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Vasyl Zhelykh[1], Yurii Furdas[1], Stepan Shapoval[1],
Olena Savchenko[1], Volodymyr Shepitchak[2]

ENERGY SAVING OF MODULAR BUILDINGS WITH THE HELP OF BIOGAS TECHNOLOGIES

[1] Department of Heat and Gas Supply and Ventilation
[2] Department of Heat Engineering and Thermal and Nuclear Power Plants,
Lviv Polytechnick National University
yurii.v.furdas@lpnu.ua

Ukraine has significant land resources for agriculture and is able to provide its population not only with food but also with raw materials for bioenergy.

The article presents a graph of heat capacities and the distribution of heat flows in a bioreactor. The dependences for determining the heat fluxes of flat and cylindrical surfaces are presented. The article outlines the present state of utilization of fallen leaves of trees. The method of utilization by anaerobic fermentation is proposed. The design of bioreactors and the main factors influencing the methane formation process are considered. The methodology for calculating the biogas production process is presented. The productivity of the bioreactor has been determined, depending on the temperature of the raw material and the time of hydraulic resistance

Keywords: biogas plant, bioreactor, biofertilizers, alternative energy source, thermal insulation, anaerobic fermentation, theory of graphs, fallen leaves, raw materials.

Introduction

The main condition for any biogas plant is maintaining the chosen temperature regime inside the tank, regardless of the temperature of the surrounding environment (Ulewicz M., 2021; Biernat, K., 2021; Hosseini, S.E. 2013; Chłopek, Z.; 2017).

Since, in the amplitude of the internal temperature fluctuation over than 15 ºC, the methane formation process is stopped, therefore, it is necessary to provide the bioreactor with the required amount of thermal energy throughout the fermentation cycle, at the same time consuming as little energy as possible (Ulewicz, M., 2020; Zhelykh, V., 2017; European Commission. Nearly Zero-Energy Buildings. 2014; Majumder, A.; 2021).

Heat-exchange surfaces are used for heating the substrate, which are located inside or outside of the bioreactor. In order to maintain the temperature required for the fermentation process, it is necessary to constantly bring the heat to the fermentation mass (Gokcol, C. 2009; Muresan, A.A. 2017; Miciuła, I.; 2020). The need for it consists of the amount of heat needed to heat the substrate from the temperature at which the raw material is fed into the reactor, to the fermentation temperature, and the heat going to compensate for the losses (Panwar, N.L. 2011).

In the cold period of the year maintenance of the temperature regime is quite costly. To reduce heat loss, insulation of the walls of the reservoir is carried out by heat-insulating material.

The productivity of a biogas plant depends on the following parameters: reactor volume: the larger the volume of the installation, the greater the output of biogas; temperature in the reactor at which fermentation occurs; internal temperature regime – methane-forming bacteria in oxygenless conditions can emit gas in the temperature range from 0 °C to 70 °C (Bielski, S., 2021; Marks-Bielska, R.; 2021).

Fluctuations in the temperature of organic raw materials in a bioreactor have a negative effect on the fermentation time. The longer the oscillation, the stronger its impact. For example, with a temperature drop of 50 °C to 40 °C and maintaining it for two days, and then increasing it to 50 °C, the biogas output will decrease by about 11 % over the next few days, and with a temperature of 40 °C for a period of five days – by 37 %. Lowering the temperature from 50 to 20 °C and maintaining it from two to five days completely stops the process of methane formation (Marks-Bielska, R.; 2019; Bielski, S.; 2018).

The purpose of the article

The aim of the article is determination of the distribution of heat flows in a bioreactor, taking into account the temperature of the surrounding environment and thermal insulation in the reservoir wall construct.

Confirmation of the possibility of utilization of fallen leaves in urban parks by anaerobic fermentation, which would result in obtaining biogas and biofertilizers.

Methology

Formation of physical models of thermal processes of a bioreactor.

To estimate the temperature regimes of a bioreactor, it is necessary to make a calculation scheme of heat exchange. In this scheme, heat fluxes must be fully taken into account. Since the technological process of biogas generation is continuous, the bioreactor must maintain a constant thermal regime.

The theory of graphs is widely used to simulate and identify thermal regimes. This approach allows to effectively solve the direct and inverse problems of heat transfer in the part of modeling, identification and optimization of heat engineering physical processes and is based on the system approach for solving complex heat transfer problems. The bioreactor is represented as a system of thermal capacities, between the elements of which is heat transfer and which interacts with heat sources (Fig. 1).

