# CHARACTERISTICS OF THE VIRGINIA FANPETALS BIOMASS AS CO-FEEDSTOCK IN A BIOGAS PLANT

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**Abstract**: This paper presents results of an assessment of the chemical composition and energy value of the Virginia fanpetals biomass harvested from a field experiment which included three different levels of fertilization and different harvest dates. A preliminary evaluation of the gas yield potential of the crop's green mass was also accomplished. It has been demonstrated that the way the biomass was harvested had a stronger impact on the basic chemical composition and shares of selected carbohydrate fractions than the mineral fertilization of the Virginia fanpetals. A large content of dry matter in the green biomass, quite a favourable C:N ratio and a high percentage of methane in biogas obtained by digestion of this feedstock implicate that the Virginia fanpetals biomass can be used as a co-feedstock in agricultural biogas plants.

## Introduction

The principal aim of agricultural biogas plants is to utilize waste generated by the agricultural produce and foodstuff processing [3]. Besides, biogas plants are more and more often used as an important source of energy and a significant element in the energy diversification strategy. Another type of feedstock in biogas plants could consist of the biomass from dedicated energy crop plantations, either digested alone or in combination with other matter to improve the course and efficiency of fermentation [3]. For this purpose, maize silage is the most popular choice because maize is a high yielding plant, whose cultivation and biomass production technologies are well-developed. Moreover, maize silage is in general easily available raw material that yields much biogas [2]. However, securing sufficient food supplies in the country, limiting the risk of spreading diseases and pests and rising prices of maize challenge researchers to look for alternative plants [9; 12], e.g. the Virginia fanpetals (*Sida hermaphrodita* Rusby) [7]. This plant is highly productive, with year-to-year stable yields and the ability to regenerate after a cut during a growing season [8; 11]. It can be grown on lands unsuitable for food crops, as it has modest soil requirements, high tolerance to drought, lodging and frost as well as moderate susceptibility to diseases and pests [14].

The aim of this study was to determine the chemical composition and energy value of the Virginia fanpetals depending on the level of fertilization and harvest technology. Another purpose was to present a preliminary gas yielding evaluation of silage made from this plant.

## Methods

The determinations were made on samples collected in 2013 from a field experiment on the Virginia funpetals started in 2010 at the Research Station in Bałdy. The experiment comprised three fertilization levels (zero, $N_{80}P_{21,6}K_{58}$ and $N_{160}P_{43,2}K_{116}$) and three harvest dates (1st cut from a two-cut, 2nd cut from a two-cut and a one-cut system). The moisture content of green biomass was determined with the over-dry weight method; the ash content was assayed in a thermogravimetric analyzer ELTRA TGA 701; crude fibre and cellulose were determined in a FOSS Fibertec 2010 system, while the content of fat was analyzed with the Soxleth method in a B-811 extractor made by BÜCHI. Determinations of the concentrations of carbon, hydrogen and sulphur were performed in a CHS500 analyzer made by ELTRA, while nitrogen was checked by the Kjeldahl method in a FOSS Fibertec 2010 system (BÜCHI) used for mineralization and distillation. The content of lignin was determined by the Tappi T-13m-54 method in a FOSS Fibertec 2021 system. Fractions of structural carbohydrates (ADF and ADL) were analyzed by the Van Soest method. The heat of combustion was assessed in an IKA C 2000 calorimeter according to the dynamic method.

The digestion process was carried out on a laboratory scale under static conditions. The biogas production efficiency, including methane and carbon dioxide yields, was determined by respirometric analysis on a Micro Oxymax® respirometer (Columbus Instruments). Prior to placing in a digestor, samples were ground and inoculated with inoculum containing 3.25% of dry matter and 49.32% of organic dry matter (to samples were also added 30 ml of demineralized water). Digestion sludge originated from the Closed Digestion Chamber (CDC) of the Łyna Wasterwater Treatment Plant in Olsztyn. The load of the digestion chamber with a dose of organic compounds was set at 3.0 kg $o.d.m. \cdot m^{-3}$. Digestion tanks, each of the capacity of 0.5 l, were placed in a water bath with a shaking system (Memmert WNB 29). The digestion process was run for 12 days under mesophilic conditions (37°C).

