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Technology for the production of extruded starter feed for juvenile fish

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Abstract. The latest advances in science, combined with the growing possibilities of modern technology, contributed to the improvement of fish feeding technology and fish farming in general. It is obvious that the expansion of the species composition of cultivated fish farming objects will continue, and the importance of feed and fish feeding technology will steadily increase. The developed recipes of starter feeds for

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juvenile fish and the technology of their production would make it possible to establish the production of these feeds for fish farms in Kazakhstan, as a result, the survival rate and growth rate of juvenile fish grown in industrial conditions would increase. The aim of the work was to develop recipes for starter feeds for pikeperch fry and technology for their production by extrusion, the development of these feeds to improve the efficiency of growing pikeperch in industrial conditions. According to the developed recipe, a starter feed for zander juveniles, balanced in terms of basic nutrients, was developed, a study was made of the effect of this feed on the efficiency and speed of growing zander juveniles. The dynamics of rearing juvenile pikeperch was studied when feeding the starter feed developed by the Kazakh Research Institute of Processing and Food Industry, with a feed coefficient of 1.28 and as a control foreign starter feed for trout "Aller Aqua" – 1.2. The materials of the article are of practical importance and the need for further research, they will help replenish the formulas of compound feed for the industrial cultivation of juvenile pike perch in fish farms of the Republic of Kazakhstan

Keywords: pike perch; fish fry; extrusion; starter diet; feed ratio

INTRODUCTION

Pike perch *Sander lucioperca* is a promising object of aquaculture – it is a valuable fast-growing fish that matures well and spawns well in cage conditions, lives well in cages, corresponds to the temperature optimum of nutrition and the temperature regime of reservoirs in Kazakhstan. According to V. Zyabrev *et al*. (2019), farmed pike perch remains one of the most difficult species to breed, given that aquaculture techniques are not fully developed. The difficulty in working with this species lies in raising the larvae and providing them with sufficient food. The need to grow pike perch is determined by a number of reasons: due to high nutritional qualities – an increase in demand, an increase in productivity, use in inland waters and the restoration of industrial fish stocks. The main problem in the development of aquaculture is the organization of a food base for fish of different breeds and at all stages of cultivation: starter feed for fry, production feed for fingerlings and breeding stock, mixed feed for adults and breeding stock.

Á. Hernández-Contreras *et al*. (2023) investigated how varying temperatures and fish sizes affect juvenile wolffish growth rates and feeding efficiency. They discovered that juvenile spotted wolffish had the highest growth rates at moderate temperatures, with growth efficiency decreasing at both higher and lower temperatures. The feed conversion ratio (FCR), an important metric of feed efficiency, was shown to improve as fish size rose, particularly at lower temperatures. This meant that as the fish mature, they will be able to better use feed in colder settings. Furthermore, the study found that temperature had a greater impact on growth performance than fish size alone, emphasising the necessity of maintaining ideal environmental conditions in aquaculture to maximise development efficiency. As noted by M.J. Bektursunova *et al*. (2021), in the Kazakh market of mixed feed raw materials there was a number of advanced technologies for the rational use of feed resources, which were mainly characterized by the feed extrusion method, consisting in a balanced diet of at least 20 different ingredients, combined depending on the chemical composition, type and method production, as well as the physiological needs of fish.

According to Aquatic Sciences and Fisheries Abstracts, the total volume of fishery and aquaculture production reached 214 million tons, including 178 million tons of aquatic animals and 36 million tons of algae. At the same time, according to forecasts, until 2030, the volumes of production, consumption and marketing of aquaculture products will grow at a low pace. Annual fish consumption should be at least 15 kg per capita, but today the figure does not exceed 5 kg per year, in contrast to developed countries where Japan consumes 70 kg of fish per capita per year, Spain – 43 kg, Norway – 53 kg. Given the statements of J. Wan *et al*. (2022), the production of fish feed is currently the most expensive in comparison with prescription feed for other types of farm animals. This is due to the fact that the fish has a short digestive system and needs easily digestible food. For optimal consumption, feed should be as free of various contaminants as possible. The shape and size of the food should match the preferences of the fish. Depending on the size of the fish and the density of the food that can sink or float on the surface of the water, pellets of different diameters should be made.

According to Z. Koshak (2022), at present, the variety of fish feed offered by domestic producers is limited, and this leads to a decrease in the development of industrial aquaculture in Kazakhstan, as enterprises use outdated dry pressing technology. Modern realities in the feed production system require theoretical understanding and identification of technological conditions, they can ensure the sustainable use of granulation and extrusion technologies, which are widely used in the production of feed for the world's aquaculture.

