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ORGANIC WASTE POTENTIAL FOR BIOGAS PRODUCTION

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Abstract. In this scientific work we have analyzed biogas production from organic waste, in compliance with an acute need to reduce the consumption of traditional energy resources. The purpose of the work was to determine the appropriateness of the use of widespread organic waste for biogas production. The prospects of using waste for biogas production have been confirmed. Among the investigated organic wastes the potato peelings, corn waste and fallen leaves were found to be the most productive in relation to the biogas yield. This method is environmentally safe, and gives the possibility to reduce the emission of greenhouse gases, such as methane, into the atmosphere.

Keywords: potato peelings, corn waste, fallen leaves, biogas, greenhouse emission.

Introduction

The purpose of the work was to determine the appropriateness of the use of widespread organic waste for biogas production. To achieve this goal, the following tasks were solved:

- to establish the most widespread organic waste;
- to get biogas from established waste;
- to assess the appropriateness of the use of certain organic waste for biogas production.

One of the most important problems of our time is waste. We are trying to solve this problem with all the means we can afford, we can’t only solve this problem, but also make our existence more comfortable and this solution is biogas.

According to the specific values of waste generation, Ukraine is in the middle link of European countries (Fig. 1). Its indicator per person is 9.9 t/person/year. Higher figures are fixed from data of Eurostat in countries such as Bulgaria, Finland, Estonia, Russia, Romania. The latter is due to large-scale mining activities in these countries.

Specialists distinguish three categories of countries, taking into account the composition of their waste (Table 1) (Мусорная эра: от рассвета … 2001).

Industrial complex both in our country and abroad, biogas plants are becoming increasingly popular, which simultaneously solve a number of environmental, socio-economic and energy problems, especially in Western Europe, where about ¾ of their number falls on small installations, with a reactor volume of 100 to 300 m³.

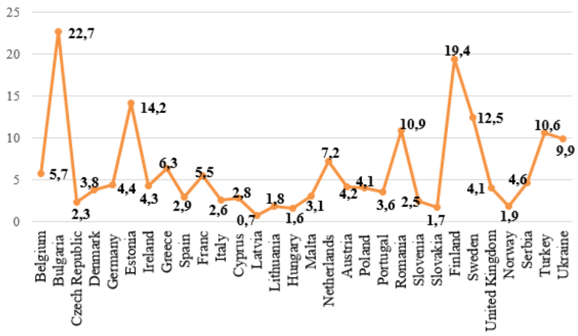

Fig. 1. Waste generation in European countries and Ukraine calculation per capita.

Table 1. Distribution of waste by categories in different countries, % .

Types of waste	The type of the country		
	developed	developing	underdeveloped
Paper	34	16	1.5
Organic	26	45	64
Other	12	9	22
Glass	11	1.5	4
Plastic	7	12	0.5
Metals	7	1.5	1
Textiles, rubber, leather	3	15	7

Experts count that processing of 120 million tons of organic waste in dry form can produce 36–75 billion m^3 of biogas (Deublein e*t al.* 2008). Nowadays Ukraine produces less than 20 billion m^3 of natural gas, and in 2017 the demand was 31.9 billion m^3.

Under the reduction of production activity and the rising cost of traditional types of fuel (coal, oil products, natural gas, etc.), the potential of organic, animal waste, plant residues of agricultural production, solid waste as a raw material for biogas production will increase significantly and, if not completely, at least partially, will meet the country's energy needs. Environmentalization of economic activity requires structural and technological restructuring of the energy complex management based on the transfer of innovative, energy-saving, environmental friendly technologies.

The production and use of biogas energy is one of the important sectors of renewable energy sources (RES) in the world. The production of biogas can prevent methane emissions into the atmosphere. Methane has an effect on the greenhouse effect 21 times stronger than CO_2, and exists in the atmosphere of 12 years. Methane capture is the best short-term way to prevent global warming.

