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CHEMICAL AND ENERGETICAL PROPERTIES IN METHANE FERMENTATION OF MORPHOLOGICAL PARTS OF CORN WITH DIFFERENT VARIETY EARLINESS STANDARD FAO

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ABSTRACT

In the last decades, the production of biomass biofuels for thermochemical conversion to replace fossil fuels has attracted increasing attention as it offers significant environmental benefits. A very common way to convert biomass to energy is methane fermentation. The importance of biogas as a source of energy is growing. The use of biomass to biogas production on a large, global scale may lead to controversial competition for arable land, water, and consequently, food. Therefore, only waste materials and agricultural by-products and residues should be used for biogas production. Corn stover is a good example of agricultural residues for biogas production. Therefore, the aim of these studies was to determine the influence of corn variety earliness FAO on the chemical compositions and energy value of morphological parts (fractions) of corn plants. The research material consisted of morphological parts of corn plants: stalks, leaves, husks, and cobs of selected corn cultivars, differing in terms of their FAO earliness: early (FAO 220), medium-early (FAO 240) and late (FAO 300) varieties. The research included laboratory investigations, elemental analysis, methane fermentation and statistical analyses of results. Based on the results of the study, it was concluded that the FAO earliness of a corn variety had a significant impact on the elemental composition, ash content, biogas, and methane yield in the corn morphological fractions. The highest methane yield of 267.4 $m^3 \cdot Mg^{-1}$ TS was found for the cucurbit cover leaves of a variety with an FAO 240 earliness standard.

Introduction

The energy is one of sources of human life and a major factor in economic growth (Cergibozan, 2022). The massive use of fossil fuel energy resources has led to growing concerns about future energy supplies and worries about the harmful climate impacts caused by their combustion (Aghbashlo et al., 2017; Aghbashlo et al., 2018; Rajaeifar et al., 2017; Wojcieszak et al., 2022). Therefore, there has been an ever-increasing interest in environmentally friendly alternative energy sources (Hosseinpoura et al., 2017). In the last decades, the production of biomass biofuels for thermochemical conversion to replace fossil fuels has attracted increasing attention as it offers significant environmental benefits (Aghbashlo et al., 2016; Aghbashlo et al., 2017; Hajjari et al., 2017; Khalife et al., 2017; Kraszkiewicz et al., 2013). A very common way to convert biomass to energy is methane fermentation (Cieślik et al., 2016; Li et al., 2011; Menardo et al., 2015; Niedziółka and Zaklika, 2016; Wojcieszak et al., 2018; Wojcieszak et al., 2020; Balanda et. al 2022). Many countries developed the renewable energy sector by using biogas (Bayrakci et al., 2012; Budzianowski and Chasiak, 2011). The importance of biogas as a source of energy is growing (Budzianowski, 2012; Budzianowski and Chasiak, 2011; Dach et al., 2014; Hajjari et al., 2017; Czekała et.al., 2023).

The use of biomass for biogas production on a large, global scale may lead to controversial competition for arable land, water, and consequently, food (Hajjari et al., 2017). Therefore, only waste materials and agricultural by-products and residues should be used for biogas production.

Corn stover is a good example of agricultural residues for biogas production (Cieślik et al., 2016; Hassan et al., 2017; Mazurkiewicz et al., 2019; Menardo et al., 2015; Wojcieszak et al., 2018; Wojcieszak et al., 2020; Wojcieszak et al., 2022). After corn grain harvest, post-harvest corn residues - corn stover, composite of four morphological parts, namely, stalks, leaves, husks, and cobs, stay on a field (Shinners et al., 2007). According to Shinners et al. (2007) and Zych (2008), residues after grain harvest constitute 47-50% of the yield of dry matter of whole corn plants.

Properties of the corn morphological parts were investigated in terms of their multiple application. For example, corn stover biomass is used as an insulating material (Czajkowski et al., 2019; Bovo et al., 2022). Maj et al. (2019) presented the results of chemical compositions and calorific value of husk and cobs cores. Zając et al. (2020) tested chemical compositions of corn cobs and husks and based on these results estimated greenhouse gases emissions. Menardo et al. (2015) presents the results of carbon and nitrogen content for four morphological parts of corn and the methane yield, but only for varieties FAO class 600. Wojcieszak et al. (2020) presents the results of the chemical composition content for four morphological parts of corn and the methane yield too, but only for varieties FAO class 200. Wojcieszak et al. (2022) presents the results of the chemical composition and a high heat value only for cobs cores of six different corn of FAO variety earliness index.

