INVESTIGATION OF GRAIN BIOMASS PROPERTIES AS AN ALTERNATIVE FUEL

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Abstract: *In connection with the observed dynamism of changes on the energy market regarding generation of energy from sources other than coal, more attention was paid to the use of "clean", low-emission technologies. Bearing in mind the need to search new, alternative energy sources, the aim of the study was to investigate and analyze the properties of grain biomass, such as rice and corn, as a fuel. To achieve the goal, the research problem has been formulated: how the fragmentation degree and the type of biomass affects such energy properties as heating value and heat of combustion. To resolve the problem, the properties of white rice, black rice, red rice and corn before and after grinding were analysed. The results show that white rice has the biggest value of heat of combustion before grinding, red rice – the lowest. White rice has the biggest heating value for whole grain, red rice – the lowest. The research allows to state that grinding operations result in increasing energetic properties of biomass. It can be also assumed that biomass is a good substitute of fossil fuel*.

Keywords: RICE, CORN, HEATING VALUE, HEAT OF COMBUSTION, ALTERNATIVE FUEL

1. Introduction

Biomass has been used by humankind as a source of heat since immemorial time. Many different definitions of the concept of biomass can be found in the literature. According to the Ordinance of the Minister of Economy and Labour dated 9 December 2004, "biomass" refers to solid or liquid biodegradable substances of plant or animal origin, obtained from products, waste and residues from agricultural and forestry production and from industries processing waste, as well as fractions of other biodegradable waste [1].

The current trend to use biomass to replace coal is mainly related to the EU goals concerning CO_2 emission reduction [2], [3]. As compared to burning coal, emissions of harmful substances, including CO_2, are much lower when burning biomass, as it's shown in table 1 [4], [5].

Table 1. *Calorific values and emissions of harmful gases for coal and biomass* ***[4]***

Pollutants emitted to the environment	Fuel / heating value [MJ/kg]			
	Coal/25	Straw/17	Wood/19	Waste/10-40
Carbon dioxide	100	-	-	128
Nitrogen oxides	0.3-0.4	0.16	0.16	0.55
Sulphur oxides	0.5-10	0.07	-	1
Dusts	0.05	0.20	0.20	0.11

Biomass used as a source of energy can be in many different forms: waste wood, straw, energy plant plantation crops, organic waste (manure, sewage sediments, waste from sugar refineries, distilleries, etc.), as well as liquid biofuels or biogas. Of the biomass types listed above, straw and energy plants can be most suitable for heat and power generating plants [6], [7].

Energy can be obtained from both, processed and unprocessed biomass. Conversion can occur in the process of direct combustion, gasification or processing into liquid fuels. The simplest and cheapest way to obtain energy from biomass is direct burning in special boilers, co-burning with such conventional energy sources as coal or heating oil and burning processed biomass products: methanol, ethanol, biogas or biodiesel [8] - [10].

The world biomass supply is estimated to deliver ca. 44 EJ of energy per year, which accounts for ca. 10% of the global energy consumption. The available supply that can be used reaches 276 EJ/year [11]. Table 2 shows the technical potential of biomass in selected European countries.

Table 2. *The technical potential of biomass in selected Central European countries [11]*

Central Europe	Technical potential of biomass [PJ/year]
Austria	368
Czech	299
Germany	1200-1700
Hungary	100-190
Italy	1000-1200
Poland	927
Slovakia	40-90
Slovenia	20-53

Energy can also be obtained from grain, e.g. from such commonly cultivated crops as corn, rice, wheat and other cereals that cannot be processed into food or feed due to bad quality. Many grains - whole or ground - remaining as waste from production processes, could be successfully used as a valuable fuel material or as an input to a biogas production plant.

The aim of the study was to investigate and analyze the properties of grain biomass, such as rice and corn, as fuel. To achive the goal, the research problem was formulated as a question: how the fragmentation degree and the type of biomass affects such energy properties as heating value (W) and heat of combustion (Q_w). To resolve the problem, the following properties were investigated: moisture content, particle size and shape, heat of combustion and heating value of white rice, black rice, red rice and corn before and after grinding.