In a number of countries, bioenergy has taken an important part in the energy balance. Denmark, for example, accounts for more than 7% of bioenergy, Austria – 12%, Sweden – 21%, Germany – more than 24%. The latter is the leading producer of biogas in the European Union. Annually in the EU, 14% of the total energy is received from biomass. The European biogas plant market is evaluated at 3 billion dollars and should grow to 25 billion by 2020. At the same time, 75% of biogas is produced from agricultural waste, 17% – from organic waste of private households and enterprises, and 8% – from sewage treatment plants (Strategy for the Security of Energy Supply 2016).

Today biogas technologies, which are based on anaerobic fermentation of the initial product, are operating in more than 65 countries of the world , namely in the USA, France, Great Britain, China, India and others, for the production of electricity from agricultural and livestock waste, food industry waste, selected household waste (food, paper, etc.), energy-rich plants (corn, grass, etc.). The total amount of biogas plants (BP) in Europe exceeds 11,000; 7,200 of which are located in Germany (Strategy for the Security of Energy Supply 2016).

We would like to draw attention to the scheme (Fig. 2), which shows the priorities of waste management in the European Union. Before that, we must strive for it. In Ukraine, unfortunately, we are still at the very bottom of the "junk" development.

According to the European Commission's forecast regarding energy generation from the renewable sources, in 2020, the share of electricity from biogas in the EU will be 8 %, which will improve the contribution of small hydroelectric power plants, geothermal and solar energy. In opinion of analysts, the biogas market will continue to grow rapidly, replacing other energy sources in the overall structure of the energy balance of various countries.

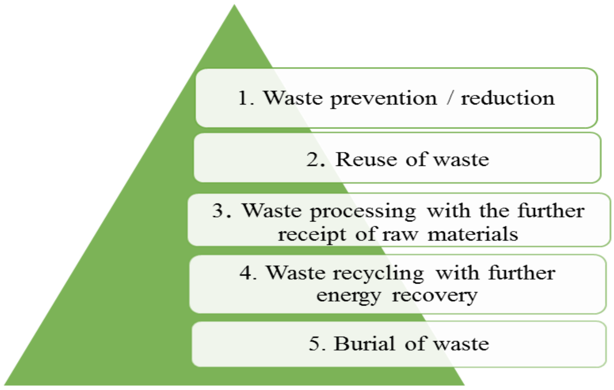

Fig. 2. Prioritize waste management in the EU.

When processing biodegradable organic waste as an alternative source of energy, they are fully used. As a result, the sanitary conditions of the territory are improved, the pathogens of infectious diseases are annihilated, bad smell of rotting plants and weed seeds is destroyed. Moreover, the valuable high quality mineral fertilizers with high content of humus are formed (Karpenko 1998). Organic and mineral remains after biogas production are much better to be used as complex fertilizers for agriculture compared with other ones (manure, garbage, peat and chemicals (Karpenko 1995). They do not have adaptation period and do not contain pathogenic flora but have an active microflora that promotes intensive plant growth. Due to their form the fertilizers begin to ferment immediately after the introduction into the soil. Studies (Naik, *et al.* 2013; House 2007; Deublein e*t al.* 2008) confirmed the effectiveness of plant waste (wheat and corn silage, Sudan grass) and livestock (manure of pigs and cattle) for the production of biogas.

Biogas Production

The main trends in the development of bioconversion systems are determined by the requirements of environmental protection and can be achieved through the production of biogas as an alternative source of energy. The production and composition of biogas is determined by a significant number of factors, but basically it depends on the composition of raw materials (Baader 1982). The biogas composition is (%): methane 50–70; carbon dioxide 30–40; hydrogen 5–10; small amounts of nitrogen, water vapor and hydrogen sulfide (Hejnfelt e*t al.* 2009).

The problem of waste conversion into biogas and fertilizers is solved in the world via fermentation of organic matter in the methane reservoir under anaerobic conditions (Zhang 2012; Angelidaki *et al.* 2009).

