring and laboratory analyses. Crucial aspects in gaining success are careful preliminary study of available geological and paleogeographical information, experience of the personnel in field work, good establishment of GPR profiles and coring points, careful interpretation of gained data as well as appropriate preparation of set of recommendations for further works if more detailed study is needed. Hereby GPR profiles have shown main topography features, approximate boundaries between various stratigraphic and lithological complexes and helped significantly reduce the number of coring points in study and simultaneously keep the quality of dataset.

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References

1. Anselmetti, F., Fuchs, M., & Beres, M. (2004). Sedimentological Studies of Western Swiss Lakes with High Resolution Reflection Seismic and Amphibious. GPR Profiling, *10th international conference on ground penetrating radar*, 21st – 24th June, Delft, The Netherlands. DOI: 10.1109/ICGPR.2004.179809.
2. Asprion, U., & Aigner, T. (1999). Towards realistic aquifer models: three-dimensional georadar surveys of Quaternary gravel deltas (Singen Basin, SW Germany). *Sedimentary Geology.* 129, 281-297. DOI: 10.1016/S0037-0738(99)00068-8.

3. Bano, M., Marquis, G., Niviere, B., Maurin, J.C., & Cushing, M. (2000). Investigating alluvial and tectonic features with ground-penetrating radar and analyzing diffractions patterns. *Journal of Applied Geophysics.* 43, 33-41. DOI: 10.1016/S0926-9851(99)00031-2.
4. Barone, P.M., Matei, E., & Pettinelli, E. (2013). Non-invasive archaeological exploration in stratigraphically complex rural settings: an example from Ferrento (Viterbo, Italy). *Archaeological and Anthropological Sciences.* 5, 267-273. DOI: 10.1007/s12520-013-0138-3
5. Beres, M., Fuchs, M., Girardclos, S., Corboud, P., & Sastre, V. (2006). Using High-Resolution Seismic and GPR Methods in Sedimentological Studies of the Geneva Bay Area (Switzerland). *Near Surface 2006 – Helsinki, Finland*, pp. 1-6.
6. Bērziņš, D., & Karušs, J. (2014). Mapping shallow groundwater surface in terrigenous sediments using ground penetrating radar. *In*. Zelčs, V., Nartišs, M. (eds.), *Excursion guide and abstracts of the INQUA Peribaltic Working Group Meeting and field excursion in Eastern and Central Latvia, August 17-22, 2014*, Eastern and central Latvia. University of Latvia, Riga, pp. 97-98.
7. Blumberg, D.G., Neta, T., Margalit, N., Lazar, M., & Freilikher, V. (2004). Mapping exposed and buried drainage systems using remote sensing in the Neged Desert, Israel. *Geomorphology.* 61, 239-250. DOI: 10.1016/j.geomorph.2003.12.008.
8. Boll, J., van Rijn, R.P.G., Weiler, K.W., Ewen, J.A., Daliparthy, J., & Herbert, S.J. (1996). Using ground penetrating radar to detect layers in a sandy field soil. *Geoderma.* 70, 117-132. DOI: 10.1016/0016-7061(95)00077-1.
9. Bristow, C.S., & Jol, H.M. (2003). *Ground Penetrating Radar in Sediments*. The Geological Society, London.
10. Comas, X., Slater, L., & Reeve, A. (2004). Geophysical evidence for peat basin morphology and stratigraphic controls on vegetation observed in a Northern Peatland. *Journal of Hydrology.* 295, 173-184. DOI: 10.1016/j.jhydrol.2004.03.008.
11. Daniels, D.J. (2004). *Ground Penetrating Radar*, vol. 1. 2nd ed. The Institution of Engineering and Technology, London.
12. Davis, J.L., & Annan, A.P. (1989). Ground-penetrating radar for high-resolution mapping of soil and rock stratigraphy. *Geophys Prospect.* 37, 531-551. DOI: 10.1111/j.1365-2478.1989.tb02221.x.
13. Eberhards, G., & Saltupe, B. (2000). Geological history, relief, and deposits of Lake Engure area along the Baltic Sea.*Proc. Latvian Acad. Sci., Sect. B,* 54(5), 141-147.
14. Heiri, O., Lotter, A.F., & Lemcke, G. (2001). Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. *Journal of Paleolimnology*. 25, 101-110. DOI: 10.1023/A:1008119611481.
15. Hickin, A.S., Kerr, B., Barchyn, T.E., & Paulen, R.C. (2009). Ground penetrating radar and capacitively coupled resistivity to investigate fluvial architecture and grain-size distribution of a gravel floodplain in Northeast British Columbia, Canada. *Journal of Sedimentary Research*. 79, 457-477.
16. Jol, H. (2009). *Ground Penetrating Radar Theory and Applications*. 1st ed. Elsevier Science, Amsterdam.
17. Jol, H.M., & Smith, D.G. (1995). Ground penetrating radar surveys of peatlands for oilfield pipelines in Canada. *Journal of Applied Geophysics.* 34, 109-123. DOI: 10.1016/0926-9851(95)00018-6.
18. Karušs, J., Segliņš, V., & Pipira, D. (2012). Mālainās gruntīs iegūto radiolokācijas signālu analīze. (Analysis of GPR signals in clayey soils). *Material Science and Applied Chemistry.* 21-27. (in Latvian).
19. Karušs, J. (2015). *Ģeoradara izmantošana purvu nogulumu pētījumos*. (*Use of GPR in peat research*). LU Akadēmiskais apgāds, Rīga, 136. lpp. (in Latvian).
20. Koh, G. (2012). Effects of soil texture and moisture on dielectric behavior at GPR frequencies. In: *Proceedings of the 14th International Conference on Ground Penetrating Radar*, June 4 – 8, 2012 Shanghai, China, (eds L. Liu, M. Sato, X. Xie, F. Kong, & Y. Zhao) Volume I, pp. 51-55.
21. Leclerc, R.F., & Hickin, E.J. (1997). The internal structure of scrolled floodplain deposits based on ground penetrating radar, North Thompson River, British Columbia. *Geomorphology.* 21, 17-38. DOI: 10.1016/S0169-555X(97)00037-8
22. Lunt, I.A., Hubbard, S.S., & Rubin, Y. (2005). Soil moisture content estimation using ground-penetrating radar reflection data. *Journal of Hydrology.* 307, 254-269. DOI: 10.1016/j.jhydrol.2004.10.014.
23. Neal, A., & Roberts, C.L. (2000). Applications of ground-penetrating radar (GPR) to sedimentological, geomorphological and geoarchaeological studies in coastal environments. In: Pye, K., Allen, J.R.L. (Eds.), Coastal and Estuarine Environments: Sedimentology, Geomorphology and Geoarchaeology. Geol. Soc. Lond. Spec. Publ. 139-171. DOI: 10.1144/GSL.SP.2000.175.01.12.

24. Neal, A. (2004). Ground-penetrating radar and its use in sedimentology: principles, problems and progress. *Earth-Science Reviews 66*, 261-330. DOI: 10.1016/j.earscirev.2004.01.004.
25. Prieditis, A. (2002). Impact of Wild Horses Herd on Vegetation at Lake Pape, Latvia. Acta Zoologica Lituanica. 12(4), 392-396. DOI: 10.1080/13921657.2002.10512529.
26. Reynolds, M.J. (1997). *An Introduction to Applied and Environmental Geophysics*. West Sussex, John Wiley & Sons. pp. 682-745.
27. Sadura, S., Martini, I.P., Endres, A.L., & Wolf, K. (2006). Morphology and GPR stratigraphy of an end moraine of the Laurentide Ice Sheet: Paris Moraine near Guelph, ON, Canada. *Geomorphology.* 75, 212-225. DOI: 10.1016/j.geomorph.2005.01.014.
28. Sass, O., Friedmann, A., Haselwanter, G., & Wetzel, K.F. (2010). Investigating thickness and internal structure of alpine mires using conventional and geophysical techniques. *Catena.* 80, 195-203. DOI: 10.1016/j.catena.2009.11.006.
29. Słowik, M. (2011). Changes of river bed pattern and traces of anthropogenic intervention: The example of using GPR method (the Obra River, western Poland). *Applied Geography.* 31, 784-799. DOI: 10.1016/j.apgeog.2010.08.004.
30. Słowik, M. (2012). Influence of measurement conditions on depth range and resolution of GPR images: The example of lowland valley alluvial fill (the Obra River, Poland). *Journal of Applied Geophysics.* 85, 1-14. DOI: 10.1016/j.jappgeo.2012.06.007.
31. Słowik, M. (2014). Analysis of fluvial, lacustrine and anthropogenic landforms by means of ground-penetrating radar (GPR): field experiment. *Near Surface Geophysics*, 12, 777-791. DOI: 10.3997/1873-0604.2014033. DOI: 10.3997/1873-0604.2014033.
32. Steelman, C.M., & Endres, A.L. (2010). An examination of direct ground wave soil moisture monitoring over an annual cycle of soil conditions. *Water Resources Research.* 46(11) 533-540. DOI: 10.1029/2009WR008815.
33. Tatum, D., & Francke, J. (2012). Radar suitability in aeolian sand dunes – a global review. In: *Proceedings of the 14th International Conference on Ground Penetrating Radar*, June 4 – 8, 2012 Shanghai, China, (eds L. Liu, M. Sato, X. Xie, F. Kong, & Y. Zhao), Volume III, 701-706. DOI: 10.1109/ICGPR.2012.6254951.
34. Tran, A.P., Wiaux, F., & Lambot, S. (2012). Soil moisture estimation using full-wave inversion of near- and far-field ground-penetrating radar data: A comparative evaluation. In: *Proceedings of the 14th International Conference on Ground Penetrating Radar*, June 4 – 8, 2012 Shanghai, China, (eds L. Liu, M. Sato, X. Xie, F. Kong and Y. Zhao), Volume I, pp. 300-304. DOI: 10.1109/ICGPR.2012.6254877.
35. Van Dam, R.L., & Schlager, W. (2000). Identifying causes of groundpenetrating radar reflections using time domain reflectometry and sedimentological analyses. *Sedimentology.* 47, 435-449. DOI: 10.1046/j.1365-3091.2000.00304.x.
36. Van Dam, R.L. (2012). Landform characterization using geophysics – Recent advances, applications and emerging tools. *Geomorphology*. 137, 57-73. DOI: 10.1016/j.geomorph.2010.09.005.
37. Van Heteren, S., Fitzgerald, D.M., McKinlay, P.A., & Buynevich, P.V. (1998). Radar facies of paraglacial barrier systems: coastal New England, USA. *Sedimentology.* 45, 181-200. DOI: 10.1046/j.1365-3091.1998.00150.x.
38. Vandenberghe, J., & van Overmeeren, R.A. (1999). Ground penetrating radar images of selected fluvial deposits in the Netherlands. *Sedimentary Geology.* 128, 245-270. DOI: 10.1016/S0037-0738(99)00072-X.
39. Yilmaz, Ö., & Doherty, S. (2001). *Seismic Data Analysis*, vol. 2. 2nd ed. Society of Exploration Geophysicists, Tulsa.

THE ABANDONED BLOCK-CUT PEAT EXTRACTION FIELD INFLUENCE ON THE NATURAL RAISED BOG HYDROLOGICAL REGIME

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Abstract
Peat is still mined in many parts of the world for production of peat substrates and energy. Many peatlands were affected by drainage in the past also for forestry and agricultural needs. Nowadays a raised attention to peatlands is focused, especially to drained peatlands due to their carbon reserves and their potential influence to the climate on the one hand, but on the other hand - due to raising awareness on protection of environment, habitats and biotopes. There are many examples on restoration activities in peatlands found worldwide, especially their water regime is the subject of regulation, which plays the major role to bring back original functions. In most cases in Latvia as the aim for protection and restoration of degraded peatlands was protection of EU biotopes and habitats. Of course, peatlands play an important role in emissions of the greenhouse gases CO_2, CH_4 and N_2O, produced during mineralization of the drained peat organic matter. In literature, we can find only few cases where hydrological regimes are described for natural raised as well as restored block-cut peat extraction fields. This research analyses block-cut peat extraction field water level fluctuation influence on naturally raised bog hydrological regimes. Hourly data is analysed for six groundwater monitoring wells as well as for determination needs of water level fluctuations in excavated peat quarry as a response to precipitation.
Key words: Hydrological regime, block-cut peat, bog.

Introduction

The bog is a poorly drained usually acid area rich with accumulated plant material, with specific flora and fauna (Walker & Lowe, 1981; Nusbaums & Rieksts, 1997; Holden, 2009). The world's bogs cover around 3% of the total land area, but in Latvia even approximately 10% of the total land area is covered by bogs (Nusbaums & Rieksts, 1997). The bog formation is very important component of carbon, nitrogen, water and other substances in biogeochemical cycles (Brown, 2000). Latvian bog classification is mainly determined by the water regime and vegetation. Three groups of bogs are classified: a raised bog or high moor; transition mire, transitional fen or mixotrophic mire; fen or minerotrophic mire (Overbeck, 1975). In Latvia, raised bogs are mostly formed on watersheds of catchments in plains and lowlands (Brakšs, 1961). During accumulation of peat layer the central part of a bog rises above the surface (Edom, 2001). A raised bog is one of the most important terrestrial ecosystem, which acts as significant carbon accumulator, stabilizes water regime, reduces nutrient run off and plays significant role in climate regulation (Bragg, 2002). Although bogs make up only 3% of the land surface of the world, they contain 30% of soil carbon. Raised bogs hydrological regime is determined by precipitation, surface water and groundwater (Laitinen *et al*., 2007). Raised bogs are characterised by accumulation of precipitation in dome thus supplementing surface waters and groundwater in surrounding areas (Price, 1996; Edom, 2001; Bragg, 2002). Raised bogs are significant water accumulators. Bogs consist of 89-94% of water and only 6-11% of dry matter, which mostly consists of peat. Water is associated with peat-forming dry matter, and water flow in bog body is formatting only form free water (Romanov, 1968). Peat upper layers are characterized with relatively low decomposition level <20% and have good filtration properties; however, deeper layers - higher decomposition level and are densely compacted where water flow is rather low. Normally the water flow dominates in active layer around +0.4 till +0.9 m from bog surface level (Romanov, 1968; Маслов, 2008). The water flow at active layer of raised bog regarding characteristics is of dual nature: surface water and groundwater. This active layer also incorporates activity of surface water and groundwater runoff, which determines the water level in the raised bog. Raised bog hydrological regime and runoff fluctuate naturally. By increasing the size of a bog dome, a link with groundwater declines. However, more significant changes are caused by digging ditches in the raised bogs thus promoting the water outflow out of the dome. Ditches are splitting active layer, intercept therein water and drainage in bog domes are becoming more rapid. Within ditch influence zones there are significant increases of water level fluctuations.

- Normal groundwater regime in raised bogs is from +0.15 to +0.20 m;
- Disturbed groundwater regime amplitude in raised bogs may exceed ± 1 meter (Delina, 2011).

In study area more than fifty years after peat extraction drainage ditches in the edges of quarries are still functioning and are affecting the hydrological regime of the raised bog. As a result of more than fifty years drainage, the peat decomposition is elaborated; more active compaction takes place and invaded vegetation comes in raised bogs. Peat extraction has left significant amounts of degraded areas and territorially separated the Zalais bog and Caukciems bog domes. Peat pits sites are developed as two water reservoirs of Zalais bog (Purmalis, 2014). The water level in the peat layer of natural part of Zalais bog is only slightly below the bog surface and is characterized as normal raised bog water level regime. Two peat pit and ditch drainage systems with a run off to Slocene River and the Baltic Sea significantly influence bog hydrological regime (Purmalis, 2014).

In literature, we can find several studies of affected peatlands, but there is limited knowledge about former mining quarries effects to hydrological regimes in raised bogs. The aim of this research is to identify the distance of disturbed hydrological regime of raised bogs affected by block-cut peat extraction fields.

Materials and Methods

Zalais Bog

The research was performed in the Zalais bog near Kemeri National Park nature reserve, around 3.5 km east from Smarde village in Latvia. It covers an area of 1,586 ha, most of them (1,047 ha) are occupied with raised bog, transition mire takes 286 ha and minerotrophic mire - 253 hectares. Raised bog maximum peat layer thickness is 6 m, the average depth of the peat layer is approximately 3.3 m. In 100 ha of Zalais bog area from 1950 to 1960 the drainage and peat extraction works were performed. A peat extraction quarry was developed there, and the western part of the bog was drained. The drainage flow was redirected to Smirdgravis (Sera gravis), which discharges in the Slocene river. A block-cut peat extraction method with having two peat excavation pits and water pumping station was used. Peat was extracted in two pits with a length of 2.35 km and 1.20 km and a width of 120 m and 130 m respectively (Fig. 1). In 1960, peat extraction works at Zalais bog were interrupted and the area included into the Kemeri resort sanitary protection zone, because of hydrogen sulphide minerals formation process under Zalais bog peat layer. Currently, drainage ditches with the length of ~300 m each are functioning around water reservoirs. Although there are monitoring wells in edges of water reservoirs, hereby we analyze only hydrological regimes in the bog part without drainage ditches (direction of south-east).

