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Research Article

GIANT MISCANTHUS AS A SUBSTRATE FOR BIOGAS PRODUCTION

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ABSTRACT
One unconventional source of energy, which may be applied in numerous production and municipal processes, is energy accumulated in plants. As a result of photosynthesis, solar energy is transformed into chemical energy accumulated in a form of carbohydrates in the plant biomass, which becomes the material that is more and more sought by power distribution companies and individual users. Currently, a lot of research on obtaining biogas from energy crops is conducted. Corn silage is used most often, however, there is a demand for alternative plants. The experiment described in this article was conducted with the use of giant Miscanthus (*Miscanthus Giganteus*).

Keywords: energy crops, biogas, methane fermentation, giant Miscanthus.

INTRODUCTION

Depleting resources of conventional energy sources, with constantly growing fuel demand and usage in many sectors of economy, industry and transportation, result in a concentration of research centres on improving technologies of obtaining energy from renewable sources and on increasing its application on the global scale [Kacprzak et al. 2012]. It is estimated that the usage of biotechnological processes will positively influence the improvement of our country energy balance as well as considerably decrease natural environment pollution [Ledakowicz and Krzystek 2005].

Biogas is one of the most important sources of renewable energy. Methane-rich biogas is a perfect fuel to produce electric and thermal energy [Brudniak et al. 2013; Lewandowski 2007; Schulz 2004]. Biogas production includes also advantages to the environment and may generate more income for farmers [Kazimierowicz 2014; Kopiński et al. 2011]. Many kinds of biomass may be used to produce biogas [Gradziuk 2003a; Kościk and Kowalczyk-Juśko 2004]. Energy crops can be an excellent source. They are characterised by a big annual growth. The majority of them grows best on fertile soil, however, with the use of proper technologies, it is possible to grow them on low-quality soli, wastelands and brownfields [Romanowska-Duda et al. 2007, 2009]. It is advised to grow energy crops on soil fertilised with treated sludge from municipal sewage treatment plants [Grzesik and Romanowska-Duda 2008; Romanowska-Duda and Grzesik 2010a,b].

Production of biomass for energy purposes may be a chance for crops diversification as well as for the development of farming in Poland [Roszkowski 2003]. It may also contribute to decrease the excess of some plants grown for food [Gradziuk 2003b; Gradziuk and Szmidt 1998; Jeżowski 2001, 2003; Majtkowski 1998].

The aim of the research was to define the amount and composition of biogas obtained as a result of giant Miscanthus fermentation in order to indicate that it is a plant suitable for biogas production.

METHODS

The material used in the experiment was giant Miscanthus, which belongs to the Poaceae (true grasses). It is a hybrid of Amur silver grass (Miscanthus sacchariflorus) and Chinese silver grass (Miscanthus sinensis). This is an impressive clump grass originating from South-East Asia. Giant Miscanthus is a C-4 photosynthetic plant and, therefore it is characterised by greater carbon dioxide (CO_2) absorption. It grows very fast and due to plantation longevity (15–20 years) as well as big biomass productivity, it is recognised as a valuable, alternative source of energy (Sørensen et al. 2008, Zawadzka et al. 2010).

The experiment was conducted three times. The substrate was crushed mechanically with the use of Robot Coupe Blixer. The content of dry, mineral and organic matter in the plant was described and averaged. Biomass was introduced into respirometric sets Oxi-Top Control type by WTW company, inoculated with activated sludge, in which the amount and composition of gas products of metabolism were measured. The equipment was composed of reaction chambers connected hermetically with metering and recording instruments. They recorded changes in partial pressure in the measuring chamber, caused by biogas production anaerobic processes made by microorganisms. The entire measurement set was placed in thermostatically controlled cabinet with hysteresis not exceeding ±0.5 °C. The measurements were conducted in the temperature of 36 °C. 25 cm^3 of sludge was introduced to the reaction chambers and calculated, on the basis of the content of dry organic mass, amount of plant substrates in the amount equivalent to the load A = 2.0 kg s.m.o./m^3. Then, trials were purged with nitrogen. Sets were placed in thermostatically controlled cabinet for 20 days and the pressure in the reaction chamber was measured every 15 min. Three days before the end of the measurement, 30% sodium base NaOH was introduced into a special container inside the reaction chamber. It allowed to precipitate carbon dioxide (CO_2) from the gas phase. Pressure drop in the reaction chamber corresponded to the content of carbon dioxide, whereas the content of methane was responsible for the remaining pressure head.

