Techniques for up-to-date aquaculture compound feed production facilities

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Abstract. The subject of research was the techniques for the feed industry to select the main areas for improving the production of fish feed using promising competitive technologies and equipment. The research was carried out using information and analytical monitoring, as well as analysis and generalization of data obtained from open information sources. In the course of the research, the advantages of extrusion processes for the production of compound feed for aquaculture were identified and substantiated, in particular, such as sterilization; homogenization; stabilization of raw materials; increasing the digestibility of feed; reduced crumbling and less water pollution during feeding. These processes, due to their high efficiency and the possibility of using waste and secondary agricultural raw materials, can be considered as the best available technologies. The paper provides specifications of up-to-date feed extruders from foreign and domestic manufacturers. The advantages of using foreign technologies and equipment in the production of extruded fish feed at large enterprises are shown. It has been proven that mobile feed mills and mini-shops are promising for launching production directly at the farm using the available own raw materials and domestic equipment. The results of the work will contribute to the formation of an open source of information on the scientific and scientific-engineering groundwork in the field of innovative technologies and equipment for the production of feed for aquaculture. This includes providing their implementation at agricultural enterprises and the implementation of the state program of the Russian Federation titled ‘Development of the fishery industry’.

1. Introduction

The fishery sector plays an important role in ensuring the country's food security. At this stage, the importance of aquaculture is increasing. Currently, the world fish production is about 171 million metric tons where 53% (90.9 million metric tons) are fishery products and 47% (80 million metric tons) are aquaculture of the above-mentioned amount [1]. Russia's contribution to world aquaculture is now estimated at 0.3%. Annually, fish-breeding enterprises produce about 300,000 marketable products, while the fish catch is up to 5 million tons. Unsatisfactory state of fish feed production, low quality feed and limited assortment, as well as the lack of up-to-date feed production processes are among the main reasons hindering the development of aquaculture in the country. The domestic market is dominated by imported feed accounting for about 2/3 of the consumption amount [2]. The State Program of the Russian Federation titled ‘Development of the Fisheries Industry’ taking into
account the Food Security Doctrine has determined the achievement of the level of self-sufficiency in the main types of fish products in the amount of 85% by 2024. This is due to an increase in aquaculture production at a level of 6% to 10% annually. To ensure this output, high-quality domestic feed, new efficient processes and equipment are required.

2. Methods
The subject of the study was process equipment provision of the compound feed industry to select the main areas for improving the techniques of fish feed production facilities using domestic equipment and promising technologies for the preparation of compound feed having increased nutritional value, balance and uniformity. The study was carried out using information and analytical monitoring, analysis and generalization of open information sources regarding promising technologies and equipment for the production of animal feed.

3. Results and Discussion
Industrial production of feed in Russia is mainly represented by stably operating large factories (agricultural holding compound feed mills make up 61% of the total output, while feed mills for poultry farms and livestock complexes make up 27%. Independent feed mills make up 10%, and small-capacity feed shops make up 2% of the total output). The main aspects of effective production of compound feed are resource saving, reducing feed cost and improving feed quality. These parameters are largely determined by the correct choice of production organization that is most suitable for the conditions of a particular enterprise, and by the use of up-to-date processes and equipment. In this case, low-energy-intensive technical means, local raw materials and all the processes should be used that contribute to the highly productive action of the compound feed produced [3].

Table 1 summarizes the features, scope and advantages of the techniques of compound feed mills.

Thus, mobile compound feed mills are promising in the case of launching the production directly at a farm and using the available own raw materials.

It has been proven that currently the key link in the process for the production of high-quality compound feed, which meets up-to-date requirements, is various types of heat treatment of compound feed and its ingredients. Heat treatment is able not only to improve the nutrient properties of compound feeds and ensure its disinfection to the required level, but also helps to significantly expand the raw material base during its production. The analysis has showed that the current production of fish feed uses three manufacturing methods: pelletizing using a pellet press, expansion followed by pelleting, and extrusion.

As a result of the research, it has been proven that the most effective way to obtain fish feed, especially for valuable fish species, is the extrusion of raw materials. The main advantages of this technology are: sterilization of raw materials (pathogens, fungi, and mold are completely destroyed); increasing the digestibility of feed due to the rupture of molecular chains of starch and cell walls when leaving the extruder; homogenization (the product becomes completely homogeneous); stabilization (the action of enzymes that cause rancidity of the product is neutralized and anti-nutritional substances are inactivated); decrease in humidity.

In addition, the particles of extruded feed are more durable and their crumbling and screening is less than 1%, while those of pelleted feed are up to 8%. The use of extruded feed reduces the amount of particles entering the water when feeding fish by 75%, which significantly reduces water pollution [4–6]. The results of fish-breeding biological tests performed by the Pacific branch of the Russian Federal Research Institute of Fisheries and Oceanography have confirmed the effectiveness of extruded compound feed for juvenile chum salmon (*Oncorhynchus keta*). Juveniles significantly outpaced the development rates of underyearlings fed with conventional feed.

