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BIOGAS YIELD FROM SORGHUM BICOLOR OF BIOMASS 140 VARIETY

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Summary. The paper presents results of physicochemical analysis of sorghum bicolor of Biomass 140 variety and pig liquid manure. Sorghum silage of different degree of chaff length was subjected to methane fermentation in two variants, taking the quality of pig liquid manure as a criterion. German standard DIN 38 414-S8 constituted a methodological basis. It was proved that both at better as well as at worse physicochemical parameters of pig liquid manure, sorghum bicolor silage of Biomass 140 variety may obtain high yield of methane in biogas. Research results prove that sorghum silage may be successfully used as a substrate for biogas plants. Sorghum because of its low water and soil requirements may constitute an alternative for maize on weaker stands. Sorghum ensilage method is the same as an ensilage technique of the most popular substrate for biogas plants, i.e. maize. During 26-days methane fermentation the highest average biogas yield was reported in a sample with silage A in variant I (254 l_N.kg·smo^{-1}) and in a sample with silage C in both variants, respectively 193l_N·kg·smo^{-1} i 207 l_N·kg·smo^{-1}.

Key words: biogas, sorghum bicolor, pig manure, methane fermentation

Introduction

Recently, one can notice popularization of the biomass use, including biogas with simultaneous growth of crops acreage for energy purposes. Sorghum is one of plants which may be used this way. Sorghum belongs to *Poaceae* family of photsynthesis type C_4. It is on the fifth place among the most important grains after maize, rice, wheat and barley on a global scale [Audilakshmi et al. 2010]. This type includes 25 varieties, which are cultivated around the world. Sorghum bicolor (regular – *Sorghum bicolor* (L.) Moench.), is one of the most important varieties which may be used in many ways, inter alia, for seeds, fodder, for production of sugar, alcohol and paper and as an energy plant [Sowiński, Liszka-Podkowa 2008; Mahmood 2011].

In Polish conditions sorghum may be an alternative crop to maize especially on weaker soils. The uuthors list number of chief assets of sorghum, including: high yield of green mass, high resistance to lodging, high content of soluble sugars and tolerance to draught [Sowiński, Liszka-Podkowa 2008; Vasilakoglou 2011; Mahmood 2011; Księżak et al. 2012; Kaczmarek et al. 2012; Whitfield et al. 2012].

Sorghum bicolor gives high yield at good energy efficiency which is proved by usefulness of this variety for biomass production for agricultural biogas needs [Burczyk 2011].

Hallam et al. [2001] indicate that within 4-year field experiments a higher yield of dry mass from sorghum bicolor was obtained (15.3–20.7 $t \cdot ha^{-1}$) in comparison to other annual plants, inter alia maize (11.5–17.9 $t \cdot ha^{-1}$). Sorghum bicolor Biomass 140 variety is placed in a community catalogue of agricultural plants varieties [Official Journal of the European Union 2010].

Due to low popularity of sorghum cultivation in the Polish climate, they decided to check biogas production efficiency, including methane yield for sorghum bicolor of Biomass 140 variety. Simultaneously, biogas productivity of sorghum silage as a co-substrate with pig manure was verified depending on its quality. Research results presented below are initial analysis of biogas produciton potential from sorghum bicolor of Biomass 140 variety.

The objective and the scope of the study

The objective of the research was to analyse and assess a biogas yield from sorghum silage of varied chaff length depending on the quality of pig manure quality. During analysis special attention was paid to correlation between biogas volume and content of methane.

Research methodology

The initial research was carried out in Laboratorium Biogazu w Katedrze Budowy i Użytkowania Urządzeń Technicznych ZUT [the Biogas Laboratory in the Department of Construction and Use of Technical Devices ZUT] in Szczecin. Silage made of sorghum bicolor Biomass 140 variety and pig manure constituted research material. Sorghum bicolor was obtained from the Experimental Centre ZUT with the seat in Lipnik. While, pig manure was collected from a breeding farm Kołki located in Choszczeński province in Zachodniopomorskie voivodeship.

