The Poultry Waste Management System

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Abstract. Wastes Management System is a set of measures to collect, transport, recycle, reuse or dispose of wastes, as well as control over implementation of these processes. In agriculture, the system primarily aims at environmental safety of production by recycling agricultural wastes. Disposal of organic animal wastes is main task of the system. Fresh bird excrement from poultry farms is unsafe for human, being the 3rd class environmental hazard. Proposed by us technology of bird excrement utilization is new, having no analogues in Russia. Based on process of excrement bioconversing by Black Soldier Fly's larvae (Hermetia illucens L.), it solves a number of problems: environment protection from toxic poultry farming’s wastes (bioconversion speed: 3.7...7.6 kg/m²/day), production of ecologically clean fertilizers – zoohumus (output: 11.3…14.8% per 1 kg of wastes), and obtaining high-protein food additive for poultry (1.9…3.5 kg of larvae/day/m²). The system is profitable and of low costs: adding Fly’s larvae to the poultry’s food, consumption of combined feeds can be reduced by 49%; 360 kg of zoohumus per 1m² is produced by recycling 3 tons of excrement by larvae; selling larvae as high-protein food additive is 28 times as much in contrast to selling excrement as granular fertilizer.

1. Introduction

Traditional methods of domestic organic wastes disposal are focused on reducing wastes’ dangerous impact on the environment by isolating landfills, cleaning discharge of waste incineration plants, as well as organisation of agriculture organic waste management system. This system provides development of an integrated complex of organisational, managerial, juridical, regulatory, methodological, technical and economic means related to the management of agricultural waste.

As of today, one of the priorities in Russia is to increase the volume of agricultural production, ensuring food security of the country, thereby meeting the needs of the population in local products and organizing its sustainable export. Taking into account the experience of the advanced agricultural countries (China, India, USA, etc.), the problem of ensuring environmental safety of agricultural production which is associated with rational use of natural resources and recycling of agricultural waste becomes urgent. First of all, this is the problem of disposal of large volumes of organic waste from animal husbandry: manure and droppings from farm animals and poultry. At the moment, one farm enterprise is capable to produce up to 300 – 450 thousand tons of these organic wastes per year [9]. In particular, one poultry farm of average power is capable to produce about 30 tons of bird droppings daily. Bird droppings are unsafe for human health and belong to the 3rd class of environmental hazard, and according to a number of current laws, namely, "On ecological expertise"
Modern practice of agricultural waste utilization offers several ways to destroy bird droppings, that is digging directly into the soil; chemical, biological, and physical methods [10, 11, 12, 13, 15]. Offered by us the technology of utilization of fresh and old bird droppings is absolutely new, having no analogues in Russia. It is based on the bioconversion process of droppings from poultry farms by Black Soldier Fly larvae (Hermetia illucens L.). The technology is intended for solving such important tasks as protection of the environment from toxic waste of the poultry industry; production of an ecologically clean fertilizer – zoohumus (the waste product of larvae), and most importantly, obtaining high-protein food additive for poultry, in the form of live larvae or high-protein feeding meal made of Fly's larvae.

Black Soldier Fly is a large American fly from the Soldier family (Stratiomyidae), the natural distribution area of which is considered to be North and South America, although the insect is able to develop in a pure environment in a closed space of artificial conditions year-round, which enables the use of the species for biotechnological purposes, for the bioconversion process [1,2,3,5,6,7,8].

Studies on adding Black Soldier Fly larvae to the poultry’s daily allowance were carried out only on the basis of the research Institute of Organic Agriculture (Switzerland). Feeding meal made of dried larvae was used as a food additive for small groups of laying hens of Lohmann breed. Feeding allowance contained 12 g and 24 g / 100 g of larvae instead of 50 or 100% soybean cake. After three weeks of feeding with such allowance, there were not any significant differences in egg production and feed consumption between experimental groups [2, 14].

The purpose of our work is to develop the waste management system for poultry farms with the help of bioconversion of poultry droppings by Black Soldier Fly larvae with further use of larvae in poultry food as a high protein food additive.

