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Research and Development of Closed Ecological and Biotechnical Systems in Live Stock

A. Chmil[1], L. Chervinsky[2], Y. Oliinyk[3]

[1. FirstAuthor&CorrespondingAuthor] D. Sc., prof. National University of Life and Environmental Sciences of Ukraine. Email: a.chmil@ukr.net
[2.] D.Sc., prof. National University of Life and Environmental Sciences of Ukraine. E-mail: lchervinsky@gmail.com
[3.] graduate student. National University of Life and Environmental Sciences of Ukraine. E-mail: oljinik1202@ukr.net

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Abstract

This article addresses issues related to environmental pollution.Particular attention is paid to the prevention of environmental pollution by livestock waste, which prompted the creation of closed ecological and biotechnical systems as environmentally closed production structures that can fit into the equilibrium system of the environment with minimal damage to it. An energy-saving and environmental protection technology for the processing and disposal of livestock waste with a maximum coefficient of energy transfer to livestock products has been developed, which consists in a combined treatment of waste in three stages, by transferring waste from one technological module to another, which makes it possible to completely utilize mineral substances in waste. The focus is on vermicultivation, microalgae cultivation and anaerobic fermentation in a bioenergy plant. To increase the productivity of growing microalgae, the authors proposed a deep type cultivator with submerged movable light sources.The technological parameters of the bioenergy installation for waste treatment are determined. An energy-saving and environmental-friendly technology has been developed for processing The main contribution of the study is the development of energy-saving and environmental technology for the processing and disposal of livestock waste with a maximum coefficient of energy transfer to livestock products.

Keywords: Energy Saving, Electrified Technologies, Ecology, Disposal of Livestock Waste.

Major classification: Environmental Safety and Engineering

1. Introduction

The relationship of man with nature in the production process is dramatically complicated.The continuously growing metabolism and energy, manifested in the increased use of natural resources and an increase in livestock and other types of waste that return to the environment, dramatically enhances the overall effect of agricultural production on nature.Nature's ability to reproduce intensively used resources and self-purify pollution is limited.Therefore, the problem of preventing environmental pollution by livestock waste determines the need to create closed ecological-biotechnological systems, as ecologically closed production structures that can “fit” into the equilibrium system of the natural environment with minimal damage to it.

Based on ecological, energy and sanitary-veterinary requirements, an integrated energy-saving and environmental protection technology of utilization of organic mass of livestock complexes and poultry farms was developed (Chmil, 2015a).

Research objective-development of energy-saving and environmentally friendly technology for processing and disposal of livestock waste.

2. Basic research materials.

The essence of the integrated system is the combined bioconversion of organic waste in three stages, by transferring the waste from one technological module to another, for which the waste serves as raw material, in order to obtain fertilizers, feed and fuel, intensify the biodegradation process, completely utilize the mineral substances in the waste, protect the environment and preventing the spread of epidemics.

3. Results of the research.

At the first stage, the processing of organic waste is carried out under anaerobic conditions in a bioenergy installation.This allows you to get biogas, which consists of 2/3 of methane, with a calorie content of 20-24 Mj / m^3, and can be used not only to meet your own energy needs, but also as fuel for the heat and energy needs of a livestock enterprise.In addition, the overall microbial contamination is reduced, helminth eggs die, the germination of weed seeds is lost, and nitrogen losses do not exceed 5%.

For the normal course of the process of anaerobic decomposition of livestock waste, it is necessary to create optimal conditions for the life of bacteria, which are influenced by the following factors: quality of raw materials, substrate temperature, nutrient concentration, pH of the medium, anaerobic conditions, duration of fermentation, method and effectiveness of mixing the substrate.

It is known that methane is formed as a result of the activity of two main groups of microorganisms: acid-forming and methane-forming. In the first stage, acid-forming (hydrolytic) bacteria convert complex organic compounds (proteins, lipids, polysaccharides, etc.) into fatty acids with the release of hydrolysis gas, which consists mainly of carbon dioxide and hydrogen sulfide.

Thus, in order to make the process more efficient and economical, fermentation in the bioenergy installationis preferably carried out in two stages. This will help maintain optimal conditions for each group of microorganisms, as well as obtain biogas consisting of 80% methane (compared with 70% in a single-stage bioenergy installation).

