Equalization of the moisture content of the mixture for obtaining fertilizers from high-moisture waste of poultry farming by extrusion

M A Potapov¹, A A Kurochkin¹, and D I Frolov¹,²

¹ Penza State Technological University, 11, Gagarin Str., Penza, 440039, Russia
E-mail: *frolovdmiv@gmail.com*

Abstract. The article examines the problem of processing poultry waste using extrusion technology. Bird droppings contain elements necessary for plant nutrition. This chemical composition makes it a valuable organic raw material for use as organic fertilizer. However, manure requires processing before being introduced into the soil. The main goal of the study is to reduce the moisture content of the mixture of high-moisture poultry waste to a level sufficient for high-quality extrusion into fertilizer. Reducing the moisture content of the mixture is possible by mixing them with vegetable fillers. Litter components or plant waste were selected as fillers. As a result of measuring the moisture content of the components of the mixture, it was determined: poultry manure with litter (PP) turned out to be the least wet and can be used for processing by extrusion; bird droppings from young stock (PM) and bird droppings from adult birds (PV) can be used for extrusion processing when mixed with vegetable fillers in a ratio of 1: 1 and 1: 2, respectively.

1. Introduction

The development of agriculture in Russia has affected poultry farming both by an increase in the number of farms that meet the personal needs of the owners and by the organization of large poultry farms. Modern breeding and use of poultry is characterized by a high concentration of livestock and significant volumes of production wastes (poultry droppings, waste from incubation and slaughter of poultry, dead birds, etc.).

Analyzing the percentage of various types of waste from poultry keeping per year on the example of one farm for breeding chickens per 100 - 150 heads, one can see that the highest proportion - 98.45% belongs to the litter. Other waste is segregated as follows: incubation waste 0.64%, dead birds 0.1%, slaughter waste 0.71%, feathers and down waste 0.1%. The percentage of waste is directly related to the livestock population.

Litter can be divided into two types - fresh and rotted. Fresh droppings account for approximately 73% of the total.

Fresh bird droppings (chicken, duck, goose, etc.) are classified as hazard class III by the Federal Waste Classification Catalog of Russia (FKKO). Agricultural producers have to pay for the placement and storage of such waste on the basis of a decree of the government of the Russian Federation from January 1, 2017. At the same time, rotted manure belongs to the IV hazard class and its storage does not require additional payments.

Based on the above, we can conclude that at present there is a problem of processing fresh poultry
manure [1]. Large volumes of excreted droppings are due to its high humidity (up to 85%). The rest of the production wastes belong to the IV (rotted droppings, waste of feathers and down) and V (waste of incubation and slaughter of poultry) hazard classes, which are not encumbered with payments for placement. Their storage and disposal does not require such volumes of storage facilities and difficulties with processing as in fresh manure.

Bird droppings contain elements necessary for plant nutrition. This chemical composition makes it a valuable organic raw material for use as organic fertilizer [2]. However, manure requires processing before being introduced into the soil [3].

The most promising method at present is the processing of poultry waste using extrusion [4, 5, 6]. The important indicators that affect the performance of the thermal vacuum extruder are the humidity and consistency of the droppings [7].

Most models of food extruders are limited by the moisture content of the processed raw materials 12 - 45% [8, 9, 10]. The moisture content of the initial raw material that does not correspond to this range does not provide a change in its characteristics and properties [11, 12]. High-moisture raw materials are poorly homogenized and insufficient formation of a porous structure occurs at the exit from the extruder die [13, 14, 15].

The main goal of the study is to reduce the moisture content of the mixture of high-moisture poultry waste to a level sufficient for high-quality extrusion into fertilizer. To achieve this goal, it is necessary to solve the problem of developing an optimal mixture of poultry waste with vegetable fillers.

2. Materials and methods

To process waste and obtain organic fertilizer, the processed raw materials are crushed using a crusher to a particle size of no more than 10 mm, followed by processing in an extruder equipped with a vacuum chamber with a pneumatic steam suction.

Samples of three types of poultry droppings were taken as poultry waste (Figure 1): poultry droppings with litter (LB); bird droppings from young animals (PM); bird droppings from adult birds (PV).

![Figure 1. Bird droppings: a - bird droppings with litter (PP); b - bird droppings from young animals (PM); c - bird droppings from an adult bird (PV).](image)

The following equipment was used to measure the initial moisture content of dung and vegetable fillers: thermogravimetric infrared moisture meter MA-45 C "Sartorius", laboratory scales of the 4th accuracy class MASSA VK-300.1.

Some plant materials (straw, fallen leaves and waste waste) later used as filler were crushed on a crusher to a size of 10 mm. As fillers to create the mixture were used: straw, grain waste, coniferous sawdust, deciduous sawdust, fallen leaves, waste paper.

