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I. Vitázek, P. Andoč, B. Vitázková
Slovak University of Agriculture, NITRA, Slovak Republic

Gravimetric analysis of selected solid biofuels

Widespread recognition and use of renewable energy sources is a result of the increase in prices of fossil fuels and the effort to cut down on gaseous emissions. In particular, solid biofuels are becoming widely used as a source of thermal energy. For their proper use it is essential to know their physical and chemical properties. The paper refers to a gravimetric method for determining the proportion of moisture, ash and combustible in selected solid biofuels. The quality of fuel as an energy source depends on the quality of combustible and content of unexploitable substances – moisture and ash. The results are processed graphically and illustrate the characterization of the examined fuel.
solid biofuels, moisture, combustible, ash, gravimetric method

И. Витазек, П. Андоч, Б. Витазкова
Словацкий сельскохозяйственный университет, г. Нитра, Словакия
Гравиметрический анализ некоторых видов твердого биотоплива

Широкое признание и использование возобновляемых источников энергии является результатом роста цен на органическое топливо и усилий, направленных на сокращение выбросов в атмосферу. В частности, твердое биотопливо начинает широко использоваться в качестве источника тепловой энергии. Для надлежащего использования этого вида топлива необходимо знать его физические и химические свойства. В работе представлен гравиметрический метод определения доли влаги, золы и горючего вещества в разных видах твердого биотоплива. Качество топлива, в качестве источника энергии, зависит от качества горючего вещества и содержания неэксплуатируемых веществ – влаги и золы. После обработки результаты исследований представлены в виде графиков и характеризуют качество топлива.
твердое биотопливо, влага, горючее вещество, ясень, гравиметрический метод

Drying of biological materials as a vital part of post-harvest processing is considered one of the most energy-consuming processes in agriculture. With respect to increase in fossil fuel prices, alternative power sources are being explored. Exploitation of self-produced biofuels seems by far the most effective option. On top of that, harnessing of solid biofuels enhances competitiveness in agriculture. The term biomass refers to organic matter which is either a product of photosynthesis or of animal origin. Biomass also involves plant matter suitable for energy purposes as a renewable energy source. Biofuel is a fuel from biomass. Biofuels are divided into solid, liquid and gaseous. The quality of solid biofuel as an energy source depends on the moisture and ash content as well as on the composition of combustible (*Vitázek, 2011a*).

Proper usage of various biofuels requires identification of their physical and chemical properties. The present paper deals with analysis of selected physical properties of solid biofuels, namely moisture content, ash content and combustible content carried out by the means of device which works on the principle of gravimetrics.

Material and method. Exploitation of biomass as a source of energy is of considerable importance. This fact is also obvious from Fig.1 which shows the potential of utilization of particular energy sources in Slovakia.

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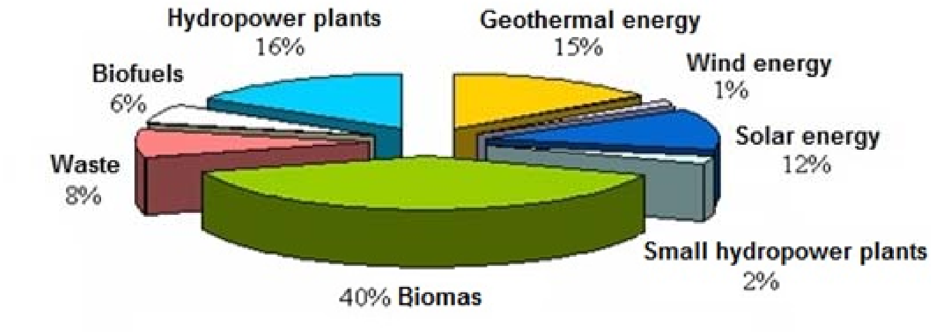

Figure 1 – Potential of energy sources utilization in Slovakia

Dry matter, i.e. residue after any moisture has been removed from the solid biofuel, consists of ash and combustible. The proportion of combustible can be divided into volatile and solid. However, this value does not determine the energetic content of the fuel, because heat of combustion varies with specific chemical composition of each fuel. The proportion of ash determines its production after combustion of the fuel.