2. Methods

The proposed system of agricultural waste management (in particular, hen droppings) was studied on Uemskaya Poultry Farm in Arkhangelsk region producing 3-4 tons of droppings daily on average. Studies of bioconversion process of Black Soldier Fly larvae were made in cooperation with LLC NordTehSad on the basis of the agricultural enterprise AO "Vazhskoe," selo Blagoveshenskoe, Velsk district, Arkhangelsk region, Russia. To utilize droppings of the Uemskaya Poultry Farm we developed the technology on the basis of gravimetric (estimated) method of measuring both larvae and utilized feed. Before the experiment began, the control weighing of 10 larvae was carried out ten times to determine their initial mass, and then the average mass of one larva was calculated (M av.larva = 0.009 g). 7-10 days old (from the day of laying) larvae were used in the experiment. The density of larvae arrangement per 1 cm² in a container was 50 and 100 pieces / cm². Experiments were carried out in containers, the size of which depended on the density of arrangement that is 9.5*14.5 *12.5 cm, where 12.5 is the height (for arrangement density of 50 pieces / cm²) and 22*27*14.5 cm, where 14.5 cm is the height (for arrangement density of 100 pieces /cm²).

The loading of larvae into the containers was performed by means of gravimetric method taking into account the mass of a single larva, container’s area, and the optimum density of larvae arrangement. Once the loading had finished, pre-weighed food was added. The food portion was calculated depending on fly’s larvae mass. Hen droppings served as food in its pure form (experiment #1) and droppings mixed with spoiled fodder barley soaked in milk (experiment #2). The experiment of studying the bioconversion had been lasting for 6-7 days.

The research was performed in a production room, having the same conditions for keeping larvae and one type of feeding for them: room temperature is 28 ° C, humidity is 75-85%. Feeding took place only in the morning hours of each experiment day.

At the end of the experiment there was re-weighing of residual feed and Black Soldier Fly larvae by means of the gravimetric method. The average daily increase in the Fly larvae’s biomass and the mass of eaten feed for the entire period of experiment, as well as the actual yield of live larvae for
further use as a feed additive in poultry feed, were calculated on the basis of the results. The results were statistically processed using STATISTICA, version 10, StatSoft, Inc., 2011 with calculation of arithmetical mean values and standard errors.

3. Results

Efficiency of the hen dropping bioconversion process by Black Soldier Fly larvae with further use of larvae as high-protein food additive in poultry feed was calculated by means of statistical indicators of the larvae biomass at the beginning and the end of the experience, droppings bioconversion, and actual yield of live larvae at the end of the experiment (table 1).

Table 1. Data on hen droppings bioconversion.

| Experiment number | Larvae arrangement density, pieces / cm² | Weight of larvae, g | Feed mass, g | Bioconversion, kg/m²/day | Average daily increase in larvae biomass, kg/day/m² | The output of zoogumus from 1 kg of waste, % |
|-------------------|-----------------------------------------|--------------------|-------------|--------------------------|-------------------------------------------------|------------------------------------------|
|                   | at the beginning of the experiment       | at the end of the experiment | at the beginning of the experiment | at the end of the experiment | at the end of the experiment |
| Experiment #1     | 50                                      | 65±1.02            | 235±2.17    | 720±1.23                 | 396±2.24                                       | 3.7±0.32                                | 1.9±0.02                                | 11.3                                      |
|                   | 100                                     | 130±2.28           | 329±2.69    | 1400±4.29                | 808±2.57                                       | 6.8±0.58                                | 2.3±0.03                                | 12.6                                      |
| Experiment #2     | 50                                      | 65±0.97            | 286±2.28    | 760±2.54                 | 281±1.77                                       | 4.7±0.19                                | 2.1±0.04                                | 13.1                                      |
| (Droppings+barley with milk) | 100                                      | 130±0.97           | 485±2.55    | 1090±3.51                | 320±1.30                                       | 7.6±0.47                                | 3.5±0.09                                | 14.8                                      |

According to the studies, at the end of the experiment the average daily growth in the Black Soldier Fly larvae biomass increased by average of 2.0...4.4 times. The maximum result is observed during bioconversion of hen droppings with the addition of frozen barley soaked in milk - 3.5 kg/day /m². With the optimum arrangement density of 100 pieces/cm², the larvae are able to dispose of 6.8 kg of droppings in its pure form from 1 m² per day, and when droppings contain barley soaked in milk the capacity of waste disposing increases 1.1 times and equals to 7.6 kg/m²/day. It should be noted that the mass of feed (droppings+barley in milk) at the end of the experiment also significantly decreased 3.4 times (1090 g and 320 g respectively). Due to the content of fat, amino acids and protein in milk, the obtained feed provides the larvae with a significant increase in weight and ability to accumulate a complex of macro- and microelements in their organism. It enlarges the nutritional value of the larvae and ability to use it as a food additive in a poultry diet.

As a result of droppings bioconversion by Black Soldier Fly, it appears to be able not only to recycle droppings but also to provide the poultry farm with its own feed, which shows double benefit and fully complements each other – the larvae recycle the poultry farms waste, and become good feed for birds. The proposed technology makes it possible to supply poultry farms with 2-3 kg/m²/day of live or dried larvae as a high protein additive to the poultry diet.

