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PRELIMINARY RESULTS OF THE OPTIMIZATION OF BIOGAS PRODUCTION AT THE BIOGAS STATION OF THE NATIONAL RESEARCH INSTITUTE OF ANIMAL PRODUCTION IN GRODZIEC SLĄSKI – KOSTKOWICE

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Aim. To optimize the methane digestion process while using different recipes of substrate components of agricultural origin. **Methods.** The chemical composition of separate components of the substrate of agricultural by-products, industrial wastes, fats of the agrorefinery and corn silage was studied. Dry (organic) mass, crude protein (fat) fiber, loose ash, nitrogen-free exhaust were estimated in the components and the productivity of biogas was determined along with the methane content. These data were used as a basis for daily recipes of the substrate and the analysis of biogas production at the biogas station in Kostkowice. **Results.** The application of by-products of agricultural production solves the problem of their storage on boards and in open containers, which reduces investment costs, related to the installation of units for their storage. **Conclusions**. The return on investment for obtaining electric energy out of agricultural biogas depends considerably on the kind of the substrate used and on technological and market conditions.

Key words: agricultural biogas, biogas unit, substrate, biomass of by-products, methane digestion, electric energy.

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INTRODUCTION

The application of by-products of agricultural production solves the problem of their storage on boards and in open containers, which reduces investment costs, related to the installation of units for their utilization. In addition, the biomass, accumulated in the open space, is a source of greenhouse gases, which penetrate the atmosphere and pollute environment. Agricultural biogas units use biomass from agricultural by-products of animal and plant origin as well as biomass, formed due to the cultivation of energetic crops, and wastes (press cake, pulp, fats, *etc.*). The use of so called differentiated recipes requires the optimization of methane digestion process for the purpose of obtaining high industrial results while producing biogas and of reducing the costs of its production via the utilization of waste components.

The work was aimed at the study of the optimization of the methane digestion process while using different recipes of substrate components of agricultural origin.

MATERIALS AND METHODS

The chemical composition of separate components of the substrate of by-products of agricultural production (manure heap, liquid manure, manure), industrial wastes (from the production of grain coffee, pomace, brewing dishwash), fats of the agrorefinery, as well as corn silage [1] was studied. Dry mass, dry organic mass, crude protein, crude fat, crude fiber, loose ash, nitrogen-free exhaust [2] were estimated in the components. Then the productivity of biogas was determined along with the methane content therein, which was formed as a result of methane digestion of separate components [3]. These data were used as a basis for daily recipes of the substrate and the analysis of biogas production at the biogas station in Kostkowice.

The digestion process was optimized in three stages – in the period from January 1, 2013 till June 30, 2014 (Table 1). At the first stage (from January to June 2013) in addition to liquid components the manure and corn silage (28.6 % of substrate) were used which are standard components, applied at the majority of biogas stations. At the second stage (from July and December 2013) the content of silage was limited down to 10.7 % which led to the increase in the amount of wastes. And at the last stage (from January to June 2014) the share of corn silage was decreased down to 7.5 %, whereas that of by-products – increased up to 73.6 % due to which the amount of wastes was reduced by 2.7 % compared to the second stage. A product from the agrorefinery with the 40 % content of rape oil, which amounted to 1 % in the substrate, was an additional component at the third stage.

Each of the study stages included the control of the accuracy of the course of methane digestion and the determination of pH, the content of volatile fatty acids (VFA or FOS) using the example of acetic acid, total inorganic buffer carbonate solution (TAC) – alkalinity in the enzyme. The content of FOS and TAC was found by the method of titration of the enzyme sample of 20 ml (pH 5 and pH 4.4) using 0.1 N of sulfuric acid (VI) [4].

RESULTS AND DISCUSSION

The study of the animal by-products revealed the highest dry mass for cow manure [5], whereas the highest dry organic mass was that of pig manure heap, obtained while growing pigs with no bedding. Among substrate components, presented in Table 2, the highest content of protein, fat and crude fiber is noted for cow manure. The concentration of the former is lower in liquid components, except for nitrogen-free exhaust, which is of the highest importance in the pig manure heap.