Plants were cut before ensilage into different chaff lengths: up to 1 cm (sorghum A), > 1cm to 3 cm (sorghum B), 3 cm to 5 cm (sorghum C), > 5 cm do 8 cm (sorghum D) (fig. 1). Then, plant mass was ensilaged in mini silos where it was placed for 6 months. Before tests were carried out, silage and pig manure were subjected to physicochemical analyses according to the binding standards. A static methane fermentation process was carried out in two variants (criterion: pig manure quality). German standard - DIN 38 414-S8 was accepted as a methodical basis, changing preparation of samples before fermentation. Modification consisted in resignation from using nitrogen for air uplift from bottles, on which eudiometric biurets are placed. Volume and content of biogas were measured in 24 hours intervals.

Before preparation of co-substrate mixture their weight ratio was determined with maintaining parameters of wet methane fermentation on the level of 12 % of dry mass. Biogas production process with the use of sorghum silage and pig manure was carried out on a research stand consisting in the set of eudiometric biurets and water bath.

A B C D

Fig. 1. Plant material varied on account of chaff length
Rys. 1. Materiał roślinny zróżnicowany pod względem długości sieczki

Analysis of the research results

Before proper methane fermentation was initialized, physical and chemical analyses of basic components in plant material and pig manure were carried out (table 1), i.e. pH, dry mass (d.m.) organic dry mass (o.d.m.), total nitrogen, total phopshorus and potassium. Content of dry mass of sorghum silage was within the range of 29% (sorghum D) up to 34% (sorghum A and C). Whereas, two types of pig manure used in experiment differed considerably with the content of dry mass: manure A - 7.2%, manure B -0.7%.

Table 1. Physicochemical composition of sorghum silage of different degree of chaff length and pig manure
Tabela 1. Skład fizykochemiczny kiszonek z sorgo o różnym stopniu długości sieczki oraz gnojowicy świńskiej

Specification	pH	d.m. [%]	o.d.m. [% s.m.]	Total N [g·kg^{-1}]	Total P [g·kg^{-1}]	K [g·kg^{-1}]
Sorghum A: (up to 1 cm)	5.9	34	94	10.1	9.4	17.2
Sorghum B (1.1-3cm)	7.5	33	93	8.7	13.1	15.0
Sorghum C (3.1-5 cm)	6.9	34	96	6.0	8.2	16.6
Sorghum D (5.1-8 cm)	6.6	29	94	7.9	8.6	19.7
Pig manure A	7.3	7.2	72	3.8	23.1	2.7
Pig manure B	7.9	0.7	59	2.7	0.4	1.5

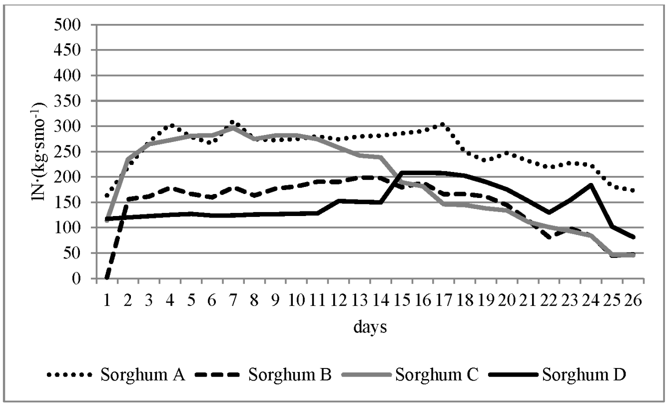
Source: author's own study

Taking into consideration the results of physical and chemical analyses, one could have expect the highest biogas yield, including methane, from samples where silage from sorghum A was used as a co-substrate (chaff length up to 1 cm).

Mesophillic static fermentation process lasted 26 days and was carried out in two variants:

– variant I - particular silages from sorghum and pig manure A constituted mixture of co-substrates,
– variant II - particular silages from sorghum and pig manure B constituted mixture of co-substrates.

In variant I of the experiment (fig. 2) silages from sorghum of different chaff length and pig manure A were used for methane fermentation. Silage A and C had the highest biogas yield. While, the lowest biogas yield was reported in a sample with silage D.