The development of starter rations was of particular importance, as it will increase the efficiency of growing pike perch fry, given the critical period of exotrophy of larvae to an acceptable stage, and expand the possibilities for breeding these fish species in Kazakhstani aquaculture. Extrusion will allow feed manufacturers to select suitable processing temperatures that affect the

density of feed raw materials, structural changes, nutritional and physiological properties of feed, improve digestibility and nutritional value of feed ingredients. The purpose of this study was to develop and evaluate a specialised starter feed for juvenile pike perch (Sander lucioperca), and to compare its effectiveness to that of a commercial trout feed manufactured by Aller Aqua. It was to see if the newly created feed could adequately meet the nutritional needs and development of pike perch fry, a species noted for its aquaculture problems. The study looked at the feed's physical and chemical properties, tested fish growth and survival rates, and estimated the FCR.

LITERATURE REVIEW

The general pattern of obtaining functional fish feeds is poorly understood, and modern technology for the processing of feeds for valuable fish species is based on the use of extrusion processes of multicomponent mixtures to obtain various buoyancy values and control the sinking rate. Extruded products are resistant to water and retain their shape, and in combination with vacuum liquid emulsification and deeper hydrothermal processing of ingredients, it is possible to create compound feeds with programmable characteristics, maximally adapted to various breeds of valuable fish. According to X. Zhao *et al*. (2021), the formation of fish is accompanied by the development of its digestive system; therefore, starter diets should contain easily digestible carbohydrate and high-protein ingredients, the presence of which is possible by converting the nutrients of feed raw materials using static extrusion conditions: dynamic effects of temperature, osmotic pressure, and water exchange. A. Martin *et al*. (2019), in his work evaluated the high density, dry matter content, long shelf life of extruded feed raw materials. The main difference between pellets and extruded foods is that the pellets sink while the extrudates have controlled buoyancy in the water. The settling rate of pellets for fish such as pike perch, sturgeon, catfish, tilapia should be as low as possible to allow enough time for product consumption, so producing feed with a density adapted to the way the fish eat is a prerequisite for efficient fish farming.

The extrusion parameters of starter feed raw materials are set within the temperature range of 110-138°C and steam pressure of 4-6 MPa. At temperatures above 140°C, sugar caramelization occurs and the extruded granules become too strong, and their swelling is 30-40 minutes. The extrusion conditions promote gelatinisation of the starch upon deformation of the outer layer of the granules formed by amylopectin. M.O. Oke *et al*. (2012) stated that after extrusion, the rate of starch hydrolysis increased the activity of α-amylase by 6 times, and in corn – by 8 times, in glucose – by 15 times, before that the enzyme acted only on the amylase of starch granules. N.P. Mishurov *et al*. (2019), reported that extrusion increases the dextrin content in grain ingredients by 2-4 times, due to the solubility of non-starch polysaccharides or crude fibre. As far as feed ingredients are concerned, water is activated by binders and forms a film on the feed components: starch, protein, fibre and fat, affecting the hardness, durability and expansion of the granules. Vegetable oils and fats are rapidly oxidised, reducing the shelf life of compound feed, so they are introduced into the composition by spraying at a temperature of 50°C, its amount should be up to 35-40% to achieve 100% starch degradation.

Z. Koshak (2022) stated that proteins are one of the most important nutrients that affect growth and all physiological systems of the body, which play an important role in the energy metabolism of fish, since nitrogen consumption by fish is 3-5 times higher than that of warm-blooded animals. The high protein level contributes to a low feed ratio and rapid fry growth. Extrusion changes the protein portion of the feed and protein solubility may vary depending on the type of product due to denaturation. Due to the research of E. Skarbøvik *et al*. (2014), it was noted that during extrusion at a temperature of 110°C and a pressure of 6 MPa, proteins are denatured and most of the anti-nutritional components are destroyed. The unfolding of the polypeptide chain facilitates the contact of digestive enzymes with the active site of the protein molecule, thereby facilitating hydrolysis, but the reverse process can also occur in parallel. At high temperature and pressure, additional bonds are formed between the polypeptide chains with the formation of protein complexes of glycoconjugates.

In blends, the overall increase in protein content of the starch recovered from the extrudates is accompanied by a significant decrease in starch solubility. When studying the properties of extrudates from starch-containing and protein-containing raw materials, it was found that with an increase in the protein content in the formulation up to 50%, feeds with the lowest moisture-absorbing capacity are obtained. J. Wan *et al*. (2022) found that an optimal diet would require additional amino acids and lipids to reduce starch conversion during extrusion and prevent mechanical degradation of the granules and prevent water uptake. The practice of L. Horváth *et al*. (2008) has shown that extrusion almost completely disinfects feed from fungal and bacterial microflora. For example, extruding soy and peas reduces the total bacteria count by 67-100% and completely inactivates E. coli. Extrusion is an effective means of suppressing the activity of protease inhibitors, trypsin amylases. After extrusion, nutrients are more easily absorbed, especially in predatory fish species. A.K. Imsland *et al*. (2006) noted that fish feeding includes more than a hundred different feeds and feed additives made from food industry waste, including products of microbial synthesis, various salts, vitamins, enzymes and amino acids, polyunsaturated fatty acids, antibiotics, adsorbents, antioxidants and flavours.