Three analyzes were carried out with each of the dung types and vegetable fillers at 60, 70 and 90 °C. A sample weighing from 1.5 to 2.5 g was placed in an aluminum container for sampling and dried at a given temperature until the device was turned off.

To clarify the formulation of the created fertilizer in order to achieve the moisture content of the
processed mixture of 27 - 32%, the amount of used vegetable filler was calculated by the formula:

\[ m_p = \left( \frac{f_p + f_n}{f_{sm}} - 1 \right) m_p \]

where \( m_p \) is the mass of the vegetable filler, kg; 
\( f_p \) is the humidity of droppings,%; 
\( f_n \) is the moisture content of the filler,%; 
\( f_{sm} \) is the moisture of the processed mixture,%; 
\( m_p \) is the weight of droppings, kg.

3. Results and discussion
The results of measuring the moisture content of all types of litter showed that bird droppings with litter (PP) was the least wet. The results of the analyzes performed are presented in table 1.

| Litter type | Humidity at temperature, % | Average humidity, % |
|-------------|-----------------------------|---------------------|
|             | 60 °C | 70 °C | 90 °C |                   |
| PM          | 47.78 | 48.15 | 48.61 | 48.18 |
| PV          | 64.10 | 64.45 | 65.04 | 64.53 |
| PP          | 28.07 | 28.21 | 28.32 | 28.20 |

The moisture content of bird droppings with litter depends on the material of which the litter is composed. If chopped straw, sawdust or grain waste is taken as the basis, then the moisture is usually 23-31%, and when using peat 35-48%. This type of manure is superior to that of the other two groups in terms of the content of the mass fraction of organic matter, as well as nitrogen, phosphorus and potassium due to the plant components that make up the litter.

As vegetable fillers for the developed mixture, both components used as bedding (straw, sawdust, grain waste) and various waste (fallen leaves, waste paper) were taken. To ensure the efficiency of the working process of the energy-saving technology for processing poultry waste, the moisture content of the vegetable filler should be 5-15%. Peat was not used as a filler as it is a good fertilizer in itself.

The results of measuring the mass fraction of moisture in fillers are presented in table 2.

| Filler           | Humidity at temperature, % | Average humidity, % |
|------------------|-----------------------------|---------------------|
|                  | 60 °C | 70 °C | 90 °C |                   |
| Straw            | 7.19  | 7.23  | 7.27  | 7.23              |
| Grain waste      | 10.44 | 10.46 | 10.52 | 10.46             |
| Coniferous sawdust | 10.42 | 10.43 | 10.45 | 10.43             |
| Deciduous sawdust | 11.91 | 11.94 | 11.95 | 11.93             |
| Fallen leaves    | 8.24  | 8.25  | 8.27  | 8.25              |
| Waste paper      | 7.19  | 7.23  | 7.27  | 7.23              |

The moisture percentage of each of the herbal filler samples taken is within the required range of 5 - 15%, which will ensure sufficient moisture absorption when mixed with the droppings. Achievement of the required particle size of the filler, which provides better moisture absorption, is carried out by preliminary grinding.

The development of a fertilizer formulation for energy-saving technology consisted in the selection of the correct ratio of mixed components. To achieve the desired result, the PM (average moisture
48.2%) was mixed with all vegetable fillers in a 1:1 ratio. With each of the resulting mixtures, three analyzes were carried out to determine the moisture content on a moisture meter at a temperature of 60, 70 and 90 °C. The average measurement values of the mass fraction of moisture in the resulting samples are presented in Table 3.

**Table 3. Mix moisture (litter with vegetable fillers in a 1:1 ratio).**

| Litter type | Sample moisture depending on vegetable filler, % | Straw | Grain waste | Coniferous sawdust | Deciduous sawdust | Fallen leaves | Waste paper |
|-------------|-----------------------------------------------|-------|-------------|-------------------|------------------|---------------|-------------|
| PM          |                                               | 27.7  | 29.4        | 29.5              | 29.6             | 28.2          | 26.2        |
| PV          |                                               | 35.6  | 37.0        | 37.1              | 38.7             | 35.6          | 34.6        |

The results of the analyzes show that a decrease in the moisture content of the mixture is possible when PM and PV are combined with vegetable fillers in a 1:1 ratio. The resulting moisture content of the waste mixture is sufficient for processing in an extruder. The optimal recipe for moisture content will provide the required moisture content and texture of the finished product.

The results of the analyzes of moisture content for determining the mass fraction of moisture in a mixture with vegetable fillers in a ratio of 1:2 are presented in Table 4.