In addition, extrusion processes are classified as the best available technology (BAT). The best available technology is the process of manufacture of products (goods), performance of work, and rendering services to be determined based on current science and engineering achievements and on the
best combination of criteria for achieving environmental protection objectives, provided that it is technically possible to apply it. Rational use of secondary raw materials and secondary resources are of great importance for increasing production efficiency and improving environmental protection. Extrusion can be used to process various waste of grain crops (oilcakes or meal), as well as waste from the processing of meat, poultry and fish mixed with vegetable filler [7].

Table 2 shows the specifications of up-to-date extruders used in the production of feed, including that for fish [8].

Such foreign companies as Amandus Kahl GmbH & Co. KG., Germany; Andritz Feed and Biofuel, Denmark, Clextral, France; and Insta-Pro, the USA, offer high-performance extruders and extruder based lines for the production of extruded fish feed. The production process consists of the stages of weighing, fine grinding, mixing, extrusion, drying, vacuum oiling, cooling and packaging. As a result, feeds of different properties and purposes are obtained, such as floating or very slowly sinking feeds for carp (Cyprinus) and catfish (Silurus glanis); slow sinking pellets for cutthroat trout (Salmo clarkii lewisi), salmon (Salmo), and perch (Perca fluviatilis); waterproof granules for loricates (Loricata). One of the features of the technology is the oiling system for applying oils, fats and micro-components to the finished product under vacuum. The degree of starch dextrinization reaches 80 to 90%. In addition, foreign processes are highly automated. Special systems monitor the accuracy and efficiency

### Table 1. Comparative features of compound feed mills.

| Type of techniques               | Brief description                                                                                                                                                                                                 | Advantages                                                                                                                                                                                                 |
|----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Mobile compound feed production facilities | They are suitable for small businesses. It is most effective for small businesses to attract mobile compound feed production facilities once or twice a month. Enterprises that should output 500 to 2,000 metric tons of compound feed monthly have reason to purchase mobile compound feed production facilities. Reconfiguration to a new formulation is required. There are domestic projects; however, they are inferior in performance and material consumption, but cheaper than imported counterparts. | Compound feed is produced at a farm; it is always fresh; local raw materials are used; transport costs are reduced; handling operations and production time are decreased. The product output cost is 40% lower than that of fixed facilities. |
| Modular compound feed production facilities | They can also be used for large outputs. It is possible to automate and track important processes and addition of modules (increasing output); customization; possibility of presetting a formulation; testing and configuration check of each module; implementation of remote control. There are domestic projects; however, imported components are often used. | They reduce the equipment range; allow reducing the time of installation and mastering of modular equipment by the service personnel; form the prerequisites for the creation of a wide range of dedicated industries; reduce material costs for launching production. |
| Fixed compound feed production facilities | The facilities include the main and auxiliary structures; production process is fully automated; up-to-date but most often imported equipment is used. Innovations in production processes are constantly being introduced to reduce the environmental burden and save resources. Verified compound feed formulations are available. | The best quality of feed is ensured based on the production and check equipment. Automation ensures high competitiveness of finished compound feed or premixes. |
of the immersion speed of the pellets, the density of extrudates outside the extruder, and the state of the starch during the extrusion process. Such lines are used in large factories.

**Table 2. Feed extruders.**

| Designation                   | Capacity (MT / h) | Installed power (kW) | Manufacturer                                      |
|-------------------------------|-------------------|----------------------|---------------------------------------------------|
| OEE 25 NG Extruder            | Up to 10          | Up to 450            | Amandus Kahl GmbH & Co. KG (Germany)              |
| EX Series Extruders           | 1 to 20           | -                    | Andritz Feed and Biofuel (Denmark)                |
| X125 Extruder                 | 1 to 1.8          | 90                   | Setrem (France)                                   |
| Y200 Extruder                 | 3.8 to 5          | 160                  |                                                    |
| MS 3000 Series Extruder       | 0.68 to 1.0       | -                    | Insta-Pro International (CIIIA)                   |
| PE Series Press Extruders     | 0.8 to 2.1        | 11.12 to 117         | JASKO (Russia)                                   |
| EKSPRO Series Turbine         | 0.5 to 1.0        | 55 to 132            | NPP EKSPRO (Russia)                               |
| DROE-1 Extruder               | 1.0               | 113.25               | Scientific and Production Center, All-Russian Research Institute for Compound Feed Industry, VNIIKP (Russia) |
| PE Series Extruder            | 0.11 to 1.25      | 11.55 to 112.65      | AgroPostavka (Russia)                            |
| ES Series Extruders           | 0.025 to 1.4      | 3.5 to 113.2         | A-Engineering Scientific and Production Company (Russia) |
| EM Extruder                   | 0.09-1.25         | 11-90                | Progress (Russia)                                 |
| ETR KO Type Extruder          | 0.1-0.8           | 12.65-78             | Agro-Stimulus Scientific and Production Association (Russia) |