Data collecting

In the territory, six chemically inactive perforated PVC monitoring wells with the length of 2 m and

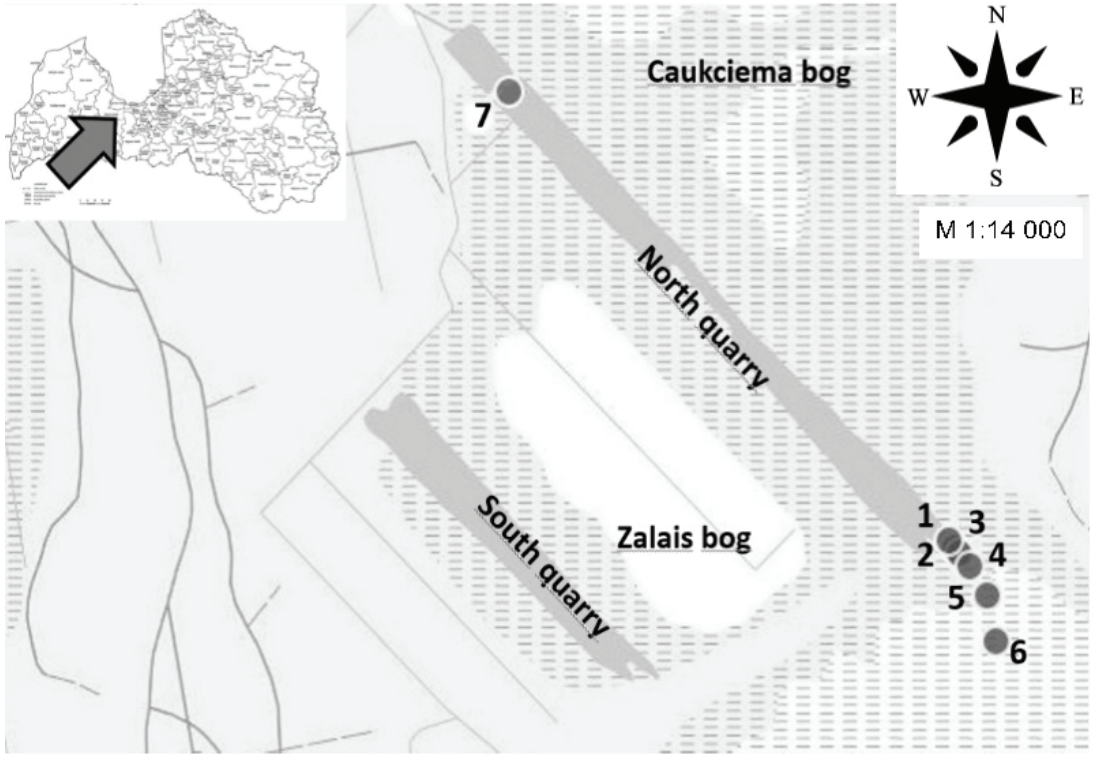

Figure 1. Location of Zalais Bog and water level monitoring points.

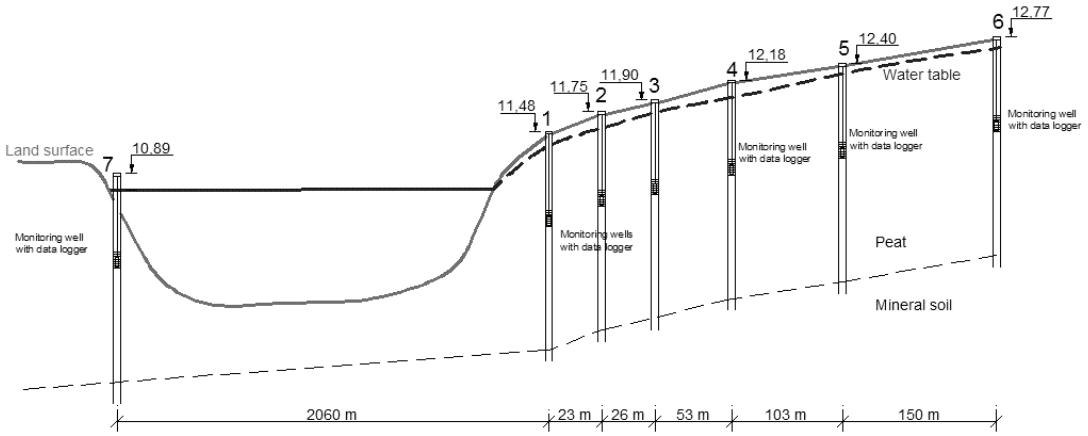

Figure 2. The scheme of monitoring wells and relative heights of water level peat quarry.

diameter of 50 mm were established. Additional points of study in peat quarry pond were established. Hydrological monitoring data were collected with the frequency of each 30 minutes by using Mini-Diver data loggers with barometric diver to compensate fluctuations of atmosphere pressure. Data treatment was performed by using Diver-pocket software.

Results and Discussion

Research field was affected by peat mining and establishment of drainage ditches. Drainage system during past 60 years was working extremely well and now around water reservoirs there are functioning drainage ditches with length ~300 m each. Final succession of vegetation (mostly birches, shrubs, marsh tea) is established that is not corresponding to typical raised bog vegetation. Moreover, upper peat layers are decomposed and compressed and natural renewal of raised bog in this scenario is not prospective. First of all, a forest has already formed there, the drainage system is still operating; however, hydrogen sulphide under the peat layer is forming. In this particular case, it causes large problems as during restoration we should prevent infiltration of oxygenated groundwater. During block-peat excavation peat producers have excavated peat down

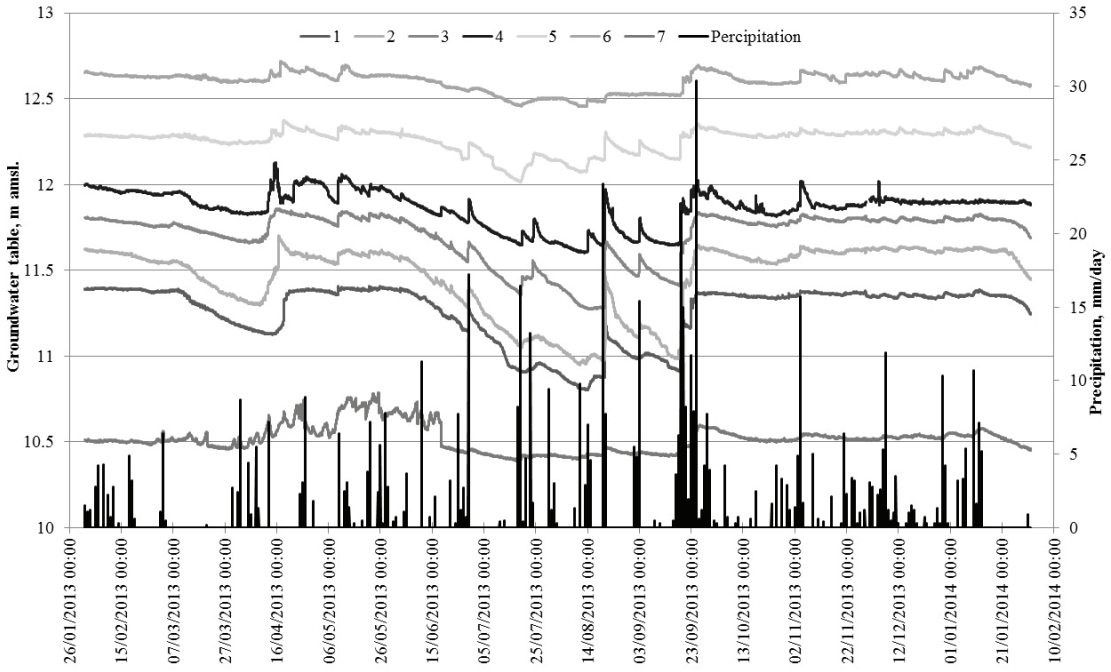

Figure 3. The groundwater fluctuation and precipitation daily rates.

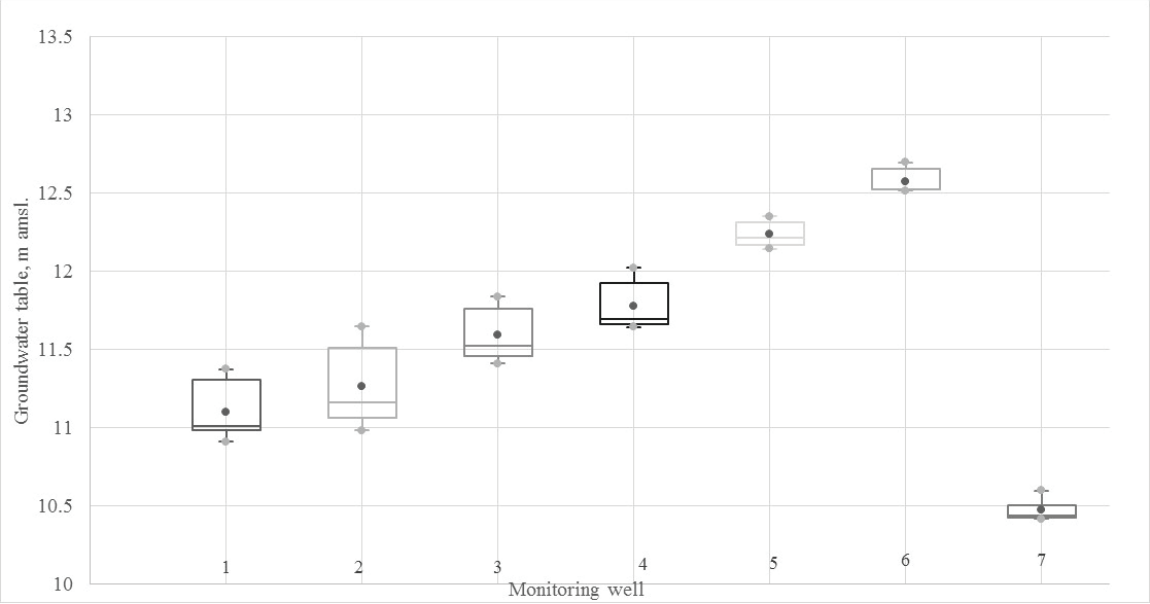

Figure 4. The yearly water level fluctuations in monitoring wells.

to the sandy bottom. In between this contact zone water conductivity increases up to 1618 µS cm^{-1} and pH level to 6.1 disturbing development of sphagnum mosses. Additionally affected territory by these drainage ditches has unknown effects to hydrological regime in relatively undisturbed part of bog (direction of south-east), where there are no drainage ditches, but major influence to undisturbed bog part could be form water reservoir, especially, taking into account differences of absolute altitude to bog surface and water reservoir (Fig. 2).

Groundwater level fluctuation dependence on rainfall over the trial period from 1 February 2013 to 31 January 2014 is shown in Fig. 3. It can be concluded that the groundwater level fluctuations are closely dependent on rainfalls and dominant evaporation from bog surface rather than run-off through active layer, because even affected water reservoir shows lower response to precipitation. Of course, in this case water reservoir water level fluctuations cannot be same as bog surface, as the water regime is completely different in bogs in comparison to water reservoirs. Monitoring well No. 6 represents results of natural hydrological regime for the bog with a fluctuation margin of ± 0.27 m.

To improve understanding of groundwater level fluctuations in the period of time, we analysed annual data with the boxplot diagram (Fig.4.). From the boxplot chart we can conclude that the quarry has affected hydrological regime with gradually decreasing effect in the next few wells (No. 1; 2; 3; 4) where a wider asymmetric statistical distribution of water levels is represented. The boxplot diagram clearly identifies the area with affected hydrological regime with directly detectable influence of the quarry to the fourth monitoring well (Fig. 2.).

Paired samples Mann-Whitney (Lehmann, 1975) (Table 1) was used to determine average differences among monitoring points with control point (well no.6) and their correlation to chosen control point

Table 1

Paired samples Mann-Whitney test results between pairs of monitoring wells in Zalais Bog

Pair	Mean difference	Std. Deviation	Std. Error Mean
Pair 1(Well 7 and Well 6)	2.09136*	0.04737	0.00204
Pair 2 (Well 1 and Well 6)	1.37566*	0.11459	0.00493
Pair 3 (Well 2 and Well 6)	1.12282*	0.13558	0.00583
Pair 4 (Well 3 and Well 6)	0.88925*	0.08236	0.00354
Pair 5 (Well 4 and Well 6)	0.73739*	0.05902	0.00305
Pair 6 (Well 5 and Well 6)	0.34342*	0.02270	0.00098

*-$p<0.05$

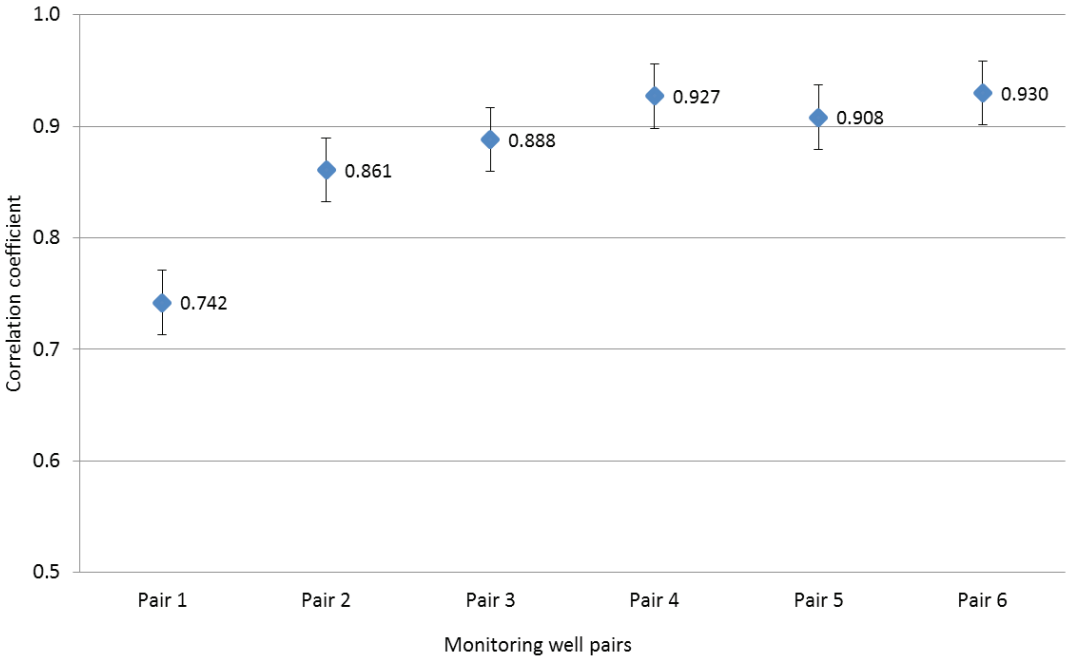

Figure 5. Paired samples correlations between pairs of monitoring wells in Zalais Bog.

(well no.6). Similarities in disturbances in hydrological regimes can be seen in boxplot diagram and paired samples Mann-Whitney as well as approved by correlations between pairs of monitoring wells (Fig. 5). Correlation between couples of wells shows that the control point (no. 6) located further away from the peat quarry has a weaker link with the other monitoring wells, showing relatively undisturbed conditions of water regime. Mean water level fluctuation in monitoring wells decreases with the distance from water reservoir, and statistically the mean value of variable per meter changes around 122 m from the water reservoir. It means that the peat quarry impact on hydrological regime of undisturbed bog falls from around 122 m distance in Zalais Bog case.

Conclusions

Lately there is an increasing number of restoration activities for bog ecosystems as well as increased knowledge gained on restoration activities and hydrological regimes in bogs, sensitivity of these systems. Quality of biotopes and hydrological regimes for whole bog catchment basins are influenced additionally to greenhouse gas emissions due to economic activities. Nevertheless, similarities in various bog ecosystems there can be identified also plethora of differences, e.g., in Zalais Bog. There are significant differences in groundwater levels, type of vegetation, peat density and decomposition degree in undisturbed bog dome and edges of water reservoir. Even further away from explored bog areas, also in an undisturbed bog we can detect influenced water regimes, which remain affected by gravity forces due to the elevation of bog surface in comparison to the water reservoir. The decreasing influence can be identified up to 122 m from water reservoir.

Acknowledgements

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References

1. Bragg, O.M. (2002). Hydrology of peat-forming wetlands in Scotland. The Science of the Total Environment 294; 111-129. DOI: 10.1016/S0048-9697(02)00059-1.
2. Brakšs, N. (1961). *Purvi un kūdra*. (Bogs and peat). Rīga: LPSR ZA izdevniecība, 90 lpp. (in Latvian).
3. Brown, P.A., Gill, S.A., & Allen, S.J. (2000). *Metal removal from wastewater using peat*. Water Research. 34, 3907-3916. DOI: 10.1016/S0043-1354(00)00152-4.
4. Dēliņa, A. (2011). *Hidroloģiskie apstākļi Aizkraukles, Aklajā, Rožu un Melnā ezera purvā*. (Hydrological conditions in Aizkraukle, Aklais, Rožu & Melnais Bog). LIFE+ projekts 'Augstie purvi'. (LIFE+ project 'Raised Bogs'). (in Latvian).