**Table 4. Mix moisture (litter with vegetable fillers in a 1:2 ratio).**

| Litter type | Sample moisture depending on vegetable filler, % | Straw | Grain waste | Coniferous sawdust | Deciduous sawdust | Fallen leaves | Waste paper |
|-------------|-----------------------------------------------|-------|-------------|-------------------|------------------|---------------|-------------|
| PV          |                                               | 26.4  | 28.4        | 28.5              | 29.5             | 27.2          | 25.0        |

According to the results of the analyzes, it can be seen that the decrease in moisture, with a ratio of PV and vegetable filler of 1:1, although it is sufficient for processing in an extruder, will not be able to provide the necessary moisture content of the finished product for its preservation. Therefore, for this type of manure, the amount of vegetable filler was increased to a ratio of 1:2.

4. Conclusion

The main waste of poultry farming is manure of various types, which accounts for almost 98.5% of the total amount of poultry waste and requires storage fees and special disposal conditions. The most promising method at present is the processing of poultry waste by means of extrusion. The important indicators that affect the performance of the thermal vacuum extruder are the moisture content and the consistency of the droppings.

Reducing the moisture content of the mixture of high-moisture poultry waste to a level sufficient for high-quality extrusion into fertilizer is possible by mixing them with vegetable fillers. Litter components or plant waste were selected as fillers.

The influence of vegetable fillers on the safety of the finished product was investigated, which consists in reducing the moisture content of the fertilizer to 15% or less, which excludes the development of decay and decomposition processes. The optimal mixture for creating fertilizer from poultry waste with the addition of vegetable fillers, which consists in mixing manure with fillers, until the mixture reaches a moisture content of 28-33%. As a result of measuring the moisture content of the components of the mixture, it was determined: poultry manure with litter (PP) turned out to be the least wet and can be used for processing by extrusion; bird droppings from young stock (PM) and bird droppings from adult birds (PV) can be used for extrusion processing when mixed with vegetable fillers in a ratio of 1:1 and 1:2, respectively.

References

[1] Petric I, Helić A, Avdić E A 2012 Bioresource Technology Vol 117, 107-116
https://doi.org/10.1016/j.biortech.2012.04.046

[2] Sun T, Xiao W, Jiang C, Wang J, Liu Z 2019 Bioresource Technology Reports Vol 7, 100268 https://doi.org/10.1016/j.biteb.2019.100268

[3] Kong X, Xu S, Liu J, Li H, Zhao K, and He L 2016 Journal of Environmental Management Vol 166, 31-37 https://doi.org/10.1016/j.jenvman.2015.10.002

[4] Bianchini A, Stratton J, Weier S, Hartter T, Plattner B, Rokey G, Hertzl G, Gompa L, Martinez B, and Eskridge A M 2012 J Food Prot Vol 75, 1646-1653 https://doi.org/10.4315/0362-028X.JFP-12-085

[5] Alam M S, Kaur J, Khaira H, Gupta K 2016 Crit Rev Food Sci Nutr Vol 56, 445-475 https://doi.org/10.1080/10408398.2013.779568

[6] Dou Z, Toth J D, Westendorf M L 2018 Global Food Security Vol 17, 154-161 https://doi.org/10.1016/j.gfs.2017.12.003

[7] Frolov D, Kurochkin A, Garkina P, Zimnyakov V, Kukharev O 2019 Volga Region Farmland Vol 2(2), 87-94 https://doi.org/10.26177/VRF.2019.2.2.020

[8] Martin A, Osen R, Greiling A, Karbstein H P, Emin A 2019 Aquaculture Vol 512, 734316 https://doi.org/10.1016/j.aquaculture.2019.734316

[9] Dalbhagat C G, Mishra H N 2019 Journal of Cereal Science 89, 102782 https://doi.org/10.1016/j.jcs.2019.05.016

[10] Wan L, Li L, Jiao W, Mao L, Li B, Zhang X 2018 LWT 98, 398-405 https://doi.org/10.1016/j.lwt.2018.08.019

[11] Frolov D, Potapov M 2020 Innovative Machinery and Technology Vol 2 (23), 42–47

[12] Liu C, Zhang Y, Liu W, Wan J, Wang W, Wu L, Zuo N, Zhou Y, Yin Z 2011 Journal of Cereal Science Vol 54, 473-480 https://doi.org/10.1016/j.jcs.2011.09.001

[13] Filli K B, Nkama I, Jideani V A, IBOK I U 2012 Nigerian Food Journal Vol 30, 82-100 https://doi.org/10.1016/S0189-7241(15)30017-5

[14] Guo Q, Joseph M, Setia R, Vikhona H, Sharma K, Alavi S 2018 Journal of Cereal Science Vol 79, 486-493 https://doi.org/10.1016/j.jcs.2017.12.012

[15] Kamarudin M S, Cruz C R, Saad C R, Romano N, Ramezani-Fard E 2018 Animal Feed Science and Technology Vol 236, 122-130 https://doi.org/10.1016/j.anifeedsci.2017.12.007