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Anaerobic digestion of maize hybrids for methane production

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ABSTRACT

Purpose: This research project was aimed at optimising anaerobic digestion of maize and find out which maturity class of corn and which hybrid of a particular maturity class produces the highest rate of biogas and biomethane. Also the chemical composition of gases was studied.
Design/methodology/approach: Biogas and biomethane production and composition in mesophilic (35 degrees C) conditions were measured and compared. The corn hybrids of FAO 300 - FAO 600 maturity class were tested. Experiments took place in the lab, for 35 days within four series of experiments with four repetitions according to the method DIN 38 414.
Findings: Results show that the highest maturity classes of corn (FAO 500) increases the amount of biogas and biomethane. The greatest gain of biogas, biomethane according to maturity class is found with hybrids of FAO 400 and FAO 500 maturity class. Among the corn hybrids of maturity class FAO 300 - FAO 400, the hybrid PR38F70 gives the greatest production of biogas and biomethane. Among the hybrids of maturity class FAO 400 - FAO 500, the greatest amount of biogas and biomethane was produced by the hybrid PIXXIA (FAO 420). Among the hybrids of maturity class FAO 500 - FAO 600 the hybrid CODISTAR (FAO 500) the highest production of biomethane. Production of biomethane, which has the main role in the production of biogas varied with corn hybrids from 50-60 % of the whole amount of produced gas.
Research limitations/implications: Economic efficiency of anaerobic digestion depends on the optimum methane production and optimum anaerobic digestion process.
Practical implications: The results reached serve to plan the electricity production in the biogas production plant and to achieve the highest biomethane yield per hectare of maize hybrid.
Originality/value: Late ripening varieties (FAO ca. 600) make better use of their potential to produce biomass than medium or early ripening varieties.
Keywords: Technological devices and equipment; Maize hybrids; Methane production; Fermentor

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1. Introduction

The world in the 21st century is faces problems due to growing energy consumption and diminishing supplies of fossil fuels, which has led to researches at the use of renewable energy sources and, consequently, the development of new technological processes of energy production [1].

It is essential to develop sustainable energy supply systems aimed at covering the energy demand from renewable sources [2]. Renewable resources of energy are a part of the European battle against climate changes, at the same time they contribute to economic growth, increasing the number of employed people and provide energetic safety. Biogas production from agricultural biomass is of growing importance as it offers considerable environmental benefits [3] and is an additional source of income for farmers. Renewable energy is produced.

Biogas from sewage digesters usually contains 55% to 65% methane, 35% to 45% carbon dioxide and <1% nitrogen, biogas from organic waste digesters usually contains 60% to 70% methane, 30% to 40% carbon dioxide and <1% nitrogen while in landfills the methane content is usually 45% to 55%, 30% to 40% carbon dioxide and 5% to 15% nitrogen. Typically the biogas also contains hydrogen sulphide and other sulphur compounds, compounds such as siloxanes and aromatic and halogenated compounds. Although the amounts of trace compounds are low compared to methane, they can have environmental impacts such as stratospheric ozone depletion, the greenhouse effect and/or reduce the quality of local air [2, 3, 4].

Suitable substrates for the digestion in agricultural biogas plants are: energy crops, organic wastes, and animal manures. Maize (*Zea mays L.*), herbage (*Poacae*), clover grass (*Trifolium*), Sudan grass (*Sorghum sudanense*), fodder beet (*Beta vulgaris*) and others may serve as energy crops [5, 6]. Maize is the most dominating crop for biogas production. Maize is considered to have the highest yield potential out of field crops grown in Central Europe, as in Slovenia. The quality of energy crops, used for biogas production, is determined on the field. The content and availability of substances which are able to produce methane is influenced by variety, cultivation and stage of maturity at harvesting time [2]. Methane production from organic substrates mainly depends on their content of substances that can be degraded into CH_4 and CO_2. Composition and biodegradability are key factors for the methane yield from energy crops and animal manures. Crude protein, crude fat, crude fibre, cellulose, hemi-cellulose, starch and sugar markedly influence methane formation [7, 8].