Li et al. (2012) presented stalk rind, stalk pith, and leaf fraction, and found differences in their tissues, cell morphology, and chemical compositions. Pordesimo et al. (2005) presented the variation in corn stover composition and energy content with crop maturity.

Corn varieties differ in maturation time for harvest. The index of earliness of corn varieties was adopted in the 1950s by the Food and Agriculture Organization of the United Nations (FAO). Now is known as FAO numbers. According to this system, varieties are divided into nine earliness classes denoted by three digits (100-190...900-990). Each digit indicates a parameter. The first digits indicate an earliness class, the second digit - the earliness group as part of the basic class. The last digit indicates the color of the caryopsis (Wojcieszak et al. 2022). In Poland, the following division of corn earliness applies: up to FAO 190—very early; FAO 200–220–early; FAO 230–240–medium-early; FAO 250–290–medium-late; and FAO 300 and above–late (Wojcieszak et al., 2022). Corn is also divided with regard to its use as silage and grain variety.

After the literature studies at the identified area new knowledge is needed. Therefore, the aim of these studies was to determinate the influence of corn variety FAO earliness on the chemical composition and energy value in methane fermentation of morphological parts (fraction) of corn plants.

Materials and methods

Research material

The research material consisted of morphological parts of corn plants: stalks, leaves, husks and cobs of selected corn cultivars, differing in terms of their FAO earliness. The materials were collected in November 2022 from corn plantations located on a farm in Kołybki, Poland, near Poznań. The corn plants were harvested by hand from the field. The plants were decomposed into four morphological parts in the laboratory of the Department of Biosystems Engineering in Poznań. Laboratory tests were performed on morphological parts corn plants early (FAO 220), medium-early (FAO 240) and late (FAO 300) varieties.

The structure of the corn variety yield with an earliness standard of FAO is shown in Figures 1-3. The corn yield of the variety with an earliness standard of FAO 220 consisted of 50% grain, 20% stalks and 14% leaves. In contrast, cob cores and cob cover leaves accounted for 11 and 5%, respectively, in the plant yield structure of this corn variety (Fig. 1).

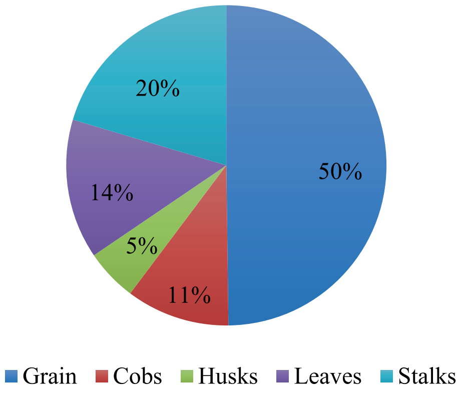

Figure 1. Percentage structure of corn variety with an earliness standard of FAO 220

The yield of corn of the variety with an earliness standard of FAO 240 consisted of 53% grain, 19% stalks and 15% leaves. In contrast, cob cores and cob cover leaves accounted for 8 and 5%, respectively, in the plant yield structure of this corn variety (Fig. 2).

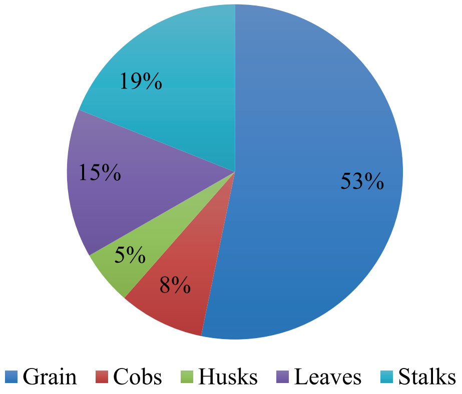

Figure 2. Percentage structure of corn of variety with an earliness standard of FAO 240

The corn yield of the variety with an earliness standard of FAO 300 consisted of 36% grain, 31% stalks and 19% leaves. In contrast, cob cores and cob cover leaves accounted for 7 and 7%, respectively, in the plant yield structure of this corn variety (Fig. 3).

