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# JUSTIFICATION OF CONDITIONS FOR RESEARCH ON A LABORATORY BIOGAS PLANT

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**Summary.** The residence time of microorganisms in the environment (retention time) is considered to be one of the factors of any microbiological process. To provide effective decomposition of complex organic compounds up to $CH_4$ and $CO_2$ it is necessary that microorganisms were enough sufficient and their presence in the environment was sufficient as well in order to provide metabolism of substrate and thus there was no bacteria leaching. The paper presents the calculation of mixed nutrients for methane generation process as well as the basic parameters affecting the qualitative biogas production process.

**Key words:** biogas, methane generated bacteria, fermented mass, green mass, anaerobic process, energy value.

## INTRODUCTION

The lack of reliable data concerning the energy balance of the system «soil-feed-animal-organics-soil" and methodology of reasoning parameters of this system with the help of energy evaluation method make it possible to objectively judge the presence of the problem of the effective use of organic resources at livestock facilities as the basic material for increasing environmentally generated and resource productive ecosystem functions.

## MATERIAL AND METHODS

Researches have revealed that the best composition of the methane generated raw stuff includes 500 gr. of green grass, minced into pieces of 5 mm, 800 gr. of fresh manure and 300 ml of warm water (Table 1). This composition produced the gas within 526 days with different intensity (fig. 1) [1-5, 13,14].

**Table 1**: Composition of organic stuff control mix

| Mixture options | Raw stuff components | | | Energo, MJ |
|---|---|---|---|---|
| | Mass of the green grass, gr. | Cattle manure, gr. | Water, ml | |
| 1 option | 300 | 800 | 500 | 0,83 |

The total amount of the produced biogas amounted 334 $dm^3$ in 526 days. The whole process can be divided into three stages.

The first stage, lasting for 50 days, includes the extension of methane generated bacteria, with biogas emitting equals to 0, 5 $dm^3$.

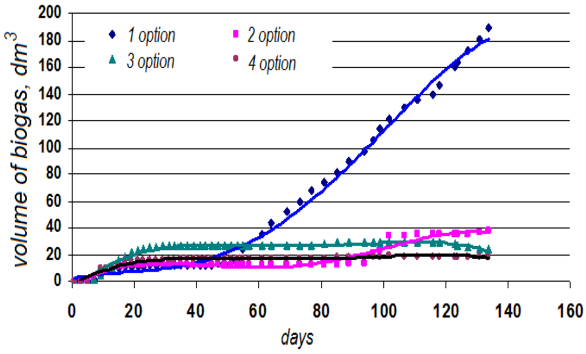


**Fig. 1.** Dependence of the produced gas on the time of methane generated process

The second stage, lasting for approximately 100 days (from 50 to 150 days), includes an intensive processing of organic raw stuff with the help of methane generated bacteria into biogas. Herewith, the daily biogas excretion remains at the level 2,5 $dm^3$. Approximately 200 dm of biogas had been excreted within this period of time.

Within 390 days, at the third and the last stage approximately 150 $dm^3$ of biogas had been excreted, with daily excretion, like at the first stage – 0,5 $dm^3$. The third stage is characterized by the considerable decline in methane generated bacteria activity as the result of the complete depletion either energy value, or a sustenance of the organic raw stuff.

## RESULTS AND DISCUSSION

*Objectives of the article:* increasing the efficiency of organic resources use at livestock facilities on the base of anaerobic processing of organic raw stuff by intensifying substrate methane digestion process optimizing its structure.

*The supply of nutrients.* Bacteria, in order to form their cells, are in need of nutrients, vitamins, Nitrogen soluble compounds, mineral substances and microelements. These substances in required amounts contain in liquid and solid manure. These substances contain in hay, corn (fresh or tinned), food wastes, animal entrails, dairy products as well - all these products can ferment in a pure state without adding other substrates.

We may take such nutrients ratios as the approximate value for mixing substrates [7,15]:

- C: N: P = 75:5:1 or 125:5:1,
- C: N = 10:1 or 30:1,
- N: P = 5:1.

