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Agroecological prospects of using corn hybrids for biogas production

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Abstract. Ukraine is an agricultural country with great agricultural potential for biogas production, which is the key to fertile soils and favorable climatic conditions for energy crops, including corn. The article analyzes the experience of using biogas in Ukraine and the world, its mechanism of production. The leader in biogas production in the world is the European Union in general and Germany in particular. The total number of biogas plants in Europe exceeds 11 thousand, of which 7.2 thousand in Germany. Installed biogas, which is released in the process of complex fermentation of organic waste, consists of a mixture of gases: methane – 55–75%, carbon dioxide – 23–33%, hydrogen sulfide – 7%. An important sector of renewable energy sources in biogas production is presented and the prospects for its use are determined. The energy dependence of our country on the volumes of imported natural gas is analyzed. The main aspects of biogas production are explored using renewable energy sources that are inexhaustible in our crane and the phased operation of the biogas plant is investigated. The real advantages of the need for biogas production and use in our country are outlined. Problems aimed at the development of alternative energy have been proved in order to detect environmental pollution. It has been established that in Ukraine the use of corn silage to improve the efficiency of biogas production at existing biogas stations has not been used so far. The problems of increasing the yield of corn plants have been proved not only by breeding and genetic methods, but also by cultivation technology.

Key words: biogas, corn, renewable energy, the intensification of production, pollution.

INTRODUCTION

Total EU biogas production in 2017 was 10.9 million tonnes (equivalent to 13.5 billion cubic meters of natural gas), of which 6.7 million tonnes was produced in Germany, with an annual increase of 31.3%. One of the important sectors of renewable energy in the world is the production and use of biogas. Ukraine is an agricultural country with great agricultural potential for the production of alternative energy sources, which is the key to fertile soils and favorable climatic conditions for growing energy crops (Kaletnik, 2010; Klimchuk, 2017; Bezvikonnyi, 2018). However, our country still remains energy dependent. The irreversible depletion of the world's energy reserves, the rising cost of energy, and the problems of environmental pollution are forcing most developed countries to formulate their energy strategies for the development of alternative energy.

Experimental research has shown that scientists' views on the feasibility of producing biofuels such as biodiesel and bioethanol are controversial. This is all due to the high cost of technology. Given this, it is extremely important to produce biogas based on corn hybrids (Kolchinskij, 2008; Kaletnik, 2010).

One of the promising areas of energy conservation in agricultural enterprises is the production of biogas as a type of renewable energy sources, which is supplied by agriculture for raw materials (Alimov et al., 1994). After all, the production of biogas and high-yield crops, including corn, is ensured on the basis of the use of plant material obtained as a result of cultivation. It is the diversification of energy sources based on the principles of sustainable development that is a global trend and an urgent need in Ukraine. One of the important sectors of renewable energy. According to the International Energy Agency, by 2030, the share of electricity generated from alternative sources will double compared to today, accounting for about 16% of total production (Wilkie et al., 2000).

The common practice of intensifying and increasing gross biogas production is the use of co-occurring methane fermentation of various raw materials, including those specifically grown for biogas production. In Ukraine, the use of corn silage to improve the efficiency of biogas production at existing biogas stations has not yet been used. There is also limited scientific and practical data on the basis of which it is possible to justify the technological modes of operation of the biogas plant, depending on the proportion of corn silage in the mixture with manure waste (Thran, 2010; Westerholm et al., 2012; Klimchuk, 2017).