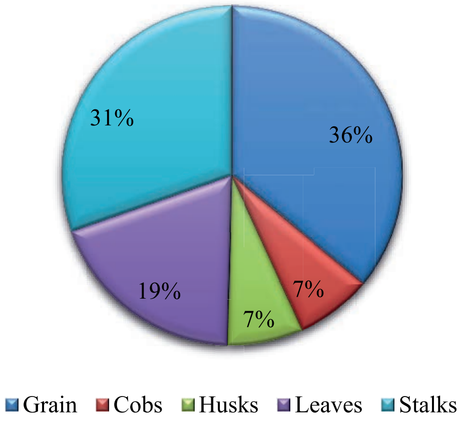

Figure 3. Percentage structure of corn of variety with an earliness standard of FAO 300

Laboratory investigations

Before measuring the biogas and methane yield the total solids (TS) content was analyzed (at 105°C ± 1°C) according to EN 12880:2004 in laboratory drying chamber Binder FD 56. The organic dry matter (LOI) of samples equivalent to loss on ignition (at 550°C ± 25°C) EN 12879:2004 was measured on muffle furnace Nabertherm L3/11/B410.

Elemental analysis

The carbon (C), hydrogen (H), nitrogen (N), sulfur (S) and oxygen (O) content were determined using a Flash 2000 elemental analyzer (Thermo Fisher Scientific, Waltham, MA, USA) in CHNS/O configuration according to the EN 15104 standard. The instrument was calibrated with standard Methionine (Thermo Fisher Scientific, Waltham, MA, USA).

Methane fermentation

The methane fermentation was measured in the Ecotechnology Laboratory at the Department of Biosystems Engineering, Poznan University of Life Sciences according to the modification of DIN standard 38 414-S8.

Daily biogas production was measured every 24 h, with accuracy of ± 0.01 dm^3. The composition of the fermentation gases was determined with a Geotech GA5000 as analyzer whenever the gas volume in the reactor exceeded 0.45 dm^3. The gas analyzer GA5000 had the quality certificate: ATX II 2G ib IIA T1 Gb (Ta= -10°C to + 50°C IECEx, CSA and calibration certificate UKAS ISO 17025. The GA5000 is calibrated ones a week with calibration mixtures (Air Products) at the following concentrates 65% CH_4, 35 CO_2, 500 ppm H_2S and 100 ppm NH_3 while oxygen sensor was calibrated in synthetic air.

Statistical analysis

The experimental data were statistically analyzed using STATISTICA 13.3 software (TIBCO Software Inc., Palo Alto, CA, USA). An analysis of variance (two-factor ANOVA) was performed to test whether corn varieties and morphological parts influenced the chemical compositions, biogas end methane yield. Significance was established at the $p < 0.05$. Tukey's Honest Significant Difference (HDS) tests (post-hoc) were applied of mean values examined properties of the corn plants morphological parts. The significance of differences in the average values of the analyzed properties are shown by superscripts a, b, c, d. Identical superscripts represent non-significant differences between analyzed values.

Pearson (r) correlations between the variable were also calculated. The strength of the correlation was described using the ranges suggested by Evans (1996) for the absolute value of r: 0.00-0.19 very weak, 0.20-0.39 weak, 0.40-0.59 moderate, 0.60-0.79 strong and 0.80-1.0 very strong (Wojcieszak et al., 2020).

Results and discussion

Results of laboratory investigations

For the morphological parts of three corn varieties with different earliness standard of FAO, the content of total solids, loss on ignition and ash were determined. The morphological parts of different corn varieties were similar with regard to total solids and loss on ignition. The least ash content was in case of cobs 1.6-2.9%. The highest content of ash was in case of stalks and leaves (Table 1).

Table 1.
Average total solids, loss on ignition and ash in samples

Earliness standard of FAO	Fraction	TS (%)	LOI (%)	Ash (%)
220	Stalks	90.4	92.9	7.1
	Leaves	77.0	93.6	6.4
	Husks	91.9	96.5	3.5
	Cobs	52.3	97.1	2.9
240	Stalks	91.8	91.8	8.2
	Leaves	90.3	93.9	6.1
	Husks	88.7	96.3	3.7
	Cobs	44.0	98.4	1.6
300	Stalks	91.4	93.8	6.2
	Leaves	88.0	92.5	7.5
	Husks	89.4	93.8	6.2
	Cobs	48.4	98.2	1.8

Lizotte et al. (2015) determined the ash content in the morphological parts of corn of two varieties of Elite 46T07 and Elite 30A27 (FAO 180–210). According to these authors, the ash content in corn cob cores was the lowest compared to other parts of corn and was about 2.07 and 2.26% of cob weight. In contrast Wojcieszak et al. (2020) found that the ash content was the highest for corn cobs late varieties earliness FAO. Li et al. (2012) presented that the ash content in leaves of corn plants was 11.3%. It is a value that is twofold higher that the results of this research.