MATERIALS AND METHODS

The starter feed for pike perch juveniles was produced strictly according to the recipe developed under the production conditions of the Kazakh Research Institute of Processing and Food Industry, on a professional extruder OEE 25 NG. The new generation of extruders is based on the Amandus Kahl, crushed feed raw materials with a moisture content of 12-16% were fed into the system, the mass was heated to 120-150°C at a high pressure of 2.8-3.8 MPa. Then the process quickly passed from the area of high pressure to the area of ambient pressure, the homogeneous mass expanded, resulting in the formation of a product of a porous structure.

The proportions of the ingredients created a complete biological complex that ideally meets the physiological requirements of juvenile fish, allowing to balance the diet in terms of nutritional value, digestible protein, limiting amino acids, vitamins and minerals. Starter feed for pike perch fry mixed well, had a coarse-grained texture from dark brown to light brown. The technology for the production of microgranules with a size of 0.1-0.5 mm was not available, it was used only at some feed mills with world brands. Therefore, the starter feed was made with a granule size of 2 mm, which was subsequently crushed and sieved into grain fractions of 0.2-0.5 mm, which are dense multifaceted particles of crushed granules without impurities, with the original color and smell preserved. The technical parameters of the compound feed were determined in accordance with the current ISO 12875:2011 (2011).

The preparation of the test samples of the starter feed for juvenile fish was carried out in accordance with ISO 6498:2012 (2012), while the weight of the experimental feed sample for physical and chemical studies was taken at least 600 g. During the research, the experiments were carried out in triplicate, after which the average was calculated. Friability of feed pellets of starter feed for fish was determined in accordance with ISO 12099:2017 (2017). The water resistance and swelling capacity of starter compound feed granules was determined according to ISO 6495-1:2015 (2015). Chemical study of starter feed for fish was carried out according to ISO 6496:1999 (1999) for moisture content, ISO 5983-2:2009 (2009) – crude protein, ISO 6865:2000 (2000) – crude fiber, ISO 6492:1999 (1999) – crude fat, ISO 5984:2002 (2002) – raw ash, the content of nitrogen-free extractive (NFE) and nutritional value was determined by the calculation method.

A scientific experiment on the productivity of the starter feed was carried out in cage-grown production cooperative (PC) "Zhambyl" for 30 days. During the experiment, the hydrochemical regime in cages was optimal. Feeding was done by hand six times a day. The fry was stocked in cages at a density of 10,000 larvae per cubic meter. The feeding regime consisted of manual feeding six times a day, with control fishing conducted every 10 days to monitor progress. The experiment involved the control group, and the experimental group. The control group was fed the commercially available Aller Aqua starting feed, which is primarily intended for trout but was employed in comparative research due to its nutritional profile. The choice to utilise this feed in the control group enabled researchers to establish a baseline for growth, survival, and feed efficiency. The experimental group was fed a starter meal prepared by the Kazakh Research Institute of Processing and Food Industry particularly for pike perch juveniles. The goal was to compare the performance of the newly formulated feed with the widely used trout feed. The Aller Aqua feed was compared to a pike perch-specific feed to guarantee that the new feed meets or surpasses industry requirements, indicating possible improvements. Based on the results obtained, the growth rate of zander fry was determined and the daily feeding rate was calculated. Upon completion of the experimental work, the theoretical and practical conclusions were refined, the results obtained were summarised and systematised. All procedures performed using animals were revised and approved by the Scientific Committee of Ethics of the Kazakh Research Institute of Processing and Food Industry, Almaty. AuthoriSation No. 68-15.

