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BIOGAS UNINTERRUPTED PRODUCTION PROCESS INTENSIFICATION

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Biomass anaerobic fermentation accompanying with methane yield takes a long time. Because of permanently forming organic wastes and sewage sludge anaerobic digesters of significant volumes are needed. To change the situation, the article presents practical ways of intensification of fermentation processes and mathematically sound scheme download reactor.

Key words: Organic waste, Biogas production, Intensification of anaerobic digestion

INTRODUCTION

One of the perspective methods of organic waste recycling is anaerobic fermentation allowing producing biogas and ready for applying fertilizers. This technology is mainly used in Russian Federation on urban sewage disposal plants and very seldom for organic waste recycling on agricultural enterprises. First of all it is explained by high cost of biogas stations and appeared difficulties during harmonization with supervisors. The situation can be changed if save reactors with ferment processes intensification are developed and placed. It significantly cuts down capital costs on designed systems and hereinafter it will become the stimulating factor of their active application. The last will influence on protected territories ecosystem and provide the consumers with cheap high quality fuel and of cause is socially and economically significant for the regions where the developed central gas supply net is absent.

METHODS TO IMPROVE THE RELIABILITY AND INTENSIFICATION OF PROCESSES

Analyzing the problems of interruptible alternative gas supply it is necessary to create conditions for bioreactors productivity improvement. It can be reached both by duplicating equipment with new structural designs including additional devices for waste heating and by activating additives, accelerating the decay process with mass temperature rise and not worsening the obtained gas quality [01-10].

Anaerobic raw material fermentation as a rule takes place during 24 – 30 from the moment of anaerobic digesterloading [02,03,04,]. Thus the biogas discharge rate changes at every decay stage, reaching its maximum on 15th or 16th day. Minimal amount of fuel is released during short periods just after the reactor loading and before obtained manure removal from it. That is why the equipment productivity depending on time of organic mass presence in reactor has cyclic changes charactering for trigonometric functions. Considering the mention regularity the following equation shows the factual change of biogas discharge in dependence on raw decay duration in reactor:

$$v = c_1 \sin^2\left(\frac{\pi \cdot n}{n_{fer}}\right) \quad 1)$$

or at more marked productivity increase in intensive gas evolution period:

$$v = c_2 \sin^4\left(\frac{\pi \cdot n}{n_{fer}}\right) \quad 2)$$

where v - bioreactor productivity, m^3/day; c_1, c_2 - constants of fermentation process, depending on raw material kind; n - days under analysis from anaerobic digester loading moment, day.; n_{fer} - total duration of biogas production process, days.

Then the total amount of produced gas, in m^3 for operation period is:

$$V = \int_0^{n_{fer}} c_1 \sin^2\left(\frac{\pi \cdot n}{n_{fer}}\right) \quad 3)$$

$$V = \frac{c_1 n_{fer}}{\pi}\left(\frac{1}{2}\cdot\frac{\pi \cdot n}{n_{fer}} - \frac{1}{4}\sin\left(2\frac{\pi \cdot n}{n_{fer}}\right)\right)\Bigg|_0^{n_{fer}} \quad 4)$$

At integration expression 2 in the same limits we receive

$$V = \frac{c_2 n_{fer}}{\pi}\left(\frac{3}{8}\cdot\frac{\pi \cdot n}{n_{fer}} - \frac{1}{4}\sin\left(2\frac{\pi \cdot n}{n_{fer}}\right) + \frac{1}{32}\sin\left(4\frac{\pi \cdot n}{n_{fer}}\right)\right)\Bigg|_0^{n_{fer}} \quad 5)$$

Taking into consideration that at anaerobic fermentation 1 ton of cattle manure escape V=60 m^3 of gas during the reactor working period n_{fer}=30 day, from the expressions 4 and 5 we get c_1=4 and c_2=5,333

One reactor day specific capacity with 1 ton of raw material in it with consideration of accepted dependence 1 is