Chemical compositions of corn morphological parts

This initial approach to comparing the corn to three different varieties of FAO earliness, yielded valuable information regarding the underlying differences between the corn morphological parts distributions. The dry matter of carbon, hydrogen, nitrogen, sulfur and oxygen content was extremely valuable for determination of methane yields and subsequent energy efficiency.

Carbon and nitrogen levels were measured because the carbon-to-nitrogen ratio in a substrate significantly influences methane fermentation (Szemmelveisz et al., 2009).

Table 2 shows the results of the multivariate analyses of variance (two-factor ANOVA) for the chemical composition of elements i.e., the content of carbon, hydrogen, nitrogen, sulfur, and oxygen. The results of the analysis indicated the effect of the variety earliness standard FAO of the fraction type on the content of hydrogen and sulfur (for $p < 0.05$). The second factor included in the analysis i.e., a morphological fraction significantly affects (for $p < 0.05$) the content of each of the elements. In addition, the results of the analysis indicate that there are strong interactions of the factors (a × b) i.e., the type of variety of earliness standard FAO and fraction on the hydrogen and sulfur.

Table 2.
Two-factor ANOVA tables for chemical composition of elements (C, H, N, S, O) for morphological parts of corn account the effects of fractions and variety earliness standard FAO

Chemical composition	Effect	SS	df	MS	F value	p-value
C [% TS]	Intercept	232454.2	1	232454.2	162373.6	0.000000
	FAO (a)	1.0	2	0.5	0.4	0.698029
	Fractions (b)	57.5	3	19.2	13.4	0.000000
	a × b	9.4	6	1.6	1.1	0.370983
	Error	154.6	108	1.4		
H [% TS]	Intercept	170.3517	1	170.3517	6745.317	0.000000
	FAO (a)	2.1939	2	1.0970	43.436	0.000000
	Fractions (b)	11.8837	3	3.9612	156.851	0.000000
	a × b	2.6580	6	0.4430	17.541	0.000000
	Error	2.7275	108	0.0253		
N [% TS]	Intercept	3911.886	1	3911.886	106510.8	0.000000

	FAO (a)	0.032	2	0.016	0.4	0.650546
	Fractions (b)	0.526	3	0.175	4.8	0.003660
	a × b	0.486	6	0.081	2.2	0.047876
	Error	3.967	108	0.037		
S [% TS]	Intercept	0.372238	1	0.372238	1848.010	0.000000
	FAO (a)	0.010110	2	0.005055	25.96	0.000000
	Fractions (b)	0.172387	3	0.057462	285.277	0.000000
	a × b	0.016277	6	0.002713	13.468	0.000000
	Error	0.021754	108	0.000201		
O [% TS]	Intercept	288479.7	1	288479.7	145966.4	0.000000
	FAO (a)	5.1	2	2.6	1.3	0.276377
	Fractions (b)	36.7	3	12.2	6.2	0.000645
	a × b	9.9	6	1.7	0.8	0.542871
	Error	213.4	108	2.0		

SS – a sum of squares, df – degrees of freedom, MS – mean squares, F – Fisher`s F-test

The results of the post-hoc Tukey`s (HSD) test for chemical composition of elements C, H, N, S and O measured in the investigations of the effect of the variety earliness standard FAO and the type of fraction are presented in Table 3. The significance of differences in the average values of the content of individual elements is shown by superscripts a, b, c, d. Identical superscripts represent non-significant differences between the analyzed values.

The carbon (C) content was 45.0-42.8%, depending on the variety and fraction. The highest C content was found in the cores of the cultivar with FAO 240, and the lowest in the cover leaves of the cultivar with FAO 300. The highest C content was found in the cores of cobs, regardless the variety (Tables 3).

