Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 86, 2014:86-91
(Ann. WULS - SGGW, For. and Wood Technol. 86, 2014)

Quantification of the ash content from biofuel - wood according to *ISO 1171 (2003)* and *EN 14775 (2010)*

LADISLAV DZURENDA – ĽUBOMÍR PŇAKOVIČ
Faculty of Wood Sciences and Technology at Technical University in Zvolen (Slovakia)

Abstract: In this paper there are presented the results of works realized to quantify the ash content from annealing wood according to *EN 14775:(2010)* and *ISO 1171:(2003)*. From the performed analyses it can be stated that the average ratio of ash from annealing process at a temperature t = 550 ± 10 °C (*EN 14775:(2010*)) for the tree species *Picea excelsa* is A^d = 0.29 ± 0,01 %, for *Fagus sylvatica* A^d = 0.44 ± 0,04 % and for *Salix alba* A^d = 0.461 ± 0.03%. The values in comparison to the ash content from annealing process wood at a temperature t = 815 ± 10 °C (*ISO 1171:(2003*)) by the form of the relative rate of increase the ash content are by ΔA^d= 22,91 ÷ 44,83 % higher. For the objectification of the information on the ash content produced in the combustion process of wood there should be taken into account the appliance of certain standard for determining the ash content, depending on the temperature of wood combustion in the furnace power equipment. Not respecting this fact can be a source of errors in the energetic, environmental and ecological analyses and statements of wood – as biofuel from the point of view of the production of ashes.

*Keywords***:** ash, biofuel - wood, *EN 14775:(2010, ISO 1171:(2003)*

INTRODUCTION

Ash is the inorganic residue after combustion of fuel in solid forms. According to the works of *Nikitin (1956), Buchanan (1963), Blazej et al. (1975), Dzurenda (2005), Dobrowolska et. al. (2010)*, the ash from the combustion of biofuel - wood is a mixture of oxides: K_2O, Na_2O, CaO, MgO, Fe_2O_3, Al_2O_3, SiO_2, P_2O_5 with a quantitative representation of A^d = 0.3 – 07 %. The Standard *EN 14961-1 Solid biofuels* indicates the average value of A^d = 0.3 % in the interval: <0.1% ÷ 1%> for the wood of softwood and <0.2% ÷ 1>% for the wood of hardwoods. Ratio of ash from the combustion of dendromass in comparison with the combustion of fossil fuels is, if proceeding from firewood, 15 to 30 times lower than from coal or coke combustion *Dzurenda-Jandačka (2010)*.

Determination of the ratio of ash from the combustion of fuels for the energy needs is performed in accordance with *ISO 1171 Solid mineral fuels Determination of ash*. In 2009, the European Committee for Standardization adopted for biofuels the standard *EN 14775 Solid biofuels. Determination of ash content*, which in comparison with the standard *ISO 1171 Solid mineral fuels. Determination of ash* differs so in the thermal decomposition temperature of the fuel, and also the annealing temperature of the non-volatile combustibles fuel.

In this paper there are presented the results of experimental works carried out to assess the standards *EN 14775:(2010)* and *ISO 1171:(2003)* content via quantification of the ratio of ash from biofuel – wood.

MATERIALS AND METHODS

For the laboratory works to quantify the production of ash there was used biofuel - wood proceeding from the following tree species: Spruce (*Picea excelsa*), Beech (*Fagus sylvatica*), Willow (*Salix alba*).

The density of wood in the dry state of the individual tree plants, from which there were taken the samples to determine the ratio of ash, was determined by: STN 49 0108:

(1993) Wood - Determination of density. The density was calculated from the measured weight of the sample and its volume, according to the following equation:

$$\rho_0 = \frac{m_0}{V_0} \quad \left[kg.m^{-3}\right] \tag{1}$$

where:

ρ_0 – density of dry sample [kg.m^3]
m_0 – weight of dry sample [kg]
V_0 – volume of dry sample [m^3]

The resulting value of the density of wood samples from analysed dendromass of the individual tree species is determined in the form of mathematical writing: $\rho_0 = 0 \pm U_A$, i.e. the average value density of wood in dry state = $\overline{\rho}_O$ and the standard measurement uncertainty of type U_A. Calculation of the standard measurement uncertainty of type U_A on the border of statistical confidence level of 95% quantifies the equation no. 2:

$$U_A = k \cdot \sqrt{\frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n.(n-1)}} \tag{2}$$

where:

