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The effect of an extruded feed with a symbiotic formulation on the production of clary catfish

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Abstract

Background and Aim. This article presents the results of a study on the effectiveness of extruded feed containing a formulation of symbiotic bacteria on the performance of catfish production and its meat quality as assessed by veterinary and sanitary indicators. The study aimed to develop extruded feed based on a symbiotic formulation and to determine the effectiveness of the feed on the production of clary catfish meat.

Materials and Methods. Experimental work was carried out on the platform of the International Scientific Research center “Fisheries” and S.Seifullin Kazakh Agrotechnical Research University (S. Seifullin KATRU). In total, 135 kg of feed was used to feed young African clary catfish at a rate of 30 g per fish per day over 40 days. The fish were divided into two pools, with 100 individuals in each group. To assess the effectiveness of feed, a weekly total catch of the two pools was carried out to determine the mass of fish. To determine the Fulton fatness coefficient (kc), 20 fish were measured from each group. Veterinary and sanitary assessments of fish meat were carried out using generally accepted organoleptic and physico-chemical research methods.

Results. On the 40th day, a significant difference was observed in all weight gain indicators on day 40: the mean fish weights were 570 ± 17.8 and 565 ± 18.2 g in the Control and Experimental groups, respectively ($P < 0.01$). Indeed, the chemical composition of meat improved in terms of the mass fractions of protein and fat: the mass fraction of protein was 16.22 and 17.38% for the Control and Experimental groups, respectively, and 3.90 and 4.90% for the mass fraction of fat.

Conclusion. The novelty of this research is to develop extruded feed based on a symbiotic formulation and to determine the effectiveness of the feed on the production of clary catfish meat. One formulation of extruded feed with a symbiotic was obtained. The effect of symbiotic feed on the productive performance of the African catfish has been studied. A veterinary and sanitary assessment was carried out to determine the nutritional value of fish meat. All indicators of the amino acid, vitamin, and mineral composition of fish meat in both groups were normal.

Keywords: Clariid catfish; extruded feed; fish meat; symbiotic; veterinary and sanitary assessment.

Introduction

With the development of fish farming intensification, there is an urgent need to develop effective technologies for growing various species of fish, including new aquaculture facilities. Tilapia and catfish are two of the most promising objects of industrial fish farming in Kazakhstan [1]. The African clary catfish (also known as the marbled clary catfish and the Nile clarias) is a favorite among fans of non-pond fish farming due to its adaptability and rapid growth in conditions of closed water supply [2]. Adequate nutrition is an important factor for the proper growth of fish, and this is especially critical when using closed-circuit water supply installations [3-5]. The African catfish is an opportunistic predator that requires animal-based feed. According to domestic and foreign literature sources, it has been established that extruded feed with a symbiotic supplement can serve as a good food source, increasing the performance of fish production and having a direct positive effect on the chemical composition and nutritional value of fish meat [6-10].

In aquaculture, feeding rate and nutritional value are important factors influencing fish growth. Therefore, determining the optimal feeding rate is important for fish production [11]. The growth rate is also affected by the nutrient content in the feed [12]. Thus, the development of a feed extrusion formulation is an important process of mixing various feed components and processing the components by extrusion to meet nutritional needs [13]. In his article, Shaw reported that, in a closed water supply, the replacement of animal protein by 25% led to a low feed conversion rate and protein efficiency in the African catfish, and replacement at 75% reduced the ash content of the body [14].

In this study, we aimed to develop the first dry, water-resistant, full-fledged extruded feed based on a symbiotic formulation and to determine the effectiveness of this feed on the performance of fish meat production.

Materials and Methods

Experiments were conducted at the International Scientific Research Center “Fisheries” S. Seifullin KATRU. Extruded waterproof dry food was produced by extrusion and granulation in the production and testing workshop of NFT-KATRU LLP at the Faculty of Veterinary Medicine and Animal Husbandry Technology of S. Seifullin KATRU. The extrusion process was carried out as follows: the crushed grain was moistened in a screw mixer (moisture was introduced in the amount of 275 - 400 liters per 1 ton of product), after which it entered the receiving chamber of the extruder. In the extruder, the grain was subjected to compaction, compression, and high temperatures, reaching 25-50 atmospheres and 110 °C in the extrusion zone. The processing time of the product in the extruder was 8-10 s. All raw materials used for feed after extrusion and granulation were coated with fish oil and gelatin in order to ensure that the granules had a stable shape.