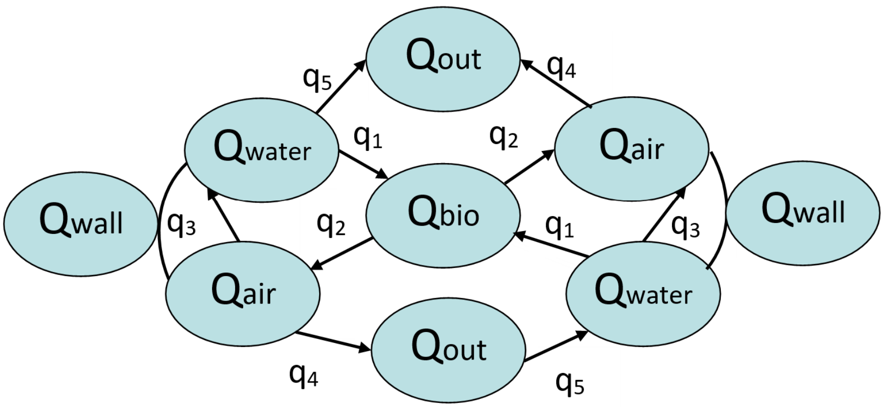
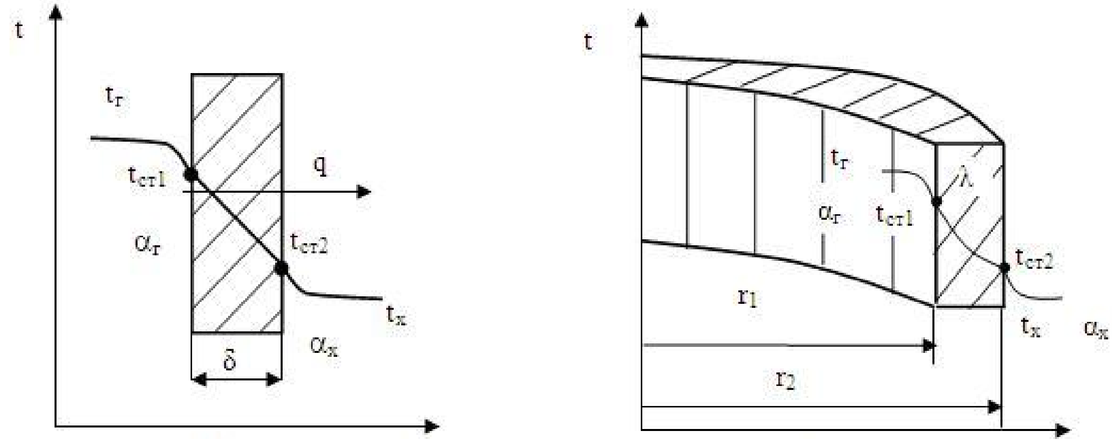


Fig. 1. A graph of thermal capacities of a bioreactor

Heat capacities – Q_{wall} – the wall of the bioreactor (Q_{water} – the layer was filled with water, Q_{air} – the layer was filled with air), Q_{bio} – biomass, Q_{out} – the environment. Heat flows are q_1, q_2, q_3, q_4, q_5.

General Information

A significant factor in determining the heat loss is heat transfer. Heat transfer (heat transfer) is called the process of transferring heat from a warmer ("hot") coolant to a less heated ("cold") coolant through a separating wall. Heat transfer is a complex heat exchange, which consists of a chain of its individual types. From a hot coolant to the wall of heat transfer is carried out by convective heat transfer. Inside the wall, heat is transferred by heat conduction. From the wall to the cold coolant heat is transferred by convective heat transfer. It should be added that with convective heat transfer simultaneously can be carried out and radiant heat transfer. The intensity of the transfer of heat in certain types of heat exchange is determined by the corresponding formulas. The separating wall may be flat or cylindrical, single-layer and multilayer (Fig. 2).



a *b*

Fig. 2. The character of temperature changes in the wall:
a – flat wall; b – cylindrical wall

For a single-layered flat wall, the value of the specific heat flux in the case of heat transfer is determined by the formula

$$q = \frac{t_г - t_x}{\frac{1}{\alpha_г} + \frac{\delta}{\lambda} + \frac{1}{\alpha_x}} = \frac{\Delta t}{R_{\alpha г} + R_{cm} + R_{\alpha x}} = k \cdot \Delta t \frac{1}{2}.$$
$$k = \frac{\Delta t}{R_{\alpha г} + R_{cm} + R_{\alpha x}} = \frac{1}{\frac{1}{\alpha_г} + \frac{\delta}{\lambda} + \frac{1}{\alpha_x}} \quad (1)$$

where – coefficient of heat transfer; $a_Г$ i a_X – coefficient of heat transfer from the hot coolant to the wall and from the wall to the cold coolant, respectively; $t_г$ i t_x – temperature of hot and cold coolant; $\Delta t = t_г - t_x$ – temperature pressure; δ i λ – thickness and coefficient of thermal conductivity of the wall; $R_{\alpha г}$ – thermal resistance of heat transfer from the side of the hot coolant; R_{cm} – thermal resistance of the thermal conductivity (walls); $R_{\alpha x}$ – thermal resistance of heat transfer from the cold coolant.

The coefficient of heat transfer characterizes the intensity of the transfer of heat and represents the thermal flow for a unit temperature pressure ($k = \frac{q}{\Delta t}$), $W/(m^2 \cdot K)$. The value of the inverse coefficient of heat transfer is called the total thermal resistance of the heat transfer.