5. Edom, F. (2001). Hydrologische Eigenschaften. (Hydrological properties) In: Landschaftsoekologische Moorkunde. Eds. Succow, M., Joosten, H.). Stuttgart. (in German).
6. Holden, J. (2009). Flow through macropores of different size classes in blanket peat. *Journal of Hydrology*, 364 (3-4), 342-348. DOI: 10.1016/j.jhydrol.2008.11.010.
7. Holden, J., Wallage, Z.E., Lane, S.N., & McDonald, A.T. (2011). Water table dynamics in undisturbed, drained and restored blanket peat. Journal of Hydrology, 402(1-2), 103-114. DOI: 10.1016/j.jhydrol.2011.03.010.
8. Laitinen, J., Rehell, S., Huttunen, A., & Tuhvanainen, T. (2007). Mire systems in Finland – special view to aapa mires and their water – flow pattern. Suoi, 58 (1), 1-26.
9. Lehmann, E.L. (1975). Nonparametrics: Statistical Methods Based on Ranks, San Francisco. Holden-Day, Inc., 480.
10. Nusbaums, J., & Rieksts, I. (1997). Purvi. (Bogs). Latvijas daba. Latvijas Enciklopēdija, 4. Rīga, 195-199. (in Latvian).
11. Overbeck, F. (1975). *Botanisch – geologisch Moorkunde*. (Botanical-geological characterization of raised bogs) Neumūnster: KarlWacholtz Verlag, 719 s. (in German).
12. Price, S. (1996). Hydrology and microclimate of a partly restored cutover bog, Quebec. John Wiley & Sons, Ltd., Hydrological Processes Vol. 10, 1263-1272.
13. Price, J. (1997). Soil moisture, water tension, and water table relationships in a managed cutover bog. Journal of Hydrology, 202:1-4, 21-32. DOI: 10.1016/S0022-1694(97)00037-1.
14. Purmalis, O. (2014). Augstā purva biotopa atjaunošana Zaļā purva teritorijā. (Restoration of ombrothropic bog in Zalais Bog territory). LIFE+ projekts „Ķemeru nacionālā parka hidroloģiskā režīma atjaunošana". (LIFE+ project "Restoring the hydrological regime of Ķemeri National Park"). Vides risinājumu institūts. (in Latvian).
15. Romanov, V.V. (1968). Hydrophysics of bogs. Kaner N. (Traslator); Heimann (Editor), Israel program for scientific translations Ltd, Jerusalem; 299.
16. Šņore, A. (2004). Kūdra Latvijā. (Peat in Latvia). Rīga, Latvijas Kūdras ražotāju asociācija, 63. lpp. (in Latvian).
17. Walker, M.J.C., & Lowe, J.J. (1981). Postglacial environmental history of Rannoch Moor, Scotland III. early-and mid-Flandrian pollen stratigraphic data from sites on western Rannoch Moor and near Fort William. Journal of Biogeography, 8 (6), 475-491.
18. Маслов, Б.С. (2008). Гидрология торфяных болот. (Hydrology of peat bogs). Томск: Томский государственный университет, 2008. Т. Учебное пособие. (in Russian).

HARMFUL FACTORS IN THE WORKPLACES OF TRACTOR DRIVERS

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Abstract
Results of various studies show that the most prevailing risk factors on workers of agricultural sector are noise and vibration. These hazards are especially important in transportation and most field works. Results from previous studies show that vibro-acoustic environment in tractors operated in Lithuania usually cannot be attributed as acceptable, but technical solutions implemented by manufacturers had definitely positive influence on working conditions. Noise level reduced from 90 dB(A) (tractors of 1980 – 1990 years of manufacture) to 73 dB(A) (tractors manufactured from year 2000). As renewal of tractors is not sufficient, there is still a large number of old machinery i.e. noise levels might be as high as 92 dB(A) which allows to work safely only one hour per day without personal protection. It was found that values of whole body vibration (WBV) during ploughing operation might be as high as 1.5 $m \cdot s^{-2}$ which excess the vibration limit value of 1.15 $m \cdot s^{-2}$, while hand-arm vibration (HAV) did not exceed the vibration action value of 2.5 $m \cdot s^{-2}$. Significant effect of tyre pressure was noticed on vibration values measured on driver's seat. Vibration acceleration values may be reduced to safe 0.5 $m \cdot s^{-2}$ by selecting appropriate tyre pressure.
Key words: Tractor, noise, vibration, noise exposure, vibration exposure.

Introduction

Agriculture is attributed to one of the most risky economic activity sectors. Large number of occupational injuries and diseases are diagnosed to operators of tractors and combine harvesters in various countries. The most common risk factors in tractor cabs are noise, vibration and dust. According to the results obtained by Spirgys and Vilkevičius, 70% of work accidents occur because of incorrect operators' actions or inappropriate work organization. More than 70% of all occupational diseases are diagnosed to the operators of various mobile machinery, which are usually caused by high levels of noise and vibration (Spirgys *et al*., 2008). Research findings provided by Melemez & Tunay (2010) show that noise and vibration levels at tractor cabs are mostly influenced by a tractor type, exploitation duration and operating conditions. Technical solutions used for cab noise insulation and vibro-isolation as well as tyre pressure and soil conditions are also influencing factors. Construction of tractor cab depends mostly on technology, which means that modern machinery offers better working conditions (Melemez & Tunay, 2010). Futasuka provides the results of 10 tea plucking machines and their WBV effects on workers in Japan. 68.6% of these workers have complaints manifesting as stiff shoulders syndrome, while 31.4% are complaining about backache (Futasuka *et al*., 1998).

Research results provided by Strelkauskis, Merkevičius & Butkus (2012), reveal the fact that WBV might be 1.38 times higher for used machinery in comparison to modern tractors when driving on gravel road at speed of 7.5 $km \cdot h^{-1}$. Similar results were also presented in the study of Starkus & Butkus (2010) and Butkus & Vasiliauskas (2013), where they found that noise levels in cabs of old tractors might exceed the exposure action values. Their results also revealed that noise levels might be as high as 95 dB(A) in tractors, manufactured around 1980. Such machinery constitutes approx. 50% of tractors operated in Lithuania.

The EU Directive 2003/10/EC regulates the minimum health and safety requirements to workers arising from noise. Limit values and exposure action values in respect of the daily noise exposure levels ($L_{EX,\,8h}$) and peak sound pressures (p_{peak}) are fixed at:

a) peak sound pressure (p_{peak}): maximum value of the C-weighted instantaneous noise pressure;

b) daily noise exposure level ($L_{EX,8h}$) for a nominal eight-hour working day as defined by ISO 1999:2004;

c) weekly noise exposure level as a time-weighted average of the daily exposure levels for 5 working days.

The exposure limit values and exposure action values in respect of the daily noise exposure levels and peak sound pressure ($L_{C,peak}$) are fixed at:

- ***Exposure limit values***: $L_{EX,8h}$ = 87 dB(A), p_{peak} = 200 Pa, $L_{C,peak}$ = 140 dB(C);
- ***Upper exposure action values***: $L_{EX,8h}$ = 85 dB(A), p_{peak} = 140 Pa, $L_{C,peak}$ = 137 dB(C);
- ***Lower exposure action values***: $L_{EX,8h}$ = 80 dB(A), p_{peak} = 120 Pa, $L_{C,peak}$ =135 dB(C).

Vibration exposure values according to EU Directive 2002/44/EC (Directive 2002/44/EC, 2002) are as follows:

Hand arm vibration:

- ***Exposure limit value*** (ELV) calculated for 8 hours: $A(8) \leq 5\ m \cdot s^{-2}$;
- ***Exposure action value*** (EAV) $A(8) \leq 2.5\ m \cdot s^{-2}$.

Whole body vibration:

- **ELV:** 1.15 $m\ s^{-2}$ or vibration dose of 21 $m \cdot s^{-1.75}$;
- **EAV**: 0.5 $m\ s^{-2}$ or vibration dose of 9.1 $m \cdot s^{-1.75}$.

Aim of the work was to investigate noise and vibration levels in agricultural tractors and to

determine exposure levels and provide safe work recommendations.

Materials and Methods

Results obtained in this study were gathered by several stages. Tendencies of noise level were derived from 30 agricultural tractors, while vibration values were collected from 10 tractors. All tractors were manufactured over the time period 1980 – 2013. Detailed measurements of noise and vibration were carried out in five wheeled tractors (three of them were made over 2006 – 2012 period and two – 1988 – 1999) which were: Massey Ferguson 6480 (manufactured in 2008, 1900 moto hrs.), Claas Atles 926 RZ (2006, 2100 hrs.), Belarus 920.4 (2012, 860 hrs.), T–150K V8 (1988, 6860 hrs.) and New Holland 8870 (1999, 9200 hrs.).

Noise level measurements and exposure calculations were carried out according to the requirements of international standard ISO 9612. Noise level measurements in tractor cabs were done by using first class sound pressure level meter DELTA OHM HD-2010. Parameters, such as continuous equivalent A-weighted sound pressure level ($L_{A,eq}$), equivalent C-weighted sound pressure ($L_{C,eq}$) and peak C-weighted sound pressure level ($L_{C,peak}$) were measured. Measurements were carried out in the tractors' cabs when all doors and windows were closed. Position of the measurement microphone was at the driver's ear level approx. 100 mm from the ear. Tractor crankshaft rotation frequency was 1500 – 1800 min^{-1} and the driving speed was 7.5 $km \cdot h^{-1}$. Noise and vibration measurements were carried out on asphalt paving, while detailed analysis and noise exposure calculations were done from the measurement results which were carried out on gravel paving and ploughing operations. Duration of noise level measurements was at least 60 s and the measurements were repeated three times. Results of noise levels are presented as arithmetic average and standard deviation. Noise exposure was calculated as follows:

$$L_{EX.8h} = L_{Aeq.Te} + 10 \lg(T_e/T_0), \text{ dB(A)} \quad (1)$$

where: $L_{Aeq.Te}$ – equivalent A-weighted sound pressure level over exposure duration T_e;
T_0 – reference duration of 8 hrs.

According to the lower exposure value of 80 dB(A), duration of particular operation was calculated during the work shift.

Vibration measurements in tractor cabs were carried out according to the requirements of ISO 5349 and ISO 2631-1. Human vibration meter *Bruel & Kjaer* (B&K) type 4447 was used to perform the measurements.

Hand-arm vibration was measured on the steering wheel. Accelerometer B&K type 4524 was placed between the wheel and hand and fixed as required by ISO 5349. Weighted average acceleration values of x, y and z axis and total vibration acceleration value a_h were measured.

WBV measurements at driver's seat were performed by using the seat-pad with built in triaxial accelerometer B&K type 4524. Vibration acceleration a_w and vibration dose value for eight working hours were calculated VDV(8). Vibration exposure value $A(8)$ was calculated as follows:

$$A(8) = \sqrt{\frac{1}{T_0}\sum_{i=1}^{n} a_{wi}^2 T_{i,}} \quad (2)$$

where: a_{wi} – frequency weighted acceleration average (RMS) during *i–th* operation;
T_i – duration of *i–th* operation in seconds;
T_0 – work-shift duration in seconds (28 800s).

Calculations were also performed according to equation (2) in order to find the duration which should not be exceeded in order to have the $A(8)$ value lower than vibration action value of 0.5 $m \cdot s^{-2}$.

Whole body vibration measurements were also carried out under the same working conditions but different tyre pressures. Tractors New Holland 8870 and Belarus 920.4 were used for these measurements. Tyre pressures were reduced from 2.6 bar to 0.8 bar in steps of 0.3 bar (7 cases in total). Measurements were carried out on uneven gravel road and repeated three times. Parameter VDV(8) was used to assess the WBV and calculated as follows:

$$VDV(8) = \sqrt[4]{\frac{\sum a_{wi,eq,8h}^4 \; T_i}{8}} \text{ , m} \cdot \text{s}^{-1.75} \quad (3)$$

where: a_{wi} – frequency weighted acceleration average (RMS) during *i–th* operation;
T_i – duration of *i*–th operation in seconds;
T_0 – work-shift duration in seconds (28 800s).

Vibration dose was used as estimate of vibration as it is more sensitive to the peaks in the acceleration levels.

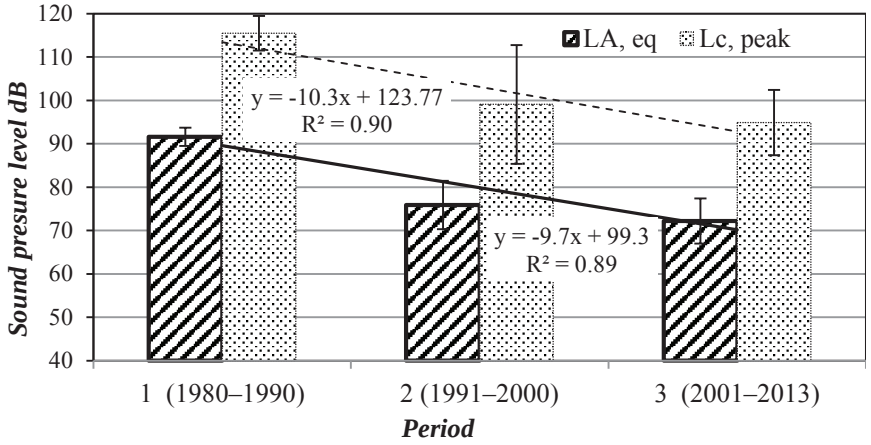

Figure 1. Tendencies of $L_{A,eq}$ and $L_{C,peak}$ sound pressure levels according to manufacturing year.

Results and Discussion

Equivalent A-weighted sound pressure ($L_{A,eq}$) and C-weighted peak ($L_{C,peak}$) levels of 30 tractors were divided into three categories by manufacturing year. Tendencies in noise levels are shown in Figure 1.

As shown in Figure 1, technical modernization and manufacturing quality had significant influence on noise levels which reduced from 92 dB(A) (manufacturing period of 1980 – 1990) to 73 dB(A) (manufacturing period of 1991 – 2000). These results were obtained by using the methodology,which complies with the requirements of EU Directive 2009/76/EC.

Measured noise levels $L_{A,eq}$ and $L_{C,peak}$ are presented in Figure 2 for ploughing and transportation (on gravel paving). Maximum A-weighted SPL registered in tractors was as high as 92.3 dB(A) in transport and 89.7 dB(A) when ploughing. This means that 8 hour exposure would exceed the exposure limit value of 87 dB(A). Lowest noise levels were found 74.2 dB(A) in transport operations and 71.5 dB(A) in ploughing. Considering the fact, that $L_{EX,8h}$ should not exceed 80 dB(A) it is recommended to shorten work duration or to use hearing protection. Exposure durations to reach the exposure of 80 dB(A) for five different tractors are presented in Table 1.

Average WBV and HAV acceleration values are shown in Figure 3.

Hand-arm vibration acceleration values changed from 0.81 $m \cdot s^{-2}$ to 2.28 $m \cdot s^{-2}$ and did not exceed the action value of 2.5 $m \cdot s^{-2}$. Maximum WBV acceleration value was 1.4 $m \cdot s^{-2}$, while it was slightly lower in other cabs. Special attention must be given to if the work duration is full work shift, i.e. 8 hours. This would exceed the vibration action value of 0.5 $m \cdot s^{-2}$ and in 2 tractors would exceed vibration limit value of 1.15 $m \cdot s^{-2}$ and in one tractor exposure level close to 1.15 $m \cdot s^{-2}$. Values of vibration exposure are presented in Table 1 and these results show that noise exposure action value of 80 dB(A) or vibration action value of 0.5 $m \cdot s^{-2}$ is reached over 1 or 2 hours of operation when used old tractors are exploited.

Noise exposure might be reduced to acceptable level by using personal protection, meanwhile reduction of vibration and its effects on operators is complicated. One of the most effective and practicable

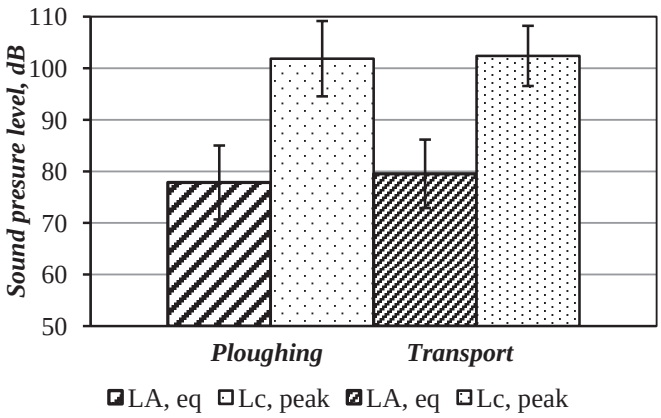

Figure 2. $L_{A,eq}$ and $L_{C,peak}$ noise levels in tractor cabs for ploughing and transportation.

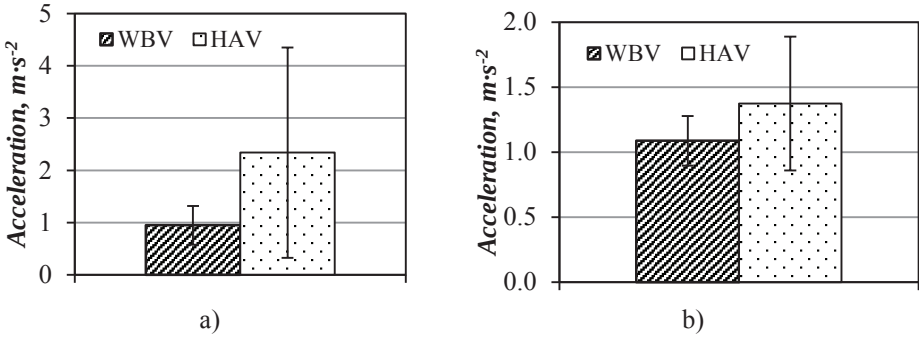

Figure 3. Average values of WBV and HAV in tractor cabs when driving on gravel road (a) and ploughing (b).

Table 1

Durations to reach exposure lower value of noise and action value of vibration ($L_{A,eq}$ / a_w) in ploughing

Tractor	1	2	3	4	5
$L_{A,eq}$ / a_w	74 / 1.12	72 / 0.96	72 / 1.25	90 / 0.99	83 / 1.48
t, H:MM	>8:00 / 1:30	>8:00 / 2:10	>8:00 / 1:18	0:48 / 2:00	4:00 / 0:55

solutions might be tyre pressure reduction. Vibration acceleration values and time history (passing the same distance and time of 40 s) of acceleration values at different tyre pressures (2.6 and 0.8 bar) are presented in Figure 5.

As seen in Figures 4 and 5, tyre pressure decrease has a significant effect on vibration values, which might decrease by 0.5 m·s^{-2} when comparing the case 1 (2.6 bar) and 7 (0.8 bar). Vibration dose VDV(8) analysis show similar results, as vibration dose reduced from 43.8 m·s$^{-1.75}$ to 25.1 m·s$^{-1.75}$ and from 28.5 m·s$^{-1.75}$ to 19.0 m·s$^{-1.75}$ respectively for different test objects.