The analysis of other substrate components revealed (Table 3) that the highest dry mass was noted for fats and corn silage, the highest content of crude protein – for brewing dishwash, and the highest amount of

Table 1. The percentage of substrate components at different stages of the study

Parameter	Measurement unit	Stage		
		I	II	III
By-products	t	5,383.4	8972.9	11,346.5
	%	64.8	68.7	73.6
Waste recovery products	t	549.3	2692.1	2771.5
	%	6.6	20.6	17.9
Fats	t	0.0	0.0	154.2
	%	0.0	0.0	1.0
Silage	t	2,378.5	1394.9	1151.7
	%	28.6	10.7	7.5

Table 2. The physical and chemical indices of the main substrate components

Parameter, %	Substrate components		
	Cow manure	Cow manure heap	Pig manure heap
Dry mass	19.47	2.80	10.10
Dry organic mass	74.66	60.22	85.06
Crude protein	1.19	0.56	0.64
Crude fat	1.37	0.38	0.44
Crude fiber	4.36	0.60	0.78
BNW	1.83	0.30	6.55

Table 3. The physical and chemical indices of other substrate components

Parameter, %	Component				
	Grain residues	Brewing dishwash	Pomace	Corn silage	Fats
Dry mass	22.00	24.00	31.50	33.00	40.00
Dry organic mass	95.91	96.25	98.38	92.79	100.00
Crude protein	2.00	6.15	2.79	2.67	0.00
Crude fat	0.70	2.10	0.45	1.10	40.00
Crude fiber	6.00	4.25	8.06	7.60	0.00
BNW	12.40	10.60	19.18	19.25	0.00

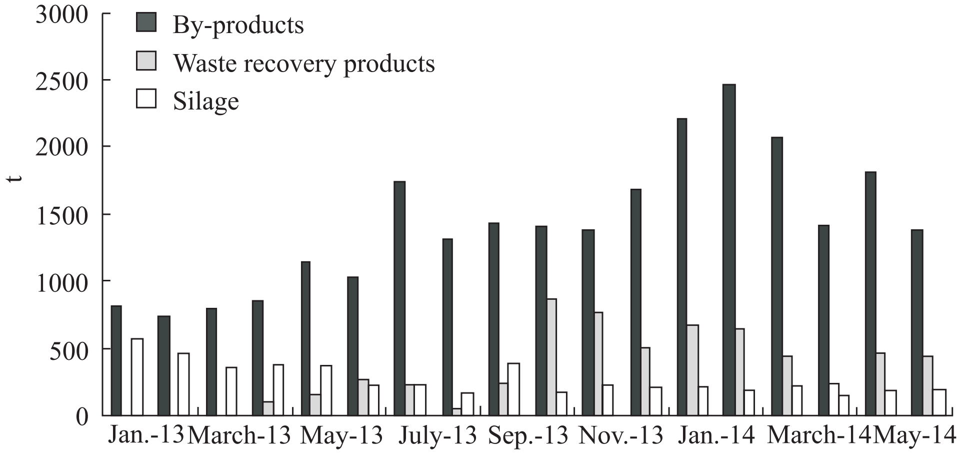

Fig. 1. The share of the main groups of substrates, used in the agricultural biogas station Kostkowice, at the Experimental Station of the National Research Institute of Animal Production in Grodziec Śląski

