

Agricultural waste processing technology and its relationship with the organic products industry

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Abstract

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In Russia, the total amount of agricultural waste reaches 630–650 million tons annually. This waste, on the one hand, creates serious environmental and sanitary problems, almost half of this waste is manure (approximately 300 million tons), on the other hand, it is valuable raw material for the production of organic fertilizers. The state of the problem of processing agricultural waste as a newly emerging industry for the disposal of such waste in conjunction with the development of the industry for the production of organic products and the market for organic fertilizers is considered and solutions are proposed. Information on the legislative support of the organic farming industry and the production of organic fertilizers is presented. Specific measures are proposed to stimulate the development of the industry of processing waste into organic fertilizers and the industry of producing organic products. The growth of the Russian market for organic products since 2010 has been approximately 10% per year, in 2015–2016 the growth was approximately 4%, in 2017–2019 the situation with the development of organic products has recovered, and now there is a steady growth of 8–10% per year. Special attention is paid to priority technologies for processing waste into organic fertilizers, designs based on turbo-vortex shredding and drying machines for the production of highly concentrated dry finely dispersed organic fertilizers and designs based on aeration reactors (biotrenches) for use in large-scale production are considered.

Keywords: agricultural waste; organic fertilizers; animal manure; organic farming; waste processing; organic production; environment

Introduction

The perception of the value of agricultural waste, the most part of which is animal manure, changed during the last century, from a valuable natural fertilizer to a problematic excessive waste. A large number of studies are devoted to the processing of agricultural waste (Aleksandrova, 1980; Vasilyev & Filippova, 1988; Arhipchenko, 2005; Bot & Benites, 2005; Kovalev & Baranovskiy, 2006; Bittman et al., 2014). There are many researches, but there is still no practical re-

sult, expressed in an increase in the volume of waste processing and the share of the use of organic fertilizers (Agapkin, 2020).

Manure has been used as an effective soil additive since the beginning of civilization and was the main additive used in agriculture until the advent of chemical fertilizers in the 1940s. Today, manure is still a valuable agricultural resource as it is an important source of nutrients for plants and is known to improve the physical and biological properties of the soil by adding organic substances.

Animal manure is an excellent source of nutrients to support the growth of agricultural crops, but it may also carry a variety of human pathogens of great public health concern. With the increasing production of food-producing animals, how to recycle those nutrients in enormous amount of animal wastes safely while preventing adverse impacts on the environment is very challenging.

The issue of utilization of agricultural waste should be considered within the chain from the formation of waste and their processing into organic fertilizer to the cultivation of organic products and their sale to final consumers. Organic farming creates a demand for the production of organic fertilizers, in turn, there is a need for the necessary technologies, equipment for environmentally friendly low-cost production of such fertilizers from agricultural waste. The organic fertilizer industry further forms the requirements for raw materials (agricultural waste).

Sectors of agriculture (crop farming, livestock industry, poultry production, fur farming) and related other sectors of the agro-industrial complex (post-harvest processing and storage of crop products, processing of agricultural products, food industry) annually produce hundreds of million tons of organic waste in Russia (Bryuhanov et al., 2012; Bobozhonova et al., 2021). According to the data (Golubev, 2011) the total amount of agricultural waste reaches 630-650 million tons. The largest part of the waste falls on the livestock industry (56%), the second place is occupied by crop waste (35.6%). The share of processing industries accounts for 4.7% of waste. For poultry farming – 3.7%.

In the whole world (including losses of already produced food) the amount of agricultural waste reaches billions of tons (Nagendran, 2011; Kaza et al., 2018).

This waste, on the one hand, creates serious environmental and sanitary problems, because almost half of this waste is manure (approximately 300 million tons annually). Safe utilizations of animal manure and other agricultural wastes must not result in new routes of pathogen and disease transmission between animals, humans, and the environment. The main contaminants can be bacteria, viruses, intestinal parasites, and more recently transmissible spongiform encephalopathies. In addition, the manure contains a large amount of weed seeds, which cause significant economic damage in the production of crop products.