The anaerobic decomposition of organic matter is carried out by two main groups of microorganisms. The first group is heterotrophic acid-forming bacteria, which hydrolyze (decompose) complex organic compounds (proteins, fats, carbohydrates) into monomers by enzymes and use them to form low molecular acids, carbon dioxide, ammonia, hydrogen sulfide and water.

The second group of anaerobic organisms is metamorphic bacteria, which use only low molecular organic substances, namely exchange products of acid-forming bacteria. Methane fermentation of organic substances forms ammonia, methane (biogas), free nitrogen, carbon dioxide and water (Mohamad *et al.* 2016).

The heat power of organic substances can be converted into methane and hydrogen by more than 80 %. The heating value of biogas is on average 25·103 kJ/m^3 and varies depending on the carbon dioxide content. Properly treated biogas (with sufficient degree of purification) is an analogue of natural gas, but in contrast to it, biogas is a renewable and environmental friendly energy source. Therefore, biogas can be used not only as automotive fuel, but also for the production of heat and electricity.

Our experiment was carried out without additional processing of raw materials.

The raw materials (corn waste, straw, branches, fallen leaves and potato peelings) were used without further processing. To collect gas we used a vessel by volume of 1.5 dm^3 with rubber cork and a gas-escape tube. One end of the tube was situated over wet biomass, and elastic gas collector was connected to the second one. All connections were hermetical. The vessel contained 0.5 kg of biomass and 0.5 dm^3 of warm water (313-323 K). An excess of water was poured out after 4 h.

The experiments were carried out at three temperature regimes: 288–291 K; 291–293 K and 293–296 K. The diameter of gas collector was measured every 3-4 days, until the constant value. At the end of the experiment the obtained biogas was tested for combustion and then used in the laboratory. The experiment was repeated three times.

Results and Discussion

Fig. 3 represents the experimental results obtained during biogas production from one kilogram of different raw materials for a certain period.

It is obvious that the biogas generation from all kinds of investigated waste was uniform throughout the entire experimental period. Potato peelings, corn waste and fallen leaves were the most productive in terms of biogas production.

The obtained data confirm the dependence of the biogas yield on the dry matter content in the substrate (Table 2) (Fehrs 1999; Angelidaki *et al.* 2011; Naik *et al.* 2013).

Table 2. Dependence of the biogas yield on the substrate content.

Raw material	Dry matter, %	Organic dry matter, %	Biogas yield, m^3/t
Potato peelings	88	94.7	91.66
Corn waste	65	98	81.81
Fallen leaves	40	89.2	63.13

Since potato peelings have a dry matter content of 88%, corn waste 65 % and fallen leaves 40% (Fehrs 1999), then the yield of biogas produced from potato peelings is higher compared with corn and fallen leaves.

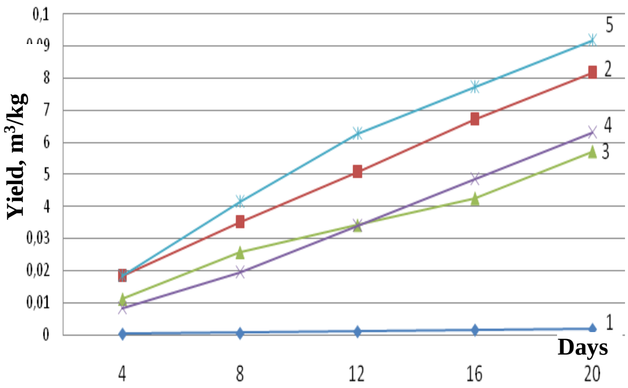

Fig. 3. The yield of biogas from different raw materials: branches (1); corn waste (2); straw (3); fallen leaves (4) and potato peelings (5).

It is well-known that straw and corn utilization is widely used for biogas production in the world, but the results of our experiments showed that the production of biogas from fallen leaves (63.13 m^3/t) is higher compared with that from straw (57.01 m^3/t) and some lower than from corn waste (81.81 m^3/t), while from potato peelings biogas production has the highest value (91.66 m^3/t).

