ANALYSIS OF HEATING VALUE VARIATIONS IN STORED WOOD

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Abstract. This paper presents dynamics of calorific value variations in wood grown in Lithuania that can be used for fuel, namely: Scotch pine (*Pinus sylvestris*), osier willow (*Salix viminalis*) and silver birch (*Betula pendula*). Felled wood with a moisture content of *Pinus sylvestris* – 42.95 %, *Salix viminalis* – 43.34 % and *Betula pendula* – 37.82 % respectively, was stored in 3 variants of environmental conditions: on the ground, lifted above the ground and under a blow-off shelter. Purpose of the study – to analyse variations of moisture content in growing and felled wood, depending on the ambient air (weather) and storage conditions, influencing wood fuel production. To determine regularities of lower thermal energy variations in cut wood. Experimental trials had been conducted at the Department of Heat and Biotechnological Engineering, Lithuanian University of Agriculture. It was determined that moisture content and calorific value of wood stored outdoors depended on ambient air humidity and rainfall variations. Lower thermal energy value of wood stored under the blow-off shelter increased during spring period, and had always been approx. by 40.55 % (4.88 $MJ \cdot kg^{-1}$) higher than that in open storage yards.

Keywords: wood, bio-fuel, calorific value, ambient air, moisture exchange.

Introduction

Moisture content of wood depends on the ambient air parameters: relative air humidity and air temperature [17]. Wood is hygroscopic material and hygroscopicity is one of the distinctive (characteristic) properties of wood. Usually equilibrium moisture content of wood stored in outdoor conditions is sufficiently high ~25-30 % [16]. In order to prevent and to protect wood from microbiological agents and self-heating, its handling-storage processes should be controlled.

From thermodynamic point of view, could be justified only wood drying in naturally circulating ambient air up to equilibrium moisture content, while protecting wood from direct rainfall. During storage, natural drying process takes place with minimal labour and energy consumption [18].

From November to April vegetation of osier willow slows down and its moisture content is ~50 % [9]. Hall affirms that moisture content of wood just after cutting is approx. ~55-60 % [5].

When felled in spring wood is stored 3 or 4 months in open air conditions, its moisture content decreases to 20 % [1].

Pari L. et al. showed that wood (poplar), stored in stacks in field conditions from March to November, reduced its moisture content by 41.4 % and reached equilibrium level equal to 18.3 %. Dry matter losses of the dried-up wood amounted to 8.5 %. After felling, storage of poplar in piles (stacks) was the best method of wood drying in ambient air, thus maintaining the highest quality of fuel in terms of energy saving [12]. When whole wood is stored in stacks as bio-fuel, there are no problems regarding self-heating, increasing moisture content and dry matter losses. In natural environment conditions, wood demoisturises and dries-up naturally, using wind and solar energy. Maximal dry matter losses could be 1 % per month. Large stacks of wood over 6 m high are exception, as splinters of wood, bark and branches of lower diameter form a coherent stack layer. Microbiological processes and self-heating can take place in those stacks [6].

Wood branches tied in bundles can be successively stored on the ground for several months with low losses as well. The moisture content decreases, whereas dry matter losses range from 6 to 10 % [8, 13].

Moisture content of wood stored under the blow-off shelter can decrease from 45 % to 25 % in 6 months. When the wood pile is covered with a waterproof material such as tent-cloth, moisture from its central part transfers to the upper pile layers [14]. A pile without a waterproof cover demonstrates better moisture evaporation depending on weather conditions (relative air humidity, ambient air temperature, rainfall). Lower thermal energy value of wood, stored in a forest site during May to June, increased from 6 to 14 $MJ \cdot kg^{-1}$ [5].

Purpose of the study – to analyse variations of moisture content in growing and felled wood, depending on ambient air (weather) and storage conditions that have impact on fuel production. To determine regularities of lower heat energy variations in cut wood.

Materials and methods

Wood moisture content determination methods. The research work was started on March 15th, 2008 and was carried out for one year. Object of the study – trees growing in Lithuania: Scotch pine (*Pinus sylvestris*), osier willow (*Salix viminalis*) and silver birch (*Betula pendula*). Cut wood of the above mentioned species (12 pieces in each bulk) with moisture content of 42.95 %, 43.3 % and 37.82 % respectively was stored in open field conditions in 3 sites: under the blow-off shelter, of 0.4 m height, on the ground and lifted above the ground (Figure 1). The wood was stored above the soil, and pieces of wood of the tested species lay on a sheet of roof cover, which was put on two balks, thus preventing a contact with growing grass. Diameter of cut wood was Ø30 mm ± 10 and its lengths were 3 to 4 meters. Wood moisture content and lower thermal energy values had been determined periodically every 10 days, at a laboratory of Heat and Biotechnological Engineering Department, Lithuanian University of Agriculture.