For a multilayer flat wall, the heat transfer coefficient is equal to

$$k = \frac{1}{\frac{1}{\alpha_г} + \sum_{i=1}^{n} \left(\frac{\delta_i}{\lambda_i}\right)_{cm} + \frac{1}{\alpha_x}}, \quad (2)$$

For a single-layer cylindrical wall, the values of the linear heat flux are determined by the formula

$$q_l = \frac{\pi(t_г - t_x)}{\frac{1}{\alpha_г d_B} + \frac{1}{2\lambda}\cdot ln\frac{d_3}{d_B} + \frac{1}{\alpha_x d_3}} = \pi \cdot q_k \cdot \Delta t, \tag{3}$$

where d_B i d_3 – inner and outer diameter of the cylindrical surface, m.

From the relation (3) linear (for 1 m length of the pipe), the coefficient of heat transfer is equal to

$$k_l = \frac{1}{\frac{1}{\alpha_г d_B} + \frac{1}{2\lambda}\cdot ln\frac{d_3}{d_B} + \frac{1}{\alpha_x d_3}}, \tag{4}$$

The denominator (4) represents the linear thermal resistance of the heat transfer, which is equal to the sum of the individual thermal resistance – the thermal resistance of the thermal conductivity cylindrical wall $\frac{1}{2\lambda}\cdot ln\frac{d_3}{d_B}$ and thermal resistance of heat transfer $\frac{1}{\alpha_г d_B}$ and $\frac{1}{\alpha_x d_3}$.

For a multilayer cylindrical wall, the linear coefficient of heat transfer is as follows:

$$k_l = \left[\frac{1}{\alpha_г d_B} + \sum_{i=1}^{n}\frac{1}{2\lambda_i}\left(\frac{d_{i+1}}{d_i}\right) + \frac{1}{\alpha_x d_3}\right]^{-1}, \tag{5}$$

The linear heat flux is determined by the formula

$$q_l = p\cdot k_l(t_г - t_x) = p\cdot k_l\cdot\Delta t, \tag{6}$$

Provided $\frac{d_3}{d_B}$ < 1,2 cylindrical wall is considered thin-walled, since the value of the heat flux does not depend on the surface's curvature. In this case, it is important to apply the formula for a flat wall, which will have the form

$$k_l = \left[\frac{1}{\alpha_г d_B} + \sum_{i=1}^{n}\frac{1}{2\lambda_i}\left(\frac{d_{i+1}}{d_i}\right) + \frac{1}{\alpha_x d_3}\right]^{-1}, \tag{5}$$

$$q_l = \frac{\pi\cdot\bar{d}\cdot(t_г - t_x)}{\frac{1}{\alpha_г} + \left(\frac{\delta}{\lambda}\right)_{cm} + \frac{1}{\alpha_x}}, \tag{7}$$

where $\bar{d} = 0{,}5(d_B + d_3)$ – average diameter of the pipe, m.

If it is necessary to reduce the intensity of heat transfer, you need to increase the thermal resistance. This is achieved by applying a layer of isolation to the wall. For thermal insulation, materials with low thermal conductivity are used. Increasing thermal resistance of heat transfer reduces thermal losses in the environment. The equation of convective heat transfer from the layer of insulation in the environment for a flat and cylindrical surface will be as follows

$$Q = \lambda_x(t_{iз} - t_x)\cdot F_{cm};$$
$$Q = \lambda_x(t_{iз} - t_x)\cdot\pi\cdot d_{iз}\cdot l. \tag{8}$$

In these formulas $t_{iз}$ – temperature of the outer wall of insulation; F_{cm} – surface area of the flat wall; $d_{iз}$ – outer diameter of the insulation; l – pipe length.

Based on the foregoing, it is obvious that with an increase in the thickness of the insulation temperature $t_{iз}$ decreases in both cases. In this case, the surface area F of the flat wall remains constant, and the surface area of the cylinder increases as a result of increase d_{iz}. In the case of a flat wall, the heat flux Q decreases. In the case of a cylindrical wall, this conclusion can not be made, because Q_n determined by the product $(t_{iz} - t_x) \cdot d_{iz}$, in which the first multiplier decreases, and the second increases. This indicates the existence of an extremum. In (7) it is shown that in the case of isolating a cylindrical surface with a single-layer insulation, the additional thermal resistance in comparison with the non-insulated surface is

$$\Delta R_l = \frac{1}{2\lambda_{iz}} \cdot ln\left(\frac{d_{iz}}{d_3}\right) - \frac{1}{\lambda_2} \cdot \left(\frac{1}{d_3} - \frac{1}{d_{iz}}\right), \tag{9}$$

where λ_{iz} – coefficient of thermal conductivity of the material to isolate.

