Renewable source of full protein for animal feeding

T E Marinchenko
Rosinformagrotekh, Pravdinsky Township, Moscow Region 141261, the Russian Federation

E-mail: 9419428@mail.ru

Abstract. Existing technologies for industrial production of agricultural products lead to inefficient consumption and loss of natural resources and an increase in the environmental burden on the environment. To saturate the domestic market with high-quality foodstuffs, intensification of agricultural production is required through technological modernization of the agricultural sector of the economy and the introduction of modern resource-saving technologies. The growth of food production requires planning a mechanism for the production waste management, so this issue is very relevant for many manufacturers in connection with the tightening of environmental requirements in many countries. Several promising technologies for the entomologically poultry waste management, which provide complete protein for feeding farm animals and therefore increase the profitability of production, are discussed.

1. Introduction
The annual increase in food production leads to an increase in agricultural waste, which often carries a serious environmental burden. The accumulated amounts of waste after appropriate treatment can acquire new beneficial properties [1]. Therefore, over the past few decades, the research around the world has focused on the development of new technologies for processing waste from the agricultural and food industries to produce value-added products [2].

According to the statistics given by FAO (2013), 27 % of the global agricultural products, which account for 1.6 billion metric tons, are being wasted annually [3]. These losses should also be involved in processing.

In Russia, research is also being actively conducted in the field of waste management, including poultry droppings, which in its native state cannot be used and requires some treatment or processing before use.

2. Problem statement
On average, more than 200 metric tons of poultry litter droppings or litterless droppings are formed at the poultry farm per day. The latter ones are a mixture of solid and liquid animal excretions with admixtures of water and undigested feed. A big problem for producers is the disposal of poultry mortalities, slaughterhouse and hatchery waste, which require the solution of environmental, organizational and financial issues.

The traditional technology for dropping processing requires the availability of equipped dropping storage facilities and a sufficient number of agricultural land; the disadvantages of this approach, among other things, are the dropping maturation time and the high humidity of the waste generated. All this complicates the processing.

The main problem of dropping recycling is its high humidity, which usually amounts to 93-97 % for liquid droppings (formed during cage management with hydraulic washing) and more than 85 % for...
semi-liquid droppings. Most processing flows (with the exception of biogas production) include energy-intensive stages of evaporation and drying.

At the same time, poultry droppings are a promising feed reserve, which is confirmed by foreign studies [4, 5, 6].

3. Research questions
Are there technologies in the world and in the Russian Federation that would allow the poultry industry to become waste-free? Non-waste production refers to production in which all raw materials and waste are converted into finished products. The concept of such a process provides for the processing of any products and waste, and those that, in accordance with environmental requirements, provide for recycling while turning production into a closed cycle comparable to natural ecological systems, which are based on biogeochemical cycles of substances.

4. Purpose of the study
The purpose of the study is searching for practically proven technologies and the rationale for their replication.

5. Materials and methods
The research material was foreign and domestic scientific publications on the problems of poultry waste management, data on Russian developments in the field of their processing. Methods used are monographic and comparative methods, system analysis, idealization and mental modeling, as well as a logical approach.

6. Research results
In accordance with the “Strategy for the Environmental Safety of the Russian Federation for the period until 2025”, environmental safety must be ensured, including that through the introduction of innovative and environmentally friendly technologies, and the development of environmentally friendly industries. Existing technologies for industrial production of agricultural products lead to inefficient consumption and loss of natural resources, an increase in the environmental load on the environment [7].

According to estimates, environmental damage is 6% annually, and taking into account the effects on human health, it is 10 to 15% of GDP. The GDP growth potential is estimated by experts as 2 to 3 times one at the existing levels of raw materials withdrawal and reduction in environmental load. One of the development vectors in environmentally reasonable and environmentally safe management is becoming a high-tech and competitive agribusiness with regional specialization in terms of production efficiency and climate-friendly orientation [8].

Today, the agricultural production implements, within the framework of programs at the federal and regional levels, measures for the greening of production, including measures to restore natural fertility, increase crop yields and animal productivity through biological methods of exposure, improve the quality of raw materials and products, and introduce and adapt energy and resource-saving technologies.

Closed ecological agricultural cycles that meet both environmental and economic principles of efficient agricultural production become the most effective. The resulting waste from the livestock production sector becomes the basis for maintaining soil fertility or is recycled and subsequently brought into circulation. The use of biological products to protect, as well as stimulate growth and productivity in crop and livestock production is consistent with the principle of environmentally friendly agricultural production [2, 3].

