Recycling of animal waste

V V Kasatkin¹,²,*, N Yu Kasatkina¹, S P Ignatyev¹ and A A Litvinyuk²

¹ FSBEI HE Izhevsk state agricultural Academy 426069, the Udmurt Republic, Studencheskaya St., 11, Izhevsk, Russia
² FSBEI HE "Udmurt state University", the Udmurt Republic, 426034, Universitetskaya St., 1, Izhevsk, Russia

* E-mail: kasww@mail.ru

Abstract. The growth of the number of farm animals and poultry contributes to the growth of environmental problems. Recycling of animal waste will solve these problems, as well as obtain organic fertilizers and additional energy sources. The purpose of the research is to develop technological solutions that allow organic waste from agricultural production to be involved in the production of secondary marketable products and energy resources. At the initial stage of processing, organic waste is sent to methane fermentation in the methane tank. The resulting biogas is used to obtain the thermal energy necessary to maintain the temperature of methane fermentation and to dry organic fertilizers laid for storage. The substrate at the outlet of the methane tank mixed with filler is sent to the production of compost, including using vermiculture. The carbon dioxide formed during the combustion of biogas, to increase the efficiency of the process of recycling organic waste from animal husbandry, is used for air nutrition of plants. Thus, the technology proposed as a result of the theoretical synthesis will allow reducing the environmental burden from agricultural production, as well as obtaining marketable products and secondary energy resources.

1. Introduction

In 2019, the Russian agricultural supervision detected violations of the requirements of land legislation related to the contamination (littering) of agricultural land by livestock / poultry products (manure / bird droppings) on a total area of about 1.9 thousand hectares. Violations related to the contamination of agricultural land with manure of large / small cattle on a total area of more than 320 hectares, pig manure on a total area of more than 600 hectares, bird droppings on a total area of more than 930 hectares were revealed. With regard to the level of concentration of greenhouse gases, it should be noted that the increase in the concentration of CO₂ observed in 2019 exceeded the values of 2018 and for the previous ten-year period (about 2.26 million⁻¹/year). The methane concentration registered in the Russian Federation also increased compared to 2018 and exceeded the average annual growth rate over the past decade (about 10 billion⁻¹/year). [1]. The power supply system of an agricultural enterprise is the most important element of the energy base. Its significance also lies in ensuring the continuity of technological processes and reducing their labor intensity, thereby the use of electric energy can significantly increase the productivity of live labor and reduce the cost of production. [2]. Recycling of animal husbandry waste will solve these problems, as well as obtain organic fertilizers that positively affect the properties of the soil, increasing the efficiency of agricultural production.
2. Materials and methods
The main methods used in conducting research are analysis and synthesis. The implementation of the theoretical synthesis made it possible to systematize patent information and the main results of dissertations, which made it possible to synthesize more deeply the knowledge aimed at studying the recycling of animal waste.

3. Results
The analysis of the topics of dissertations over the past 20 years presented in Figure 1 and the review of patent information graphically selected in Figure 2 showed that the problem of reducing the negative impact of animal waste on the environment is of constant and steadily growing scientific interest [3, 4].

![Figure 1. Dynamics of preparation of dissertations on the research topic.](image1)

The analysis of the structure of scientific research devoted to the problem of animal waste disposal and reflected in dissertations over the past 20 years has revealed the main technological trends. Schematically, the frequency of mentions of technological solutions aimed at solving the problem with livestock waste is shown in Figure 3.

![Figure 2. Dynamics of patent publications on the research topic.](image2)
Studying the patent information [4], it was revealed that most often in the author's certificates it is proposed to use technological solutions aimed at reducing the humidity of livestock waste and substances obtained as a result of their processing, Figure 4. Drying and dewatering are used to prepare waste for subsequent processing, to prepare the resulting fertilizers for storage or combustion. The conducted patent search confirmed the tendency of the predominant use of microorganisms for the disposal of household waste. In this case, the waste is processed by composting or methane fermentation. It is most often suggested to use various variations of composting. The process of methane fermentation due to rational energy supply [5] makes it possible to significantly expand the possibilities of this method of processing animal waste. The analysis of the author's certificates over the past 30 years has shown that the most popular technology for using macroorganisms is the processing of animal waste by fly larvae than vermicultivation. At the same time, it is important to remember that the processing of animal waste by fly larvae requires careful attention to their storage and transportation, since fly eggs carry the risk of spreading various infections. Electrical technologies, in particular IR heating, can be used to separate macroorganisms from the processed mass [6]. The use of dried animal waste as fuel is usually offered with integrated technologies for recycling animal waste. The use of extruders in the recycling of household waste makes it possible to obtain porous granular fertilizers, [7]. When applying mineral components, organomineral fertilizers are obtained. A review of patent information showed that the processing of livestock waste uses the integrated use of various technological solutions [7, 8, 9, 10, 11].

