Agronomy Research **14**(1), 134–142, 2016

Mechanical durability and water absorption of pellets made from different tree species - a case study

K. Makovskis[1,*], D. Lazdina[1], A. Arsanica[2] and V. Solodovniks[2]

[1]Latvian State Forest Research Institute 'Silava', 111 Riga street, LV–2169 Salaspils, Latvia
[2]LTD NewFuels, 169a Atbrivosanas aleja, LV – 4604 Rezekne, Latvia
[*]Correspondence: kristaps.makovskis@silava.lv

Abstract. Seven different tree species (coniferous and broad leaved) were selected for small scale pelletizing tests: birch (*Betula sp.)*, aspen (*Populus tremula L.*), grey alder (*Alnus incana L.*), poplar (*Populus sp.*), European larch (*Larix decidua* Miil.*)*, pine (*Pinus sylvestris*) and lodgepole pine (*Pinus contorta*). Tree species were mixed in different combinations and proportions. Wood mixture from one tree specie (several tree species were tested as base material during study) was used as base material with volume share in the mix at least 70% and mixtures from other tree species were used as additives. In total 49 different tree mixes were tested in pellet production where mechanical durability and water absorption was later measured for each sample. Mechanical durability where grey alder was mixed with pine was 98.8% (fulfils ENplus quality class). Poplar also showed high results and in some mixes meet the criteria for mechanical durability with best result 99% in mixes with European larch and lodgepole pine (proportions 80:10:10). From 9 different poplar mixes 7 of them showed mechanical durability higher than 97.5%. In tests where no additives was added (100% poplar), poplar pellets mechanical durability was 98.8%. Other mixes with birch, aspen and grey alder when they were taken as base material for pellet production (base material wood volume share in the mixture at least 70%, where remaining 30% consists of other tree specie mixtures) didn't meet the mechanical durability limit for ENplus quality classes and it was lower than 97.5%. Also in samples where birch and grey alder were used without adding other tree species durability was under 97.5%. European larch was the only one from coniferous trees was tested as base material and the best results in mechanical durability showed in mixes with lodgepole pine (proportion 70:30). From 9 different European larch mixes 7 of them showed mechanical durability higher than 97.5%, which is suitable for ENplus certification. Water absorption in pellets with different tree species composition does not change significantly and ranges from 0.70 to 0.73 ml g^{-1} when in commercially available litter material it is 0.75–0.8 ml g^{-1}. Water absorption tests leads to a conclusion that if pellets mechanical durability is not sufficient to sell it as combustion material in could be sold as litter material for animals.

Key words: pellets, coniferous pellets, deciduous pellets, poplar pellets.

INTRODUCTION

Europe Union (EU–28) is the main wood pellet market, in 2013 the market share was 49% of the global production and 80.3% of the global wood pellet consumption (Calderon et al., 2014). Expected wood pellets consumption in European countries according to European Biomass Association in 2020 will be 50Tg (Pirragila et al., 2010).

In the last two decades European demand for wood pellets has increased steadily, mostly stimulated by public policies and governmental supports (Karkania et al., 2012, Olsson et al., 2011, Sikkema et al., 2011, Mola–Yudego et al., 2014). Wood pellets are important fuel in heat and power production with a high potential to grow in the future. Industrial pellets for co–firing and combined heat and power production are the main product in pellet market. However, demand for high quality wood pellets from medium to small scale users in residential heating sector is increasing (Kristofel et al., 2016), where they can be purchased in small quantities and be more affordable on a limited budget. (Thomson & Liddell, 2015). Small and medium pellet consumers usually purchase pellets from domestic traders with national or regional supply chains (Hiegl and Janssen, 2009). Typical medium scale users are public, commercial and apartment buildings (e.g. administrative buildings, schools, family houses). Small scale users are private households using pellets in pellet boilers and pellet stoves (Kristofel et al., 2016).

Pellets quality issues are important for all users. Many European countries have developed pellets quality standards. Pellet quality depends on chemical, mechanical and physical properties of biomass (Kaliyan & Vance, 2009; Obernberger & Thek 2004). Some parameters are related to raw material (Arshadi et al., 2008) and some to quality management of the manufacturing process (Lehtikangas, 2001). One of the main quality indicators is mechanical durability. High content of fine particles in the fuel, which is dependent on mechanical durability, can cause problems in transportation and can favour ash melting (Garcia–Maraver et al., 2011).