Results presented in this study clearly show the necessity to perform risk assessment arising from noise and vibration in the workplaces of machine operators. Farmers should also consider either the use of personal protection or any organizational changes in order to reduce the negative effects of noise and vibration in agriculture.

Conclusions

1. Results of noise measurement in tractor cabs of different manufacturing year revealed that technical development of tractor cabs had a significant effect on noise level, which decreased

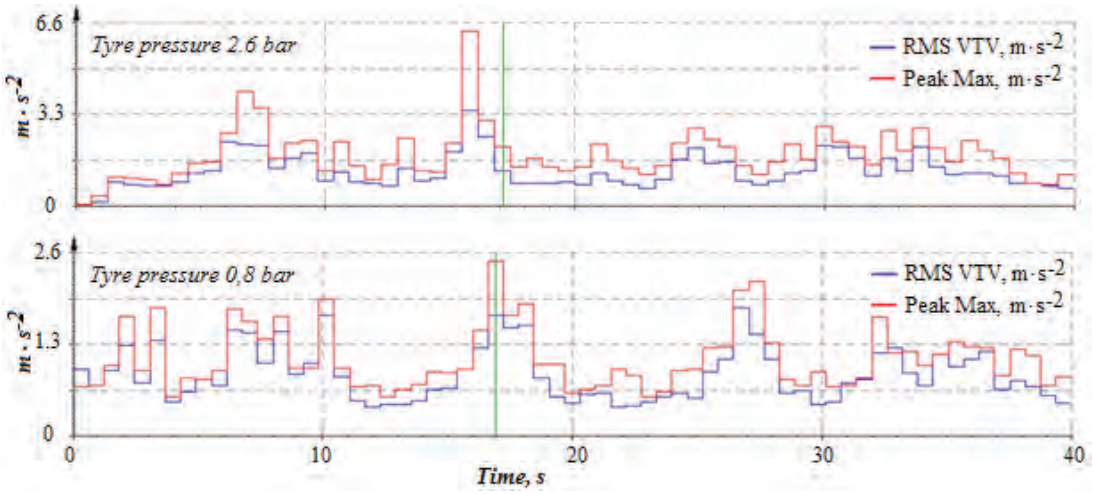

Figure 4. Time history of whole body vibration acceleration values at different tyre pressures (*peak Max* is the above curve in all cases).

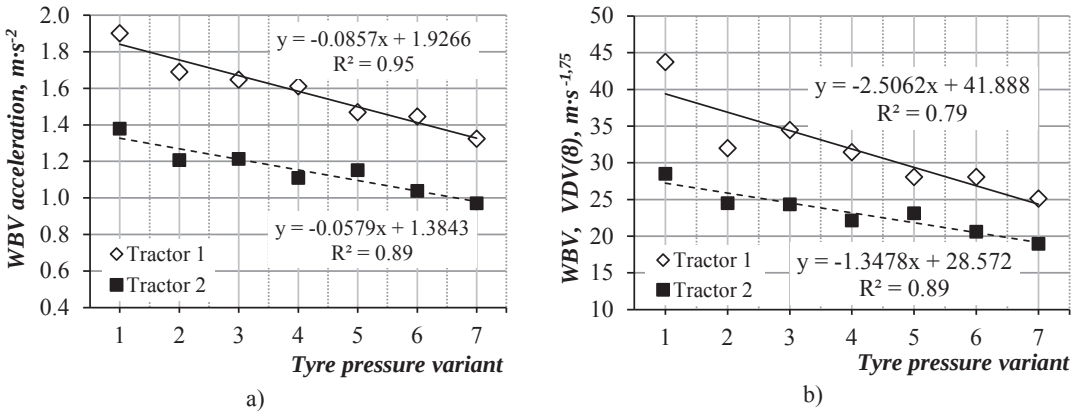

Figure 5. Dependence of *WBV* acceleration (a) and dose (b) to tyre pressure.

from 90 dB(A) (manufacturing year 1980 – 1990) to 73 dB(A) for newer machinery (the year 2000 and later).

2. Noise measurement results carried out in the cabs of tractors Massey Ferguson 6480, Claas Atles 926 RZ, T–150K, Belarus 920.4 and New Holland 8870 during ploughing and transportation operations show that noise levels were in the range from 71.5 dB(A) to 92.3 dB(A). Safe working conditions with exposure value of less than 80 dB(A) are satisfying when working duration is 30 min (when $L_{A,eq}$=92 dB(A)) and 4 hrs. (when $L_{A,eq}$=83 dB(A)).
3. Results of whole body vibration measurements during ploughing operations show that vibration acceleration values varied from 0.96 $m \cdot s^{-2}$ to 1.48 $m \cdot s^{-2}$, which means that action value of 0.5 $m \cdot s^{-2}$ was exceeded in all tractors when work shift duration is 8 hours. Exposure limit value of 1.15 $m \cdot s^{-2}$ was exceeded in two tractors. Hand-arm vibration action value was not exceeded in any case.
4. Tyre pressure decrease from 2.6 to 0.8 bar significantly influence whole body vibration, which was reduced on average by 0.5 $m \cdot s^{-2}$ while vibration dose value was reduced by one third.

References

1. Butkus, R., & Vasiliauskas, G. (2013). Research of vibro-acoustic environment in cabs of agricultural tractors: International conference Engineering for Rural Development, 23-24 May 2013 (pp. 20-26), Jelgava, Latvia.
2. Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 'On the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise)' (Seventeenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) // OJ, 2003, L 42/38.
3. Directive 2002/44/EC of the European Parliament and of the Council of 25 June 2002 'On the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration)' (sixteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) // OJ, 2002, L 177/13.
4. Futatsuka, M., Maeda, S., Inaoka, T., Nagano, M., Shono, M., & Miyakita, T. (1998). Whole – body vibration and health effects in the agricultural machinery drivers. *Industrial health.* Vol. 36, 127-132.
5. International Organization for Standardization. (2001). International standard: Mechanical vibration - Measurement and evaluation of human exposure to hand-transmitted vibration - Part 1: General requirements. ISO 5349-1:2001.
6. International Organization for Standardization. (2001). International standard: Mechanical vibration - Measurement and evaluation of human exposure to hand-transmitted vibration - Part 2: Practical guidance for measurement at the workplace. ISO 5349-2:2001.
7. International Organization for Standardization. (2001). International standard: Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration - Part 1: General requirements. ISO 2631-1:1997/Amd.1:2010.
8. International Organization for Standardization. (2009). International standard: Acoustics - Determination of occupational noise exposure - Engineering method. ISO 9612:2009.

9. Memelez, K., & Tunay, M. (2010). The investigation of the ergonomic aspects of the noise caused by agricultural tractors used in Turkish forestry. *African Journal of Agricultural Research*. Vol.5 (3), 243-249. DOI: 10.5897/AJAR09.436.
10. Spirgys, A., & Vilkevičius, G. (2014). Mobilios žemės ūkio technikos naudojimo saugos problemų analizė ir jų sprendimo būdai (Safety problems and their analysis and solutions in mobile agricultural machinery). Proceedings of International Scientific-Practical conference Human and Nature Safety, 7-9 May, 2014, Iss. 2, 91-104, Akademija, Lithuania (in Lithuanian).
11. Starkus, T., & Butkus, R. (2010). Traktorininkus veikianti vibroakustinė aplinka ir jos priklausomybė nuo technikos eksploatacijos trukmės (Tractor driver vibroacouctic environment and its dependence on tractor exploitation duration). Proceedings of International Scientific-Practical Conference Human and Nature Safety, 12-15 May, 2010, Iss. 1, 25-28, Akademija, Lithuania (in Lithuanian).
12. Strelkauskis, R., Merkevičius, S., & Butkus, R. Metodologiniai mobilių mašinų generuojamų vibracijų operatoriui keliamos rizikos nustatymo aspektai (Methodological Mobile Machines Generated Vibrations Caused by the Operator' Risk Evaluation Aspects). Proceedings of International Scientific-Practical Conference Human and Nature Safety, 11-13 May, Iss. 1, 39-41, Akademija, Lithuania (in Lithuanian).

WEATHER IMPACT ON THE HOUSEHOLD ELECTRIC ENERGY CONSUMPTION

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Abstract
The aim of the article is to ascertain the interaction between weather conditions and electric energy consumption in the Latvia household. The electric energy consumption data in the Saurieši village, Riga region, Latvia, for the year 2012 were collected, and the climate data for the same period including the duration of the sun-shine, ambient air temperature, precipitation intensity, and wind speed were obtained. The research hypothesis that there is strong relation between weather conditions and electric energy consumption was proved partially – there is rather strong correlation between household electric energy consumption and air temperature (r = 0.91), and medium correlation between household electric energy consumption and precipitation (r = 0.61), as well as between household electric energy consumption and duration of the sunshine (r = 0.67).
Correlation found between weather conditions and electric energy consumption in the household allows to forecast the trends in energy consumption based on weather measurements, and even to use the weather forecasts for electric energy future demand trends development. The equations developed explain the household energy consumption patterns in Latvia with its geographical location and economic conditions, but the methodology developed can be applied for any region if necessary data are available.
Key words: electric energy consumption, weather impact, ambient air temperature, duration of sunshine, precipitation, wind speed, seasonal changes.

Introduction

New electric energy supply line development is rather complicated task, because of several factors influencing the final decision. One of them is electric power consumption regularity – if power consumption fluctuates, the electricity supply line must be established at the maximum power level. The main question for power line designer is – when to acquire the energy consumption data which will be used for the calculations. The same problem arises for electric energy producer – it would be nice to have possibility to forecast electricity consumption beforehand. In order to ease the life for both electric net designers and electricity suppliers, it was decided to find out, how the weather conditions influence the power consumption. If there is a clear trend observed, then this relation can be used for power consumption forecasts.

Common sense tells us that electric appliances use is somehow – directly or indirectly, linked to external conditions, especially to the weather conditions outside of a human being living space. One can call electricity as the supplier of the comfort in the household, because almost all devices used in the kitchen, living room or bedroom (lighting appliances – lamps, communication devices – phones, computers with internet connection, entertainment devices – TV and radio sets, processing devices – mixers, microwave and convenient ovens, grinders and cookers, etc.) use electric power, and they increase comfort level. At the same time current living standards state that lack of these devices will be recognized as discomfort, and almost inappropriate conditions for living.

Geographic location on the globe sets specific conditions for weather – there are countries and states, where the average annual temperatures are well above 0 °C, at the same time large part of mankind is living in the conditions where there are four different seasons – dark winter, which is cold and snowy, spring with rising temperatures and high precipitation, sunny, dry and rather hot summer, and windy and wet autumn. These conditions lead to different patterns in electric appliances use in household, which could be revealed.

If trends in electric energy use have substantial correlation with weather conditions, this can help electric energy suppliers and producers to forecast consumption, and thus organize and manage production of electric energy, which at the end will lead to much more stability in energy supply.

Previous research (Jakusenoks & Laizans, 2015b) substantially raising the electric energy consumption in private sector. On other hand, serious technological developments like luminescent (fluorescent also revealed that the number and variety of electric appliances used in Latvia household have been increasing substantially within the last decade, which leads to serious changes in electricity supply grid operation quality and efficiency. Power factor is particularly affected by this trend, and any result which could support energy consumption forecasting would also lead to more efficient quality management in the electric grid.

Current power factor forecasting model developed (Jakusenoks & Laizans, 2015)and the research revealed that the power factor there has visually recognizable repeated daily (day/night allows to describe the dependence of power factor from the time period during the year only by 86 %. If substantial correlation with other factors besides date in the

calendar will be revealed, the power factor forecasting quality could also be improved.

Human behavior is being affected by seasonality - if it is cold and dark, people will rather stay home, and use lot of energy to provide heat and light (inside and outside lights – to reduce darkness depression). Rainy and windy conditions can also increase household energy consumption – because of drying and house heating needs. While staying at home people will more extensively use local entertainment devices (TV, radio, etc.,) and use kitchen appliances to prepare food and drinks. As the opposite – when days are sunny and hot, people tend to get out of their houses, and try to spend as much as possible time having rest near water.

Research shows that people feel comfortably when the room temperature is 19 – 22 ℃ (winter period) and 22 – 25 ℃ (summer period) – values established by bioenergetics processes in the human body and thermodynamic heat exchange between the human body and external environment (Dwyer, 2007). The temperature level, which is recognized by human body as neither cold nor hot, is 23 – 24 ℃, (‘Human Comfort and Health Requirements,’ n.d.).

Extensive use of electric ovens is one of the reasons for substantial increase in household electric energy consumption – data of Latvia Central Statistic Bureau for 2010 show that electric ovens and other food processing appliances (18.7% of all electric devices used at home) consumed 11.4% from total annual household electric energy (Latvia Central Statistical Bureau, n.d.-a), but 79.5% of electric energy were used to produce comfortable temperature at home – for heating and conditioning (‘Types of energy resource consumption (%),’ n.d.).

Materials and Methods

The research and data collection took place in Latvia – a country with wide set of weather conditions, which is growing its electric energy consumption in the household sector, but still is rather far from EU average annual electric energy consumption, because of economic conditions.

The research object chosen was the village Saurieši, which is located in Riga county, Latvia. This village is a private individual and multistore house area, inhabited by people working nearby and in Riga city. Economic conditions of the inhabitants are rather homogenous, with above-the-average income and medium class living conditions, which have also a particular set of household electric appliances.

Some of common features for this environment are the following:

- Set of electric appliances rather homogenous;
- There is a variety of house design used in Saurieši, and the insulation/heat losses level fluctuates from house to house substantially;
- No particular household behavior trends are recognized in Saurieši;
- Although this might be the fact that different people have different comfort settings, the average behavior trends do not differ from the behavior of people from other Latvia regions with similar economic conditions too much;
- Results revealed can be adapted to the energy consumption trends in other villages in the countryside of Latvia.

Electric energy consumption data for the village Saurieši were collected from the commercial electric energy measuring and counting device belonging to

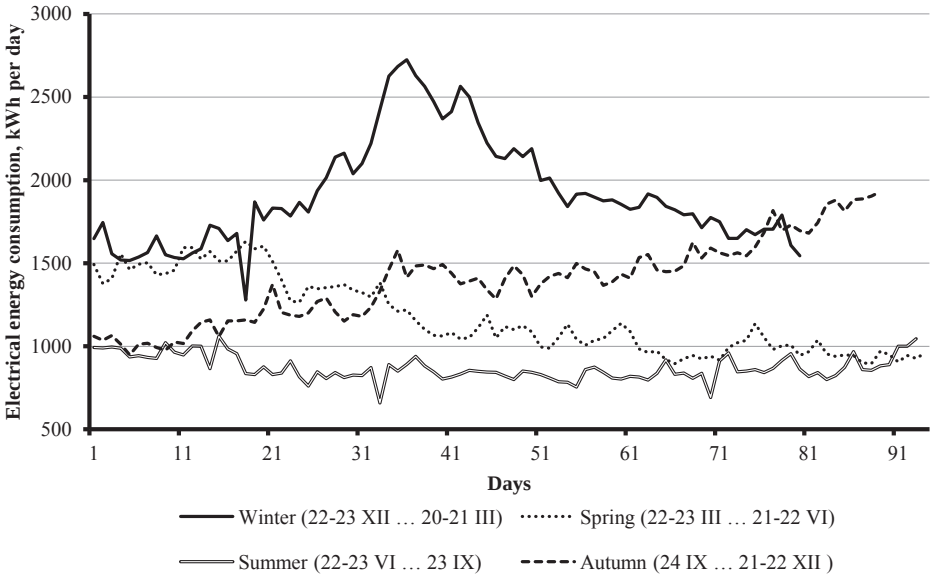

Figure 1. Electrical energy consumption in calendar seasons.

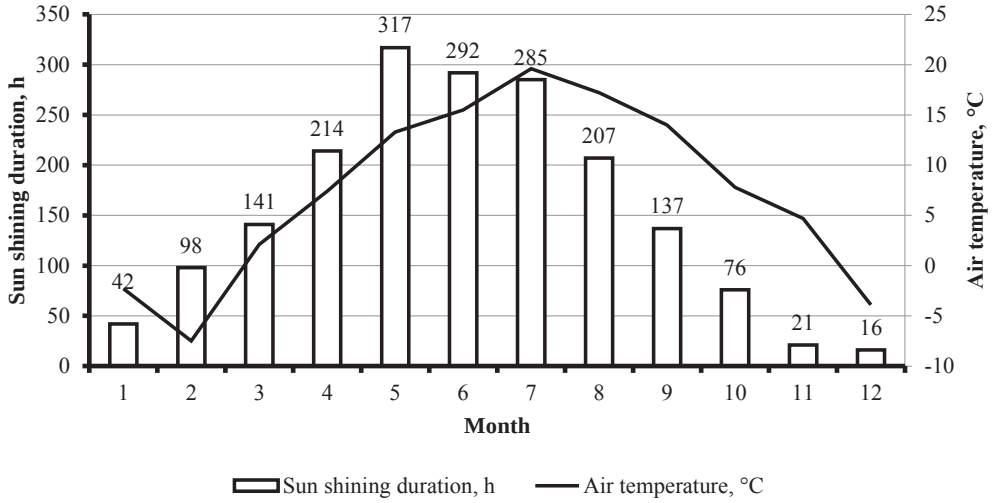

Figure 2. Sunshine duration and air temperature monthly data, 2012.

JSC 'Sadales tīkls' using the automatic electric energy counting system and particular data reading and collecting device. Electric energy consumption data with time step 10 minutes were obtained.

Weather data (monthly air temperature, precipitation, sun shining time, and air moisture content) for the year 2012 were used in this research, because the available weather conditions were available for this year (Latvia Central Statistical Bureau, n.d.-b).

Results and Discussion

Electric energy consumption data were divided in four parts based on annual seasonality ('Gadskartas (Anniversary),' n.d.) – spring, summer, fall and winter (Fig.1). Visual graphical data analysis revealed that there is a substantial difference in energy consumption between these time periods. Also, colder the season, more electric energy consumption took place in the village Saurieši.