From the last expression it is clear that the thermal resistance of the insulation (the first term) increases, and the second term decreases due to the growth of the outer surface ($d_{iz} > d_3$). To reduce the heat loss it is necessary to $\Delta R > 0$. Given this, the solution of the inequality (9) is relatively λ_{iz} gives

$$l_{iz} \ \mathbf{p} \ \frac{1}{2} a_2 d_2 k, \tag{10}$$

where $k = \left[ln\left(\frac{d_{iz}}{d_3}\right)\right] / \left[1 - \left(\frac{d_3}{d_{iz}}\right)\right]$.

The smallest value of k is equal to one provided $d_{iz} \to d_3$. The analysis shows that the isolation material is selected correctly if inequality is performed

$$\frac{\lambda_{iz} \pi \alpha_2 d_3}{2}, \tag{11}$$

and the so-called critical diameter of the insulation should be equal

$$d_{kp} = 2\frac{l_{iz}}{a_2}. \tag{11a}$$

The total coefficient of heat transfer by convection and radiation from the surface of insulation to air can be determined by the approximate formula (6), W/(m^2·K)

$$a_x = 5{,}74 + 0{,}07(t_{iz} - t_{pov}). \tag{12}$$

The formula is valid for t_{iz} < 150 °C.

Taking into account the poor thermal conductivity of the air, in the walls of apartment houses and in the lining of heat plants, air layers are left. If these layers are sealed, the process of transferring heat between two walls can be considered as an elementary process of heat transfer by thermal conductivity. In this case, the heat flux is determined by the ratio:

$$Q = k_n \cdot F \cdot (t_{cmm} - t_{cmm}) = \frac{\lambda_{ek}}{\delta} \cdot F \cdot (t_{cmm} - t_{cmm}), \tag{13}$$

where k_n – coefficient of heat transfer through the layers by contact; λ_{ek} – the equivalent coefficient of thermal conductivity, for which through the layers the same heat flux is transmitted as in the complex heat transfer process. If the ratio λ_{ek}/λ is denoted by ε_k, then the heat transfer formulas through the layers have the form (7):

– for flat layers

$$q = (\varepsilon_k \frac{\lambda}{\delta} + \alpha_{np}) \cdot (t_{cm1} - t_{cm2}) = \varepsilon_k \frac{\lambda}{\delta} \cdot (t_{cm1} - t_{cm2}) + + \varepsilon_k \cdot c_0 \left[(T_{cm1}/100)^4 - (T_{cm2}/100)^4\right], \tag{14}$$

– for cylindrical layers

$$q_l = \frac{2\pi\pi_k\lambda}{ln(d_3/d_B)}(t_{cm1} - t_{cm2}) + \varepsilon_n \cdot c_0 \cdot \pi \cdot d_B \left[(T_{cm1}/100)^4 - (T_{cm2}/100)^4\right]. \tag{15}$$

If the layer is only part of a complex wall, it is necessary to determine the effective coefficient of thermal conductivity of the layers taking into account the radiant heat exchange by the formulas (8):

– for flat layers

$$l_{e\phi} = e_k l + a_{np} \cdot d \; ; \qquad (16)$$

– for cylindrical layers

$$\lambda_{e\phi} = \varepsilon_k \lambda + 0.5\, \alpha_{np} \cdot d_B \cdot ln(\frac{d_3}{d_B}) , \qquad (17)$$

where α_{np} – radiant coefficient of heat transfer.

Relevance of the theme:

The current level of urban development requires significant energy costs, including oil and gas and their deposits are constantly decreasing.

Therefore, there is a need to find alternative energy sources. One of the solutions to this issue is the use of biomass as an alternative energy source.

Fallen leaves from trees is a valuable raw material which has significant energy potential and on the other hand - this garbage that must be disposed of. The most effective way to solve these problems is to use an anaerobic or methane fermentation method. This process is the decomposition of organic substances to end products, mainly methane and carbon dioxide, due to the vital functions of a complex microorganism complex under anaerobic conditions. Under certain conditions, these gases are formed in quantities that make up 90-95% of the decomposed organic matter. The remaining 5-10% is spent on the recovery of bacterial cells.

Analysis of existing data:

According to McCarthy's theory, the complete destruction of organic matter is as follows (http://ert.hol.es/book/e2.2.html):

$$C_{10}H_{19}O_3N + 4{,}5H_2O \rightarrow 6{,}25CH_4 + 3{,}75CO_2 + NH_3 + HCO_3 . \qquad (18)$$

Pursuant to modern ideas, anaerobic methane fermentation has four related stages::

1. The stage of enzymatic hydrolysis of insoluble complex organic substances with the formation of simple soluble substances;
2. Stage of the acid-forming process with the release of volatile fatty acids (VFA), amino acids, alcohols, hydrogen and carbon dioxide (acidogenic stage);
3. Acetogenic stage of transformation of VFA, amino acids and alcohols into acetic acid;
4. The methanogenic stage is the formation of methane from acetic acid and the reduction of hydrogen carbon dioxide.

