Quail Droppings Utilization System

A Antonov¹, G Ivanov², N Pastukhova¹

¹Northern (Arctic) Federal University named after M.V.Lomonosov, 163002, Severnaya Dvina embankment 17, Arkhangelsk, Russia
²OOO Biolaboratory, 121205, Moscow, Scolcovo Innovative Centre Territory, Nobel St. 7, Et 3 / Pom 82 / Rm 3

E-mail: hope203@yandex.ru

Abstract. Agriculture creates a greater impact on nature than any other sector of the economy. Pollution of the environment by poultry and livestock enterprises is most often due to the imperfection of the technologies and technical means used, non-compliance with established environmental requirements. Special attention should be paid to the problem of processing poultry farms' and enterprises' waste, a large proportion of which is droppings. Fresh bird droppings from a poultry farm is dangerous for human health, and considered to be environmental hazard of the third class. The technology proposed for the utilization of fresh bird droppings is brand new and have no analogues in Russian Federation. It bases on the bioconversion process of the droppings from poultry farms with the help of Black Soldier Fly larvae (Hermetia illucens L.). The system proposed gives a solution to several problems: utilization of poultry wastes (bioconversion: 4.9...6.3 kg/m²/day.), using dried fly larvae as a protein rich feed additive in feed production (0.2...2.1 kg/day/m² larvae); it also supplies agricultural enterprises with organic fertiliser (zoohumus) (zoohumus output: 11.3 12.5 % from 1 kg of wastes). The proposed system has features of production greening, the technology is characterized by the maximum efficiency of agricultural waste recycling and enables to increase the diversity of poultry enterprises functions.

1. Introduction

Nowadays there are many poultry enterprises in Russia that produce not only meat and eggs, but also waste, and its quantity has much greater weight than that of the main products of poultry farms. The first place among all the waste is for bird droppings. The issue of manure processing is one of the most relevant in the world from the point of ecology. Droppings processing, the amount of which sometimes reaches tens and hundreds of thousands of tons per one year, has become a very difficult task for most poultry farms, as it requires considerable expenses and large areas for its solution. A poultry farm of average power can produce approximately 30 tons of bird droppings per day. Daily output of a large amount of poultry farm droppings is the most significant environmental impact factor. Illegal droppings storage areas not only significantly pollute the soil, water reservoir and groundwater surrounding the poultry farm areas, but also cause a sharp odour, contribute to the accelerated growth and development of worms’ and flies’ eggs and larvae, as well as many other microorganisms, which may be a source of dangerous diseases pathogens. Bird droppings are hazardous for humans and considered to be the environmental hazard of the third class, and according to a number of laws, namely, "On ecological expertise" (November 23, 1995); "On environmental
protection" (January 10, 2002), and "On the sanitary-epidemiological welfare of population" (March 30, 1999), it should be disposed of.

The easiest and cheapest way to dispose of bird droppings is direct application to the soil. Usage of droppings as a fertiliser for growing plants is widespread among owners of household plots. This is due to the high concentration of nutrients and the rapid inflow of microelements into a plant. Many gardeners use mainly chicken droppings, but in some cases quail ones are also used as a fertilizer. Quail droppings, unlike chicken, is considered to be a fertiliser of high quality, it is used to enrich soil composition, as well as to feed vegetable crops since it contains necessary plant minerals and has a more saturated composition. However, when applying quail droppings to a soil, especially fresh ones, it is necessary to strictly observe the dosage and remember that uric acid contained in this fertiliser inhibits the development of seedlings of young and adult plants, and can cause "burns" on leaves and roots of vegetation. Fresh quail droppings are toxic, and when making it into the ground, the plant is exposed to diseases that are difficult to cope with, so fresh droppings is used as a fertiliser very rarely. Consequently, there is a question of developing ways to dispose of fresh quail droppings, as its storage on the territory of poultry farms or outside leads to an increase in nitrates in a soil, leaching of nutrients and to a sharp depletion and decrease in soil fertility. The technology proposed by us for fresh bird droppings utilization is brand new and have no analogues in Russian Federation. It is based on bioconversion of quail droppings of poultry farms by Black Soldier Fly (Hermetia illucens L.) larvae. The technology aims at solving such important problems as the protection of the environment from the poultry industry toxic wastes, production of ecologically friendly fertilisers – zoohumus (larvae's waste product), and most importantly, production of high protein feed additives for non-productive animals, in particular aquaculture, in the form of live larvae or high protein feed made of dried larvae's flies.