Figure 3. The structure of technological solutions for recycling animal waste studied when writing dissertations.

- Anaerobic digestion
- Composting and biofermentation
- Vermicultivation
- Separation of factions
- Granulation of organic fertilizers
- Hydromechanization
- Application of atmospheric fertilizer
- Gas generation

The figure shows the structure of technological solutions for recycling animal waste, with the most used methods being composting and biofermentation.
The technology of processing chicken manure into fertilizer proposed at the Izhevsk State Agricultural Academy [12], shown in Figure 5, takes into account most of the technological solutions considered by scientists when studying issues of animal waste disposal.

The initial raw material for the technological process is manure (humidity 75%) entering the methane tank and filler (humidity 30%) entering the composter (vermicomposter). When constructing the diagram, an important condition was compliance with the humidity regime. Anaerobic digestion proceeds more efficiently at a humidity of 90 ... 95%. In this regard, the humidification of the manure entering the processing is necessary, for this we use a liquid fraction at the outlet of the dehydrator. We assume that its humidity is 100%. To moisten 100 units of litter with a humidity of 75% to a humidity of 90%, 150 units of liquid are required.

**Figure 4.** Structure of technological solutions for recycling animal waste based on the results of patent research.

**Figure 5.** Mass diagram of the line operation:
P – poultry farm; M-metantank; O-dehydrator; K/V-composter/vermicomposter.
During methane fermentation, 50% of the dry matter is converted into biogas, so 12 units of the mass of the substrate passes into biogas. At the same time, the moisture content of the substrate is 94.5%.

After dehydration of the substrate and removal of 150 units of liquid to direct it to moisten the litter, we obtain units of the substance with a moisture content of 85.2%.

The optimal humidity for the development of worms in the process of vermiculture is 80% humidity, and when composting, the optimal humidity is 60%, which is achieved by adding a filler, while the mass of the substance in the reactor will be 97.2 units. To speed up the composting process, it is recommended to aerate the treated mixture [13].

As a result, from 100 units of raw materials, we get fertilizers, vermiculture and biogas in the amount of 64.2+9.7+12=85.9 units. Consequently, the involvement of bird droppings in the economic turnover exceeds 85%.

The analysis of information sources revealed a number of solutions that increase the efficiency of animal waste recycling. To do this, the technological scheme presented in Figure 5 should include the following technological operations: granulation, burning of biogas, atmospheric fertilization of plants of closed soil, drying and grinding of excess biomass. The scheme of recycling of household waste is shown in Figure 6.

It is most rational to form the organic mass at the output of the technological line in the form of large dense particles [14, 15, 16]. In this form, a high percentage of assimilation and prolonged action of useful substances is provided. After application to the soil, water penetrates into the granules and gradually releases substances into the soil.

Biogas produced by methane fermentation of organic waste is a source of thermal energy for the needs of agriculture. The carbon dioxide generated during the combustion of methane is supposed to be used for air nutrition of plants in an enclosed ground, which will reduce the emission of greenhouse gases. A similar solution is proposed by Mironov V. N. to increase the efficiency of using ventilation emissions of cowsheds, [17].

![Figure 6. Scheme of recycling of animal waste: 1-methanetank; 2-gas tank; 3-boiler; 4-dehydrator; 5-biomass dryer; 6-shredder; 7-composter / vermicomposter; 8-granulator; 9-dryer.](image_url)

4. Conclusion
The analysis of the main results of dissertation works and a review of patent information aimed at studying the issues of animal waste disposal revealed the expediency of adjusting the technology of processing chicken manure and other agricultural organic waste into fertilizer developed in the
Izhevsk State Agricultural Academy. Organic animal waste prepared for anaerobic digestion is sent to the methane tank. The resulting biogas is used to obtain the thermal energy necessary to maintain the temperature of methane fermentation and to dry organic fertilizers laid for storage. The substrate at the outlet of the methane tank mixed with the filler is sent for composting/vermicomposting. To improve the commercial qualities of compost/vermicompost before drying, their granulation is included in the previously developed technological scheme. The carbon dioxide formed during the combustion of biogas, to increase the efficiency of the process of recycling organic waste from animal husbandry, can be used for air nutrition of plants. Thus, for the most effective utilization of animal waste, it is necessary to introduce closed cycles of agricultural production.