One of the important factors of the fermentation process is the temperature regime, the most common of which are mesophilic, and thermophilic.The thermophilic process is more productive, however, it requires a significant expenditure of energy to maintain the optimum temperature, and significantly increases the cost of the fermentation process. On the other hand, it is the thermophilic mode of fermentation that makes it possible after 2–3 days of fermentation to reduce the total number of bacteria in livestock runoff by 4 orders of magnitude, while in the mesophilic mode, even after 2-month fermentation, by 2 orders of magnitude. Loss of germination of weed seeds in thermophilic mode occurs in 1-2 days, and in mesophilic mode - in 3-4 weeks.Therefore, in the first stage, fermentation in bioenergy installation is carried out in the thermophilic mode for 36-48 hours, and in the second stage, in the mesophilic mode for 6-7 days.

In order to obtain the temperature necessary for the fermentation process, it is necessary to heat the substrate, feed it into the digester to the fermentation temperature and then pidgrimuvat it at a constant level using a thermal stabilization system.

Most of the energy in the form of heat (75-80%) is required to heat the substrate to the fermentation temperature. Therefore, to improve the efficiency of the bioenergy installation, a recuperative heat exchanger was used, which allows utilizing up to 50% of the heat of the effluent to heat the substrate entering the first stage of the bioenergy installation.

As a result of the conducted research, the following technological parameters of the bioenergy installation were determined:

• fermentation temperature:
at the first stage - 52-54 °C;
at the second stage - 32-35 °C;
• substrate moisture content 90-92%;
• daily loading dose -10-12%
• active reaction of the substrate - 6.8-7.3;
• degree of decomposition of organic matter - 40-50%;
• biogas output - 500-1000 m^3/ t a.d.s.
• part of methane in the gas - 75-80%.

Since after anaerobic fermentation, the organic mass of waste decomposes only by 40-50%, it must also be disposed of, which is done after decomposition of the effluent into solid and liquid fractions.

At the second stage, the solid fraction is used for vermicultivation - industrial cultivation of earthworms in open areas or in enclosed spaces.

For cultivation by artificial conditions, the worm of the species deserves the most attentionEiseniafoetida, which is better adapted to life in captivity, has a short maturity and high fecundity. The main danger for him is the possibility of poisoning with an excessive concentration of protein in organic matter with incomplete fermentation.

A well-known biological method of processing using vermiculture of organic waste and obtaining vermicompost and biomass of worms, where organic waste was previously fermented in pile, the duration of which depended on the type of waste and its physico-chemical properties (2-15 months).There is also known a method of accelerated fermentation process.For this, an air duct is laid in the collar through which aeration of the substrate is carried out.In this case, the organic waste is heated to a temperature of 60-70 °C and the fermentation process is reduced to 30 days. The disadvantage of both methods is the long period of fermentation of organic waste. If fermentation is carried out in bioenergy installation, then the fermentation process is reduced to 7 days.

The processed substrate (vermicompost) is mainly coprolites of earthworms, held together by gastric mucous secretions, contains all the nutrients necessary for the plant as well as biologically active substances that stimulate the growth and development of crops. A number of studies show that vermicompost can be recommended for all crops, but it is most appropriate to use it in vegetable growing, where it provides an increase in the yield of cabbage, tomatoes and pepper up to 40% and eliminates the accumulation of nitrates and heavy metals in products. In addition, biohumus has the ability to bind radionuclides found in soil and organic waste. Worms themselves are also important, the body of which contains 61-71% of protein, and which can be used in animal husbandry, poultry farming and fish farming, as well as raw materials for the pharmacological and perfume industry.

In the third stage, the liquid fraction of the bioenergy installation effluent is used for the cultivation of microalgae, such as chlorella, spirulina, scenedesmus, and ets. Under conditions of sufficient nitrogen nutrition, microalgae contain more than 50% protein with a set of essential amino acids, 30-35% hydrocarbons, 7-10% fat, vitamins C, group B, carotene, antibiotics and trace elements.It has also been established that spirulina removes heavy metals and radionuclides from the body. For a long time now, in Ukrainian households, the protein deficit in animal diets has been 25-30% of the demand, or about 1.5-1.8 million tons per year, and therefore about 32% of livestock production is not being received.Microalgae can partially solve the protein problem. Microalgae intensively develop when they create the appropriate conditions - certain values of the temperature of the suspension, the intensity of optical radiation, the concentration of biomass in the suspension, the composition and concentration of the nutrient medium and the concentration of carbon dioxide in the air supplied to the culture.