## Results and discussion

The green matter harvested from plants fertilized with half a dose and full dose of NPK was characterized by a higher content of fibre and fat compared to that obtained from unfertilized plots (tab. 1). The full NPK fertilization dose caused a significant decrease of the dry matter in green plants compared to the other two treatments, which did not differ from each other statistically significantly. There was no tendency observed for the content of ash in the green matter of Viginia fanpetals plants related to the level of fertilization.

The Virginia fanpetals biomass in a single-cut technology had a higher content of dry matter than the one grown in a two-cut cycle. The former biomass also contained more ash and crude fibre. The green biomass from the two-cut system was characterized by a higher content of dry matter and higher concentrations of ash, fibre and lipids than that from the one-cut treatment.

Table 1.

Basic chemical composition of the Virginia fanpetals biomass

| Factor | | Dry matter [%] | Ash [%d.m.] | Fibre [%d.m.] | Fats [%d.m.] |
|---|---|---|---|---|---|
| Fertilization | zero | 28.6 | 8.78 | 34.9 | 2.23 |
| | $N_{80}P_{21,6}K_{58}$ | 28.7 | 9.15 | 39.4 | 2.37 |
| | $N_{160}P_{43,2}K_{116}$ | 27.1 | 8.33 | 38.7 | 2.33 |
| Harvest | two-cut first cut | 22.5 | 7.17 | 31.9 | 1.27 |
| | two-cut second cut | 24.9 | 8.21 | 37.6 | 3.43 |
| | one-cut | 37.1 | 10.88 | 43.4 | 2.24 |
| Mean | | 28,2 | 8.75 | 37.7 | 2.31 |
| LSD(0,05) | fertilization | 0.86 | 0.050 | 0.29 | 0.034 |
| | harvest | 0.86 | 0.050 | 0.29 | 0.034 |

Mineral fertilization of Virginia fanpetals plants increased the content of cellulose, lignin and the analyzed structural carbohydrates (ADF, ADL) in green matter compared to the unfertilized samples (tab. 2). Notwithstanding that, the dose of applied fertilizers did not tend to have any significantly differentiating effect on concentrations of these components in the Virginia fanpetals biomass.

Green plants harvested in the one-sut system contained significantly more cellulose and acid-detergent fibre than in the two-cut technology. The highest concentrations of lignin and acid lignin was found in the second cut of the two-cut system. Biomass obtained from the first cut had lower levels of the above components than the biomass harvested in the second cut, with the difference equal 11% for cellulose and 30% for lignin. Celluloses and lignins are the main components of plant raw materials [4]. They create a compact and durable lignocellulose complex, which necessitates some pre-processing before digestion [6].

The heat of combustion was characterized by relative stability and was rather weakly differentiated by the analyzed factors. The highest calorific value was determined for the biomass fertilized with the full dose of NPK nutrients; regarding a harvest technology, biomass achieved at the end of the growing season in the one-cut system was most calorific.

Table 2.

Analysis of nutrients in the Virginia fanpetals biomass [% d.m.]

| Factor | | Cellulose | Lignin | ADF* | ADL** | Gross energy |
|---|---|---|---|---|---|---|
| Fertilization | zero | 33.1 | 9.30 | 43.4 | 10.26 | 17.9 |
| | $N_{80}P_{21,6}K_{58}$ | 37.4 | 10.46 | 47.9 | 11.51 | 18.2 |
| | $N_{160}P_{43,2}K_{116}$ | 36.6 | 10.24 | 48.9 | 11.24 | 18.3 |
| Harvest | two-cut first cut | 31.6 | 8.09 | 40.5 | 8.84 | 17.9 |
| | two-cut second cut | 35.6 | 11.50 | 48.1 | 12.54 | 17.8 |
| | one-cut | 39.9 | 10.39 | 51.6 | 11.62 | 18.7 |
| Mean | | | 10.00 | 46.7 | 11.00 | 18.1 |
| LSD (0.05) | fertilization | 0.43 | 0.235 | 0.34 | 0.266 | - |
| | harvest | 0.43 | 0.235 | 0.34 | 0.266 | - |