Table 1. The amount of nutrients contained in the manure of various animal species (Agro-industrial complex of the Ministry of Agriculture of Russia, 2017)

Animal species	The content of nutrients in dry matter, %		
	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
Cattle	3.2	1.8	5
Pigs	6	3.2	2.5

On the other hand, this waste is a valuable raw material for the production of useful products, primarily organic fertilizers for use in organic farming. Manure contains a large amount of nutrients (Table 1), which define it as a valuable organic fertilizer. For example, a laying hen produces about 0.8 kg of nitrogen and 0.2 kg of phosphorus per year.

Thus, on the one hand, manure is a valuable organic fertilizer, and on the other, its direct use without preliminary preparation poses a serious hazard to the environment, animals and people.

Ways to Solve the Problem

The solution that will eliminate the environmental harm of agricultural waste, and, at the same time, involve this waste in commercial circulation as a valuable raw material for the production of organic fertilizers should be complex, including:

- state policy focused on the development of organic farming and careful attitude to the nature with a regulatory framework corresponding to such a policy (regulatory component of the solution);

- economic conditions stimulating the complete processing of agricultural waste and the economically profitable use of the products of such processing (organic fertilizers), the formation of a competitive market for these products (the economic component of the solution);

- technologies and equipment that ensure efficient processing of waste into useful products on an industrial scale, that are competitive in their consumer qualities and price (technological component of the solution).

Let us consider each of the indicated components of the solution. At the same time, we will limit the scope of consideration to the direction of using waste as a raw material only for the production of organic fertilizers and leave out the direction of processing waste into biogas, as well as incineration of waste to generate heat or to destroy it.

This limitation is caused by the authors' belief that organic waste should be returned to the crop production system as much as possible in the form of organic fertilizers in order to preserve the natural cycle of biomass movement to maintain soil fertility due to its organic component. Organic matter is needed by the soil and plants not only because of its valuable nutritional qualities, but also as a habitat for soil bacteria,

that activate the mineral components of the soil in an inert, hard-to-reach form for plants, and also as a material for the formation in the soil necessary for nutrition plants and soil structures of moisture and air exchange and conditions for the development of soil microbiota. That is, organic fertilizers play an important role in crop production, and in organic farming.

Regulatory Component of the Solution

The problem of agricultural waste is of national importance. According to the studies (Bryuhanov, 2016), about 300 million tons of organic waste are created annually by poultry and livestock on the territory of the Russian Federation. According to experts, livestock and poultry farms of the country receive 286 million tons of manure including: cattle manure – 217 million tons, pork – 46 million, poultry – 17 million tons, manure of other animal species – 6 million tons per year (Figure 1) (Agro-industrial complex of the Ministry of Agriculture of Russia, 2017).

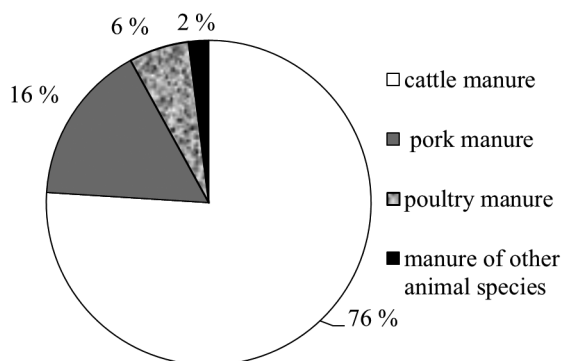


Fig. 1. The structure of livestock waste generation

As mentioned above, this waste is a dangerous pollutant of nature, a source of infectious and invasive diseases for humans and animals. The most part of manure is still not utilized, accumulates in manure storages, losing nutritional qualities, and then is transported without processing to the fields, contaminating the soil with weed seeds.

According to Federal Service for Surveillance on Consumer Rights Protection and Human Wellbeing (Rospotrebnadzor) of Russia, only 3.5% of agricultural facilities meet sanitary and hygienic requirements (Bryuhanov, 2016). In the regions where large livestock enterprises and poultry farms operate the incidence rate of the population is 1.6 times higher than the average in the Russian Federation.