Fig 1. **Samples of a Scotch pine (*Pinus sylvestris*), osier willow (*Salix viminalis*) and silver birch (*Betula pendula*)**

Wood moisture content was determined according to the EU approved methodology CEN/TS 14774–1 [1]. At first a piece of wood of 50 mm lengths was cut away, and it was not used in further tests. Only after that we cut two separated 10 mm long rods of different wood species, which were used for a moisture content determination by drying with MEMMERT SFP600 oven at 105 ˚C ± 2 temperature, to its constant weight for 24 hours and for thermal energy value determination. Before the trail, the sliced samples were stored in sealed packages. The test wood was chopped in a laboratory using a wood shear. 20 g samples of different wood species, two samples of each kind, were used for a moisture content determination. Parameters of the ambient air were determined by analysis of weather observation data from Kaunas hydro-meteorological station. In order to obtain more reliable results, experimental data from the yearlong period were statistically compared with annual average monthly temperature data.

Moisture evaporation from porous material in natural air flow conditions depends on one of the parameters of moist air – deficiency of moisture content in the air Δd, $g \cdot kg_{d.a}^{-1}$ and on temperature.

In order to determine a level of evaporation from wood, it is necessary to know the amount of heat which comes with ambient air flow. During evaporation in evaporation zone, the blown air loses portion of its heat. Air humidity increases and its temperature decreases at drying, because heat energy is wasted for water evaporation. Enthalpy of wet air *i*, $kJ \cdot kg_{d.a}^{-1}$ is a basic parameter for thermal drying process evaluation.

Equilibrium moisture content of wood depends on humidity and on temperature of the ambient air. The difference between sorption and desorption is known as hysteresis of sorption and amounts to 2.5 % [7].

Analysis of the experimental data has shown a correlation between moisture content of wood under blow-off shelter, lying on the ground, above the ground and growing wood, and moisture deficiency in the air.

Methods of lower thermal energy value determination. We have determined lower thermal energy value of felled, growing and stored in mentioned above places wood and of completely dry wood, using the EU method [1], as soon as moisture content was determined. The upper thermal energy value of wood was determined in accordance with the standard CEN/TS 14918:2005 using calorimeter IKA C2000 at its constant volume. Material used for calibration was certified benzoic acid (its calorific value was known). According to this process, amount of heat energy, needed to raise temperature in a calorimeter system by 1°K is used for thermal capacity (specific heat) estimation. The upper calorific value of a material is calculated according to this.

Crucibles with wood samples were weighed with accuracy of 0.1 mg, using analytical balance KERN ABJ–120–4M. Biomass energy was measured as a lower thermal energy value. Therefore, upper thermal energy value of wood, measured with a calorimeter was converted, according to moisture content of the wood samples and their chemical composition, into lower thermal energy value Q_l^t, MJ·kg^{-1} according to the equation [10]:

$$Q_l^t = Q_u^t \times (1 - \frac{w}{100}) - 2.447 \times \frac{w}{100} - \frac{h}{100 \times 2} \times 18.02 \times 2.447 \times (1 - \frac{w}{100}), \quad (1)$$

where Q_u^t – upper thermal energy value, MJ·kg^{-1};

w – wood moisture content, %;

h – hydrogen content in wood, %.

Results and discussion

Variation regularities of wood moisture content and deficiency of air humidity. Air temperature and humidity, rainfall, seasonality and wood storage method are the main factors determining dynamics of moisture content in stored wood and the resulting wood losses. In our experiment, moisture content of growing wood in vegetation period ranged 56.8 % ± 11.2 for *Pinus sylvestris*, 51.2 % ± 10.3 for *Salix viminalis* and 46.3 % ± 7.9 for *Betula pendula*, whereas in cold period moisture content of wood varied 50.3 % ± 2.8 for *Pinus sylvestris*, 48.1 % ± 0.7 for *Salix viminalis*, and 45.7 % ± 1.2 *Betula pendula* respectively. Wood bio-fuel quality depends on storage conditions.