Fig. 1 illustrates influences on the biomass quality considering as example maize for all stages of biogas production. Key influences on the quality of maize for anaerobic digestion can already be found in phase I, when maize is grown on the field. Location, climate and maize variety are important. Plant management and the stage of vegetation when maize is harvested must be optimally chosen to maximise the methane yield. In phase II (harvest, conservation and supply) farmers can positively influence methane yield by choosing the optimum harvesting time and conservation technology and by possibly applying additives. In phase III, energy in the organic substrates is transformed to methane energy in the biogas. Environmental conditions in the digester such as pH, temperature or inhibitors and the nutrient composition of organic substrates determine the methane yield. Amount and quality of the biogas and of the digestate in phase IV result from the influences shown in phases I–III [2].

In this study, we optimize anaerobic digestion of maize and find out which maturity class of corn and which hybrid of a particular maturity class produces the highest rate of biogas and biomethane. Also the chemical composition of gases was studied.

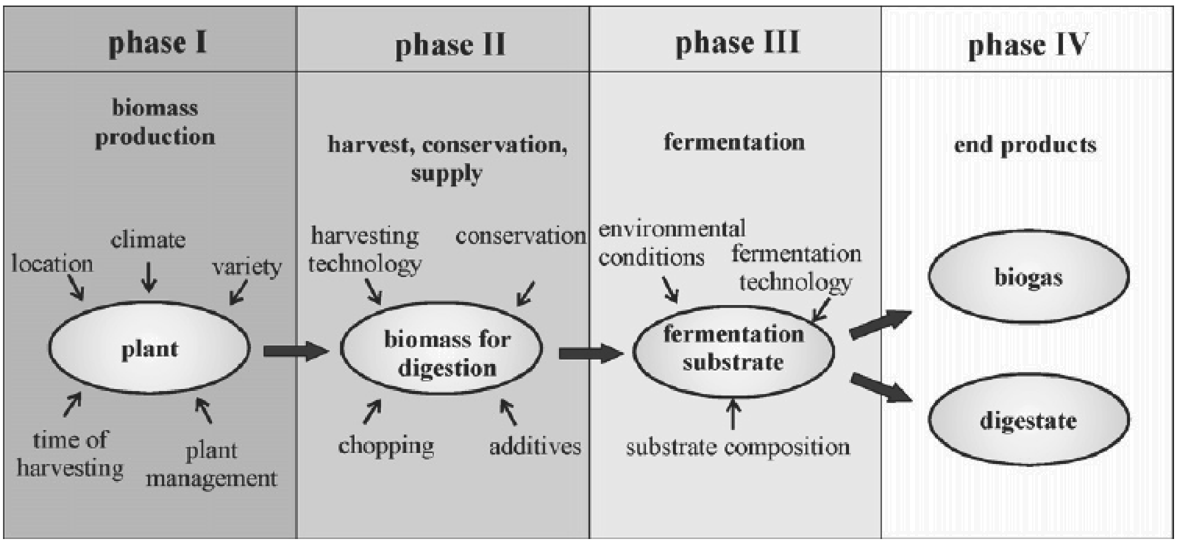

Fig. 1. Influences on biogas production from maize along the production process

Table 1.
Design of experiment - distribution of experiment plots

V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
V14	V7	V11	V1	V13	V8	V10	V12	V15	V9	V3	V5	V2	V4	V6
V3	V12	V7	V15	V4	V1	V2	V10	V13	V5	V14	V6	V9	V8	V11
V4	V9	V13	V7	V3	V12	V4	V6	V7	V2	V12	V8	V11	V10	V1

2. Description of the approach, work methodology, materials for research, assumptions, experiments etc.

2.1. Design of experiment

For the field experiment 15 different corn hybrids were plaited. Each of them was planted in four lines or so to say at 3 metres of width and 65 m of length and at distance of 70 cm and at distance in line of 15.3 cm. For each corn hybrid we had 4 repetitive plots. On four plots were reaped by hand, coincidently chosen with dimension of $10 m^2$ and the yield of whole plants was weighed. Then the plants were grained with tractor harvester Vihar 40 made by Sip. The mass of a particular plot was put into a plastic kitchenware of 15 litres size, it was closed impermeably, marked and the release and production of biogas from particular corn hybrid were measured. Design of experiment - distribution of experiment plots is shown in the Table 1.

