TEKA Kom. Mot. i Energ. Roln. – OL PAN, 2011, 11c, 118–125

RECRUITING AND USING AGRICULTURAL BIOGAS

Anna Kowalska

Katedra Inżynierii Środowiska i Przeróbki Surowców, Akademia Górniczo–Hutnicza w Krakowie

Summary. We are calling gas acquired of biomass, in particular from the installation alterations of animal wastes or plant, of the sewage treatment plant and landfill sites. The large potential of the biogas production has the farming. In farm households considerable quantities of waste which can be used in the fermentation are arising. Special agricultural cultivations and waste of the food production are a next source of biomass. In the article vital statistics were described about biogas, the process of the biogas production and conditions in which he should run.

Key words: biogas, biomass, renewable energy, biogasworks, farming.

ADMISSION

Using the conventional sources of energy is connected with destroying natural resources and the environmental pollution. Petroleum, hard bituminous coal and dark brown are ranking the natural gas oneself to raw materials, of which stores are slowly ending. In the today seeking and applying alternative energy sources is an important call. According to the principle of the sustainable development we are obliged to use resources of the Earth this way in order to guarantee the equal access to them for future generations. Using on account of large stores arranged on the entire territory of the country the energy of biomass besides the wind power and solar is becoming increasingly common more and more. Biomass can be used in the form of the constant as fuel for direct burning, however subjected to specific processes can be processed into liquid or gas fuel. Biogas technologies apart from the production of the renewable energy enable the recycling of many troublesome waste in it from food-processing plants.

BIOGAS AS ONE OF SOURCES OF THE RENEWABLE ENERGY

Renewable energy sources are widely available, boundlessly rich, renewable spontaneously in natural processes, having the smallest influence on the environment [11]. For electricity generated from renewable sources include heat or electricity generated from sources that produce energy from biomass, renewable generation from biogas, hydropower, wind power, solar collectors and geothermal sources.

Biogas is coming into existence in the biochemical process. In terms of physics he constitutes gas solution consisting mainly of methane and carbon dioxide. Particulates can be found in biogas also, water into forms of steam, the carbon monoxide, volatile hydrocarbons and trace amounts halocarbon whether volatile siloxanes (table 1) [8]. Methanogenesis process often occurs in natural conditions, among others on peat bogs, at the bottom of oceans and lakes, during volcanic eruptions, in paunches of ruminants and in liquid manure. He ranks among anthropogenic sources of methane: getting coal, natural gas and petroleum, landfill sites and sewage treatment plants and breeding of the domestic animals.

Table 1. Percentage composition of biogas [8]

element	content	
	scope %	on average %
methane (CH_4)	42-85	methane (CH_4)
carbon dioxide (CO_2)	14-48	carbon dioxide (CO_2)
hydrogen sulphide (H_2S)	0,08-5,5	hydrogen sulphide (H_2S)
hydrogen (H_2)	0-5	hydrogen (H_2)
carbon monoxide (CO)	0-2,1	carbon monoxide (CO)
nitrogen (N_2)	0,6-7,5	nitrogen (N_2)
oxygen (O_2)	0-1	oxygen (O_2)

The production and energy using agricultural biogas, even though he is one of the most favourable methods of acquiring the renewable energy, she didn't still find the universal application in Poland. In Europe the most for biogas is located in Germany, Denmark and Austria [21]. While in Germany amount for biogas in 2010 exceeded six thousand, in Poland it acted scarcely 150. Poland has the high potential of the biomass production, therefore the structure will enable biogas fulfilment of the obligations concerning achieving 15% to 2020 year of participation of the electric energy generated from the renewables. It is estimated that the agricultural products, liquid and solid manure and by-products and residues of agro-food industry can gain a sufficient amount of materials needed to produce approximately 5-6 billion m^3 of biogas per year, with a purity of methane gas [5,7].

Biogas obtained in the fermentation can be developed to a lot of ways. They most often use biogas for the production of electricity in engines ignition or turbine as well as of thermal energy in adapted gas boilers. From $1m^3$ it is possible to produce biogas 2.1 kWh of the electric energy (at the assumed efficiency of arrangement 33%) or 5.4 kWh of the warmth (at the assumed efficiency of arrangement 85%) [23]. Arrangements associated, enabling the simultaneous production of electricity are also applied and thermal. A possibility of the transfer exists to the gas mains after prior treating [20].

