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GROSS CALORIFIC VALUE OF LEAVES, BARK, AND BRANCHES OF SELECTED DECIDUOUS TREES

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Research article

Abstract: If we want to reduce the flammability of wood and wood materials we must be based on deep knowledge of the composition of these materials, their structure and their elementary building and other factors influencing many aspects of their flammability. The most important aspects of the flammability characteristics are important indicators as to the dynamics of fire development, determination of fire load and fire risk and smoke production and its subsequent toxic gases. The paper deals with characteristics such as flammability and gross calorific value. Measurements were conducted on six selected species of deciduous trees, particularly in their leaves, twigs, bark and wood. Gross calorific value was determined in oven-dry sample.

Keywords: Gross calorific value, forest fire, deciduous trees.

Introduction

Forests are an integral part of nature and have paramount importance for man. They are a rare source of material, which is always renewed; their fruits in many cases provide food and vitamins. The extensive forest complexes and also forests in the vicinity of human settlements are an important component of air regeneration and direct the production of oxygen, but also minimize the harmful effects of various air pollutants and dust. In addition, the diversity form and variety of colours during active season is aesthetic and relaxing (Pagan and Randuška, 1987).

Forest ecosystems except the positive properties, currently represent a danger of forest fires in our area. The cases of the past year confirm the previous sentence. Changes in climatic conditions, methods and systems in forestry and climatic and geographic conditions create an environment in which forest fire may occur. The terms "recorded" not only fire but also its development and that way we record forest fires with large scale, high damages to forests and costly work of a fire-works (Černý and Šenovský, 2010).

Most studies of forest fires have focused on forests with dominant of conifers wood. However, the mentioned fires (Old Mountains and Bošáca) occurred in mixed environment with greater representation of deciduous trees. There was a new phenomenon, new fuel - leaves that complicate the work of firemen and threatened affecting components. For this reason we deal with gross calorific value of selected deciduous species in this article. Of these species, we selected those parts (leaves, branch and bark), which contribute mostly to the development of a forest fire (Tureková, 2009).

Materials and methods

Selective deciduous wood

Red oak, *Quercus rubra Linnaeus*

Red Oak is 30 to 50 m tall, fast growing deciduous tree, its crown is conical at first, in the elderly age large and spherical.

Leaves: alternate, stem is 2 - 5 cm long, the blade in the outline is elliptical, 10 - 25 cm long and 5 - 15 cm broad, at base cuneate to rounded, lobed to slit on each side with 4 - 6 indented irregularly spiny lobes. The lobes are rounded wedge-shaped cores and cuttings mostly do not extend deeper than ¼ the width of the blade. The obverse is red oak leaves matt dark green colour, lighter on the reverse. Autumn colour is orange-red to scarlet.

Bark: gray, long smooth dark gray bark, scaly thin (Aas and Riedmiller, 1997).

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Beech, *Fagus sylvatica L.*

Beech is one of our most common species. Root system early passes into the heart shape. The bark is greyish brown in young age, later constantly grey-white and remains smooth.

Branches are from mature green to brown twigs. The buds are long spindle, alternate, pointed, built-row. Leaves are alternate, ovate, shortly pointed and short stem, with a bright upside.

Physical age of beech is 200 to 500 years. Beech is a timber, which increases the importance of developing chemical treatment of wood. Soil protects shading and litter enriched with nitrogen and lime and a good rooting contributes to its aeration. We anticipate that beech litter supplies 80 kg of lime for 1 h.

Beech is very sensitive to smoke, so it is not a suitable tree species for cities. Wood is a multiple porous, glossy, hard and heavy, not a different colour core. However, it often creates a false heart. (Aas and Riedmiller, 1997; Mračková, 2005).

White birch, *Betula pubescens Ehrh*

White Birch is a medium-high (up to 20 m), deciduous tree with ellipsoidal crown, its branches rigid stand out at an acute angle to equilibrium. The tops are usually not over- hag twig.