Table 3.
Chemical composition of elements (C, H, N, S, O) for morphological parts of corn account for the effects of fractions and variety earliness standard FAO

FAO	Fraction	C	H	N	S	O
220	Stalks	$43.8^{abcd}\pm0.4$	$5.5^{ab}\pm0.1$	$1.1^{c}\pm0.1$	$0.02^{d}\pm0.00$	$49.5^{ab}\pm0.6$
	Leaves	$43.6^{abcd}\pm1.1$	$5.8^{a}\pm0.2$	$1.8^{a}\pm0.1$	$0.13^{a}\pm0.01$	$48.7^{ab}\pm1.3$
	Husks	$43.8^{abd}\pm0.8$	$5.8^{a}\pm0.1$	$1.1^{c}\pm0.3$	$0.05^{c}\pm0.01$	$49.3^{ab}\pm1.0$
	Cobs	$45.0^{ab}\pm1.1$	$5.7^{ab}\pm0.1$	$1.4^{b}\pm0.1$	$0.06^{c}\pm0.01$	$47.8^{b}\pm1.3$
240	Stalks	$44.5^{abcd}\pm2.3$	$5.6^{ab}\pm0.3$	$1.0^{c}\pm0.1$	$0.02^{d}\pm0.00$	$48.9^{ab}\pm2.7$
	Leaves	$43.1^{cd}0.7$	$5.6^{ab}\pm0.2$	$2.0^{a}\pm0.1$	$0.14^{a}\pm0.01$	$49.2^{ab}\pm0.8$
	Husks	$43.6^{abcd}\pm0.8$	$5.8^{a}\pm0.1$	$1.1^{c}\pm0.2$	$0.05^{c}\pm0.03$	$49.4^{ab}\pm0.9$
	Cobs	$45.2^{a}\pm0.7$	$5.8^{ab}\pm0.1$	$0.7^{de}\pm0.0$	$0.02^{d}\pm0.00$	$48.3^{b}\pm0.8$
300	Stalks	$44.6^{abcd}\pm1.7$	$5.7^{ab}\pm0.3$	$0.7^{e}\pm0.3$	$0.01^{d}\pm0.01$	$49.0^{ab}\pm2.0$
	Leaves	$43.3^{bcd}\pm1.7$	$5.7^{ab}\pm0.2$	$1.4^{b}\pm0.2$	$0.09^{b}\pm0.03$	$49.5^{ab}\pm1.9$
	Husks	$42.8^{d}\pm1.0$	$5.7^{ab}\pm0.2$	$1.0^{c}\pm0.1$	$0.05^{c}\pm0.02$	$50.4^{a}\pm1.3$
	Cobs	$44.8^{abc}\pm0.6$	$5.8^{a}\pm0.2$	$0.9^{cd}\pm0.1$	$0.03^{d}\pm0.01$	$48.4^{ab}\pm0.4$

Mean value (n = 4) ± standard deviation; identical superscripts (a, b, c, d) denote no significant difference ($p < 0.05$) between mean values according to post-hoc Tukey's HSD test

The highest hydrogen (H) content was observed in the leaves of FAO 240 (2.0%) and FAO 220 (1.8%) varieties. The lowest content of H was in cobs of FAO 240 and stalks of FAO 300 varieties – 0.7%. The nitrogen (N) content was 5.5-5.8% and was equalized. The leaves, husks variety FAO 220, husks and cobs variety FAO 240, cobs variety FAO 300 had the highest content 5.8% of N. The sulfur (S) content was 0.01-0.14% and depended on the fraction and variety. The highest S content was characterized by leaves varieties FAO 240. The lowest S content was observed in stalks. The average oxygen content of the samples was 47.8-50.4% and differed significantly depending on the corn morphological fraction.

The results obtained in this study were similar to those reported in the literature. Maj et al. (2019) obtained about 48.5% content of C, 5.9% content H, 0.29% content N and 0.52% content of S for corn cobs. The same scientific team obtained for corn husks 31.1% content C, 3.6% content H, 1.1% content N, 3.4% S and 32.6% of O content. Wojcieszak et al. (2020) Wojcieszak et al. (2020) for morphological fraction plants of corn varieties FAO 200 have obtained average content 43.3-44.8 % C and 0.3-1.0% N depending on fractions.

Methane fermentation

Tables 4 shows the results of the multivariate analyses of variance (two-factor ANOVA) for the biogas and methane yield. The results of the analysis indicated the effect of the variety earliness standard FAO on the biogas and methane yield (for $p < 0.05$). The second factor included in the analysis i.e., a morphological fraction significantly affects (for $p < 0.05$) the biogas and methane yield too. In addition, the results of the analysis indicate that there are strong interactions of the factors (a × b) i.e., the type of variety earliness standard FAO and fraction on the yield biogas and methane.

