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Enhancing the Environmental Safety of the Region by Introducing Innovative Methods for Recycling of Production Biowaste

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***Abstract*: The main specifics of poultry waste management, characteristic of the Russian Federation, have been presented in the article. The goal of the study is to identify problems and ways of processing waste from the poultry farm activities.**

The situation with waste management has been analyzed in the article, and the specifics of the production activities of the poultry farm have been considered by the example of the largest company in Russia, JSC Roskar. Aside from technological specifics, the methods and processes for processing poultry droppings, the most common in Russia and abroad, have been examined in detail.

As a result, the most priority method for processing production biowaste has been defined as incineration to produce a byproduct of biochar; the characteristics of the plant and its features have been defined based on the waste composition and the amount of its formation as a result of agricultural activities.

***Keywords*: production waste management, incineration, biochar, poultry farm, waste recycling, recycling principles.**

I. INTRODUCTION

The *goal* of the study is to identify the challenging issues and to search for optimal ways of recycling waste from the activities of the poultry farm.

This is not the first time the authors are studying waste recycling. The foreign publication is of interest: "Actual issues related to organizing the work on the market of services on collecting, transporting and cleaning liquid household waste in the private housing on the territory of the urban agglomeration" [1], which is devoted to the methods and technologies for the recycling and disposal of liquid waste from the sectors of private residential buildings directly adjacent to St. Petersburg. In the current article, the authors continue to search for improving the technology for recycling of production biowaste at the poultry farm JSC Roscar, located in the Leningrad region within 1.5-hour transport access from Saint Petersburg.

Poultry farms are production enterprises that significantly pollute the environment. The problem of waste recycling and disposal is relevant and significant for the industrial and agricultural complex in the modern reality. This refers to all the technological processes of the poultry farm: from the production and preparation of eggs and egg products to the poultry meat processing.

The *objectives* of the study are the following:

1. Conducting an analytical study regarding the dynamics and structure of the poultry farm activities;
2. Describing the object under study and the specifics of the technological process;
3. Analyzing the generated waste characteristic of the poultry farm and the existing methods for its recycling; and
4. Considering and defining the option of incineration and disposal of droppings waste for the poultry farm.

The *object of study* is the poultry farm JSC Roskar.

The *hypothesis of the study* is that the construction and further operation of a plant for incineration of poultry droppings and the production of a new byproduct, biochar, is the optimal method of the waste recycling for poultry farms, including for the enterprise JSC Roskar.

II. MATERIALS AND METHODS

According to experts and based on the results of the statistical analysis of the data, there was a significant increase in production volumes of poultry meat from 1,751 thous. tons per year in 1991 to 5,070 thous. tons in 2018. It can be concluded that the demand for domestic products has increased significantly, which is associated with sanctions, improved quality of products from domestic manufacturers, the creation of sustainable brands in recent years, etc.

The cost structure per egg sale is presented in the chart below (Figure 1).

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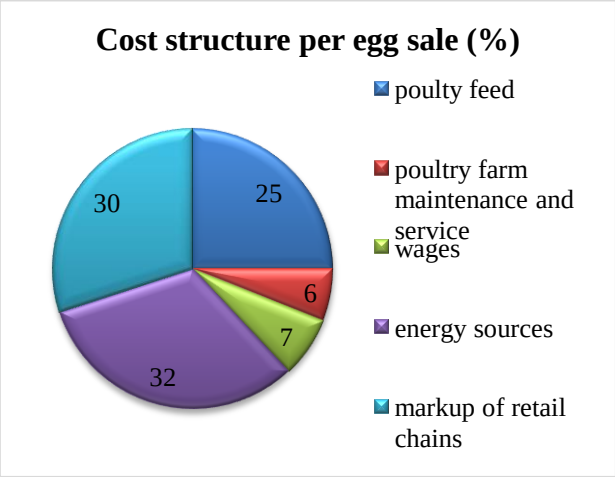

Fig. 1: Cost structure per egg sale [2]

The following elements can be defined in the cost structure per egg sale: 32 % is the cost of energy, 25 % is the cost of poultry feed, and a significant share of 30 % is the markup from retail chains and hypermarkets.