Weather data obtained were presented graphically in order to make visual observation of trend and correlation presence between different weather conditions. Monthly based sun shining duration and air temperature is presented in Fig. 2, showing common trends of temperature and sunshine over the year.

Statistical analysis revealed rather strong positive correlation, which was calculated for these two variables - r = 0.76, which means that 76% of air temperature changes can be described by the sunshine duration at a particular month of the year (Table 1). As the Sun is the main energy supplier to the Earth in general, this positive correlation makes sense. Variations in this relation can be described by local temperature changes due to air mass movement from North and South.

Average (medium strong) negative correlation (r = -0.617) was revealed between air temperature and precipitation intensity. This can be described by the fact that snowfalls take place at temperatures below zero, and strong rains – in spring and fall, as well as in summer, so this could not be revealed by statistical analysis as a positive relation between temperature and precipitation.

Table 1

Weather data and electrical consumption data correlation

	Electrical energy consumption, kWh per month	Air temperature, °C	Precipitation, monthly sum, mm	Sun shining duration, monthly sum, h
Electrical energy consumption, kWh per month	1			
Air temperature, °C	-0.875	1		
Precipitation, monthly sum, mm	-0.617	0.609	1	
Sun shining duration, monthly sum, h	-0.670	0.755	0.210	1

Medium strong negative correlation (r = -0.57) was revealed between air temperature and relative air humidity – with increase in air temperature air humidity decreases (result not included in Table 1). This is usual condition in Latvia in summer, but this correlation does not describe the air humidity decrease in cold winter days, so this relation should be researched more deeply, and was not analyzed further in this article. The same was found for wind speed and electric energy consumption in the household.

The trend-line describing the relation between sunshine duration and ambient air temperature is presented in Fig. 3. This is linear regression – with the increase in sunshine duration ambient air temperature increases.

Monthly changes in electric energy consumption and air temperature (Latvijas vides, geologijas un meteorologijas centrs (Latvian Environment, n.d.) are presented in Fig.4. Visual analysis reveals negative correlation, and statistical data analysis proves this hypothesis - r = -0.875, showing a strong negative correlation.

Trend line and the equation describing electric energy change based on air temperature change is presented in Fig.5.

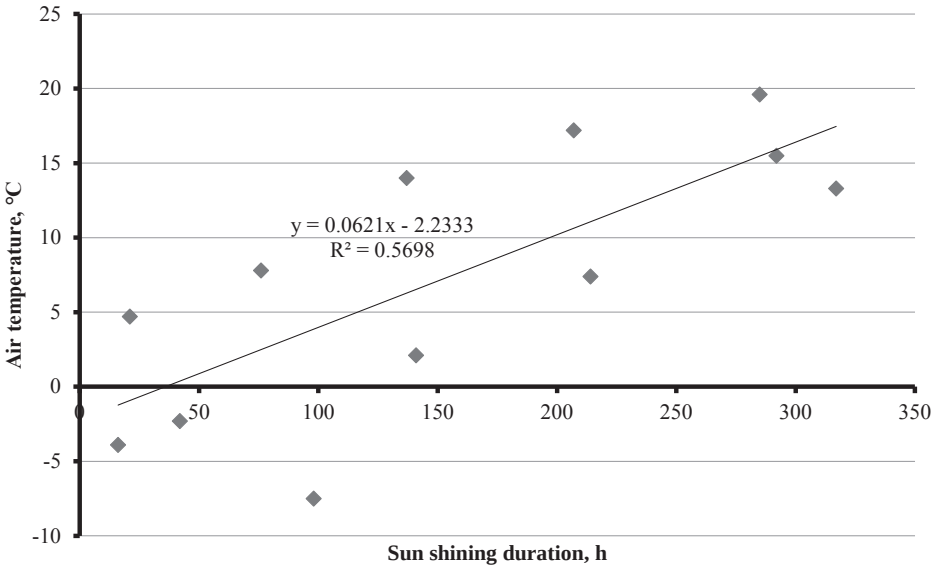

Figure 3. Sunshine duration and air temperature month data correlation.

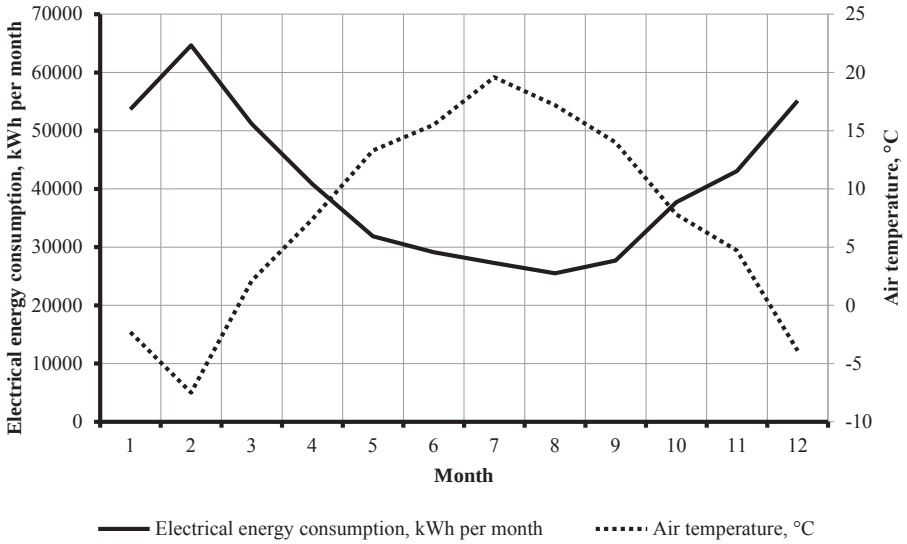

Figure 4. Ambient air temperature and electrical energy consumption monthly trends, 2012.

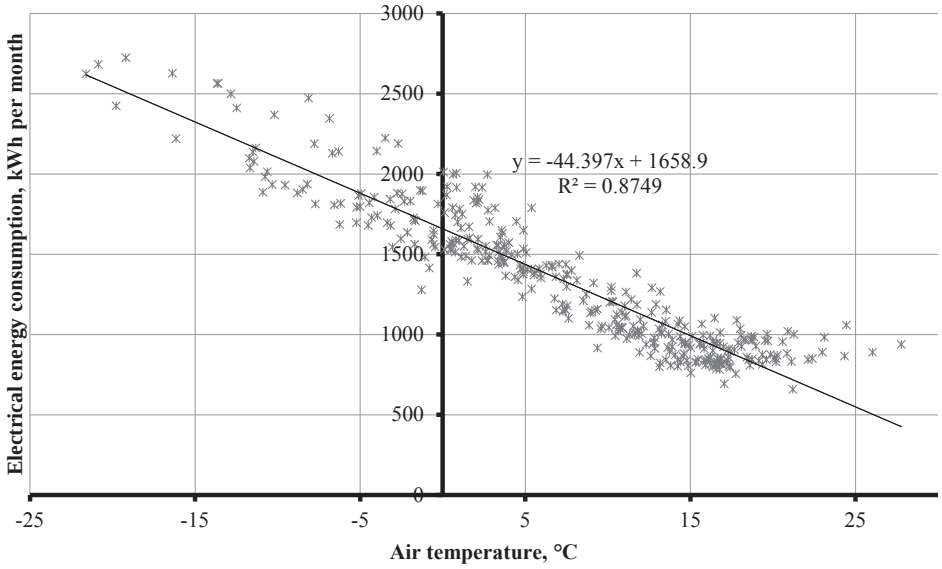

Figure 5. Electric energy consumption and average air temperature data correlation, 2012.

Monthly changes in electric energy consumption and monthly sunshine duration are presented in Fig. 6.

Visual analysis reveals negative correlation, and statistical data analysis proves this hypothesis - r = -0.670 – the correlation is medium to strong. As this variable has lower correlation with electric energy consumption, and both air temperature and sun shining duration are related, showing positive correlation, only the one – the strongest correlation showing variable, can be used for the model development. In this case ambient air temperature substantially better describes the electric energy consumption trends in household in Saurieši village.

As a result, mathematic model of village Saurieši electric energy consumption dependence on ambient air temperature can be described by the linear regression formula 1:

$$E = 1658.9 - 44.397 \cdot T, \qquad (1)$$

where E – energy consumption, kWh · month^{-1};
T – temperature, °C.

In order to use this model, the ambient air temperature forecast results can be used.

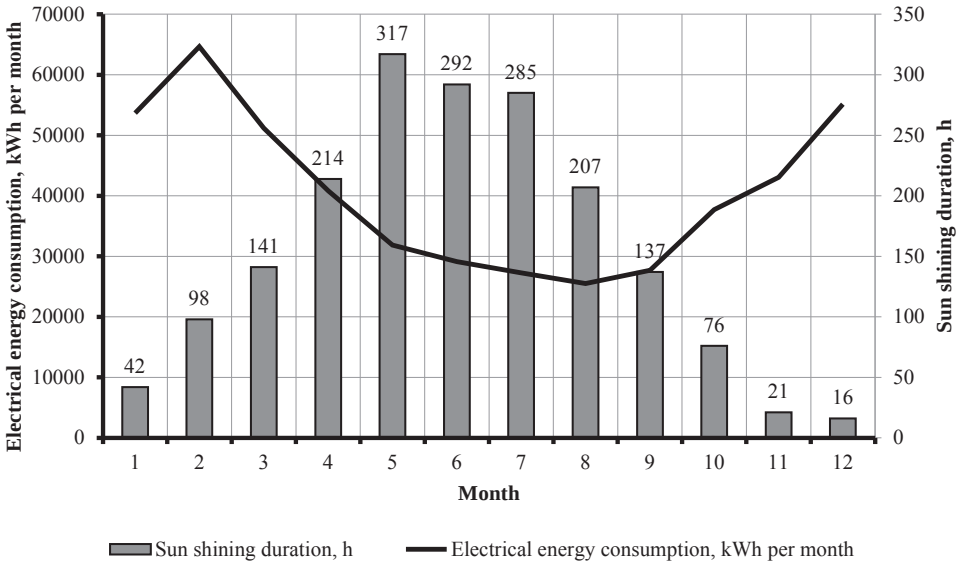

Figure 6. Sunshine duration and electrical energy consumption monthly data.

Conclusions

- Annual electric energy consumption data splitting by seasons showed significant difference in household electric energy consumption.
- Statistically significant evidence was revealed that the electric energy consumption in household is affected by weather conditions:
  - It is possible to forecast the electric energy consumption using ambient air temperature – the model explains 87.5% of variation;
  - Sunshine duration data can explain 67% of household electric energy consumption variations.
  - At the same time there is a strong correlation ($r = 0.755$) between sunshine duration and ambient air temperature, the model developed should include only one variable – the one with the strongest impact;
  - Precipitation intensity and wind speed have substantially smaller impact on electric energy consumption – more information is needed to include these weather conditions in the model.
- Electric energy consumption and weather data from more places and for longer time must be collected in order to improve model validity.

References

1. Dwyer, T. (2007). Thermal comfort. *Cpd Supplement 06.07*, 11-13.
2. Gadskartas (Anniversary). (n.d.). Retrieved February 17, 2016, from http://folklora.lv/skola/gadskartas.shtml.
3. Human Comfort and Health Requirements. (n.d.). Retrieved February 17, 2016, from http://courses.washington.edu/me333afe/Comfort_Health.pdf.
4. Jakusenoks, A., & Laizans, A. (2015a). Household electric power supply grid power factor trends. In *14th International Scientific Conference Engineering for rural development 2015* (p. 6). Jelgava.
5. Jakusenoks, A., & Laizans, A. (2015b). Impact of household electric energy usage trends on electrical power supply net power factor. In *Research for Rural Development 2015* (p. 6). Jelgava.
6. Latvia Central Statistical Bureau. (n.d.-a). Type of energy resources used for cooking (%). Retrieved February 17, 2016, from http://data.csb.gov.lv/pxweb/lv/vide/vide__energ_pat/0310.px/?rxid=cdcb978c-22b0-416a-aacc-aa650d3e2ce0.
7. Latvia Central Statistical Bureau. (n.d.-b). Weather in Latvia by selected cities and towns. Retrieved February 23, 2016, from http://data.csb.gov.lv/pxweb/lv/visp/visp__isterm__geogr/GZ010m.px/?rxid=cdcb978c-22b0-416a-aacc-aa650d3e2ce0.
8. Latvijas vides, geologijas un meteorologijas centrs (Latvian Environment, G. and M. C. (n.d.). LVGMC Meteorologija / Datu meklesana - Apraksts (LEGMC Meteorology Data search - Discription). Retrieved February 24, 2016, from http://www.meteo.lv/meteorologija-datu-meklesana/?nid=461.
9. Types of energy resource consumption (%). (n.d.). Retrieved February 17, 2016, from http://data.csb.gov.lv/pxweb/lv/vide/vide__energ_pat/0305.px/?rxid=cdcb978c-22b0-416a-aacc-aa650d3e2ce0.

CLASSIFICATION OF DIFFERENT FOREST TYPES WITH MACHINE LEARNING ALGORITHMS

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Abstract
In this study, forest type mapping data set taken from UCI (University of California, Irvine) machine learning repository database has been classified using different machine learning algorithms including Multilayer Perceptron, k-NN, J48, Naïve Bayes, Bayes Net and KStar. In this dataset, there are 27 spectral values showing the type of three different forests (Sugi, Hinoki, mixed broadleaf). As the performance measure criteria, the classification accuracy has been used to evaluate the classifier algorithms and then to select the best method. The best classification rates have been obtained 90.43% with MLP, and 89.1013% with k-NN classifier (for k=5). As can be seen from the obtained results, the machine learning algorithms including MLP and k-NN classifier have obtained very promising results in the classification of forest type with 27 spectral features.
Key words: Forest types, Multilayer perceptron, k-NN classifier, Data Mining.

Introduction

Today, as the number of measuring devices increases, so does the number and types of data. As a result of these advancements, it is required that so much information is stored in databases, and that this stored information is needed to be analyzed by intelligent and automated processes which convert the data into useful information and knowledge (Dener, Dörterler, & Orman, 2009). Consequently, data mining has become an important research area.

Data mining is a computational process that reveals patterns in data sets by using such methods like artificial intelligence, machine learning, statistics etc (Chen, Han, & Yu, 1996). The methods used in data mining are investigated in two groups as predictive and descriptive. In predictive methods, a model is created by using a dataset whose results are known. For example in a bank, the properties of customers who pay their credits back can be revealed, and a model can be created by using previous data sets about funding of them. Afterwards this model can be used on new customers for determining the possibility of paying their credits back. In descriptive methods, a relationship can be searched between two data sets. For example, the shopping haAabits of two different cultures may be investigated for similarity (Özekes, 2003).

Data mining methods can be divided into three groups due to their function.

- Classification and Regression
- Clustering
- Association Rules

In this study data mining methods are used to classify the data set. In classification, training examples are used to learn a model that can classify the data samples into known classes. The classification process involves following these steps: creating a training data set, identifying class attributes and classes, identifying useful attributes for classification, relevance analysis, learning a model using training examples in the training set and using the model to classify the unknown data (Sharma & Jain, 2013). The causes of selecting of machine learning algorithms in data mining are that we can identify the tree types automatically based on the spectral features of trees and we can get very high identification success by means of machine learning algorithms.

There are many studies in the literature in which data mining classification algorithms are used. The main areas are medical, food and agriculture. Jamuna *et al*. (2010) used different classification algorithms and compared these methods in order to ascertain the productivity of cotton seed in the oncoming stages of development. Although Decision Tree Classifier and Multilayer Perceptron Methods produce results at the same level of accuracy, it was observed that the Decision Tree Classifier method produces results in a much shorter time. Sabanci and Aydin (2014) used image processing techniques to detect and spray weeds on rows in sugar beet fields. The images captured with the CCD camera on the spraying robot were processed using image processing algorithms in Matlab software. Weeds in the row were detected by using Multilayer Perceptron Algorithm with the data which are obtained from the images and spraying liquid was applied on them. Kiani *et al*. (2010) pointed out at the fact that the use of chemicals for weed control in wheat fields caused environmental pollution. Due to this pollution, they stated that alternative methods such as image processing could be used for detecting weeds. Accordingly, Multilayer Perceptron Algorithm was used in the study in order to classify and analyze the

properties of energy, entropy, contrast, homogeneity and inertia. Babalik *et al*. (2010) used artificial neural networks and image processing techniques to determine the vitreousness of hard wheat, they used artificial neural networks to classify the vitreous and non-vitreous kinds of Type-1252 wheat. In this study, the classification success rates of self-regulated mapping (SRM) and multilayer perceptron (MP) were examined. Sabanci *et al*. (2012) classified potatoes in terms of their size with the help of image processing techniques and artificial neural network. Before the classification process, potatoes with surface defects and deformities were detected using Otsu method and morphological processes, and they were excluded from the classification. Then potatoes were classified based on their sizes. For this process, the images of small, medium and big sized potatoes were captured and the system was trained using multilayer artificial neural networks. Using image processing techniques and artificial neural networks, the classification success rates of potatoes were analyzed. Karthikeyan *et al*. (2015) obtained the dataset values (from the UCI database) of hepatitis disease that occurs on the liver and applied J48, Naïve Bayes, Multilayer Perceptron, random forest classification algorithms using these datasets. As a result of the study, the highest percentage rate in the classification of hepatitis patients based on sick cells was obtained using the Naïve Bayes algorithm. Polat and Gunes (2009) offered a genuine hybrid classification system that is based on the C4.5 decision tree classifier and a one-against-all approach to classify the multi-class problems including image segmentation, dermatology and lymphography datasets obtained from the UCI MRL database. Sabanci *et al*. (2015) used the EEG eye state dataset obtained from the UCI machine learning repository database. 14 continuous EEG measurements constitute the basics of the dataset. The duration of the measurement was 117 seconds (each measurement had 14980 samples). They used Multilayer Perceptron Neural Network Models and k-Nearest Neighbor Algorithm to calculate the classification success rate. The classification success rates were measured for varying number of neurons in the hidden layer of the Multilayer Perceptron Neural Networks model. The highest classification success rate was achieved when the number of neurons in the hidden layer was 7. And the success rate was 56.45%. The classification success rates were measured using k-Nearest neighbor algorithm for varying neighborhood values. The highest classification success rate was achieved using kNN algorithm. In k-Nearest neighbor model, the success rate regarding 3 nearest neighbors was measured as 84.05%. Yu *et al*. (2015) classified the forest trees in Zijin Mountains National Forest Park in Nanjing, China. The data is of the year 2011. Three types of band combinations were compared based on the accuracy of the classification. Using the obtained optimal band combination, decision tree classifier, neural networks and support vector machine classification methods were compared. The best result was obtained using 8-bant combination for decision tree classification, and the success rate was 87.10%. It was determined that artificial neural networks produced the worst results with the success rate of 73.85%. Aguiar *et al*. (2010) identified forages in the state of Mato Grosso do Sul in Brazil and their varying decomposition levels. In order to obtain the plant cover index and fractional images, MODIS duration series were used. Using ripple technique at various decomposition levels, the input parameter required for WEKA J48 classifier was obtained. This way, forages were successfully selected from Cerrado. The segregation between different forages caused lower performance; the best results were obtained for forages that include common plants. Yang *et al*. (2014) classified trees in Boreal forests in Canada. Using LiDAR, RapidEye and the combination of these two data along with the support vector machine classification method, the success rates were compared. The data they used composed of six components. These are digital elevation model, slope, red-edge NDVI, red-edge, canopy height and near infrared bands of RapidEye data. The best result was obtained using the combination of LiDAR and RapidEye data.