Adrian Leip et al. Consider that droppings should be considered as a by-product until it is disposed of, wasted or used beyond the nutrient requirements of crops, in which case it should be treated as waste [9].

There are several modern areas for the processing and use of poultry droppings: application to the soil without additional treatment; processing by passive and active composting; vermicomposting; entomological processing; dehydration and drying (mechanical, thermal, vacuum); pyrolysis at a temperature of 450 to 550 °C; plasma gasification; thermal depolymerization technology; direct combustion in
steam and hot water boilers; microbiological conversion; anaerobic digestion in digesters with the formation of biogas; using as a feed additive [10]. In the Russian Federation, more than 10 plants have been patented to automate the process.

In our opinion, one of the promising areas of dropping processing is using synanthropic fly larvae. Van-Huis and Oonincx also note that since most insect species can use nutrients from organic waste, it can be a promising alternative to prevent the loss and conversion of low-quality organic by-products to high-quality proteins [11].

The technology is considered environmentally friendly, and vermicompost and protein biomass of larvae are its output products. Moreover, this is a fast-flowing technology: one can get 640 to 700 kg of vermicompost and 60 to 100 kg of larvae biomass for 5 to 6 days from one metric ton of dropping. Biohumus at a dose of 3-5 MT / ha increases the productivity 1.2-1.5 times [10].

The biomass of housefly larvae contains 48 to 52 % of protein, 7 to 14 % of fat, 7 to 10 % of fiber, 7 % of nitrogen-free extractive substances, 11 to 17 % of ash, and biologically active substances (vitamins, ecdysone, etc.) [12]. Rumpold and Schluter report that protein and fat content in larvae flour can reach large values equal to 40 to 70 % of protein and 5 to 40 % of fat [5].

The amount of nutrients in droppings is largely determined by the conditions of feeding and keeping poultry. On average, natural humidity droppings of egg poultry contain 1.74 to 2.74 % of nitrogen; 1.18 - 2.00 % of phosphorus; 0.61 - 0.78 % of potassium. There is more phosphorus in broiler chicken droppings than nitrogen and potassium. The value of one metric ton of broiler droppings is equivalent to 180 kg of multicomponent mineral fertilizer.

The average content of trace elements in poultry droppings in terms of dry matter percentage (semi-liquid droppings) is 5.0 to 8.2 mg / kg of boron; 6.7 to 16.7 mg / kg of copper; 35.5 to 91.6 mg / kg of manganese; 0.25 - 0.36 mg / kg of molybdenum; 51.5 to 127.8 mg / kg of zinc; 273.7 to 601.9 mg / kg of iron [12].

Besides the nutritional benefit, insect-derived products such as fat, oil or chitin have shown great potential as immunostimulants and gut modifiers [6].

A wide range of element content is justified by the different composition of feed containing different trace elements [12].

**Table 1. Chemical composition of poultry droppings.**

| Dropping type  | Moisture content [%] | Content in terms of moist substance [%] |
|---------------|----------------------|----------------------------------------|
|               |                      | Organic substance | Ash | N  | P2O5 | K2O |
| Dry           | 14                   | 80                | 6.0 | 4.10 | 3.90 | 2.0 |
| Litter dropping | 40                   | 54                | 6.0 | 2.0  | 1.81 | 0.97|
| Semiliquid    | 85                   | 11                | 4.0 | 0.90 | 0.90 | 0.30|
| Liquid        | 96                   | 4.0               | 1.0 | 0.28 | 0.26 | 0.10|
| Waste fluids  | 98                   | 1.8               | 0.2 | 0.12 | 0.11 | 0.06|

Fly larvae grown on organic waste show an extremely high growth energy: during the week, their weight increases 300 to 500 times. It is estimated that the biomass from a pair of flies and their offspring, with the full realization of the genetic potential at the end of the year, will be more than 87 metric tons [13].

Different types of insects are optimal for different types of agricultural waste (figure 1). For manure processing can be used: black soldier fly and house fly (see figure 1) [5].
Figure 1. Species of insects and the types of waste they need as a substrate

L. K. Ernst All-Russian Research Institute of Animal Husbandry, together with a number of other scientific institutions, has developed a technology for recycling of organic waste from pig and poultry farming using housefly larvae (Musca domestica L.). 60 to 100 kg of biomass of fly larvae and 640 to 700 kg of biohumus are obtained, from one metric ton of native manure or poultry droppings after 5 to 6 days [12].