Leaves: alternate, rather rigid, stem 1 to 2.5 cm long, hairy at least initially, to egg-shaped diamond blade, rounded at the corners, usually shorter than the pointed and upturned white birch, 3 - 5 cm long, just to double saw blade on the cheek more or less bare, the reverse have down look and later (except veined leaves) bald.

Bark: Initially mat-white, annular peels off in thin lateral strips, bark is hilarious, blackish, hard, and is made later (Aas and Riedmiller, 1997).

Maple, *Acer saccharum Linnaeus*

Maple is 25 (35) m tall deciduous tree with a dense spherical crown with large branches.

Leaves: opposite, very variable size, the stem is 17 cm long, blade 8 - 17 cm long, 10 - 20 cm wide, with 5 - 7 lobes, lobes of the front teeth, teeth sharply pointed and upturned, rounded cores, on the obverse and reverse slightly glossy, pale green. Fall colour yellow to yellow - red.

Bark: light gray, smooth bark dark gray to blackish, densely longitudinally hilarious, does not peel off in scales (Aas and Riedmiller, 1997).

Aspen poplar (aspen), *Populus tremula Linnaeus*

Aspen poplar is rapidly growing to 30 m tall deciduous tree with large sparse crown.

Leaves: alternate, stem side compressed, about as long as 3 - 8 cm large, round to egg-shaped blade on the edge of thick blunt teeth, hairy only at first, early glabrous, on the face shine-green, lighter on the reverse. Leaves of long shoots are more powerful (up to 15 cm), ovate to triangular, rather short-petiolate.

Bark: Initially gray-green, long, smooth, black-gray, longitudinal bark hilarious. (Aas and Riedmiller, 1997)

Purple Willow, *Salix purpurea Linnaeus*

Purple Willow is a shrub, sometimes occurs as a 10 m tall deciduous tree. It has thin branches, rod, and tension upright.

Leaves: alternate, but opposite, lanceolate, short pointed and upturned, the widest in the upper third, 4 - 12 cm long and 1.5 cm wide, the top of the finely serrated on both sides of the bare, blue-green on the back to grey-green, always without add leaves.

Bark: Willow has abundant, watery bark, its sap is heavily charged with salicylic acid. (Aas and Riedmiller, 1997, Požgaj et al., 1997, Durenda et al., 2010).

Of these trees, was prepared samples of leaves, branches and bark for further search. Removed samples were homogenized to the same size, and dried at 0 % moisture (oven-dry sample).

Determination of gross calorific value with the bomb calorimetric method

The essence of determining gross calorific value is complete combustion of mass or volume of flammable substances in pure oxygen at a given pressure. Water, which burned, contained flammable substance, is excreted in the liquid state.

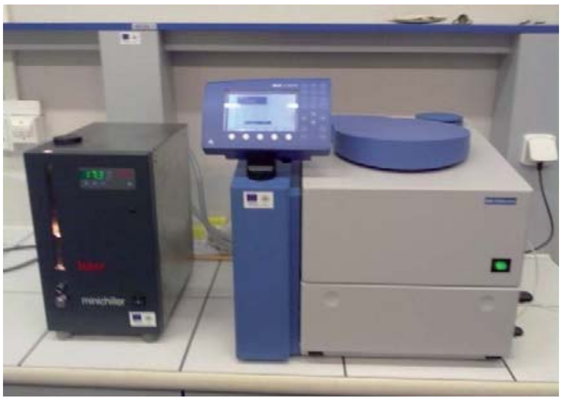

Fig. 1 Calorimetric equipment IKA C5003 control

The calorimetric determination of gross calorific value was performed according to the standard ISO 1928. Calorific value was determined for all these broad-leaved trees, especially the leaves, branch and bark.

For experimental determination of gross calorific value, calorimeter IKA C5003 control device is used (Fig. 1). Used equipment meets the requirements of standard EN ISO 1928 and ČSN EN 14918 (Kalorimetrický systém IKA C 5000, 1999).

Calorimetric measurement is based on the fact that in the calorimeter, the combustion process occurs under precisely defined conditions. For this purpose, to the decomposition is given a weighing of sample containers of fuel, it ignites and measures the temperature rise in the calorimetric system. Specific gross calorific value of the sample is calculated from the following:

- sample weight of fuel,
- heat capacity (C) calorimetric system,
- increase the water temperature in the inner container, a measuring device.