Rotting organic waste leads to an annual emission of more than 30 billion m³ of methane into the atmosphere,

which is 21 times more harmful than carbon dioxide in terms of the greenhouse effect. The area of fields that are located near settlements and contaminated with organic waste in Russia exceeds 2.5 million hectares. The annual environmental damage caused by violation of the regulations for the use of manure is estimated at 450 billion rubles (6.2 billion US dollars) (excluding damage from diseases of the population and animals) (Bryuhanov, 2016).

A veterinary safe utilization of agricultural wastes implies some basic principles:

- livestock health control: no utilization of animal manure and slurries from any livestock with health problems (zoonoses, transmissible spongiform encephalopathy, etc);

- waste selection: hazardous waste types must be excluded from any utilization and canalized towards suitable, safe disposal methods (e.g. incineration);

- pre-treatment: before utilization certain waste categories require controlled sanitation through thermal treatment (e.g. pasteurization at 70°C for 1 h, pressure sterilization, etc.);

- follow-up and regular control of pathogen reduction efficiency (& Holm-Nielsen, 2004).

The Federal Law of the Russian Federation of January 10, 2002 No. 7-FZ “On Environmental Protection” provides the harmonization of domestic environmental legislation with international legislation on the basis of the introduction of the best available technologies (BAT).

The list of applications for the best available technology includes the breeding of pigs, poultry, and enterprises that generate more than 50 tons of waste every day (this category includes large cattle farms) (Decree No. 2674-r, 2014).

The following regulatory documents have been developed and put into effect in Russia: National Standard of the Russian Federation GOST R 113.00.01–2019 “The Best Available Technologies”; Methodological recommendations for determining technology as the best available technology, approved by order of the Ministry of Industry and Trade of Russia No. 3134 of 23.08.2019; Information and technical guides on the best available technologies, including “Intensive Breeding of Pigs”, “Intensive Breeding Of Poultry” (section 2.5 “Processing of Poultry Manure”) (ITS 41, 201; ITS 42, 2017)].

The legislation provides some incentive measures (tax incentives, exemption from payments for negative environmental impact, subsidizing interest payments on loans, etc.) for enterprises implementing BAT. At the same time, for those enterprises that do not comply with BAT, an increase in the rates of payments and taxes is envisaged.

In accordance with the current environmental legislation of the Russian Federation, rotted cattle manure (storage for

at least six months) belongs to the fifth class of hazard to the environment, fresh cattle manure to the fourth, fresh manure from pigs is hazard class 3, rotted manure from pigs (storage for at least one year) is hazard class 4. Poultry droppings are considered as toxic industrial waste of hazard class 3 (Golubev et al., 2011).

The responsibility of the owner of such wastes is to dispose of them with a decrease in the hazard class to the fifth. In cases where the owner of the generated waste does not recycle and does not use them as secondary resources, it is envisaged to charge a fee for the negative impact on the environment. In 2021, the fee for the negative impact on the environment is about 1450 rubles (20 US dollars) / ton per year for waste of the third class and more than 700 rubles (9.6 US dollars) / ton per year for waste of the fourth hazard class and slightly more than 30 rubles (0.4 US dollars) / ton for waste of the fifth class. For a large poultry farm, where up to 100 thousand tons of manure is produced per year, the amount of the fee can be up to 145 million rubles (2 million US dollars) in a year (Resolution N 913, 2016).

Thus, it can be stated that the policy based on BAT and new requirements of environmental legislation oblige, and economic instruments (fines, benefits, subsidies, preferences) should induce poultry and livestock enterprises to organize a complete and efficient disposal of waste in accordance with BAT.

But, this is one half of the required solution as part of the regulatory component. The second half, which has remained unused until recently, is the policy regarding the regulation and support of organic farming as the main consumer of waste products (organic fertilizers). Without this second part of the regulatory component, waste processors will face a difficult to overcome barrier of lack of demand for organic fertilizers, which can only partially be resolved by increasing fines for non-compliance with waste disposal requirements or their improper (in violation of the rules) disposal.

