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IMPACT OF COFFEE GROUNDS ADDITION ON THE CALORIFIC VALUE OF THE SELECTED BIOLOGICAL MATERIALS[1]

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ABSTRACT

The objective of the paper was, inter alia, to determine the impact of coffee grounds on the heat of combustion of their combination with other biological materials. Research on the heat of combustion and calculations of the calorific value were carried out with the use of a KL-12 Mn calorimeter according to the technical specifications and standards PN-81/G–04513 i PN-ISO 1928:2002. Coffee grounds, tea grounds, pine wood and yellow wheat straw were used in the research. The heat of combustion of particular substrates was determined and then their mixtures with coffee grounds in the following proportion were prepared: 75% substrate – 25% coffee grounds, 50% substrate – 50% coffee grounds, 25% substrate – 75% coffee grounds. Calorific value of particular substrates was increasing with the amount of added coffee grounds. Their biggest flow was reported in the mixture of 50%/50% of coffee grounds and wheat straw and the smallest in case of coffee grounds and wood on account of a similar calorific value of both substrates.

Used symbols:

k – coffee grounds
h – tea grounds
d – pine wood
s – wheat straw

Introduction

Coffee (except for tea) is one of the most popular beverages in the world. Global production of coffee in 2014 was over 8.5 million tonnes (ICO, 2015). Import of coffee in Poland in 2013 was 123.4 thousand tonnes (import of tea – 32.3 thousand tonnes) (Main Statistical

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Office, 2015). Both coffee and tea are products which after use generate the amount of waste which is equal to import and sales.

Moreover, a considerable impact of coffee on the natural environment is known in the global scale (Rousso et.al., 1998; Hue et.al., 2006). On account of the specificity of consumption of both coffee and tea (restaurants, cafés, households) it is difficult to organize a collection of spent grounds to obtain them in a pure form. In Poland they occur the most frequently as a mixture with other biological waste from restaurants or households.

Table 1.
Composition of coffee grounds

Parameter	Reference value
Total carbon	47.8-58.9 [b,c]
Total nitrogen	1.9-2.7 [a,b,d]
Protein (gprotein·100^{-1} g)	6.7-17.44 [a,e]
Cellulose	8.6-12.4 [a,f]
Hemicellulose	39.1 [a]
Lignin	23.9-33.6 [a,g]
Fat	2.29 [a]
Ashes	1.3-1.43 [a,g]

Composition (g·100^{-1} g dry material). (a) Ballesteros et al., 2014; (b) Melo et al. 2007; (c) Bizo 2003; (d) Nogueira and Costa 1999; (e) Mussato et al.,2011a; (f) Mussato et al.,2011b; (g) Caetano et al., 2012.

Rich content of organic compounds (table 1.) in coffee grounds justifies variety of tests on the possibility of their use:

- for biodiesel production (Caetano et.al., 2012; Mebrahtu, 2014),
- for pellet production (Caetano et al., 2012; Kondamudi et.al., 2008),
- as the source of sugars (Mussatto et.al., 2011a),
- from production of activated carbon (Kante et.al., 2012; Tsai et.al., 2012),
- in the composting process (Hachicha et al., 2012; Liu and Price 2011; Zuorro and Lavecchia, 2012),
- as a sorbent for removing metal ions (Fiol et.al., 2008; Oliveira et.al., 2008).

On account of the unfavourable impact of biological waste, such as coffee grounds, on the environment, effective methods of their utilization should be searched for. Despite many possibilities of using grounds there is no information on the effectiveness of their combustion with other biological materials. The objective of the paper was, inter alia, to determine the impact of coffee grounds on the heat of combustion of their combination with other biological materials.

Objective and scope of research.

The objective of the research was to determine the usefulness of coffee grounds as a fuel and as an additive to biological materials. The heat of combustion was defined – and on this basis – the calorific value – of coffee grounds, tea grounds and their mixtures with pine wood and what straw.

Research methods

Research on the heat of combustion and calculations of the calorific value were carried out with the use of a KL-12 Mn calorimeter according to the technical specifications and standards PN-81/G-04513 and PN-ISO 1928:2002.

