INFLUENCE OF THE TEMPERATURE COMBUSTION OF FUEL-WOOD TO CONTENT ASH

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ABSTRACT

In this contribution, there are presented the results of experiments determining the influence of combustion temperature of fuel-wood on the production of ash. They confirm current knowledge about the low production of ash from wood, and specify the functional dependences between the influence of temperature at intervals of *t* = 500°C – 1000 °C on the production of ash from the wood of tree species: Norway spruce, White birch, European beech, English oak and Black locust.

The functional dependences of ash production on the combustion temperatures are instrumental for objectification of information about ash production from energy facilitiesfor energy, environmental, and ecological analyses and balances.

The proportion of ash from fuel-wood can be done according to standard ISO 1171:2003, or standard EN14775:2010. These standards differ in the temperature of combustion of the fuel wood sample. ISO 1171:2003 burns fuel at *t* = 815 °C while EN14775:2010 at *t* = 550 °C. Disregarding the aforementioned facts about the dependence of production of ash on the combustion temperature causes errors. By interchanging the norms ISO1171:2003 with EN14775:2010, the balances from combustion of spruce wood generate a relative error of 44.58%. The balances from combustion of wood of black locust generate a relative error of 19.10%.

Key words: fuel, wood, combustion, temperature, ash.

INTRODUCTION

Ash is the inorganic residue after combustion of fuel. Inorganic proportion of wood is formed by minerals which trees gain during growth from the soil through the root system. These are mainly carbonates, sulfates, calcium, magnesium, potassium, and in substantially less amount, phosphates, chlorides and silicates as well as other elements.

The content and concentration of individual elements and mineral substances, as stated by the authors (Blažej *et al.* 1975, Simanov 1995, Zevenhoven 2001, Pitman 2002, Zuleand Dolenc 2012, Gochev*et al.* 2012, Dzurenda *et al.*2013, Hytönenand Nurmi 2015, Pérez *et al. 2015,* Dzurenda and Banski 2015, Pňakovičand Dzurenda 2015) slightly differ between individual wood species. Needles, leaves, bark, wood of branches and roots contain a higher concentration of inorganic substances than the wood of the tree stem. There are also differences related to the age of the tree; young individuals contain a higher concentration of mineral substances than older individuals and, additionally, the wood of deciduous wood species is richer in minerals than the wood of coniferous wood species.

Data on the amount of inorganic substances in dendromass is mainly obtained from indirect determination, i.e. from ash (residue after combustion of dendromass). In terms of ash production from the combustion process, the dendromass ranks amongst fuels with a low ash content with values for dry wood of A^d = 0.21–0.67% and bark of A^d = 1.80–5.55%. According to works by (Nikitin 1956, Buchanan 1963, Blažej *et al.*1975, Misra*et al.* 1994, Dzurenda and Jandačka 2010, Zevenhoven *et al.* 2010),ash from burning wood is a mixture of oxides: K_2O, Na_2O, CaO, MgO, Fe_2O_3, Al_2O_3, SiO_2, and P_2O_5.Although the amount and content of ash from dendromass depends upon the wood species and the abovementioned factors, for quantitative representation of individual oxides in ash from wood and bark, (Blažej*et al.* 1975) state the following ranges: CaO = 40–70%, K_2O = 10–30%, MgO = 0.5–10% and Fe_2O_3 = 0.5–2%. The inorganic fraction of wood is also dependent on the combustion temperature of biofuels according to the works of (Misra *et al.* 1994, Malaťak and Vaculík 2008, Zevenhoven *et al.* 2010, Fernandes *et al.* 2013, Dzurenda and Pňakovič 2014, 2015). The proportion of ash decreases with a growth in the combustion temperature of the dendromass. Ash from the combustion process of dendromass below 750 °C also contains thermally undecomposed carbonates, sulphates and silicates.

The aim of the given work is to present the results of the influence of combustion temperature t = 500 °C – 1000 °C of fuel-wood of tree species: Norway spruce, White birch, Beech, Oak, and Black locust to produce ash from energy facilities.

EXPERIMENTAL METHODS

Samples of fuel-wood of wood species: Norway spruce, White birch, European beech, English oak and Black locust for analysing the influence of the burning temperature of fuel-wood on the production of ash were taken from the logs in the dispatch stores of Gabčíkovo and Žarnovica Forest Management.

Determination of the proportion of ash from the analysed wood species was carried out by burning samples of dry wood (W^r = 0%) weighing circa 10 g placed in a ceramic dish in muffle furnace: LAC LMH 04/12, (Fig. 1).