The ratio C:N shows the general coefficient of carbons to the general nitrogen. One percent of phosphorus takes 5% of nitrogen and 75-125% of carbons. An optimal ratio of carbon to nitrogen equals to 30:1 and 10:1. If the ratio declines up to 8%, the formation of bacteria of ammonia is delayed because of the great content of ammonium.

The calculation of substances ratio is possible for the earlier received substrate mixture.

For the first evaluation of substrates mixture, one can do such calculation (Table 2). With its help it is possible to timely determine the possible delay of the formation process because of too much nitrogen concentration.

The ratio calculation C:N:P of mixture with 2,7% of manure and 1% of green grass(see table 1).

**Table 2**: Output data for calculating ratio of nutrients in substrate mixture to be studied

| Name of the substrate | Content of nutrients, gr/kg | | | |
|---|---|---|---|---|
| | Carbon, C | Nitrogen, N | Phosphorus, $P_2O_5$ | The ratio C:N:P |
| Manure | 40 | 3,2 | 1,6 | 25/2/1 |
| Green grass | 96 | 3,9 | 0,7 | 137/5,6/1 |

The content of nutrients (for carbon) in a mixture is determined according to the formula: [7]

$$C_C = \frac{ГC_C \cdot П_{ГC} + ЗT_C \cdot П_{ЗТ}}{П_{ГC} + П_{ЗТ}}, \quad (1)$$

where: $ГC_C$, $ЗT_C$ – content of carbons in a manure and green grass respectively, gr/kg; $П_{ГС}$, $П_{ЗТ}$ – percent of manure and green grass in a mixture respectively (percent).

$$C_C = \frac{40 \cdot 2,7 + 96 \cdot 1}{2,7 + 1} = 55,1 gr / kg$$

The content of N и $P_20_5$ is calculated similarly (Table 3).

**Table 3**: The result of calculation for the final mixture

| Name of the substrate | Content of nutrients, gr/kg | | | | | |
|---|---|---|---|---|---|---|
| | Carbon, C | Nitrogen, N | Phosphorus, $P_2O_5$ | The ratio C:N:P of the mixture | The ratio C:N of the mixture | The ratio N:P of the mixture |
| Substrates mixture | 55,1 | 3,4 | 1,63 | 34:2:1 | 17:1 | 2:1 |

The mixture of nutrients is acceptable and within permissible limits. The ratio C: N is in the lower third, so when supplying the additional substrate, with nitrogen content, it is necessary to pay attention to the delay of the formation due to the great amount of ammonia.

Heavy metals and microelements are required for optimal bacteria livelihood. But at the same time heavy metals can have a deterrent or even toxic affect. Nickel, cobalt, molybdenum, tungsten and iron are especially necessary bacteria for forming enzymes. [14,15]

The experimental laboratory equipment for studies with the following loading of coenzymes into the reactor with the proportion, having been already defined, (see above) was developed (fig.2). A reactor has a warm casing, which will support the necessary temperature, for mesophilic mode of methane generation 30…40°C.