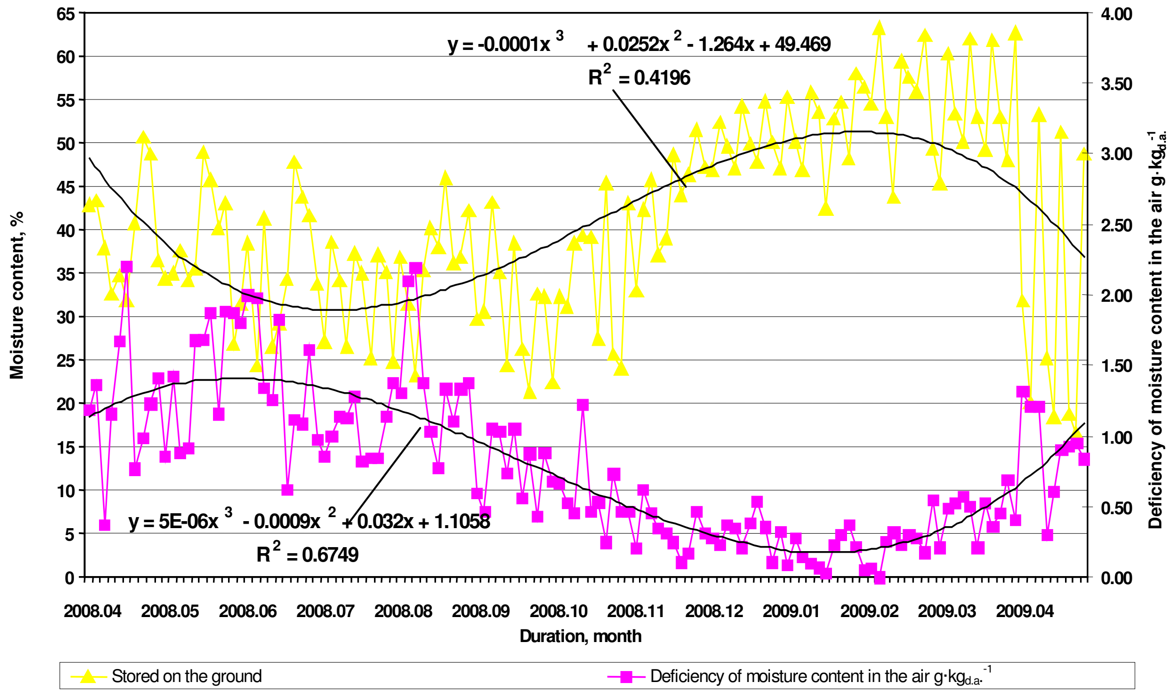

Fig. 2. **Variation of moisture content of wood stored on the ground**

Contact of stored wood with the ground is a key factor which determines sorption characteristics of wood, depending on weather conditions (Figure 2). Felled wood, stored on the ground during spring – summer period dried up approximately from 41.4 % ± 2.51 to 32-37 % of moisture content, when moisture deficiency in air ranged approximately to 1.06 $g \cdot kg_{d.a}^{-1} \pm 0.23$, whereas in winter its moisture content had increased to 49.9-63.2 %, when moisture deficiency varied approximately in 0.4 $g \cdot kg_{d.a}^{-1} \pm 0.04$ range.

In order to control the rate of moisture content of wood stored on the ground, it would be useful to protect it from direct rainfall from early September.

In blow-off shelter the moisture content of felled wood during the spring over 100 days had decreased (wood dried up) from 41.4 % ± 2.51 and had always fallen in 12-15 % range (Figure 3).