Ideal gas equation was the basis for calculations in respirometric research:

$$n = \frac{p \cdot V}{R \cdot T}$$

where: n – number of gas moles [mol],
p – gas pressure [Pa],
V – gas volume [m^3],
R – gas constant [8,314 J/mol·K],
T – temperature [K].

The content of carbon in the gas phase was described using the formula:

$$n_{CO_2} + n_{CH_4} = \frac{p_1 \cdot V_g}{R \cdot T} \cdot 10^{-4}$$

where: $n_{CO_2} + n_{CH_4}$ – the number of carbon dioxide and methane moles [mol],
p_1 – the difference in the gas pressure in the research container at the beginning and at the end of the experiment caused by oxygen consumption and absorption of the forming of CO_2 [hPa],
V_g – volume of the gas phase in the measuring chamber [ml],
T – incubation temperature [K],
10^{-4} – conversion coefficient.

The content of carbon dioxide in the gas phase was calculated using the formula:

$$n_{CO_2} = \left[\frac{p_1 \cdot V_g - p_2 \cdot (V_g - V_{NaOH})}{R \cdot T}\right] \cdot 10^{-4}$$

where: n_{CO_2} – number of created carbon dioxide moles [mol],
p_2 – the difference in gas pressure in the proper research container at the end of the experiment minus the pressure at the beginning of the experiment minus the pressure in the blank test after NaOH solution was added [hPa],
V_{NaOH} – the volume of NaOH solution [ml].

The content of methane in the gas phase was calculated:

$$n_{CH_4} = (n_{CO_2} + n_{CH_4}) - n_{CO_2}$$

Biogas production was determined on the basis of respirometric research. Pressure measurements were conducted by analyser in 15 minutes intervals and pressure measurements inside the chamber allowed to define the process rate. Applying the programme Statistica 8.0, reaction rate constants were fixed on the basis of the experimental data obtained by nonlinear regression method. Iterative method was used, i.e. in every iterative step, the function is replaced by a linear differential in relation to the determined parameters. By the determined parameters, φ^2 coefficient of agreement was assumed as a measure of curve fitting into the experimental data. This coefficient is a ratio of the sum of squares of the deviations of values calculated on the basis of the determined function from the experiment values to the sum of squares of the deviations of experimental values from the mean. The smaller φ^2 coefficient value, the better adjustment of the model. Such an adjustment of the model to the experiment points was assumed by which the coefficient of agreement did not exceed 0.2.

Table 1. Specification of giant Miscanthus and obtained biogas

Dry matter	Mineral dry matter	Organic dry matter	CO_2 content	CH_4 content	Biogas net calorific value	Biogas production in normal condition	The amount of gas in normal conditions
[mg/g]			[%]		[Wh/dm³]	[dm³]	[dm³/g s.m.]
350	20	330	4.6	50.4	4.99	0.098	0.30

RESULTS AND DISCUSSION

The results of conducted research are compared in Table 1. Using fresh giant Miscantus biomass as a substrate to the process of methane fermentation, 0.30 dm^3/g s.m. of biogas were obtained in the experiment conditions. The desired component, i.e. methane, constituted 50.4% of its content.

Dinuccio et al. 2010 researched the capacity of biogas production and the content of methane in such substrate as corn, grapes, straw, rice or tomato skins. In all cases, the content of methane in biogas stabilised up to the value from 50% to 60%, therefore, it was comparable to the giant Miscanthus case.

Klimiuk and others researched silage biogassing efficiency of four species of plants: corn, Sorghum, giant Miscanthus and Amur silver grass. Due to the high amount of lignin in Miscathus, biogassing efficiency of these plants was on a lower level than in the case of corn and Sorghum, and in the case of giant Miscanthus it amounted to 48.2%.

Grala et al. 2011 received 0.30 dm^3/g s.m. of biogas with 50.4% of methane content, as a result of a similar experiment. Comparable tendency may be seen in the research described in this article.

CONCLUSIONS

The use of giant Miacanthus as a substrate in the process of methane fermentation, aiming at biogas acquisition, is connected with many positive aspects. Created biogas may be an alternative to non-renewable fossil fuels. Miscanthus can be a great substitute to corn silage, used the most widely, because from 1 hectare of crops may be obtained a lot more cellulose biomass than from a biomass containing starch or from oil plants from which only particular parts and not the whole plants are used. Additional advantage is the fact that lignocellulosic biomass may be stored for many years without losing its energy content.

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