For the formation of biogas from plant material, it is necessary, first of all, to create comfortable anaerobic conditions for the life of three types of bacteria. These bacteria are among themselves successors, that is, the following species feeds on the products of life of the previous species. First, it is hydrolytic bacteria (they are responsible for the processes of biomass destruction under the action of water and temperature), the second type of acid-forming bacteria (they allow to obtain from hydrolyzed products of the molecule of organic acids) and, finally, methane-forming, which regulate the processes of consumption of organic acids and biogas generation. In the process of biogas production, not only bacteria of the class of methanogens take part, but all three species.

Methane bacteria manifest their livelihoods within the temperature range from 3–4 °C to 70–90 °C. If the temperature is higher, they begin to die, at a negative temperature they survive, but stop their livelihoods.

Since metabolic activity and the level of reproduction of methane bacteria are lower than acid-forming, the excess of acids (pH below 6.5) reduces the activity of methane bacteria. On the other hand, an increase in the pH value above 8.0 (an excess of amino acids) also leads to the decay of the methane formation process. Usually the pH value is maintained at a constant level. Also, for active life of organisms it is necessary to maintain normal pressure, for example, to accumulate biogas into an elastic reservoir. Humidity of raw materials should be 85–92 %.

Biogas is a mixture of methane (60–85 %) and carbon dioxide (15–40 %). It is obtained in special installations of a variety of design execution, depending on local conditions.

The advantage of using this type of renewable energy source in the simplicity of the technical implementation of the process, the raw material is constantly restored in nature. In the process of recovery, up to 90 % of organic matter is converted into gas and water. There is a complete disinfection of recyclable waste received highly bio (compost).

Biogas is produced in reactor-methane tanks in volume from 0.5 m^3 to several thousand cubic meters directly near sources of waste, it is simply transformed into heat and electric energy and consumed in everyday life.

Production and consumption of biogas solves at once three general problems: energy, economic, agrochemical. The heat of combustion of solid fuels, for example coal, is 6–32 MJ/kg. Biogas has a heat of combustion from 21–36 MJ/kg under normal conditions. From one ton of organic substances released from 250 to 600 m^3 of biogas (http://ert.hol.es/book/e2.2.html). After the methioning process, compost remains. From different substances you will receive an unequal amount of biogas (table 1) (http://ert.hol.es/book/e2.2.html). It should be noted that if you add up to 30 % of cellulose in biomass, the biogas output will increase 2–3 times.

Kilogram of manure gives: 0.18 kg of methane, 0.32 kg of carbon dioxide, 0.2 kg of water and 0.3 kg of humus. One kilogram of biogas provides heat, which allocates 0.6 kg of kerosene, 1.5 kg. coal, 2–3 kg of firewood. To date, more than 70 types of biogas technologies have been developed (Khan, S. 2015; Adnan, A.I. 2019).

Table 1

The amount of biogas from 1 kg of dry matter liter/kg

№	Raw	The amount of biogas from 1 kg of dry matter liter/kg	Percentage of methane in gas %
1	Grass	630	70
2	Fallen Leaves	210–294	59
3	Pine branches	37	69
4	Potato leaves	420	60
5	Corn stems	420	53
6	Wheat straw	342	58
7	Rye straw	359	59
8	Domestic waste and rubbish	600	50

Table 2

Volume of fallen leaves (Tkachenko S., 2004)

Name	Volume	kilogram per cubic meter – a mass of 1 m^3	specific gravity or volume density in g/cm^3
Fallen leaves, weight 1 m^3	1 m^3	300	0.30

At present, there are the following schemes for handling fallen leaves:

1. Removal of fallen leaves on landfills of solid household waste;
2. Preservation of fallen leaves at the place of education in order to prevent the violation of the ecological well-being of the territory;
3. Composting of vegetable waste.

Results

Taking into account the specifics of the utilization of organic wastes, the authors propose the following scheme of treatment of fallen leaves:

1. Fallen leaves in places of its largest accumulation are stored in tight transportable containers – bioreactors volume 1–1,5 m^3.
2. After full filling of this capacity, it is transported to places of defense.
3. This may be a special warehouse with a temperature that corresponds to the process of methane fermentation.
4. The term of hydraulic defending will be from 3 to 6 months.
5. The peculiarity of the proposed scheme is that due to small capacities, it is possible to increase the number of reactors and constantly increase the number of fallen leaves that is being processed.
6. All tanks are interconnected by a gas collector, through which the gas enters the gasholder in which it accumulates for storage.
7. After the fermentation process (4–6 months), the perforated leaves can be used as biohumus for the fertilization of crops.

Biogas plant is intended for ecological processing of organic waste. The basis of the bioreactor's work is the biological processes of digestion and decomposition of organic substances under the influence of methane-forming bacteria in anaerobic conditions characterized by the absence of free oxygen, high humidity and constant temperature environment (Sun, L.; 2013).

Biogas plant solves the problem of utilization and efficient use of organic wastes for the benefit of the environment. The resulting gas is partly converted into electricity, and the balance is used for the needs of the economy.