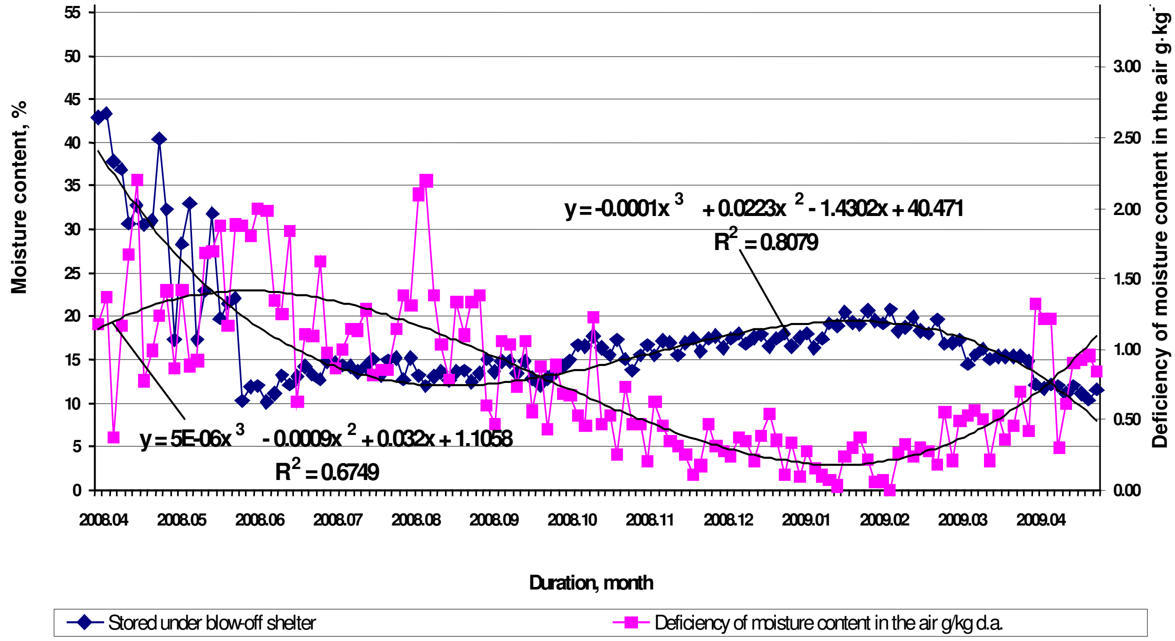

Fig. 3. **Variation of moisture content of wood stored under the blow-off shelter**

Whole wood loaded in piles and branches tied in bundles can be stored under blow-off shelter all through the year, without any significant variation of moisture content.

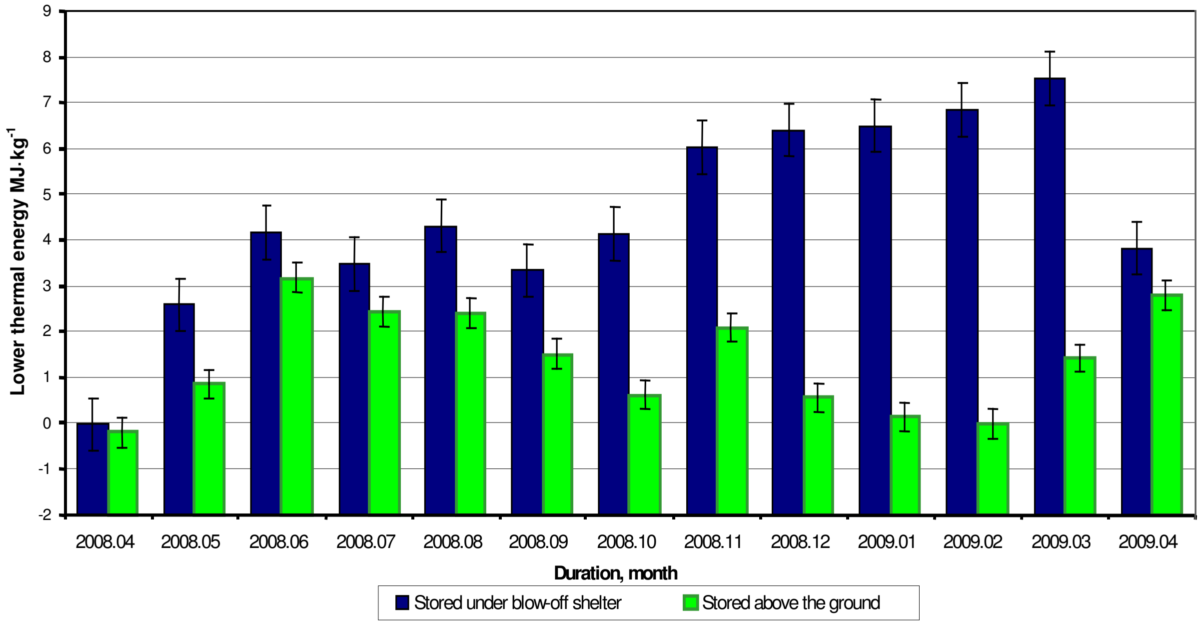

Fig. 4. **Efficacy of lower thermal energy of wood, compared to LTE value of wood stored on the ground**

Lower thermal energy value – 10.83 MJ·kg^{-1} ± 0.11 of wood stored under blow-off shelter decreased to 16.91 MJ·kg^{-1} over 100 days period in spring, and had always been by approx. 40.55 % (4.88 MJ·kg^{-1})

higher than that in open storage yards. Lower thermal energy value of wood stored under blow-off shelter was by 3.90 MJ·kg^{-1} ± 0.30 higher in warm period, whilst in cold period - by 6.66 MJ·kg^{-1} ± 0.51 higher as compared to wood stored on the ground (Figure 4).

Lower thermal energy value of wood stored above the ground during warm period was by 2.46 MJ·kg^{-1} ± 0.55 higher, and over the cold period it was by 0.59 MJ·kg^{-1} ± 0.51 higher as compared to wood stored on the ground (Figure 4).