Table 2.
Maturity classes of corn hybrids used in the experiment

	CORN HYBRID	FAO - maturity class
V1	PR38F70	FAO 330
V2	PR38H20	FAO 340
V3	NKTHERMO	FAO 370
V4	NK CISKO	FAO 390
V5	PR37D25	FAO 400
V6	PR37F73	FAO 410
V7	PR37M34	FAO 410
V8	PIXXIA	FAO 420
V9	NK PAKO	FAO 440
V10	RAXXIA	FAO 450
V11	PR36K67	FAO 450
V12	POXXIM	FAO 490
V13	TIXXUS	FAO 500
V14	CODISTAR	FAO 500
V15	PR34N43	FAO 500

In course of the vegetation period, the following parameters were determined for all varieties: nutrient composition, gross energy, dry matter and organic dry matter content at wax ripeness, specific methane yield and biogas quality during anaerobic digestion in eudiometer batch experiments; methane and biogas yield per hectare for each harvesting time.

Whole maize crops were anaerobically digested and methane yields were compared.

Maturity classes of corn hybrids used in the experiment is shown in Table 2. 15 different corn hybrids were plaited.

2.2. Measuring methane production

Substance and energy turnover during anaerobic digestion of maize were measured in 0.5 l eudiometer batch digesters at 35 ºC. Methane yields from each treatment were measured in four replicates.

Measurements were conducted according to DIN 38 414 [9]. Laboratory device consists of twelve digesters. A water bath tempers the digesters. A magnetic stirrer mixes the substrates for 10 s every 10 min. The biogas is collected in an equilibrium vessel and the biogas production is monitored every day. Biogas production is given in norm litre per kg of volatile solids (Nl/kg VS), i.e. the volume of biogas production is based on norm conditions: 273 K, and 1013 mbar. Biogas quality (CH_4, CO_2, O_2) was analysed 10 times in course of the 5 - week digestion. Each variant was replicated two to four times. Biogas production from inoculum alone was measured as well and subtracted from the biogas production that was measured in the digesters that contained inoculum and biomass.

Maize was chopped after harvest, prior to the ensiling process. Particle size was 0.5-3.0 mm. Inoculum was received from biogas plant that digest energy crops (maize, sun flower, grass) at 38 ºC. Hydraulic residence time was 70-80 days. 30-70 g maize silage were digested together with 350 g inoculum. Maize silage : inoculum ratio was 1:2 (basis: dry matter). This resulted in a dry matter content of the sample of 9% which corresponds to the dry matter content that is commonly found on commercial biogas plants.

The experiment lasted 35 days, or as long as a little bit of gas was still produced. The main amount of biogas is developed in the first week of experiment, after 35 days biological degradation is finished. At each reading of gas volume in the tube of eudiometer the temperature and air pressure were estimated to calculate the volume of gas in the normalized state.

2.3. Structure of gas apparatus for lab experiment

For making the experiment a gas apparatus (Fig. 2), made from a tube for eudiometer with volume of 400 ml, graduated upside down was used. It was placed on a self - standing bottle of 500 ml volume [9]. Through the bottom of the tube of eudiometer a connecting tube enabling the biogas in the bottle to enter the measuring tube is located. The connecting tube is placed with glass sticks, located on four sides. On the lower edge of eudiometer there is a glass olive, from there a pipe link goes to a layer of container. On the upper edge of eudiometer tube there is a cone pipe for taking gas samples and for estimating the level [10, 1, 8].