2. Materials and methods

2.1. Analyzed grains

The study involved samples of four types of cereals: corn, white rice, red rice and black rice. Table 3 shows a list of cereals tested and their characteristics.

Rice and corn are considered to be plants with the largest acreage globally. Corn is usually ground for animal feed, for food industry and also for energy purposes in biogas plants. Corn is very commonly used as heating fuel in the USA and Canada. Special corn-burning stoves have been designed for this purpose there. Shredded rice is used to make products such as rice noodles. It can also be a valuable energy source in combustion processes. Rice waste is most commonly used in the form of briquettes. The fact that rice and corn are used for energy generation should not cause any deficit of these materials in the food processing industry, considering the huge volume of global production of these crops [12] - [16].

***Table 3.** Characteristics of tested materials [own work]*

CHARACTERISTICS OF TESTED MATERIALS				
Grains	Red rice	White rice	Black rice	Corn
				
Application	Food industry	Food industry, Energy purposes ex. briquette production	Food industry	Animal feed, food industry, biogas plants, solid fuel

2.2. Research plan

Tests were performed for each sample in accordance with the plan shown in Figure 1.

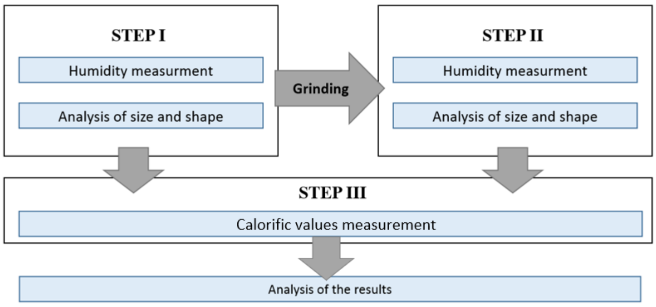

***Fig. 1.** Research plan of particles size and shape of biomass [own work]*

The research was divided into three parts. The first step was humidity measurement and whole grains size analysis. The samples were then ground. In the next step, an analysis of ground material moisture content was performed, followed by the analysis of particle size using the CAMSIZER. The third step was energy content examination and finally - the results obtained were analysed.

2.2. Methods

Samples of grain were ground in the five disc mill located in the Laboratory of Comminution Research at the Faculty of Mechanical Engineering UTP in Bydgoszcz.

Before and after grinding, particle size analysis was performed using Retch CAMSIZER analyser. The analyser takes photographs of the falling particles and enables the shape and size of fractions to be determined, as well as their percentage share in the sample.

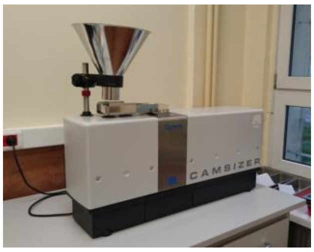

***Fig. 1.** CAMSIZER analyser [own materials]*

The particle size analysis results were used as a basis for determining the degree of grain fragmentation. It can be determined using a number of methods, e.g. the maximum degree of fragmentation i_g:

$$i_g = \frac{D_{max}}{d_{max}} \qquad (1)$$

D_{max} - arithmetic mean of diameters of the largest grains fed to the grinder, d_{max} - arithmetic mean of diameters of the largest grains in the product of grinding.

The maximum degree of fragmentation is biased due to the fact that the grains being fed into the grinder and the grinding product are not ideally spherical. The degree of fragmentation can also be determined from the dependence at the 80% degree of fragmentation (2) based on the knowledge of the sample particles size distribution. In this study, an 80% degree of fragmentation is used for biomass tests.

$$i_{80} = \frac{D_{80}}{d_{80}} \qquad (2)$$

D_{80} – the sieve mesh opening size allowing 80% of the grains though, d_{80} - the sieve mesh opening size allowing 80% of the grinding product through.