Table 4.
Two-factor ANOVA tables for biogas and methane yield for morphological parts of corn account for the effects of fractions and variety earliness standard FAO

Yield	Effect	SS	df	MS	F value	p-value
Biogas ($m^3 \cdot Mg$ TS)	Intercept	7300609	1	7300609	57553.93	0.000000
	FAO (a)	6719	2	3359	26.48	0.000001
	Fractions (b)	39797	3	13266	104.58	0.000000
	a × b	11103	6	1850	14.59	0.000001
	Error	3044	24	127		
Methane ($m^3 \cdot Mg$ TS)	Intercept	2259665	1	2259665	58025.12	0.000000
	FAO (a)	895	2	448	11.49	0.000315
	Fractions (b)	15194	3	5065	130.06	0.000000
	a × b	2454	6	409	10.50	0.000010
	Error	935	24	39		

SS – a sum of squares, df – degrees of freedom, MS – mean squares, F – Fisher`s F-test

An average biogas yield was 409.3-546.3 $m^3 \cdot Mg^{-1}$ TS. The highest amount of biogas (546.3 $m^3 \cdot Mg^{-1}$ TS) was obtained from husks variety FAO 220 and 505.1 $m^3 \cdot Mg^{-1}$ TS was obtained from husks variety FAO 300. Methane yield from husks variety FAO 240 was 458.4

$m^3 \cdot Mg^{-1}$ TS. The lowest average biogas yield was 409.3 $m^3 \cdot Mg^{-1}$ TS from cobs varieties FAO 240 (Fig. 4).

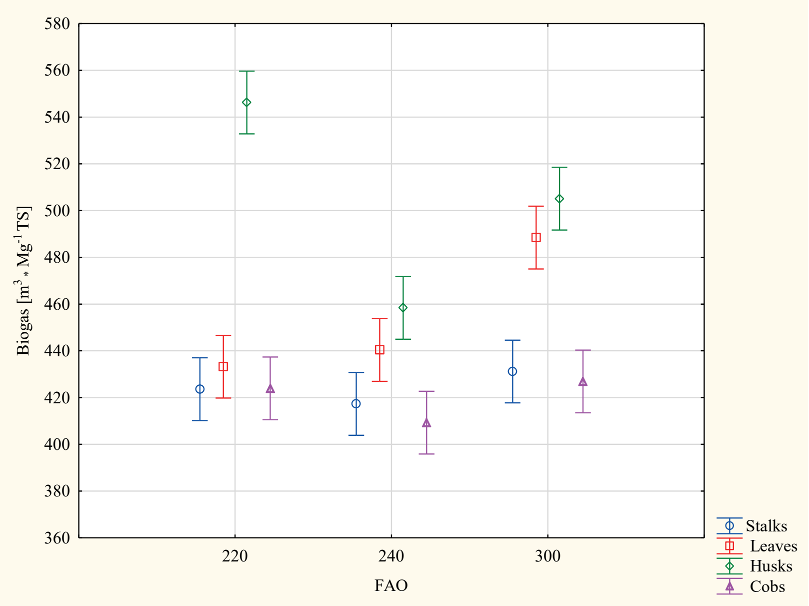

Figure 4. Average value of biogas yield with regard to variety earliness FAO and fractions (vertical bars indicate 0.95 confidence intervals)

The results obtained in this study were similar to those reported in the literature. Wojcieszak et al. (2020) conducted a study of the biogas yield of corn stover fractions varieties of earliness FAO 200. Authors presented that, the greatest biogas yield had corn cobs and husks, average 469.2 and 466.6 $m^3 \cdot Mg^{-1}$ TS. For the contrast, Cieślik et al. (2016) presented the biogas yield from silage corn stover in mesophilic fermentation 443 $m^3 \cdot Mg^{-1}$ TS and in thermophilic fermentation 481 $m^3 \cdot Mg^{-1}$ TS. However, the effect of corn earliness varieties FAO pattern on biogas yield has not been determined previously.

Figures 5 and 6 show average methane yields by variety and fraction. More methane was obtained from the fraction of the variety with an FAO 300, and the least from the fraction of the FAO 240 variety (Fig. 5).