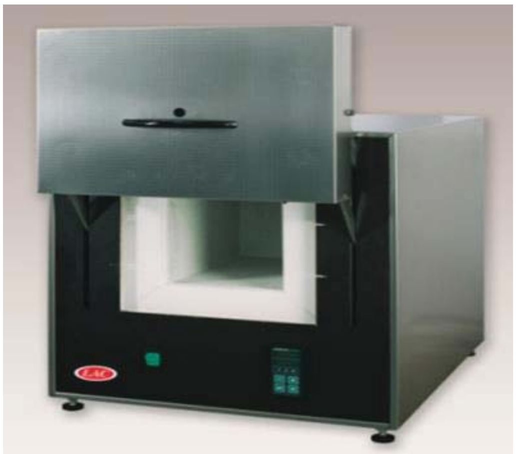

Figure 1: Muffle furnace: LAC LMH 04/12

Heating and combustion of wood in the first phase at temperature t = 500 °C was carried out by even heating of the wood sample at a rate of 8 °C.min^{-1} for 60 min. and subsequent maintenance of this temperature in the muffle furnace for a further 390 min. A similar method was used for burning in temperatures t = 600 °C to 1000 ºC. In the first phase of burning the wood sample was heated to 500 °C at a rate of 8 °C.min^{-1} and was maintained at this temperature for a further 30 min. In the second phase we proceeded in heating the non-volatile combustible matter of the sample for 60 min. to the required temperature and this temperature was maintained in the muffle furnace for 360 min. (Fig. 2). The content of ash A^d was calculated using the equation:

$$\boldsymbol{A^d} = \frac{(m_3 - m_1)}{m_2 - m_1} \cdot \mathbf{100}\ [\%] \qquad \textbf{(1)}$$

where:

A^d– ash content in the fuel [%],

m_1 – weight of the empty dish [g],

m_2 – weight of the dish with the fuel sample [g],

m_3 – weight of the dish with the ash [g].

The weighing of wood samples and cold ash samples was carried on the Radwag WPS 510 C scales with a weighing accuracy of 0.001 mg.

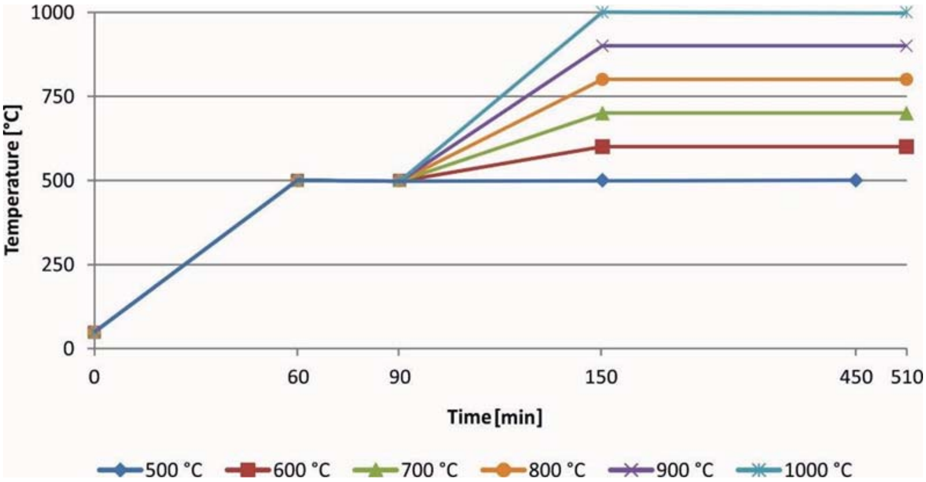

Figure 2: The temperature profile of the sample heating and combustion of biofuels in a muffle furnace

RESULTS AND DISCUSSION

The results of laboratory works determining the production of ash from of the analysed wood species at temperatures t = 500 °C to 1000 °C are shown on (Fig. 3).

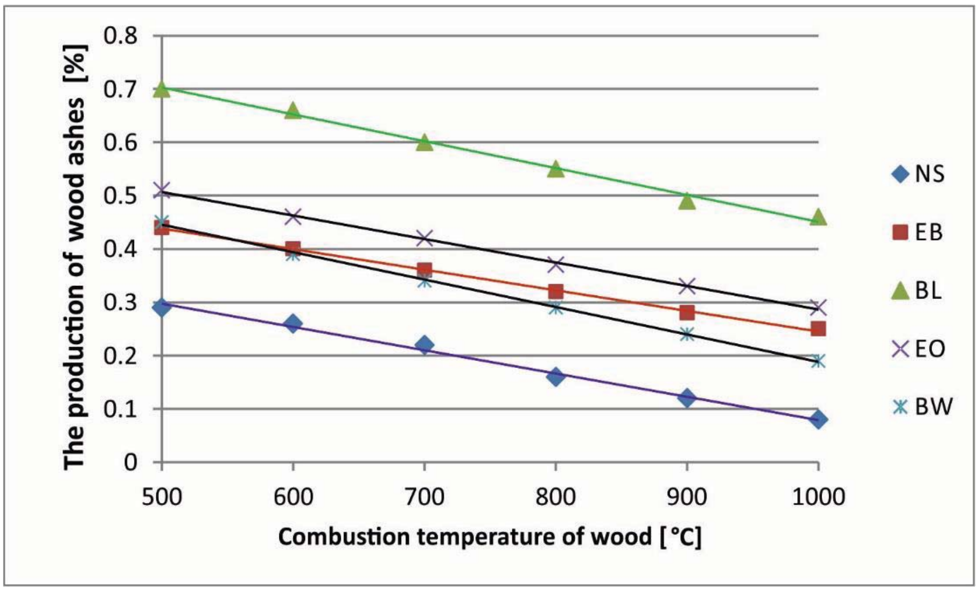

Figure 3: Ash depending on the wood species: Norway spruce (NS), White birch (BW), European beech (EB), English oak (EO), Black locust (BL)

