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Higher and lower heating values of selected lignocellulose materials

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Abstract: Biomass is a promising alternative energy source. The most common raw material is straw in the form of bales, briquettes and pellets, although considerable demand is also observed for other energy crops. Introduced alien plants are used for various purposes: as fodder, in fermentation and as energy crops. This study aimed at the determination of higher heating value of plants of three species from the families *Miscanthus* and *Sorgum* in terms of their potential use as energy source before and after methane fermentation. Higher heating value of the tested raw materials was high both before and after the fermentation process.

Keywords: biomass, *Miscanthus, Sorghum,* heating value,

INTRODUCTION

Irrespective of the geographical location, since the beginnings of civilisation people worldwide have been using heat energy produced by combustion of available fuels. In terms of their origin fuels may be divided into:

- Natural fuels: hard coal, lignite, peat, biomass (including wood), crude oil, natural gas, biogas;
- Synthetic fuels: produced by processing natural fuels (cokehttp://pl.wikipedia.org/wiki/Koks, heating oil, diesel oil, petrol, wood distillation gas, town gas, LPG).

Biomass is the most important energy source, highly promising in terms of its development potential. Due to the high energy potential (formed as a result of photosynthesis during the plants' lifetime) it constitutes an excellent energy source. As it is reported by Gostomczyk [2011], lower heating value of coal is approx. 21.10 – 8.85 MJ/kg, while for liquid fuels it is approx. 47.31 – 42.3 MJ/kg and for gas fuels it is approx. 50.00 MJ/kg. Studies conducted worldwide concerning biomass potential indicate that the development of power engineering based on solid biomass needs to focus on the generation of electric and thermal energy in the Combined Heat and Power (CHP) systems [Jasiulewicz 2005]. Such a concept is justified, since in industrial heat and power generation systems reduction of primary fuels is around 35% [Fritzsche 2005].

This study comprised analyses of lower and higher heating values of *Miscanthus* and S*orghum* before and after fermentation. Tests were conducted on four grass species from the family Poaceae: Chinese silver grass *Miscanthus sinensis*, Amur silver grass *Miscanthus sacchariflorus* and *Miscanthus giganteus* as well as milo *Sorghum bicolor* [Niedziółka 2006].

Presented investigations aim at the determination of lower heating value of plants selected for heat production as substitutes in the combustion process. In order to realise the assumed objective it was necessary to perform the following tasks:

- determination of raw material moisture content;
- determination of higher heating value;
- calculation of lower heating value of raw materials.

MATERIAL AND RESEARCH METHODS

Plants from the family *Miscanthus,* originally grown in Asia, and *Sorghum,* a plant grown in South America and Mexico, were selected for this study.
Species *Miscanthus sacchariflorus*, *Miscanthus sinensis* and *Miscanthus×giganteus* came from experimental plots in Poznań belonging to the Institute of Plant Genetics, the Department of Energy Crops, PAS. All plants from the genus *Miscanthus* were harvested in July, when the plants were still in the vegetation period. Milo *(Sorghum bicolor)* from experimental plots in Mochełek near Bydgoszcz was also harvested in July.

Fresh material was cut manually into pieces of approx. 2 - 3 cm. A portion of the raw material was subjected to methane fermentation. In turn, raw material for analyses of higher and lower heating value was conditioned under laboratory conditions at a temperature of 20°C to provide constant moisture content of the material. Analyses of heating value were also conducted on fermentation residue. Material both before and after fermentation was dried and ground in a Pulverisette 15 laboratory mill by Fritsch and next it was sorted on sieves collecting the dust fraction of 0.1 – 0.4 mm particle size.

Heating value was determined according to the standard PN-81/G-04513 in a ZKL-4 calorimeter, designed to measure heating value (Q^a_s) of solid fuels. Analytical samples of 1 g raw material were completely combusted in the atmosphere of oxygen under pressure of 3 MPa.

To provide a more comprehensive characteristic of the analysed raw material also its lower heating value was calculated, i.e. by subtracting heat of vapourisation of the water vapour released from the fuel during its combustion from the higher heating value.

Dry matter content was determined by gravimetry by drying the raw material at 105^{o}C.

RESULTS

Tab. 1.