References
[1] On the state and environmental protection of the Russian Federation in 2019 2020 State report (Moscow: Ministry of Natural Resources of Russia; Lomonosov Moscow State University) pp 1000
[2] Kuvshinov N M and Kuvshinov M N 2014 Ways of solving the problem of energy efficiency and power supply in agricultural enterprises Bulletin of the Bryansk State University 3 288-296
[3] Scientific electronic library of dissertations and abstracts URL: https://www.dissercat.com/
[4] Federal Institute of Industrial Property. The search engine URL: https://www1.fips.ru/elektron
nye-servisy/informatsionno-poiskovaya-sistema/
[5] Svalova M V, Burlakova F M, Kasatkin V V [et al.] Patent 2404240 Russian Federation IPC C 12 M 1/107, C 02 F 3/28. Biogas plant: No. 2009103613/13: application 03.02.2009: publ. 10.08.2010 the applicant and the patent holder of the Izhevsk State Agricultural Academy pp 6
[6] Vyuzova M A, Kasatkin V V, Litvinyuk N Yu [et al.] Patent 2530514 Russian Federation, IPC C 05 F 3/00 Method of production of vermicompost and installation for its implementation: No. 2013113190/13: application 25.03.2013: publ. 10.10.2014 the applicant and the patent holder of the Izhevsk State Agricultural Academy pp 5
[7] Ignatiev S P Patent 193201 Russian Federation, IPC A 23 P 10/25. Extruder for processing wet mass in the form of bird droppings or manure: No. 2019113281: application. 29.04.2019 applicant and patent holder of the Izhevsk State Agricultural Academy pp 6
[8] Dubrovin A V, Krausp V R, Chirkov V G Patent 2327675 Russian Federation, IPC C 05 F 11/00, C 12 M 1/107 Spo-sob and control device for economical processing of poultry manure in industrial poultry farming: No. 2006141798/12: application 28.11.2006: publ. 27.06.2008 applicant and patent holder of the GNU RESH pp 21
[9] Kurochkin A A, Garkina P K, Shaburova G V [et al.] Patent 198439 Russian Federation, IPC A 01 C 3/00. Extruder with a vacuum chamber: No. 2020110297: application 10.03.2020: publ. 09.07.2020 the applicant and the patent holder of the FGBOU IN Penza State Technical University pp 6
[10] Mironov O G and Safulin D M Patent 2017367 Russian Federation, IPC A 01 C 3/02. Line for converting bird droppings into fertilizers: No. 4860810/15: application 10.09.1991: publ. 15.08.1994 applicant and patent holder Mironov O G, Safulin D M pp 3
[11] Tumchenok V I Patent 2033014 Russian Federation, IPC A 01 C 3/00. Installation for processing manure: No. 4779071/15: application 05.01.1990: publ. 20.04.1995 applicant and patent holder Joint-stock company "Autoremles" pp 5
[12] Kasatkin Vladimir, Ignatiev S P and Litvinyuk N Yu [et al.] 2010 Justification of the technological scheme of the line of manure in fertilizer-nie Bulletin of Izhevsk state agricultural Academy 2 70 – 73
[13] Ivanov A G, Dorogov P V, Shakirov R R and [al] 2020 Aerator dung heap SEL mechanic 10 24-25
[14] Sidelnikov D A 2018 Improvement of the process of wet granulation of the solid fraction of fermented bird droppings in a screw granulator "Technologies and means of mechanization of agriculture": abstract. dis. ... candidate of Technical Sciences (Stavropol) pp 24
[15] Smirnov A N 2015 Improving the efficiency of biocomposts by granulating them "Technologies and means of mechanization of agriculture": abstract. ... candidate of Technical Sciences (Cheboksary) pp 19

[16] Ivanov A G, Ignatiev S P, Kasimov N [et al.] 2020 Extruder for waste utilization in livestock and poultry SEL mechanic 10 28-30

[17] Mironov V N 2011 The improved utilization of ventilation-tion emissions barns by optimizing the system settings of their utilization in cultivation facilities "Technology and mechanization of agriculture" : author. dis. ... candidate of Technical Sciences (St. Petersburg) pp 19