The determining condition for increasing the productivity of microalgae is the efficient use of optical radiation, which ensures the physiological processes in the cells and, above all, photosynthesis.Since the suspension of microalgae is a suspension of light-scattering, selectively absorbing cells, therefore, with an increase in the cultivator depth and biomass density, a significant drop in optical irradiation occurs and the lower layers of the suspension practically do not participate in the process of photosynthesis.

In order to increase the productivity of the plant for growing microalgae, we proposed a deep-type cultivator with submerged movable sources of optical radiation.The technological scheme of the proposed integrated system of treatment and utilization of organic waste in fuel, fertilizers and feed is shown in (Figure. 1).

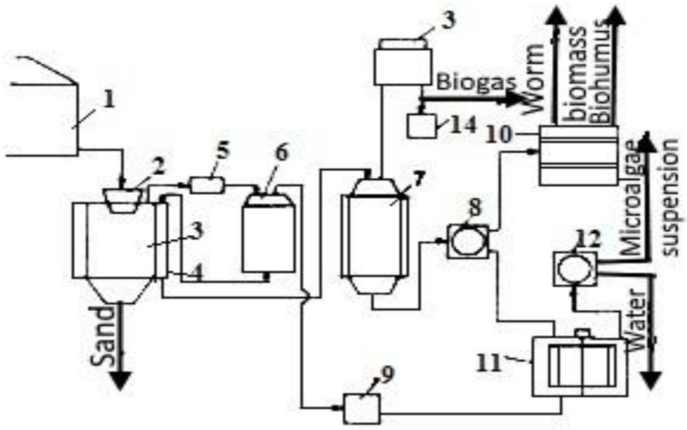

Figure 1. The technological schemeintegrated system of treatment and utilization of the organic waste in the fuel, fertilizer and feed:1 - livestock building; 2 - chopper-separator; 3 - drive; 4,5 heat exchangers; 6 - first stagebioenergy installation; 7 - second stage bioenergy installation; 8 - filter; 9, 12 centrifuge; 10 - vermicultivator; 11 - algae cultivator; 13-gas holder; 14-gas water heater.

From the livestock building 1, waste (feces, water, residues of feed, wool, feathers, sand, etc.) with a moisture content of 86-90% through the chopper 2 goes to drive 3, where the organic mass is separated from sand and other foreign objects. Here the heating of the waste coming from the recuperative heat exchanger 4 takes place, which allows you to utilize the heat of the suspension after the first degree of bioenergy installation. After that, the organic waste goes to the first stage 6 of the two-stage bioenergy installation, after passing through the heat exchanger 5, where the substrate is brought to the fermentation temperature. Here the heating of the waste coming from the recuperative heat exchanger 4 takes place, which allows you to utilize the heat of the suspension after the first degree of bioenergy installation. After that, the organic waste goes to the first stage 6 of the two-stage bioenergy installation, pre-passing through the heat exchanger 5, where the substrate is brought to the fermentation temperature. At this stage, hydrolysis gas is formed, which is used as a source of carbon dioxide after cleaning it from hydrogen sulfide in the filter 8. After holding the substrate in the first stage of the bioenergy installation for 36-48 hours at a temperature of t_s = 52-54 °C, it enters the second stage 7, after passing through the heat exchanger 4. At this stage, in the mesophilic mode at a temperature of t_s = 32-34 °C, the process of methane formation and intensive decomposition of organic matter occurs. After 6-7 days, when the crude protein content in the fermented mass does not exceed 25-30%, it is discharged from the digester and in a centrifuge 9 is divided into solid and liquid fractions. The solid fraction with a moisture content of 60-80% is the substrate (food) for the worms and enters the vermicultivator 10. A bed of 15-20 cm thick is formed from the substrate and the mother stock of worms is laid (1.5-2 thousand individuals per 1 m^2).As a result of biological processing at a temperature of 20-22 °C in 30 days from 1 ton of substrate, you can get 100 kg of biomass of worms and 600 kg of vermicompost. The liquid fraction from the centrifuge 9 enters the microalgae cultivator 11, where further utilization of the organic matter and the growth of microalgae biomass takes place. In the case of creating optimal conditions (suspension temperature 36-38 °C, optical irradiation mode 80-100 W / m^2, feeding the culture with carbon dioxide concentration of 2%) with I m2 of the surface of the cultivator for a day you can get 1 kg of dry organic matter of algae.