As the next step, the heat of combustion was determined for corn and rice samples in a calorimetric bomb (Fig. 3)., in oxygen at 25°C, according to the PN-81/G-04513 standard. The water equivalent of calorimeter was determined according to the PN-71/G-04062 standard, using 99.5% benzoic acid $C_6 H_5$ COOH. The sample combustion heat is: Q = 26417 kJ/kg.

a)

***Fig. 2.** The workstation used for determining the heat of combustion[own mayerials]*

3. Research results

The first step of the research was humidity measurement. Table 4 presents the results of humidity analysis. The results show, that white rice was characterized by the highest humidity (before and after grinding). Black rice had the lowest humidity before and after grinding. Humidity of tested materials increased after grinding.

***Table 4.** Results of analysis of humidity of tested biomass grains [own study]*

HUMIDITY OF THE SAMPLES TESTED [%M]				
Name / Form	Red rice	White rice	Black rice	Corn
Grains	12,630	13,600	8,723	9,378
Shreded	13,176	13,896	11,527	12,264

Four samples with different degrees of fragmentation were selected for each biomass category. Table 5 shows the results of the particle size analysis for the three rice types and corn grains. Based on the equivalent grain diameters (D_{80} i d_{80}), fragmentation degree i_{80} was determined for each of the samples (table 5).

***Table 5.** Results of particles size and fragmentation degree [own study]*

		Sample no			
Grain type	Characteristics	1	2	3	4
Black Rice	d_{80} [mm]	1.10	1.35	1.30	1.20
	D_{80} [mm]	2.08	2.08	2.08	2.08
	I_{80}	1.89	1.54	1.60	1.73
Red rice	d_{80} [mm]	1.10	1.35	1.30	1.20
	d_{80} [mm]	2.08	2.08	2.08	2.08
	I_{80}	1.89	1.54	1.60	1.73
White rice	d_{80} [mm]	1.20	0.75	0.80	1.30
	D_{80} [mm]	2.18	2.18	2.18	2.18
	I_{80}	1.82	2.91	2.73	1.68
Corn	d_{80} [mm]	2.35	1.65	2.00	2.55
	D_{80} [mm]	7.85	7.85	7.85	7.85
	I_{80}	3.34	4.76	3.93	3.08

With the fragmentation degree determined, grain calorific values were analysed. In the case of whole grains, white rice shows both the highest heating value (16401 kJ/kg) and the highest combustion heat (17575 kJ/kg), while the lowest values were recorded for red rice (W=15972 kJ/kg, Q_w=17142 kJ/kg) (Fig. 4). The results of tests for whole grains of corn or rice are consistent with the values presented in other studies [17]-[21].

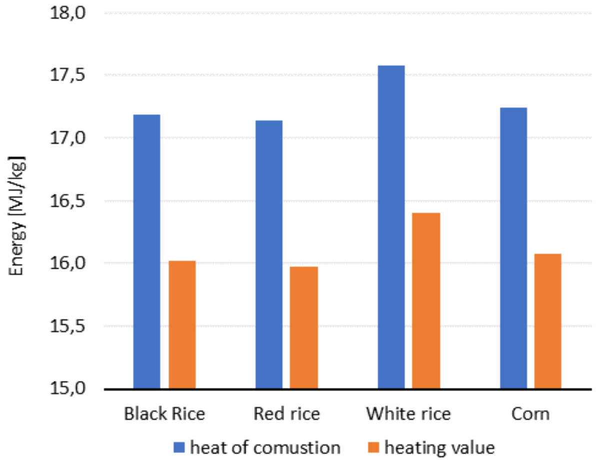

Fig. 4. *Combustion heat and heating value of grains before grinding [own study]*

After grinding, both the heating value and combustion heat of the biomass samples increased as compared with the values recorded for whole grains (Fig. 5-6). The highest increase of the heating value and combustion heat was recorded for black rice (by 4.5% and 4.3% respectively), the lowest – for white rice (by 0.3% and 0.3%0.