The feeding efficiency of pike perch fry was evaluated according to the feeding coefficient, growth rate, survival rate, and physiological state. The experiment assessed feeding efficiency by measuring the FCR, which compared the amount of feed given to fry to the total weight gained by the fish. A lower ratio suggested improved feed conversion into body mass, as measured by experimental analysis of feed inputs and fish weight outputs. The study measured pike perch fry's weight at the beginning and the end of a 30-day experiment, utilising absolute growth rate and specific growth rate as direct and percentage increases, gathered at regular intervals. The survival rate of fry was assessed by counting them at the beginning and end of the experiment, yielding a percentage-based survival rate that reflects their adaptation to the feed and conditions, allowing for a quantitative analysis of mortality or survival trends. The study assessed the fry's physiological health using both qualitative and quantitative methodologies. Researchers employed the condition factor to assess general body health, visual inspections to detect symptoms of sickness, deformities, or stress, and behavioural observations to identify anomalies in swimming or feeding behaviour, offering a full picture of the fry's well-being. The hydrochemical parameters in the cages were monitored throughout the experiment to provide a favourable environment for pike perch development. Water factors such as dissolved oxygen (5.8-8.3 mg/l), pH (6-8), and temperature were maintained at ideal levels for juvenile fish growth. Regular checks guaranteed that the water quality remained appropriate for the fry's development and survival.

All experiments were performed in triplicate, and the average results were calculated for each parameter. Statistical analysis was used to compare the performance of the control and experimental groups in terms of FCR, growth rates, and survival rates. The significance of differences between the groups was assessed, and conclusions were drawn based on the results.

RESULTS

Starter feed for pikeperch juveniles is not industrially produced, so it is necessary to study the parameters of the manufacturing processes of the extruded product, the porous structure and expanded volume, moisture content, granulometric and chemical composition (crude protein, crude fat, carbohydrates). According to the organoleptic and physico-mechanical properties of the starter feed, a dark brown color and a fishy smell were established. The features of the use of the studied feed are that, when feeding, the granules are introduced into the water, where they float on the surface, sink at a certain speed, or remain intact for a given period of time. For aquafeeds, "water properties" are of paramount importance: bulk density, 880.3 kg/m^3; water resistance (swelling), 165 min; crumbling – 1.1%, moisture absorption coefficients – 0.002 g/min, granule size – 0.1-0.2 mm.

The assessment of the chemical composition of water is important for rearing juvenile pike perch, and the natural state of pond water, which is determined by physical and chemical properties, determines whether it is suitable for fish farming. Water has a high solubility and contains minerals, organic substances, gases, therefore it is extremely important for the development of phytoplankton and zooplankton. Minerals dissolved in water are used by bacteria, lower and higher aquatic plants, which are used as food for fish. The content of dissolved oxygen in water varies from 5.8 mg/l to 8.3 mg/l, and the saturation of water with oxygen from 58.7% to 88.7%. An important aspect of fish breeding is the active reaction of the water. It can be acidic (pH less than 6), slightly acidic (pH 6-7), neutral (pH 7) or slightly alkaline (pH 6-8). In order for gas exchange between blood and water to be efficient, the pH of the blood must be adjusted to the pH of the water. The biomass of zooplankton is represented by three groups of organisms: Rotatoria, Copepoda, and Cladocera; also, planktonic forms of chironomid larvae and other insects were found in small quantities in the samples. Fish food is produced in the form of grains and granules, differing in diameter, and as the fish move from one age group to another, the size increases accordingly, as noted in Table 1.

***Table 1**. Diameter of starter feed for fish depending on weight*

Diameter, mm	Weight of fish, g	Feeding period, days
Up to 0.2 – nibs	Up to 0.1	1-10
0.2-0.4 – nibs	0.1-0.3	10-20
0.4-0.6 – nibs	0.3-1	20-45
0.6-1 – nibs	1-2	45-60

***Source:** compiled by the authors based on M. Bektursunova et al. (2022)*

Pike perch is a predatory fish by its nature. therefore, feed of animal origin prevails in the diet: fish 50-60%, meat and bone and meat 10-20% meal. Vegetable feed proteins: soybean meal – 20%, soy isolate – 15%, are similar in terms of crude protein content, however, the growth rate of zander fry is much lower. Table 2 shows the physico-chemical parameters of feed according to the current ISO 12875:2011 (2011) and its comparison with the chemical quality indicators of the experimental starter feed for fish juveniles after extrusion. The extrusion parameters required to obtain the specific physical qualities of pike perch feed must be based on an accurate chemical analysis of each ingredient.

***Table 2**. Physical and chemical parameters of the starter feed for juvenile pike perch*

Components	Starter feed for pike perch	According to ISO 12875:2011
Moisture, %	8.55	no more 10
Crude protein, %	53.66	at least 52
Crude lipid, %	12.02	at least 11
Crude fiber, %	0.74	no more 1.5
Raw ash, %	10.17	no more 11
Linoleic acid, %	2.13	-
NFE, %	13.39	-
Lysine, %	4.03	at least 3
Methionine, %	1.18	at least 1.6