From the microalgae cultivator, the suspension goes to a centrifuge 12, where it is divided into a paste, used for animal feed, and a centrate that is fed to a vermicultivator to water the substrate.

The temperature regime in the first and second degree bioenergy installation, the vermicultivator and the microalgae cultivator is maintained using the heat carrier 14 heated by biogas coming from the gas holder 13.

Thus, the proposed technology makes it possible to completely utilize organic waste, protect the environment from pollution, and obtain valuable organic fertilizer - vermicompost, protein feed (biomass of worms and microalgae) and an energy source - biogas.

Let us analyze the energy efficiency of integrated system of treatment and utilization, at a complex for feeding young cattle for 12 thousand cattle places (Chmil, 2015b).

The energy flows diagram of the livestock waste management integrated system of treatment and utilization, built on the basis of energy balance schemes for bioenergy installation, a microalgae cultivator, and a vermicultivation installation, are shown in (Figure. 2).

Based on the schemes of energy flows, we present the bioenergy efficiency coefficient of the integrated system of treatment and utilization as follows:

$$\eta_{gen.}^{ISTU} = \frac{E_{bg} + E_b + E_{wb} + E_{mc}}{E_{gen.}^{BI} + E_{gen.}^{VI} + E_{gen.}^{*MC}} \qquad (1)$$

Substituting numerical values in the equation, we obtain $\eta_{gen.}^{ISTU}$ =1,046, which indicates the energy efficiency of livestock waste.

Environmental efficiency depends on the depth of disposal of organic waste, which can be determined by the formula:

$$E = \frac{L_o + L_t}{L_o}, \qquad (2)$$

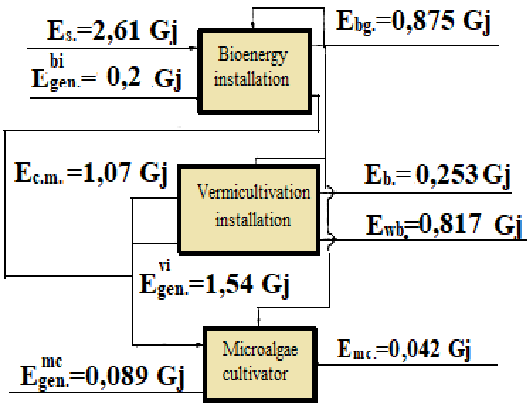

Figure 2: Scheme of energy flows of an integrated system for the treatment and utilization of animal waste.

where E is the depth of disposal of organic waste;
Lo is the concentration of pollution at the inlet, g /l;
Lt is the concentration of pollution at the outlet, g /l.

(Table. 1) shows the indicators of the integrated system of treatment and utilization of livestock waste of the cattle feed complex.

Table 1: Performance indicators of the integrated system for processing and disposal of livestock waste

Indicator	At the entrance of the livestock complex	At the exit bioenergy installation	At the exit microalgae cultivator	Depth recycling integrated system of treatment and utilization
pH	7,0	7,2	7,5	-
BOC_5, mg. /l.	2380	586	154	0,93
COC, mg. /l	5680	1286	320	0,94
The number of microorganisms m/mil.	85	12	0,15	-

As can be seen from the table. 1, the depth of disposal integrated system of treatment and utilization for COD equal to 0.94, and for BOD_5 - 0.93, which indicates the high environmental efficiency of the proposed system for the treatment and disposal of livestock waste.

4. Conclusions

Based on theoretical and experimental studies, an energy-saving and environmental-friendly technology has been developed for processing and disposal of livestock waste with a maximum coefficient of energy transfer to livestock products, which consists in the combined treatment of waste in three stages, by transferring waste from one technological module to another, for which the waste serves as raw material, the purpose of obtaining organic fertilizers, feed and fuel, the intensification of the bioconversion process and the possibility of complete utilization ii mineral substances found in the waste.

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