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Analysis of residual biomass of liquid biofuels using gravimetric method and combustion heat

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ABSTRACT

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The using possibilities of secondary raw materials produced during the liquid biofuels production such as bioethanol and biodiesel, and also those produced during solid fuel production was determined. The study presents combustion of distiller's dried grain with solubles (DDGS) and pressing refuse of rapeseed methyl ester (RME). The combustion was done in gravimetric oven, according to the standards, under the laboratory conditions. Combustion heat of samples was measured with calorimeter IKA C5000. The results show the average combustion heat of 20.91 MJ/kg for DDGS and 18.996 MJ/kg for RME. Results are chronologically presented in tables and figures.

Keywords: DDGS residuals; RME residuals; gravimetric method; combustion heat; ash; distiller's dried grain with soester

In 2006, the European Union passed a strategy of gradual replacement of fossil fuels produced from petroleum by fuels get from renewable energy sources. Currently, the most expanded in transportation are liquid biofuels such as bioethanol – the added component of gasoline and rapeseed methyl ester (RME) – the fuel of diesel.

Liquid biofuels are largely fuels of plant origin used either alone or in admixture with conventional fossil fuels to decrease emission rate. Biomass can generally be understood as non-fossil, renewable biological material of plant and animal origin.

In the energy sector, the term biomass means plant material available for the production of electricity and heat. Biomass as an organic source contains chemical energy bound.

This energy can be understood as a chemically conserved energy of sunlight, emerging in the process of photosynthesis. The quality of fuels as an energy source dependson the quality and quantity of flammable components and ballast content, namely moisture content and ash content.

The high content of flammable fuel components does not automatically mean a high calorific value of the fuel. Heat value depends on the chemical composition of the fuel and its combustion conditions. Branca and Di Blasi (2014) in their study also reported that DDGS has lower percentage content of the usual components of lignocellulosic materials and mainly the large presence of other classes of compounds extractives, proteins and starch.

The aim of this paper is to determine the proportion of flammable component and ballastin selected secondary raw materials produced in the production of liquid biofuels such as bioethanol and

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RME, and also to determine the degree of combustion heat of the measured samples.

MATERIAL AND METHODS

During the experiment, the distillery refuse of DDGS (corn distiller's dried grain with solubles) as a secondary product after corn distillation to bioethanol and the pressing refuse of rapeseed produced at RME production were examined.

Distillery refuse of DDGS (corn distiller's dried grain with solubles). DDGS is produced as a secondary corn product in the bioethanol production, where starch is used for distillation. Refuse contains minerals, proteins, yeasts, oil and vitamins. Their volume is about one third of the original volume of corn. The final product is supplied as pellets and is used as a feed additive for livestock, or in the production of biomethane with anaerobic fermentation in biogas plants.

Pressing refuse of RME. RME refuse is the secondary product of rapeseed pressing at RME processing. It is used similarly to DDGS as a feed for livestock.

During the measurements, the Nabertherm L9/11 oven (Nabertherm GmbH, Lilienthal, Germany) was used. The maximum power output was 3 kW, which was regulated by the control unit P330 (Nabertherm GmbH, Lilienthal, Germany). The actual heating behaviour and heating life was programmable via PC. During the experiment, the digital scale Kern EW 1500 (Kern & Sohn GmbH, Balingen, Germany) was used for weight changes monitoring of combusted material. These devices connected with PC allowed us to record the temperature and weight changes in real time measurements. The parameters of gravimetric measurements of the tested samples are shown in Table 1. The parameters were determined according to the following Slovak technical standards (STN): temperature – STN EN 14774-2:2010, moisture content of solid biofuels – STN EN 15148:2015, volatile matter content – STN EN 14775:2010, and ash content determination – STN ISO 1171:2003.

Table 1. Parameters of gravimetric measurement

Time sequence	Interval (min)	Temperature (°C)
1	60	20–105
2	120	105
3	60	105–500
4	60	500
5	60	500–815
6	60	815

Individual samples of selected materials were placed on a ceramic dish and then into the gravimetric oven.

The following equations were used for determining the individual fractions of tested samples.

– Moisture content w:

$$w = (m_1 - m_2)/m_1 \quad (1)$$

– Ash content

–of fundamental sample A':

$$A' = m_3/m_1 \quad (2)$$

– in dry matter content p_{ps}:

$$p_{ps} = m_3/m_2 \quad (3)$$

– Combustible content

– of fundamental sample h':

$$h' = m_4/m_1 \quad (4)$$

– in dry matter content p_{hs}:

$$p_{hs} = m_4/m_2 \quad (5)$$

where:

m_1 – mass of fundamental sample (g)

m_2 – mass of dry mater content (g)

m_3 – mass of ash (g)

m_4 – mass of combustible (g)

As the sample mass is 1 g according to the standard, the results were re-converted to the required mass.