Conclusions

1. Moisture content of growing wood ranged: *Pinus sylvestris* (56.8 % ± 11.2), *Salix viminalis* (51.2 % ± 10.3) and *Betula pendula* (46.3 % ± 7.9) respectively, and in winter - *Pinus sylvestris* (50.3 % ± 2,8), *Salix viminalis* (48.1 % ± 0.7), *Betula pendula* (45.7 % ± 1.2) respectively.
2. Felled wood, stored on the ground, during the spring-summer period dried up approximately from 41.4 % ± 2.51 to 32-37 % of moisture content, when moisture deficiency in air ranged approximately to 1.06 g·$kg_{d.a}^{-1}$ ± 0.23. , whereas in winter its moisture content increased to 49.9-63.2 %, when moisture deficiency varied approximately in 0.4. ± 0.04 g·$kg_{d.a}^{-1}$ range.
3. In a blow-off shelter, moisture content of felled wood during 100 days period in spring had decreased (wood dried up) from 41.4 % ± 2.51 and had always fallen in 12-15 % range.
4. Lower thermal energy value 10.83 MJ·kg^{-1} ± 0.11 of wood stored under blow-off shelter increased during spring period (increased to 16.91 MJ·kg^{-1} in 100 days), and had always been approx. by 40.55 % (4.88 MJ·kg^{-1}) higher than that in open storage yards.

References

1. Alakangas, E. Properties of Wood Fuels in Finland, Technical Research Centre of Finland, VTT Processes. Project report PRO2/P2030/05, Jyvaskyla, 2005.
2. CEN/TS 14774-1:2005, Solid biofuels – Methods for the determination of moisture content – Oven dry method – Part 1: Total moisture – Reference method.
3. CEN/TS 14918:2005, Solid biofuels – Method for the determination of calorific value.
4. Čekanavičius, V., Murauskas, G. Statistika ir jos taikymai. 1 dalis. – Vilnius.:TEV, 2000. 240 p.
5. Hall P. Effects of storage on fuel parameters of piled and comminuted logging residues. LIRO report vol. 25 No. 5. 2000.
6. Hall P. Storage Gudelines for Wood Residues for Bioenergy. EECA Te Tari Tiaki Pūngao, report by Scion, 2005, 25 p.
7. Hill C. A. S. Wood Modification: Chemical Thermal and Other Processes, Series: Wiley Series in Renewable Resources, Chichester, Sussex, UK, 2006, 260 p.
8. Hudson B., Hudson B. Technical developments in wood fuel harvesting. In Forestry Engineering for Tomorrow. Harvesting technical papers. Edinburgh University, June 1999.
9. Huisman W. Optimising Harvesting and Storage Systems for Energy crops in the Netherlands. Proceedings of International Conference on Crop Harvest and Processing, 9-11 February, Lousville, Kentucky, USA.
10. Nemestothy K. Perspektiven für die Biomasseversorgung in Österreich. In: Katzensteiner K., Nemestothy K. Energetische Nutzung von Biomasse aus dem Wald und Bodenschutz – Ein Widerspruch? Manuskript f. Mitteilungen der Österreichischen Bodenkundlichen Gesellschaft. Heft 74, 1-10, 2006.
11. Nurmi J. Properties and storage of whole-tree biomass for energy. The Finnish Forest Research Institute, Research Papers 758. 2000, 42 p.
12. Pari L., Cirielo, A., Gallucci, F. Consequence of SRF Poplar Wood Harvesting Method on Energy Content Preservation. Proceedings of 16-th European biomass Conference Exhibition, 2-6 June 2008, Valencia, Spain, pp. 517-522.
13. Pettersson M., Nordfjell T. Fuel quality changes during seasonal storage of compacted logging residues and young trees. Biomass and Bioenergy, 2007, 31, pp. 782-792.

14. Serup H. (editor). Wood for energy production, Technology – Environment – Economy. The Centre for Biomass Technology. (Contributors (Falster H., Gamborg C., Gundersen, P., Hansen, L., Heding, N., Jakobsen H. H., Kofman P., Nikolaisen L., Thomsen I.), 1999.
15. Siau J.F. Wood: influence of moisture on physical properties. Virginia Tech., Blacksburg, 1995.
16. Simpson W. T. Equilibrium moisture content of wood in outdoor locations in the United States and worldwide. USDA Forest Serv. Res. Note FPL-RN-0268, 1998.
17. Skaar C. Wood – water relations. Springer-Verlag, Berlin, 1998. 283 p.
18. Świgoń J. Suszenie biomasy (zwłaszcza odpadow drzewnych) przed spalaniem. Inż. Roln., 2003, 13, pp. 175-181.