U_A - standard uncertainty of type A
k - coefficient dependent on the number of repeated measurements
y - measurand
$\bar{y}$- sample average
n - measured values

Combustion of wood samples in a muffle furnace LAC LMH 04/12 was carried out in accordance with the two existing standards *ISO 1171 Solid mineral fuels - Determination of ash* and *EN 14775 Solid biofuels - Determination of ash content* and was realized in the laboratories of the Department of Woodworking, Faculty of Wood Sciences and Technology, Technical University in Zvolen (Slovakia).

A sample of biofuel with a weight of approximately 10 grams, during the works in the laboratory according to *EN 14775:(2010) - Solid biofuels - Determination of ash content*, was heated at a rate of 4.5 °C/min. i. e. in 50 min. it was heated to a temperature of 250 °C and maintained this temperature for 60 min., due to the release of volatiles substances from the sample. Subsequently the temperature increased to t =550 ± 10 °C and annealing was carried out at this temperature for 360 min. After cooling it to the room temperature t = 25 °C the ash dish was weighed with the accuracy of 0.1 mg.

In laboratory testing, according to *ISO 1171:(2003) Solid mineral fuels - Determination of ash*, the sample of biofuel with weight of approximately 10 grams was heated to a temperature t = 500 ° C and annealed for 60 min. Then the temperature was increased to t = 815 ± 10 °C and on this temperature continued annealing for 360 min. After cooling it to the room temperature t = 25 ° C the ash dish was weighed with the accuracy of 0.1 mg.

The ash content attributable to the dry matter of wood A^d of analyzed sample, expressed as a percentage by mass, is then calculated according to equation no. 3:

$$A^d = \frac{(m_3 - m_1)}{(m_2 - m_1)} * 100 \ [\%] \tag{3}$$

where:

A_d- the ratio of ash[%]

m_1- the weight of the empty dish[g]
m_2- the weight of the dish with the test sample[g]
m_3- the weight of the dish with ash[g]

The resulting value of the ratio of ash from the analyzed samples of wood - biofuel of the individual plants is provided in the form of mathematical writing: $A^d = \overline{A^d} \pm U_A$, i. e.the average value of the ash ratio and standard measurement uncertainty of type U_A.

RESULTS

The ash content from wood samples of the analyzed tree species: *Piceaexcelsa*, *Fagus sylvatica*, *Salix alba* determined according to the standards: *EN14775:(2010) and ISO1171:(2003)* is given in Tab. 1 for each tree species respectively.

Tab. 1 The ash content from tree species sample analysed determined according to the standards *EN14775:(2010) and ISO1171:(2003)*

Tree species	Number of samples	Wood density in the dry state [kg.m^{-3}]	Method for determining the ash content	The ash content from dendromass [%]
Piceaexcelsa	12	$\rho_0 = 421 \pm 35$	*EN 14775:(2010)*	$A^d = 0{,}29 \pm 0{,}01$
			ISO 1171:(2003)	$A^d = 0{,}16 \pm 0{,}01$
Fagus sylvatica	12	$\rho_0 = 658 \pm 41$	*EN 14775:(2010)*	$A^d = 0{,}44 \pm 0{,}04$
			ISO 1171:(2003)	$A^d = 0{,}32 \pm 0{,}03$
Salix alba	12	$\rho_0 = 498 \pm 25$	*EN 14775:(2010)*	$A^d = 0{,}46 \pm 0{,}03$
			ISO 1171:(2003)	$A^d = 0{,}35 \pm 0{,}02$

Difference in the formation of ash from annealing process of wood at a temperature t = 550 ± 10 °C and annealing temperature t = 815 ± 10 °C of the analyzed tree species is displayed in visual form via the diagram in Fig. 1.