In recent years, positive developments have also been noted in the field of regulating the production of organic products. Federal Law No. 280 of August 3, 2018 "On Organic Products" came into force on January 1, 2020. During the development of the law, three national standards governing the rules for the production and circulation of organic products and certification of producers were prepared. These standards were approved and put into effect: GOST R 56104-2014 "Organic Food Products. Terms and Definitions", GOST R 57022-2016 "Organic Products. the Procedure for Conducting Voluntary Certification of Organic Production", Interstate standard GOST 33980-2016 "Organic Products, Rules of Production, Processing, Labeling and Sale". It is planned to prepare and adopt the following

standards: GOST R "Organic Products from Wild-Growing Raw Materials. Rules of harvesting, collection, storage and processing», GOST R "Organic Products. Biological Products for Plant Protection. General Specifications", GOST R "Soils. Assessment of the Quality of Soils for the Production of Organic Products in Plant Growing, Fruit Growing and Fodder Cultivation", GOST R "Organic Products. Marking: Inscriptions. Graphic Representation (Sign), Form and Order of Their Use". And also make changes based on IFOAM comments in GOST 33980-2016 and GOST R 57022-2016 (Rosstandart order N 1732, 2020).

In 2020, the Ministry of Agriculture of the Russian Federation began maintaining the Unified Register of Organic Producers in electronic form (Ministry of Agriculture of Russia, 2020).

Economic Component of the Solution

The existing and planned new regulatory legal acts in the field of agricultural waste management and in the field of regulation of the production and circulation of organic products, together with the formation of organic market institutions, provide the initial basis for overcoming barriers to the complete processing of agricultural waste into high-quality organic fertilizers and meeting the needs of organic farming.

Today, the cost of organic products in Russia is quite high, this is largely due to the fact that each producer is closed in his production, there is practically no cooperation in the sector: between producers and processors, producers and retailers, producers and the scientific community, etc. It is necessary to develop cooperation and specialization in areas of activity. This will lead to the fact that in some empty segments (for example, processing, production of bio-preparations and fertilizers, seeds), new participants will appear. And then all processes will not be closed to the manufacturer of the final product. New technologies will start coming to the sector. In the price range, the ratio of the price of organic and non-organic will decrease. Taken together will affect the price of organic products (National organic union, 2020).

It would not be an exaggeration to say about the formation of two new interdependent high-tech sectors of agriculture: the organic fertilizer industry based on the processing of agricultural waste and the organic production industry using high-quality organic fertilizers.

The pace of development of these industries will depend on how quickly and efficiently the market for the consumption of organic products will develop, and, accordingly, the market for the consumption of organic fertilizers for the production of organic products, and how incentives will work for the complete processing of organic waste into fertilizers.

The organic market is one of the most dynamically de-

veloping in the world. From 2000 to 2020, it grew more than fivefold (from 18 to 129 billion euros). The market will continue to grow at a rate of 10-12% per year and will reach about 212-230 billion US dollars in 2025. It is planned that by 2025 the volume of the market for organic products may be from 3 to 5% of the world market of agricultural products. In 2019, there were 3.1 million registered organic producers worldwide. A total of 72.3 million hectares in organic farming at the end of 2019, representing an increase of 1.6 percent or 1.1 million hectares over 2018. The number of people constantly consuming organic products in the world has also grown at least five times over 15 years, and amounted to approximately 700 million people.

Until 2014, the Russian market showed quite intensive growth: on average since 2010, approximately 10% per year, but the crisis and a number of indirect factors led to the fact that in 2015-2016 the growth was approximately 4%, although initially it was planned to catch up with the European countries and have the same growth rates as them. In 2017-2019, the situation with the development of the organic market recovered, and now there is a steady growth of 8-10% per year (National organic union, 2020; Union of organic farming, 2021).

According to the data of 2019, the commercial production of organic fertilizers in Russia exceeded 1 million tons. However, most of these products are still created and consumed by the farmers themselves and do not enter the market. Basically, the purchase and sale of organic fertilizers in Russia is concentrated on the domestic market. Domestic companies export only 0.5% of marketable products. The average prices for supplies outside the country indicate that the market for organic fertilizers in Russia is still in its infancy. Over the past five years since 2015, prices have fluctuated in a very wide range from 503 to 1220 US dollars per ton. Such volatility suggests that export deliveries are one-time, and the range of organic fertilizers is just being formed (ROIF EXPERT, 2020).