*ADF – acid-detergent fibre
**ADL – acid-detergent lignin

The NPK fertilization caused a significant increase in the content of carbon, hydrogen and nitrogen in the Virginia fanpetals biomass versus the unfertilized plots (tab. 3). The content of nitrogen increased at the higher dose of fertilization, while the content of carbon and hydrogen was the highest in response to half the dose of fertilizers. The best carbon to nitrogen ratio was found in the biomass of the plants fertilized with the full NPK dose. The content of sulphur in biomass was the highest in the unfertilized treatments, and tended to decrease under the growing doses of NPK, on average by 15% at each subsequent fertilization level.

Table 3.

Analysis of elements in the Virginia fanpetals biomass [% d.m.]

| Factor | | C | H | S | N |
|---|---|---|---|---|---|
| Fertilization | zero | 41,4 | 5,57 | 0,205 | 1,30 |
| | $N_{80}P_{21,6}K_{58}$ | 44.8 | 6.01 | 0.174 | 1.34 |
| | $N_{160}P_{43,2}K_{116}$ | 42.6 | 5.73 | 0.140 | 1.51 |
| Harvest | two-cut first cut | 39.0 | 5.55 | 0.178 | 1.50 |
| | two-cut second cut | 45.2 | 6.11 | 0.213 | 1.36 |
| | one-cut | 44.7 | 5.66 | 0.128 | 1.29 |
| Mean | | | 5.77 | 0.173 | 1.39 |
| LSD (0.05) | fertilization | 0.15 | 0.042 | 0.0039 | 0.014 |
| | harvest | 0.15 | 0.042 | 0.0039 | 0.014 |

The biomass harvest date differentiated the content of elements in the Virginia fanpetals biomass more strongly than the NPK fertilization. The highest concentrations of carbon, hydrogen and sulphur were in the second cut. The content of nitrogen was the highest in the biomass from the first cut and the lowest in the green biomass from the one-cut system.

There was an evident, close and positive relationship between the carbon concentration in the biomass and the content of structural carbohydrates, fibre, fat and hydrogen (tab. 4). Fractions of structural sugars were likewise closely correlated. A positive dependence was demonstrated between the content of crude fat and the fractions of lignins in the Virginia fanpetals biomass.

Table 4.

Matrix of correlation coefficients for selected traits of the Virginia fanpetals biomass

| variable | ash | C | H | S | N | ADF* | cellulose | ADL** | lignin | fibre |
|---|---|---|---|---|---|---|---|---|---|---|
| C | **0.58** | | | | | | | | | |
| H | 0.12 | **0.83** | | | | | | | | |
| S | **-0.36** | 0.02 | **0.32** | | | | | | | |
| N | **-0.41** | -0.23 | 0.09 | 0.08 | | | | | | |
| ADF* | **0.72** | **0.91** | **0.62** | **-0.31** | -0.19 | | | | | |
| cellulose | **0.74** | **0.83** | **0.55** | **-0.41** | -0.17 | **0.97** | | | | |
| ADL** | **0.47** | **0.83** | **0.62** | 0.05 | -0.18 | **0.78** | **0.62** | | | |
| lignin | **0.40** | **0.82** | **0.65** | 0.09 | -0.15 | **0.75** | **0.59** | **1.00** | | |
| fibre | **0.80** | **0.80** | **0.43** | **-0.49** | **-0.30** | **0.94** | **0.94** | **0.65** | **0.61** | |
| fat | 0.21 | **0.72** | **0.60** | 0.27 | **-0.32** | **0.55** | **0.38** | **0.80** | **0.81** | **0.44** |