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defined by the equation

$$v = 4\sin^2\left(\frac{\pi \cdot n}{30}\right) \qquad 6)$$

If we take two anaerobic digesters for waste processing of 1 ton weight each and load them maintaining the time distance of 15 days from first reactor loading the productivity (m^3) per day is:

$$v = 4\left(\sin^2\left(\frac{\pi \cdot n}{30}\right) + \sin^2\left(\frac{\pi \cdot (n+15)}{30}\right)\right) \qquad 7)$$

Three reactors with anaerobic period of 30 days and in every 10 days loading will produce biogas the amount of which is defined by the following dependence

$$v = 4\left(\sin^2\left(\frac{\pi \cdot n}{30}\right) + \sin^2\left(\frac{\pi \cdot (n+10)}{30}\right) + \sin^2\left(\frac{\pi \cdot (n+20)}{30}\right)\right) \qquad 8)$$

If the decay process on 15th day has the most expressed production of fuel weight the equation 2 is reasonably to be applied for definition of the plant productivity. It will be the following:

$$v = 5{,}333\sin^4\left(\frac{\pi \cdot n}{30}\right) \qquad 9)$$

Having two reactors with loading period in 15 days the day biogas discharge is determined by the formula

$$v = 5{,}333\left(\sin^4\left(\frac{\pi \cdot n}{30}\right) + \sin^4\left(\frac{\pi \cdot (n+15)}{30}\right)\right) \qquad 10)$$

Having three reactors with total waste weight of 1 ton each and described before operation conditions the total productivity should be calculated by the expression

$$v = 5{,}333\left(\sin^4\left(\frac{\pi \cdot n}{30}\right) + \sin^4\left(\frac{\pi \cdot (n+10)}{30}\right) + \sin^4\left(\frac{\pi \cdot (n+20)}{30}\right)\right) \qquad 11)$$

Plotted according to equations 6-11 dependences for methane–tanks (Figure 1 and Figure 2), in which 1 to *n* of cattle manure is fermented show that at more gradual productivity rise up to maximal values and further in the same rate its degradation two reactors improve constant amount of fuel production per day making autonomic gas supply system more reliable. In the condition of abrupt passing to maximal production the plant consisting of three and more anaerobic digesters allow eliminating irregularity of gas getting.

Obtained at agricultural and livestock waste fermentation biogas mainly consists of 50-80% of methane and 50-20% of carbonic acid. By its characteristics it is like nature gas and its calorific capacity is 6000-9500 kcal/m^3, at average caloricity of nature gas of 7900 kcal/m^3. That is why at fuel discharge from biogas plants and its delivery directly to a consumer or into the gas distributing system it is reasonably to control the amount of produced methane.

The equation of raw product balance will help define its concentration in obtained mix [10]

$$d(\rho c V) = \psi m d\tau + c G_g d\tau \qquad 12)$$

where c – methane concentration, kg/kg; ρ – gas density, kg/m^3; V – gas volume in anaerobic digester, m^3; ψ - substrate decay rate at the time moment τ, kg/hour; m –amount of product, formed at the result of substrate mass unit decay, kg/kg; G_g -consumption of gas, removed from anaerobic digester, kg/hour.

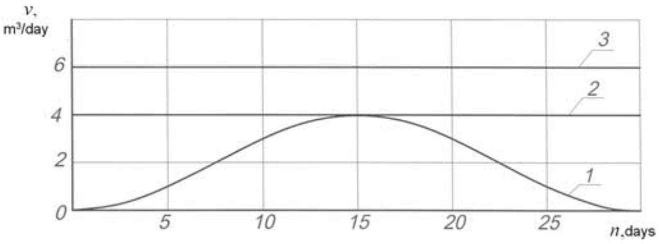

Figure1: Day biogas production v, m^3/day, at uniform rise and then reduction of raw materials decay rate: 1 – one reactor with waste mass of 1 to n depending on 6; 2 – two reactors each containing 1 to n of raw material, applying the equation; 3 – three reactors at the same operation conditions and design according to the expression 8