According to recent studies, biomass growth in future could increase due to climate changes and mean temperature rise (Jansons et al., 2013a; Jansons et al., 2013b, Jansons et al., 2014a) as well as increased tree production on former agriculture lands (Daugaviete et al., 2015).

Small scale pellet production could be useful for private forest owners who had small, but stable annual wood resource flow from forest or it could be small business niche where pellets are produced for own use or sold in domestic market. Raw material could be taken also from pre-commercial thinning, which so far has not been done in large scale. Totally Latvian pre-commercial thinning is possible in 161 kha (Lazdins et al., 2013) and some of these resources could be used in pellet production. That could open market for new players in forest energy market.

Pellets with high mechanical durability could be sold as energy material, but pellets with low mechanical durability can be used as litter material for animals. This study tested pellets mechanical durability to different tree raw material mixes, to gain insight, which tree species could be more useful in small scale pellet production.

MATERIALS AND METHODS

The aim of this study was to compare different tree mixtures from common tree species in small scale pellet production and test pellets mechanical durability and water absorption. Assuming that pellets with lower mechanical durability could be used as litter material for animals.

In this study seven different tree species (coniferous and broad leaved) were selected for small scale pelletizing tests: birch (*Betula sp.)*, aspen (*Populus tremula L.*), grey alder (*Alnus incana L.*), poplar (*Populus sp.*), Europena larch (*Larix decidua* Miil.*)*, pine (*Pinus sylvestris*) and lodgepole pine (*Pinus contorta*). Tree species were mixed in different combinations and proportions to test pellets durability and water absorption, together 49 different mixtures were tested. Pelleting material mixtures were mixed manually and the proportions were mixed according to wood volumes. In all mixtures one of tree species were taken as the base material, where the share in mixture was no less than 70%. Exceptions were in mixtures, where birch and aspen were mixed equally together and the common share was no less than 70%. Selected tree trunks with bark were chipped at first and grounded before pelleting. Bark share in mixture was not particularly measured and calculated. Peletizer capacity was 200–250 kg pellets per hour. This mill has flat, horizontally configured die with 250 mm diameter, 34 mm thickness and die rotating speed 100 rpm. Average particle size before peletizing was approximately 3.0 to 5.0 mm and pellet diameter 6 mm. Determination of mechanical durability of pellets were done according to LVS EN 15210–1:2010 standard 'Solid biofuels – Determination of mechanical durability of pellets and briquettes – Part 1: Pellets'. Pelletizing for every tree mix was done in 2 repetitions, mechanical durability was measured for every repetition and average mechanical durability of these two repetitions is shown in this paper. This study was done like pilot project, where production conditions were close as possible to real and simple small scale pellet production system. Therefore there was no possibility to measure energy input and this factor was not measured.

For water absorption certain amount of pellets were weighted and placed on a sieve in one round, then the pellets were watered with 10 ml of water for 15 seconds, waited until the surplus water drained and then weighed again. Weight difference between dry pellets and pellets after watering is the water absorption, expressed in ml g^{-1}.

RESULTS AND DISCUSSION

The ENplus certification scheme defines three pellet quality classes and they are based on the classes of ISO 17225–2 and are named ENplus A1, ENplus A2 and ENplus B. To fit in these classes several parameters must be met. One off the parameter is mechanical durability (wt.%) which for ENplusA1 class should be ≥ 98.0 and for ENplus A2 and ENplus B ≥ 97.5 (ENplus quality certification...2015).

In the paper deciduous and coniferous trees were tested for pellet production. In one case deciduous tree was taken as the base material for pellet production and coniferous trees were added as supplements. In other case base material was coniferous tree and deciduous trees were added as supplements.

In the beginning three single species (poplar, birch and lodgepole pine) were tested in pellet producing, where no other species were added. Best results in pellets mechanical durability showed poplar durability as 98.8%, which would met the ENplus certification requirements in mechanical durability. Lodgepole pine (96.8%) and birch (92.3%) pellets showed lowed durability and will not meet the ENplus certification requirements in mechanical durability.