In this paper, the forest type mapping including three tree types have been automatically classified based on machine learning algorithms including k-NN, Multilayer Perceptron, J48, Bayes Net, Naïve Bayes and K-Star classification methods using spectral features belonging to these tree types.

Materials and Methods

Dataset

In this study, Advanced Spaceborne Thermal Emission and Reflection Raidometer (ASTER) satellite images (15m resolution) in a forestland of approximately 13 x 12 km in Ibaraki Prefecture, Japan were used. In this area, there were mainly Cryptomeria japonica (Sugi) trees, Chamaecyparis obtuse (Hinoki) trees, mixed broadleaf, angiosperm natural trees and also a few non-forest structures (such as buildings, roads and cultivated areas) (Johnson, Tateishi, & Xie, 2012). The orthorectificated ASTER images were obtained at three different dates in order to determine the coniferous and broadleaf tree types. Each pixel identifies a distance of 15m. The images were obtained at green (0.52 – 0.60 μm), red (0.63 – 0.69 μm) and near infrared (NIR) (0.76 – 0.86 μm) bands (as a total of nine bands) (Johnson, Tateishi, & Xie, 2012). The data obtained from the UCI Forest

type mapping data set are composed of two parts as training and test. There is a total of 524 data. The 38% of the data is for training and 62% is for test. Each data consists of 27 attributes. Each data is classified as Sugi, Hinoki, mixed broadleaf and others (UCI, 2016). Using the data obtained for each channel by processing the orthorectificated ASTER images using the inverse distance weighting (IDW) method, a map for Sugi and Hinoki type trees was created. The nearest 15 neighbor pixels were used for IDW process. Using the training data, the average spectral values of Sugi and Hinoki types at each band were obtained. For Sugi, pred_minus_obs_S was obtained by subtracting the values obtained with IDW from average values. For Hinoki, pred_minus_obs_H was obtained by subtracting the values obtained with IDW from average values. Therefore, a 27 attribute set composed of 9 original values, 9 pred_minus_obs values and 9 pred_minus_obs_H values was obtained (Johnson, Tateishi, & Xie, 2012).

Software-WEKA

Developed by Waikato University in New Zealand, WEKA is an open-source data mining software with a functional graphical interface which incorporates machine learning algorithms (Witten, Frank, & Hall, 2011.). WEKA includes various data pre-processing, classification, regression, clustering, association rules, and visualization tools. The algorithms can be applied on the data cluster either directly or by calling via Java code (Patterson *et al*., 2008; Hall *et al*., 2009). They are also suitable for developing new machine learning algorithms.

Machine learning algorithms

K-Nearest Neighbor Algorithm: The k-NN is a supervised learning algorithm that solves classification problems. Classification is the examination of the attributes of an image and the designation of this image to a predefined class. The important point is the determination of the features of each category in advance (Wang, Neskovic, & Cooper, 2007). According to the kNN algorithm used in the classification, based on the attributes drawn from the classification stage, the distance of the new individual that is wanted to be classified to all previous individuals is considered and the nearest k class is used. As a result of this process, test data belongs to the k-nearest neighbor category that has more members in a certain class. The most important optimization problems in the kNN method are the identification of the number of neighbors and the method of distance calculation algorithm. In the study, the identification of the optimum k number is performed with experiments, and the Euclidean Distance Calculations method is used as a distance calculation method.

Euclidean calculation method (Zhou, Li, & Xia, 2009):

$$d(x_i, x_j) = \left(\sum_{s=1}^{p} (x_{is} + x_{js})^2 \right)^2$$

x_i and x_j are two different points, and we need distance calculation process in between.

Multilayer Perceptron: It is a feed forward type artificial neural network model which maps input sets onto appropriate output sets. A multilayer perceptron (MLP) is composed of multiple layers of nodes where each layer is connected to the next. Each node is a processing element or a neuron that has a nonlinear activation function except the input nodes. It uses a supervised learning technique named back propagation and it is used for training the network. The alteration of the standard linear perceptron, MLP is capable of distinguishing data which are not linearly separable (Hall *et al*., 2009).

J48: It is a widely used machine learning algorithm that is based on J.R. Quilan C4.5 algorithm. Data that will be examined will belong to the categorical type, so continuous data will not be examined at this step. However, the algorithm will leave room for adaptation in a way to include this capability (Hall *et al*., 2009; Arora, 2012).

Bayes Net: Bayes Net is a probabilistic graphical model and a statistical model representing a group of random variables in addition to their conditional dependencies through a directed acyclic graph. For instance, a Bayesian network can represent the probabilistic relations between diseases and symptoms. When the symptoms are given, the network can calculate the probabilities of the existence of various diseases (Hall *et al*., 2009).

Naive Bayes: In a learning problem, Naïve Bayes classifiers have a high degree of scalability and they entail a number of parameters that are linear with the number of variables (predictors/features). The maximum-likelihood training could be performed by examining a closed-form expression that takes linear time instead of by expensive iterative approximation unlike many other types of classifiers (Hall *et al*., 2009).

KStar: K* or K-Star is a classifier based on instance. A test instance class depends on the training instances that are similar to it, and it is determined by various similarity functions. The point it is different from other instance-based learners is that it uses a distance function that is based on entropy (Cleary & Trigg, 1995).

Results and Discussion

In the study, WEKA software was used in order to classify 3 different forest types (Sugi, Hinoki, mixed broadleaf). Using the kNN algorithm, the classification success rates of different forest types were obtained for different k-neighbor values. Also, root mean square error (RMSE) and mean absolute error (MAE) values were obtained. The classification success rates obtained with kNN algorithm, and MAE and RMSE values can be seen in Table 1. The diagram demonstrating the changes in MAE and RMSE error values based on the number of neighbors in the classification performed with the kNN algorithm is shown in Figure 1.

The data in the same dataset were processed using the multilayer perceptron model, and the classification success rates of different forest types were obtained. The classification success rates of different number of neurons in the hidden layer, and MAE and RMSE error values were obtained. In the multilayer perceptron model, the training was performed by taking the learning rate value as 0.3, momentum value as 0.2 and iteration number as 500. The classification success rates, and MAE and RMSE values obtained using the multilayer perceptron model can be seen in Table 2. The diagram demonstrating the changes in MAE and RMSE error values based on the number of neighbors in the hidden layer is demonstrated in Figure 2.

Then the same data was processed using J48, Naïve Bayes, Bayes Net, KStar machine learning algorithms and classification success rates and MAE and RMSE error values of different tree types in the forest were obtained. The success and error rates obtained using 6 different classification algorithms (Multilayer Perceptron, kNN, J48, Naïve Bayes, Bayes Net, KStar) can be seen in Table 3. The diagram demonstrating the error values obtained based on different machine learning algorithms can be seen in Figure 3.

Table 1

The Success Rate and Error Values Obtained by using kNN Classifier

Neighborliness Number (k)	Classification accuracy (%)	MAE	RMSE
1	83.3652	0.0856	0.2872
2	83.3652	0.0839	0.2412
3	88.1453	0.0834	0.2271
4	87.9541	0.0836	0.2198
5	**89.1013**	**0.0877**	**0.2169**
6	88.7189	0.0903	0.2181
7	88.7189	0.0908	0.2158
8	88.1453	0.0922	0.2139
9	88.9101	0.0941	0.2145
10	88.3365	0.0954	0.2141

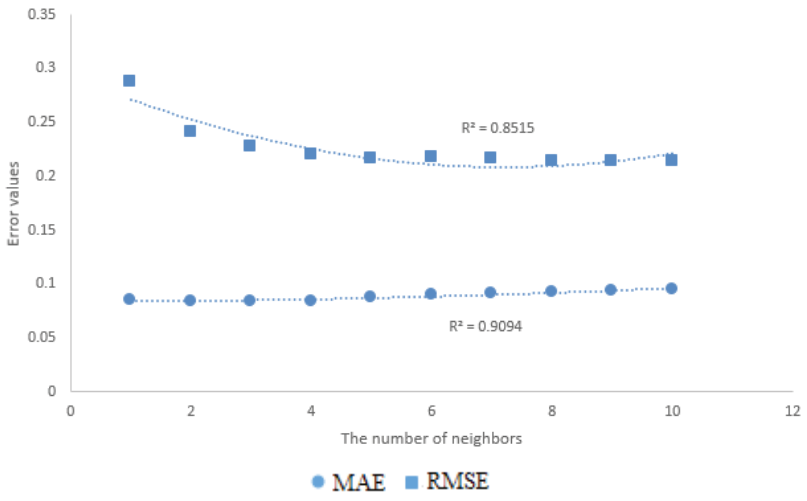

Figure 1. Variation of error rate based on the number of neighborhood.

Table 2

Success Rate Obtained By Using Multilayer Perceptron Classifier Error Values

The number of neurons in the hidden layer	Classification accuracy (%)	MAE	RMSE
5	88.9101	0.0611	0.2157
10	90.0574	0.0585	0.2068
15	88.7189	0.0621	0.2127
20	90.0574	0.0563	0.2007
25	89.4837	0.059	0.2091
30	89.6750	0.0569	0.2094
40	90.0574	0.0563	0.2054
50	89.6750	0.0566	0.2062
60	89.6750	0.0549	0.2056
70	89.8662	0.0543	0.2027
80	88.9101	0.0601	0.2146
90	**90.4398**	**0.0572**	**0.2078**
100	89.8662	0.0557	0.204

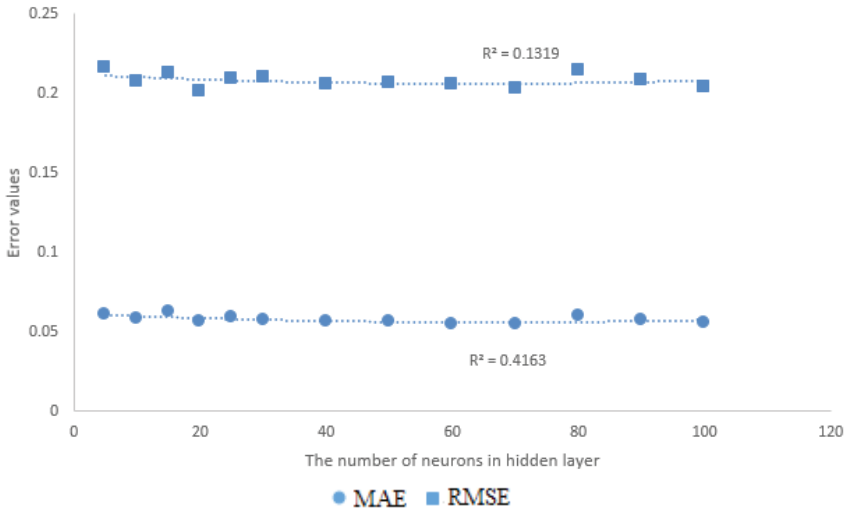

Figure 2. Variation of error rate based on the number of neurons in hidden layer.

Table 3

Success Rate Obtained By Using Various Machine Learning Algorithms

Machine learning algorithms	Classification accuracy (%)	MAE	RMSE
Multilayer Perceptron	**90.4398**	**0.0572**	**0.2078**
kNN	89.1013	0.0877	0.2169
J48	86.0421	0.0810	0.2543
Naive Bayes	85.6597	0.0708	0.2562
Bayes Net	85.4685	0.0729	0.2593
KStar	81.4532	0.0933	0.2933

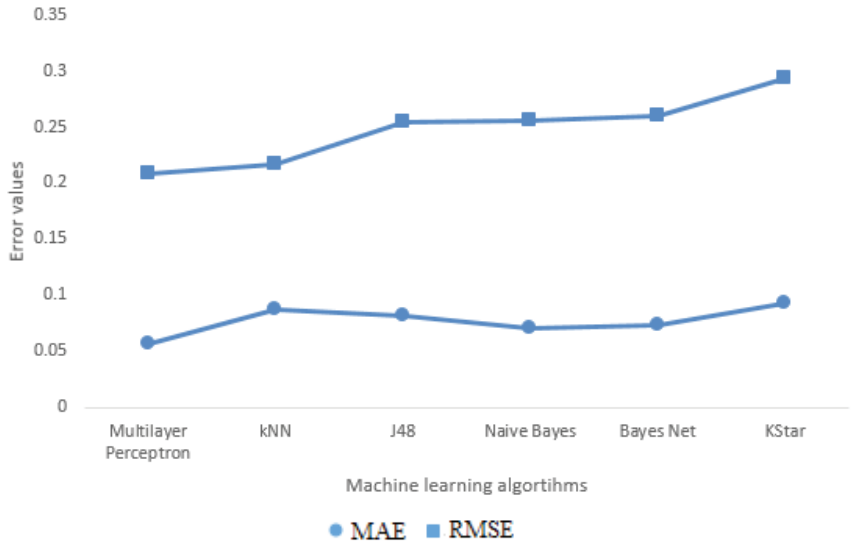

Figure 3. Variation of error rate based on the machine learning algorithms.

Conclusions

In this study, three different forest types in Japan (Sugi, Hinoki, mixed broadleaf) were classified using machine learning algorithms (Multilayer Perceptron, kNN, J48, Naïve Bayes, Bayes Net, KStar). The classification success and error values of machine learning algorithms were calculated. It was observed that the success rate was higher for the classifications performed using the Multilayer Perceptron Algorithm. The highest classification success rate was achieved when the number of neurons in the hidden layer was 80 and the success rate was 90.4398%. The MAE error value was 0.0572 and the RMSE error value was 0.2078 for the number of neurons in the hidden layer. For the classification success rates obtained using K-Nearest Neighbor Algorithm, the highest classification success rate was achieved for 5 neighborhood values, and it was 89.1013%. For this neighborhood value, the MAE error value was 0.0877 and the RMSE error value was 0.2169. The success rates obtained using J48, Naïve Bayes, Bayes Net and KStar classification algorithms were found as 86.0421%, 85.6597%, 85.4685% and 81.4532% respectively.

References

1. Aguiar, D.A., Adami, M., Fernando Silva, W., Rudorff, B.F.T., Mello, M.P., & Da Silva, J.D.S.V. (2010). MODIS time series to assess pasture land. In Geoscience and Remote Sensing Symposium (IGARSS), 2010 IEEE International (pp. 2123-2126). IEEE.
2. Arora, R. (2012). Comparative analysis of classification algorithms on different datasets using WEKA. *International Journal of Computer Applications*, 54(13), pp. 21-25.
3. Babalık, A., & Botsalı, F.M. (2010). Yapay sinir ağı ve görüntü işleme teknikleri kullanarak durum buğdayının camsılığının belirlenmesi (Determination of durum wheat vitreousness using artificial neural networks and image processing techniques). Selcuk Teknik Online Dergisi, 9(1): 163-174 (in Turkish).
4. Chao, Y., Mingyang, L., & Mifang Z. (2015). Classification of Dominant Tree Species in an Urban Forest Park Using the Remote Sensing Image of WorldView-2. 2015 8th International Congress on Image and Signal Processing (CISP 2015) 742-747. IEEE.
5. Chen, M.S., Han, J., & Yu, P.S. (1996). Data mining: an overview from a database perspective. Knowledge and data Engineering, IEEE Transactions on, 8(6), 866-883.
6. Cleary, J.G., & Trigg, L.E. (1995). K*: An instance-based learner using an entropic distance measure. In Proceedings of the 12th International Conference on Machine learning Vol. 5, pp. 108-114.
7. Dener, M., Dörterler, M., & Orman, A. (2009). Açık kaynak kodlu veri madenciliği programları: Weka'da örnek uygulama (A sample application of Weka which is an open source data mining software). Akademik Bilişim, 11 – 13 Şubat 2009 (pp. 787-796). Harran Üniversitesi, Şanlıurfa, Türkiye (in Turkish).
8. Hall, M., Frank, E., Holmes, G., Pfahringer, B., Reutemann, P., & Witten, I.H. (2009). The WEKA Data Mining Software: An Update. ACM SIGKDD Explorations Newsletter, 11(1), 10-18.