The studies included coffee grounds of the same variety obtained from one household (k), tea grounds of the same variety from one household (h), pine wood (d) and yellow wheat straw (s). The heat of combustion of particular substrates was determined and then mixtures of substrates with coffee grounds in the following proportion were prepared: 75% substrate – 25% coffee grounds, 50% substrate – 50% coffee grounds, 25% substrate – 75% coffee grounds.

The research consisted in total combustion of the fuel sample (1 g) in the oxygen atmosphere at the pressure of 2 MPa in the calorimetric bomb immersed in water and in determination of the temperature growth of the water. The heat of combustion is calculated automatically and presented on the computer screen. The measurement of the temperature growth is provided with a precision of 0.001ºC. Moisture was determined according to the requirements of PN-80/G04511 with the use of the MAC 50 moisture analyser which has a precision of the moisture read-out of 0.001% and the maximum drying temperature of 160ºC.

Samples for research were dried, ground and carefully mixed. In each case, three samples of determination of heat of combustion were carried out. An arithmetic mean of three measurements was taken as a basis. In case of differences between the samples for a given mixture higher than 20%, the test was repeated. The heat of combustion so defined was used for calculation of the calorific value of particular substrates and mixtures.

Research results

According to the assumed methodology of research, calorific value of particular substrates and mixtures was determined. Averaged results were presented in table 2 and 3.

The calorific value was calculated with the use of a computer programme, in which a controlling unit of the calorimeter operation is equipped (pursuant to standards PN – 80 / G – 04513 and PN – ISO 1928:2002).

Table 2.
The heat of combustion of substrates

Substrate	Q ($kJ \cdot kg^{-1}$)
Coffee grounds	22,890
Tea grounds	19,754
Pine wood	22,156
Wheat straw	20,453

Table 3.
The heat of combustion of mixtures

Mixture of coffee grounds (k) and tea grounds(h)	Heat of combustion Q (kh) (kJ·kg^{-1})	Mixture of coffee grounds (k) and straw (s)	Heat of combustion Q (ks) (kJ·kg^{-1})	Mixture of coffee grounds (k) and pine woods (d)	Heat of combustion Q (kh) (kJ·kg^{-1})
k25%, h75%	20,158	k25%, s75%	2,0856	k25%, d75%	22,175
k50%, h50%	21,254	k50%, s50%	21,870	k50%, d50%	22,321
k75%, h25%	22,055	k75%, s25%	22,138	k75%, d25%	22,702

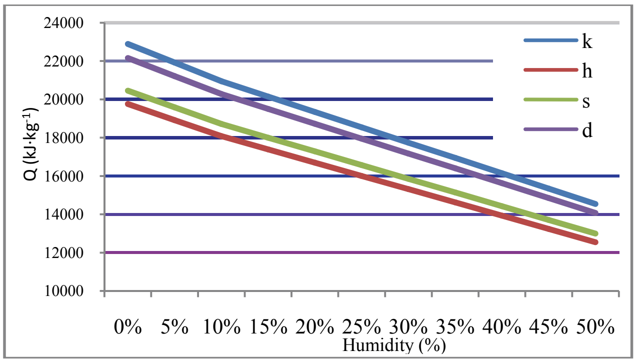

Figure 1. The calorific value of uniform substrates

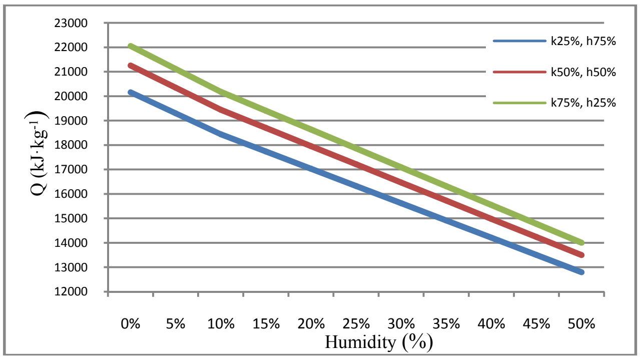

Figure 2. Calorific value of the mixtures of coffee and tea grounds depending on their moisture