PROCESS OF COMING INTO EXISTENCE OF BIOGAS

Coming into existence of biogas is a multistage process occurring in anaerobic conditions at the participation of special micro-organisms and at the appropriate pH. The methane fermentation is a step-by-step process, and in individual stages other group of micro-organisms is dominating [6]. We distinguish four stages in a process of coming into existence of biogas: hydrolytic phase, acid phase, acetate phase and methanogenic phase.

The hydrolytic phase relies on the schedule polimeryzed, largely of insoluble organic compounds, at the catalytic participation of enzymes of the bacterium from the group of relative anaerobes. Polysaccharides are surrendering to the hydrolysis to simple sugars, fats for alcohol polyhydric and of fatty acids, proteins to aminoacids.

In the phase of the acidity processing water-soluble chemical substances is taking place, in it of products of the hydrolysis through specialist micro-organisms in metabolic processes to simple organic acids, alcohol, aldehydes and hydrogen and carbon dioxide. The rest part is being bioreduced to acetates. Products from this phase are characterized by an intense unpleasant smell.

Acetogenic phase consists in processing bacterium of the ethanol and volatile fatty acids by appropriate species to acetic acid, and carbon dioxide and hydrogen, that is to substrates which in the next phase can to be converted into methane.

In the last phase, methanogenic bacteria produce methane, of which 70% is being generated of the acetic acid or alcohol, and 30% is coming into existence as a result of the reduction in the carbon dioxide in the reaction with hydrogen with the participation of some methanogenic bacteria [14]

As a result of the first and second stage acids are staple products (acetic acid, propionic acid, lactic acid, valerian acid), therefore they are often named fermentation sour. Two next stages closely are also connected with themselves from the consideration, the fact that they are directly responsible for the production of methane. Therefore the third and fourth determined stage is a name of the methanogenic fermentation. Considering above, it is possible to talk about the two-stage course of anaerobic transforming organic substance [9].

In the steadily proceeding fermentation the speed of creating intermediates in the determined phase is directly proportional to a velocity of their decay in the next phase. As a result almost an entire quantity of biomass biodegradable, is staying converted into final products: methane, ammonia, hydrogen sulphide and carbon dioxide [16].

DIVISION OF METHODS OF THE BIOGAS PRODUCTION

Four criteria of identity of systems of the biogas production are most often applied. They belong to them: temperature, in which a process is proceeding, number of stages of the fermentation, dry matter content in substrates and mode of filling fermentation chambers.

On account of the temperature of the process we distinguish the fermentation psychrophylic, mesophilic and thermophilic. In the first stage of the fermentation bacteria are dominating, of which the optimum of the height is taking place in the temperature from 10°C to 20°C. in the phase mezophilic the scope of temperatures fluctuates from 37°C to 35°C. It is noteworthy, that in this temperature range is the most well-known active methane bacteria. The optimal temperature in the thermophilic phase is action of micro-organisms from 50°C to 60°C. Bacteria cultures participating in the last stage are applied in the event that it is necessary hygienisation leading for killing pathogenic bacteria [10].

Depending on the dry matter content in the fermentation chamber we are distinguishing the dry and wet fermentation. There is a speech about the wet fermentation, when substrate in the chamber through the entire duration of the process remains for the fermentation in the fluid state. Content of dry mass in fermenter is taking out from 12% to 15% and at such a consistency pumping and interspersing material is possible. If the number of dry mass will rise above 16%, then material is losing the ability to pump and we are ranking such a fermentation to dry [1].

In the dry fermentation the batch about the high dry matter content stored is having more free time in the state. The chamber of the fermentation has the cylinder shape, and it is made of steel or of reinforced concrete. In the chamber an agitator being used mixing up and transferring substrate is installed. Substrate is being dispensed into the container in the constant way, with the help of the agitator he is mixt up and moved toward the mouth from the chamber. An optimal use of the capacity of the chamber is an advantage of this method and relatively high productivity of the fermentation. Arable farms which don't have the sufficiency apply this technology manure.

Straight majority for biogas is working in the system of the wet fermentation, and integrated chambers of the fermentation and buffer containers of biogas are most often an applied technological solution. The container of the chamber as a rule is made of the reinforced concrete and he is covered gas-tight with roof. He is equipped with the pipework heating installed on the floor slab or on the wall of the tank. An agitator also has. Containers of chambers are low 6-8m and relatively wide – about the diameter coming up to 35m. Since the dispensed batch is in the way constant, chambers of the fermentation have the great capacity (a few thousand m^3). A great stability of litigating is an advantage of the wet fermentation, applying conventional techniques of mixing up and the transport, possibility of partial separating individual fermentations, even decay of substrate, bacterial biomass and biogenic elements [7].