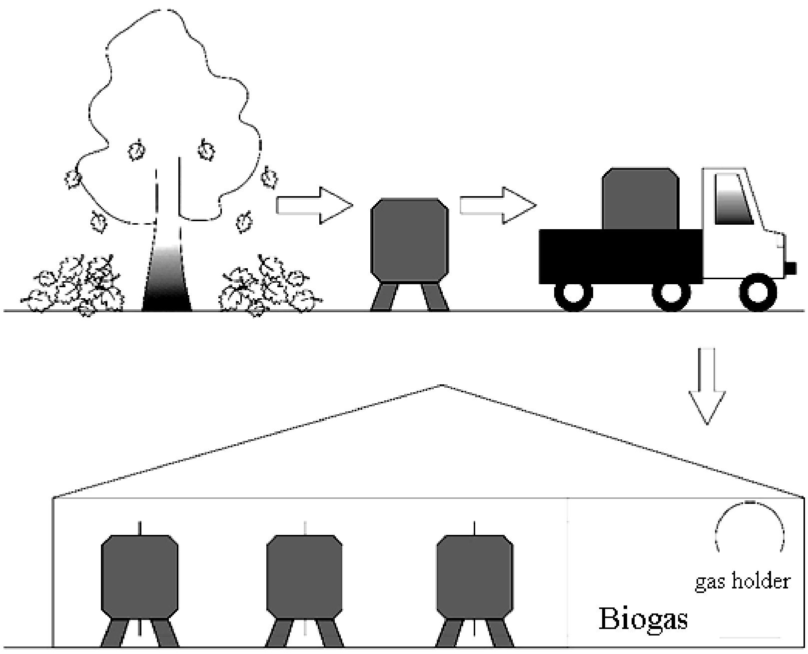


Fig. 3. Scheme of utilization of fallen leaves

The bioreactors in the form of vertical capacities for static reasons mainly have a round cross-sectional shape (Fig. 4). Their advantage lies in the fact that in comparison with the horizontal version they are more compact, have a favorable ratio of surface area to volume, which reduces the cost of materials and heat loss.

The existing geometric forms of domestic biogas digesters were analyzed and bioreactor of cylindrical shape with truncated cones upwards and downwards was proposed, which takes into account energy saving characteristics and features of the process. (https://90zavod.ru/raznoe/ves-1m3-listvy-skolko-vesit-1-m3-opavshix-listev-sobrannyx-grablyami-v-kuchi-dlya-vyvoza.html)

From a technical standpoint, this form provides the smallest area of contact of the surface of the reservoir with the surrounding medium which in turn minimizes heat loss.

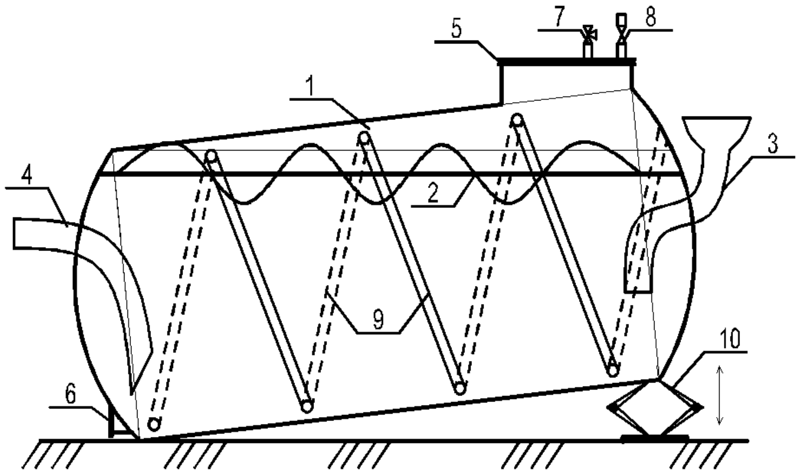


Fig. 4. Scheme of bioreactor for utilization of fallen leaves
1 – tank; 2 – mixing system; 3, 4 – pipe loading and unloading of raw materials;
5, 6 – upper and lower service hatches; 7 – discharge valve;
8 – a branch pipe of an exit of biogas; 9 – heater; 10 – movable support

An important characteristic of a bioreactor is the ability to produce a certain volume of biogas. Therefore, there is a need for a theoretical calculation of the estimated amount of biogas output. The basis of the calculation is a method for determining the volume of biogas from solid household waste, and adapt it for fallen leaves of trees:

One of the important factors affecting the amount of biogas generated is the kind of fossilized biomass. This is due to significant differences in the chemical composition of organic raw materials. Therefore, designing the volume of methane tank (fermentation chamber) of a biogas reactor begins with the collection of data on the type of organic waste that is to be recycled (Ymeri, P.; 2020; Mattioli, A. 2017; Leckner, B. 2015).

Output data: t_{in} – biomass temperature,°C; W, % – humidity of the substrate; A, % – ash content of dry organic raw material.

1. Determine the concentration of organic substances, kg/m^3:

$$S = \rho_V \cdot (100 - W) \cdot (100 - A) \cdot 10^{-4}, \quad (19)$$

where W – humidity of the substrate, %; A – ash content of dry organic raw material, %; ρ_V – volume biomass density, kg/m^3.