Deciduous trees in 2014 covered 54.8% of all forest lands in Latvia (Latvian forest sector...2015). Most of the deciduous stands are forests that emerged naturally on former agricultural land and consist mainly of so-called pioneer species including birch (*Betula* spp.), grey alder (*Alnus incana* (L.) Moench) and aspen (*Populus treemula* L.). (Liepins et al., 2015). According to area common species are birch (28%), grey alder (10%) and aspen (8%) (Latvian forest sector...2015). Low quality and small dimension timber could be used in pellet production. In this study all three main deciduous tree species were tested as main material for pellet production and mixed with coniferous trees. Birch was mixed with larch and pine, grey alder mixed with pine and lodgepole pine, aspen was mixed with pine and larch and mixture of birch and aspen (50:50) was mixed with pine and larch. In all cases deciduous trees were the base material and their share was at least 70% of the mixture.

Two mixes with grey alder were tested where it was mixed with pine (proportion 75:25) and lodgepole pine (proportion 70:30). Mechanical durability where grey alder was mixed with pine was 98.8% (fulfils ENplus quality class) and with lodgepole pine 95.5%. In this particular case grey alder mix with pine showed better durability results than mix lodgepole pine.

Pellets where only birch wood was used showed low mechanical durability – 92.3%. To improve durability other coniferous tree species were added to birch and tested. Mixtures were made mixing birch wood (where total birch share was 85–70%) with pine and larch (with total share in mixture 15–30%). (see Fig 1)

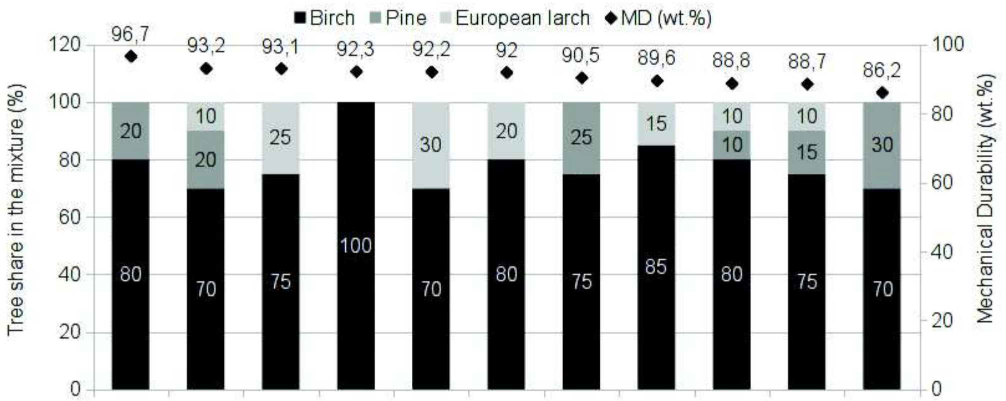

Figure 1. Pellets mechanical durability where birch is the base component.

Durability for pellets where birch was mixed with pine and larch ranged between 96.7% and 86.2% which is not enough to meet any of the ENplus quality classes. These pellets could be used as lower quality burning material or used as litter material for animals. Tests showed that mixing birch with coniferous trees will not improve pellets durability, at least in this case where birch proportion is at least 70% and pellets are made in small scale machine. Significant difference between added coniferous species was not detected.

Aspen was mixed with pine and larch in different proportions where aspen share was at least 70%. All mixes shoved low mechanical durability where the highest number was 94.6% and the lowest 88.1%. All mixtures are under ENplus durability standards. Pellets with added pine shoved better results than mixtures with added larch (see Fig. 2).