In Russia, such companies as JASKO (Volgograd), NPP EKSPRO (Belgorod region), Agro-Stimulus Scientific and Production Association (Kirov), A-Engineering Scientific and Production Company (Novosibirsk), Scientific and Production Center, All-Russian Research Institute for Compound Feed Industry, VNIIKP (Voronezh), etc., develop and manufacture feed extruders. This equipment can be installed both in large production facilities and in low-capacity production facilities for the preparation of complete feed based on local high-protein raw materials. Legumes, cakes and meal of grain crops are used from the high-protein plant components for fish feed production. Promising sources of vegetable protein and digestible carbohydrates are seeds of sorghum (*Sorghum*), lupine (*Lupinus L.*), rapeseed meal, coriander meal, etc. Corn or wheat gluten, as well as vegetable feed concentrates and isolates (soybean or pea ones) are also substitutes for fish meal. The use of flaxseed cake and flour made of it are promising. In terms of amino acid composition, flaxseed cake is in many ways analogous to fishmeal, and the content of the vitamin composition of the cake makes it possible to reduce the use of expensive vitamin premixes [4, 8, 9].

A promising area of feed production for aquaculture is the creation of mini-shops having a capacity of up to 30 kg / h. Such production facilities are economically feasible, since they provide the ability to quickly change compound feed formulations taking into account the available raw material base and output of a minimum batch of products. The positive side of the effect of extrusion on plant components is the structural destruction of carbohydrate ingredients, such as fiber, that are difficult to digest by fish. At the same time, its maximum fiber destruction, according to the research results of the
Pacific branch of the Russian Federal Research Institute of Fisheries and Oceanography, occurs at an extrusion temperature of 150 °C up to 160 °C, at a raw material moisture content of 12.0 to 15.0%, and at a raw material grinding fineness of 0.6 to 1.6 mm [10].

4. Conclusion
The most efficient way to obtain feed for valuable fish species and starter feed is the extrusion process. Extruded feed has improved starch modification and increased conversion and sinks more slowly in water as compared to pelleted feed. Its particles have less crumbling, which results in less water pollution. To launch production directly at a farm while using the available own raw materials, mobile feed mills can be used. A promising area of feed production for aquaculture is also the creation of mini-shops having a capacity of up to 30 kg/h, which is due to the possibility of producing a small batches and quickly changing compound feed formulations taking into account the available raw material base. Legumes, cakes and meal of grain crops can be used from local high-protein plant components for fish feed production. The use of flaxseed oil is promising, which in terms of its amino acid composition is in many ways analogous to fishmeal. Necessary extrusion conditions under which the maximum destruction of cellulose occurs are an extrusion temperature of 150 °C to 160 °C, a raw material moisture content of 12.0 to 15.0%, and a raw material grinding fineness of 0.6–1.6 mm.

References
[1] FAO 2018 The state of world fisheries and aquaculture. Achieving sustainable development goals (Rome: FAO)
[2] Ageev A V 2018 State and prospects of world and domestic production of feed for aquaculture facilities, production and consumption of fish meal Fishery 4 92-95
[3] Fedorenko V F, Mishurov N P, Davydova S A and Lozovsky A R 2019 Analysis of the state and development prospects of the production of compound feed and feed additives for animal husbandry (Moscow: Rosinformagrotekh)
[4] Mishurov N P 2012 Technologies and equipment for the production of animal feed at farms (Moscow: Rosinformagrotekh)
[5] Zyabrev V, Dolud M and Luht X 2019 Feeds. Aquaculture: optimal production processes Sphere. Fish 1(22) 17
[6] Ushakova N A, Bastrakov A I, Pavlov D S, Ponomarev S V and Fedorovyh Y V 2020 Physiological basis of the nutritional value of a concentrate of hermetiaillucens larvae in fish diets Biology Bulletin 47 276-282
[7] Nemenushchaya L, Konovalenko L and Shchegolikhina T 2019 Production and use of basic technological facilities for BAT in the food and processing industries of agribusiness IOP Conference Series: Earth and Environmental Science 403 012104
[8] Mishurov N P, Konovalenko L Yu, Syrovatka V I and Ponomarev S V 2020 Production of competitive feed for aquaculture Machinery and equipment for rural area 10 15-18
[9] Lagutkina L Yu and Ponomarev S V 2018 Organic aquaculture as a promising area for the development of the fishery industry (a review) Agricultural biology 2(53) 326-336
[10] Artemov R V, Arnautov M V, Bochkarev A I, Baskakova Yu A, Artemov A V, Koksharov A E and Bindyukov S V 2019 Substantiation of rational parameters for extrusion of plant components using low-power equipment for obtaining compound feed for aquaculture Proceedings of the Pacific branch of the Russian Federal Research Institute of Fisheries and Oceanography 176 182-192