According to researches, the output of zoogumus during hen droppings bioconversion is an average of 11.3...of 14.8% per 1 kg of waste. Its use as a complete organic fertilizer in local nursery gardens, arboretums and farms of the region will enable to locally produce organic cereal, fruits and vegetables.

The waste management system offered by us for poultry farms (figure 1) clearly shows in details all stages of poultry farming waste utilization with their further recycling and use of the received production.
Figure 1. The poultry waste management system by means of poultry droppings bioconversion by Black Soldier Fly larvae.

The proposed system solves several problems at once: disposal of poultry waste; providing poultry farms with their own food in the form of live or dried fly larvae, as well as providing agricultural enterprises with an organic fertilizer (zoohumus) for growing crops with the further use of grain as the main ingredient in poultry feed. Also, when producing combined feeds, it is possible to add crushed dried larvae into them which will reduce the rate of feed application and consumption in the bird diet due to its high energy efficiency.

After having calculated technical and economic indicators (table 2) it was determined that the offered waste management system by means of hen droppings bioconversion by Black Soldier Fly larvae on the example of Uemskaya Poultry Farm is characterised by profitability and low economic costs of production with the maximum efficiency of wastes utilization process that is especially actual for development of ecological orientation of the region.

Table 2. Feasibility study of the waste management system of Uemskaya Poultry Farm.

| Technical and economic indicators                                      | Per all poultry population |
|------------------------------------------------------------------------|-----------------------------|
| Amount of feed consumed kg/day                                         | 2052                        |
| Costs of combined feed, 16 rub/kg                                      | 32832                       |
| Droppings amount (humidity 71%), kg/day                                | 3000                        |
| Droppings bioconversing workshop area, m²                              | 107²                        |
| Resulting larvae biomass, kg/day                                       | 1014                        |
| Zoohumus amount, kg/day                                                | 360                         |
| Droppings price for selling, rub/day                                   | 1605                        |
| As fertilizer, 6 rub/kg                                                | 7200                        |
| As larvae, 200 rub/kg                                                  | 202800                      |
| Provision of poultry with feed by means of bioconversion technology    | 49                          |
| by Fly larvae, % of the day norm                                       |                             |

*² the area for daily disposal of droppings is in the numerator, the area after 15-day growing cycle of Black Soldier Fly larvae is in the denominator.

When implementing proposed waste management system for poultry farms, feed consumption can be reduced by 49% having replaced part of the poultry’s diet with live or ground Black Soldier Fly larvae. As a result of the disposal of 3 tons of poultry droppings the yield of live larvae per day is 1014 kg, zoohumus - 360 kg per 1m², which defines this system as highly promising and cost-effective for the development of farming in the region. However, at the moment, due to the lack of automated conveyor belts for the implementation of waste bioconversion by Fly's larvae, the proposed technology is rather labour-intensive and is characterized by large amount of manual labour. As a result, the
larva's commercial value increases (up to 200-500 roubles (3-7 €) per 1 kg), which makes it necessary to create an automated system for poultry waste disposal.

Economic advantage of the bird droppings recycling by larvae is also due to the fact that revenue after selling larvae is larger than selling droppings as a fertilizer for farms. Revenue from selling hen droppings as a granular fertilizer is 7200 roubles/day (102 €/day) on average while using the proposed technology of waste disposal will increase income from selling larvae up to 202800 roubles / day (2872,57€/day), which is especially effective for the development of the Arkhangelsk region economic potential.

4. Discussion

The maximum bioconversion in proposed waste management system of bird droppings by Black Soldier Fly larvae is provided by larvae with optimal arrangement density of 100 pieces/cm² which are capable of recycling 6.8 kg of hen droppings in their pure form from 1 m² per day in a short time; and recycling 7.6 kg/m²/day when droppings contain spoiled fodder barley soaked in milk.

The waste management system for poultry farms, implying bioconversion of poultry droppings, enables solving a number of problems: recycling poultry waste, providing poultry farms with their own food in the form of live or dried Fly larvae, as well as providing agricultural enterprises with an organic fertilizer (zoogumus). The system is characterized by profitability and low economic costs: poultry farms will be able to have 49% provision with poultry feed as live Fly's larvae or as high-protein feeding meal made of larvae. The system is capable of the most ecologically efficient disposal of poultry farms’ waste, and provides an opportunity to obtain additional income when selling Fly’s larvae to concerned companies producing combined feed for productive and non-productive animals. It is of high importance to continue research on this topic and work on the creation of automated lines for organic waste bioconversing.

5. Resources

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