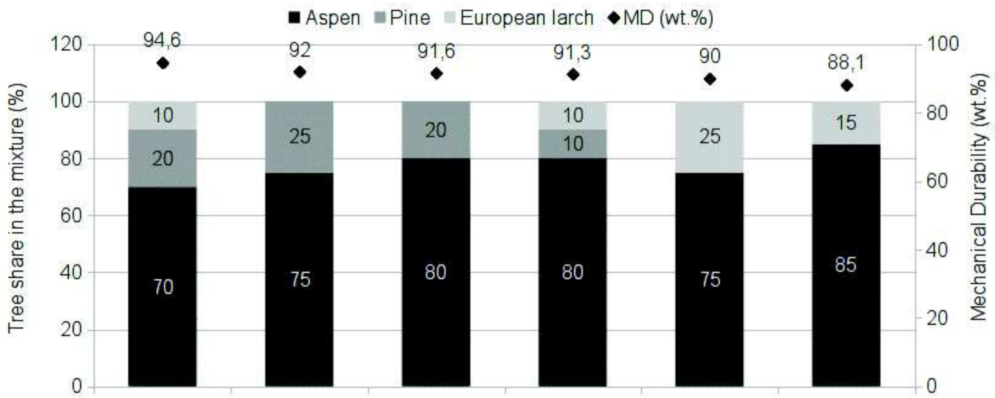

Figure 2. Pellets mechanical durability where aspen is the base component.

Birch and aspen in equal parts were mixed with pine and larch, where deciduous tree share was at least 70%. All mixes showed low mechanical durability where the highest number was 95.4% and the lowest 88.5%. All mixtures are under ENplus durability standards (see Fig. 3). Birch and pine mixture as base material didn't show noticeably better results in mechanical durability than single specie used as base material.

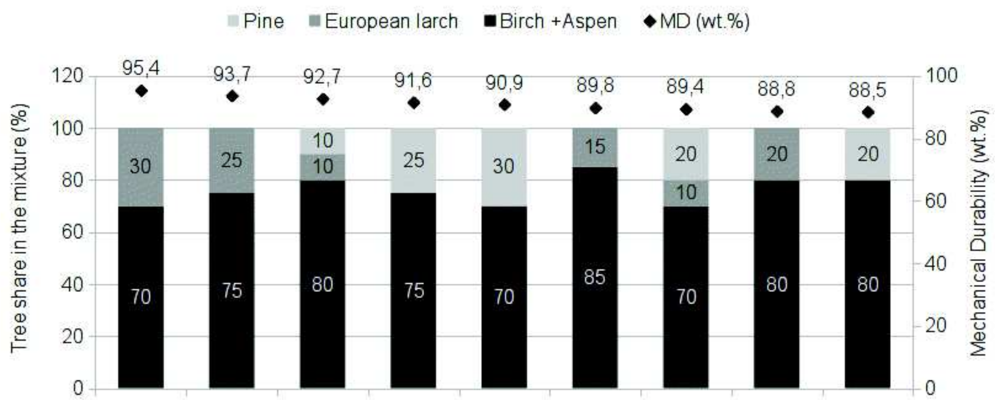

Figure 3. Pellets mechanical durability where birch and aspen mixture is the base component.

Best pellet mechanical durability from deciduous trees was with poplar. Poplar was mixed with larch and lodgepole pine, where poplar share was at least 70%. Best durability was 99% where poplar was mixed with larch and lodgepole pine (proportions 80:10:10). Totally from 9 different mixes 7 of them showed pellets mechanical durability higher than 97.5% which is enough to fulfil the ENplus durability standards. From all deciduous tree species that were tested for pellet productions, poplar shoved the best results in mechanical durability (see Fig. 4).

Previous studies shows that poplar hybrid (*Populus balsamifera x P. laurifolia*) planted density 5,000–7,000 trees ha^{-1} at the age 54–65 mean annual volume increment is 7.5–21 m^3 ha^{-1} y^{-1} and total above-ground dry biomass increment reached

4.2–9.8 t ha^{-1} y^{-1}. This suggests that poplar could be a viable alternative for biomass production in Latvia (Jansons et al., 2014b).