Description of the activities of the poultry farm JSC Roskar

Aside from the main products, the enterprise produces incremental ones, including egg processing products: protein, yolk, and melange.

The technological process of the enterprise is flexible and is rebuilt depending on the demand for the resource and its maximum completeness. Therefore, in addition to the whole product (egg), it offers products in dry, liquid and frozen types of separated yolk and protein. Types of liquid products are filtered and then packaged and sealed. The use of processed egg products reduces the amount of waste and the full use of the total amount of resources at the enterprise. Byproducts are used for culinary purposes and in the manufacture of confectionery products. Another positive trend is the safety of this product: the absence of pathogenic microorganisms and of the need for additional processing of egg mass [3].

The main environmental objective of JSC Roskar is to produce an environmentally friendly product: the strictest veterinary and microbiological control is carried out within the technological process, i.e., strictly complies with sanitary standards. The current quality of poultry products meets world-class standards. The enterprise is certified according to the groups of standards ISO 22000 (Food Safety Management System), 9000 (Quality Management System), 14000 (Environmental Management System), and 18000 (Labor Protection System) [4, 5].

The Roskar Poultry Farm is the leading agricultural enterprise in Russia today, located in the Leningrad region. Its main production processes include: a) production of food eggs and b) production of broiler chicken meat and further processing of products.

The company constantly improves and expands its product range and is a regular partner and supplier of chain stores, supermarkets, and other large points of sale. The constant modernization of products should also be noted: the company is trying to improve the safety and environmental friendliness of products and to vitaminize them (the products currently contain vitamins A, B, E, D, and K) [6, 7].

The farm has its own egg processing plant, which produces dry and liquid products.

As such, the Roskar Poultry Farm is a modern enterprise with the latest innovative equipment, which allows producing efficient, high-quality, and environmentally friendly products that comply with the certification obtained by the company.

The goal of the enterprise is to retain leadership positions in the field of quality and continuous improvement of all stages of the production process [8, 9].

The company's mission is the widespread distribution of its products: eggs, broiler meat, and incremental products made from chicken protein and yolk. The enterprise uses modern technologies in the production process adjusted for economic, environmental, and social aspects in its activities [10, 11].

The main stages of processing in the main production of the enterprise are as follows (Figure 2):

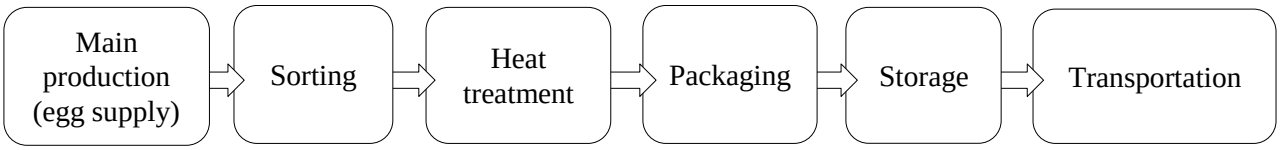

Fig. 2: Description of the production processes at the enterprise

Production waste is generated from each of these stages, which the enterprise handles differently: waste that can be disposed of is recycled, and waste that cannot be disposed of is transported to a landfill for disposal.

As such, the poultry farm JSC Roskar is a modern industrial complex engaged in poultry farming with a closed cycle of technology, focused on safety, quality, and environment (Figure 3).

