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POSSIBILITIES OF USE OF STRAW, GRAIN OF SELECTED CROPS, AND RAPE SEED FOR ENERGY PURPOSES

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Summary. The study presents the properties of straw, wheat grain, barley grain, and rape seed that are used for energy purposes. Combustion heat and fuel value were analysed. The fuel value of the raw materials that were analysed ranged from 15,14 to 24,72 MJ kg^{-1}. The study revealed signifficant differences in the content of humidity and ash, as well as the content of nitrogen and sulphur.

Key words: straw, grain, biomass, energy value

INTRODUCTION

A surplus of straw can be used in energy industry. Only the surplus of straw obtained from the excess of straw on farms can be used for energy purposes, because, first and foremost, straw ought to be used to balance soil organic matter [Harasimowicz-Hermann and Hermann 2004]. Any type of straw obtained from all kinds of crops, rape and buckwheat can be used for energy purposes. However, the most commonly used types of straw are: rye straw, wheat straw, rape straw, buckwheat straw, and corn straw and rachis, due to their properties. Oat straw is not recommended as a fuel because of its low ash melting temperature.

The straw that is used for energy purposes must fulfill certain technological requirements. The evaluation of straw quality is made with regard to fuel value, humidity, and degree of straw withering.

Grain of crops, mainly oat, and corn is also used for energy purposes [Kwaśniewski 2010, Żabiński and Sadowska 2011]. Grain, due to its small dimensions, is more convenient for transportation and storage, as compared to straw, and also, makes the process of fuel supply to the furnace fully automatic.

The grain combustion process takes place in special burners which require a supply of a proper amount of air and maintaining different combustion temperatures than the temperatures commonly used for biomass [Janowicz 2006].

MATERIAL AND METHODS

The samples of straw, crop grains, and rape seed were collected from five randomly chosen 1 m^2 areas in individual farmers' fields with brown soils and grey brown podsolic soils made from loess in Lublin Upland, Działy Grabowieckie part, Grabowiec commune. Only fully developed, rape plants were collected for the purpose of the investigation. Dried straw and grain were subject to specialist analysis which determined the usability of the biomass that was obtained for energy purposes.

Basic analysis of the energy value of the biomass of the selected plants were carried out in the Laboratory of Renewable Energy Sources at the State Vocational High School in Zamość. The results are a mean of 5 measurements. The following were determined: combustion heat, fuel value, content of ash, and humidity. The procedure of evaluation of combustion heat and calculation of fuel value in solid fuels is described in detail in the Polish norm [PN-81/G-04513], as well as the gravimetric method of ash estimation [PN-80/G-04512]. Additional analysis were carried out in the laboratory to assess the biomass as an energy material and evaluate the content of: coal, nitrogen, sulphur, and hydrogen with the elementary analysis method. Commonly used analytical methods were applied in the study [Harkot *et at*. 2007, Szyszlak-Bargłowicz and Piekarski 2009].

The results were statistically elaborated with variance analysis method. The significance of differences were evaluated by means of Turkey's test, at the level of significance $p = 0.05$

RESULTS AND DISCUSSION

Elementary analysis of the investigated biomass revealed that straw and crop grains contained significantly less coal and hydrogen in comparison with rape straw and rape seed (Tab. 1). The straw of the investigated crops has significantly higher content of nitrogen than rape straw. The crop grain had significantly lower content of nitrogen and sulphur than rape seed. The analysis of chemical composition revealed small amount of sulphur in the straw of the investigated crops and rape, which is confirmed by other studies [Golec 2004, Gierasimczuk *et al*. 2009].

The study that was carried out revealed that the greatest, statistically significant content of ash was found in wheat straw (6.21%), as compared to barley straw and rape straw (Tab. 2). In the case of crop grain and rape seeds the content ranged from 1.64 to 4.00%, and was statistically important. Grzybek *et al*. [2001] claim that the content of ash in the crop straw is smaller and ranges from 3 to 4%. Whereas, Wilk [2006] assesses the content of ash in the crop straw within the range 4.3–10.4%.

Table 1. Chemical composition of straw, grain and seeds of selected cultivar plants

Specification	Coal, %	$NIR_{0,05}$	Hydrogen, %	$NIR_{0,05}$	Nitrogen, %	$NIR_{0,05}$	Sulphur, %	$NIR_{0,05}$
Wheat straw	43.48	0.89	6.00	r.n.	1.26	0.07	0.229	r.n.
Barley straw	43.60	r.n.	6.14	0.146	0.99	0.07	0.184	0.01
Rape straw	44.51	0.30	6.29	0.02	0.71	0.08	0.199	0.01
Wheat grain	41.52	0.85	6.79	0.09	2.57	0.06	0.246	0.02
Barley grain	41.61	r.n	6.78	r.n.	1.96	0.10	0.214	r.n.
Rape seeds	56.97	0.83	8.71	0.07	3.80	0.10	0.552	0.05