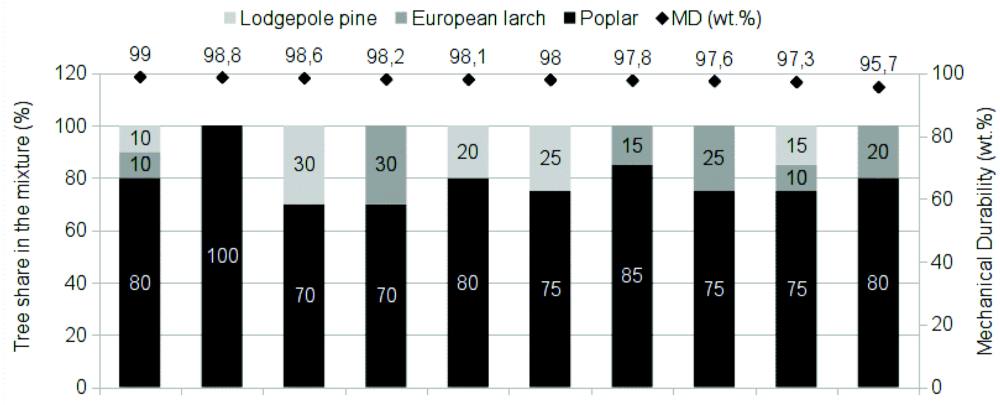

Figure 4. Pellets mechanical durability where poplar is the base component.

Coniferous trees in 2014 covered 45.2% of all forest lands in Latvia with main species - pine (29%) and spruce (17%). (Latvian forest sector...2015). Main species were not taken as base material in study, pine was used only as added material. In this study basic material was from coniferous trees taken European larch, which is introduced species with total area of 1139 ha (Dreimanis, 1995). European larch was mixed with other coniferous trees -pine and lodgepole pine and deciduous trees–birch and grey alder and larch share in all cases was at least 70% of the mixture. Better results showed from mixtures with lodgepole pine and little worse in mixtures with grey alder and pine. Totally from 9 different mixes 7 of them showed pellets with mechanical durability higher than 98% what is enough to fulfil the ENplus durability standards. Pellets only from lodgepole pine were made and mechanical durability was 96.8% which is not enough for ENplus standard (see Fig. 5).

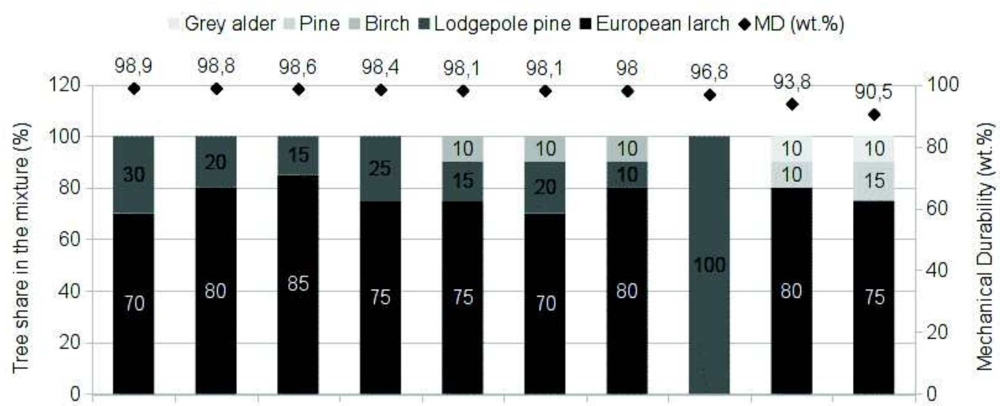

Figure 5. Pellets mechanical durability where European larch is the base component.

In cases where pellets quality is not sufficient as combustion material, instead of remaking them, they could be used as litter material for animals. All pellet samples that were used for durability tests also were tested for water absorption. The results of experiments show that the water absorption in pellets with different tree species wood composition does not change significantly and ranges from 0.70 to 0.73 ml g^{-1}. Pellets that are sold in market as animal litter pellets also were tested for water absorption according to the same methodology. Tests were done to three different manufacturers of wood pellets which were manufactured as litter material. Water absorption for pellets sold in retail shops as litter material was 0.75–0.8 ml g^{-1}. Results showed that commercially available pellets water absorption is not significantly higher than in this study manufactured pellet, which lead to an option that pellets that could not meet the durability criteria could be sold as litter material for animals.