Experiments with using droppings in compound feed for cattle, bull-calves, sheep, pigs, broilers and other animals showed that the reduction in feed costs reached up to 20%. So, the use of diets, which have a high content of roughage, as a protein source for young cattle works better than other sources of non-protein nitrogen [14].

The New Biotechnology Company has developed a process for the production of high-protein feed from dried and crushed larvae of green meat flies, which are grown on waste from slaughterhouses, incubators, mortality, etc. The average mortality in poultry farms is 5% of the total population. This type of waste gives a lot of trouble to poultry farms, such as environmental, organizational and financial waste management issues. Therefore, the application of this method is most effective directly at a poultry farm, which allows making poultry production waste-free.

The process is justified by the sufficient supply of substrate: to make 1 kg of product, it is necessary to grow 3.5 kg of live larvae, which requires 10 kg of meat waste.

It is known that at a poultry farm that counts 2 million heads, about 100 metric tons of waste are generated monthly. The cost of disposal is at least 350,000 rubles per month. But if technology is used to process waste using larvae of flies, the farm "transforms" them into feed, that is, into raw materials. As a result, 10 metric tons of feed protein and 30 metric tons of organic fertilizer are obtained from 100 metric tons of raw materials. Feed protein is returned to feed production, and organic fertilizer is used in the fields or sold to farmers.

In Lipetsk, the production of protein from the larvae of the well-known green bottle flies (Lucilia Caesar) in special insectariums has been established. If in nature one fly makes of 60-egg batch, then, under special conditions, the egg batch (and, consequently, the number of larvae and the resulting feed) is on average three times more, which is the result of selection as well.

Flies are kept in special cages, in which there is water, sugar, milk powder and boxes with minced meat, where the flies make egg batches. The egg batch is removed daily. Quality control and control of purity of the population are performed by the chief technologist. To do this, larvae are selected, which
pupate in special conditions and are stored in the form of pupae in a refrigerator. If necessary, pupae are placed in insectarial cages, and flies appear from them after some time.

The room is constantly maintained at the optimum temperature and humidity for the flies, and staff access is limited there. As soon as larvae emerge from the eggs, they are transferred to the growth workshop. The fodder substrate and egg batch are placed in special trays on the sawdust litter. Larvae are very voracious and grow rapidly while increasing in size up to 350 times per day. The period of feeding and active growth is 3 to 4 days. Then the grown larvae are forced. This is the name of the process of separation of larvae from the organic substrate. Then the biomass is dried and sent for storage.

Larvae grown on poultry meat have higher levels of nutrients than those cultivated on manure and droppings.

In pig breeding, the use of protein as a biological additive in the diet of piglets, pigs, boars can increase the digestibility of food and the body's natural resistance to diseases and viruses, increase weight gain due to the content of a large number of enzymes, chitin, melanin, and immunomodulators.

In poultry, the introduction of feed protein in the diet allows increasing the daily weight gain and reduce the total cost of feed. In laying hens, an increase in egg production is observed, the resistance to diseases and viruses increases, and mortality decreases.

The Novosibirsk State Agrarian University, L.K. Ernst All-Russian Research Institute of Animal Husbandry, and A.N. Severtsov Institute of Ecology and Evolution keep working in this area.

7. Conclusions

Russian agriculture is one of the most dynamic sectors of the Russian economy. Further development of the agricultural sector, increased exports and increased competitiveness in the world market are impossible without further growth in production, including poultry products. Therefore, the idea of a closed cycle in the economy, which solves the issues of both environmental and economic plan, is advisable.

Most modern waste processing technologies are aimed at using waste rather than destroying it. These are environmentally friendly and cost-effective biotechnologies for processing droppings, which makes it possible to turn organic waste into valuable raw materials for obtaining feed, fuels, fertilizers, and substrates for the chemical and microbiological industries. The best of them are based on the so-called nature-like approaches when the waste is not processed using sophisticated equipment, but with the help of bacteria, yeast, worms, larvae, etc.

