Innovative technology to obtain forage flour from keratin-containing waste by extrusion

V N Vasilenko, L N Frolova, N A Mikhailova and I V Dragan

Voronezh State University of Engineering Technology, 19, Revolution Ave., Voronezh, 394036, Russia

E-mail: vvn-1977@mail.ru

Abstract. When processing animals and birds in the form of by-products, a fairly large amount of keratin-containing waste (horns, hooves, hair, wool, fluff and feather) was formed. In secondary poultry evisceration products, almost 80% of the protein is found in feather-down raw materials, so solving the problem of converting pen keratin into a digestible form is more important from the point of view of mobilization of native protein reserves and environmental problems. To produce a high-quality feed product, which preserves the biological value of the raw materials as much as possible, it is necessary to minimize the time of heat treatment. At the same time, it is desirable to use cost-effective and environmentally friendly technologies. The latest biological waste recycling techniques that meet these requirements include extrusion technologies. The article proposes the technology of obtaining a forage protein supplement, which can completely replace fish flour in the diet without reducing the zootechnical and feasibility indicators of growing poultry, valuable species of fish and furry animals. The main advantage is that none of the existing technologies in the world without rigorous chemical treatment is not able to bring the digestion of keratin of feather raw materials to 85-90% in 1.5 minutes of processing with maximum preservation of the most valuable amino acids. We presented the results of the production check on the effectiveness of feeding extruded feed with feed additive from keratin-containing waste for fish, providing a significant increase in body weight growth and improvement of meat.

1. Introduction
The poultry industry is one of the leading agricultural industries and is able to meet the population's need for raw materials. The bird provides the products in the necessary quantity regardless of the season of the year, but further development of production is constrained by a limited amount of feed. Lack of individual components, such as raw protein, a balanced amino acid composition for feed production, is a major factor inhibiting the increase in poultry population, reducing its productivity and increasing costs feed for production [1, 2].
The few Russian enterprises producing feed for fish (the share of domestic products in the market of feed for salmon, sturgeon, whitefish and catfish varies between 5-10%), import technology, equipped with imported technological equipment. The recipes for feed for fish include mainly imported raw materials (fish flour, blood flour, soybean meal, etc.). Due to the high cost of such feeds, the cost of commercial fish products also increases significantly.
The use of food waste in modern feed production will provide deep processing of food raw materials of animal and plant origin, reducing the cost of production of basic products by selling additional
products. There is also expanding the range of modern forage base, development of agro-industrial complex, which will make food and processing shops environmentally safe.

The search for new raw materials for the production of feed, the development of the technology of its manufacture are topical issues for the modern agro-industrial complex [3-7].

Food waste is an easily renewable cheap and affordable source of raw materials for new high-quality and nutritious feeds and after appropriate treatment it can acquire feed properties that are 1.5-3 times higher than the forage grains of good quality [8, 9].

According to official data of the Ministry of Agriculture of the Russian Federation, in the first 8 months of 2017, the production of poultry for slaughter in body weight amounted to 4.01 million tons, which is 7.4 % more than a year earlier - during the same period of time only 3.7 million tons of meat were produced. The Ministry noted that several regions provided this increase. Among them there are Voronezh, Tambovskaya, Belgorodskaya, Kursk. In poultry production, the Voronezh region is in the 16th place - 133.5 thousand tons in body weight (99.6 thousand tons in slaughter weight) - 2.2 % of the Russian production of poultry meat (Table 1).

| Scorecards                  | PF 10 million heads per year, tons per year | Total for Russia, thousands of tons per year |
|-----------------------------|--------------------------------------------|---------------------------------------------|
| Live bird mass              | 22000.0                                    | 3200.0                                      |
| Feather dry                 | 880.0                                      | 128.0                                       |
| Total waste for recycling   | 6574.0                                     | 950.6                                       |

For example, the volume of low-value (secondary) products received during poultry processing is almost 1.0 million. And this is a significant problem in the poultry industry. At the same time, secondary products are a valuable source - animal protein. The animal protein content in by-products is almost 200.0 thousand tons (Table 2).

| Scorecards                  | PF 10 million heads per year, tons per year | Total for Russia, thousands of tons per year |
|-----------------------------|--------------------------------------------|---------------------------------------------|
| Protein mass                | 1386.0                                     | 200.1                                       |

2. Setting a problem

The current state and dominant technology for the production of aquaculture feeds, which is based on "fish feeding" (that is fish meal feeds and fish oil), do not meet the goals of long-term sustainable development of the world's rural and severely restrict the development of aquaculture [10].

