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DEVELOPMENT OF THE STURGEON FEEDING PROGRAM IN UKRAINE

Abstract: Aquaculture is one of the fastest growing food industries in the world today. The share of aquaculture in world fish production is growing every year. Over the past 50 years, the volume of fish farming in the world has increased by more than 50 million tons, while the growth in the volume of world fish catch stopped in the 80s of the last century. Aquaculture is one of the most promising and at the same time underestimated areas of economic activity in the agro-industrial complex of Ukraine, which, with the rational use of water resources, is able to provide consumers with a wide range of fish and fish products in a short time. A certain increase in the production of aquaculture products, especially the cultivation of sturgeon and salmon in Ukraine, is due to the use of imported feed, which has a high cost. However, its further development cannot rely on imported feed products, at the same time, the development of industrial fish farming methods is impossible without full-fledged balanced feeding of cultivated objects. Due to the aquatic environment, the need of fish for energy, nutrients and biologically active substances has its own specificity, in comparison, for example, with warm-blooded agricultural animals: it is the need for a high level of protein, another, a special ratio of protein and total energy, fat and polyunsaturated fatty acids, sensitivity to an excess of carbohydrates. Thus, in natural feed for fish, more than 60 % of the gross energy falls on protein, about 36 % — on fat and only 4 % — on carbohydrates. The development of domestic feed for sturgeon is an important task of the feed industry in Ukraine. The paper investigates the current state of fish farming in the country, the relevance and volume of production of compound feed for sturgeon fish, provides the advantages of growing sturgeon fish in Ukraine, analyzes the needs of sturgeon fish in nutrients, micro- and microelements and vitamins, analyzes the physical properties of compound feed for sturgeon fish recipes, an analysis of existing ones was carried out and a proprietary program for feeding sturgeon fish was developed. The developed sturgeon feeding program allows industrialists of the feed industry in Ukraine to use this information when calculating compound feed for sturgeon and their production.

Keywords: aquaculture, sturgeon fish, compound feed, feeding programs, sturgeon feeding, feed ingredients

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РАЗРАБОТКА ПРОГРАММЫ КОРМЛЕНИЯ ОСЕТРОВЫХ В УКРАИНЕ

Аннотация: Аквакультура сегодня является одной из самых быстрорастущих отраслей пищевого производства в мире. Доля аквакультуры в мировом производстве рыбы ежегодно растет. За последние 50 лет объем выращивания рыбы в мире увеличился более чем на 50 млн. т, в то время как рост объемов мирового отлова рыбы прекратился в 80-х годах прошлого века. Аквакультура является одной из наиболее перспективных и одновременно недооцененных сфер хозяйственной деятельности в АПК Украины, которая при рациональном использовании водных ресурсов способна в короткие сроки обеспечить потребителей рыбой и рыбной продукцией широкого ассортимента. Определенный рост производства продукции аквакультуры, особенно выращивания осетровых и лососевых в Украине, обусловлен использованием импортных кормов, имеющих высокую стоимость.Однако дальнейшее ее развитие не может опираться на импортную кормопродукцию, вместе с тем развитие индустриальных методов рыбоводства невозможно без полноценного сбалансированного кормления объектов культивирования. Благодаря водной среде потребность рыб в энергии, питательных и биологически активных веществах имеет свою специфику, по сравнению, например, с теплокровными сельскохозяйственными животными: это потребность в высоком уровне протеина, другое, особое соотношение белка и общей энергии, жира и полиненасыщенных жирных кислот, чувствительность к избытку углеводов. Так, в природных кормах для рыб более 60 % валовой энергии приходится на протеин, около 36 % — на жир и только 4 % — на углеводы. Разработка отечественных комбикормов для осетровых является важной задачей комбикормовой отрасли Украины.В работе исследовано современное состояние рыбоводства в стране, актуальность и объем производства комбикормов для осетровых рыб, приведены преимущества выращивания осетровых рыб в Украине, проанализированы потребности осетровых рыб в питательных веществах, микро- и микроэлементах и витаминах, проанализированы физические свойства комбикормов для осетровых рыб рецептуры, проведен анализ существующих и разработана собственная программа кормления осетровых рыб. Разработанная программа кормления осетровых позволяет промышленникам комбикормовой отрасли Украины использовать данную информацию при расчете комбикормов для осетровых и их производстве.