Table 2. Results of gravimetric measurements of individual samples of tested materials

Sample	DDGS			RME		
Measurement No./average	1	2	$\bar{x}$	1	2	$\bar{x}$
Moisture content w (%)	10.434	10.355	10.395	10.733	11.293	11.013
Ash content A (%)	4.321	3.991	4.156	6.303	6.332	6.318
Combustible content h (%)	85.195	85.654	85.425	82.964	82.374	82.669
Ash ratio p_{ps} (%)	4.827	4.452	4.64	7.061	7.138	7.099
Combustible ratio p_{hs} (%)	95.172	95.543	95.358	92.939	92.361	92.65

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Table 3. Combustion heat of tested samples

Sample	DDGS			RME		
Measurement No./average	1	2	$\bar{x}$	1	2	$\bar{x}$
Mass of sample (g)	344	406	375	599	349	474
Combustion heat (MJ/kg)	20.205	19.977	20.091	19.016	18.976	18.996

Calorimeter IKA C5000 (IKA® Werke GmbH & Co. KG, Staufen, Germany) was used to determine the heat combustion of the tested compounds. Before the measurement, the samples were weighed and the weight of tested sample was inserted in the calorimeter. The sample was completely burnt (under the effect of pure O_2). According to the built-in mathematical algorithms, the heat of combustion per unit mass of 1g was recalculated.

RESULTS AND DISCUSSION

Tables 2 and 3 show the obtained results. The ratios of moisture content, ash and combustibles are calculated according to Eqs (1–5).

Studied samples are used as a dietary supplement in feed premixes for livestock. Given the current decline of livestock in Slovakia and increasing production of biofuels (committed towards the European Union), there is a risk of excessive commodities and the question of further use of these materials arises.

Results show that the hygroscopicity of measured materials is approximately at the same level. The obtained results show (Fig. 1) that DDGS samples had slightly higher combustibles ratio (2.7%) in comparison to RME samples (Fig. 2), at all measurements. Although RME had lower combustibles ratio, a higher proportion of ash content (approximately 2.4%) was observed.