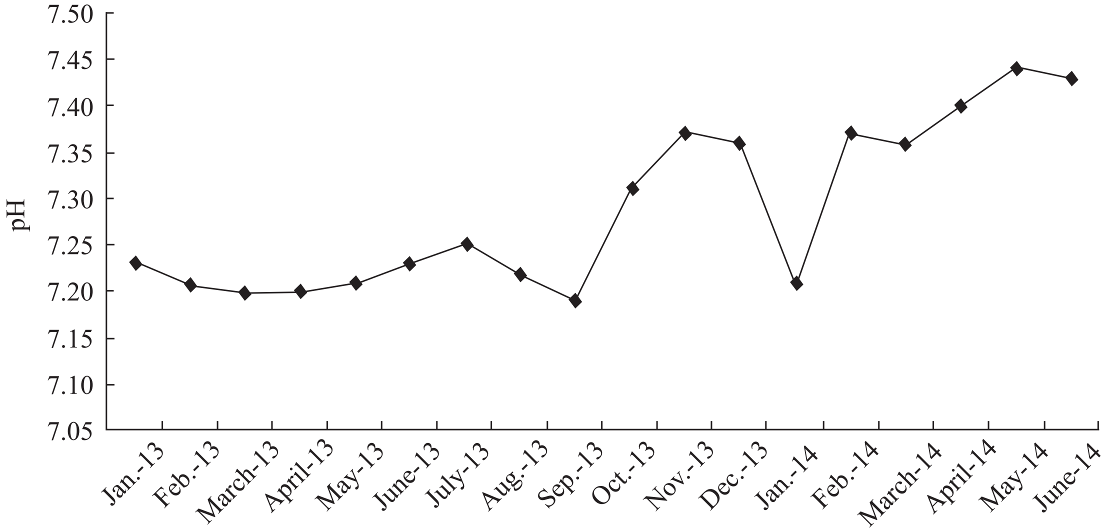

Fig. 2. pH values of enzymes during the testing period

Table 4. The yield of biogas and methane in biogas as a result of fermentation of tested components (estimated according to [6])

Component	Biogas productivity [ln/kg SSO]	Methane productivity [ln/kg SSO]	Content of methane in biogas, %
Cow manure heap	486.18	287.15	59.06
Pig manure heap	525.24	272.59	51.90
Cow manure	285.21	158.52	55.58
Grain yield	211.87	121.33	57.27
Brewing dishwash	536.97	319.90	59.58
Pomace	492.42	252.08	51.19
Fats	1,200.00	816.00	68.00
Corn silage	576.85	302.08	52.37

crude fiber was registered for pomace. The values for nitrogen-free exhaust in corn silage and fruit residues were at a relatively high level. A fat component from the agrorefinery was found to be the mixture of water and rape oil, remarkable for the highest content of fats among other applied components.

The study of components, subjected to methane digestion, from the standpoint of increasing the production of biogas