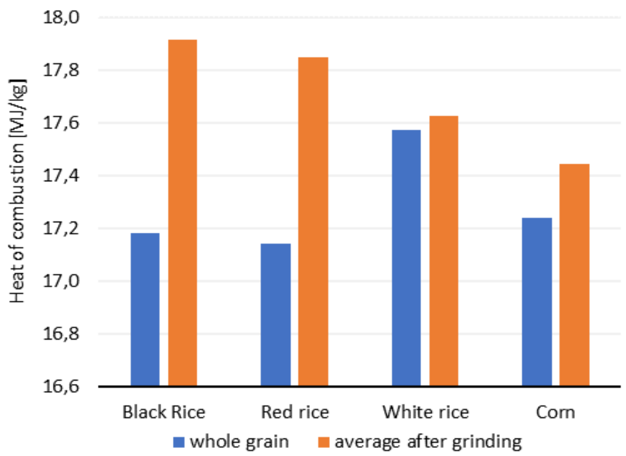

Fig. 5. *Combustion heat of samples, before and after grinding [own study]*

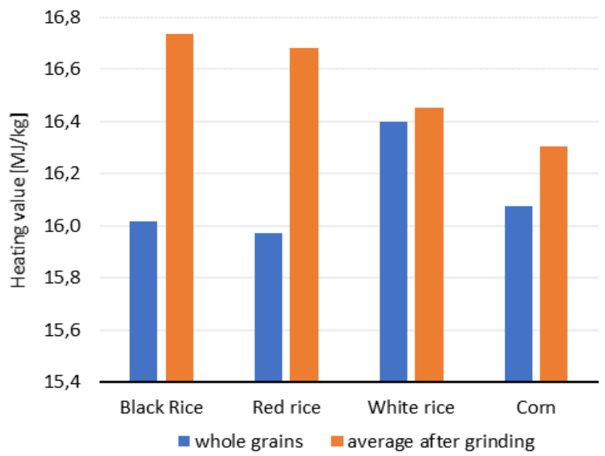

Fig. 6. *Heating value of the samples before and after grinding [own study]*

Figures 7-10 illustrate heating values of the samples tested, depending on the fragmentation degree. The best results of heating values after grinding were obtained for black rice (17154 kJ/kg) with the fragmentation degree (1.23), the worst for corn (15836.5 kJ/kg) for fragmentation degree (3.08). The highest combustion heat (18321 kJ/kg) was recorded for black rice with the fragmentation degree (1.23), while the lowest – for corn (16923 kJ/kg) with the fragmentation degree (3.08).

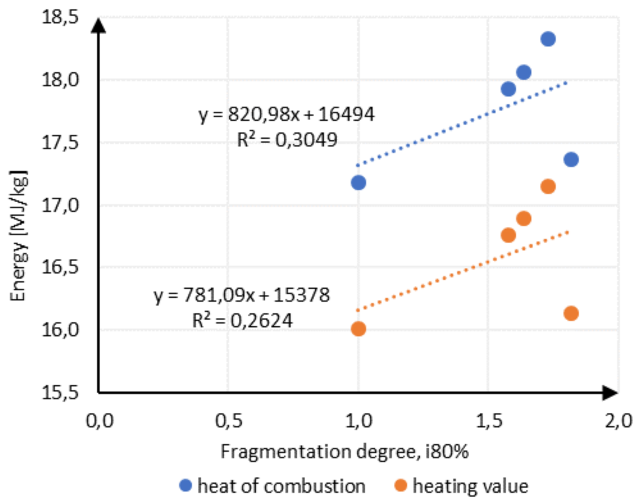

Fig. 7. *Combustion heat and heating value of black rice, depending on the fragmentation degree [own study]*

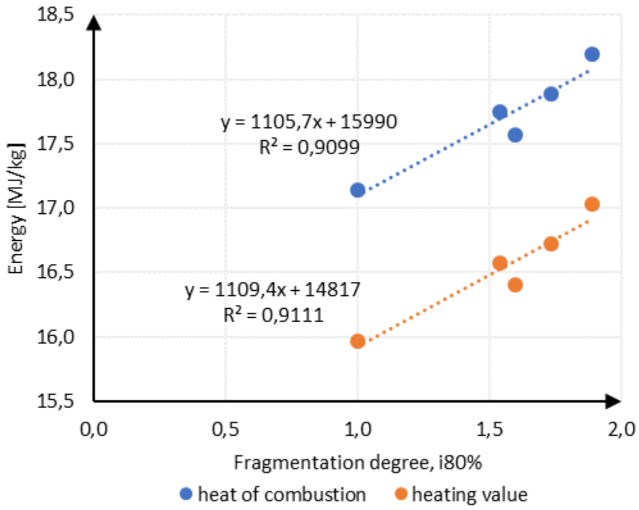

Fig. 8. *Combustion heat and heating value of red rice, depending on the fragmentation degree [own study]*