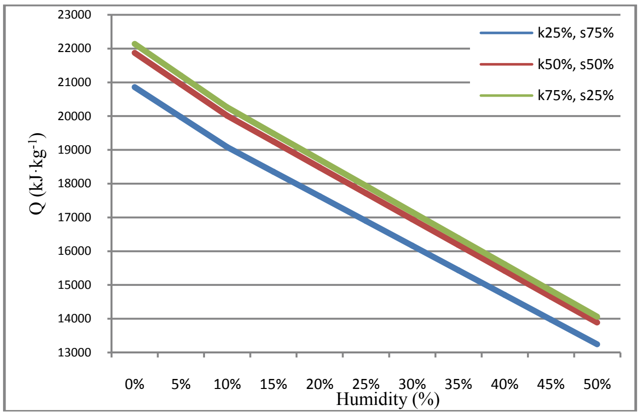

Figure 3. Calorific value of the mixtures of coffee grounds and wheat straw depending on their moisture

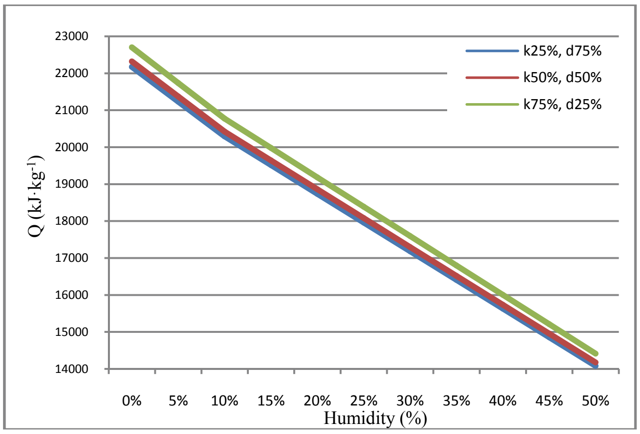

Figure 4. Calorific value of the mixtures of coffee grounds and pine wood depending on their moisture

Summary and conclusions

Based on the test on the calorific value of coffee grounds and their mixtures with tea grounds, wheat straw and pine wood, it may be stated that the calorific value was within the range of the determined calorific value of the used substrates.

Due to a high calorific value of coffee grounds, combustion seems to be one of the best methods of utilization of this biological waste which is burdensome for the environment.

In case of the mixture of coffee and tea grounds, the increase of the calorific value of tea grounds was proportional to the increase of the content of coffee grounds in the mixture. The biggest impact was reported in the mixture of 50%/50% of coffee grounds and wheat straw and the smallest in case of coffee grounds and wood on account of a similar calorific value of both substrates.

Coffee grounds on account of their physical and chemical properties may constitute a perfect additive to the selected types of biomass raising their calorific value.

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WPŁYW DODATKU FUSÓW KAWY NA WARTOŚĆ OPAŁOWĄ WYBRANYCH MATERIAŁÓW BIOLOGICZNYCH

Streszczenie. Celem badań było m.in. określenie wpływu zawartości fusów kawy na ciepło spalania ich mieszaniny z innymi materiałami biologicznymi. Badania ciepła spalania i obliczenia wartości opałowej przeprowadzono za pomocą kalorymetru KL-12Mn zgodnie ze specyfikacją techniczną i normami PN-81/G–04513 i PN-ISO 1928:2002. Do badań wykorzystano fusy kawy, fusy herbaty, drewno sosnowe oraz słomę pszenną żółtą. Określono ciepło spalania poszczególnych substratów, a następnie przygotowano ich mieszaniny z fusami kawy w stosunku: 75% substratu – 25% fusów kawy, 50% substratu – 50% fusów kawy, 25% substratu – 75% fusów kawy. Wartość opałowa poszczególnych substratów wzrastała wraz z ilością dodawanych fusów kawy. Największy ich wpływ odnotowano w mieszaninie 50%/50% fusów kawy i słomy pszennej, a najmniejszy w przypadku fusów kawy i drewna ze względu na zbliżoną wartość opałową obu substratów.

Słowa kluczowe: fusy kawy, ciepło spalania, wartość opałowa, mieszanina