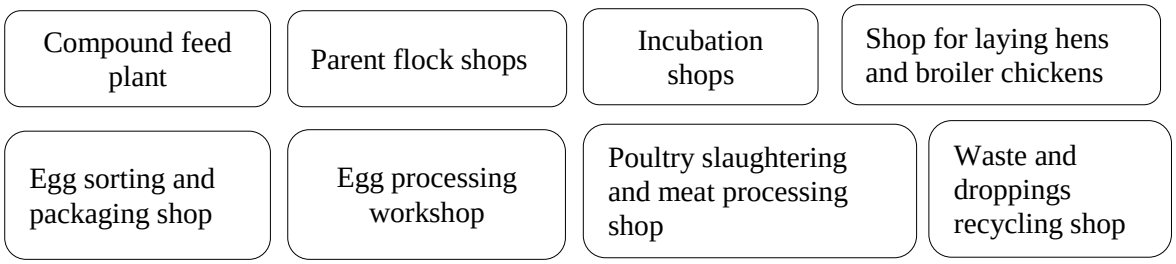

Fig. 3: Main shops of the poultry farm Roskar, excluding warehouses for finished products [12]

As such, considerable attention is paid to poultry feeding and subsequent processing, and the availability of the independent feed production plant allows balancing the feed and predicting the poultry development. The plant produces more than 20 types of poultry feed. Such feeding affects the result of egg production and improvement of its properties: eggs have a strong shell, a bright yolk, good taste, and a high content of vitamins.

The farm is being regularly rebuilt – cages for poultry are replaced, which allows making bird seats more compact and reducing operating costs. Production is computerized and automated.

The eggs are initially sorted: washed, selected, sorted, and packaged in various types of containers.

Finnish and Dutch equipment is used to grow broiler chickens, a line for the deep processing of poultry meat is currently introduced, and primary and secondary products and semi-finished products are also produced.

The company has developed a system of waste management methods that differ from well-known ones. The main differences are as follows.

The company is establishing a logistics component at the moment: there is a system of warehouses, batching orders, and deliveries of products.

First of all, waste from the poultry farm should be treated not as a problem, but as a resource, valuable strategic raw materials that can be used to improve land fertility, as fodder protein, and as a means of producing biogas of energy value. There are following ways to increase the efficiency of using poultry products at JSC Roskar [13]:

1. Increasing production due to breeding activities;
2. Introducing new means for feeding poultry and compound feed, as well as other ways to improve the efficiency of poultry breeding processes;
3. Increasing the technical and technological level of production of poultry complexes;
4. Using environmentally friendly and resource-saving technologies;
5. Using original resources most completely: compound feed, vitamin complexes and other types of food products;
6. Using deep poultry processing technologies; and
7. Aiming for the provision of environmentally friendly products of high quality.

A system of organizational, technical, and technological measures was planned to improve the poultry farm activities, which included a set of measures to implement innovative technologies, reduce harmful effects on the environment, and improve the product quality, which would subsequently influence economic performance [14]. Their implementation required updating technological processes, strict laboratory control, re-equipment of fixed assets, development of new approaches to manufacturing and procurement of products, to marketing and service approaches, etc.

Description of poultry droppings recycling techniques to be improved at JSC Roskar [15]:

1. Disposal to landfills or specialized sites

Accumulation of poultry droppings in the fields in significant concentrations is unfavorable, because it leads to the accumulation of heavy metals in water, crops, and vegetation. This is due to the need to introduce droppings as fertilizers in a certain dose in the established soil layers. Excessive amounts of nitrogen, phosphorus, and organic substances lead to a decrease in the concentration of oxygen in water structures, which, in combination with toxic components, leads to fish kill and water enrichment.

2. Composting procedure

Specialized sites, technical equipment, and additional materials are required for the composting procedure. The use of the proper technology will result in high-quality biological humus.

The idea behind the technology is as follows: the first layer is a peat coating and the second layer is droppings; these two layers are mixed and covered by peat.

3. Application of bioenergy methods

The use of bioenergy solves many problems at the same time: application of environmentally friendly processing technologies, production of high-quality, odorless fertilizers, and production of methane, which is used as gaseous fuel at a mini thermal power plant. The methane fermentation method is used in conversion. Limitations in the use of this method are as follows: poultry droppings are difficult to recycle in their pure form and must be mixed with other raw materials. Various types of crops can serve as examples of mixing components.

4. Using droppings as feed

According to expert estimates, approximately 40 % of the feed is not digested by poultry and excreted with droppings, and thus the droppings are partially used to feed cattle – for example, cows digest nonprotein sources of nitrogen well. Droppings in the feed are dried, and taste characteristics are improved by adding feed fat.