The functional dependence producing ash from burning spruce, beech, oak and black wood in the temperature range: t = 500°C –1000 °C is given in Table 1.

Table 1: The functional dependence of production of ash on combustion temperature

Wood species	Functional dependence	Correlation coefficient
Norway spruce *Piceaabies* L.	$A^d = 0.5162 - 0.0004 \cdot t$	$R^2 = 0.9928$
White birch *Betula pendula Roth*	$A^d = 0.7024 - 0.0005 \cdot t$	$R^2 = 0.9990$
European beech *Fagus sylvatica* L.	$A^d = 0.6310 - 0.0004 \cdot t$	$R^2 = 0.9982$
English oak *Quercusrobur*	$A^d = 0.7267 - 0.0004 \cdot t$	$R^2 = 0.9984$
Black locust *Robiniapseudoacacia*	$A^d = 0.9538 - 0.0005 \cdot t$	$R^2 = 0.9937$

The results of analyses stating the proportion of ash from burning of fuel-wood of the analysed wood species have been confirmed by current knowledge of the low proportion of ash from wood presented in the works of (Simanov 1995, Geffertová and Gefert 2003, Vesterinen 2003, Jandačka*et al*. 2007, Malatak and Vaculik 2008, Dzurenda *et al*. 2013) and at the same time, they show a certain dispersity of values of inorganic residue within a wood species, induced by its thermal decomposition. The inorganic proportion of wood is highly heterogenic and mainly formed of carbonates and sulphates, $CaCO_3$, $MgCO_3$, $FeCO_3$, $CaSO_4$, $MgSO_4$, which, at individual temperatures, decompose with varying intensity into carbon dioxide CO_2 and the appropriate metal oxides. This is also confirmed by our analysis of the proportion of calcium carbonate $CaCO_3$ in ash from black locust wood, according to which, at burning temperature of t = 500 °C, the ash contained 78% calcium carbonate $CaCO_3$, at burning temperature t = 700 °C the value of calcium carbonate decreased to 66% and at burning temperature t = 800 °C the proportion of calcium carbonate $CaCO_3$ in the ash decreased to 13%. Another thermal process contributing to a decrease in the production of ash, according to the works of SIPPULA et al. (2007), TISSARI (2008), is the evaporation of potassium during thermal decomposition of K_2CO_3, KCl and K_2SO_4.

Determining the functional dependences between a decrease in the content of ash and the combustion temperature of wood of the Norway spruce, White birch, Beech, Oak, and Black Locust can be considered as a contribution towards widening current knowledge since it can be used for energy, environmental and ecological analyses.

The proportion of ash from fuel-wood can be done according to standard ISO 1171: 2003, or standard EN14775: 2010. These standards differ in the temperature of combustion of the fuel wood sample. ISO 1171: 2003 burns fuel at t = 815 °C while EN14775: 2010 at t = 550 °C. Disregarding the aforementioned facts about the dependence of production of ash on the combustion temperature causes errors. By interchanging the norms ISO1171:2003 with EN14775:2010, the balances from combustion of spruce wood generate a relative error of 44.5%. The balances from combustion of wood of black locust generate a relative error of 19.10%.

CONCLUSIONS

The results of experiments determining the influence of burning temperature of fuel-wood on the production of ash confirm current knowledge about the low production of ash from wood, and specify the functional dependences between the influence of temperature at intervals of t = 500°C –1000 °C on the production of ash from the wood of tree species: Norway spruce, White birch, European beech, English oak and Black locust.

With increasing combustion temperature of fuel-wood, the production of ash decreases due to thermal decomposition of minerals forming the inorganic proportion of wood. Disregarding of the stated fact in balances of ash production from energy facilities burning fuel-wood is accompanied by certain errors.

By interchanging the norms ISO 1171: 2003 with EN14775:2010, the balances from combustion of spruce wood generate a relative error of 44.58%. The balances from combustion of wood of black locust generate a relative error of 19.10%.

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ACKNOWLEDGEMENT

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.

UNIVERSITY OF FORESTRY

FACULTY OF FOREST INDUSTRY

INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN

1/2017

INNO vol. VI Sofia

ISSN 1314-6149
e-ISSN 2367-6663

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