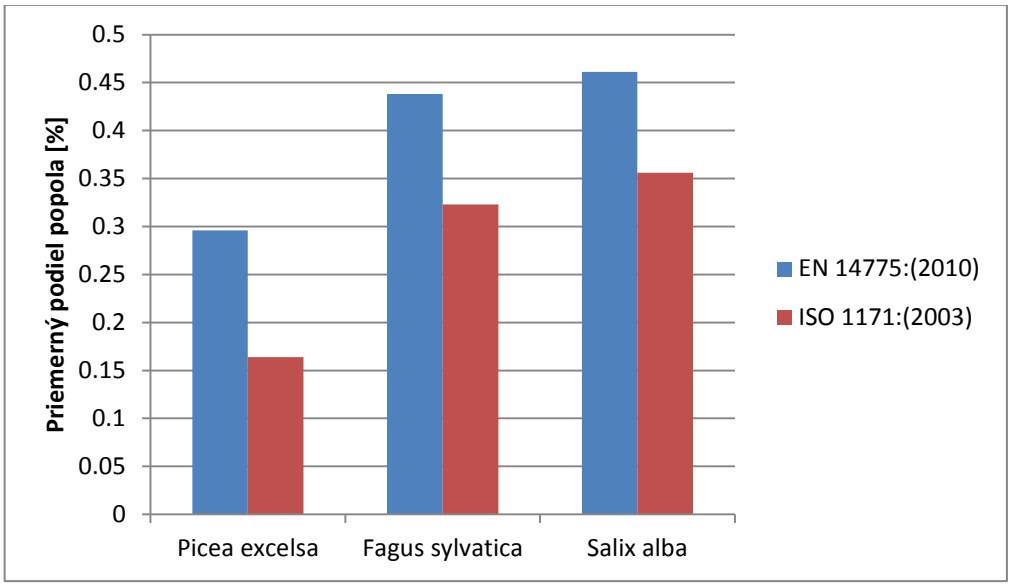

Fig.1 The ash content from annealing process of wood analyzed tree species at a temperature t = 550 ± 10 °C (*EN 14775:2010*) and temperature t = 815 ± 10 °C (*ISO 1171:2003*)

Relative rate of increase of the ash content from annealing process of the dendromass at a temperature t = 550 ± 10 °C and annealing temperature t = 815 ± 10 °C of the analyzed tree species, determined according to equation (4), is stated by the Tab 2.

$$\Delta A^d = \frac{A^d_{t=550} - A^d_{t=815}}{A^d_{t=550}} \cdot 100 \ [\%] \qquad (2)$$

where:

$A^d_{t=550}$- the ash content from annealing dendromass at a temperature t = 550 ± 10 °C [%]

$A^d_{t=815}$- the ash content from annealing dendromass at a temperature t = 815± 10 °C [%]

Tab. 2 Relative rate of increase of the ash content determined according to *EN 14775:(2010)* and *ISO 1171:(2003)*

Tree species	Relative rate of increase of the ash content ΔA^d[%] determined according to *EN 14775:(2010)* and *ISO 1171:(2003)*
Piceaexcelsa	44,83
Fagussylvatica	27,27
Salixalba	23,91

DISCUSION

The density of spruce, beech and willow wood in the dry state (Tab. 1), which samples were taken to determine the ash content, can be described as average wood density values of the analyzed tree species.

The fact that the ash content from the combustion of dendromass decreases with an increase in annealing temperature for all of the performed analyses is in accordance with the works concerned with the transformation of the ash, contained in the dendromass for heating in the temperature range of 500 ÷ 1400 °C - authors: *Misra et al. (1993), Otepka - Tóthová (2011)*. The significant loss of ash mass begins at about 600 °C and arises because of the decomposition of carbonates of calcium, magnesium and potassium, depending on the tree species.

Based on analyses, and for the objectification of information on the ash content produced in the combustion process of biofuel, there should be taken into account the appliance of certain standards for determining the ash content, depending on the temperature in the furnace power equipment. Not respecting this fact can be a source of errors in the energetic, environmental and ecological analyses and statements of wood – as biofuel from the point of view of the production of ash.

CONCLUSION

From the realized experimental measurements aimed to establish the ash content from wood according to *EN 14775*, respectively *ISO 1171* there can be stated the differences in production of ash. The production of ash at the annealing temperature of wood t = 550 ± 10 °C (*EN 14775: 2010*) is higher than the annealing temperature of the wood of the same tree species at t = 815 ± 10 °C (*ISO 1171: 2003*).