5. Using vermiculture

Vermiculture is cultivation and selection of worms living on droppings. This technology is widely used in the US, England, Japan, Canada, and other countries. The positive aspects of this technology are waste disposal, increasing the fertility of soils and soil cover, as well as obtaining feed protein, since the biomass of worms is a common feed for poultry and pigs.

As such, droppings can be used as a promising tool for the development of agriculture, therefore it is possible to choose the most economically advantageous way of developing agricultural technologies in the future, taking the environmental factor into account.

III. RESULTS

The system for waste management, disposal, and recycling described below has been introduced at JSC Roskar after the implementation of the program for improving the production technology.

The poultry farm JSC Roskar is one of the 20 largest agricultural holdings in Russia, the leaders in this field being the group of companies Mirotorg, Cherkizovo, Rusagro, and others. It must be noted that the company recycles waste, and there is also nonrecyclable waste. The profit estimates are presented in Table 1.

Table 1: Estimates of the costs of waste disposal

Types of waste	Amount of waste, kg/month	Price, rub./kg	Amount, rub.
Cardboard (brown cardboard, office paper, newspapers, magazines, packaging paper)	8,530.8	5.5	46,919.4
Polyethylene (clean stretch film, bag liners, bags from washing powder)	4,254.8	9.0	38,293.2
Polyethylene (stretch film contaminated with food, polyethylene)	3,687.9	4.5	16,595.6
Plastic packing (PET bottles, detergent containers, cans, plastic pallets, plastic boxes, big bags, pipes, film, buckets, gondola car liner)	4,398.4	4.5	19,793.0
Scrap metal (scrap of products from various metals)	19,902.1	11.7	232,854.6
Glass (vaccine containers, food packaging, laboratory glass)	563.7	0.5	281.9
Polypropylene (base for meat products, marking tape, foamed PVC for pipe insulation, shoes)	594.5	4.5	2,675.3
Batteries (lead with electrolyte from vehicles and electric cars, external batteries for chargers of various computer and household appliances, various batteries)	177.8	18.0	3,200.4
Total processing (income):	**42,110.0**		**360,613.2**
Tires (rubber products for various purposes)	2,105.0	11.0	23,155.0
Sodium (spent laboratory reagents)	18.0		0.0
Waste oil (oil from vehicles, machines and compressors, oil filters, fuel filters)	1,696.5	6.0	10,179.0
Mercury lamps (energy-saving, LB, DRL, mercury thermometers)	183.0	146.0	26,718.0
Equipment (used multicomponent spare parts, automatic machines, sensors, boards, office equipment, compressors, relays, used power tools)	411.1	45.0	18,498.6
Total recycling (consumption):	**4,413.6**		**78,550.6**
Overalls (leather boots, rubber boots, tarpaulin boots, outerwear, cotton gloves)	269.1	1.6	426.2
Household waste from employees (food waste, cutting circles, scraps of cable products, air filters, cans from under lubricants and paints, used painting tools)	4,793.9	1.6	7,593.1
LED lamps	41.6	1.6	65.9
Disposable clothing (bathrobes, overalls, hats, shoe covers, respirators)	152.4	1.6	241.4
Oiled rags, sawdust	75.7	1.6	119.9
Insulation (mineral wool, polystyrene)	294.0	1.6	465.7
Garbage from the mechanical mesh of the waste water treatment facility	583.0	1.6	923.4
Sweeps from sewer wells	442.5	1.6	700.9
Sweeps from car wash containers	416.5	1.6	659.7
Total nonrecyclable waste:	**7,068.7**		**11,196.1**

The disposal of the following waste is the most profitable: scrap metal (scrap of products from various metals), cardboard (brown cardboard, office paper, newspapers, magazines, packaging paper), and polyethylene (clean stretch film, bag liners, bags from washing powder).

The summary data on the comparison of waste and income and disposal costs are presented in Figure 4.