9. Jamuna, K.S., Karpagavalli, S., Revathi, P., Gokilavani, S., & Madhiya E. (2010). Classification of seed cotton yield based on the growth stages of cotton crop using machine learning techniques. International Conference on Advances in Computer Engineering, 20 – 21 June 2010 (pp. 312-315). Bangalore, Karnataka, India. IEEE. DOI: 10.1109/ACE.2010.71.
10. Johnson, B., Tateishi, R., & Xie, Z. (2012). Using geographically weighted variables for image classification. Remote Sensing Letters, 3(6), 491-499.
11. Karthikeyan, T., & Thangaraju, P. (2015). Best First and Greedy Search based CFS-Naive Bayes Classification Algorithms for Hepatitis Diagnosis.Biosciences and Biotechnology Research Asia, 12(1), 983-990.
12. Kiani, S., Azimifar, Z., & Kamgar, S. (2010). Wavelet-based crop detection and classification. In Electrical Engineering (ICEE), 2010 18th Iranian Conference on. 11 – 13 May 2010 (pp. 587-591). Isfahan. IEEE. DOI: 10.1109/IRANIANCEE.2010.5507003.
13. Özekes, S. (2003). Veri madenciliği modelleri ve uygulama alanları (Data mining methods and application areas). Istanbul Ticaret Universitesi Dergisi, vol 3, 65-82. (in Turkish).
14. Patterson, D., Liu, F., Turner, D., Concepcion, A., & Lynch, R. (2008). Performance Comparison of the Data Reduction System. Proceedings of the SPIE Symposium on Defense and Security, Mart, Orlando, FL, pp. 27-34.
15. Polat, K., & Güneş, S. (2009). A novel hybrid intelligent method based on C4.5 decision tree classifier and one-against-all approach for multi-class classification problems. Expert Systems with Applications, 36(2), 1587-1592.
16. Sabanci, K., Aydin, C., & Ünlerşen, M.F. (2012). Görüntü İşleme ve Yapay Sinir Ağları Yardımıyla Patates Sınıflandırma Parametrelerinin Belirlenmesi (Determination of the classification parameters of potatoes by the help of image processing and artificial neural network). Igdir Universitesi Fen Bilimleri Enstitusu Dergisi, 2(10), 59-66. (in Turkish).
17. Sabancı, K., & Aydın, C. (2014). Görüntü İşleme Tabanlı Hassas İlaçlama Robotu (An image processing based precision spraying robot). Tarim Bilimleri Dergisi, 20(4), pp. 406-414. DOI: 10.15832/tbd.33629 (in Turkish).
18. Sabancı, K., & Koklu, M. (2015). The Classification of Eye State by Using kNN and MLP Classification Models According to the EEG Signals. *International Journal of Intelligent Systems and Applications in Engineering*, 3(4), 127-130.
19. Sharma, T.C., & Jain, M. (2013). WEKA approach for comparative study of classification algorithm. *International Journal of Advanced Research in Computer and Communication Engineering*, 2(4), 1925-1931.
20. Johnson, B. (2015). UCI Machine Learning Repository: Forest type mapping Data Set, Retrieved March 1, 2016, from https://archive.ics.uci.edu/ml/datasets/Forest+type+mapping.
21. Wang, J., Neskovic, P., & Cooper, L.N. (2007). Improving nearest neighbor rule with a simple adaptive distance measure, Pattern Recognition Letters, 28(2):207-213.
22. Hall, M., Frank, E., Holmes, G., Pfahringer, B., Reutemann, P., & Witten, I.H. (2009). The WEKA Data Mining Software: An Update, SIGKDD Explorations, Volume 11, Issue 1, pp. 10-18.
23. Witten, I.H., Frank, E., & Hall, M.A. (2011). Data mining: practical machine learning tools and techniques. Elsevier, London.
24. Yang, X., Rochdi, N., Zhang, J., Banting, J., Rolfson, D., King, C., & Purdy, B. (2014). Mapping tree species in a boreal forest area using RapidEye and LiDAR data. In Geoscience and Remote Sensing Symposium (IGARSS), 2014 IEEE International (pp. 69-71). IEEE.
25. Zhou, Y., Li, Y., & Xia, S. (2009). An improved KNN text classification algorithm based on clustering, *Journal of computers*, 4(3):230-237.

THE ROLE OF DIGITIZED SERVICES TO IMPROVE INTERNATIONAL ACTIVITIES OF BANKS

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Abstract
Due to the globalization, the financial sector has undergone major changes in the way services are provided and delivered. Customers increasingly prefer to receive services remotely, which is a more convenient and faster way, but the majority of European banks are not ready to provide it. 90% of European banks invest less than 0.5% of total spending on service digitization; therefore, only 20 – 40% of the processes are digitized. The service digitization can be a major challenge for banks in the future. Only banks that provide a full range of digitized services will be able to increase profitability and revenues and reduce costs. Therefore, it is necessary to analyse the satisfaction of international corporate customers and define the role of digitized services to improve international activities of banks. Quantitative and qualitative research methods, including the statistical data analysis, graphical analysis, linear and multiple regression analysis, correlation, comparison and grouping methods, as well as survey have been used for the research, and SPSS 20 has been used for data processing. So far there are no analyses of the digitized services in Latvia that would be based on international customer experience and needs. The results of the research concluded that the higher usefulness indicator, the higher is the possibility that international corporate customers will continue to use internet banking services. The digitized services strategy ensures the availability of essential daily digitized services in internet banking and ensures the savings in time and in financial resources for the bank and its international corporate customers.
Key words: service digitization, banking sector, internet banking.

Introduction

Technological developments over the last 20 years have opened up even greater possibilities for cooperation throughout the world, and both personal and professional life is inconceivable without them. Companies try to provide services accessible to everyone, and the distance is not an obstacle to successful mutual cooperation. The competition between companies influences the development of innovative solutions to ensure digital services, with the possibility to use them remotely.

Theoretical and practical research is being conducted in the financial industry looking closely at banking sector. The digitized services strategy applies to the banks internet banking to improve their international activity; therefore, the aspects of internet banking usage and its advantages and disadvantages have been studied in depth.

The aim of the research is to analyse the role of digitized services to improve activities of banks in order to clarify the trends of digitized service development, to ensure digitized banking services in Latvia. In order to achieve the objective, the following tasks have been set:

1. To explore the historical aspects of the digitized services and previous research carried out in the framework of digitization and its connection with banking activities;

2. To summarize and analyse the statistical information on the internet banking users and the digitization impact on banks' activities;

3. To make a structured survey for international banking customers who use digitized services.

Materials and Methods

Quantitative and qualitative research methods have been used for the research. The statistical data analysis, comparison, graphical analysis and grouping methods have been used for the collection of statistical data. In order to analyse the factors affecting the choice of internet banking included in the developed questionnaire, the linear and multiple regression analysis, as well as correlation have been used. A 5-point Likert scale (where 1 – strongly disagree; 5 – strongly agree) have been used in the survey to measure the quality of internet banking and the respondents' satisfaction with the received service. The program of statistical calculation SPSS (Statistical Package for the Social Sciences) 20 has been used for data processing. The research was done in the period from October 23 to November 4, 2015. The target audience was international corporate customers who are using internet banking services. During the research period 65 questionnaires were sent to respondents via e-mail. 57 completed questionnaires were received and analysed.

Results and Discussion

Digitized services and banking activities

As a result of the digitization, the world economy gained almost 193 billion US dollars and 6 million jobs were created in 2011. (Sabbagh, Friedrich, & El-

Darwiche, 2013, 37) Such developed regions as North America and Western Europe accounted for 29% in gross domestic product (GDP) and created just 7% of new jobs. In the developing countries the situation is dramatically different. For example, in East Asia and the Pacific, Latin America and Africa the impact of digitization on GDP accounted for 50%, and there were created more than 50% new jobs. The world's population, which uses the Internet, is increasing every year. This means that in the number of internet banking users will also increase in the future. Since September 2000 the number of internet users has increased by 806% to nearly 3.3 billion. The number of internet users in Latvia is 1.6 million. (Internet Usage..., 2015) Analysing data on the internet banking use in different regions of the world, it can be concluded that the leader is North America. In 2012, 45% of North American Internet users used also the internet banking services. It is almost 1.5 times more than average worldwide (28.70%).

According to the statistics, Europe was lagging behind North America with 37.80% internet banking users. The least number of internet banking users was in Middle East and Africa (8.80%). (Global online…, 2012). If the indicators of European internet banking users are analysed separately, the internet banking users in 2014 has increased to 44%, approaching the figures of North America in 2012. Most active internet banking users have been in Iceland (91%). In the first ten positions there are also Scandinavian countries, the Netherlands, Estonia, Luxembourg, Belgium and France. It is mainly related to the developed banking systems of these countries. 57% active internet banking users are in Latvia, and it is 11th place on the list. The least internet banking users in Europe are in Bulgaria and Romania 5% and 4%. (Online banking…, 2015) respectively.

In 2011, a research on Latvian internet banking users was carried out by Association of Latvian Internet Banking. (Latvijas internetbanku…, 2011, 6) The aim of this research was to follow up with the internet banking development trends in Latvia, as well as to assess the dynamics of internet banking users and their activities in the usage of offered digitized services. The authors conclude that the largest number of internet banking users in the private individual segment in 2011 was for Swedbank – 831 202 users, followed by SEB Bank with 617 042 users while 61 026 legal entities were using SEB Bank internet banking, followed by Swedbank – 55 268 users. The least number of internet banking users both in the private individual segment and legal entities was for UniCredit Bank (Figure 1).

Comparing the proportion of private individuals and legal entities which are using internet banking, research shows that 92% of internet banking users are private individuals, while only 8% legal entities; therefore, it is important to ensure the high level service for digitized services to promote the loyalty of legal customers. During the period from 2007 to 2011, the number of internet banking users increased from 1.4 million to 2.5 million users. The rapid increase is explained with the introduction of new digitized services in banks' internet banking and the modernisation of user interface, which improved the customer satisfaction with the services provided by banks. However, starting from January 2012 the number of customers had decreased. As part of the banks' customers and internet banking users are foreign individuals and companies, the decrease in the number of internet banking users during this period is due to the fragile international economic relations, as well as changes in bank lending policies. However, there is a positive trend in 2015. The number of

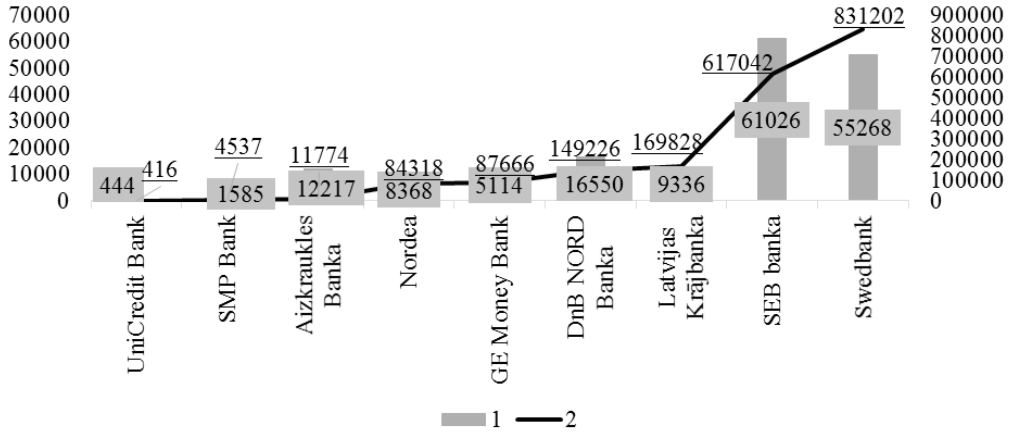

Figure 1. Number of internet banking users in Latvian commercial banks in 2011, in units: 1 – Legal entities, 2 – private individuals, units (Latvijas internetbanku…, 2011, 6).

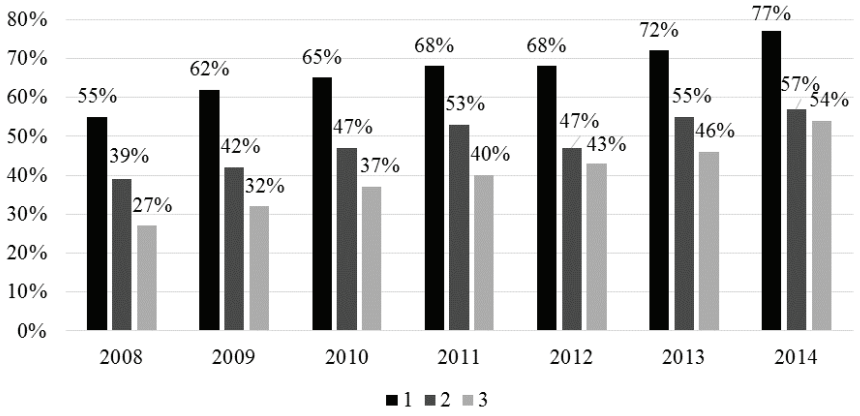

Figure 2. Number of internet banking users in Baltics 2008 – 2014 (%): 1 – Estonia, 2 – Latvia, 3 – Lithuania (Figure made by authors).

internet banking users in second half 2015 is higher than figures in 2012 and 2014, reaching 1.4 million users. A result of globalization, which is affected by changes in the financial sector, the large Scandinavian banks have developed successful operation in the Baltic countries, which allows to strengthen the leading position in the Baltic financial markets. Baltic financial market is one of the most open in the world. Estonia, Lithuania and Latvia are characterized by the ability to attract foreign direct investment and promote trade within the country and beyond national borders, in cooperation with other EU Member States, because Estonia and Latvia already have become the members of Eurozone, followed by Lithuania on January 1st, 2015. Baltic banking sector is mainly dominated by foreign banks. The largest Baltic banks are subsidiaries or branches of Scandinavian banks, which account for 95% of total assets and domestic loans in Lithuania and Estonia, while this ratio is slightly different in Latvia – 53% of total assets and 80% of domestic credit. This difference is explained by the non-resident deposits, as well as foreign assets held by domestic banks. (Tůma, 2014, 7) In all three Baltic countries foreign banks mainly provide credits to private individuals, therefore it is necessary to pay more attention to cooperation with companies in the future to promote the competitiveness in the legal entities segment. Despite the global financial crisis the number of internet banking users in Baltic countries has grown (Figure 2). The largest increase in the number of internet banking users took place in Lithuania. 27% of bank customers used internet banking in Lithuania in 2008. In 2014, the number doubled (54%), increasing by 27 percentage points, while in Estonia and Latvia there was a moderate increase in numbers of internet banking users.

Digitization impact on banks' activities

While banks provide similar digitized internet banking services, one of the biggest drawbacks is insufficient range of digitized services. Companies in other sectors are able to offer most of their services remotely; therefore, customers want to receive digitized services offered by banks at a lower cost. This is one of the risk moments when the number of loyal customers could also decrease in major commercial banks. In order to implement digitized services, it is necessary to understand whether the customer

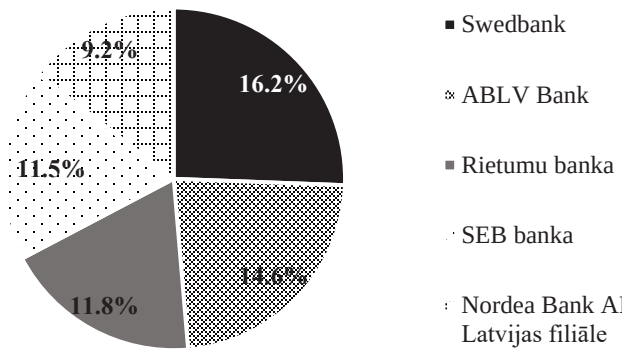

Figure 3. The market share of the largest Latvian commercial banks in the 2nd quarter, 2015 (%) (Figure made by authors).

changes will affect the banks' performance; therefore, authors analysed the main indicators characterizing the operation of major Latvian commercial banks firstly.

In the 2nd quarter of 2015, 17 banks and 7 bank branches were operating in Latvia. Their total assets amounted to 31.4 billion euro and have risen by 10.9% compared to 2nd quarter of 2014. (Banku aktīvi…, 2015). The largest market share in terms of assets is held by five Latvian commercial banks (Figure 3), which will be analysed in detail.

The largest Latvian bank in the 2nd quarter, 2015 was AS 'Swedbank' with a market share of 16.2% or 5.1 billion euro. The market share has risen by 0.6% compared to 2nd quarter of 2014. The second largest Latvian bank in terms of asset value was AS 'ABLV Bank' with a market share of 4.6 billion or 14.6% of the total banking sector. Among five largest banks, AS 'ABLV Bank' had the biggest asset growth, it increased by 26.4% compared to the 2nd quarter of 2014. AS 'Rietumu Banka' had 11.8% market share, its assets increased by 17.8% during the year, reaching EUR 3.7 billion euro. AS 'SEB banka' ranked in the fourth place with 11.5%, increasing the market share by 0.2%, and reached 3.6 billion euro. AS 'Nordea Bank AB Latvijas filiāle' concluded the top five of the largest Latvian commercial banks with 9.2%. The market share in terms of asset value has remained unchanged (2.9 billion euro). Successful banking is based on the ability to attract new customers and ensure customer satisfaction providing high quality internet banking services; therefore, within the framework of this report the changes in the number of bank customers were analysed. In 2015, the number of active clients (client, which carried out at least two transactions within 6 months, with the exception of the bank fee deduction) reached 2.2 million, which has decreased by 2% of 41 thousand since September 2014. AS 'Swedbank' has taken the first place in both volume of banking assets and the number of customers. The number of customers has continued to increase in the last four years, reaching almost 950 thousands in the 2nd quarter 2015. In contrast, the number of customers has slightly decreased for other four largest banks at the same period. The number of customers of AS 'SEB banka' is twice as low as AS 'Swedbank' – 478 thousands. In turn, the number of customers of AS 'Nordea Bank AB Latvijas filiāle' does not exceed 100,000. AS 'Rietumu banka' and AS 'ABLV Bank' the client base is less than 30,000. Comparing customer changes since September 2012, there were no significant differences in terms of number of clients. The number of customers in the major banks is stable. Minor changes in the number of clients in banks indicate positive trend. The trend shows that the collaboration partners are chosen deliberately by customers and the choice has been changed rarely. Despite the changes of the total number of bank customers, the number of internet banking users continues to increase. Due to this fact, the banks' interest is to ensure wider range of digitized services via internet banking to attract new users.