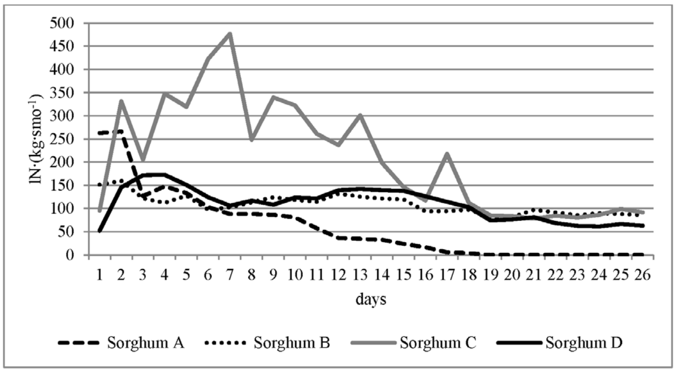


I_N·(kg·d.o.m^{-1}) – a normalised unit of gas volume (1 litre) in regular conditions / one kilo of dry organic substance

Source: author's own calculations;

Fig. 2. Biogas yield from sorghum silages in variant I of the experiment
Rys. 2. Uzysk biogazu z kiszonek z sorgo w wariancie I doświadczenia

In case of variant II (fig. 3) sorghum silages and pig manure B were used for the experiment. Silage C had the highest biogas yield, while silage A had the lowest. It was reverse to variant I. While silage B and D had a similar biogas yield during 26-days methane fermentation.



l_N·(kg·d.o.m.$^{-1}$) – normalised unit of gas volume (1 litre) in regular conditions / one kilo of dry organic substance

Source: author's own calculations;

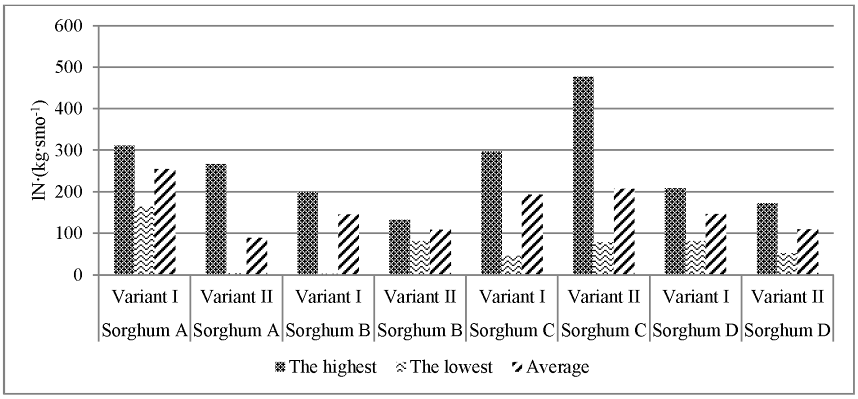
Fig. 3. Biogas yield from sorghum silage in variant II of the experiment
Rys. 3. Uzysk biogazu z kiszonek z sorgo w wariancie II doświadczenia

The highest unit biogas yield (fig. 4) was reported in variant II of the experiment with the use of sorghum silage C (477 l_N·kg·d.o.m.$^{-1}$). Efficiency of biogas production from A sorghum silage (311 l_N·kg·d.o.m.$^{-1}$ and 267 l_N·kg·d.o.m^{-1}) and D (208 l_N·kg·d.o.m.$^{-1}$ and 173 l_N·kg·d.o.m.$^{-1}$) in both variants of the experiment was at a comparable level. While, silage B had the lowest unit biogas production in variant I (1.8 l_N·kg·d.o.m.$^{-1}$) and silage A in variant II of the experiment (3.6 l_N·kg·d.o.m.$^{-1}$).

During 26-days methane fermentation the highest average biogas yield was reported in a sample with silage A in variant I ((254 l_N.kg·d.o.m.$^{-1}$) and in a sample with silage C in both variants, respectively 193l_N·kg·d.o.m.^{1} and 207 l_N·kg·d.o.m.$^{-1}$.

Comparing biogas yield between variants including silage of the same chaff length, it is found that there was 65% of sorghum A silage during methane fermentation in variant I and in case of sorghum B and D silage by 25% more biogas than in variant II. While, in case of sorghum C in variant II, there was more biogas by 7.5% than in variant I.