CONCLUSIONS

During this study 49 different tree wood mixes were pelletized in a small scale pelletizer where mechanical durability and water absorption for produced pellets was later tested. Quite big difference was observed between different deciduous tree species that were tested. Mechanical durability where grey alder was mixed with pine was 98.8% (fulfils ENplus quality class). Poplar also showed good durability results and in some mixes meet the criteria for mechanical durability with best result 99% in mixes with European larch and lodgepole pine (proportions 80:10:10). From 9 different poplar mixes 7 of them shoved mechanical durability higher than 97.5%. Other mixes with birch, aspen and grey alder when they were taken as base material for pellet production (wood volume share in the mixture at least 70%) didn't meet the mechanical durability limit for ENplus quality classes and it was lower than 97.5%. Also in samples where birch and grey alder were used without adding other tree species durability was under 97.5%. Poplar also showed high pellets durability results–98.8% when no additives was added to poplar in pelletizing process. After first trials it was concluded that not all deciduous tree species could be used in pellet production, at least with regard to concerns of mechanical durability and when they are pelletized on small scale pelletizer. On the other hand tree species like poplar and grey alder in some mixes showed promising results in pellets mechanical durability tests and advanced researches on these species could be desirable.

Coniferous trees in this study mostly were used as additives to deciduous tree mixes and added wood volume did not exceed 30%. European larch only from coniferous trees was tested as base material, with share proportion in the wood mixes at least 70%. Best results in mechanical durability European larch showed in mixes with lodgepole pine (proportion 70:30). From 9 different European larch mixes that were tested, 7 of them showed durability higher than 97.5%, what is sufficient for ENplus certification. In test where lodgepole pine with no additives was used in pellets showed unsatisfactory results in mechanical durability. European larch shoved promising results as base material in pellet productions and advanced researches could be desirable.

In small scale pelletizing most of the activities are done manually which may have impact of quality issues. Mechanical durability could be improved by adjusting pelletizer and work methods to specific tree specie or mixture. In this tests several tree species were tested in short time period and in relatively small volumes. According to previous experience different tree species could have different regulations on the pellet machine and it could be done more precisely when larger amount of one tree specie or the same tree mixture is pelletized.

According to literature studies, no single factor in pellet production, including tree species or different tree specie fraction mixing can't be assumed as dominant factor. Many different factors could influence the pellet mechanical durability and in most of the cases it's the interaction of all these factors. However, tree species or tree specie mix is one of the factors that could influence the pellets mechanical durability and should be taken into account before starting small scale pellet production.

Water absorption in pellets with different tree species composition does not change significantly and ranges from 0.70 to 0.73 ml g^{-1}. For pellets sold in market as litter material water absorption was 0.75–0.8 ml g^{-1}. Preliminary tests leads to conclusions that if pellets mechanical durability is not satisfactory to sell it as combustion material in could be sold as litter material for animals.

ACKNOWLEDGEMENTS. Research were done by implementation of European Regional Development Fund projects No 2013/0049/2DP/2.1.1.1.0/13/APIA/VIAA/031.

REFERENCES

Arshadi, M., Cref R., Geladi P., Dahlqvist, S., Lestander T. 2008. The influence of raw material characteristics on the industrial pelletizing process and pellet quality. *Fuel Processing Technology* **89**, 1442–1447.

Calderon, C., Gauthier, G., Jossart, J.M. Bioenergy outlook 2014. *Statistical Report 2014, European Biomass Association (AEBIOM)*, Brussel.

Daugaviete, M., Lazdina, D., Bambe, B., Bardule, A., Bardulis, A. & Daugavietis, U. 2015. Productivity of Different Tree Species in Plantations on Agricultural Soils and Related Environmental Impacts. *Baltic Forestry* **21**(2), 349–358.

Dreimanis, A. 1995. Dižskabārdis un lapegle Šķēdes mežniecībā. *In: Forestry education 75th anniversary conference proceedings oj Latvia University of Agriculture*. 94–97.

ENplus Quality Certification Schemes For Wood Pellets. *EN plus Handbook for countries no managed by any national licenser/supporter. Part 3:Pellet Quality Requirements. Version 3.0*, August 2015.

Garcia–Maraver, A., Popov, V., Zamorano, M. 2011. A review of European standards for pellet quality. *Renewable Energy* **36–12**, 3537–3540.

Hiegl, W., Janssen, R., 2009. *Pellet Market Overview Report Europe, WIP Renewable Energies Wolfgang Hiegl Rainer Janssen under the EIE programme (EIE/06/020/SI2.448557)*, Munich.