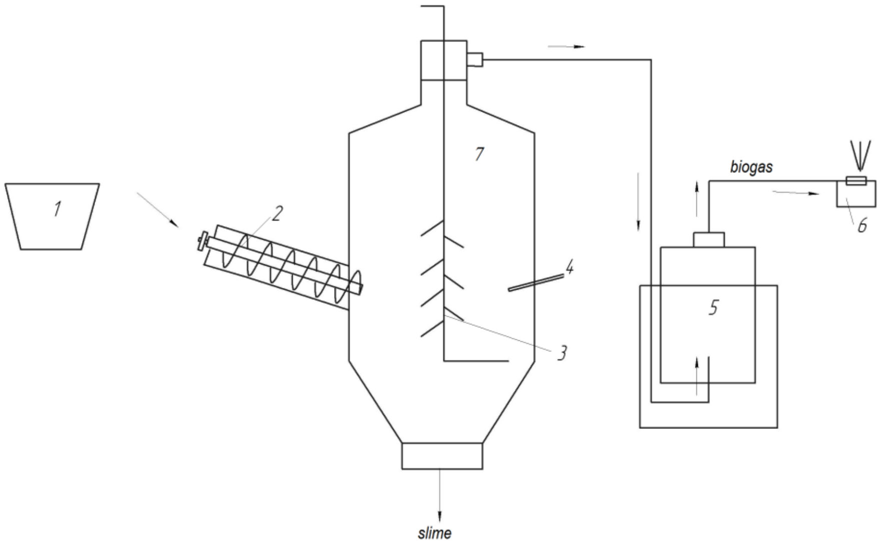


**Fig. 2.** Constructive technological scheme of the laboratory equipment: 1- liquid manure, 2 - raw stuff charging auger, 3 - blade mixer, 4 - temperature sensor, 5 - gasholder, 6 – burner, 7 – reactor

*Loading of fermentation chamber.* Loading of fermentation chamber means the number of organic dry substance, to be daily supplied to the reactor 1 (fig.1). It is definitely specified in kilograms of organic dry substance per $m^3$ of reactor's capacity per a day (kg oDS/$m^3$·day). The size of the possible fermentation chamber loading depends firstly on the selected fermentation temperature and fermentation time. The lower the temperature and the more the fermentation time are, the higher level of reactor's loading is and the more organics can be added.

The loading of fermentation chamber, depending on the installation type, may be increased up to the maximum level. The higher fermentation chamber loading is, the more risk in receiving the threshold of decomposing bacteria and the whole process can be simply overloaded.

In practice it is possible to stumble upon the loading of a reactor in 2-3 kg oDS/$m^3$ per a day. It should be observed that there's no reducing of gas emission due to the delay of bacteria formation. If the loading of the chamber for the fermentation process equals to 4-5 kg oDS, so the productivity of bacteria declines, resulting in the decrease of gas production. The system is considered to be overloaded. There's no problem when the loading is 1 kg oDS/$m^3$.

Such a capacity of a reactor results in reducing fermentation time, if the amount of the substrate, to be supplied daily, increases. Hereupon, bacteria have less time for decomposing material and that is why undigested material will come out of the equipment. So loads of fermentation chamber as well as fermentation time must be coordinated.

The load of the reactor is the control parameter of the equipment loading.

The load of the fermentation chamber, Br, kg oDS/$m^3$·day, may be calculated according to the formula:

$$B_r = \frac{K_{\partial} \cdot \Pi_{OB}}{V_p}, \qquad (2)$$

where: $K_{\partial}$ - the amount of substrate, to be daily supplied, kg; $\Pi_{OB}$ – percent of the organic substance; $V_p$ - general capacity of the reactor $V_p = 0{,}05\ m^3$.

Knowing that the load of fermentation chamber must equal to 2-3 kg oDS/$m^3$ per day [18,19], it is possible to define the necessary amount of the substrate $K_{\partial}$, to be daily supplied

$$K_{\partial} = \frac{B_r V_p}{\Pi_{OB}}.$$

The percent of organic substrate substance $\Pi_{OB}$:

- 1 kg of manure contains approximately 25% of dry substance; the rest of it is water;

- 1 kg of dry mass contains 80% of organic dry mass, the rest are – ash, minerals, fragments of stones and so on.

$$K_{\partial} = \frac{2{,}5 \cdot 0{,}05}{0{,}25 \cdot 0{,}8} = 0{,}63 kg.$$

The equipment will receive 0, 63 kg of fresh substrate daily.

0,63 kg of manure has been supplied, and gas can be obtained out of 0,13 kg since they contain organic substances. Others substances include water and inorganic, mineral manure components.

In general the reactor may be loaded with 2,5 kg oDS/m$^3$ per day. Therefore, it has an average congestion to be increased further, if necessary.

*Fermentation time.* The hydraulic fermentation time – is the time with the substrate theoretically being inside the reactor [8,10]. For reactors with the complete mix, the fermentation time is a calculated average value.

The generation time of the definite bacteria type serves as a measuring unit for the minimal decay time. So if the fermentation time is to be chosen too short and they will not manage to double their bacterial masses, there is a loss of bacteria net and the process of gassing declines.