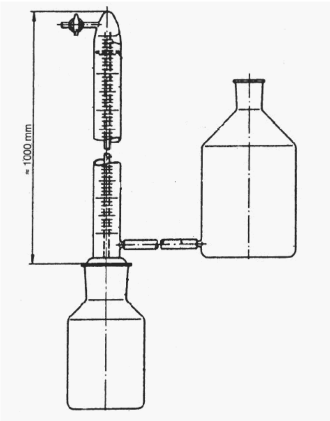

Fig. 2. Eudiometer for estimating gas from applied substrate

The basic structure is built from stainless steel (inox), 2500 mm long, 1000 mm high and 350 mm wide. On the highest part there is a shelf with external container for excess liquid. Downstairs there is a sink 2500 x 200 x 200 mm covered with styrofoam preventing excessive loss of warmth. In the sink, is placed another heating pump, enabling constant temperature and cycling of water is placed.

A steady water temperature in the whole sink can be achieved. Eudiometers are placed on a metal profile above the structure in order not to turn over. On the left side of the structure there is a thermometer and a barometer measuring the water temperature in the sink with a sensor and especially, the temperature of surrounding [10].

2.4. Statistical data analysis

It was made with statistic al package SPSS, version 15 [11]. Each treatment was measured in four replicates. With analysis variance the statistically significant differences in production ofbiogas, biomethane and the chemical composition of gas among the maturity classes of corn. Mean, standard deviation and frequency distributions of the data were determined. Differences between treatments were tested with comparative statistics. Variance analysis methods were applied to find significant differences in the means. Values of treatment were tested at 5% risk with Tukey's test. Homogeneity of variances was analysed with the Levene test statistic. Normal distribution was checked by the rule 0.8 < mean < 1.2 and 4 s < mean. The Methane Energy Value Model was developed by carrying out a multifunctional analysis of full regression models [11, 12].

3. Description of achieved results of own researches

For testing 15 hybrids of corn were used and it was established which class of corn and which hybrid of maturity class ensures the greatest production of biogas, biomethane and chemical composition of gas was examined.

3.1. Composition of substrates and specific biogas and methane yield

Table 3 gives the nutrient composition of the samples: XP = crude protein; XL = crude fat; XF = crude fibre; XA = crude ash; ADL = lignin; Cel = cellulose; Hem = hemi-cellulose; C/N = C:N ratio; Nl = norm litre (273 K, 1.013 bar). Biogas and methane yield per norm litre of volatile solids are listed as well [13, 14, 15].

The nutrients crude protein (XP), crude fat (XL), cellulose (Cel) and hemi-cellulose (Hem) proved to have a significant influence on methane production [16].

3.2. Production of gas from hybrids of maturity class FAO 300 - FAO 400

Table 4 shows the results of biogas and biomethane production in N1/kg VS and in Nm^3/ha from hybrids of maturity class FAO 300 - FAO 400. The results of chemical composition of biogas and (CH_4, CO_2 and O_2) are indicated.

The greatest return of biogas (Nm^3/ha) of maturity class FAO 300 was reached by the hybrid PR38F70 and i.e. 13778.5 Nm^3/ha of biogas, but it does not differ statistically significances at 5% risk from hybrids PR38H20 and NKCISKO. The statistically significant and worst recovery of biogas was ensured by the hybrid NKTHERMO that produced 11410.5 Nm^3/ha of biogas. Production of biomethane (Nm^3/ha) was also the greatest with hybrid PR38F70 i.e. 7646.2 Nm^3/ha and the lowest with hybrid NKTHERMO i.e. 6995.6 Nm^3/ha methane (Fig. 3).

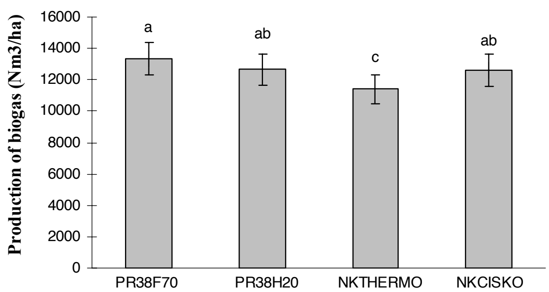

Fig. 3. Production of biogas (Nm^3/ha) with hybrids of maturity class FAO 300 - FAO 400