Ключевые слова: аквакультура, осетровые рыбы, комбикорма, программы кормления, кормление осетровых, компоненты комбикормов

Introduction. According to the recommendations of the World Health Organization, a person should consume at least 20 kilograms of fish annually[1].The Ukrainians have not yet succeeded in reaching this norm. One of the reasons: 80 % of fish in Ukraine is imported, which means it is expensive. Today fish consumption in Ukraine is 12–14 kg per person [2].

More than 70 % of the total global aquaculture production is dependent upon the supply of external feed inputs. Global aquaculture feed sales rose 4 percent to reach 41 million tonnes in 2019, according to the 2020 Alltech Global Feed Survey [3]. In 2018 Alltech Global Feed Survey shows that the aquafeeds sector grew by 4 percent [4]. Production volumes are growing for the sixth consecutive year, following an increase in consumption of aquaculture products. The most notable growth over the past year has occurred in Europe, which accounts for 9 % of world production. 75 % of the world production of compound feed for aquaculture falls on the countries of the Asia-Pacific region, 10 % — in Latin America, 5 % — in North America, 1 % — in the Middle East and Africa [5].

According to the results of aquaculture production of 2020 year, the best results were shown by the fisheries of Sumy (2.9 thousand tons), Cherkaska (2.6 thousand tons), Vinnitsa (1.9 thousand tons) and Kirovograd (1.5 thousand tons) regions. In these regions (as well as throughout Ukraine), the main objects of aquaculture are carp and herbivorous species. This trend has remained unchanged for a long time[6].

Sturgeons are fish species of biological and economic importance. Sturgeon species are grown more by fish farms located in the Zaporozhie, Cherkaska, Odesa, Chernivtsi and Kiev regions [7]. The development of sturgeon farming in Ukraine in recent years is also associated with the development of recirculating aquaculture, to a lesser extent with the development of horticultural fish farming. Leading farms of Ukraine that are engaged in the cultivation of sturgeon fish species: LLC “Sturgeon” (Kiev region), PE “NPSP” Bester “(Kiev region), PJSC” Chernigovrybkhoz “(Chernihiv region), LLC” Ukrainian service company “(Kiev region)), Private Enterprise “Fortuna-XXI” (Kiev), LLC “Kind fish” (Kiev region), “Odessa sturgeon complex” (Odessa region), FH “Ishkhan” (Chernivtsi region), LLC “Oasis Bisan” (Nikolaev region)), GC “Aquasvit”, LLC “Aqua Top” (Odessa), LLC “Scientific and Production Center” Trout “(Volyn region), State Enterprise” Irklievsky fish nursery “(Cherkasy region), LLC” Brig LTD “(Zaporozhye region), LLC “Biosila” (Kiev), LLC “Olesya” (Kherson region).

At the state level, the restoration of the sturgeon population is carried out by the S.T. Artyuschik Dnieper experimental production sturgeon fish hatchery (Kherson region). This state-owned enterprise was created back in 1984 — specifically to revive the stocks of Russian sturgeon, stellate sturgeon, beluga, sterlet, etc. Since then, more than 50 million sturgeon young have been released in the lower reaches of the Dnieper. In particular, in 2018, the fish factory introduced 1.6 million Russian sturgeon, sterlet and stellate sturgeon. In Ukraine, there are fifteen farms engaged in the cultivation of sturgeon fish species. In 2018, more than 200 kilograms of black gourmet caviar were supplied to the domestic domestic fish market. They have exported 67 kg of black caviar [8]. Over the past few years, more than ten sturgeon farms for the production of caviar have opened in Ukraine, therefore, the competition is already high on the market. In addition, active Chinese exporters in Ukraine are dumping at prices for caviar. If in Ukraine the prices for sturgeon caviar harvested by the classical method start at $ 800/kg, now a lot of Chinese caviar at $ 250–300 has appeared on the market.One kilogram of feed for fry costs more than 300 UAH (11.5 US dollars), and for adult fish — more than 55 UAH. The farm needs a ton of this feed per week.