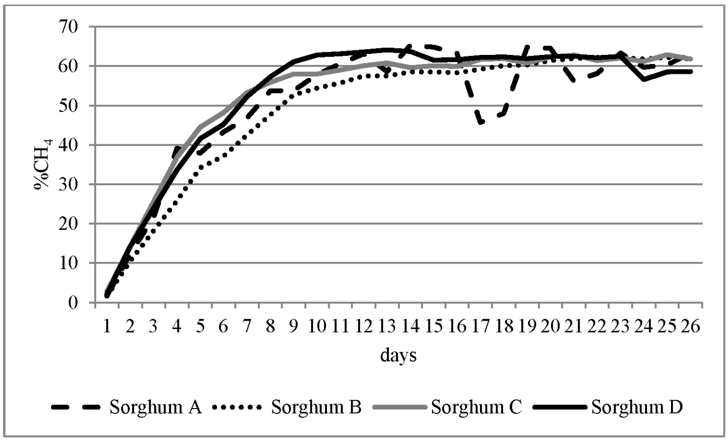
Taking into consideration, the content of methane in the produced biogas during 26-days fermentation in two variants, one may find that in case of sorghum B, C and D, the value of CH_4 was on a similar level (fig. 5 and 6). Only in case of sorghum A in variant II the process was broken (after 19 days of fermentation), which resulted in stopping the biogas production. While in variant I including silage of sorghum A, a considerable decrease on the 14th day of fermentation may be reported, and then another increase of methane content in the produced biogas occurred (fig. 5).



Source: Author's own calculations;

Fig. 4. Biogas production efficiency from Biomass 140 sorghum silage in two variants of the experiment

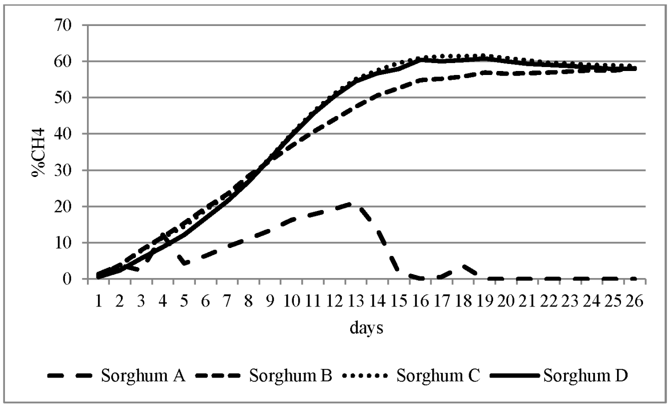
Rys. 4. Wydajność produkcji biogazu z kiszonek z sorgo odmiany Biomass 140 w dwóch wariantach doświadczenia



Source: author's own calculations

Fig. 5. Biogas yield from sorghum silage in variant I of the experiment

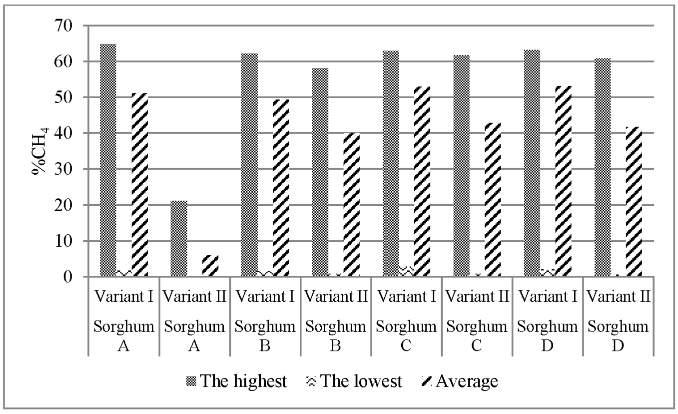
Rys. 5. Zawartość metanu w biogazie z kiszonek z sorgo w wariancie I doświadczenia



Source: author's own calculations;

Fig. 6. Biogas yield from sorghum silage in variant II of the experiment
Rys. 6. Zawartość metanu w biogazie z kiszonek z sorgo w wariancie II doświadczenia

Figure 7 proves that the highest methane yield was reported in case of sorghum A in variant I (64.8% CH_4) and then in sorghum D in variant I (63.1% CH_4). A comparable value of methane was obtained in a sample from sorghum C in both variants, respectively (62.9% CH_4 and 61.6% CH_4). While, the lowest values were on the level from 0.1% CH_4 (sorghum A, variant I) to 2.8% CH_4 (sorghum C, variant I).