***Source:** compiled by the authors*

Table 2. Continued

Components	Starter feed for pike perch	According to ISO 12875:2011
Methionine + cystine, %	1.75	-
Tryptophan, %	0.68	-
Carbohydrate, %	0.41	-
Starch, %	4.57	-
Phosphorus, %	1.68	at least 0.6
Calcium, %	2.51	-
Gross energy, MJ/kg	20.78	-
Exchange energy MJ/kg	17.45	at least 17

Source: *compiled by the authors*

Evaluating the data, it was found that it was possible to obtain food with a sufficiently high energy, nutritional and biological value, which can be suitable for the industrial production of feed oriented towards feeding larvae and juvenile pike perch. The carbohydrates that make up the diet are the cheapest source of food and energy, quantitatively the largest component of the diet is 40-55%, including them in the diet can save on expensive food proteins and get more energy. The main sources of carbohydrates in the diet of fish are grains (wheat, oats, corn, etc.) and legumes (soybeans, chickpeas, peas), but their digestibility and the ability of the digestive system to break them down should be taken into account. The experimental extruded diet for pikeperch fry in terms of nutrient content included 53.7% crude protein, 12% crude lipid, 0.7% crude fiber, 10.2% crude ash, 13.4% NFE, 4% lysine, 1.2% methionine, 1.8% methionine and cystine. According to the established physiological needs of fish and the technology for the production of feed by extrusion, the appropriate norms for introducing components into starter and production compound feeds for pikeperch juveniles are used, shown in detail in Table 3.

Table 3*. Norms for adding components to starter and production feeds for fish, %*

Components	Starter feed for pike perch
Wheat	0-15
Wheat bran	0-5
Soybean meal	0-20
Sunflower meal	0-10
Gluten corn	0-15
Meat and bone meal	0-15
Meat meal	0-10
Blood meal	0-15
Fish meal	0-60
Feed yeast	0-20
Casein	0-15
Bentonite	0-1
Soy isolate	0-15
Wheat gluten	0-4
Soybean oil	0-10
Sunflower oil	0-3
Linseed oil	0-4
Fish oil	0-8

Source: *compiled by the authors based on E. Puzevich (2021)*

Feed protein can fully perform its function if all components are present in the required amount. Due to the growing shortage of fishmeal, in recent years, feeds containing raw materials of plant origin have become widespread. To develop the formulation of the starter compound feed, a chemical analysis of feed raw materials was carried out, which included: fish meal, blood meal, meat and bone meal; gluten and corn germ; fodder yeast; meal, isolate and soybean oil; corn, wheat germ, bran and gluten; fish oil; as a mineral additive – bentonite. Table 4 shows the ingredients that were used in the calculation of the diet, their quality indicators and the value of satisfying the physiological requirements of juvenile pike perch, since the composition of the extruded mixture is an important condition for obtaining high-quality feed.

***Table 4**. Chemical composition of the ingredients of the starter feed ration for pike perc*

Diet Ingredients	Indicators											
	crude protein	crude lipid	crude fiber	raw ash	NFE	starch	total carbohydrate	lysine	methionine	methionine + cystine	phosphorus	calcium
Fish meal	56.2	8.9	-	17.9	6.4	-	-	4.5	1.6	2.2	3.1	4.8
Blood meal	75.2	1.1	-	5.6	9.3	-	-	6.4	0.9	1.8	0.4	0.4
Meat and bone meal	48	20.3	-	23	11.3	-	-	1.7	0.5	0.8	4.8	9
Corn gluten	51.1	5.0	5	2	17.2	13.8	1.4	1.3	1.5	2.6	0.5	0.4
Corn germ	18.2	46	3.3	5.8	24.9	10.1	-	0.6	0.3	0.4	0.3	0.2
Feed yeast	41.5	1.2	1.6	4.7	46	-	1.5	2.6	0.4	0.8	1.4	0.8
Soybean meal	41.9	1.2	7.7	7.4	32.9	1.8	4.8	2.5	0.5	1.1	0.7	0.4
Soy isolate	86.6	4	-	5	-	-	-	6.9	1.9	2.8	0.3	0.4
Wheat	11.6	1.62	2.73	1.8	72.8	54.9	2.4	0.3	0.2	0.3	0.3	0.1
Wheat germ	28.4	11	3	5.8	37	-	-	1.4	0.7	0.8	0.4	0.3
Wheat gluten	75	1.2	0.8	-	14.2	-	-	6.2	0.9	1.9	0.3	0.4
Wheat bran	14.4	4.1	9.6	4.7	54.6	-	4.7	0.5	0.16	0.33	1	0.22
Fish oil	-	98.1	-	-	-	-	-	-	-	-	-	-
Soybean oil	-	99.9	-	-	-	-	-	-	-	-	-	-
Bentonite	-	-	-	-	-	-	-	-	-	-	2.3	-