A certain increase in the production of aquaculture products, especially the cultivation of sturgeon and salmon in Ukraine, is due to the use of imported feed, which has a high cost [9]. However, its further development cannot rely on imported feed products, at the same time, the development of industrial fish farming methods is impossible without full-fledged balanced feeding of cultivated objects.

The aquatic feed produced in the world is mainly intended for feeding carp (32 %), shrimp (21 %), sturgeon (12 %) and salmon (12 %). Although certain segments of the aquaculture industry, such as salmon, face sustainability challenges with terrestrial feed sourcing, the share of global animal feed used as aquafeed is small — estimated at 4 % (compared with roughly 40 % for poultry, 30 % for swine, and 25 % for ruminants) [10].

The objective of this review is to provide information on sturgeon feeding programs and provide a basis for recommendations for future research and use by fish feed manufacturers of the developed own sturgeon feeding program.

Main part. Sturgeons mainly live in temperate waters (from subtropical to sub-Arctic) of the Northern hemisphere; some grow and sexually mature in marine and brackish waters but migrate to freshwater to spawn, while others are land locked in freshwater for their entire life cycle[12].

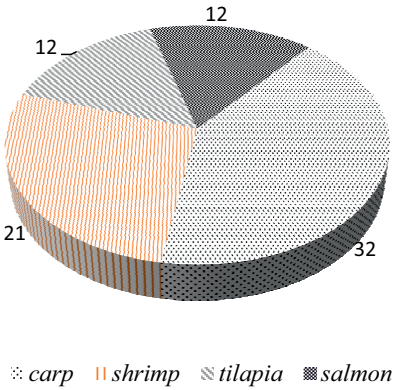

Fig. 1. The structure of production of feed for aquaculture

These species belong to the phylum Chordata, superclass Osteichthyes, class Actinopterygii, order Acipenseriformes and family Acipenseridae. There are 27 species in the Acipenseridae family, but 4 species are extinct. The 23 extant species are grouped into 4 genera with 2 species in Huso, 2 species in Scaphirhynchus, 3 species in *Pseudoscaphirhynchus* and 16 species in *Acipenser* [13]. Technologies for the commercial culture of various sturgeon species have been established over the last 20–30 years and they are now available for fish farmers. The production of sturgeon meat for human consumption has begun more recently. White sturgeon (*A. transmontanus*) and Russian sturgeon (*A. gueldenstaedtii*) and various sturgeon hybrids showed an increase weight between 1 and 2 kilograms and 100 % survival. Pelleted feeds were daily given 3–6 % of body weight, and food conversion ratio (FCR) was relatively at 4.5–5.0, likely generating a high load of wastes. At temperatures of 21–23°C, market size (1.0–1.3 kilograms) was attained in 12 months.

Physical properties of compound feeds for sturgeon. The habits of this fish are taken into account in the production of compound feeds. For sturgeon feed should be floating, because this species of fish feeds on the surface of the water, as a rule [14]. The physical properties of compound feed for fish are characterized by such indicators as size, moisture, fragility, bulk density, angle of natural slope, etc [15]. Today, compound feed for sturgeon, as well as for other fish species, is produced in extruded and pelleted form, which is very popular today. Paste-like compound feed for fish was produced in the 70s of the 20th century, but due to the high (up to 50 %) leaching of nutrients by water, they were abandoned [16].