Table 3.
Nutrient composition of the samples

Maize hybrid	XP	XL	XF	XA	ADL	Cel	Hem	C/N	Biogas (Nl/kg VS)	Methane (Nl/kg VS)
PR38F70	9.2	1.7	23.7	5.8	7.1	33.6	30.4	42.3	544	312
PR38H20	8.7	2.2	30.2	5.3	6.6	35.4	25.4	35.7	535	300
NKTHERMO	7.7	2.1	22.7	6.4	7.7	28.4	27.6	33.3	455	251
NKCISKO	7.9	1.9	20.6	6.1	6.9	29.8	30.2	40.2	515	290
PR37D25	9.8	2.6	19.5	5.9	8.8	30.3	30.3	37.7	526	306
PR37F73	6.7	2.4	27.7	6.5	7.3	33.8	27.8	32.2	603	349
PR37M34	7.3	1.8	24.6	5.4	7.5	29.2	26.5	29.8	603	339
PIXXIA	7.5	2.4	31.5	7.2	6.9	24.6	26.7	30.8	602	345
NKPAKO	6.8	2.0	28.7	6.8	8.4	20.3	30.1	31.5	507	281
RAXXIA	9.6	1.9	19.8	7.6	6.6	22.2	28.2	36.6	546	309
PR36K67	7.6	2.5	20.3	5.3	8.5	24.3	30.4	30.8	572	331
POXXIM	9.8	2.2	23.2	7.3	6.1	27.8	29.9	31.2	527	291
TIXXUS	7.6	1.8	29.4	7.0	7.8	23.3	28.6	38.1	545	308
CODISTAR	8.9	1.9	20.3	6.8	6.4	22.6	24.4	33.5	559	330
PR34N43	7.3	1.7	22.2	6.2	4.2	21.2	27.7	34.1	521	294

XP = crude protein; XL = crude fat; XF = crude fibre; XA = crude ash; ADL = lignin; Cel = cellulose; Hem = hemi-cellulose; C/N = C:N ratio; Nl = norm litre (273 K, 1.013 bar)

Table 4.
Production of biogas, biomethane and chemical composition of biogas of corn hybrids of maturity class FAO 300 - FAO 400

Hybrid maize FAO 300 - 400	Biogas production (Nl/kg oSS)	Biomethane production (Nl/kg oSS)	Biogas production (Nm^3/ha)	Biomethane production (Nm^3/ha)	Composition of gas (%)		
					CH_4	CO_2	O_2
PR38F70	544	312	13778.5[a]	7646.2	57.3	38.4	0.6
PR38H20	535	300	12649.4[ab]	7096.1	56.1	42.1	0.8
NKTHERMO	455	251	11410.5[c]	6995.6	55.3	43.2	0.3
NKCISKO	515	290	12596.6[ab]	7104.5	56.4	37.7	0.5

Table 5.
Production of biogas, biomethane and chemical composition of gas of corn hybrids of maturity class FAO 400 - FAO 500

Hybrid maize FAO 400 - 500	Biogas production (Nl/kg oSS)	Biomethane production (Nl/kg oSS)	Biogas production (Nm^3/ha)	Biomethane production (Nm^3/ha)	Composition of gas (%)		
					CH_4	CO_2	O_2
PR37D25	526	306	12606.3[d]	7575.6	58.2	39.3	0.7
PR73F73	587	349	14591.8[bc]	8054.7	55.2	35.6	0.5
PR37M34	603	339	15830.1[ab]	8912.3	56.3	33.4	0.6
PIXXIA	602	345	16447.2[a]	9440.6	57.4	34.8	0.4
NKPAKO	507	281	13456.4[cd]	7481.7	55.6	37.3	0.4
RAXXIA	546	309	12391.7[d]	7026.6	56.7	38.9	0.6
PR36K67	572	331	12413.8[d]	7187.7	57.9	38.7	0.4
POXXIM	527	291	13501.8[cd]	7642.2	55.3	40.2	0.5

3.3. Production of biogas from hybrids of maturity class FAO 400 - FAO 500

The Table 5 show the production of biogas (Nm^3/ha) with hybrids of maturity class FAO 400 - FAO 500.