Thus, in the field of aquaculture, the qualitative and quantitative limitations of traditional feed-producing technology based on fish meal and fish oil do not provide the necessary rates at present or in the future the development of an industry in need of increasing food. Although it is aquaculture that the world community has the task of adequately responding to challenges such as population growth, hunger and environmental problems.

Effective and competent use of all types of forage protein - animal and plant origin - is a priority and serves as a basis for the preservation of the environment by reducing emissions of undeveloped nitrogen and phosphorus into reservoirs.

One of the sources of animal protein is recycled raw materials obtained from poultry processing, in particular, feather raw materials. Assessment of the per-puff raw materials allows us to positively assess the potential of these protein resources [11, 12]. They contain up to 85% protein with a near-complete set of amino acids. Keratin (proteins) is highly resistant to the effects of various reagents and is not broken down by enzymes of digestive juices of humans, animals and birds that is almost
indigestible. Therefore, in order to use this secondary raw material rationally, disulfide bonds must be broken down in the protein molecule.

Recycling of poultry waste and poultry processing is becoming increasingly economic, significantly increasing the cost of poultry production. This fact has a significant impact on the competitiveness of poultry farms right now. It will be further affected in the future, as there is a tendency to increase the cost of fish flour and strengthen state control over compliance with environmental legislation, as well as overall increased competition in the market [13].

The efforts of the researchers are aimed at finding ways to break the disulfide bridges, which will allow one to transfer keratin from unassimilated to digestible form. Traditional technologies, both domestic and foreign, allow one to obtain from waste feed flour with low absorption protein (digestion of protein 25-50%), while 50-75% of available protein is lost due to the harsh temperature hours-long processing process [14, 15]. In addition, traditional processing processes require significant energy and pollute the environment.

3. The purpose of the work
Development of the technology of obtaining forage flour from keratin-containing waste for fish using extrusion.

4. Research materials and methods

4.1 Objects of study
There is a method of extrusion in the processing of keratin-containing waste with the help of an extruder, implementing the principle of thermovacuum impact on raw materials.
In the proposed technology of processing keratin-containing waste into feed flour, the process is divided into several stages: preparing raw materials for the process of extrusion, extruding, grinding and packaging of Figure 1.

During the preparation for the extrusion process, the raw materials are dried up to 28% humidity and cleaned of mechanical impurities. In the second stage, the pen is fed into the extruder and pushed into its barrel by the pressure of the screw press. In the trunk of the extruder we gradually raise the temperature, while increasing the pressure. The feather from a solid state goes into a melting state. The undigested keratin protein of the pen is transformed into a polyspecies amino acid containing 90% of the digestible raw protein. At this stage, the pen turns into a crumbly product of cylindrical shape. In the third stage, the pen is crushed and packed in flour.

Figure 1. Technology to obtain forage flour from keratin-containing waste by extrusion: 1 – storage hopper, 2 – dispenser, 3 – screw conveyor, 4 – press for pressing moisture, 5 – screw extractor, 6 – screw, 7 – extruder, 8 – dryers, 9 – heater, 10 – fan, 11 – hopper, 12 – chopper, 13 – filling machine
The main advantage of this technology is the transition from many hours (6-12 hours) of discrete processing of raw materials with high initial humidity (more than 80%) to the short-term processing of semi-dry raw materials at a temperature of more than 160 ° for 60-90 seconds. The short duration of hydrothermal treatment ensures the almost complete preservation of thermolabile amino acids in a physiologically digestible state. At the same time, through 10 with hydrothermal treatment, the industrial sterility of the puff-feather raw materials is achieved. The proposed technology ensures that industrially sterile protein concentrates are obtained from the pen while maintaining their feed value almost completely. Protein content and digestibility of supplements are more than 85 % at humidity of 6-8%.