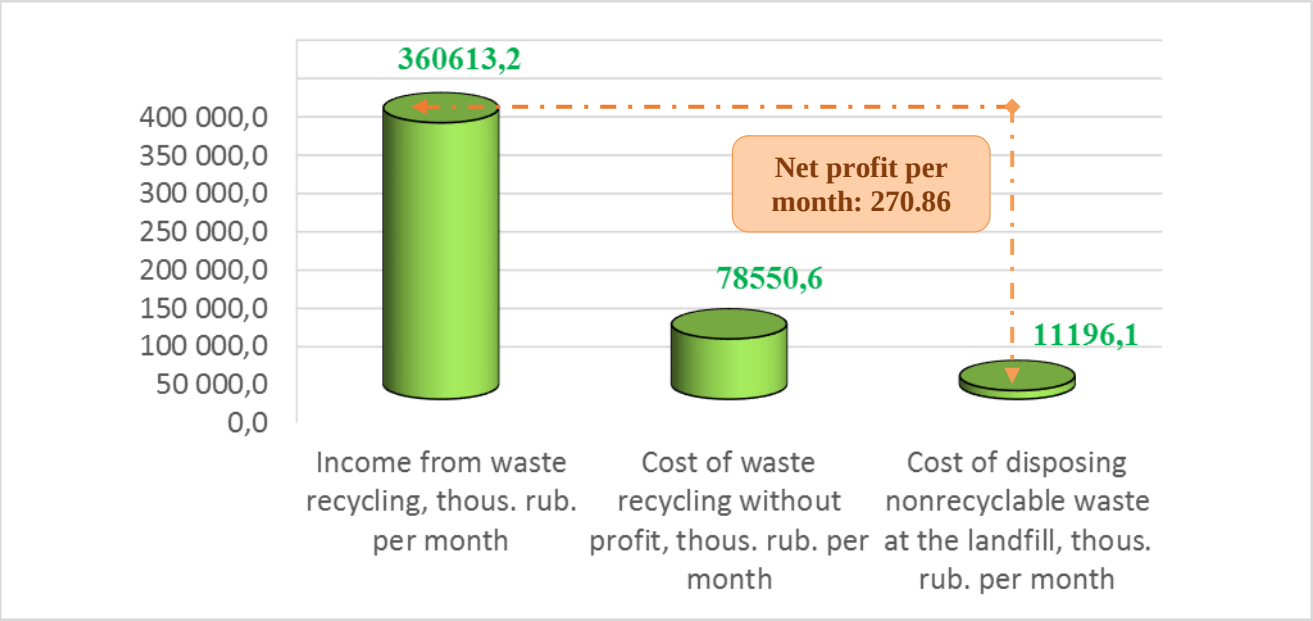

Fig. 4: Summary data on the valuation of income and expenses of the enterprise

A comparative analysis of the data allows to find out that the profit of the enterprise from waste disposal is 270.86 thous. rub. Next, the mass of waste by the structure of its processing is presented in Figure 5.