2. Calculate the density of biomass, kg/m^3:

$$\rho_V = \frac{\rho_{out}}{100 + W \cdot (\rho_{out} \cdot 10^{-3} - 1)} \cdot 100, \quad (20)$$

where ρ_{out} – density of solid biomass fraction, kg/m^3.

3. We calculate the kinematic coefficient K according to the formula

$$K = \frac{K_r(\mu_m \cdot S - d)}{(B \cdot S - K_r \cdot d)}, \tag{21}$$

in wicth K_r – coefficient of proportionality.

4. Determine the coefficient of proportionality:

$$K_r = \frac{(38 \cdot S - 205) \cdot P}{100 \cdot (t_{in} - 17.8)}, \tag{22}$$

where t_{in} – temperature of the fermentation process, °C; P – correction factor, (P=1 by t_{in} =33–53 °C).

5. Calculate the maximum rate of growth of microorganisms μm in biomass, day-1:

$$m_m = 0{,}013 \cdot t_{in} - 0{,}129. \tag{23}$$

6. Determine the daily output of biogas V_B, m^3/m^{3}day:

$$V_B = \frac{B \cdot S}{\tau}\left(1 - \frac{K}{\tau \cdot \mu_m - 1 + K}\right), \tag{24}$$

where B – maximum biogas output, m^3/kg; S – concentration of organic substances in the feedstock, kg/m3; τ – time of fermentation, days.

The results of the study are shown in Fig. 5.

Fig. 5 clearly illustrates the peaks of daily methane formation; they are characterized by an increase in the internal temperature in the reservoir.

Since the additional effect of anaerobic utilization of organic waste is biohumus, then we have the following advantages of leaf humus (http://organic.ua/uk/lib/3074-lystjanyj-peregnij-koryst-sadu-prynese-lystopad):

– Leaf humus, introduced into the soil, helps to retain moisture longer at the plant roots, helping them to survive the summer drought.

– In the deciduous humus, rain worms live and breed well, which greatly loosen the soil and effectively transform organic residues into high quality humus.

– Hardwood (even semi-finished) is an excellent component of garden compost.

– How mulch Leaf humus prevents weed growth, weathering and erosion of the upper layers of the soil.

1

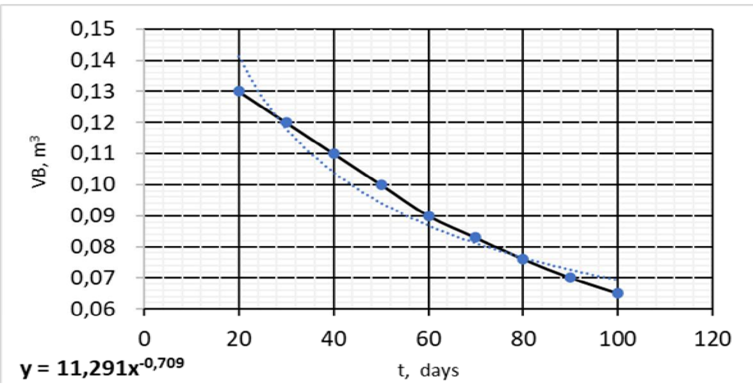


Fig. 5. Daily output of biogas V_B from 1 m^3 of bioreactor depending on the time τ of fermentation and the internal temperature of the process tin::
1 – tin = 20 °C;