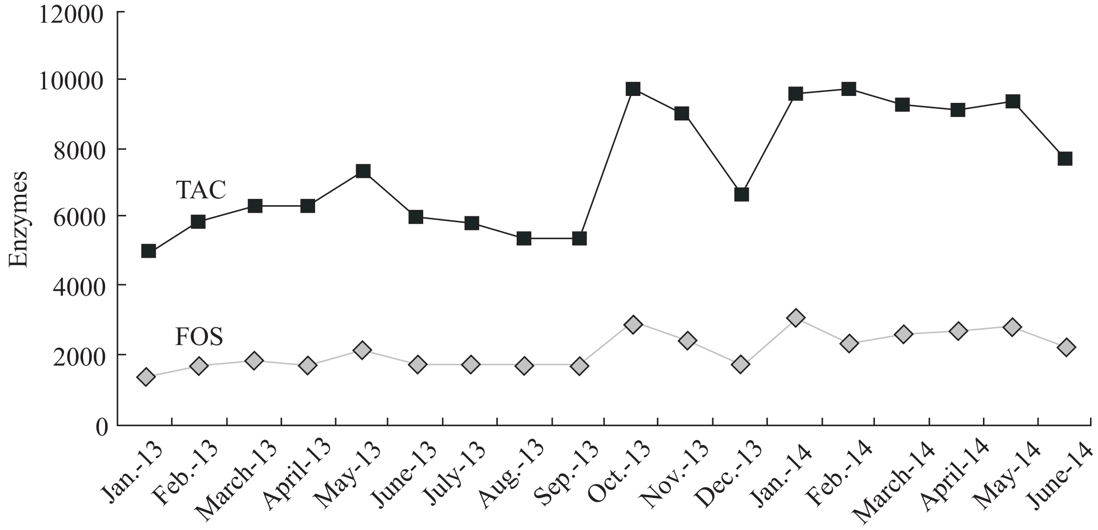

Fig. 3. The parameters of TAC and FOS enzymes during the analyzed period

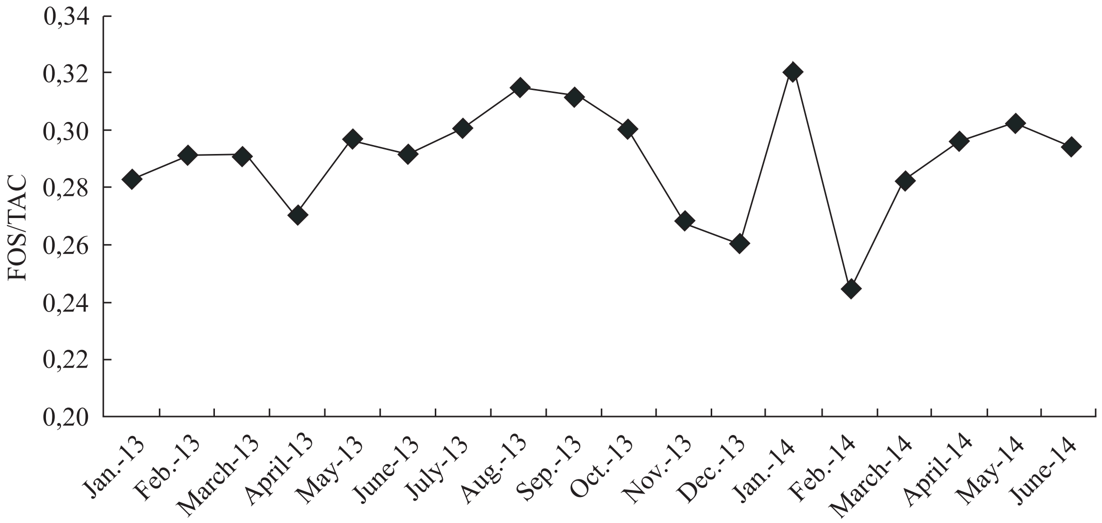

Fig. 4. The biology of methane fermentations of FOS/TAC

and the content of methane therein confirmed that fats, corn silage, brewing dishwash and pomace are characterized by high biogas productivity. The fermentation of products of animal origin, such as manure, manure heap and liquid manure, and fat components has considerable impact on the increase in methane content in biogas (Table 4).

25,703 t of by-products, 6,167 t of waste recovery products and 4,925 t of silage were used from January 2013 till June 25, 2013. The largest share (70 %) is that of by-products, 17 % – of waste recovery products, and the rest (13 %) – of silage (Fig. 1).

The values of pH for the analyzed period were normal regardless of the substrates used. There was an insignificant decline of pH compared to the norm in the period of September–October 2013 (Fig. 2).

The parameters of enzymes FOS and TAC revealed no mistakes in the course of methane digestion either (Fig. 3).

As for FOS/TAC parameter, demonstrating the state and course of the methane digestion process, there is an insignificant excess of the norm (over 0.3) at stage II (Fig. 4). It testifies to the accumulation of products during the formation of acids, which is also manifested by an insignificant decline in pH, shown in Fig. 2.

2,834,455 cubic meters of biogas were produced from the substrate, the main components of which were by-products and wastes, during the period of January 2013–June 2014 (Fig. 5).

During the production of biogas there was an insignificant decline of production at stage II, and the pro-

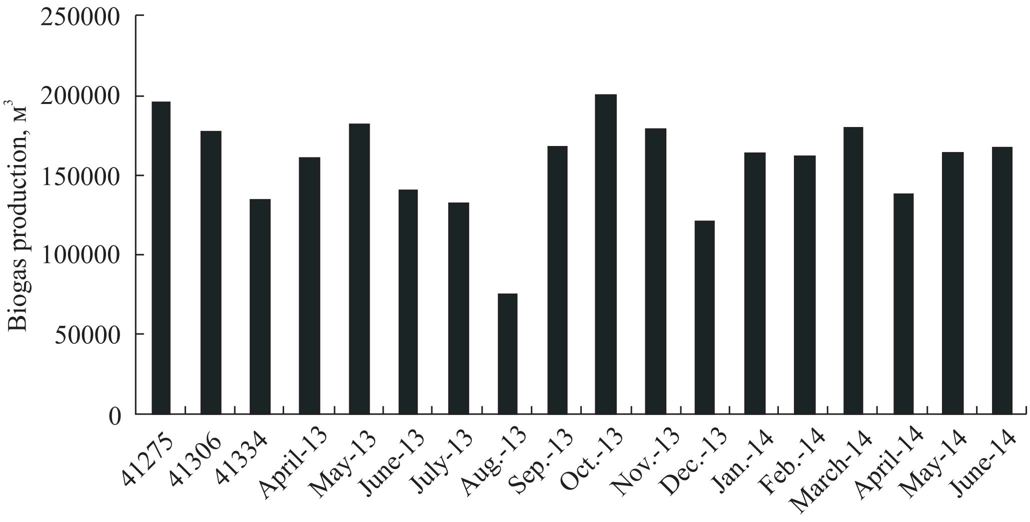

Fig. 5. The production of biogas for the studied period

duction volume of stage III is similar to that of stage I, which might have been impacted by the introduction of fat. With increased amount of by-products, wastes and the introduction of fat to the recipe of substrate components there was a noted increase of methane in biogas up to 1 % (Table 5).