The statement that banking customers increasingly prefer to do business remotely is true. It is also reflected in the changes of the bank branch network, which includes branches, settlement groups and customer service centres. Since 2008 the number of customer service centres has been rapidly decreasing. There were 647 commercial banks branches or settlement groups in 2008 in Latvia, while the number dropped to 297 in 2015. The most rapid decrease in branches and settlement groups in absolute figures were in 2012, when 406 units continued to provide services for customers compared to 538 units at the end of 2011 (Banku sektors..., 2015).

Evaluating the dynamics of number of the largest Latvian commercial banks' customer service centres from 2012 to 2015, the authors conclude that the sharpest reduction was carried out by AS 'SEB banka' (Figure 5). In 2.5 years, the number of customer

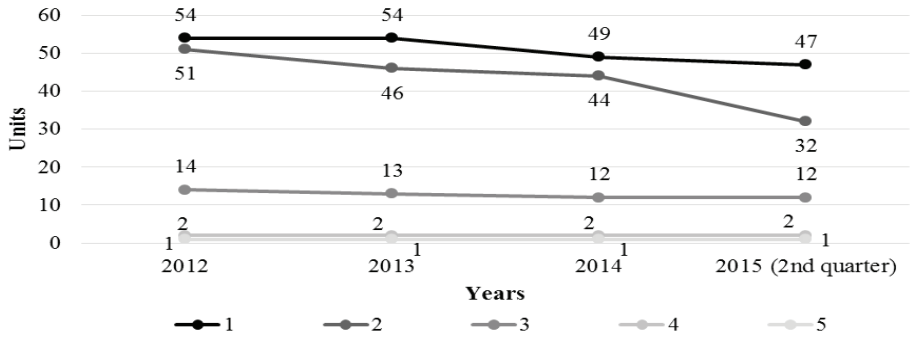

Figure 5. The dynamics of the largest commercial banks' customer service locations (branches, settlement groups) 2012 – 2015, by units: 1 – Swedbank, 2 – SEB banka, 3 – Nordea Bank AB Latvijas filiāle, 4 – ABLV Bank, 5 – Rietumu banka (Figure made by authors).

service locations has decreased by 19 units, because of the lack of customer attendance at branches and increase in the use of remote services. AS 'Swedbank' has decreased the number of branches and settlement groups by 7 units, however, AS 'Swedbank' still has the biggest network of branches and settlement groups in Latvia – 47 customer service locations. AS 'Nordea Bank AB Latvijas filiāle' has less branches and settlement groups. In 2012, the bank had 14 units that decreased to 12 in 2014. Since 2012 AS 'ABLV Bank' and AS 'Rietumu banka' have had a fixed number of customer service centres – only 2 and 1 (Banku darbība, 2015).

In order to determine the exact changes of the number of customer service locations' in banking sector, the chain and the absolute increase was calculated, as well as the growth rates of the banking sector as a whole and the largest commercial banks. Calculating the chain absolute growth of branches and settlement groups, there was the biggest absolute reduction by 132 units of 24.5% in 2012 compared with 2011. The second largest reduction in the numbers of units was in 2010 compared with 2009, when the number of branches and settlement groups was reduced by 70 of 11.4%. The authors conclude that the negative dynamics of units in 2010 is due to the cost optimization, which was carried out by banks in the post-crisis period. Analysing the base absolute growth, the trend is negative, because the number of customer service locations was reduced by 350 units of more than 50% in 2015 compared with the base period of 2008. Based on previous research, it can be expected that the negative trend will continue in upcoming years. Banks will continue to reduce the number of branches and settlement groups.

AS 'SEB banka' branch network decreased by 27.27% in 2015 compared with 2014. The base growth rate is negative (-37.25%) compared with 2012. Comparing data of AS 'SEB banka' and AS 'Swedbank', it can be concluded that the number of customer service centres for AS 'Swedbank' has decreased three times slower. The reduction in the base rate was 12.96% in 2015. The most rapid reduction of AS "Swedbank" branches and settlement groups was in 2014, when the total branch network was cut by 5 units compared to 2013. In 2012, the customer service centres of AS 'Nordea Bank AB Latvijas filiāle' were four times less than AS 'Swedbank' and AS 'SEB banka'; therefore, the bank has not taken such a sharp reduction in the branch network as the other two banks. In 2013 and 2014, the number of bank's branches and settlement groups were reduced by 2 units. The chain reduction was 7.14% and 7.69%, while the base reduction was 14.29 % in 2015.

Not only in Latvia, but also in the EU there has been a similar trend – the liquidation of bank branches. The number of bank branches and settlement groups in the EU has decreased by almost 19,000 or 9% (Šteinfelde, 2015). Due to the decrease of bank branches, there were about 200,000 branches in the EU at the end of 2013 (Data shows…, 2014).

The assets of banks, the number of customers or branch network provides the conception of the bank's market power, however, one of the major banks' profitability indicators is return on assets (ROA), which indicates how profitable a bank is relative to its total assets (Return On…, 2015). The formula (1) is used to calculate ROA:

$$\text{ROA} = \frac{\text{Net Income}}{\text{Total Assets}} \quad (1)$$

where ROA – return on assets;
Net Income – gross profit-administrative costs;
Total Assets – average total assets of a business during a financial year.

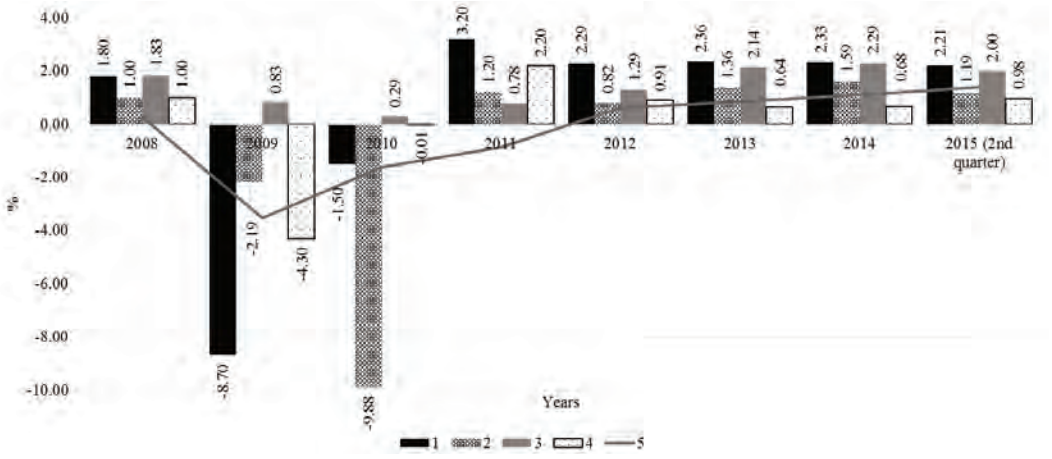

Figure 6. ROA of the largest Latvian commercial banks 2008 – 2015 (%):1 – Swedbank, 2 – ABLV Bank, 3 – Rietumu banka, 4 – SEB banka, 5 – ROA in banking sector (Figure made by authors).

The equity of AS 'Nordea Bank AB Latvijas filiāle' is not separated from Nordea Bank group; therefore, ROA for this bank cannot be compared with other major commercial Latvian banks, thus authors analyse the four major commercial banks in Latvia.

Based on ROA analysis, the authors conclude that the largest banks' ROA began to decrease in 2009. Three out of four largest Latvian commercial banks had negative ROA in 2009 and 2010. Only AS 'Rietumu banka' ROA was positive. In 2009, the bank's ROA was 0.83%, and it decreased to 0.29% in 2010. AS "ABLV Bank" experienced the largest ROA drop (-9.88% in 2009). In the 2nd quarter of 2015, the best asset management efficiency was shown by AS 'Swedbank'. The bank's ROA was 2.21%. The second highest level is for AS 'Rietumu banka' (2.00%), followed by AS 'ABLV Bank' with 1.19%. ROA of AS 'SEB banka' is 0.98%. Due to the global financial crisis in 2009, the banking sector's efficiency and performance was significantly reduced. The crisis affected not only the global economy in general but also the economy of each country individually.

Since 2010 performance indicators continue to improve every year, and the overall trend remains positive. Since 2011 the average ROA of the largest Latvian commercial banks is higher than on average level of ROA in banking sector. From 2013 to 2015 AS 'SEB banka' had not been able to exceed the average level, while the difference between AS 'ABLV Bank' and the average level of banking sector was 0.22 percentage points in 2015. It can be concluded that AS 'Swedbank' achieved the highest efficiency (2.21%) in 2015, while it decreased by 0.03 percentage points in 2014 compared to 2013. The reduction could probably be explained by the geopolitical situation worldwide, the government's decisions relating to the issue of temporary residence permits to non-residents and changes of banks' lending policy for non-residents. The less effective was AS 'SEB banka' (0.98% in 2015). ROA decreased from 0.91% in 2012 to 0.68% in 2014. AS 'ABLV Bank' and AS 'Rietumu banka' focus mainly on the co-operation with non-residents. Evaluating the banks' approaches for the operations, the authors conclude that various strategies of banks affect also ROA.

Analysis of international banking customers' survey

Authors carried out banks' international corporate customers' survey via e-mail in 2015. In order to find out as broad view as possible, the survey was sent out to international companies in different sectors with different number of employees (Figure 7).

To assess the use of internet banking, 6 factors – Usefulness, Easy to use, Trust, Security, Confidentiality and Satisfaction with internet banking were included in the survey. In order to evaluate the credibility of respondents' view regarding the satisfaction with internet banking, the reliability test of factors was made using Cronbach's Alpha coefficient. The Cronbach's Alpha coefficient indicated high confidence level – 0.924 or 92.4%. 87.8% of respondents believe that the usefulness of the internet banking is very important, because using 5-point Likert scale the most selected answers are 4 and 5. 12.2% of respondents have given a neutral evaluation. 87.7% of respondents consider that the use of internet banking services provides economic benefits, and that the digitized reports provide the necessary information. Respondents have given the highest assessment for the factor 'Trust' (93%). Almost one-third of the respondents assessed the security of the internet banking neutral, which means that customers do not pay increased attention to security issues when they use digitized services. However, 73.6% of the respondents are convinced about the security of transactions in the internet banking and the stability of the system and its protection. The lowest average rating (3.47 of 5) is given for satisfaction with the range internet banking

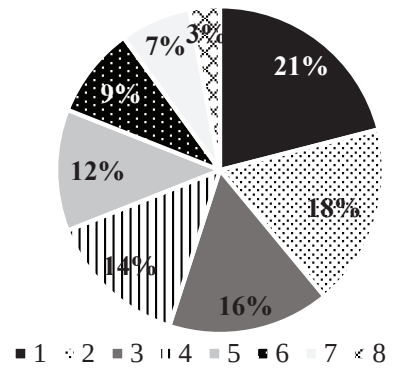

Figure 7. Allocation of respondents by sectors (%); 1 – Trade and services, 2 – Construction and real estate, 3 – Food and drinks, 4 – Information Technologies, 5 – Transport and logistics, 6 – Financial services, 7 – Manufacturing, 8 – Insurance. (Figure made by authors).

services. 17.6% of respondents are not satisfied with digitized services in the internet banking in general, while satisfaction level for 48.2% of respondents is high. The main factor for dissatisfaction on international corporate customers is the condition that they cannot receive daily banking services remotely. Based on the correlation analyses, it was concluded that there is a strong correlation between satisfaction with the internet banking and usefulness (0.694), as well as a moderate correlation between satisfaction with internet banking and security (0.674) and trust (0.585). Low correlation exists between satisfaction with internet banking, confidentiality (0.389) and ease of use (0.148). The ease of use means that customers can make transactions very fast, and it is convenient. Further, multiple regression analysis examined which factors influence the international corporate customers' satisfaction with internet banking the most. Using stepwise method, only statistically significant figures were included in the multiple regression equation. The results demonstrate that usefulness and security contribute significantly and predict 59% (R Square – 0.59) of variation with satisfaction with internet banking. The ANOVA results also confirm that the variables are significant ($p<0.001$), and the coefficient summaries bring out the β values of usefulness ($\beta=.454$, $p<0.05$) and security ($\beta=.407$, $p<0.05$). According to these results, usefulness is the major variable that affects the satisfaction with internet banking, followed by security. 91% of respondents have pointed out that there should be a possibility for customers to make automatic bank financial transaction limit increase to improve business efficiency and ensure faster circulation of financial resources. 84% of the respondents indicated that it is important for them that they are able to submit financial reports in the internet banking. This service could save the time and financial resources for customers and also for the bank. The originals of financial reports must be submitted quarterly, half-yearly or annually. From the customers' perspective the third most important improvement is the possibility to fill in and approve the AML or anti-money laundering reports in internet banking. The bank currently offers already existing solution for different digitized services, which gives customers the ability to receive remote digitized services that are the most important for them, for example, to increase the limits of the financial transactions. To receive this service, it is necessary to give the permission to one or more of the company's employees to make all transactions and other activities in internet banking. 75% of respondents indicated that they do not use this service, because companies' managers do not want to give the power to one employee to manage unrestricted activities in companies' bank accounts. 10% were not informed about this kind of digitized service, and 15% of companies' managers approved the payments in the internet banking by themselves.

The results of the research concluded that the higher usefulness indicator the higher is the possibility that customers will continue to use internet banking services. For international corporate customers it is important to receive daily banking services remotely. Internet banking functionality at the moment is incomplete, because customers do not use the proposed self-service options, due to the fact that in the framework of existing service there is big responsibility for one employee of the company to do wide range of actions in the internet banking. The digitized services strategy ensures the availability of essential daily digitized services in internet banking and ensures the savings in time and in financial resources for the bank and its international corporate customers.

Conclusions

1. The digitization is one of the tools by which companies can provide competitive products or services in the market to meet customers' expectations and needs.
2. Comparing the Baltic States, Estonia has the highest ratio in the digital development index of EU Member states, followed by Lithuania, and the lowest – Latvia, however, the digitized services provided by banks in all countries are similar, and banking customers consider the internet banking as the most appropriate channel for digitized transactions.
3. The results of the research demonstrate that usefulness, security and trust have an influence on international corporate customers satisfaction with the internet banking.
4. The higher the usefulness of internet banking is, the stronger intention international corporate customers use internet banking services offered by banks.
5. The higher the security of internet banking is, the greater possibility that international corporate customers will continue to use these services.
6. While banks provide similar digitized internet banking services, one of the biggest drawbacks is insufficient range of digitized services.
7. To improve business efficiency and ensure faster circulation of financial resources, there should be a possibility for customers to make automatic bank financial transaction limit increase.

References

1. Sabbagh, K., Friedrich, R., & El-Darwiche, B. (2013). Digitization for Economic Growth and Job Creation: Regional and Industry Perspectives, *Insight report. The Global Information Technology Report 2013: Growth and Jobs in a Hyperconnected World*, Geneva: World Economic Forum and INSEAD, pp. 35-42.
2. *Data shows slight decline in number of bank branches in most EU countries* (2014). Retrieved October 30, 2015, from https://www.ecb.europa.eu/press/pr/date/2014/html/pr140711.en.html.
3. *Global online banking penetration in April 2012, by region* (2012). Retrieved October 10, 2015, from http://www.statista.com/statistics/233284/development-of-global-online-banking-penetration/.
4. *Internet Usage Statistics: The Internet Big Picture* (2015). Retrieved October 11, 2015, from http://www.internetworldstats.com/stats.htm.
5. *Online banking penetration in selected European markets in 2014* (2015). Retrieved October 10, 2015, from http://www.statista.com/statistics/222286/online-banking-penetration-in-leading-european-countries/.
6. *Return On Assets – ROA* (2015). Retrieved October 28, 2015, from http://www.investopedia.com/terms/r/returnonassets.asp.
7. Tůma, Z. (2014). *Banking Executive Survey 2014.* Retrieved October 18, 2015, from http://www.kpmg.com/LV/lv/IssuesAndInsights/ArticlesPublications/PresesRelizes/Documents/Banking%20Executive%20Survey%202014_WEB.pdf.
8. *Banku darbība (Banks' activities)* (2015). Retrieved October 28, 2015, from http://www.lka.org.lv/lv/statistika/banku_darbiba.html. (in Latvian).
9. *Banku sektors skaitļos (Banking sector in numbers)* (2015). Retrieved October 28, 2015, from http://www.lka.org.lv/lv/statistika/. (in Latvian).
10. *Banku aktīvi uz 2015. gada 30. jūniju, tūkst. Eiro (Assets of banks on 30th of June, 2015, thousand euro)* (2015). Retrieved October 28, 2015, from http://lka.org.lv/lv/pdf/Banku_statistika_www_06_2015.pdf. (in Latvian).
11. *Latvijas internetbanku pētījums (Latvian internet banking research)* (2011). Retrieved October 12, 2015, from http://www.lia.lv/media/uploads/LIA_Latvijas_internetbanku_petijums_2011.pdf. (in Latvian).
12. Šteinfelde, I. (2015). *Bankas aizver filiāles un grib iznīdēt skaidru naudu (Banks close the branches and tend to uproot cash).* Retrieved October 30, 2015, from http://nra.lv/latvija/132838-bankas-aizver-filiales-un-grib-iznidet-skaidru-naudu.htm. (in Latvian).

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