4.2 . Research Methods

The used work generally accepted standard and original research methods [16-18]. The results were recorded and processed by statistical and regression analysis methods. Sampling and preparation for analysis were conducted on GOST P 51447-99; GOST P 51448-99. Physics and chemical indicators were determined by standard methods by GOST P 51479-99.

The mass share of the protein was determined by Kjeldal's method by GOST 25011-2017. The method is based on the mineralization of the sample's organic matter followed by the determination of nitrogen by the amount of ammonia formed.

The mass proportion of amino acids was determined on an amino acid analyzer based on the liquid chromatograph "LC-20 Prominence" (Shimadzu). The separation and definition of amino acids was carried out by the method of ion-exchange chromatography with post-color derivation of ninhydrin.

The mass proportion of fat was determined by the GOST method 23042-2015. The method is based on repeated extraction of fat by solvent from the dried analyzed sample in the extracting apparatus of Soxlet, followed by the removal of the solvent and the drying of the allocated fat to a constant mass.

The mass share of ash was determined by the GOST method 31727-2012. The principle of the method is based on drying, charring, ash at a temperature (550±25) of the sample for testing and subsequent determination of the mass share of common ash.

5. The results and their discussions

Based on the research, the technology of obtaining forage flour from keratin-containing waste for canal has been developed and tested in the conditions of the testing laboratory of Pavlovskrybkhoz (Voronezh Oblast, Pavlovsk).

Analysis of the chemical composition of keratin-containing waste allows us to positively assess the potential of these protein resources. They contain up to 87 % protein with a near-complete set of amino acids. Table 3 presents the comparative content of protein and essential amino acids in meat-bone, fish and feed flour.

Table 3 shows that feed flour has the highest protein content of 86.2 %, but its concentration of lysine is less than in meat and fish flour, 1.41 and 3.40 times, respectively. The level of methionine is lower than that in fish flour, 2.44 times, but more than in meat-bone, 0.64 times.

Developed feed formulations using feed flour for canal catfish, balanced by the level of essential nutrients, essential amino acids, essential polyunsaturated fatty acids.

Table 3. Comparative content of protein and essential amino acids in raw materials

| Indicators, % | Meat-bone flour | Fish flour | Feed flour |
|--------------|----------------|------------|------------|
| Dry substance | 90.8           | 91.6       | 92.7       |
| Moisture     | 6.41           | 8.25       | 2.93       |
| Raw protein  | 50.3           | 70.8       | 86.2       |
| Raw fat      | 12.4           | 6.7        | 2.4        |
| Ash          | 20.14          | 15.21      | 1.67       |
| Lysine       | 2.24           | 5.41       | 1.59       |
| Methionine   | 0.64           | 1.98       | 0.81       |
| Cystine      | 0.34           | 0.65       | 4.16       |
In the development of new feeds (figure 2) modern solutions for replacing animal protein (fish, bone, bone flour) with new sources of full-fledged protein feed flour Performed balancing recipes of feed for young, production (optimal and economical) for the uterine herd.

![Figure 2](image)

**Figure 2.** a – recipe for channel catfish weighing up to 50 g, b – recipe for channel catfish weighing over 50 g

Developed feed formulations with programmable properties for canal catfish will increase the digestibility of feed by 10-12 %, increase weight by 12-17%, reduce the cost of final fish products by reducing the cost of feed by 10-15 % due to deep hydrothermal feed treatment in rational extrusion modes.