The measurements of moisture, ash and combustible content were carried out by the means of the gravimetric furnace Nabertherm L9/11/SW/P330 (Fig.2). The device is a muffle furnace with volume of 9 litres, while power consumption of the heater is 3.0 kW. Heating of the samples can be tested to the temperature of 1100˚C. Installed controller P330 can program selected heating and endurance rates and may be operated either manually or by the means of the computer. The design of the furnace enables continuous measurement of weight of the analysed sample during the experiment by the means of digital scales Kern EW 1500 (Fig.3). Moreover, the obtained values are recorded by the computer. The device, along with special software and computer, allows precise determining of moisture, ash and combustible contents of selected solid biofuels.

Figure 3 – Digital scales Kern EW 1500

Figure 2 – Gravimetric furnace Nabertherm L9/11/SW/P330

Moisture content is identified in accordance with technical norm (*STN EN 14774-2*). The sample is heated to 105 ^{o}C ± 2 ^{o}C and is dried up to a point where the difference in weight of the sample between two following measurements carried out in 60-minute interval does not exceed 0,2% of total weight loss obtained in previous weighing. The present paper introduces values of moisture content for the analysed material.

Identification of proportion of volatile substances follows the norm (*STN EN 15148*). Ash content is determined in accordance with the norm (*STN EN 1477*5 and *STN ISO 1171*). The analysed sample was combusted at the temperature of 815 ^{o}C during the period of 60 minutes.

The sample of analysed solid biofuel in ceramic bowl is inserted into the gravimetric furnace. Values representing chosen temperatures and their impact period are programmed by the means of the computer. Precise values are presented in the Table 1.

Table 1 – Parameters for gravimetric measurement procedure

Time interval	Impact period *minute*	Temperature ^oC
1	60	20-105
2	120	105
3	60	105-500
4	60	500
5	60	500-815
6	60	815

Proportions of the particular components are calculated from the following relations:

- moisture content:

$$w = \frac{m_1 - m_2}{m_1}; \qquad (1)$$

- ash content:

- in original sample: $A' = \frac{m_3}{m_1}$; - in dry matter: $p_{ps} = \frac{m_3}{m_2}$ (2, 3)

- combustible content:

- in original sample: $h' = \frac{m_4}{m_1}$; - in dry matter: $p_{hs} = \frac{m_4}{m_2}$ (4, 5)

Where m_1 – original weight of the sample, g;
m_2 – weight of dry matter, g;
m_3 – weight of ash, g;
m_4 – weight of combustible, g.

Measured values of moisture, ash and combustible content in moist fuel and dry matter respectively are processed in tabular form (*Vitázek, 2011b*). Weight loss rates of analysed samples may be plotted on a graph. With respect to the required scope of the article are shown values of four biofuels out of eight.

Results and discussion. Ash is solid residue after complete combustion of fuel in laboratory conditions. It consists of mineral substances that are present in the fuel. Combustible is made up of the active substances, i.e. components of fuel characteristic of heat release due to oxidation, and of passive substances, which are bound to organic matter and do not provide heat.

Processed results of gravimetric measurements are shown in Table 2. The most recent values are presented out of more than 100 measurements carried out in the department. Moisture, ash and combustible contents are calculated from the relations 1 to 5 respectively. The values are presented in percentages.

Table 2 – Processed results of gravimetric measurements of analysed samples

Parameter	Biofuels				
	1	2	3	4	5
w	6,92	7,2977	9,4121	14,5934	6,0011
A^l	5,712	6,8121	5,2638	18,0999	0,1929
h^l	87,37	85,8901	85,3240	67,3062	93,8061
p_{ps}	6,128	7,3484	5,8107	21,1880	0,2052
p_{hs}	93,872	92,6515	94,1893	78,8119	99,7948

Parameter	Biofuels				
	6	7	8	9	10
w	11,447	4,6917	8,9915	4,9407	18,5190
A^l	1,4160	3,1151	6,1319	7,1291	3,0786
h^l	87,1815	92,1931	84,8767	87,9301	78,4023
p_{ps}	1,5985	3,2685	6,7377	7,4964	3,7783
p_{hs}	98,4513	96,7313	93,2623	92,5035	96,2217