These results confirm the estimation of biogas efficiency which is the highest with the application of fat components, and for methane – with the application of by-products of agricultural products and fats.

The studies of Węglarzy, Skrzyzala [7] determined that anaerobic fermentation of animal by-products prevents greenhouse gases, harmful for environment, loss of nitrogen and escape of stench, which deteriorates air quality considerably on the territories, adjacent to farms. It was also proven that methane digestion is one of the best ways to farm using solid manure and manure pits [8]. The production of biogas in the process of anaerobic fermentation and its burning in the cogeneration engine yields electric energy and heat residue due to cooling of the engine, which may successfully be used to meet the needs of the farm or to be sold at the energy market.

Table 5. The production of biogas at different stages of the experiment

Parameter	Stages		
	I	II	III
Biogas production, cubic meters	988228.7	872350.0	973875.9
Content of CH_4	53.7	53.9	54.9

Raw material of plant production is an important component of the substrate for agricultural biogas stations, for instance, crop residues, peels, feed residues, grains, oil-seeds and silage, unsuitable to feed animals. Another source of substrates of agricultural origin is growing energetic plants, corn in particular, for the needs of the biogas station. Waste recovery products may also be referred to the substrates, used in agricultural biogas units. The recovery of milk fermentation wastes occurs at the fermentation plate, and the recovery products are used as a substrate for the biogas station, following a careful analysis of the content of volatile fatty acids, pH value and quality assessment according to Fliega method. The work of Banel [9] demonstrated that volatile fatty acids have considerable impact on the process of transforming organic matter into methane. Only strict control allows optimizing the process and avoiding environment pollution [10]. The studies, conducted at the biogas station in Kostkowice, demonstrate that the alternative of energetic crops, corn silage mainly, is such wastes as pomace and brewing dishwash, the physical and chemical parameters and energetic value of which are similar to standard components, used in biogas stations. A perfect energetic additive is fatty components, which cause both the increase in the performance of biogas products and the increase in methane content. Differentiated amounts of biogas with different methane content are obtained from the substrate of agricultural origin. The rate of dissociation for some bonds is also different [11]. Saccharides are susceptible to fermentation the most, followed by proteins and fats. The largest amount of methane is obtained due to the decomposition of proteins, and biogas productivity is the highest due to the application of fats. It is possible to maintain a stable level of biogas production in the process of methane fermentation using relevant C:N ratio, balanced in terms of energy recipes, the content of dry mass of substrates, as well as the content of dry organic mass and hydration, directly influencing the moisturization of the fermenting mass. The studies, conducted at the agrobiogas station of the Experimental Enterprise in Grodziec Sląski, indicate that the enrichment of the recipes of agricultural substrates (manure pit, liquid and solid manure) using the biomass from wastes, in particular, fruit residues or brewing dishwash, may facilitate the increase in biogas production while maintaining optimal parameters of methane fermentation and limiting environment pollution via the reduction of uncontrolled leaks and exhaust of greenhouse gases. These studies have also been confirmed by the publication of Bohdziewicz, Kuglarz [12], who came to the conclusion that the fermentation of agricultural by-products conducted in combination with the production and utilization of produced biogas is a reasonable solution.

A relevant issue in the optimization of the process of biogas production is biological maintenance of the biogas station, mainly based on the estimation of the enzyme from the standpoint of dry mass content, pH, FOS, TAC and temperature. During an accurately running process the pH value is 7.2–8.0 and its even insignificant changes may cause some disruptions in the course of anaerobic fermentation. The pH reduction indicates the accumulation of products of the second stage, which is the formation of acids. It leads to the inhibition of the following stages of methane fermentation. The fermentation process may be blocked both by substances, supplied from the outside along with the substrate, and by the ones, formed inside the fermentation reactor chamber. The temperature of the process is another significant parameter of methane fermentation process. In optimal conditions the mesophilic digestion takes place at 40 °C. Another relevant parameter is dry mass in the fermenter. Hydration has a considerable impact on the course of methane fermentation, and on the work of mixers. The optimal content of dry mass to prevent overloading and damage of mixers is 8–9 % for the main fermenter and 6–7 % – in the final fermenter (pre-fermenter). The changes in FOS/TAC parameter testify to the problems, related to the amount of introduced substrate. It is believed that in conditions of accurate course of the fermentation process FOS/TAC should be equal 0.2–0.3. If this index is lower, the process productivity is not optimal, *i. e.* the substrate dose should be increased. If it exceeds 0.3, the load should be controlled via dose reduction or even temporary stops in the work until the parameters stabilize within the optimal framework. The requirement of biological control of the fermentation process, prevention of sudden changes and gradual introduction of the substrate is also discussed by Głodek *et al.* [13].