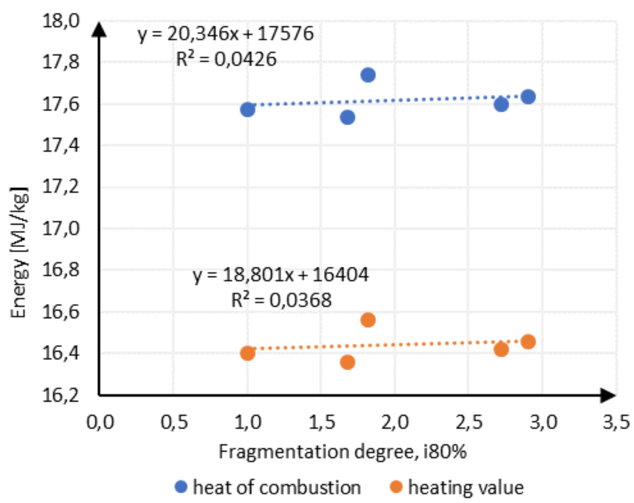

Fig. 9. *Combustion heat and heating value of white rice, depending on the fragmentation degree [own study]*

The results obtained do not allow of the unambiguous determination of the heating value and the heat of combustion. Yet, both the heat of combustion and the heating value can be observed to grow together with the degree of fragmentation. In a general case, the statement that grinding causes energy obtained in the process of grain burning to grow can be considered as true. Similar results can be found in studies [22] - [24].

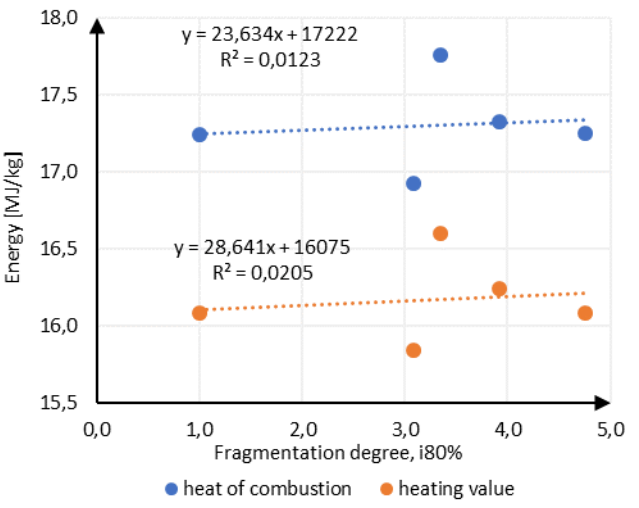

Fig. 10. *Combustion heat and heating value of corn, depending on the fragmentation degree [own study]*

4. Summary and conclusion

The results show white rice has the biggest value of heat of combustion before grinding, red rice - the lowest. White rice shows the biggest heating value for whole grain, red rice - the lowest. The research revealed that the values of heat of combustion and heating value increased for almost all tested samples after grinding. The best results of heating values after grinding were obtained for black rice (17154 kJ/kg) with the fragmentation degree (1,23), the worst - for corn (15836,5 kJ/kg) for fragmentation degree (3,08).

The research allows to state that grinding operations results in an increased energy properties of biomass. It can be also assumed that biomass is a good substitute of fossil fuel, owing to the high heating values of tested grains. The results show that of all the materials tested, ground black rice was the best energy source. For complete analysis of the tested grains properties as fuel, the exhaust gases analysis should be done.

Acknowledgments

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