MATERIALS AND METHODS

In the process of research used conventional methods. Dry organic matter (Table 2) content was determined by weighting of the initial biomass samples, drying in dry matter weights Shimazu at 105 °C and then placed for ashing in oven (‘Nabertherm’ type) at 550 °C. All the components were carefully mixed together and filled in bioreactors. All bioreactors were placed into heated thermostat SNOL in the same time before starting of anaerobic digestion. Gas released from each bioreactor was collected in storage bag positioned outside of the thermostat container. Gas volumes were measured using flow meter (Ritter drum-type gas meter). The composition of gases, including oxygen, carbon dioxide, methane, and hydrogen sulphide was measured help by gas analyser (model Pronova SSM). The substrate pH value was measured before and after finishing off the AD process, using a pH meter (model TDS-986) with accessories. Scales (Certus CBA-300-0) was used for weighting of the total weight of substrates before and after the AD process. Fermented cattle manure (from 120 L bioreactor working in continuous mode) was used as the inoculum. Batch mode AD process was ongoing at temperature 38 ± 0.5 °C. Biogas released was collected in gas bags for further measurements of gas volume and elemental composition. Biogas and methane volumes and gases composition were measured during AD process at regular time intervals. The AD process was provided until biogas emission ceases. Obtained experimental data were processed using appropriate statistical methods. All data was recorded in the experiment log and on the computer. All bioreactors were connected to calibrated gas storage bags and taps, placed in an oven and set at a working temperature of 38 ± 0.5 °C. The amount and composition of the released gas was measured daily. Bioreactors were also shaken daily by mixing the substrate to wet and reduce the floating layer. The fermentation took place in a single filling (batch) mode and lasted until the biogas was released (25 days). The material for the research were hybrids of corn Bogatyr, Emilio, Dialog.

RESULTS AND DISCUSSION

Biogas production is efficient and attractive to investors technology, but Ukraine is at the beginning stage of introducing renewable energy sources, and the scientific and technical problems of biogas production and use are not quite formal (Rakotojaona, 2013; Mazur et al., 2018; Pantsyreva, 2018; Guo et al., 2020). Therefore, the study, analysis and borrowing of the experience of biogas production in the world and its implementation at agronomic enterprises of Ukraine is of particular relevance.

Biogas, which is released in the process of complex fermentation of organic waste, consists of a mixture of gases: methane – 55–75%, carbon dioxide – 23–33%, hydrogen sulfide – 7% (Angelidaki et al., 2009; Mazur & Pantsyreva, 2017; Pantsyreva, 2019b; Vdovenko et al., 2018a;). One of the main trends in crop and livestock production is the development of complex technologies using methane digestion processes for biomass utilization, for biogas production (Noorollahi, 2015; Vdovenko et al., 2018b; Alavijeh et al., 2020).

Silage corn is by far the most important crop for use in biogas plants. Corn is also called the C4 plant because of its high dry mass yield (Wellinger et al., 2013). The technology needed to process this culture is usually always available in the business or well-known and inexpensive. Corn is easy to silo and even when used cleanly does not cause disturbances in the operation of biogas plants (Sosnowski et al., 2018; Mazur et al., 2019; Ovcharuk, 2019; Pantsyreva, 2019a).

Today there are already special varieties for use in biogas installations. These varieties generally produce more biomass yield. The best time for harvesting is its readiness for silage, digestion and weather. As a rule, corn at harvest should have a dry matter content of 28–35% and be in a state between milky ripeness and fitness for flour.

The main indicator of the effectiveness of growing any crop is its yield. The problems of increasing the yield of maize plants are solved not only by breeding methods, but also by cultivation technology. For the 2015–2017 years, the highest yields (Table 1) were recorded in the areas of the middle-aged Emilio hybrid (12.57 t ha^{-1}).

Table 1. Agrotechnical characteristics of corn hybrids (average for 2015–2017)

Hybrid	Group ripeness	Yield, t ha^{-1}	Length of the cob, cm	Diameter of the cob, cm
Bogatyr	medium early	11.01	17.1	4.5
Emilio	medium	12.57	18.5	4.7
Dialog	medium	11.77	18.3	5.0

LSD0.5 t ha^{-1}: A-0.05, B-0.6, C-0.07, AB-0.12, AC-0.11; BC-0.14, ABC-0.09;
2015 LSD0.5 t ha^{-1}: A-0.04; B-0.05, C-0.05, AB-0.05, AC-0.06, BC-0.07,ABC-0.1;
2016 LSD0.5 t ha^{-1}: A-0.05, B-0.06, C-0.05, AB-0.08, AC-0.07, BC-0.08, ABC-0.1;
2017 LSD0.5 t ha^{-1}: A-0.06, B-0.07, C-0.05, AB-0.07, AC-0.08, BC-0.9, ABC-0.13.

The study found that the highest quantitative and linear rates were recorded in the middle-matured group of corn hybrids. Thus, the cob and its diameter averaged 18.4 cm and 4.9 cm, respectively.

As the main indicators used to evaluate the properties of each individual experimental parallel, certain agro-technical and physical-chemical parameters of maize properties intended for biogas production were taken. In particular, the yield and linear parameters of the cob, as well as the individual technological properties of biomass (dry matter, ash, N, P, K, C, hydrogen and oxygen). These physicochemical indicators are the minimum necessary to determine the prospects of using corn for biogas production (Table 2).