As the new market is not fully developed, it will be useful to form and temporary support from regional and federal state institutions of end-to-end chains from organic stores to producers of such organic products and further to producers of organic fertilizers on the basis of long-term cooperation agreements in production and sale. These agreements will reduce marketing risks and the influence of seasonality in the consumption of organic fertilizers, harmonize economic interests and create a basis for planning development and investing in projects to create production facilities at each link of the chain (Krasilynikova et al., 2017).

Another important topic in the economic component is the methodology for determining the comparative effective-

ness of chemical and organic fertilizers, as well as mixed fertilizers. This methodology influences the pricing and determines the choice of a producer of agricultural products in favor of a particular type of fertilizer. Existing approaches focus on comparing nutrients in a fertilizer that is not in favor of organic compared to concentrated chemical fertilizers. It is necessary to compare not by the content of nutrients in fertilizers, but by the amount of such nutrients assimilated by the plant. At the same time, it is necessary to include in the calculation not only the nutrients that come with the organic fertilizer, but also the mineral components of the soil that are activated due to the microflora of organic fertilizers and are in an inert form that is difficult for plants to access. It is important to take into account the additional effects on plants and soil fertility from the use of organic substances and damage to the soil from chemical fertilizers.

The decision of an agricultural producer as a buyer of fertilizers will depend on the cost of purchasing fertilizers, the actual harvests obtained, the quality of the products produced, and the prices for their sale (premiums for organic origin).

In the current conditions, there is only a relatively narrow retail and small wholesale market of organic fertilizers (household land, individual farms, organic farming enterprises), the price conditions of which provide an acceptable efficiency of investments in the processing of organic waste into fertilizers. But for the products of processing of all agricultural waste, there is still no market and its creation is a condition for the start of investments in waste processing. At the initial stage, measures to stimulate the demand for organic fertilizers are required, and as the market grows, the demand and competitiveness of such fertilizers will develop at a level that does not require the initially applied support measures.

State support for the processing of agricultural waste into organic fertilizers, primarily in terms of the formation of a large wholesale market and reducing the impact on the economy of waste processors of the seasonality of fertilizer consumption, will create conditions for solving the problem. The intensive development of online trade in Russia in recent years (Ramazanov et al., 2019) can also stimulate the growth of the organic fertilizer market.

The globalization of the world economy is a serious challenge to all sectors of the economy (Nikolskaya et al., 2020), including agriculture and the processing of agricultural waste, which indicates the need for cooperation between these industries.

Domestic organic fertilizers have an export potential, the implementation of which can also reduce the influence of seasonality in the sale of manufactured fertilizers.

Technological Component of the Solution

Currently, in the Russian Federation and abroad there are many technologies and equipment for the processing of organic waste. In Russia, the following technologies for processing manure are mainly used (Bryuhanov, 2016; ITS 41, 2017; ITS 42, 2017):

- long-term (12 months) holding in sectional manure storages, as well as heaps, piles, biotrenches with shelter made from a layer of peat or other biologically non-hazardous material (including disinfected manure);

- passive (natural) composting and disinfection for a period of up to 2-3 months of a previously prepared compost mixture with a carbon to nitrogen ratio (C / N) of at least 15-20, humidity up to 75% and weight of at least 100 tons in piles with a width of 2.5-6.0 m, height 2-3 m, placed on concreted or specially prepared field sites;

- active composting and disinfection for a period of 1.0-1.5 months in piles using special equipment for aeration by periodic (every 10-12 days) tedding of the pile to saturate the compost mixture with air oxygen with the addition of biologically active preparations;

- biofermentation in chamber type installations of periodic (discrete) action with the creation in such installations of certain conditions for the intensive development of aerobic bacteria and the process of biological transformation of the original mass of the compost mixture into organic fertilizer in 7-8 or less days.

In addition, the following are used on a limited scale:

- active biofermentation for 3-4 days or less in drum-type installations (fermenters) continuous action to obtain a microbial fertilizer with higher fertilizing properties compared to composting products;

- anaerobic digestion in methane tanks with biogas production for electricity and heat production;

- thermal drying of manure with subsequent granulation;

- incineration to obtain heat energy and use ash (mineral residue) as fertilizer.