The number of applied containers and means of implementation in them of individual stages of the process influences the amount of stages of the technological process. An one-stage process is most often applied in agricultural biogasworkses, more rarely two - or multistage. The one-stage process is proceeding in one container, therefore between individual bevels a fermentation is lacking the physical division. A large number of containers enables to conduct the process two - or multistage [4,11,17].

Mode of filling fermenter depends on two factors: of access of substrate and the structure of the installation. Under the discontinuous procedure the container is being filled in the maximum amount with fresh substrate, and then hermetically closed. After the end of the stated time the container is staying emptied. It is important in order at the bottom to leave the sparseness of the batch for vaccinating the new process. A changeable amount and a quality of produced biogas are a great defect in this process. Filling fermenter under the discontinuous procedure can be held also with using two containers. The first container is being filled with substrate slowly and evenly in order to initiate the process of decaying. In the second container an appropriate fermentation is proceeding, after which for end the content is being removed, and into her place contents of the first container are being moved. Applying such a method lets the biogas production for increasing the evenness. Constant filling is characterized by repeated filling the container fermenter in the sequence of twenty-four hours. The amount of applied substrate for filling is equaling the quantity of post-fermentation waste chosen into the container of the storage payment. This method assures the regular biogas production and good using the capacity fermenter. A mode mixt up which is an alteration of the constant mode is also applied. In this case storage container of post-fermentation waste is also fulfilling the role fermenter, and covering the container allows for the assembly of gas coming into existence. In the process mixt up a productivity of substrate is increasing as well as a regularity of producing biogas is growing [18].

CONDITIONS OF THE COURSE OF THE PROCESS OF COMING INTO EXISTENCE OF BIOGAS

Methanogenic bacteria participating in the process of secreting biogas which we are ranking among: Methanobacterium omelianski, Methanobacterium suboxydans, Methanobacterium sohngenii, Methanobacterium propionicum, Methanobacterium formicicum, Methanococcus mazei, Methanococcus vannielli, Methanosarcinia barkeri and Methanosarcinia methanica, are very sensitive to environmental conditions [3]. In order to assure for these micro-organisms optimum development, one should conduct the fermentation in closely named terms. We are ranking oxygen among important factors affecting the fermentation, temperature, reaction the pH, nutrients, inhibitors and mixing [4].

Methanogenic bacteria are compulsory or optional anaerobes. Therefore is important so that the process is conducted in fermentation containers closed tightly, without the access of oxygen from atmospheric air.

To a large extent the height of individual strains of bacteria participating in individual stages of the process depends on the pH of the environment. For acidic and hydrolyzing bacteria the pH has the sour reaction and he is ranging from 4,5 to 6,3. Higher pH in the scope from 6,8 to 7 is the best environment for bacteria producing acetic acid and methane. Carbon dioxide remains in the neutral pH range, but decreases if the buffer capacity is exhausted CO_2, causing a chain reaction. Stopping the activity of the bacterium causes reducing the reaction by the pH methanogenic, next is reaching the concentrations of acids associated with the acetic fermentation what in consequence is leading for even bigger lowering the reaction. At excessively alkaline reaction of the environment in bulks hydrogen sulphide and hydrogen are secreted, however in case of the sour reaction the fermentation is finding stopped, but in the extreme case given up [7,22].

Various types of bacteria involved in methane fermentation process developed at various temperatures and divide them into:

- psyhrophyle bacteria – they are cryophilic bacteria, below temperatures 0°C are dying and above 30°C, best are developing in temperature 15°C;
- mezophilic bacteria - below temperatures 10°C are dying and above 45°C best are developing in the temperature: 30 - 37°C. pathogenic bacteria, for which the temperature of the human body is optiumum are in this group;
- thermophilic bacteria - below temperatures 40°C are dying and above 70°C, best are developing in temperature 52°C. These bacteria live in sulphuric, ferric hot springs and in hot sewers [18].

For the majority of the methanogenic bacteria the optimal temperature is included in a mezophilic scope. With bioreactors the most spread on account of the largest outputs of biogas and the good stability of the process, are so which are working in temperatures mezophilic. If is essential higienisation, that is reduction in pathogenic bacteria, using thermophilic bacteria is necessary [1]. Conducting the process in high temperatures is guaranteeing the high output of gas relatively, however a quite great sensitivity of disruptions is his defect. Holding the adequate temperature in individual stages of the process is an important factor exquisitely. The change already against 10 steps in the sequence of twenty-four hours causes the thermal shock and dying of the methanogenic bacteria. Insufficiently heated may be due to the failure of the heating reactor. The drop in temperature directly affects the inhibition of bacteria, and indirectly to a decrease in pH and acidity.