Higher and lower heating values

Experimental material	Moisture content [%]		Higher heating value [J/g]		Lower heating value [kJ/kg]	
	before fermentation	after fermentation	before fermentation	after fermentation	before fermentation	after fermentation
Miscanthus sacchariflorus	7.22	9.31	18590	18110	17000	16460
Miscanthus sinensis	7.33	9.87	19200	18040	17600	16380
Miscanthus×giganteus	7.15	9.44	19040	17740	17450	16100
Sorghum bicolor	7.94	9.16	18010	18010	16400	17990

Analysis of data in table 1 shows that moisture content of raw materials before fermentation ranged from 7.15% to 7.94%. In turn, moisture content of raw materials after fermentation, conditioned under identical conditions, was by approx. 2% greater and ranged from 9.31% to 9.87%. Among the tested raw materials before fermentation the greatest higher heating value of 19 200 J/g was recorded for *Miscanthus sinensis.* Higher heating value of *Miscanthus × giganteus* was also high, amounting to 19 040 J/g. In turn, *Miscanthus sacchariflorus* had higher heating value of 18 590 J/g. Among the tested lignocellulose raw materials the lowest value of this parameter, amounting to 18 010 J/g, was found for *Sorghum bicolor*. Higher heating value of the tested lignocellulose raw materials is high and comparable to that of wood from fast-growing species (Waliszewska and Wiśniewska 2005, Szczukowski et al. 2008).

After fermentation higher heating value of the investigated raw materials decreased and ranged from 17 740 J/g to 18110 J/g (tab. 1). The highest value of this parameter was recorded for *Miscanthus sacchariflorus*. The difference in higher heating value of this raw material before and after fermentation was 480 J/g, i.e. it was lower by approx. 2.6%. In turn, in the case of *Miscanthus × giganteus* this difference was as high as 1300 J/g, i.e. this value decreased by over 7%. A relatively great reduction in the higher heating value, amounting to almost 6.5%, was also observed in *Miscanthus sinensis*. After fermentation higher heating value of this raw material was 18 040 J/g.

Lower heating value of the tested raw materials before fermentation ranged from 16 400 kJ/kg to 17 600 kJ/kg (tab.1). The lowest level of lower heating value was recorded for *Sorghum bicolor*, while it was greatest for *Miscanthus sinensis*. *Miscanthus sacchariflorus* before fermentation had lower heating value of 17 000 kJ/kg, while in the case of *Miscanthus × giganteus* before fermentation lower heating value was 16 100 kJ/kg. After fermentation lower heating value of the investigated raw materials ranged from 16 100kJ/kg to 17 990 kJ/kg. In the case of *Miscanthus × giganteus* having the lowest value of this parameter, the reduction was over 8% in comparison to the lower heating value of this raw material before fermentation. For *Sorghum bicolor* lower heating value after fermentation was 17 990 kJ/kg, i.e. it decreased only by 20 kJ/kg in relation to this value in the raw material before fermentation.

CONCLUSIONS

- Higher heating value of the tested lignocellulose raw materials before fermentation ranged from 18 010 to 19 200 J/g.
- The greatest lower heating value was recorded for *Miscanthus sinensis* before fermentation.
- Lower heating value of the analysed raw materials ranged from approx. 16 100 to 17 600 MJ/kg and it was comparable to that typical of wood-based materials.
- The tested plants both before and after fermentation may be used as fuel to generate heat energy.

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Streszczenie: *Ciepło spalania i wartość opałowa wybranych surowców lignocelulozowych.* Ze względu na nieustający rozkwit światowego rynku energii, coraz częściej poszukuje się alternatywnych rozwiązań. Spośród alternatywnych źródeł duży potencjał energetyczny posiada biomasa. Oprócz tego biomasa jest substratem wysoce uniwersalnym, który można eksploatować w każdej postaci, bez ograniczeń w odróżnieniu od energii uzyskanej z niekonwencjonalnych źródeł. Coraz więcej instalacji ciepłowniczych jest przystosowywana do wykorzystania biomasy, jednak musi ona być dostarczana w ilości stałej dla sprawnego jej funkcjonowania. Najbardziej powszechnym surowcem jest słoma w postaci bel, brykietów i pelletów, jednak istotne również jest zainteresowanie innymi roślinami energetycznymi. Introdukowane rośliny wykorzystywane są na różne cele: paszowe, energetyczne (paliwa drugiej generacji) itp. Przedstawiona praca miała na celu zbadanie ciepła spalania roślin trzech gatunków z rodziny *Miscanthus* oraz *Sorgum* pod względem możliwości ich wykorzystania na cele energetyczne jako surowca przed i po procesie fermentacji metanowej.

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