Therefore, the studies on the optimization of the process of biogas production while using the substrate of agricultural and consumer goods production and by-products of agricultural production revealed that high results are possible in case of using alternative residues (instead of silages) while keeping relevant biological parameters of the enzyme.

CONCLUSIONS

The return on investment for electric energy, obtained from agricultural biogas, depends considerably on the kind of the substrate used and on technological and market conditions.

Taking into consideration the fact that each farm has biomass, which may successfully be used in biogas production [14], it is reasonable to build a station in the vicinity of farms.

The introduction of residues to daily recipes allows increasing biogas production with considerable reduction of the cost of substrate components due to the limitation of corn silage utilization.

Biogas production increases the profitability taking into account the possibility of obtaining and using the energy for one's own needs and due to additional income from the sale of energy and "green" certificates [15].

The material presented does not allow defining clear optimal daily recipe of the substrate. The study of the optimization of biogas production using other components, besides silage, should be continued.

Попередні результати оптимізації продукції біогазу на біогазовій станції Інституту зоотехніки Державного науково-дослідного інституту в Гродцю Сілезьськім – Костковіце

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Мета. Метою роботи були попередні дослідження оптимізації процесу метановой ферментації при використанні різноманітних рецептур компонентів субстратів сільськогосподарського походження. **Методи**. У сільськогосподарських біогазових установках застосовують біомасу з сільськогосподарських побічних продуктів тваринного і рослинного походження (гній, рідкий гній, сеча, рештки кормів), а також біомасу, що утворилася в результаті вирощування енергетичних культур, і відходи (макуху, жом, жири тощо). У разі використання так званих диференційованих рецептур необхідною є оптимізація процесу метанової ферментації для підвищення виробничих результатів при отриманні біогазу, а також зниження витрат на його продукцію через застосування компонентів відходів. **Результати.** Використання побічних продуктів сільськогосподарського виробництва вирішує проблему їхнього зберігання на плитах і у відкритих ємностях, що знижує інвестиційні витрати, пов'язані з будівництвом установок для їхнього зберігання. **Висновки.** Окупність одержання електричної енергії із сільськогосподарського біогазу значною мірою залежить від виду використаного субстрату, а також від технологічних і ринкових обумовленостей.

Ключові слова: сільськогосподарський біогаз, біогазова установка, субстрат, біомаса побічних продуктів, метанова ферментація, електрична енергія.

Предварительные результаты оптимизации продукции биогаза на биогазов ой станции Института зоотехники Государственного научно-исследовательского института в Гродцю Силезском − Костковице

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Цель. Целью работы были предварительные исследования оптимизации процесса метаново й ферментации при использовании различных рецептур компонентов субстратов сельскохозяйственного происхождения. **Методы.** В сельскохозяйственных биогазовых установках применяют биомассу из сельскохозяйственных побочных продуктов животного и растительного происхождения (навоз, жидкий навоз, моча, остатки кормов), а также биомассу, образова вшуюся в результате выращивания энергетических культур, и отходы (жмых, жом, жиры и т. д.). При использовании так называемых дифференцированных рецептур необходима оптимизация процесса метановой ферментации для повышения производственных результатов при получении биогаза, а также снижение затрат на его продукцию вследствие применени я компонентов отходов. **Результаты.** Использование побочных продуктов сельскохозяйственного производства решает проблему их со хранения на плитах и в открытых емкостях, что снижает инвестиционные расходы, связанные со строительством установок для их хранения. **Выводы.** Окупаемость получения электрической энергии из сельскохозяйственного биогаза в значительной степени зависит от вида использованного субстрата, а также от технологических и рыночных обусловленностей .

Ключевые слова: сельскохозяйственный биогаз, биогазовая установка, субстрат, биомасса побочных продуктов, метановая ферментация, электрическая энергия.

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