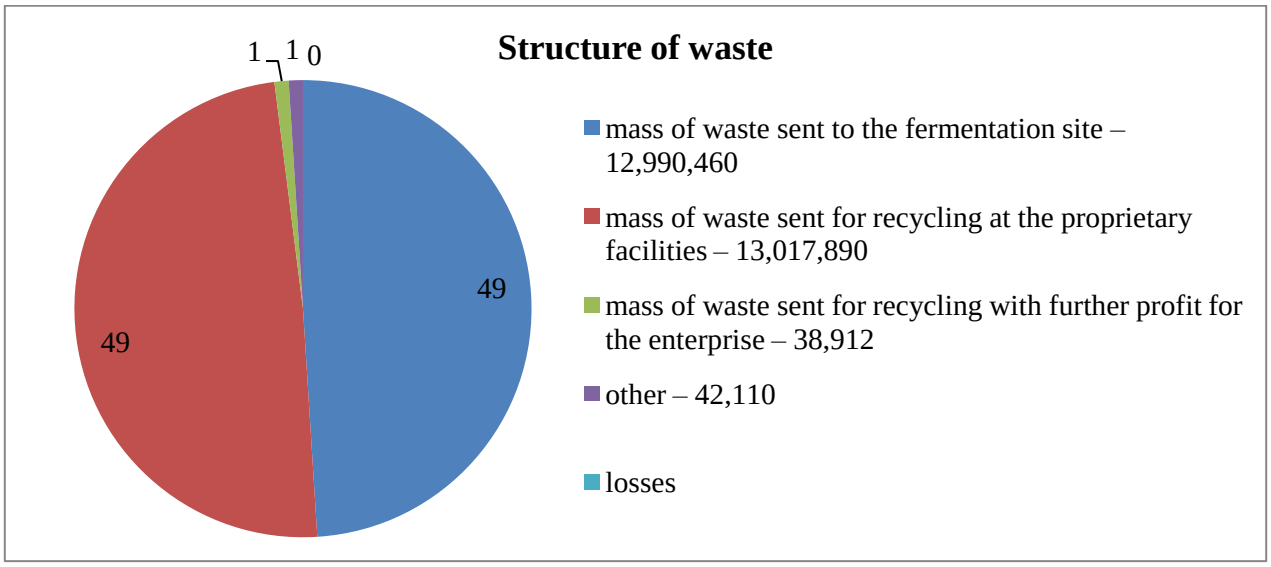

Fig. 5: Structure of the mass of waste at the poultry farm JSC Roskar, depending on the type of recycling, tons per year

As such, the enterprise is focused on recycling waste from its activities to the fullest extent and strives to implement the principles of rational resource use and nonwaste production.

The largest volume of waste recycling is characteristic for the shop with production layers and then for the pullet processing.

The following main types of waste can be identified, according to the mass of their recycling by third-party organizations: cardboard, polyethylene, plastic packing, i.e., waste generated as a result of packaging, transportation, and storage of goods.

The mass of industrial waste is presented in Table 2 and Figure 8.

Table 2: Mass of waste generated from the main activities, tons per month

Types of waste	Total mass of waste, tons / month	Structure, %
Droppings	12,655.9	99.096 %
Egg shells	63.0	0.493 %
Tankage (death loss)	35.0	0.274 %
Poultry housing cleaning	6.3	0.049 %
Egg mass from chopping	5.3	0.041 %

Tankage (sludge)	3.1	0.024 %
Boiled eggs	2.4	0.019 %
Incubation waste	0.4	0.003 %
Total waste:	**12,771.3**	**100 %**

Droppings, egg shells, and tankage make up the largest share in the structure of industrial waste.

As a result, it must be noted that the waste of the enterprise is divided into waste generated in the very technological process (egg shells), from life activities (droppings), and from auxiliary stages: waste cardboard, polyethylene and other types of packing.

IV. DISCUSSION

The norms of discharges, emissions, and waste generation are established for such type of agriculture as a poultry farm. In itself, the poultry farm waste is a potential hazard, but it may bring benefits due to the right approach to waste management: significant profits and operating costs reduction [16, 17].

According to statistical calculations, a poultry farm for 400 thous. laying hens produces 40 thous. tons of droppings per year, approximately 500 thous. cubic meters of sewage contaminated with organic substances, as well as about 650 tons of technical processing of poultry.

Traditionally, the following technology for the disposal of waste from poultry farms is used: the waste is disposed of on special equipped landfills. In addition, the smell emits from the waste, and it significantly pollutes ground and surface waters [18, 19].

The authors analyzed the situation with waste management below and considered the features of the production activities of the poultry farm by the example of the largest company in Russia, JSC Roskar. Methods and processes for recycling poultry droppings, the most common in Russia and abroad, were examined in detail in addition to technological specifics. Environmental innovative developments of the poultry farm JSC Roskar

Due to the production needs, the enterprise is constantly engaged in the introduction of innovations, including the environmental field. One of the most promising options for the enterprise is incineration of droppings. The enterprise is engaged in the construction of an incineration plant. Its description and characteristics are presented below (Table 3 and Figure 6).