Legends:
1 - pellets – wheat straw
2 - pellets – mixture of sunflower + waste barley and wheat
3 – pellets – Russian peat
4 - briquette – Ukrainian peat - crushed
5 - pellets – softwood without bark- spruce
6 - briquette – crushed corncob
7 - briquette – crushed hardwood bark – beech
8 - pellets – 40% beech sawdust, 30% rapeseed, 30% coal
9 - pellets- sunflower
10 - briquette – brown coal- crushed

Values of briquette from brown coal are provided for comparison. In contrast with biofuel it has significantly higher moisture content, while proportions of ash and combustible in dry matter are analogous to briquettes from hardwood bark. In terms of proportion of ash in dry matter, pellets from softwood without bark seem the most suitable for the consumer. Straw is used as a heat source for dryers. Obtained results indicate proportion of ash ca. 6,13 %. Various waste materials contain higher proportion of ash. Peat from Vladimirsk region (The Russian Federation) was analysed as an unconventional fuel. Proportion of ash does not exceed 6%. On the other hand, briquettes from Ukrainian peat (which are available in Slovakia) contain 3,5 times higher proportion of ash.

Biomass heating is becoming increasingly widespread alternative to natural gas and coal.

Boiler manufacturers have adapted to this situation. High proportion of ash and inadequate temperature pose a threat even to the innovative boilers due to ash sintering, which may cause temporary interruption of combustion and lead to partial or permanent damage of the combustion device. This is one of the important arguments in favour of the awareness of the proportion of ash in biofuels (*Vitázek, 2011a*).

Graphically depicted weight loss rates.

Combustion of biomass does not inevitably release the maximum amount of energy that is present in biomass itself. Thus it is more convenient to convert biomass to another type of fuel in order to exploit the energy of biomass the most efficiently. Thermal conversion is nowadays the most prevalent method of biomass conversion. This process enables transformation of biomass to liquid, gaseous or solid fuel of higher quality. Properties of the produced fuel are suitable for energetic exploitation to a great extent. According to (*Piszczalka, 2010; Jandačka et al., 2011*), content of the original solid biofuel in terms of combustion is following:

- volatile combustible matter (wood gas) 60-70%;
- solid non-volatile combustible matter (charcoal in the case of wood) up to 20%;
- unexploitable substances made up of water (up to cca 14%) and ash from combustion of charcoal 0,5-4%.

The proportion of volatile combustible matter in biomass depends on the type of fuel and is inversely proportional to ash and moisture content of the fuel. As regards long-term storage, water content of 14-15% is the most common and safe option.

Fig. 4 graphically depicts obtained weight loss rates of examined samples of solid biofuels in the range after moisture removal, i.e. after 180 minutes at temperature exceeding 105 ^{o}C. Attention was paid to the release of combustible up to the final weight of ash.