2

3

4

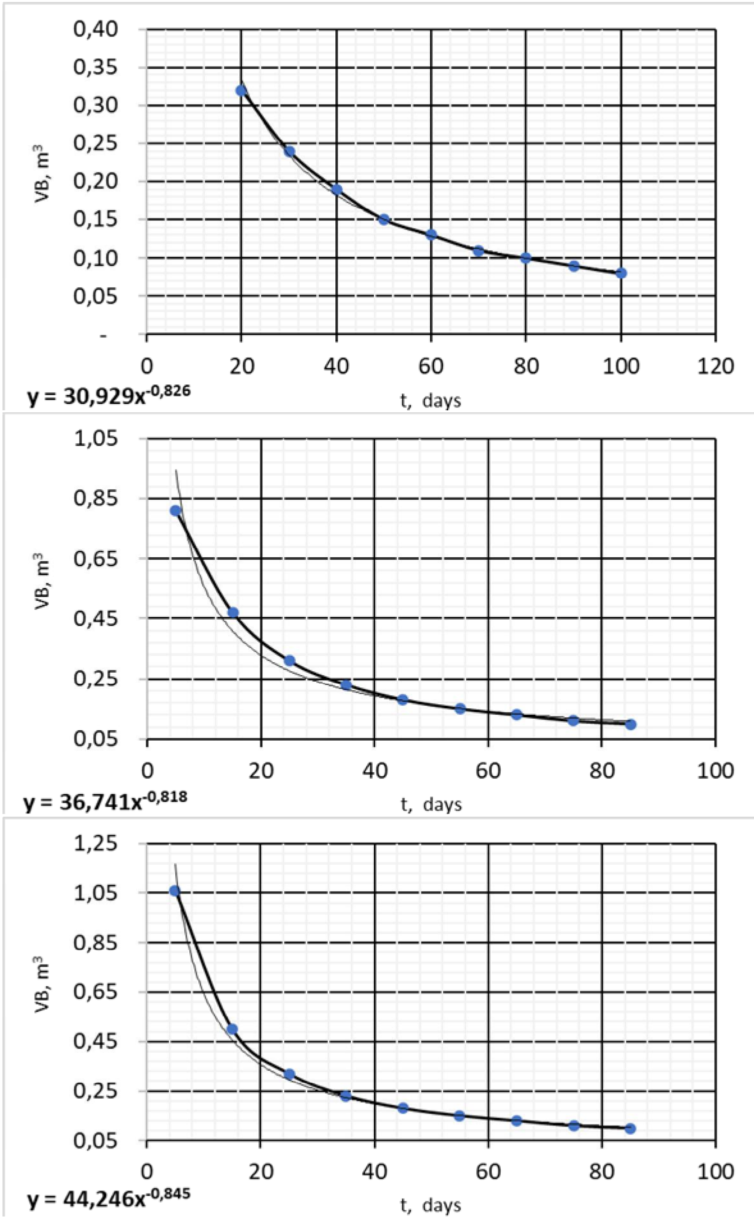


Fig. 5. (continuation). Daily output of biogas V_B from 1 m^3 of bioreactor depending on the time τ of fermentation and the internal temperature of the process tin:
2 – tin = 30 °C; 3 – tin = 40 °C; 4 – tin = 50 °C

Research carried out for the bioreactor volume 1 m^3. The internal temperature of biomass tin was taken in the range from 20 to 50 °C. As organic raw materials, the leaves of trees with a humidity of W = 59 % and ash content of dry biomass – A = 15 % with a density of solids fraction ρout = 350 kg/m^3 – were used.

Conclusions

The construction of a bioreactor with the use of spiral polyethylene tubes was proposed. A graph of thermal capacities and the distribution of heat flows in a bioreactor were provided. In addition, the dependencies for determining the heat fluxes of flat and cylindrical surfaces were presented in this article.

Is proposed the design of a bioreactor for organic waste disposal.

The possibility of utilizing fallen leaves in urban parks through anaerobic fermentation has been confirmed. The scheme of collecting and transporting the fallen leaves is proposed. The performance of the bioreactor is determined depending on the temperature and the time of fermentation. Are presented the graphs of biogas yield depending on the temperature of fermentation raw materials. The internal temperature of biomass tin was taken in the range from 20 to 50 °C. It was established that the fastest process of decomposition of organic raw material occurs at the temperature of raw materials 50 °C. From the obtained dependences it can be concluded that with increasing fermentation time the amount of daily biogas yield decreases.

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В. М. Желих[1], Ю. В. Фурдас[1], С. П. Шаповал[1], О. О. Савченко[1], В. Б. Шепітчак[2]

Національний університет "Львівська політехніка",
[1] кафедра теплогазопостачання та вентиляції,
[2] кафедра теплоенергетики, теплових та атомних електричних станцій

ЕНЕРГОЗБЕРЕЖЕННЯ МОДУЛЬНИХ БУДИНКІВ ЗА ДОПОМОГОЮ БІОГАЗОВИХ ТЕХНОЛОГІЙ

Україна має значні обсяги земельних ресурсів для сільського господарства та здатна забезпечити своє населення не тільки їжею, але і сировиною для біоенергетики. Як сировину в біоенергетиці можна використати відходи та сільськогосподарські залишки, які утворюються під час збирання сільськогосподарських культур та під час їх переробки, зокрема солома злакових культур, зернобобових культур, насіння кукурудзи та соняшнику, лушпиння соняшнику, м'якоть цукрових буряків, опале листя тощо.

При виробництві газоподібного палива із опалого листя утворюється не тільки джерело енергії – біогаз, але й високоякісні добрива, які можна використовувати для власних потреб, чи продавати фермерським господарствам. Процес виробництва біогазу відбувається у біореакторах, конструкції яких досить різноманітні і відрізняються за формою, матеріалом, способами змішування та нагрівання біомаси, обсягом переробки сировини.

Представлено графік теплових ємностей та розподілу теплових потоків у біореакторі. Наведено залежності для визначення теплових потоків плоских і циліндричних поверхонь. Наведено сучасний стан використання опалого листя дерев. Запропоновано метод використання за допомогою анаеробного бродіння. Розглянуто основні фактори, що впливають на утворення метану. Представлено розрахунок виробництва біогазу. Визначено продуктивність біореактора залежно від температури сировини та часу гідравлічного бродіння.

Ключові слова: біогазова установка, біореактор, біодобрива, альтернативне джерело енергії, теплоізоляція, анаеробна ферментація, теорія графіків.