Table 2. Physicochemical characteristics of corn hybrids (average for 2015–2017)

Hybrid	Dry matter,%	Ash,%	N, %	P,%	K, %	C, %	H_2, %	O_2, %
Bogatyr	28.5	4.6	1.00	0.30	0.80	39.8	4.3	36.5
Emilio	29.9	5.8	1.62	0.54	1.56	40.3	5.0	41.4
Dialog	28.9	4.9	1.33	0.44	1.01	39.9	4.8	37.0

Thus, the highest indicators of dry matter and ash content were recorded in the areas of the middle-aged hybrid Emilio, which were respectively 29.9% and 5.8 %. Somewhat lower rates are recorded in the hybrid Dialog, which is a genetically determined trait.

In the process of methane fermentation, the ratio C: N is constant changes because the carbohydrate is released with biogas constantly and the nitrogen is stored in the bioreactor and is only released when the sludge is unloaded (Fig. 1).

Corn silage is characterized by low NH4 content and high C: N ratio. This result can be explained by the fact that mixing cattle manure and corn silage will optimize the components of the mixture in terms of both ammoniacal nitrogen and C: N.

If the ratio C: N in the litter is large, then there will be a shortage of nitrogen serve as a limiting factor for methane fermentation. If the ratio is low, then there is a large amount of ammonia that is toxic to the methanogens. In the process of methane fermentation, the ratio C: N is constantly changing because the carbohydrate is released with biogas constantly, and nitrogen is stored in the bioreactor and is only released when the sludge is unloaded.

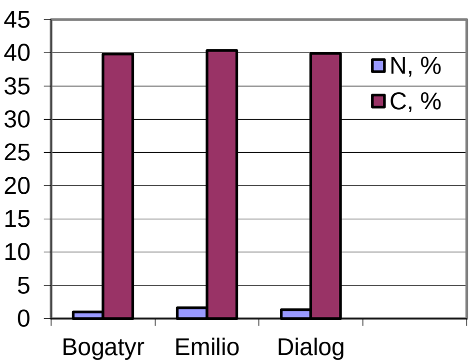

Figure 1. Value content (%) of C and N corn hybrids (average for 2015–2017).

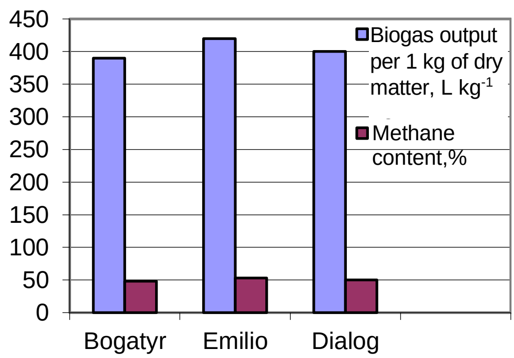

Figure 2. Biogas yield from corn hybrids and methane content (average for 2015–2017).

According to the results of the research, from the corn silage, a certain amount of biogas with different methane content can be obtained during processing (Fig. 2)

In Ukraine, biogas production from agro-industrial raw materials can be estimated at 1.6 million tonnes of conventional fuel. Considering the current technological possibilities of using green mass as raw material for biogas production, the potential of biogas fuel can be considered to be substantially high.

Therefore, biogas production is an efficient and attractive technology due to the presence of significant raw material potential, favorable natural and climatic conditions and low cost of this type of energy. However, Ukraine is at the initial stage of introducing renewable energy sources, and the scientific, technical and economic problems of biogas production and use are insufficiently studied. Thus, the study of foreign experience on these problems and its introduction in agricultural enterprises of Ukraine is of particular relevance.

CONCLUSION

Agrarian and industrial complex of Ukraine, producing large amounts of organic waste, has the resources for biogas production, capable of replacing 1.5 billion cubic meters of gas per year. With the extensive use of corn silage, this potential can be increased to 18 billion cubic meters in terms of natural gas.

The amount of biogas produced depends on the physical and chemical properties of the raw material. To predict the production of biogas, the need to develop new methods, to analyze the potential of biogas production from crop residues and manure. The model should take into account the biogas potential of agricultural crop statistics.

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