To study the impact of fodder flour, extruded on the experimental installation of extruder, on the basis of Pavlovskrybkhoz (Voronezh Oblast, Pavlovsk) we conducted an experiment on the channel catfish for different age groups according to the scheme shown in table 4.

| Table 4. Channel catfish’s feeding scheme |
|------------------------------------------|
| Feeding characteristics                   |
|                                          |
| **Control Group (Young)**         | **Experimental Group (Young)** |
| Basic diet (OR1), nutritionally balanced | OR1 with 100% replacement of fish flour with forage flour |

| **Control Group (Commodity Two-Year)** | **Experimental Group (Commodity Two-Year)** |
| Basic diet (OR1), nutritionally balanced | OR1 with 100% replacement of fish flour with forage flour |

| **Control Group (Commodity Three-Year)** | **Experimental Group** |
| Basic diet (OR1), nutritionally balanced | OR1 with 100% replacement of fish flour with forage flour |

Production tests were carried out to feed extruded feed with feed flour from keratin-containing waste for channel catfish: a recipe for young extrudate sized 3.0 millimeters; recipe for young, two- and three-year-old pellet sized 6.5 millimeters. In the production of feed we took into account that the channel catfish eats the feed, while it is in a suspended state.

Experiments were repeated 2 times. The control was young, commercial fish, which is grown on a production scale on a natural feed base and dry feeds, which were produced according to the recipe corresponding to GOST 23513-79 "Briquettes and feed pellets. Technical conditions." Canal catstome catbeater from the first days of cultivation actively consumed the test extruded feed with fodder flour from keratin-containing waste. When this feed was fed, the average daily increase in the live mass of canal catfish fish of all groups increased (table 5).
Table 5. Indicators of the productivity of channel catfish fish when feeding experimental batches of extruded feed with feed flour from keratin-containing waste

| Indicators                              | Control group (young) | Experimental group (young) | Control group (commodity two-year) | Experimental group (commodity two-year) | Control group (commodity three-year) | Experimental group of commodity three-year-olds |
|-----------------------------------------|-----------------------|---------------------------|-----------------------------------|----------------------------------------|--------------------------------------|-----------------------------------------------|
| Length of experience, days.             | 61                    |                           |                                   |                                        |                                      |                                               |
| Mass at the beginning of the experience, grams. | 31.25                | 32.29                     | 794.05                            | 805.12                                 | 1950.15                             | 2087.25                                       |
| Mass at the end of the experience, grams. | 53.48                | 57.56                     | 954.76                            | 977.18                                 | 2116.40                             | 2265.55                                       |
| Weight gain, grams.                     | 22.23                 | 25.27                     | 160.71                            | 172.06                                 | 166.25                             | 178.30                                       |
| Average daily increase in weight, grams. | 0.36                  | 0.41                      | 2.63                              | 2.82                                   | 2.72                                | 2.92                                          |
| Preservation, %                         | 89                    | 90                        | 92                                | 94                                     | 92                                  | 94                                            |
| Feed costs per kilogram of gain, kilograms. | 2.58                  | 2.45                      | 2.15                              | 1.86                                   | 2.05                                | 1.81                                          |

To characterize the nutritional value of channel catfish meat after feeding the developed feed, we determined the content of moisture, protein, fat and minerals, by the example of two-year-olds (table 6).

Table 6. The chemical composition of channel catfish meat

| Group               | Moisture ±%    | Protein ±%  | Fat ±%    | Minerals ±% |
|---------------------|----------------|-------------|-----------|-------------|
| Control             | 76.4 ±2.17     | 17.3 ±1.24  | 5.1 ±0.12 | 1.7 ±0.32   |
| two-year-olds       | 77.9 ±0.93     | 18.1 ±2.11  | 5.8 ±0.36 | 1.5 ±0.19   |

From the data of the production check of the effectiveness of feeding extruded production feed with feed flour from keratin-containing waste for canal catfish, it follows that as a result of the use of extruding for preparation of feed, we received a high-quality product, balanced on nutritional value, providing a significant increase in body weight and improvement of the chemical composition of meat.