Jansons, Ā., Zeps, M., Rieksts-Riekstiņš, J., Matisons, R., Krišāns, O. 2014a. Height increment of hybrid aspen Populus tremuloides×P. tremula as a function of weather conditions in south-western part of Latvia. Silva Fennica vol. 48 no. article id 1124. 13 p

Jansons, Ā., Zurkova, S., Lazdina, D., Zeps, M. 2014b. Productivity of polar hybrid (Populus balsimiferaX P. laurifolia) in Latvia. *Agronomy Research* **12**(2), 469–478.

Jansons, A., Sisenis, L., Neimane, U., Rieksts-Riekstiņš, J. 2013a Biomass production of young lodgepole pine (*Pinus contorta var. latifolia*) stands in Latvia. *iForest – Biogeosciences and Forestry* **6**, 10–14.

Jansons, A., Matisons, R., Libiete-Zālīte, Z., Baders, E., Rieksts-Riekstiņš, J. 2013b Relationships of Height Growth of Lodgepole Pine (*Pinus contorta var. latifolia*) and Scots Pine (*Pinus sylvestris*) with Climatic Factors in Zvirgzde, Latvia. *Baltic Forestry* **19**(2), 236–244.

Jansons, A., Matisons, R., Baumanis, I., Purina, L. 2013c. Effect of climatic factors on height increment of Scots pine in experimental plantation in Kalsnava, Latvia. *Forest Ecology and Management* **306**, 185–191.

Jansons, Ā., Matisons, R., Zadiņa, M., Sisenis, L., Jansons, J. 2015. The effect of climatic factors on height increment of Scots pine in sites differing by continentality in Latvia. *Silva Fennica* **49**(3), id 1262, 14p.

Kaliyan, N.R. Vance, R. 2009. Factors affecting strength and durability of densified biomass products. *Biomass and Bioenergy* **33**, 337–359.

Karkania, V., Fanara, E., Zabaniotou, A. 2012. Review of sustainable biomass pellets production – A study for agricultural residues pellets' market in Greece. *Renew Sust Energ Rev*. **16**, 1426–1436.

Kristöfel, C., Strasser, C., Erwin Schmid, E., Morawetz, U. 2016. The wood pellet market in Austria: A structural market model analysis. *Energy Policy* **880**, 402–412

Latvian forest sector in Facts and Figures 2015. Available https://www.zm.gov.lv/public/ck/files/ZM/mezhi/buklets/Latvian_Forest_Sector_in_Facts_and_Figures2014.pdf. Seen 12.01.2016.

Lazdiņš, A., Kalēja, S., Gruduls, K., Bārdulis, A. 2013. Theoretical evaluation of wood for bioenergy resources in pre-commercial thinning in Latvia. *Research for Rural Development* **2**, 42–47.

Lehtikangas, P. 2001. Quality properties of pelletised sawdust, logging residues and bark. *Biomass and Bioenergy* **20**, 351–360.

Liepiņš, K., Lazdiņš, A., Liepiņš, J., Prindulis, U. 2015. Productivity and cost-effectivnes of mechanized and motor-manual harvesting of Grey Alder (*Alnus incana* (L.) Moench): A case study Latvia. *Small-scale Forestry*. DOI10.1007/s11842-015-9302-1.

Mola–Yudego, B., Selkimäki, M., González–Olabarria, JR. 2014. Spatial analysis of the wood pellet production for energy in Europe. *Renew Energ* **63**, 76–83.

Obernberger, I., Thek, G. 2004. Physical characterisation and chemical composition of densified biomass fuels with regard to their combustion behaviour. *Biomass and Bioenergy* **27**, 653–669.

Olsson, O., Hillring, B., Vinterbäck, J. 2011. European wood pellet market integration - A study of the residential sector. *Biomass Bioenergy* **35**, 153–160.

Pirragila, A., Gonzalez, R., Saloni, D., Wright, J. 2010. Wood pellets: an expanding market opportunity. *Biomass magazine*.

Sikkema, R., Steiner, M., Junginger, M., Hiegl, W., Hansen, M., Faaij, A.T. 2011. The European wood pellet markets: current status and prospects for 2020. *Biofuels, Bioproducts Biorefining* **5**(3), 250–278.

Thomson, H., Liddell, C. 2014. The suitability of wood pellet heating fordomestic households: A review of literature. *Renewable and sustainable energy review* **42**, 1362–1369.