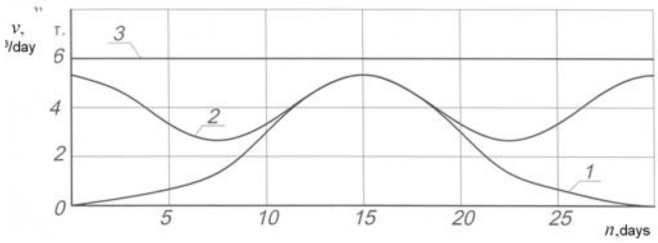

Figure2: Daily biogas production v, m^3/day, at more expressed maximal productivity period: 1 – one reactor with waste mass of 1 to n on the dependence 9; 2 – two reactors, each containing 1 on of raw material; using the equation 10; 3 – three reactors at the same operation conditions mpex and design on the expression 11

Integrating the expression 12 considering that at the moment of reactor loading that is at τ=0, the methane concentration is equal to zero we receive the dependence

$$c = \frac{\psi m}{G_g}\left(1 - e^{-\frac{G_g}{\rho V}\tau}\right) \qquad 13)$$

The expression 13 shows that the conversion rate and total number of produced gas which can be increased due to the thermophile regime maintenance and bacteria high activity mostly effects the methane concentration growth. Thus for example one ton cattle manure fermenting during 15 days total the methane concentration determined by the received dependence 13, increases every day reaching 80 % on the 8th conversion day (Figure 3).

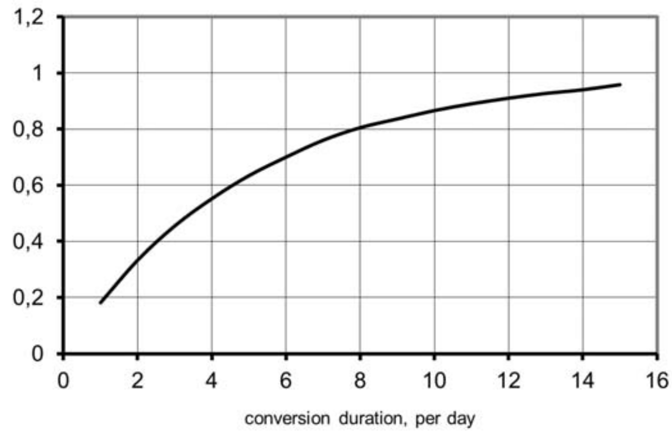

Figure 3: Methane concentration change in produced biogas during the conversion process, kg/kg

When bioreactor is loaded completely the concentration change will have insignificant amplitude oscillations depending on the organic proportion of loaded raw material. But such scheme of waste processing does not promote the achievement of produced maximal gas volumes as it does not supply the full conversion.

CONCLUSION

Analysing the problems of waste utilization and uninterrupted alternative fuel delivery to consumers it is first of all necessary to create conditions for methane fermentation processes intensification:

- reduction of raw materials decay duration at achievement of needed decay level causes the facilities volume decrease and consequently the cutting of capital expenditure for their construction;
- the amount of produced biogas increase leads to more complete loads replacement and cutting of other kinds of energy consumption;
- methane proportion growth in biogas will increase its heat of combustion and utilization effectiveness.

In further development of the alternative fuel production technology there are the following main directions:

- Methane forming improvement and intensification with all the process stages together in one reactor;
- The application of fermentation stage with creation of different conditions for the process execution in every stage;
- The development of new technologies based on application of the microorganisms peculiarities taking part in every from four main stages of fermentation stages and also their demands to media conditions;
- Placing not less than two technological lines of the waste treatments for possible partial change by substrate saturated with bacteria colonies and production of constant biogas amount;
- Obtained fuel enrichment by different technological means including nature gas.

It can be reached by new structural designings including additional facilities for waste heating and optimizationof all the processes and by additionally introduced activating components and microbes accelerating the decay process but not reducing the obtained manure quality.

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