Figure 4 shows the production of biogas (Nm^3/ha) with hybrids of maturity class FAO 400 - FAO 500. Different letters indicate significant differences with $p < 0.05$.

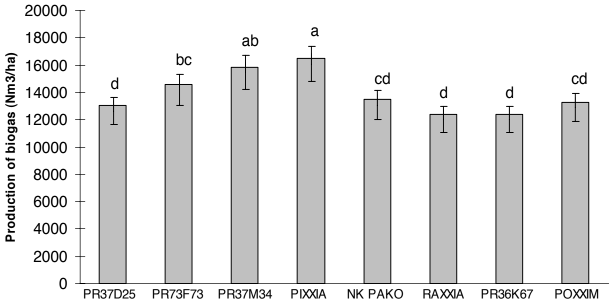

Fig. 4. Production of biogas (Nm^3/ha) from hybrids of maturity class FAO 400 - FAO 500, $p < 0.05$

Hybrids of maturity class FAO 400 provide the greatest recovery of biogas with hybrid PIXXIA (FAO 420), but it does not differ statistically significances at 5% risk from hybrid PR37M34 (FAO 410). The statistically significant lowest recovery of biogas was found with hybrids PR37D25 (FAO 400) and PR36K67 (FAO 450), and PR36K67, but they are not statistically significant lower than recovery of biogas with hybrids NKPAKO (FAO 440) and POXXIM (FAO 490). Statistically significant differences do not exist among hybrids PR73F73, NKPAKO and POXXIM. The greatest return of biomethane was reached by the PIXXIA, i.e. 9440.6 Nm^3 /ha of biomethane, the lowest by the hybrid RAXXIA, with production of 7026.6 Nm^3/ha of biomethane (Fig. 4).

3.4. Production of biogas from hybrids of maturity class FAO 500 - FAO 600

The Table 6 shows the production of biogas, biomethane and chemical composition of gas of corn hybrids from maturity class FAO 500 - FAO 600.

The greatest return of biogas was achieved by the hybrid CODISTAR, i.e. 14464.1 Nm^3/ha, but it does not differ statistically significances from production of hybrid TIXXUS at 5% risk. Production of biogas of hybrid TIXXUS is 12995.6 Nm^3/ha, statistically it does not differ from production of biogas of hybrid PR34N43.

Production of biogas PR34N43 is 12961.9 Nm^3/ha. The greatest recovery of biomethane was found with hybrid CODISTAR, which produced 7848.1 Nm^3/ha of biomethane. The lowest recovery of biomethane was found with hybrid PR34N43, i.e. 6443 Nm^3/ha of produced biomethane (Fig. 5).

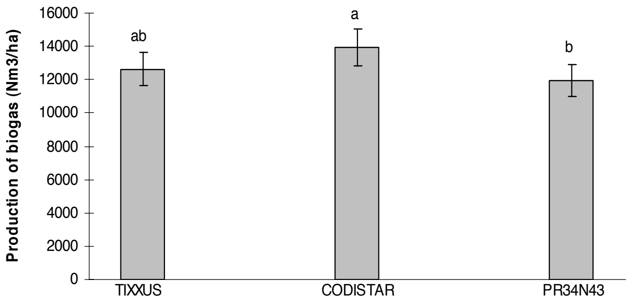

Fig. 5. Production of biogas (Nm^3/ha) from hybrids of maturity class FAO 500 - FAO 600, $p < 0.05$

Table 6.
Production of biogas, biomethane and chemical composition of gas of corn hybrids from maturity class FAO 500 - FAO 600

Hybrid maize FAO 500 - 600	Biogas production (Nl/kg oSS)	Biomethane production (Nl/kg oSS)	Biogas production (Nm^3/ha)	Biomethane production (Nm^3/ha)	Composition of gas (%)		
					CH_4	CO_2	O_2
TIXXUS	545	308	12995.4^{ab}	7355.4	56.6	41.1	0.4
CODISTAR	559	330	14464.1^{a}	8562.7	55.1	39.8	0.8
PR34N43	521	294	12961.9^{b}	6443	56.5	41.4	0.7