r.n. – insignificant differences

Table 2. Energy value of straw, grain and seeds of selected cultivar plants

Specification	Ash, %	$NIR_{0,05}$	Humidity, %	$NIR_{0,05}$	Combustion heat, MJ kg^{-1}	$NIR_{0,05}$	Fuel value, MJ kg^{-1}	$NIR_{0,05}$
Wheat straw	6.21	0.11	9.00	0.08	17.12	r.n.	15.87	r.n.
Barley straw	4.44	0.11	9.26	r.n.	16.84	r.n.	15.58	r.n.
Rape straw	3.21	0.09	9.48	0.37	17.64	0.29	16.36	0.24
Wheat grain	1.64	0.10	11.89	0.08	16.47	3.51	15.14	3.54
Barley grain	2.25	0.10	10.72	0.05	16.55	r.n.	15.23	r.n.
Rape seeds	4.00	0.12	6.89	0.04	25.99	3.52	24.72	3.54

r.n. – insignificant differences

The humidity of the crop straw and rape straw ranges from 9.00 to 9.48%. The statistical analysis showed significantly higher humidity of rape straw than the straw of the investigated crops. Denisiuk and Piechocki [2005] obtained similar humidity of wheat straw and rape straw in their studies. Much more diversified and statistically significant humidity can be found in crop grain and rape seeds (Tab. 2).

The fuel values of wheat straw and barley straw were comparable – 15,87 and 15,58 MJ kg^{-1} respectively (Tab.2). A slightly higher fuel value can be observed in rape straw 16,36 MJ kg^{-1} (Tab. 2). The results that were obtained are close to the fuel value of crop straw in the studies of other authors [Grzybek *et al*. 2001]. Also, Denisiuk and Piechocki [2005] obtained a similiar fuel value of wheat straw and rape straw in their studies. However, Niedziółka and Zuchniarz [2006], while analysing different kinds of biomass, obtained higher fuel value of crop straw and lower fuel value of rape straw, as compared to the results of this study.

The combustion value of straw, being an energy fuel, depends on its type, humidity, and storage technique. Grey straw that was exposed to atmospheric conditions for some time after it had been cut, and then dried, had better energy properties and smaller emission of sulphur compounds and chlorine compounds than yellow straw that has been freshly cut [Dreszer *et al*. 2003].

The results of the study reveal that rape seed have very high values of combustion heat and fuel value – 24.72 MJ kg^{-1}. In comparison, the fuel value of dry fuel mass of coal is 27–33 MJ kg^{-1}, and brown coal – 25–27 MJ kg^{-1}, heating oil – 39.7–42.6 MJ kg^{-1}.

Nowadays, rape is used as a food and as a biofuel. The policy of the EU with regards to biofuels and renewable energy triggered an increase in cultivation of rape and the development of rape processing. The European Union is the largest producer and consumer of biodiesel in the world. In 2010 the EU biofuel industry used about 70% of rape oil produce [Rosiak 2011].

The value of combustion heat and the fuel value (Tab. 2) reveal that the raw materials that were used can be well used in energy industry. Overproduction of crop straw and rape straw should be used as a fuel. The cost of 1 GJ of heating energy obtained from straw is about twice lower than that obtained from coal.

Table 3. Straw gaining indicator, depending on grain yield and cultivation area [Denisiuk and Piechocki 2005]

Specification	Winter crops			Spring crops		Rape
	Wheat	Rye	Barley	Wheat	Barley	
Straw yield to grain yield ratio	0.46	0.89	0.52	0.48	0.50	0.78
Straw yield in relation to cultivation area, $t \cdot ha^{-1}$ (mean value)	2.3	3.3	2.0	1.9	2.4	1.7

In a general energy balance, the surplus of straw can be highly significant with respect to biomass. The surplus of straw can be calculated on the basis of indicators (Tab. 3) that involve new technologies of harvest and new cultivars that have short stalk and high resistance to lodging. The area of cultivation, crop grain yield and rape seeds yield, as well as the indicators found in Table 3 allow one to determine the production of straw that can be used for energy purposes.

CONCLUSIONS

1. Straw, caryopsis, and seeds/grain of the investigated species of plants significantly differed in the content of ash and its chemical composition.
2. Barley straw, as compared to wheat straw, had lower content of ash, nitrogen, and sulphur, and a similar content of coal, hydrogen and fuel value.
3. Straw and rape seed, thanks to their high fuel value (16.36 i 24.72 MJ kg^{-1}) and low content of ash (3.21 i 4.00%), are raw materials of the most favourable properties with regard to their energy use.

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MOŻLIWOŚCI ENERGETYCZNEGO WYKORZYSTANIA SŁOMY I ZIARNA WYBRANYCH ZBÓŻ ORAZ RZEPAKU

Streszczenie. Przedstawiono charakterystykę słomy, ziarna pszenicy i jęczmienia oraz rzepaku, przeznaczonych do wykorzystania na cele energetyczne. Obejmowała ona analizę ciepła spalania i wartości opałowej. Wartość opałowa tych surowców kształtowała się w granicach od 15,14 do 24,72 MJ kg^{-1}. Badania wykazały istotne różnice w wilgotności, zawartości popiołu oraz azotu i siarki.

Słowa kluczowe: słoma, ziarno, biomasa, wartość energetyczna