The Black Soldier Fly is a large American fly from the family of Soldier (Stratiomyidae). Its natural habitat is North and South America. Wide popularity was obtained by the insect due to highly efficient bioconversion of different organic solid wastes as well as high nutrition of the larvae applicable for feeding farm animals and aquaculture. In 2017, the company Enterra Feed Corporation specializing in the design and manufacture of environmentally friendly feed products for aquaculture has received permission for sale of ingredients for feed made of insects in the United States of America, Canada and the European Union. Association of American Feed Control (The Association of American Feed Control Officials (AAFCO)) in the United States accepted the request by Enterra to include meal made of Black Soldier Fly larvae in the list of permitted feed ingredients for salmon fish feeding, namely Atlantic salmon, trout and Arctic char. Auxiliary materials and the changes were reviewed and supported by Food and Drug Administration (FDA) [13].

The natural habitat of the insect is an area with a warm subtropical climate, where the species is bred in open-air cages. However, in the course of studies it was noted [1,2,3,4,5,6,7,8,9] that the insect is able to develop year-round not only in the open, but also in a confined space with artificially created conditions, which enables the species to be used for bioutilization of bird droppings not only in the southern regions, but also in regions with cold climatic conditions.

The purpose of the work is to develop a waste management system for poultry farms where poultry droppings will go through the bioconversion by means of Black Soldier Fly larvae and also using larvae in poultry food as a high protein food additive.

2. Methods
The poultry farms waste management system developed by us (on the example of quail droppings) is considered on the example of private quail farm in Lipetsk region (Russia). The farm contains an average of 4200 quails and produces 1.5-2 tons of droppings per month. Studies of the droppings bioconversion by Black Soldier Fly larvae were conducted in cooperation with OOO Biolaboratory. The technology based on gravimetric (calculating) method of measuring utilized feed and larvae was developed to utilize fresh quail droppings. Before the experiment began, 10 larvae went through control weighing 10 times to determine their primary mass; then the average mass of a larva was
calculated (M \text{av.\,larva} = 0.03 \, \text{g}). Larvae of 10-12 days old (from the day of laying) were used in the experiment. The calculated density of larvae arrangement per 1 \, \text{cm}^2 of a container was 50 and 100 \, \text{pcs} / \, \text{cm}^2. The experiments were carried out in containers which size depended on the density of arrangement which was \( 22 \times 27 \times 14.5 \, \text{cm} \), where 14.5 cm is the height (for the arrangement density of 100 \, \text{pcs} / \text{cm}^2) and 9.5 \times 14.5 \times 12.5 \, \text{cm} \), where 12.5 is the height (for the arrangement density of 50 \, \text{pcs} / \, \text{cm}^2). Loading of larvae into the containers was performed with the help of gravimetric method adjusted for the mass of one larva, density of the arrangement of larvae and container’s area. Once the loading was finished, pre-weighed feed was added. The food portion was estimated depending on larvae mass in proportion 1:1-1:2. Fresh quail droppings were used as feed. The experiment lasted for 6 days.

The research was performed in a work room at the temperature of 28°C and humidity of 75...85%. Feeding was done only in the morning of each day of the experiment.