To surviving and the height nutrients and trace elements are essential for the bacterium, so as: nickel, selenium, cobalt, iron, molybdenum and tungsten. A ratio of coal to nitrogen is also essential in applied base. To the correct course of the process relationship C:N should take out 1:30. If the relation is too high (much C, little N) coal isn't undergoing a complete transformation, causing the smaller output of methane. Applying base about the high protein content is disadvantageous, since big freeing ammonium nitrogen causes the market. In case of the too large nitrogen content, a threat of the harmful height to the process of ammonia exists. So that bacteria receive the sufficient portion of nutritional substances, ratio of C: N: P: S should be 600:15:5:1 [15].

We are calling every substance the inhibitor, pollutant in fermenter which is slowing down or is stopping the fermentation, for example: antibiotics (appearing in the urine of farm animals or the municipal waste) destroying methanogenic bacteria, ammonia and some metals (nickel, copper), if are appearing in the high concentration. Selecting substrates to the biogas production, one should take the possibility of appearing of inhibitors into consideration. Every storage substance of substrate given in greater concentrations can stop the fermentation. Even important trace elements can in high concentrations work on bacteria. The part of inhibitors is finding its way to the fermentation chamber together with the substratum, the rest part is products coming into existence in individual stages of the disintegration. The most harmful substances which even in sparsenesses can stop the process of the disintegration, it: antibiotics, disinfectants and herbicide, solvents and salts. Destructively heavy metals being found in a free figure also work on the fermentation. Their neutralization is possible thanks to the hydrogen sulphide coming into existence during the fermentation. The part of inhibitors is having an influence on other substances. Nitrogen is an essential nutrient for anaerobic micro-organisms, ammonia however coming into existence during the fermentation (NH_3) in the little concentration is already litigating to the inhibition, of reducing the biogas production, the unpleasant smell and the low-quality of biogas. Since ammonia coming into existence is reacting with water, forming the ammonium ion and the ion (OH^-), therefore he constitutes the balance for the concentration of ammonium (NH_4). The height is moving the pH balance and an increase in the concentration of ammonia is taking place. Sulphur is also composing biomass. During the fermentation he can appear in the liquid form, or as the hydrogen sulphide in the mixture of liquid and gasses. Together with a rise in temperature a number of the freed hydrogen sulphide is rising in the liquid state, however together with the rise in the biogas production a pressure is growing in the bioreactor, and because of that content of freed compound. Hydrogen sulphide coming into existence during the fermentation (H_2S) in the free figure at setting 50 mg/l is already cellular poison threatening the process of the disintegration. The effect slowing down or completely hindering of different substances depends on many factors. Very much for the establishment thresholds, from which stopping the process is beginning are difficult [22].

Standardizing the temperature and good contact of the bacterium and bases, and hence heightening the biogas production are guaranteeing mixing. The lack of effective mixing the content of the fermentation container causes delaminating fermenting substrate. Bacteria gathering at the bottom fermentatora have the limited contact with base. The part of substance is rising to the surface, creating not very permeable layer for gasses coming into existence in the process. However it is worthwhile noticing, that both lack of mixing, as and are disturbing intensive mixing up process of the biogas production, therefore in fermenter free-rotational agitators are being assembled about the small cutting strength [19].

The change of for instance only one of exchanged factors causes the dismissal or in the extreme case stopping the activity of the bacterium, what the composition of biogas, that is contents in it are changing as a result of methane.

CONCLUSIONS

Amount and composition of biogas depend mainly the chemical composition of organic compounds subjected to the fermentation, the temperature of litigating, the presence of inhibitors, mixing up and the time of keeping substrates in the reactor. Bacteria participating in the methane fermentation are very sensitive to the sequence of factors. Shaking at least one parameter is disturbing the process, and in extreme cases he can entirely break it. With important advantages of the methane fermentation, beside he is providing with energy fuel in the form of biogas, reducing the environmental pollution and getting the valuable natural fertilizer.