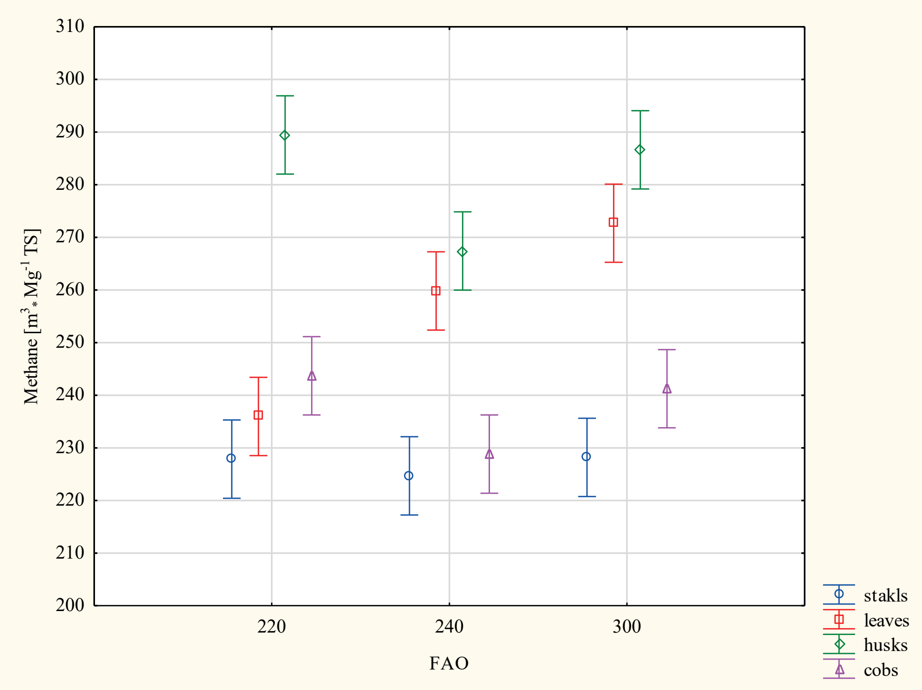

Figure 5. Average value of methane yield with regard to the variety earliness FAO (vertical bars indicate 0.95 confidence intervals)

The biogas is a mixture of flammable gases and non-flammable. The flammable components in biogas are methane (CH_4) and hydrogen (H_2), with non-flammable gases components are carbon dioxide (CO_2) and nitrogen (N_2) (Sutaryo et al., 2012). Therefore, the percentage methane content in biogas is very important parameter. Percentage methane content dependence to varieties earliness FAO and morphological fraction of corn were presented at Figure 6. The average methane concentration in this research in biogas were 53-59%. The methane concentrated in biogas varies in different literature, the methane content is 50-70% (Arini and Aep, 2018).

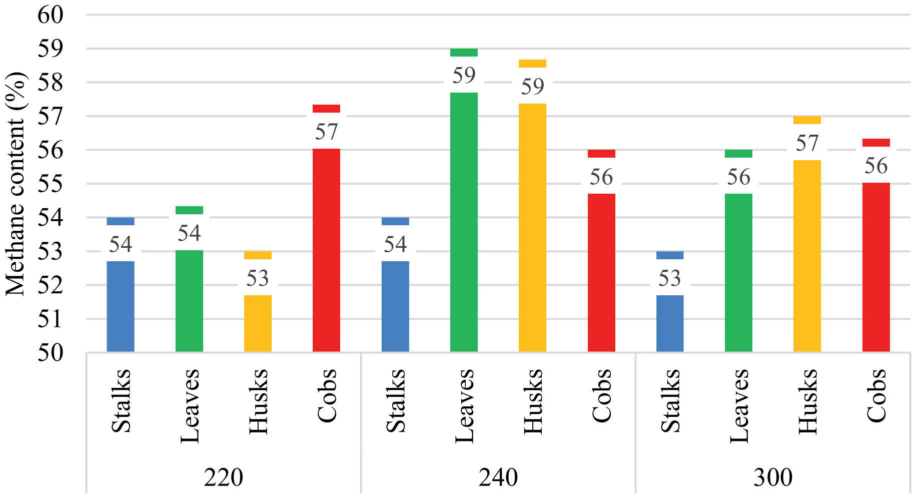

Figure 6. Methane content dependence with variety earliness FAO and morphological fraction

The results of the one-factor variational analysis indicated that depending on the morphological fraction, most methane was obtained from husks, average 281.2 $m^3 \cdot Mg^{-1}$ TS. Methane yield of corn cobs were average 237.9 $m^3 \cdot Mg^{-1}$ TS (Fig. 7).