The relative rate of increase of ash content determined according to *EN 14775 (2010)* compared with the *ISO 1171 (2003)* is for the wood of the tree species *Picea excels* on by ΔA^d = 44.83 %, for *Fagus sylvatica* on by ΔA^d = 27,27 % and for *Salix alba* by ΔA^d = 23.91 % higher.

For the objectification of information on the ash content produced in the combustion process wood, there should be taken into account the appliance of certain standards for determining the ash content, depending on the temperature in the furnace power equipment. Not respecting this fact can be a source of errors in the energetic, environmental and ecological analyses and statements of dendromass from the point of view of the production of ash.

REFERENCES

1. BLAŽEJ, A. *et al*. 1975. Chemistry of wood. 1st Ed. ALFA, Bratislava, 221 pp.
2. BUCHANAN, N. A. 1963. Extraneous Components in Wood. In: The Chemistry of Wood. New York – London – Sydney.
3. DOBROWOLSKA, E., et al. 2010. Energy use of dendromass.1st Ed. SGGW, Warsaw, 168 pp.
4. DZURENDA, L. 2005. Combustion of wood and bark. Zvolen, Technical university in Zvolen, 124 pp.
5. L. Dzurenda, J. Jandačka, "Energetic utilization of dendromass", (in Slovak) Technical University in Zvolen, Slovakia, 2010, 161 pp.
6. MISRA, M. K., RAGLAND K. W., BAKER, A. J., 1994 :Wood ash compositionas a function of furnace temperature. Biomass and Bioenergy, 4(2), p. 103 – 116.
7. NIKITIN, N. I. 1956. Wood chemistry.Prague : SNTL, 552 pp.
8. OTEPKA, P., TÓTHOVÁ, S. 2011. Properties of wood ash and its possible use in the cultivation of energy plants.Bratislava, 31 pp.
9. EN 14 961:2010 Solid biofuels – Fuel specifications and classes
10. EN 14775:2010 Solid biofuels - Determination of ash content
11. ISO 1171:2003 Solid mineral fuels – Determination of ash
12. STN 49 0108:1993 Wood – Determination of density

Streszczenie: *Ocena ilościowa zawartości popiołu w biopaliwie – drewnie zgodnie z ISO 1171 (2003) oraz EN 14775 (2010).* W niniejszym artykule przedstawiono wyniki prac realizowanych w celu oszacowania zawartości popiołu przy wyżarzaniu drewna według EN 14775: (2010) oraz ISO 1171: (2003). Z przeprowadzonych analiz można stwierdzić, że średni stosunek popiołu z procesu wyżarzania w temperaturze t = 550 ± 10 ° C (EN 14775 (2010)) dla Picea excelsa wynosi = 0,29 ± 0,01% , dla Fagus sylvatica A^D = 0,44 ± 0,04%, a dla Salix alba A^D = 0,461 ± 0,03%. Wartości te, w stosunku do zawartości popiołu z drewna przy wyżarzaniu w temperaturze t = 815 ± 10 ° C (ISO 1171: (2003)), są o ΔA^d = 22,91 ÷ 44,83% wyższe. Dla uwiarygodnienia informacji o zawartości popiołu wytwarzanego w procesie spalania drewna powinno siępodawać temperaturę wyżarzania oraz określać układ zasilania pieca. Nieprzestrzeganie tego faktu może być źródłem błędów w energetycznych, środowiskowych i ekologicznych analizach drewna - jako biopaliwa, z punktu widzenia produkcji popiołów.

Ackonwledgement: This experimental research was undertaken with the financial support based on the grant agreement KEGA–SR No: 006TU Z-4/2014, of the agency KEGA–SR.

Corresponding authors:

LadislavDzurenda,
Faculty of Wood Technology, Technical University of Zvolen,
T.G.Masaryka 24, 96053 Zvolen, SLOVAKIA,
e-mail: dzurenda@vsld.tuzvo.sk

ĽubomírPňakovič,
Faculty of Wood Technology, Technical University of Zvolen,
T.G.Masaryka 24, 96053 Zvolen, SLOVAKIA,
e-mail: dzurenda@vsld.tuzvo.sk