The obtained strains of lactobacilli were used to produce a symbiotic formulation in an amount of 1.0×10^7 CFU. For this purpose, lactobacilli were diluted in 25 ml of distilled water together with feed yeast. The symbiotic formulation was then added to the general diet after the feed was extruded by spraying it onto the surface of the granules. *Leuconostoc mesenteroides* and *Lactococcus lactis* were added to the main experimental diet in the amount of 10^7 cells/g for eight weeks.

In total, 135 kg of feed was used to feed young African clary catfish at a rate of 30 g per fish per day over 40 days. The fish were divided into two pools to form an experimental and a control group, with 100 individuals in each group. Generally accepted methods in fish farming were used to study the breeding and biological parameters of the fish. To assess the effectiveness of feed, a weekly total catch of the two pools was carried out to determine the mass of fish. To determine the Fulton fatness coefficient (kc), 20 fish were measured from each group, recording the fish mass (M), total length (L), and the length of the fish from the beginning of the head to the end of the scaly coat (l).

Veterinary and sanitary assessments of fish meat were carried out using generally accepted organoleptic and physico-chemical research methods. When conducting physico-chemical studies, a sample was cooked, and the concentration of hydrogen ions (pH) was potentiometrically determined; hydrogen sulfide was determined by heating minced meat and measuring a reaction to peroxidase according to A.M. Poluektov, a reaction to ammonia gas using the Eber method, and ammonia was determined with Nessler reagent. The nutritional value of fish meat was studied using gas chromatography in the Food Safety Laboratory of the Almaty Technological University.

Results and Discussion

We developed a formulation of dry extruded feed for juvenile catfish weighing 508 ± 0.1g with the addition of a probiotic (Table 1). An analysis of the domestic feed raw materials market confirmed the availability of all the components necessary to create a catfish feed formulation. The recipe used mainly vegetable raw materials (soybean meal, crushed wheat, and extruded peas), while fishmeal was used as an animal raw material. The formulation of the extruded water-resistant feed uses mainly raw materials of domestic production, which will reduce the cost of feed compared to imported feed by 30% (at current prices), while the chemical composition of the feed is not inferior to foreign analogs. The scientific justification for each component of the formulation is given. Taking into account the above and having analyzed the fish feed market in Kazakhstan (demonstrating a lack of specialized catfish feeds), we decided to include about 70% fish meal and soy meal in the recipe (the latter is more, since catfish prefer vegetable protein provided by the FAO).

Table 1 – Recipe of extruded feed with symbiotic supplement for catfish

Number	Components	Grams (per 5 kg)
1	Fish flour	1642.5
2	Blood meal	2100
3	Shredded wheat	350
4	Extruded peas	400
5	Potato starch	300
6	Fish oil	50
7	Tricalcium phosphate	50
8	Premix	100
9	Symbiotic supplement (mixture of *Lactobacillus* strains)	7.5

The composition of the extruded feed included crushed wheat and extruded peas in approximately equal proportions. In addition, our formulation included starch and gelatin for water resistance, with amino acids and mineral premix for fish. According to the FAO, the main nutrients for catfish are dry matter (DM), crude protein (CP), crude fat (CF), crude fiber (CF), and ash. All standards were taken from the FAO website. A chemical analysis of commercial and developed feeds was carried out, which was then used in the experiment to evaluate the effectiveness of the feed.

Table 2 – Chemical composition of extruded feed for catfish

Compound feed	Indicators (mean ± M±m, %)					
	Humidity	Protein	Fat	Cellulose	Ash	Starch
Catfish feed of KATRU (Experimental group)	9.5 ± 0.11	43.1±0.12	16.89±0.06	4.64 ±0.05	6.57 ±0.02	18.57 ±0.16
Commercial fish food (Control group)	9.3 ± 0.12	45.2 ±0.21	20.02 ± 0.08	4.43 ±0.04	6.46 ±0.09	14.22 ± 0.16

Chemical analysis showed that the extruded feed we developed for catfish, which included a symbiotic supplement, contained a protein level of 43.1 ± 0.12%, compared with 45.2 ± 0.21% in the commercial feed. The fat content also differed, being 16.89 ± 0.06% in our feed compared with 20.02 ± 0.08 in the commercial feed.