Table 7.
Production of biogas (Nm^3/ha) of maturity class hybrids FAO 300, FAO 400 and FAO 500

Maize (hybrid)	Biogas production (Nl/kg oSS)	Biomethane production (Nl/kg oSS)	Biogas production (Nm^3/ha)	Biomethane production (Nm^3/ha)	Composition of gas (%)		
					CH_4	CO_2	O_2
FAO 300	515	292	12498.1^{b}	7076^{ab}	56.6	36.7	0.5
FAO 400	568	315	13927.4^{a}	7768.4^{a}	55.5	38.1	0.5
FAO 500	530	294	12836.2^{ab}	7050.1^{b}	55.2	39.3	0.6

3.5. Production of biogas and biomethane from hybrids of maturity class FAO 300-500

It was desired to find out which maturity corn class gives the greatest production of biogas, biomethane because for the testing the hybrids of maturity class FAO 300, FAO 400 and FAO 500 were used. The majority of hybrids were in maturity class FAO 400-FAO 500, the least were in FAO 500-FAO 600.

The Table 7 shows the average production of biogas, biomethane and chemical composition of biogas hybrid maturity class FAO 300, FAO 400 and FAO 500. The greatest recovery was found with maturity class hybrids FAO 400, i.e. 13927.4 Nm^3/ha of produced biogas; they do not differ statistically significantly at 5% risk from hybrids of corn maturity class FAO 500. The lowest recovery was found with hybrids of maturity class FAO 300, producing 12498.1 Nm^3/ha produced biogas, but it does not statistically differ from maturity class FAO 500 (Fig. 6).

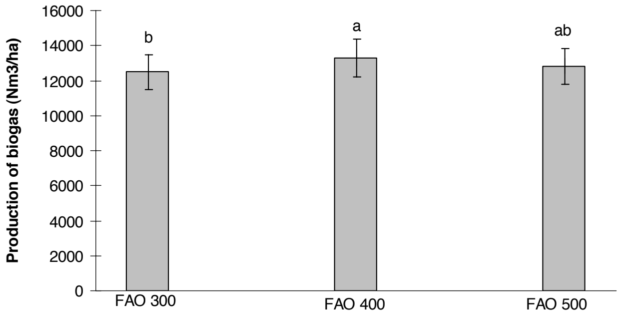

Fig. 6. Production of biogas (Nm^3/ha) of maturity class hybrids FAO 300, FAO 400 and FAO 500

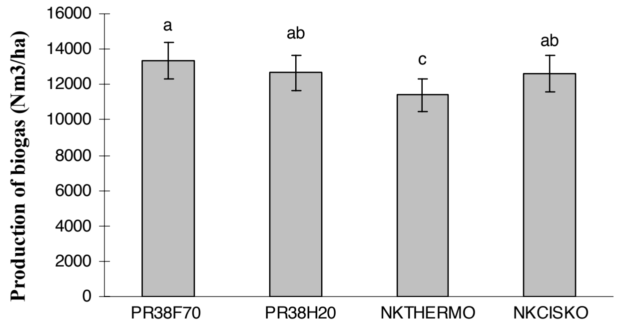

Fig. 7. Production of biomethane (Nm^3/ha) from maturity class hybrids FAO 300, FAO 400 and FAO 500

The statistically significant highest recovery of biomethane at 5% risk hybrids of maturity class FAO 400, with production of 7796 Nm^3/ha of biomethane statistically does not differ from hybrids of maturity class FAO 300, producing 7175.5 Nm^3/ha of biomethane. It statistically does not differ from corn hybrids of maturity class FAO 300 (Table 7, Fig. 7).

3.6. Chemical substance of biogas among the hybrid of maturity class FAO 400

Analysis of composition of gas was made by gas meter (Geotechnical Instruments GA 45), where the data of produced gas among corn hybrids were compared.

In Figure 8 it can be seen the value of gas methane (CH_4) for hybrid PR37D25 in the first 7 days increased and then the value until the 35th day was more or less constant.