The balanced ratio of nutrient macro- and microelements is necessary for the stable fermentation process. Among microelements the most important are carbon and nitrogen: carbon is a constructive basis of biogas; nitrogen is needed to form enzymes participated in bacteria metabolism. Therefore, the main factor for the stability of methane fermentation is the carbon/nitrogen ratio (C/N) in the substrate. If this ratio is too high, carbon can't be completely processed owing to the insufficient metabolism, and as a result, the biogas yield decreases. If there is a high content of N and negligible content of C, excess nitrogen can form a large amount of ammonia, which, even at small concentrations, slows down the bacteria growth and even can lead to complete destruction of the entire population of microorganisms. Therefore, in order to ensure the process stability, the ratio of C/N should be in the range of 10–30 (Banks *et al.* 2011).

The dependence of the biogas yield on the C/N ratio in the substrate for potato peelings, corn waste and fallen leaves is shown in Table 3 (Fehrs 1999; Angelidaki e*t al.* 2011; Naik e*t al.* 2013). One can see that the C/N ratio for potato peelings is equal to 25 and the same raw material shows the highest biogas yield.

Table 3. Effect of C/N ratio on biogas production.

Substrate	N, %	C/N	Biogas yield, m^3/t
Fallen leaves	1.0	50.0	63.13
Corn waste	1.2	56.6	81.81
Potato peelings	1.5	25.0	91.66

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If we take into account that 1 person consumes 90–100 kg of potato per year, then it is possible to obtain 19 m^3 of biogas from potato peelings; it is enough to cook for 1 person during a month. Potato average yield is 15–20 tons per hectare, and amount of potato peelings from this mass is sufficient (180–220 kg of peelings is obtained from 1 t of potato) to get 300 m^3 of biogas. Such volume of biogas is enough to cook for 3 persons during one year.

7,000–8,000 kg of green mass are formed from 1 ha of corn. About 610 m^3 of biogas obtained from this mass is enough to cook for 3 people during two years, or to heat a house with the area of 100 m^2 during 2 months in the winter.

1,800–2,000 kg of straw is obtained from 1 ha of wheat. The amount of biogas produced from this straw is 115 m^3; this volume is sufficient to cook for 3 persons during 3 months.

During spring or autumn cutting of trees in the suburban areas about 100–120 kg of branches are gotten from 10-12 trees. Taking into account that in such a case only 1.7 m^3 of biogas may be produced, this source of raw materials for biogas production is inappropriate.

On average 1,500–1,800 kg of fallen leaves are accumulated in the autumn on 1 ha of the park area. About 120 m^3 of biogas can be obtained from this mass; this is sufficient to cook for 3 persons during 3 months. One more important advantage is the reduction of harmful emissions into the atmosphere. The leaves, which remain to form humus, during decomposition evolves methane, which is twenty times stronger greenhouse gas than carbon dioxide is. Thus, the fallen leaves as a fuel have a double positive effect on the environment and they are a renewable energy source that will be formed annually.

The cost-effectiveness of biogas production from waste consists in the fact that there is no need for preliminary collection, organization and storage of waste, since it is known how much and when waste is received. The production of biogas is possible in different plants; especially it would be effective in agro-industrial complexes, where there is a possibility of a complete ecological cycle. Biogas can be used for lighting, heating, cooking, for actuating mechanisms, generators, *etc*.

Conclusions

So, the prospects of using waste for biogas production have been confirmed. Among the investigated organic wastes the potato peelings, corn waste and fallen leaves were found to be the most productive in relation to the biogas yield (91.66, 81.81 and 63.13 m^3 /kg, respectively). We propose to use fallen leaves in the city boilers. This method is environmentally safe, and gives the possibility to reduce the emission of greenhouse gases, such as methane, into the atmosphere.

References

Мусорная эра: от рассвета до заката 2001. Available from Internet: http://www.zerkalo-nedeli.com.