Source: Author's own calculations;

Fig. 7. Methane production efficiency in biogas obtained from Biomass 140 sorghum silage in two variants of the experiment
Rys. 7. Wydajność produkcji metanu w biogazie z kiszonek z sorgo odmiany Biomass 140 w dwóch wariantach doświadczenia

While, the scope of average values of methane in the produced biogas was between 6.1% CH_4 (sorghum A, variant II) to 53.1% CH_4 (sorghum D, variant I). Content of methane in C and D sorghum silage in variant II was on a similar level (42.8% CH_4 and 41.7% CH_4). A similar relation may be observed in case of silage A, B and C in variant I, respectively: 51.1% CH_4, 49.4% CH_4 and 52.9% CH_4.

Comparing methane yield between two variants of experiments with reference to silage of the same defragmentation, it may be noticed that in samples in variant I there is more methane than in variant II. In a sample with silage from sorghum A in variant I there was by 88% more methane than in variant II. Between silage from sorghum B and C, there was by 19% more methane in variant I than in variant II. In a sample with silage from sorghum D in variant I there was by 21% more methane than in variant II.

Summary

Sorghum silage may be successfully used as a substrate for biogas plants. It may constitute an alternative for maize, which is characterised by a relatively high methane yield in biogas. A method of sorghum ensilage is the same as the ensilage technique of the most popular substrate for biogas plants, i.e. maize. Biomas 140 sorghum is a good material for silage production. In the used silage dry mass content from 29 to 34 % was reported. On the basis of the research on the biogas efficiency which was carried out, it was found that:

– the highest average biogas production and the highest unit biogas production occurred in case of sorghum A silage in variant I of the experiment (respectively 254 l_N.kg·d.o.m.$^{-1}$ and 311 l_N·kg·d.o.m.$^{-1}$),
– the lowest average value of biogas production and the lowest methane content was in silage A from variant II of the experiment,
– the highest unit biogas yield was reported in case of sorghum C silage in variant II of the experiment(477 l_N·kg·d.o.m.$^{-1}$),
– the highest average content of methane was in sorghum D silage in variant I of the experiment (53.1% CH_4),
– in case of variant II with the use of manure of worse physicochemical parameters (manure B), approx. 25% lower biogas yield was reported with reference to manure of better parameters (manure A),
– at the 0.7% content of dry mass in variant II of the experiment (manure B) in sorghum B, C and D silage at the average 42% of CH_4 in biogas was obtained,
– methane fermentation of sorghum A in variant II of the experiment was disturbed by inadequate inoculation with methane bacteria of co-substrates mixture or by faster use of easily available chemical compounds by fermentation bacteria.

The above results of the initial research prove the necessity of further analysis of assessment of biogas production efficiency including methane from Biomass 140 sorghum silage of varied chaff length.

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UZYSK BIOGAZU Z SORGA CUKROWEGO (*SORGHUM BICOLOR*) ODMIANY BIOMASS 140

Streszczenie. W pracy przedstawiono wyniki analiz fizykochemicznych sorgo cukrowego Biomass 140 i gnojowicy świńskiej. Kiszonki z sorgo o różnym stopniu długości sieczki poddano fermentacji metanowej w dwóch wariantach, przyjmując za kryterium jakość gnojowicy świńskiej. Podstawę metodyczną stanowiła niemiecka norma DIN 38 414-S8. Wykazano, że zarówno przy lepszych, jak i gorszych parametrach fizykochemicznych gnojowicy świńskiej, kiszonka z sorgo cukrowego odmiany Biomass 140 może osiągnąć wysoki uzysk metanu w biogazie. Wyniki badań potwierdzają, że kiszonka z sorgo może być z powodzeniem stosowana jako substrat do biogazowni. Sorgo ze względu na małe wymagania wodne i glebowe może stanowić alternatywę dla kukurydzy, na słabszych stanowiskach. Sposób zakiszania sorgo jest tożsamy z techniką zakiszania najpopularniejszego substratu do biogazowni, jakim jest kukurydza. W trakcie trwania 26-dniowej fermentacji metanowej najwyższy średni uzysk biogazu odnotowano w próbie z kiszonką A w wariancie I (254 l_N.kg·smo^{-1}) oraz w próbie z kiszonką C w obu wariantach, odpowiednio 193 l_N·kg·smo^{-1} i 207 l_N·kg·smo^{-1}.

Słowa kluczowe: biogaz, sorgo cukrowe, gnojowica świńska, fermentacji metanowa

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