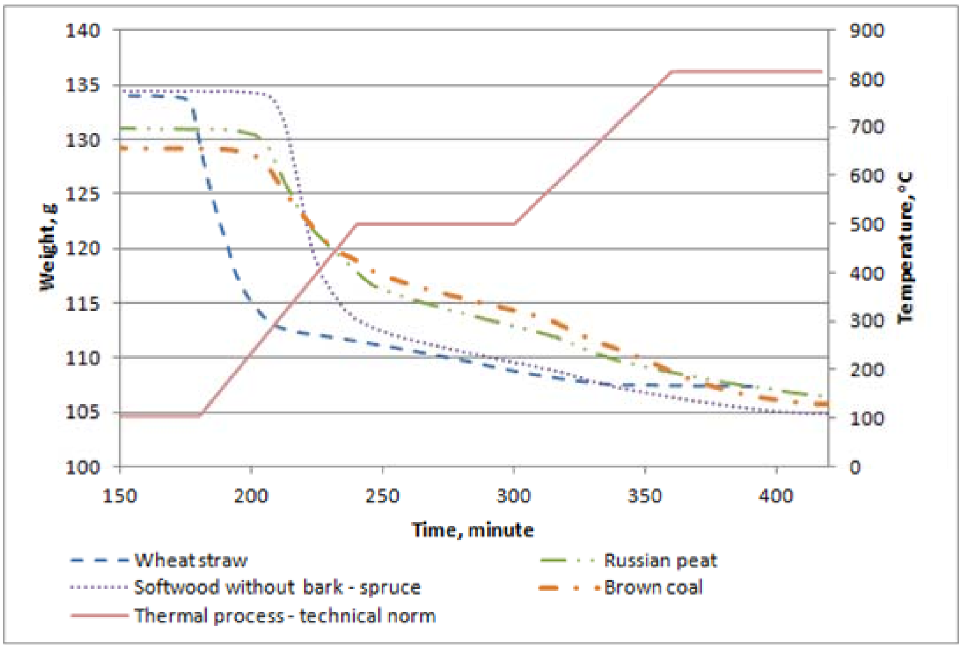

Figure 4 – Weight loss rate of analysed samples of solid biofuels

Values of proportion of ash in selected biomass types presented in the paper (*Rusňák and Šmidová, 2010*) are as follows: (%) birch wood 1,2; aspen 2,6; wheat straw 5,7; corn straw 4,6; rapeseed straw 6,9; amaranth straw 13,5; grain dust pellets 15,3; biosludge after separation from biogas plant 53,4. On the whole, it may be stated that ash content of phytomass is higher than ash content of denromass. The obtained results confirm that whole plants with grain and grain itself contain lower proportion of ash than straw phytomass without grain and therefore are analogical to wood biomass (*Vitázek and Vitázková, 2011*). (*Hutla and Jevič, 2009*) state that agropellets are produced mainly from wheat straw. Suitable combustion devices are available on the market.

Conclusion. Biomass of various amount and content is available in agrarian areas as a secondary agricultural source. It regards mainly different kinds of straw, cereals, wooden waste from vineyard cutting, waste from crop processing, logging residues etc. These materials are characteristic of different physical properties which determine their further processing (pellets, briquettes, wood pieces) and the choice of appropriate combustion device. Gravimetric method described above is particularly suitable for analysis of proportions of ash and combustible in dry matter of these materials. Utilization of the renewable energy sources improves competitiveness in agriculture.

Straw boilers designed to heat the drying environment have been successfully tested and used in practice. Simple devices operate with the exchanger combustibles-air, whereas more sophisticated computer controlled devices use the exchanger combustibles-water. Consequently, the dryer itself works with the exchanger water- air. However, the conducted experiments show high proportion of ash in wheat straw.

When using boilers with innovative technologies, it is advisable to consider the high proportion of ash and its thermal properties in the process of combustion. Exceeded level of sintering temperature may cause shortcomings of the operating parameters and even damage.

The customer in the decision-making process has to consider the recommendation of the boiler manufacturer. Apart from the price of the fuel, proportion of ash has to be taken into account. This parameter is directly linked with the frequency of cleaning of the device. The performed experiments indicate the proportion of ash ranging from 0,205% to 21,2%. Therefore further attention shall be paid to the research into thermal properties of ash in biofuels used in agricultural practice.

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І. Вітазек , П. Андоч , Б. Вітазкова
Словацький сільськогосподарський університет, м. Нітра, Словаччина
Гравіметричний аналіз деяких видів твердого біопалива

Широке визнання і використання поновлюваних джерел енергії є результатом зростання цін на органічне паливо та зусиль, спрямованих на скорочення викидів в атмосферу. Зокрема, тверде біопаливо починає широко використовуватися в якості джерела теплової енергії. Для належного використання цього виду палива необхідно знати його фізичні та хімічні властивості. У роботі представлений гравіметричний метод визначення частки вологи, золи і горючої речовини в різних видах твердого біопалива. Якість палива, в якості джерела енергії, залежить від якості горючої речовини і вмісту невикористовуємихречовин – вологи і золи. Після обробки результати досліджень представлені у вигляді графіків і характеризують якість палива.
тверде біопаливо, волога, горюча речовина, ясен, гравіметричний метод

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