*ADF – acid-detergent fibre
**ADL – acid-detergent lignin

The mean accumulated amount of biomass obtained from the Virginia fanpetals green biomass was about 202 $dm^3 \cdot kg_{d.m.}^{-1}$, in which methane made up about 74% (fig. 1). Fertilization only slightly affected the yield of biogas obtained from the Virginia fanpetals biomass. Under the $N_{160}P_{43,2}K_{116}$ fertilization regime, a decreasing methane content was observed (down to 70%). The highest biogas yield (211 $dm^3 \cdot kg_{d.m.}^{-1}$) with the highest percentage of methane (77%) was achieved from the biomass harvested in the one-cut system, which was surprising because that biomass was more woody than the one harvested from the two-cut plots. On the other hand, it had the highest dry matter content. The amounts of biogas obtained from the Virginia fanpetals grown in our study were just half the yields reported by Wojnowska-Baryła and Bernat [13]. The literature implies that methane yields from silage can be higher than from green biomass [1]. However, the available data suggest very high variations in the biogas productivity from this plant material, within the range of 110 and 700 $dm^3 \cdot kg_{d.m.}^{-1}$ [5; 10; 12].

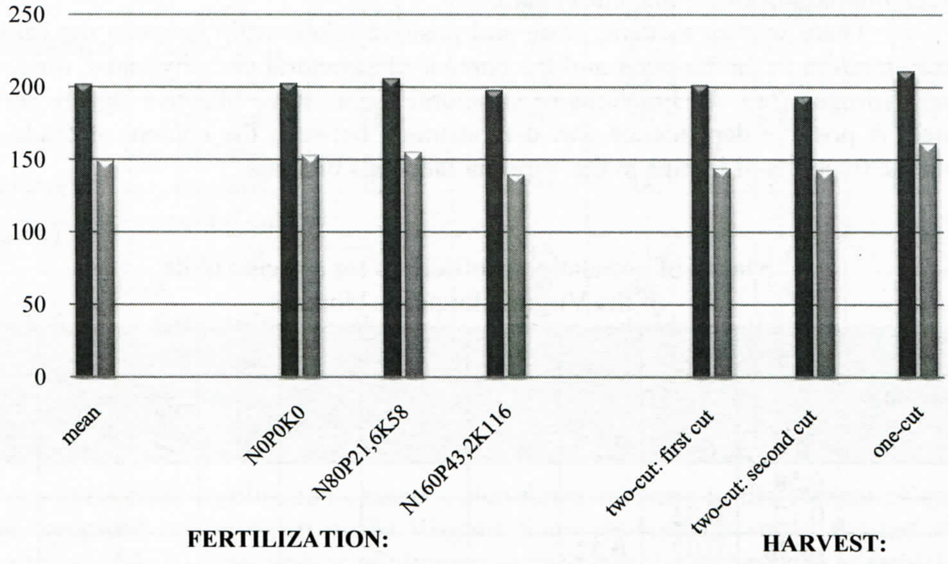


Fig. 1. Accumulated amount of biogas and methane [$dm^3 \cdot kg_{d.m.}^{-1}$]

**Summary**

Fertilization supplied under the Virginia fanpetals modified the chemical composition of biomass within a very small range, with the dose of $N_{80}P_{21,6}K_{58}$ having a stronger impact than the higher one.

The harvest term and technology had a stronger effect on the chemical composition of harvested biomass than the NPK fertilization regime. The biomass obtained from the first cut was characterized by a more favourable chemical composition, but had the lowest dry matter content.

The biogas produced from the green biomass contained much methane, which makes it a suitable product for co-fermentation with agricultural waste and other by-products distinguished by small methane productivity.

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# ECO-ENERGETICS – BIOGAS

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