***Source:** compiled by the authors*

Before the extrusion process, the feed ingredients were separately crushed in a crusher and screened through a set of sieves according to TU 25.06.1250-77. In the production of waterproof floating feed pellets, the optimal temperature range is 100-110°C and humidity 30% and steam pressure 4-6 MPa. The starter compound feed developed and produced for juvenile pike perch Kazakh Research Institute of Processing and Food Industry from ingredients of local origin differed from that produced by the popular Aller Aqua brand in terms of physicochemical, nutritional and energy properties. Kazakh Research Institute of Processing and Food Industry starting compound feed in terms of crude protein content was 53.7%, crude lipid – 12.0%, NFE – 13.4%, with an energy value of 496.8 kcal, and digestible energy of 417.3 kcal.

The starter feed intended for trout fry "Aller Aqua" had a content of crude protein 64%, crude lipid – 18%, NFE – 6%, with an energy value of 472.3 kcal, digestible energy of 396.7 kcal. It has been established that the starter compound feed developed by Kazakh Research Institute of Processing and Food Industry is physiologically ideal for pike perch, however, when formulating compound feeds, it is not recommended to exceed the level of crude lipid content tested for this age category, as well as to comply with the energy value of the feed. The productivity of feeding the starter compound feed on the fish-breeding and biological parameters of juvenile zander was studied using two groups of control and experimental. Foreign starter trout feed "Aller Aqua" was fed to the control group of juvenile pike perch, the second experimental group was the studied feed developed by Kazakh Research Institute of Processing and Food Industry. The study of the productivity of juvenile zander was carried out in the cages of the PC "Zhambyl", when feeding starter compound feeds. When feeding starter artificial feeds, the results presented in Table 5 were obtained.

***Table 5**. Productivity of juvenile pike perch*

Indicators	Groups	
	1-control	2-experienced
Growing period, days	30	30
Planting density, thousand pieces/m^3	10	10
Initial weight, mg	1 ± 0.1	1 ± 0.1
Final weight, mg	93 ± 5.8	88 ± 6.2
Absolute gain, mg	92	87
Average daily gain, mg	3.06	2.9
Survival of juveniles, %	55	52
Feed ratio, units	1.2	1.28

***Source:** compiled by the authors*

According to the results of the experiment, both starter feeds had a positive productive effect on pikeperch fry, due to the same values of feed units, which differed by 0.06 units, high normative indicators of absolute and average daily gain were observed, differing by insignificant ones by 5 mg and 0.16 mg, respectively. Also, during the experiment, the following pattern was established: the survival rate of pike perch was maximum – 55% and 52%. The results of rearing pikeperch larvae in cages showed the possibility of effective use of the domestic artificial feed Kazakh Research Institute of Processing and Food Industry for pikeperch fry, therefore it is recommended for use in the conditions of fish farms in Kazakhstan.

DISCUSSION

In Kazakhstan, scientific research was being carried out related to feeding issues in three areas: the development of rations for the production of starter feed, the cultivation of live food organisms (microorganisms, algae, invertebrates) or by adding high-protein meat or fish meal, as well as the search for the optimal ratio of dry combined and live feed. Given the scientific research of G.I. Zhelyzakov (2018), in the production of starter feeds for juvenile pike perch, it has not yet been possible to create artificial mixed feeds that would fully satisfy the nutritional needs at the early stages of postembryonic development. Undernourished juvenile pike perch lag behind in growth, and with prolonged starvation, the larvae even change body proportions and appearance. An emaciated larva has a deformed body and a degenerated intestine, so subsequently the digestive tract is destroyed, and digestion of food becomes impossible.

The artificial habitat of fish in intensive aquaculture, in contrast to the natural one, can be significant enough to cause an imbalance in genetically based metabolic systems, pathology and a decrease in vitality (Bal *et al.*, 2023). Rational feeding of animals is based on physiologically based diets, optimal feeding methods and components. Knowledge of the age characteristics of the formation of the digestive system is an important biological factor necessary for the development and survival of fish in the aquatic ecosystem, the rationing and quality of feed consumed (Alexyuk *et al.*, 2021). The initial weight of pike perch fry was 1 mg. The optimal conditions for the metabolic life of fish in the early stages of development are formed according to the amount of food that is favourable for the species of a certain type of fish (Shumka & Apostolou, 2018). The quality of fish food is influenced by: bulk density, water absorption, solubility, hardness, colour, size and shape of granules, elasticity, buoyancy. Starter compound feeds for fish, with efficient production, are fed in strict dependence on the diameter of the grains on the weight of the fish (Kondratiuk *et al.*, 2023). In the process of rearing juvenile pike perch, there is a transition from endogenous nutrition to external food. In other words, the forms of metabolism are replaced one after another, due to the restructuring of the integration mechanism both in the whole organism and in its individual parts and organs. When feeding fish, the daily rate of feed feeding is of great importance, depending on the age and growing conditions (Voronetska & Yurchuk, 2023). With an increase in the mass of fish, the relative value of the diet decreases, and with an increase in water temperature to the optimum, it increases. The development and growth of juvenile zander can occur if the diet exceeds the nutritional requirements.