REFERENCES

1. Buraczewski G., Bartoszek B. 1990.: Biogaz wytwarzanie i wykorzystanie, Państwowe Wydawnictwo Naukowe, Warszawa.
2. Głodek E. (red.) 2007.: Pozyskiwanie i energetyczne wykorzystanie biogazu rolniczego. Wydawnictwo Instytut Śląski, Opole.
3. Janczur K. 2009.: Biogazownia rolnicza – inwestycja chroniąca klimat. Czysta Energia 1/2009.
4. Janczur K., Szymandera Z. 2010.: Efekt ekologiczny biogazowi rolniczej. Czysta Energia 11/2010.
5. Juśko-Kowalczyk A. 2009.: Przegląd technologii produkcji biogazu. Czysta Energia 9/2009.
6. Kowalska A. 2010.: Overviev of technological methods of energy production from biomass. TEKA Kom. Mot. Energ. Roln. Vol. 10.
7. Kujawski O. 2009.: Przegląd technologii produkcji biogazu (część pierwsza). Czysta Energia 12/2009.
8. Kujawski O. 2010.: Przegląd technologii produkcji biogazu (część trzecia), Czysta Energia 2/2010.
9. Kujawski O., Kujawski J. 2010.: Przegląd technologii produkcji biogazu (część druga). Czysta Energia 1/2010.
10. Lewandowski W.M. 2001.: Proekologiczne źródła energii odnawialnej. Wydawnictwo Naukowo – Techniczne Warszawa.
11. Lis T.2009.: Rozwój sektora biogazu rolniczego w Polsce. GLOBenergia Odnawialne Źródło Energii 3/2009.
12. Malada A., Sobczyk W. 2005.: Uprawa roślin energetycznych jako forma aktywizacji środowisk wiejskich. Zeszyty Naukowe Katedry Inżynierii Procesowej Uniwersytetu Opolskiego, zeszyt II, Opole.
13. Mokrzycki E. (red.) 2005.: Podstawy gospodarki surowcami energetycznymi. Uczelniane Wydawnictwo Naukowo – Dydaktyczne AGH, Kraków.
14. Olesienkiewicz A. 2010.: Biogaz – szybko, wydajnie i opłacalnie. Sposoby modyfikacji technologii fermentacji metanowej. GLOBenergia Odnawialne Źródło Energii 4/2010.
15. Roszkowski A. 2006.: Agriculture and fuels of the future, TEKA Kom. Mot. Energ. Roln., Vol. 6.
16. Schenkel Y., Crehay R., Delaunois C., Schummer J. 2003.: The agricultural sector and bioenergy production. TEKA Kom. Mot. Energ. Roln, Lublin, Vol. 3.
17. Sobczyk W. 2006.: The utilization of the biomass energy as the important factor of versatile development of agrosphere. Folia Scientiarum Universitatis Technicae Resoviensis nr 229. Budownictwo i inżynieria środowiska, z. 40.
18. Sobczyk W. 2008.: Wykorzystanie alternatywnych źródeł energii w Zawoi Przysłopie (Małopolska), Folia Scientiarum Universitatis Technicae Resoviensis nr 229, Budownictwo i inżynieria środowiska, z. 47.
19. Soliński I. 2001.: Biomasa energia odnawialna. Wydawnictwo Biblioteka Szkoły Eksploatacji Podziemnej, Kraków.
20. Szymańska M., Łabętowicz J. 2009.: Dostępność i zasoby substratów do produkcji biogazu w Polsce. Czysta Energia 5/2009.

21. Żmuda K., Czerniakowska-Bojko E. 2009.: Rolniczy potencjał energetyczny – biogazownie rolnicze przyszłością polskiej wsi. Czysta Energia, 9/2009.
22. www.agroenergetyka.pl.
23. www.pga.org.pl.

Publikacja zrealizowana w ramach pracy statutowej nr 11.11.100.280.

POZYSKIWANIE I WYKORZYSTANIE BIOGAZU ROLNICZEGO

Streszczenie. Biogazem nazywamy gaz pozyskany z biomasy, w szczególności z instalacji przeróbki odpadów zwierzęcych lub roślinnych, oczyszczalni ścieków oraz składowisk odpadów. Największy potencjał produkcji biogazu ma rolnictwo. W gospodarstwach hodowlanych powstają znaczne ilości odpadów, które mogą być wykorzystane w procesie fermentacji. Kolejnym źródłem biomasy są specjalne uprawy rolne oraz odpady produkcji spożywczej. W artykule przedstawiono podstawowe informacje na temat biogazu, procesu produkcji biogazu oraz warunków w jakich powinien przebiegać.

Słowa kluczowe: biogaz, biomasa, energia odnawialna, biogazownia, rolnictwo.