At the end of the experiment re-weighing of residual feed and Black Soldier Fly larvae was carried out with the help of a gravimetric method. The mass of eaten feed for the entire period of experiment and average daily increase in the biomass of Fly larvae were calculated. The results were processed statistically using STATISTICA (version 10, StatSoft, Inc., 2011) along with the calculation of standard errors and arithmetical mean values.

3. Results

The efficiency of the bioconversion of fresh quail droppings by means of Black Soldier Fly larvae (and also using larvae as a high protein food additive in poultry feed) was measured with the help of the statistical indicators of larvae biomass at the start and end of the experiment, actual yield of live larvae at the end of the experiment, and droppings bioconversion (table 1).

| Larvae arrangement density, pcs / cm² | Weight of larvae, g | Feed mass, g | Bioconversion, kg/m²/day | Average daily increase in larvae biomass, kg/day/m² | Zoogumus output from 1 kg of waste, % |
|---------------------------------------|---------------------|--------------|-------------------------|-----------------------------------------------|----------------------------------|
|                                       | at the beginning | at the end of | at the beginning | at the end of | at the beginning | at the end of | |
|                                       | of the experiment | the experiment | of the experiment | the experiment | of the experiment | the experiment | |
| 50                                    | 207±1.59          | 226±1.63     | 650±2.54               | 311±2.19                               | 4.9±0.82                        | 0.2±0.05                        | 11.3 |
| 100                                   | 414±1.95          | 613±2.31     | 1020±2.03              | 510±1.69                               | 6.3±0.68                        | 2.1±0.03                        | 12.5 |

According to the research, when the experiment has finished, average daily growth in Black Soldier Fly larvae biomass has swelled to 1.1...1.5 times its size on average. The maximum result of quail droppings bioconversion is observed when arrangement density is 100 pcs /m². At this density, the larvae can dispose of 6.3 kg/m²/day fresh droppings, at the same time due to the average daily growth, it is possible to obtain 2.1 kg of fresh larvae for using it as a feed additive for aquaculture.

As a result of droppings bioconversing by Black Soldier Fly, it is possible not only to recycle droppings but also to acquire extra income when selling Fly’s larvae to the companies manufacturing combined feed for non-productive and productive animals. The efficiency of the developed system is due to the double benefit – Fly’s larvae recycle poultry wastes and become a good component in feed production.

On average, there are about 10,000 birds on the territory of one quail poultry farm. Quail consumes 30 grams of feed per day with droppings output of 60 %, that is 18 g/day. Consequently, one average poultry farm is capable to produce approximately 180 tons of bird droppings daily. Having larvae bioconversing bird droppings at the speed equal to 6.3 kg/m²/day, the area needed for utilization daily
droppings from 10,000 birds is 28.6 m$^2$ (180 kg.: kg/m$^2$ / day = 28.6 m$^2$). In this area, the average biomass growth of live larvae per day is 60.06 kg. As a result of larvae drying, a third of the sample weight is lost, therefore, the mass of dry larvae used as a feed additive will be 20.02 kg/day. Market cost of 1 kg of dry Black Soldier Fly larvae is €10, extra income when selling fly’s larvae to the companies producing animal feed will be €200.2 /day, and annual income – €73,073.

An important indicator for quail droppings utilizing by the larva is zoohumus output, which amounts to an average of 11.3...14.8 % per 1 kg of waste. Many nutrients of fresh droppings are in a form that is difficult for plants to assimilate, and only after processing by larvae they can turn into more accessible forms, such as organic fertiliser. Using zoohumus in local arboretums, farms and nursery gardens will enable to produce vegetables, organic cereal and fruits locally.

Proposed system solves several problems at once: recycling poultry waste, creating a high protein feed additive in feed production in the form of dried or live fly larvae, as well as supplying agricultural enterprises with organic fertiliser (zoogumus).