The experiment showed that the digestibility of dry matter, nutrients and total energy of the experimental diets is affected by the presence of selected ingredients, since an irrational starter diet leads to significant weight loss in pikeperch juveniles. For the production of a mixture of extruded feed, particles of small diameter up to 0.1 mm were burnt to the screw in the centre of the working chamber, rotating the resulting plug in one place, laying the outlet of the matrix, which resulted in a sharp pressure pulsation, and subsequently to an unstable extrusion process. With a particle size of 0.2-0.5 mm of the extruded mixture, the extrusion process was stable at low pulsations, while the extrudate was granules with fine porosity, this particle diameter is the most effective and was recommended for the production of starter feed. Also, when extruding the feed mixture with a particle size of 0.5-1 mm, the process was stable at low pressure fluctuations, however, the resulting feed had unground grains, which led to heterogeneity in mixing the feed. Subsequently, components with a particle size of 0.2-0.5 mm were loaded into the mixer, mixed, maintaining moisture content up to 28-30%. E. Delgado *et al.* (2021) give an example of extruded shrimp food, where the optimal cooking conditions are noted at extrusion parameters: temperature 130°C, humidity 14%, and screw speed 180 rpm. M. Kumar *et al.* (2018) note that the extrusion of the production method for preparing the most versatile fish food is the chosen way of feeding fish, which has multiple positive effects. Extrusion occurs: heat treatment, gelatinization, protein denaturation, hydration, texture change, partial dehydration and destruction of microorganisms and toxic compounds, it is also considered environmentally friendly because it improves the preservation and compactness of the feed in the aquatic environment.

A.G.J. Tacon (2019) noted that pike perch is a carnivorous fish, so the percentage of high-protein ingredients of animal origin in their diet was about 70%, and the percentage of vegetable ingredients is 30%. It is very important to take into account the ratio of digestible protein and digestible non-nitrogen component of the feed. The starter diet ingredients tested in this experiment showed good digestibility. Therefore, components such as soy protein isolate, soybean meal, corn

and wheat germ, corn gluten can be used as alternative sources of vegetable protein in this recipe (Grayson & Dabrowski, 2022). However, further experimentation is needed, especially with regard to the digestibility and bioavailability of the amino acids contained in the studied ingredients. This will allow us to fully understand the nutritional value of the starter diet for pike perch juveniles. An experimental goal of many scientists in the development of diets for carnivorous fish is alternative, sustainable protein sources that can replace fishmeal and ensure high fish productivity. For example, H. Dadras *et al.* (2022) cited a method of replacing fishmeal in the diet with up to 30% cottonseed and soymeal, and this research was supported by the findings of other studies reporting increased water tolerance of feeds.

The transition of zander fry to active feeding is determined by the change in their swimming behaviour. They stop floating vertically upwards, sink head down, rest against the bottom, and then begin to swim horizontally, always remaining in the water column. They switch to gill breathing, inflate their swim bladder and feed first on rotifers and then on crustaceans such as cyclops. Juvenile pike-perch tolerate transportation in plastic bags especially well during the transition to active feeding. As zander fry are small, they should be kept in cages with a No. 16 during the transition to active feeding and transfer to delicacy cages only when they grow up. Also, zander fry feed on plankton and prefer crustaceans, and they also grow poorly in cages, reaching 0.5 g at 1 month and 2 g at 4 months.

The results showed that the conditions for rearing early juvenile pike perch and the amount of feed used were close to optimal, and the artificial feed developed was adapted to the requirements of the given rearing period. The results obtained can help to increase the potential of fish farms that do not have the technical base for aquaculture. Further research is needed to determine the optimal minimum weight. It has been established that from the results of the quality indicators of feed for juvenile fish, it follows that the studies carried out on the development of a starter feed recipe and technological modes for the production of extruded feed made it possible to create a starter feed with a sufficiently high energy, nutritional and biological value. Kazakh Research Institute of Processing and Food Industry starter compound feed can be recommended for feed production and is focused on feeding juvenile pike perch.