The shift in the focus of public attention to the ecology of production stimulates research into the involvement of industrial waste in processing, as well as the introduction of modern technologies in the practice of production. In this regard, droppings are a good source of various substances useful for further agricultural use: biogas and thermal energy to reduce the need for burning natural hydrocarbons, fertilizers to restore land fertility, feed additives to reduce the need for vegetable and animal protein, environmentally neutral biologically active substances to protect and stimulate plant growth, to reduce the chemical burden on the environment, etc. The considered methods of disposal and recycling of droppings contribute to the preservation of the biosphere.

Further growth in production and modernization of existing industries require the planning of a mechanism for the disposal or recycling of production waste. Therefore, the issue of dropping recycling is very relevant for many manufacturers.

Many studies have been performed on the use of insect larvae that process biomass of waste, gain weight, after which they can be added to animal feed. This technology has a high profitability, because the growth rate of protein biomass in microbes and insects is much higher than in mammals.

The efficiency of using protein feed obtained from waste processing by fly larvae as compared to other animal proteins (of fish, and meat and bone meal) has been confirmed by many studies, including the feeding of other types of farm animals.

In the near future, those enterprises that can obtain protein using microbes or insects will have a competitive advantage.
References

[1] Krasilnikov O Yu and Marinchenko T E 2018 The relevance of effective feed production Agrarian Bulletin of the South-East 2(19) 44-6

[2] Bandara N and Chalamaiah M 2019 Bioactives From Agricultural Processing By-products Encyclopedia of Food Chemistry pp 472-480 https://doi.org/10.1016/B978-0-08-100596-5.22408-6

[3] FAO Food Wastage Footprint: Impact on Natural Resources Summary Report. Food and Agriculture Organization of the United Nations (Rome, 2013), available at: http://www.fao.org/docrep/018/i3347e/i3347e.pdf

[4] Wadhwa M and Bakshi M P S 2016 Application of Waste-Derived Proteins in the Animal Feed Industry (Oxford: Protein Byproducts, Academic Press) 10 161-92 https://doi.org/10.1016/B978-0-12-082391-4.00010-0

[5] Adebeye M J, Ravi Kanth Reddy P, Obaisi A I, Elghandour M M M Y, Oyebamiji K J, Salem A Z M , Morakinyo-Fasipe O T, Cipriano-Salazar M and Camacho-Diaz L M 2020 Sustainable agriculture options for production, greenhouse gasses and pollution alleviation, and nutrient recycling in emerging and transitional nations Journal of Cleaner Production 242(01) https://doi.org/10.1016/j.jclepro.2019.118319

[6] Gasco L, Biasato I, Dabbou S, Schiavone A and Gai F 2019 Animals fed insect-based diets: state-of-the-art on digestibility, performance and product quality Animals 9 170-202 https://doi.org/10.3390/ani9040170

[7] Saleeva I P, Sklyar A V, Marinchenko T E, Postnova M V, Ivanov A V and Tikhomirov A I 2019 Efficiency of alternative electric power industry for poultry farming E3S Web of Conferences p 04020

[8] Report on the environmental development of the Russian Federation for future generations 2016 (Moscow: State Council of the Russian Federation, Kremlin) http://www.cenef.ru/file/Doklad.pdf

[9] Leip A et al. 2019 The value of manure - Manure as co-product in life cycle assessment Journal of Environmental Management 241(1-7) 293-304 https://doi.org/10.1016/j.jenvman.2019.03.059Get rights and content

[10] Popov V N, Korneeva O S, Iskusnykh O Yu and Iskusnykh A Yu 2020 Innovative methods of poultry farming biowaste processing Bulletin of the Voronezh State University of Engineering Technologies 82 1 (83) 194-200 DOI: 10.20914/2310-1202-2020-1-194-200

[11] Arnold van Huis A and Oonincx D G A B 2017 The environmental sustainability of insects as food and feed Agron. Sustain. Dev. 37 43-57 DOI 10.1007/s13593-017-0452-8

[12] Subbotina Yu M 2016 Improving the cleaning of livestock and poultry waste using natural biocenoses New Scientific Experience, traditions, innovations 591-2 25-36

[13] Ernst L K, Zlochevsky F I and Erastov G M 2004 Recycling of livestock and poultry waste Livestock of Russia 6 33-4

[14] Marinchenko T E, Kuzmin V N, Korolkova A P and Goryacheva A V 2018 Monitoring of innovative activity in the field of agriculture (Moscow: Scientific and analytical review, Rosinformagrotekh)