6. Conclusions

Using the method of extruding the production of feed flour based on keratin-containing waste, the main condition for the production of feed is to obtain a high-quality protein product containing a complex of irreplaceable waste amino acids. Extrusion processing also makes it possible to extract up to 80 % of hard-to-reach dietary protein from low-value poultry processing products. At the same time, the nutritional value of the protein is preserved and increases its absorption, reduces raw material consumption per unit of production 2.7 times compared to traditional technologies.
References
[1] Kadyrov D, Garzanov A and Plitman V 2008 Extrusion processing of biological waste into feed Poultry 7 51-54
[2] Kurochkin A A and Frolov D I 2014 Feed production Technology based on thermo-vacuum treatment of agricultural waste Innovative technology and technology 4 36-40
[3] Antipova L V and Polyanskikh S V 1998 Use of secondary raw materials in technological processes of the poultry processing industry Izvestiya vuzov. Food technology 2 17-19
[4] Shevtsov A A, Tertychnaya T N, Tkach V V and Serdyukova N A 2019 Energy saving technology of allocation of protein-bearing fractions from oilseeds with use of the thermal pump Proceedings of Voronezh State University of Engineering Technologies 81 (2) 35-40
[5] Vasilenko V N, Frolova, L N, Mikhailova N A, Dragan I V and Tarkaeva D A 2019 Resource-Saving Press for Oil Extrusion from Plant Sources Russian Engineering Research 39 (7) 575-576
[6] Kairbayeva A, Vasilenko V, Dzhinguilbayev S, Baibolova L, and Frolova L. 2017 Development of the mathematical model for the process of oil raw materials pressing Journal of Engineering and Applied Sciences 12 (6) 7836-7842
[7] Ostrikov A N, Shevtsov A A, Lytkina L I, Shirikov D V and Kurmanakhynova M K 2015 Fish smoking process modeling International Journal of Applied Engineering Research 10 (21) 42682-42687
[8] Babich O O, Razumnikova I S, Poletaev A Yu and Morozova A I 2011 Processing of secondary keratin-containing raw materials and obtaining protein hydrolysates for food and feed purposes food production Techniques and technology 2 3-10
[9] Antipova L V, Pashchenko L P, Shamkhanov CH Yu and Kurilova E S 2003 Preparation and characteristics of food keratin hydrolysate Storage and processing of agricultural raw materials 7 63-66
[10] Vasilenko V N, Frolova L N, Dragan I V and Mihajlova N A 2019 Development of production extruded feed for tilapia industrial production Proceedings of Voronezh State University of Engineering Technologies 81 (1) 132-137.
[11] Perednya V I and Chumakov V V 2014 Obtaining a protein feed additive from waste from agricultural processing enterprises by extrusion Vestnik VNIMZH 1 (13) 38-42
[12] Shvanskaya I A and Konovalenko L Yu 2011 Use of waste from processing industries in animal husbandry: scientific. analyte. obzor (Moscow: FGBNU “Rosinformagrotech”)
[13] Agafonov G V, Novikova I V and Chusova A E 2015 Implementation of measures for occupational hygiene at enterprises of brewing industry Hygiene and sanitation 94 (9) 67-71
[14] Kurochkin A A, Shaburova G V and Voronina P K 2012 Regulation of functional and technological properties of extrudates of vegetable raw materials proceedings Izvestiya Samara state agricultural Academy 4 86-91
[15] Kurochkin A A, Shaburova G V, Frolov D I and Voronina P K 2014 Extrudates from vegetable raw materials with high lipid content Izvestiya Samara state agricultural Academy 4 70-74
[16] Petukhova E A, Bessarabova R f, Khaleneva L D and Antonova O A 1981 Zootechnical analysis of feed (Moscow: Kolos)
[17] Shentsova E S, Lytkina L I and Shevtsov A A 2015 Reduction of aflatoxin-producing fungi in infected grain by hydrothermal treatment methods Hygiene and sanitation 94 (9) 64-67
[18] Novikova I V, Yuritsyn I A and Muravev A S 2019 Effects of aeration intensity on the growth and activity of Brettanomyces bruxellensis Proceedings of universities. Applied chemistry and biotechnology 9 1 (28) 102-108