To optimize the burning process, the decomposition vessel meets with pure oxygen (99.95 %). Pressure of oxygen in the atmosphere decomposition vessel was 3.0 MPa. Accurate detection of gross calorific value is based on the requirement that the burning took place under precisely defined conditions. The applicable conditions are based on the following assumptions:

- temperature of the substance to be burned, temperature before burning is 22 °C,
- water filled in the substance and the water formed during combustion of compounds containing hydrogen are present in the liquid state after burning,
- there is no oxidation of atmospheric nitrogen,
- gaseous decomposition products are oxygen, nitrogen, carbon monoxide and sulphur dioxide,
- the reminder is a solid ash.

To ensure exactly reproducible measurement results, the calorimetric system is calibrated after launch, after maintenance, the replacement of parts and the transfer of the calorimeter to a different location in periodic intervals (once every two months). Last calibration of the used calorimeter was made on January 10, 2011, when the calorimeter was set for heat capacity of 10 736 J.°C^{-1}.

At the calibration, the heat capacity (C value) of calorimetric system (amount of heat required to heat the calorimetric system by 1 °C) is repeatedly determined. The essence lies in the determination of thermo chemical burning normal (certified benzoic acid) of known calorific value, under the same conditions, the same equipment and the same pressure vessel as determined by the gross calorific value samples. Regular calibration is absolutely necessary to maintain the accuracy of measurements (STN ISO 1928, 2003).

Calorific value was determined for samples tested at 0 % moisture (oven-dry samples). The gross calorific value is calculated for each test according to the relation:

$$H_{Oan} = \frac{C \cdot \Delta T - Q_z}{m} \quad (1)$$

where H_{Oan} calorific density in the reference state analysis of moisture [J.g^{-1}], C heat capacity of the calorimeter [J.°C^{-1}], ΔT increase of the temperature in calorimetric system during the combustion experiment [°C], Q_z excess energy from the ignition, ignition of cotton fibres, the auxiliary combustion substance, energy produced at HNO_3 [J], m mass of burnt substance [g].

Calorimetric system makes it possible to set the mode without titration. In that case, the energy produced at HNO_3 production is calculated according to the formula (Kalorimetrický systém 1999):

$$Q_N = N \cdot m \cdot 43 \quad (2)$$

where Q_N energy produced at HNO_3 production [J], N the percentage of nitrogen in sample [%], m mass of burnt substance [g].

The measured gross calorific value in an oven-dry sample state is recalculated to w % moisture. The formula for calculation of gross calorific value at constant volume for water:

$$q_{v \cdot gr \cdot d} = q_{v \cdot gr} \cdot \left(1 - 0{,}01\, M_T\right) \quad (3)$$

where $q_{v \cdot gr \cdot d}$ gross calorific value at w % moisture [J.g^{-1}], $q_{v \cdot gr}$ gross calorific value at 0 % moisture [J.g^{-1}], M_T the water content in the fuel, which was found in trial [%].

Results

The fuel at forest fires comes from all part of the tree. The first contact is the bark, branches, and we must not forget the leaves, which is the leaf litter. Each part of the tree has some representation, and the parts are evaluated separately.

First, we evaluated the leaves that have a different composition, size, shape, thickness and as confirmed by (Fig. 2), the value of gross calorific value. The beech has the largest representation percentage between selected trees and it reached the second highest gross calorific value. It is interesting that the leaves of birch reached the highest gross calorific value among other selected species. For specific fire, which we mentioned in the introduction, there were just the leaves which burnt or smouldered, creating different formations to move on steep terrain and lit another part of the forest. If so far only coniferous trees were considered the fire risk, after this experiment can be seen that also deciduous trees leaves with their high calorific value can cause some problems. The birch is in gross calorific value followed by beech and maple has the lowest calorific value.