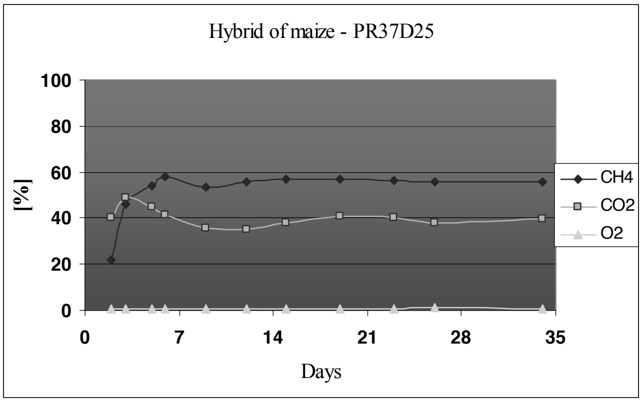

Fig. 8. The value of gas CH_4, CO_2 and O_2 during 35-days digestion

The value of CO_2 gas was increased at the beginning, and then it changed from day to day, with minimal deviation and then stood still.

The value of oxygen gas O_2, was lower than 1% during the whole lab experiment (for 35 days). The low level of oxygen is indicator for anaerobic digestion.

4. Conclusions

According to the results it can be concluded as follows:

- With the higher maturity corn class (FAO 400, FAO 500) the crop yield of biogas and biomethane increases. The greatest recovery of biogas was with hybrid of maturity class FAO 400 i.e. 568 N1/kg oSS or 13927 Nm^3/ha of produced biogas, with chemical composition 55.2% CH_4, 39.3% CO_2 and 0.6% O_2. Hybrids of maturity class FAO 500 gave 530 N1kg VS or 12836.2 Nm^3/ha of produced biogas, with chemical composition 55.5% CH_4, 38.1% CO_2 and 0.5% O_2. Production of biomethane of maturity class hybrids FAO 400 was 315 N1/kg VS or 7768.4 Nm^3/ha of produced biomethane. Hybrids of corn class FAO 500 gave 294 N1/kg VS or 7050.1 Nm^3/ha of produced biomethane.
- Among the corn hybrids of maturity class FAO 300 - FAO 400, 544 N/1 kg VS of produced biogas are given by hybrid PR38F70 (FAO 330). Production of dry substance of ensiled mass in field experiment was 26828 kg/ha, i.e. 13778.5 Nm^3/ha biogas with chemical substance 57.4% CH_4, 34.8% CO_2 and 0.4% O_2. Production of biomethane of hybrid

PIXXIA is 345 N1/kg VS or 7646.2 Nm^3/ha of produced biomethane.

- Among the hybrids of maturity class FAO 400 - FAO 500, 600 N1/kg VS of produced biogas are given by the hybrid PIXXIA (FAO 420). Production of a dry substance of ensiled mass in field experiment was 30322.8 kg/ha, i.e. 16447.2 Nm^3/ha of biogas, with chemical composition 57.4% CH_4, 34.8% CO_2 and 0.4% of O_2. Production of biomethane at field experiment was 30322.85 kg/ha, i.e. 16447.2 Nm^3/ha of biogas with chemical composition 57.4% CH_4, 34.8% and 0.4% O_2. Production of biomethane of hybrid PIXXIA is 345 N1/kg VS or 9440.6 Nm^3/ha of produced biomethane.
- Among hybrids of maturity class FAO 500 - FAO 600, the hybrid CODISTAR (FAO 500) gave 559 N1/kg VS of produced biogas. Production of dry ensiled mass in field experiment was 28782 kg/ha, i.e. 14464,1 of produced gas with chemical composition 55.1% CH_4, 39.8% CO_2 and 0.8% O_2. Production of biomethane hybrid CODISTAR was 330 N1/kg VS or 8562.7 Nm^3/ha of produced biogas.
- Production of methane that plays the main role at gas production varies with corn the hybrids from 50-60% of whole amount of produced gas. According to results of a lab experiment the hybrids PIXXIA (FAO 420) and CODISTAR (FAO500) are suggested for the production of biogas, but some further field researches should be carried out on other location and other type of soil, etc.

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