The fermentation time of the substrate together with the fermentation temperature greatly affects the degree of decomposition, gas output and gas production. The short fermentation time engenders the strong blast effect (in relation to the м$^3$ fermentation chamber), since firstly substrates, that are easily exposed to, decompose. But if one take the whole amount of the organic substrate, so the short fermentation time is connected with a bad gas output (in relation to the kg oDS) and with insignificant degree of decomposition. During the long decay time, the gas production and the degree of decay increases, and the blast effect per m$^3$ of the reactor decreases. Researches of scientists [7] show that there is a great difference between substrates, originated from different animals. The bird droppings in the thermofillic mode significantly “lose their blowing properties” within 30 days of fermentation, and at the same time liquid manure of cattle and pigs require 40 days, solid manure – 50 days. It has also been proved that gas is more produced at the initial stage of fermentation while the final stage produces less gas.

The fermentation time is calculated by dividing the capacity of the fermentation chamber V into the capacity of the substrate $V_{\partial}$, to be daily supplied:

$$t_{збр} = \frac{V}{V_{\partial}},$$

Where:

$$V_{\partial} = \frac{K_{\partial}}{\rho},$$

where: ρ - density of the substrate, ρ=670 kg/m$^3$.

$$V_{\partial} = \frac{0,63}{670} = 0,001\ m^3.$$

Therefore:

$$t_{збр} = \frac{0,05}{0,001} = 50\ days$$

For substrates, that are easily decayed and subject to over oxidation, and for substrates with the high level of nitrogen content and that are capable of causing ammonium delay during the process of bacteria formation, the prolonged fermentation time should be taken into consideration.

For the substrate in the form of liquid manure such fermentation terms are available:

• 20 - 25°C procedural temperature, 60 - 80 days of fermentation,

• 30 - 35°C procedural temperature, 30 - 50 days of fermentation,

• 45 - 55°C procedural temperature, 15 - 25 days of fermentation.

*The degree of decay.* The degree of decay indicates the percent of the organic dry substance within the limits of the set fermentation time. The complete decay up to the state of mineralization is theoretically possible in case the substrate does not contain lignin. Practically the complete decay would require a very long fermentation period, since the speed of decay does not always stays the same, vice versa, on passing the initial stage, it starts significantly reducing with a gas production respectively [7,13]. the high degree of the decay depends on the content of substrate, it represents the gas production and it is worth endeavoring. In practice the decay is observed at the level from 30 up to 70%. In average, the average fermentation period of organic substances equals to 60%.

If the substrate is subject to insignificant decay, neither positive impact on the environment nor the reduce of unpleasant odors and corrosive effects are expected to be observed.

## CONCLUSIONS

Basic conditions for further researches on the biogas plant for the earlier obtained optimal fermentation mixture (500 gr. of green grass, 800 gr. of fresh manure and 300 ml of warm water) have been reasoned. The obtained mixture of nutrients is acceptable and is within permissible limits. The ratio C:N is in the lower third, so when supplying the additional substrate, containing nitrogen, the attention should be paid to the formation delay because of the great amount of ammonia. The amount of substrate, supplied daily, will equal to 0, 63 kg. The fermentation time of the substrate must equal to 50 days at the procedural temperature 30-35°C.

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## ОБОСНОВАНИЕ УСЛОВИЙ ПРОВЕДЕНИЯ ИССЛЕДОВАНИЙ НА ЛАБОРАТОРНОЙ БИОГАЗОВОЙ УСТАНОВКЕ

**Аннотация.** Одним из ключевых факторов любого микробиологического процесса является время пребывания микроорганизмов в среде пребывания (время сбраживания). Для обеспечения эффективного разложения сложных органических веществ до $CH_4$ и $CO_2$ необходимо, чтоб микроорганизмы были в достаточном количестве, а время их пребывания в среде было достаточное для обеспечения метаболизма субстрата и при этом не происходило вымывание бактерий. В работе наведены расчет питательных веществ в смеси для метаногенеза, а также основные параметры, какие будут влиять на качественный процесс получения биогаза.

**Ключевые слова:** биогаз, метанобразующие бактерии, сбраживаемая масса, зеленая масса, анаэробный процесс, навоз, энергетическая ценность.