Table 3: Main characteristics of the droppings incineration plant

Name	Characteristics
Overall performance	Up to 250 tons per day
Target commissioning date	2020
The property value as of 01.01.2020	382.168 mln rub.
Enterprise equity investments	232.168 mln rub.
Borrowed funds	150.00 mln rub.
Target cost reduction by introducing the incineration technology	50 %
Thermal energy obtained from incineration	5.7 MMkcal/hr
Amount of fertilizer produced by incineration	4,500 tons

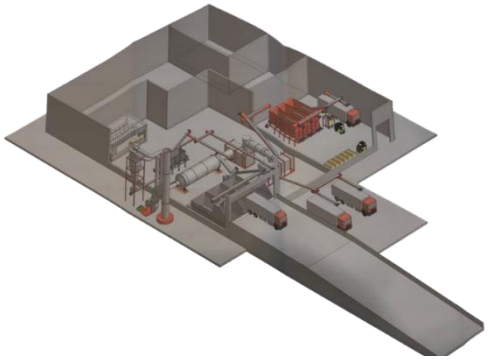

Fig. 6: Approximate scheme of droppings incineration at the JSC Roskar Poultry Farm

The JSC Roskar Poultry Farm commenced the construction of the facility "Droppings incineration plant" in 2017 as part of its project "Modernization of the poultry complex for 2017 – 2023", which is a continuation of the long-term development program of the enterprise.

The positive aspects of the plant construction are that it will bring the farm to a fundamentally new level – in particular, in compliance with international standards, which will change the approach to environmental impact. It will allow receiving profit from waste generated in the course of activities due to the production of a byproduct: energy and fertilizer. The launch and operation of the plant are scheduled for the end of 2019. The plant is equipped with modern Mavitek incinerators; their use will allow achieving maximum profitability and efficiency in the disposal of droppings. The technology allows incinerating chicken droppings and receiving energy and calcium-phosphorus-based coal biofertilizer in the remainder of the combustion. The volume of droppings recycling will amount to 75 thous. tons per year, and the plans are to receive 4.5 tons of calcium-phosphorus fertilizers as a result of recycling. The facility is currently under construction, with the installation of technological equipment being carried out.

Biochar is a carbon-rich product technologically obtained by heating biomass in a closed container or in an oxygen-free environment. Carbon is an absorbent material in this case, which includes charged particles that attract moisture and nutrients.

V. CONCLUSION

Thus, the poultry farm is a labor-intensive production generating a significant amount of production and nonproduction waste as a result of its activities.

The analysis of the waste at the Roskar Poultry Farm JSC has revealed that the enterprise already receives profits by transferring part of the secondary waste for recycling to third-party organizations,

as well as recycling part of the waste within the technological process, i.e., it strives to build a "nonwaste" production system and an efficient waste management process. The company is going to introduce a new technology in the near future – incinerating droppings at a plant for specialized incineration, which will result in the generation of useful thermal energy and biochar.

The analysis of the data has indicated that the activities of any poultry farm can become a nonwaste technology, and profits can be obtained from the sale of waste and byproducts generated from them if this type of activity is regulated and correctly matching technologies are selected.

Unpleasant odors traditionally emanate from landfills where poultry waste is disposed of, ground and surface waters are polluted, and the area of territories that can be allocated for recreation, residential buildings, etc. is reduced.

The method of processing biological waste products of the most priority for the current situation – incineration to obtain a byproduct of biochar – is described and recommended for its use at the Roskar Poultry Farm and the like; the plant characteristics and specifics are selected in in the article, based on the composition of the waste and the amount of its generation as a result agricultural activities.

APPENDIX

It is optional. Appendixes, if needed, appear before the acknowledgment.

ACKNOWLEDGMENT

It is optional. The preferred spelling of the word "acknowledgment" in American English is without an "e" after the "g." Use the singular heading even if you have many acknowledgments. Avoid expressions such as "One of us (S.B.A.) would like to thank ... ." Instead, write "F. A. Author thanks " *Sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page*.

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