Preliminary experiments were conducted to evaluate the effectiveness of the developed feed on the production of African catfish in a closed-circuit water supply system with a water temperature in the range of 26-27 °C. To control the hydrochemical regime, water was analyzed daily according to the two most important parameters (O_2 and pH), and the temperature regime was determined once every 7 days. In addition to these indicators, a comprehensive analysis of water for the content of NO_2 and NO_3 was performed. The average O_2 content during the observation period was 6.3 mg/l, with fluctuations of

between 5.2 and 7.2 mg/l. The average pH value was 7.3, with fluctuations of 6.8-7.7. The average NO_2 value was 0.3 mg/l, with fluctuations of 0.3-1.5 mg/l, while the same values for NO3 were 30 mg/l and fluctuations of 10–50 mg/l. These results indicate a good hydrochemical regime in a closed-circuit water supply installation during experiments.

The initial weight of catfish was 486 ± 12.3 g in the Control group and a slightly lower value of 480 ± 9.6 g in the Experimental group ($P < 0.05$) (Figure 1). In the following two weeks, we did not observe a significant difference between the groups. In the first week, the control fish gained weight, but the absolute increase was 2.2 ± 0.26 g higher in the Experimental group; the experimental fish were 3.6 ± 0.33 g heavier in the second week. On day 40, we observed a significant difference in all indicators of weight gain ($P < 0.05$): the weight of the Control group fish was 570 ± 17.8 g, compared with 565 ± 18.2 g in the Experimental group ($P < 0.01$). The two length measurements (L and l) were not significantly different between the groups, given that only by the third week of the experiment did the fish differ in weight. However, in terms of fatness (kc), the two groups were significantly different at weeks 3 and 4 ($P < 0.05$). Thus, the assessment of feed efficiency showed a positive result since the relative increase in the Experimental group was 12.4 ± 1.7%, while the practical gain in the Control group was two times less, at 7.6 ± 0.83%. The survival rate of the fish in the two groups was 100%.

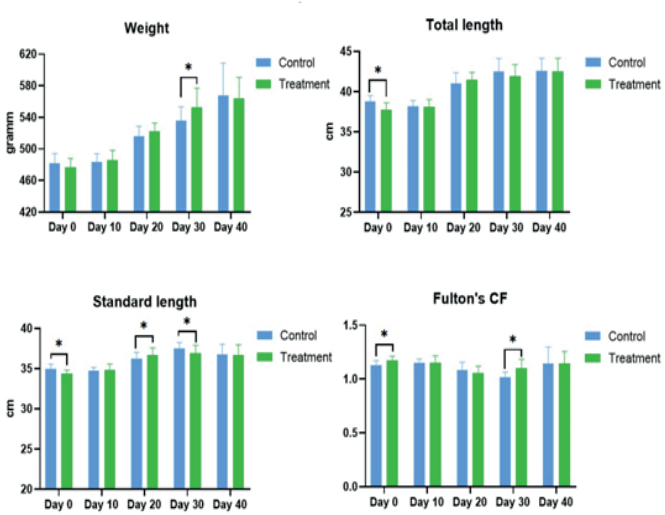

Figure 1 – Fish Breeding and Biological Indicators of African Catfish Fed with Extruded Feed with a Symbiotic Supplement

The Fulton fatness coefficient (kc) at the last measurement was 1.1 and 1.2 in the Control and Experimental groups, respectively. The veterinary and sanitary assessment of catfish meat in the Experimental group - according to organoleptic parameters - was fresh and benign, and the surface of the fish was glossy in appearance. The structure of the meat was dense and elastic. The color of catfish meat is dark gray, and it has a specific smell and taste. When tested by cooking, the color of the broth was transparent, without changes and flakes, which indicated the freshness of the meat. The pH of the meat was 6.6, corresponding to the norm for fresh fish meat. When determining hydrogen sulfide by heating the minced meat, the drop did not stain, which also served as an indicator of its good quality. When setting up the Eber reaction, a cloud of ammonia did not appear, which is considered a negative reaction to ammonia. When reacting with Nessler's reagent, the fish meat extract acquired a greenish-yellow color, which meant that the fish meat was fresh.

In terms of the chemical composition of catfish meat, the mass fraction of protein in the Experimental group was 17.38%, compared with 16.22% in the Control group; for fat, the mass fractions were 4.9 and 3.90%, respectively. The mass fraction of carbohydrates was not detected in either group. In the meat of the experimental fish, a decrease in the concentration of most amino acids was observed: arginine (3.959% compared with 4.969% in the Control group), lysine (1.527 vs. 1.104%), tyrosine (0.735 vs. 0.848%), phenylalanine (1.188 vs. 1.432%), histidine (0.933 vs. 0.906%), leucine + isoleucine (1.612

vs. 1.958%), methionine (0.820 vs. 0.789%), threonine (1.131 vs. 1.228%), and serine (0.905 vs. 1.140%). Nevertheless, all indicators of amino acid composition in both groups were normal. In terms of vitamin composition, approximately the same values of vitamin indicators were observed in both the experimental and control groups. The content of the mineral composition also corresponded to the norm, and their values were the same in both groups.