Karpenko, V.; Reutskaya, N.; Yhnatova, T. 1988. *Technologicheskaya Bioenergetika*, v.3, p.97.

Karpenko, V.; Chernyshenko, D. 1995. *Ukraina: Liudyna, Suspilstvo, Pryroda,* v.5, p.25.

Karpenko, V.; Popovych, M. 1995. *Ukraina: Liudyna, Suspilstvo, Pryroda*, v. 6, p.112.

Mohamad, Y.; Mustafaa, R.K.; Calayb, E. R. 2016. Biogas from Organic Waste, in *Proceedings 8th International Cold Climate HVAC Conference*, 2016, pp.310-317.

Strategy for the Security of Energy Supply 2016. European Communities. Green Paper: Towards a European. Luxembourg: European Commission.

Fehrs, J. E. 1999. Secondary Mill Residues and Urban Wood Waste Quantities in the United States. *Northeast Regional Biomass Program*, 1999, Washington, USA.

Naik, N.; Tkachenko, E. *et al.* 2013. The Anaerobic Digestion of Organic Municipal Solid Waste in California, in *Proceedings of University of California*, 2013, Berkeley, USA.

House, H. 2007. Today‘s Challenges…Tomorrow‘s Opportunities, in *Proceedings of London Swine Conference,* 3-4 April, 2007, London, United Kingdom, pp.119-128.

Rittmann, B. 2008. Opportunities for renewable bioenergy using microorganisms. *Biotechnology. Bioengineering*, v.100, pp. 203-212. https://doi.org/10.1002/bit.21875

Deublein, D.; Steinhauser, A. 2008. Biogas from Waste and Renewable Resources. *Wiley-VCH*. p.443. https://doi.org/10.1002/9783527621705.

Baader, V.; Done, Ye.; Brennderfer, M. 1982. Byohaz: teoryja y praktyka. Kolos, Moskwa. 256p.

Karpenko, V.; Malašenko, Ju.; Mučnyk, F.; Jastremskaja, L. 1989. *VII sъezd ukraynskoho mykrobyolohyčeskoho obščestva*, Ukrayna, Černovcы-Kyev, 1989, p.120.

Igoni, A. H.; Eze, C. L. *et al.* 2005. Potentials of biogas generation from municipal solid-waste in the Port Harcourt metropolis, in *Proceedings 1st Annual Conference of Science and Technology Forum*, 2005, v.146, pp.67-72.

Zhang, Y., Banks, C. *et al.* 2012. Anaerobic digestion of two biodegradable municipal waste streams, *Journal of Environmental Management,* 2012, v.104, pp.166-174. https://doi.org/10.1016/j.jenvman.2012.03.043

Banks, C. J., Salter, A. M. *et al.* 2011. Energetic and environmental benefits of co-digestion of food waste and cattle slurry. *Resources, Conservation and Recycling,* 2011, v.56, pp.71-79. https://doi.org/10.1016/j.resconrec.2011.09.006

Banks, C., Chesshire, M. *et al*. Biocycle anaerobic digester: performance and benefits, *Waste and Resource Management*, 2011, v.164, pp.141-150. https://doi.org/10.1680/warm.2011.164.3.141

Themelis, N. J.; Kim H. Y. 2002. Material and energy balances in a large-scale aerobic bioconversion cell, *Waste Management and Research*, 2002, v. 20, p.234-242. https://doi.org/10.1177/0734242X0202000304

Angelidaki, I.; Karakashev, D. *et al.* 2011. Biomethanation and Its Potential, *Methods in enzymology*, 2011, Lyngby, Denmark, v.494, pp. 327-351.

https://doi.org/10.1016/B978-0-12-385112-3.00016-0.

Hejnfelt, A.; Angelidaki, I. 2009. Anaerobic digestion of slaughterhouse by-products, *Biomass and Bioenergy*, 2009, v.33, pp. 1046-1054. https://doi.org/10.1016/j.biombioe.2009.03.004

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