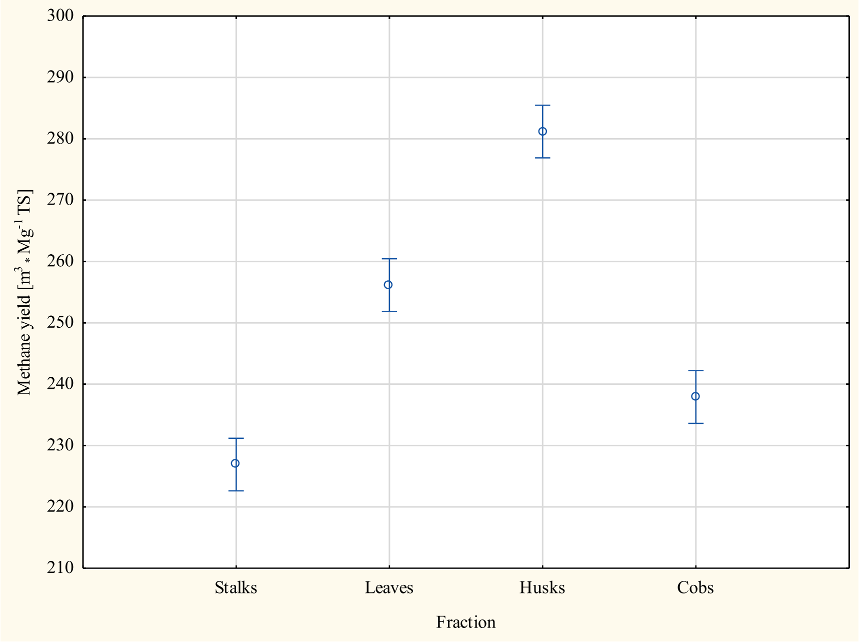

Figure 7. Average value of methane yield with regard to morphologic corn fraction (vertical bars indicate 0.95 confidence intervals)

The similar results of methane yield depending on the morphological fraction of corn are presented by Menardo et al. (2015) and Wojcieszak et al. (2020).

Conclusion

Based on the results of these investigations, the following conclusions were drawn:

1. The FAO earliness of a corn variety had a significant impact on the elemental composition, ash content, biogas, and methane yield in the corn morphological fractions.
2. The lowest of methane concentration in biogas was found for the stalks of all varieties FAO earliness corn.
3. The most biogas and methane can used from leaves and husks of corn.
4. Considering the percentage of cob cores in the total corn stover crop and their chemical and energetical properties, they are a potentially good substrate for biogas production.

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CHEMICZNE I ENERGETYCZNE WŁAŚCIWOŚCI WYNIKAJĄCE Z FERMENTACJI METANOWEJ MORFOLOGICZNYCH CZĘŚCI KUKURYDZY O RÓŻNYM WSKAŹNIKU WCZESNOŚCI ODMIANY FAO

Streszczenie. W ostatnich dekadach produkcja biopaliw z biomasy do konwersji termochemicznej w celu zastąpienia paliw kopalnianych przyciąga coraz większą uwagę, ponieważ oferuje istotne korzyści dla środowiska. Fermentacja metanowa jest bardzo popularnym sposobem konwersji biomasy na energię. Znaczenie biogazu jako źródła energii wzrasta. Zastosowanie biomasy do produkcji biogazu na dużą, światową skalę może prowadzić do kontrowersji związanych z konkurowaniem o grunty orne, wodę, a w konsekwencji o żywność. Dlatego do produkcji biogazu powinny być wykorzystywane wyłącznie odpady, produkty uboczne oraz pozostałości rolnicze. Dobrym przykładem pozostałości rolniczych do produkcji biogazu jest słoma kukurydziana. Dlatego celem tych badań było określenie wpływu wzorca wczesności odmian FAO na skład chemiczny i wartość energetyczną części morfologicznych kukurydzy. Materiałem badawczym były morfologiczne części kukurydzy: łodygi, liście, liście okrywe, rdzenie kolb wybranych odmian kukurydzy zróżnicowane pod względem wskaźnika wczesności odmiany FAO: wczesne (FAO 220), średnio-wczesne (FAO 240) oraz późne (FAO 300). Badania obejmowały analizę chemiczną, fermentację metanową oraz analizę statystyczną wyników. Na podstawie wyników badań stwierdzono, że wskaźnik wczesności odmian FAO miał istotny wpływ na skład chemiczny, zawartość popiołu, uzysk biogazu i metanu z części morfologicznych kukurydzy. Najwyższy uzysk metanu 267,4 $m^3 \cdot Mg^{-1}$ TS osiągnięto dla liści okrywowych kukuyrdzy odmiany o wskaźniku wczesności FAO 240.

Słowa kluczowe: wartość energetyczna kukurydzy, fermentacja metanowa, chemiczne właściwości morfologicznych części kukurydzy, wskaźnik wczesności odmiany