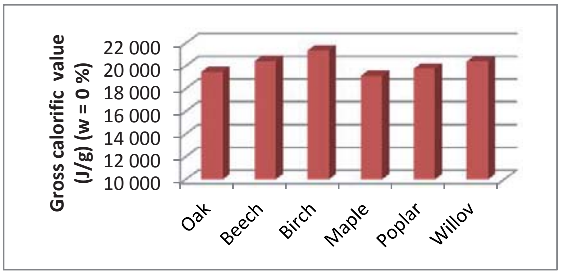

Fig. 2 Gross calorific value - Leaves

Gross calorific value of branches does not exhibit significant difference between the trees, see (Fig. 3). Birch and willow reached the highest value, while poplar had the lowest. For branches, we chose ridges 0.5 to 0.8 mm cross section and in the creation of samples to maintain the overall structure of branches, bark, fibber and woody parts of the branches.

The difference in the branches is likely to determine the structure of wood holding relatively high density of wood, making the results somewhat homogenized. The difference between the trees is minimal.

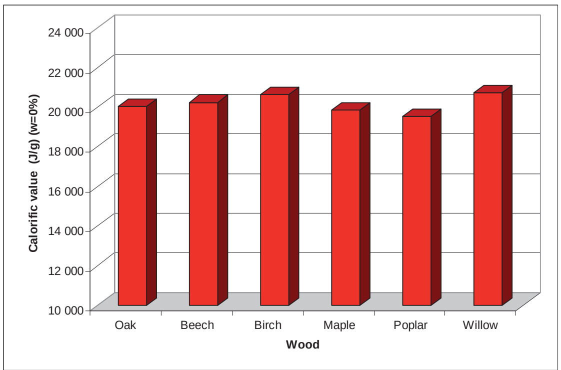

Fig. 3 Gross calorific value - Branches

Bark has a significant impact particularly on the development of fire and the transition from ground fire on treetop. Results of the experiment confirm what is known in scouting, that a circle of birch bark is the best for the ignition of fire. Calorific birch bark has reached the highest value among all testing materials thus the leaves and branches (Fig. 4).

Results which can be seen on (Fig. 5) show the tested components of diversity, leaves, branches and bark of the selected wood species. When we plan the experiment, we might even foresee that these differences will be great. Wood such as oak, birch, maple and poplar (not absolute values) have the lowest gross calorific value in the leaves, followed by branches and eventually peel which has all testing trees at the highest value. The gross calorific value of the thermal birch bark has already been mentioned, surprising results have been achieved mainly by beech trees where leaf has the largest gross calorific value among selected parts, followed by branches, and the lowest gross calorific value has bark of beech, which is thin, smooth, and shiny. The willow reaches the highest gross calorific value at branches. It's their tax structure and tree character. In particular, we evaluated the wood because it is only a secondary source of fire and a secondary fuel.

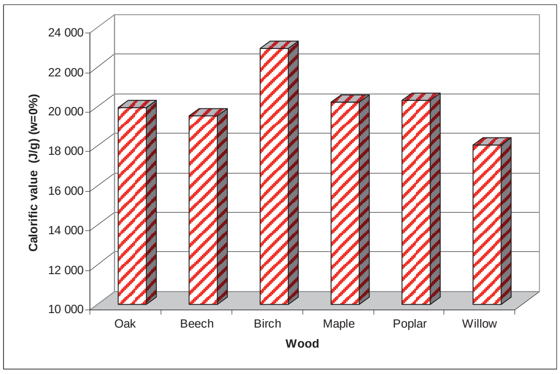

Fig. 4 Gross calorific value - Bark

Conclusion

The aim of the experiment was to evaluate the gross calorific value, at zero moisture, of leaves, branches, bark at wood (oak, beech, birch, maple, poplar and willow). Already on the basis of previous experiments, which have been carried out on conifer wood, we found differences in weight loss and the rate of burning of branches, stem and roots of conifer wood. Description and experiment confirmed the significant differences that were found also in this case. This fact is important to know in order to characterize fuel which is present in this section and which constitutes a potential risk for the emergence of a particular course of forest fires. Based on these values, forest management plans, environmental relief and other parameters can be made more accurately to determine potential development site with fire and the direction of stronger fire development by the presence of the type of fuel.

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