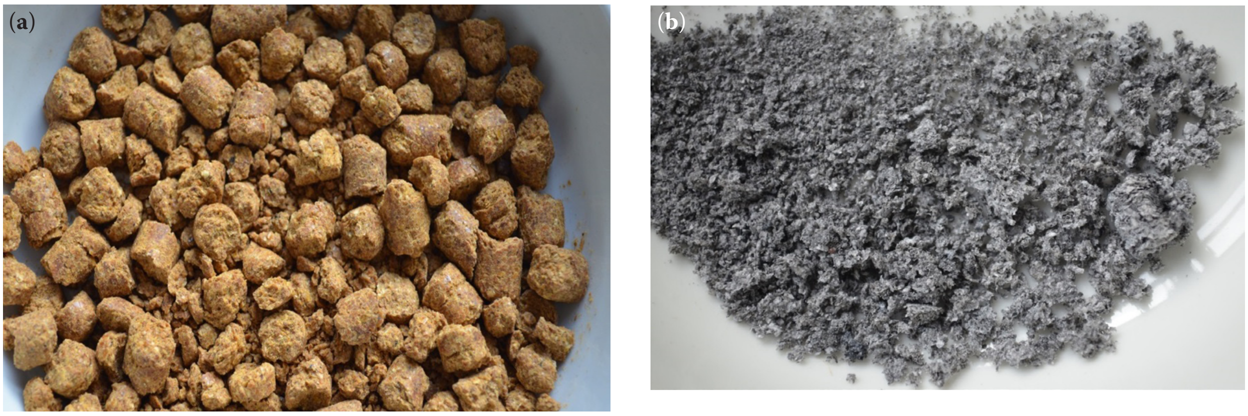

Fig. 1. Distillery refuse of DDGS before (a) and after (b) combustion

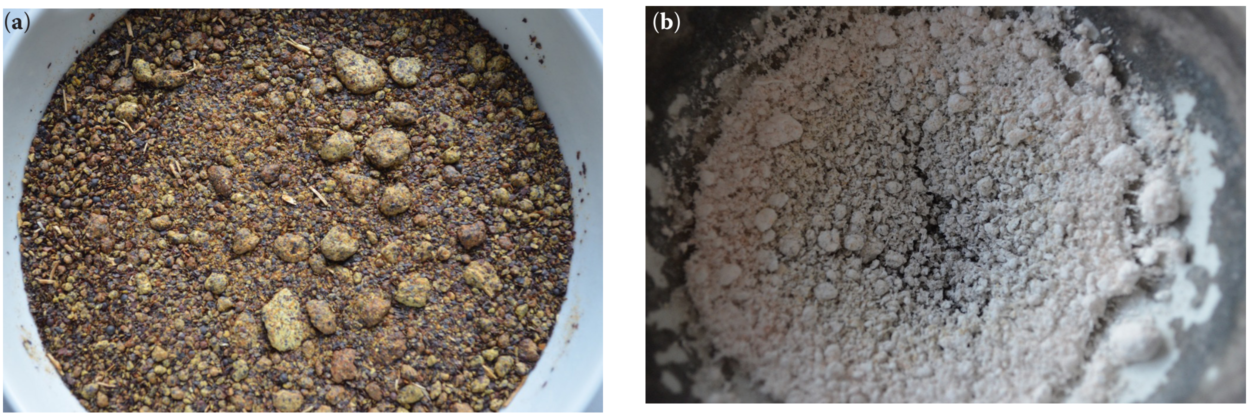

Fig. 2. Pressing refuse of RME before (a) and after (b) combustion

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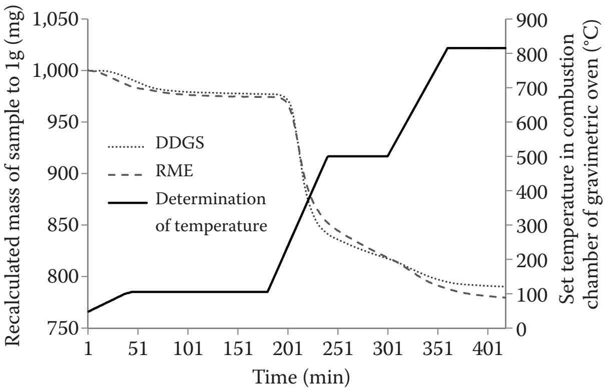

Fig. 3. Behaviour of mass losses of DDGS, RME samples depending on temperature changes in combustion chamber in time

The obtained results show that the slightly higher value of combustion heat recalculated to 1 g was obtained for the DDGS sample.

Based on measurements of combustion heat, there can be stated a slightly higher value calculated per 1 g in the DDGS sample (approximately 1.000 MJ/kg) compared to RME.

According to Hutla and Jevič (2009), Vitázek et al. (2011) and later also Kažimírová (2011, 2013), mostly straw is used for the production of agro-pellets, for which suitable pellet boilers are offered on the market. Pellets of non-wood materials have a significantly higher ash content, which has to be considered in the construction of the boiler. Ash sintering temperature is lower and it requires checking the boiler. The improvement of the mentioned parameter can be achieved by adding additives such as crushed lignite in the amount of 8% of the volume. Melting ash temperature then increased to 850°C. By using the husks of cacao beans in an amount of 5%, melting ash temperature raised to 900°C (Fig. 3).

Comparing the ash content in the dry matter of samples with pellets from straw (about 6%), we can conclude that the ash content of DDGS is lower by about 1.35%; on the contrary, with RME, it is higher by 1.1%. The combustion heat from our measured samples is greater than in straw (18.500 MJ/kg). The combustion heat of beech wood with bark was 19.700 MJ/kg and in spruce wood with bark was it 20.200 MJ/kg (Jandačka et al. 2007). Almost the same values of ash content in DDGS, from another experiment, were presented in the paper (Opáth et al. 2010).

Biomass heating is increasingly used as an alternative to natural gas. Boiler manufacturers have begun to be adapted to this situation, too. Even with the use of new innovative boilers the high ash content and inadequate temperature can be the cause of ash sintering, which can interrupt the combustion process and lead to partial or permanent damage. This is one of the reasons why is it important to know this kind of information about the ash content in biofuels.

CONCLUSION

Pressing refuse of RME and residuals of DDGS production are used as an additive of feeding mixtures for livestock. From the obtained results and also by comparing similar results obtained by Vitázek and Chrastina (2011), Vitázek and Vitázková (2012) and Kažimírová et al. (2013), we can state that the combustion of these commodities is suitable from the energy point of view under certain conditions.

Biomass, which can be classified as a secondary raw material, is available in agriculture in various amounts and compositions. There are mainly various kinds of straw, grains, grasses, wood waste from pruning vineyards, waste processing of various crops, forest logging residues, etc. These materials have different physical properties which predetermine them to a further way of processing (pellets, briquettes, pieces of wood) and are also decisive in choosing the suitable boilers.

To determine the ash content and combustibles in the dry matter of different materials, it is suitable to use the gravimetric method. Even with the use of new innovative boilers the high ash content and inadequate temperature can be the cause of ash sintering, which can interrupt the combustion process and lead to partial or permanent damage. This is one of the reasons why it is important to know the information about the ash content in biofuels.

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