CONCLUSIONS

The aquaculture feed market is represented by a wide range of special extruded and granulated compound feeds for fish of different species and ages (for juveniles, marketable fish, carp, salmon, sturgeon, catfish spawners) with a grain size of 0.1 to 2 mm and a granule diameter of 1 mm to 12 mm. Given Kazakhstan's growing demand for aquaculture products, the study underlined the importance of ongoing scientific research and practical support to develop fish feed recipes. Current feed choices included extruded and granulated compound feeds for a variety of fish species, but customising them to individual species, such as pike perch, posed distinct growth and feeding issues.

Chemical examination revealed that the meal comprised 53.7% crude protein, 12% crude protein, and 13.4% NFE, which contributed to its high energy value of 496.8 kcal. These nutritional qualities make the meal ideal for stimulating the growth of juvenile pike perch and facilitating effective feed conversion. The feed's composition guarantees that vital nutrients are accessible to promote healthy fish growth. It has been established that a larger amount of vegetable protein can be introduced into the diet using extrusion technology. Furthermore, the capacity to include a greater quantity of vegetable protein into the feed using extrusion technology, along with physiologically active compounds like amino acids, phytase, probiotics, and immunostimulants, improved the feed's efficacy. This guarantees that young pike perch get all of the nutrients they need to prosper, while also minimising dependency on more expensive animal protein sources.

When using two starter feeds developed by Kazakh Research Institute of Processing and Food Industry and foreign starter trout "Aller Aqua", good productivity was obtained. When growing juvenile zander, the effective consumption of nutrients of the extruded starter ration for absolute growth was established, which amounted to 87 mg, while in the group fed with "Aller Aqua" compound feed, the increase was 5 mg more. The feed coefficient of the experimental compound feed for the study period, on average for all size groups, was 1.28, in contrast to the control compound feed "Aller Aqua", which was 0.06 units less. But this difference was not large enough to negatively affect overall growth performance. It has been established that the process of extrusion is an effective way to obtain feed for starter diets of pikeperch fry, and the technology and developed recipes will make it possible to establish the production of grits with a grain diameter of 1 mm, accelerate the growth rate of juvenile fish, increasing the productivity of fish farming in industrial conditions. The survival rates of juvenile pike perch in both the control and experimental groups were similar (55% and 52%, respectively), indicating that the new diet is equally effective in enhancing the health and well-being of pike perch fry. These findings suggested that the locally created starting feed is a viable alternative to traditional commercial feeds. The study also revealed that the extrusion processes are effective methods for producing high-quality feed for pike perch fry. The new recipe and production method enabled the creation of feed with grain diameters as small as 1 mm, which is acceptable for juvenile fish. This results in quicker development and increased yield in fish farming operations.

Ongoing research will help feed companies that produce fish feed make optimal use of extrusion technology, obtaining feed with high nutritional value and strong physical and chemical properties, contributing to the development of waste-free technologies for processing food raw materials to obtain high-tech domestically produced feed products. Extruded complete feed for aquaculture is a promising direction that requires: additional scientific research that determines the parameters of processing processes, evaluation of various types of plant and animal raw materials and their compositions, analysis of finished extrudates with a detailed comparative description of their properties.

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CONFLICT OF INTEREST

None.

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Технологія виробництва екструдованих стартових комбікормів для молоді риб

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Анотація. Новітні досягнення науки в поєднанні зі зростаючими можливостями сучасної технології сприяють удосконаленню технологій годівлі риби та рибництва в цілому. Очевидно, що розширення видового складу культивованих об'єктів рибництва буде продовжуватися, а значення кормів і технології годівлі риб неухильно зростатиме. Розроблені рецептури стартових комбікормів для молоді риб і технологія їх виробництва дозволять налагодити випуск цих кормів для рибницьких господарств Казахстану, в результаті чого підвищиться виживаність і швидкість росту молоді риб, вирощуваної в індустріальних умовах. Метою роботи була розробка рецептур стартових комбікормів для мальків судака та технології їх виробництва методом екструзії, освоєння цих комбікормів для підвищення ефективності вирощування судака в індустріальних умовах. За розробленою рецептурою було розроблено збалансований за основними поживними речовинами стартовий комбікорм для молоді судака і було проведено дослідження впливу цього комбікорму на ефективність та швидкість вирощування молоді судака. Вивчалась динаміка вирощування молоді судака при згодовуванні стартового комбікорму, розробленого Казахським НДІ переробної і харчової промисловості, з кормовим коефіцієнтом 1,28 і в якості контролю закордонного стартового комбікорму для форелі "Aller Aqua" – 1,2. Матеріали статті мають практичне значення і необхідність подальших досліджень, вони сприятимуть поповненню рецептур комбікормів для індустріального вирощування молоді судака в рибницьких господарствах Республіки Казахстан

Ключові слова: судак; мальки; екструзія; стартовий раціон; співвідношення кормів