Depending on the applied technology and the raw materials used, a different type and quality of organic fertilizer is obtained (dried manure, compost, biocompost) with different fertilizing efficiency [GOST R 53042 – 2008, 2009]. These organic fertilizers in combination with organic additives (peat, etc.) and natural mineral additives (chalk, lime, glauconite, etc.) will create a wide range of commercial products for different crops, soils and conditions of use.

Creation of high-performance complexes for the production of high-quality organic fertilizers

In order to achieve complete processing of poultry and livestock waste without intermediate storage to minimize

the loss of their useful components, as well as a negative impact on the environment, and at the same time to obtain organic fertilizer, high-performance processing complexes are required.

A typical poultry enterprise has an output of waste (dung) up to 50 thousand tons per year. Utilization of such a volume of waste to obtain composts and biocompost is possible with the use of active composting technologies in piles (ITS 41, 2017; ITS 42, 2017) and with the use of chamber composters (ITS 42, 2017). At the same time, the resulting products will be of ordinary quality, and the production process will have seasonal and other restrictions.

High-performance biofermenter for high-quality biologically active organic fertilizers

If we focus on obtaining high-quality organic biologically active fertilizers, then in this case we are faced with the problem of low productivity of drum biofermenters for their production. The largest drum-type fermenter in Russia has a raw material capacity of 9 tons / day (Bryuhanov, 2016; Institute of Agroengineering and Ecological Problems of Agricultural Production, 2017). With such a productivity, about 15 fermenters will be required to process the annual waste of one poultry farm, which not only requires large capital costs for the fermenters themselves and associated technological equipment, but also generates the need for a large territory for their placement, the cost of creating and engineering an industrial sites, construction of buildings for the placement of fermenters.

In order for a fermenter to be highly productive, it must be: continuous operation; with a processing period of no more than 2-3 days; the capacity of its working area must be at least 100 tons of raw materials.

At the same time, chamber composters have a working area capacity of more than 100 tons of compost mixture, but they are installations of periodic operation with a processing period of 7-8 days. The advantage of chamber composters is their widespread use (VNIIMZ), while drum fermenters have not yet received industrial use. Chamber composters produce compost, and drum fermenters produce biologically active organic fertilizer (microbial fertilizer).

The design of these chamber compost installations and the process occurring in them must be redesigned so that the process becomes continuous, and in the entire volume of the fermenter it would be easy and guaranteed to maintain the specified conditions for the vital activity of communities of bacterial populations and their most efficient work on the biotransformation of organic material of the loaded raw material from turning it not into compost, but into biologically active fertilizer.

It is necessary at all points of the material processed in the reactor to ensure the constant movement of oxygen-containing air with a flow rate of $0.6 \text{ m}^3 / \text{kg}$ of the processed mass, as well as to ensure the initial temperature of the material loaded into the reactor is not lower than 10°C ; humidity not more than 60-65%, acidity in the pH range 6.0 – 8.0, the ratio of carbon to nitrogen in the range 20: 1 – 30: 1. The parameters listed above are taken from the Methodological recommendations RD-APK 1.10.15.02-17 (Agro-industrial complex of the Ministry of Agriculture of Russia, 2017). These parameters are need to be clarified on the basis of additional microbiological studies in relation to the features of the material planned for processing based on the requirements for commercial biological organic fertilizer.

Based on these requirements, the problem of three-dimensional modeling of stationary and transient (unsteady) processes of transfer of moist air and heat in an array of organic material arises, taking into account the vital activity of microbes that carry out solid-phase biotransformation of this material and taking into account the scheme for introducing air with a certain initial oxygen content in the air, its temperature and humidity. Modern means of numerical modeling used as part of software systems, for example, described in (TESIS), make it possible to calculate the dynamics of the distribution of oxygen, humidity and air temperature in organic material, taking into account the influence of additional heat sources from the vital activity of aerobic bacteria and the changing composition of the gas phase. The system of conjugate equations, in addition to the equations of heat and mass transfer and mass conservation of matter, will include equations describing the dynamics of changes in the number of microorganisms depending on the temperature, humidity and composition of the gas phase in the pores of the biotransformed material and the material balance of their waste products. That is, the model combines in its composition a model of physical and a model of biological processes in biotransformable organic material.