The demand for extruded mixed feed for fish was estimated at 29.3 million tons in 2008 and is expected to grow in step with increases in global aquaculture production. Since 1995, the production of mixed fish feeds has grown by an average of 10.9% per year [15–16]. Fish meal [17], soy meal [18], wheat [19], and blood meal [20] are mainly used in compound feeds for fish. In particular, African catfish need a large amount of animal protein as they are predators [21]; thus, fish and blood meal are used to increase dietary protein content [22]. Similarly, all of the above feed components were used in our formulation, the bulk of which was fish and blood meal. Wheat and extruded peas were also used as fillers, while gelatin, starch, and fish oil were used to shape the granules and bind the feed components.

The use of extrusion technology for the production of aquaculture feeds makes it possible to obtain pellets with high physical quality for a number of components. When the feed components are extruded, the microbial contamination of the feed is also reduced or eliminated, which makes it possible to obtain food that is safe for consumption. Some studies have also examined the effect of extruded feed with a symbiotic supplement on fish bodies and growth rates, as well as on the chemical composition of fish meat [22, 23]. Feeds prepared with a high content of vegetable protein (such as soy meal, wheat, and other economical sources of vegetable protein) may lack methionine [13]. Vegetable protein sources are poorly absorbed due to anti-nutritional factors and an unbalanced amino acid composition, which can lead to loss of nutrients in meat [3, 13]. Therefore, we included additional methionine in our formulation of the extruded feed. No significant differences in growth, body composition, and nutrient retention were found in fish fed with either extruded or granular feed with the same feeding rate ($P > 0.05$). The channel catfish fed with extruded feed had the same growth rates as those fed with granular feed with the same formulation [24]. The study found that growth - as indicated by the growth parameters and weekly growth - was influenced by the type of feed, with extruded feed having a greater impact than granular [25].

Conclusion

We developed a formulation of dry extruded feed for juvenile catfish weighing 508 ± 0.1g with the addition of symbiotic (mixture of probiotics). The recipe used mainly vegetable raw materials: soybean meal, crushed wheat, and extruded peas, fishmeal.

The chemical analysis revealed that the extruded catfish feed we created, including a symbiotic additive, had a protein concentration of 43.1% ± 0.12%, while the commercially available feed boasted a protein level of 45.2% ± 0.21%. Additionally, our feed exhibited a fat content of 16.89% ± 0.06%, contrasting with 20.02% ± 0.08% found in the commercial feed.

At the start of the study, catfish in the Control group weighed an average of 486 grams, with a standard deviation of 12.3 grams, while the Experimental group had a slightly lower average weight of 480 grams, with a standard deviation of 9.6 grams ($P < 0.05$). By day 40, a notable disparity emerged across all weight gain metrics ($P < 0.05$), with the Control group averaging 570 ± 17.8 g, while the Experimental group averaged 565 ± 18.2 g ($P < 0.01$). Although initial length measurements (L and l) showed no significant difference between the groups, this distinction became apparent in weight by the third week. Notably, the groups exhibited a statistically significant divergence in fatness (kc) during both the third and fourth weeks ($P < 0.05$).

A comparative analysis of catfish meat revealed significant differences in chemical composition between an experimental group and a control group. The experimental group exhibited a slightly higher protein content (17.38%) compared to the control group (16.22%). Fat content also showed a noticeable difference: 4.9% in the experimental group and 3.9% in the control. A detailed amino acid profile revealed a generally lower concentration of most essential and non-essential amino acids in the experimental group's meat. Specifically, arginine (3.959% vs 4.969%), lysine (1.527% vs 1.104%), tyrosine (0.735% vs 0.848%), phenylalanine (1.188% vs 1.432%), histidine (0.933% vs 0.906%), leucine + isoleucine (1.612% vs 1.958%), methionine (0.820% vs 0.789%), threonine (1.131% vs 1.228%), and serine (0.905% vs 1.140%) all showed a reduction in the experimental group.

Authors' Contributions

Supervision, conceptualization, writing - original draft preparation, writing - review and editing AP: methodology, validation, formal analysis, NS, DZh, ZhA, IA, GA, AK: all authors have read and agreed to the published version of the manuscript.

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