4. Discussion
Developed waste utilization system which implies bioconversing poultry droppings by Black Soldier Fly larvae enables to solve following problems: recycling poultry wastes, supplying agricultural enterprises with organic fertiliser (zoogumus), supplying aquafarms with a high protein feed additive in the form of the dried and/or live fly larvae. The system proposed has features of production greening which means that due to the bioconversion of droppings the ecological state of surrounding areas adjacent to poultry farms will improve, and the system enables to increase the diversity of enterprise’s functions engaged in poultry farming.

The most possible bioconversion in this droppings utilization system is when the larvae are arranged with the density of 100 pcs/cm$^2$. According to the research, when having the arrangement density as mentioned above, larvae can dispose of 6.3 kg of fresh quail waste per day from 1 m$^2$, therefore, it supplies feed industry with 2.1 kg of fresh larvae for further use of it as a feed additive. The system is capable to dispose of poultry farms’ waste in the most ecologically efficient way, and gives an opportunity to get extra income by selling larvae to the companies producing combined feed for non-productive and productive animals.

The system presented has the maximum agricultural waste utilization effectiveness, so it is necessary to go on researching on this topic and work at the creation of automated lines for the bioconversion of organic waste.

5. Resources
[1] Alvarez L 2012 The Role of Black Soldier Fly, Hermetia illucens (L.) (Diptera: Stratiomyidae) in Sustainable Waste Management in Northern Climates Electronic Theses and Dissertations P 402
[2] Diener S, Zurbrügg C, Tockner K 2015 Bioaccumulation of heavy metals in the black soldier fly Hermetia illucens and effects on its life cycle Journal of Insects as Food and Feed 1(4) pp 261–270
[3] Elwert C, Knips J, Katz P 2010 A novel protein source: maggot meal of the black soldier fly in broiler feed In: Gierus M, Kluth H, Bulang M and Kluge H (eds.) 11 Tagung Schweine- und Geflügelernährung, November 23–25, 2010, Institut für Agrar- und Ernährungswissenschaften, Universität Halle- Wittenberg, Lutherstadt Wittenberg (Germany) pp 140–142
[4] Maurer V 2016 Replacement of soybean cake by Hermetia illucens meal in diets for layers J of Ins as Food and Feed Vol. 2(2) pp 83-90
[5] Newton G L, Booram C V, Barker R W, Hale O M 1977 Dried Hermetia illucens larvae meal as a supplement for swine J. Anim. Sci. 44 pp 395-400
[6] Newton L, Sheppard C, Watson D W, Burtle G, Dove R 2005 Using the black soldier fly, Hermetia illucens, as a value-added tool for the management of swine manure Report for Mike
Williams, Director of the Animal and Poultry Waste Management Center, North Carolina State University

[7] Spranghersa T, Michielsc J, Vrancxa J 2018 Gut antimicrobial effects and nutritional value of black soldier fly (Hermetia illucens L.) prepupae for weaned piglets Animal Feed Science and Technology Vol. 235 pp 33-42

[8] Tran G, Gnaedinger C, Mélin C 2015 Black soldier fly larvae Feedipedia a programme by INRA, CIRAD, AFZ and FAO http://www.feedipedia.org/node/16388

[9] Ushakova N A, Nekrasov R V 2015 Perspectives of using insects in feeding agricultural animals, Biotechnology: status and perspectives of development Theses of viii Moscow international congress ZAO Expo-biohim-tehnologii, RHTU named after D I Mendeleev (Moscow) March 17-20 2015 pp 147-149

[10] Federal law "On the sanitary-epidemiological welfare of population" N 52-FZ of 30.03.1999

[11] Federal law "On environmental protection" N 7-FZ of 10.01.2002

[12] Federal law "On ecological expertise” N 174-FZ of 23.11.1995

[13] Aquavitro Official site Access mode: http://aquavitro.org/2018/07/23/enterra-poluchila-razreshenie-prodavat-muku-iz-nasekomyx-v-ssha-kanadu-i-evropu/ Access mode: 23.07.2018