Thus, modeling heat and mass transfer, in addition to knowledge of microbiology, opens up the opportunity to find design solutions for a bioreactor and make it so that it is «blown» with air evenly throughout the reactor and at all points of the processed material to maintain optimal conditions for bacteria, excluding the occurrence of stagnant zones with «non-working» or / and «bad» bacteria, and, consequently, zones with caked material, leading to incomplete disinfection of the product leaving the reactor.

Having solved such a problem of effective control of the blowing of organic material, its temperature, humidity and oxygen content at all points of the reactor volume, we will be able to create conditions for bacteria to produce high-quality

biologically active organic fertilizer, and not ordinary compost in a period of no more than 2-3 days.

For a newly created high-performance biofermenter of layer-by-layer fermentation, vertical cylindrical bioreactor based on the solutions proposed in (Hmyrov et al., 2007) is most preferable.

Another option is to use a biotrench as an aeration bioreactor, providing for the cover of the trench with a vault made of a light structure with a gas fraction sampling system, air supply from the base and side walls of the trench, organizing the unloading of the finished material at the base of the trench with screw devices, changing the geometry of the side walls to facilitate material sliding and elimination of stagnant zones during the movement of material from top to bottom to the screw device.

In both models of a large high-performance biofermenter, a layer-by-layer biofermentation process is organized, in which the raw material loaded from above is going down during the biotransformation period (2-3 days) and is unloaded from the bottom after the end of the process in the form of biofertilizer (microbial fertilizer).

Production of highly concentrated organic fertilizer using a turbo-vortex dryer and shredder

Another high-performance solution for poultry manure is their processing into a highly concentrated organic fertilizer by means of turbo-vortex shredding and drying. The installation for processing manure in this case is a highly automated vortex drying and shredding machine (VDSM) in a block-container design with auxiliary equipment and a control unit. A machine designed by G.L. Rassokhin [Miklyaev & Rassokhin, 2017] or described in [Fine materials plant] can be used as such an installation.

The process includes the following operations:

- feeding the raw material into the receiving hopper of VDSM;
- dehumidification in VDSM and grinding to a powdery material with a moisture content of up to 10%;
- separation, cooling and accumulation of powdered material (processed product) in the VDSM hopper;
- packing of the resulting product in big bags in powder or granular (if necessary) form;
- delivery of finished products to the warehouse for storage and subsequent shipment to consumers.

In the process of drying and shredding, the germination of weed seeds is completely suppressed, as well as complete microbiological disinfection and deworming.

The process is waste-free, the ammonia contained in the manure is captured by condensation from the steam-gas

mixture leaving the VDSM and is an additional commercial product (ammonia water).

The final product (organic fertilizer) is a stable material in powder or granular form, free from unpleasant odors, pathogenic organisms, harmful weeds and other phytotoxic substances. The product dissolves easily in water, which allows it to be applied in liquid form using commercially available machines, as well as to use it in autonomous plant irrigation systems.

Conclusions

The problem of complete processing of agricultural waste at the national level can only be solved comprehensively in conjunction with agriculture to create a large-scale demand for organic fertilizers. Such a comprehensive solution makes it possible to create new large high-tech sectors of agriculture: the production of high-quality biologically active organic fertilizers and organic farming.

The development of the processing of agricultural raw materials and their effective use in crop production shifts the strategic focus of processing from the task of only eliminating the environmental harm of waste to the task of producing highly effective fertilizers from them for various applications.

As primary processing products, it is proposed to give priority to the production of biologically active fertilizers and highly concentrated dry organic fertilizers (taking into account the preparation on their basis of bioactive organic fertilizers enriched with microorganisms in granular or dissolved form).

To eliminate the accumulated volumes of agricultural waste, the subsequent processing of newly formed waste without their accumulation, as well as the large-scale production of high-quality organic fertilizers, high-performance machines of continuous operation are required. As such designs, turbo-vortex shredding and drying machines are recommended for the production of highly concentrated dry finely dispersed organic fertilizers and installations which are based on aeration reactors (biotrenches) with the selection of the finished product at the bottom of the reactor and layer-by-layer fermentation with controlled air supply to all areas of the reactor.

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