The pellet length for all group numbers must be less than 1.5 times the diameter. The fragility of granules is not more than 8 %, water resistance is not less than 25 minutes. The size of the granules (crumbs) of compound feed depends on the body weight of the fish. Also, evaluating the quality of compound feed for sturgeon, indicate the mass fraction of protein, fat, ash, fiber, calcium, phosphorus, lysine, methionine and cysteine, some vitamins, the presence of metal-magnetic and harmful impurities, pest infestation [16].

Nutritional value of compound feed. Fish, like warm-blooded animals, need up to 40 different components, which are contained in 5 groups of nutrients: nitrogenous substances, fats, carbohydrates, vitamins and minerals [15]. Feeding it is necessary to ensure not only the amount of nutrients and biologically active substances, but also their ratio.

Sturgeon compound feed recipes are usually composed by combining individual components according to their chemical composition. Since the chemical composition and nutritional value of individual feed types differ, it becomes necessary to combine feeds with each other in certain proportions. In practice, this happens in the formulation of feeding rations. The chemical composition of compound feed gives a general idea of its potential biological value. The actual value of the compound feed is determined after adjusting for the inevitable losses arising in the processes of digestion and assimilation of nutrients of compound feed in the fish organism [17].

Young fish, having a high growth rate, require a higher concentration of protein in the feed than older age groups, which is associated with a decrease in the potential for growth of fish with an increase in body size.

Optimum dietary protein at 40.5 %, 40 %, 40 % to 45 %, 40 % and 37 % has been reported for the maximal growth of white, Siberian, Chinese, Persian and hybrid sturgeons, respectively [18].

To provide fast-growing larvae with a sufficient amount of essential and non-essential amino acids, starter feeds should contain 50–65 % protein. At the same time, the amount of water-soluble protein fraction, by analogy with natural food, should be sufficiently high. The specific needs of the larvae can be satisfied by including various types of hydrolysates, microbial products that contain degraded protein components in the starting feed of fish.

The main feature of the needs of the larvae of most sturgeon fish is the need for increased availability of protein components. The original feed requires the presence of digested protein products containing low molecular weight peptides and free amino acids [17]. Requirements of sturgeon in amino acids and vitamins are shown in table1 [19].

Table 1. **Requirements of sturgeon in amino acids and vitamins [19]**

% Protein	1993 year	2011 year
Arginine	1.20	4.8
Histidine	0.60	2.3
Isoleucine	0.80	3.0
Leucine	1.30	0.2
Lysine	1.60	5.4
Methionine	0.60	2.0
Cysteine	0.90	0.2
Phenylalanine	0.07	3.0
Tyrosine	1.60	2.3
Threonine	0.70	3.3
Tryptophan	0.20	0.3
Valine	0.80	2.3
Thiamine	-	60-120
Riboflavin	-	80
Vitamin A, mg/kg	-	2.5
Vitamin D, mg/kg	-	100
Vitamin E mg/gk	-	90
Vitamin K mg/gk	-	35

The importance of fats in sturgeon feeds is determined by their high calorie content in comparison with other nutrients, however, this does not exhaust their biological significance. The physiological value of fats depends on the composition and availability of fatty acids and vitamins. Since energy and plastic metabolism are two sides of the same process, the requirements for fat and protein are interrelated - the higher the protein content in the feed, the more fat should be.

The most important element of a balanced diet is the presence of the required level of essential highly unsaturated fatty acids with 4–6 double bonds in the lipids of the feed, which are recruited on diets with a large amount of yeast or bacterial mass, i.e. growth and development. Analysis has showed that dietary lipid requirement for maximum growth of juvenile hybrid sturgeon was at 11.1 % [18].

Table 2 shows the Requirements of 1993 and 2011 years of sturgeon fish in minerals according National Research Council [19]; they have changed with new scientific research.

Table 2. **Requirements of sturgeon fish in minerals [19]**

Macroelements, %	1993	2011
Calcium	1E	-
Chlorine	0.9E	-
Magnesium	0.05	0.05
Phosphorus	0.60	0.70
Potassium	0.70	-
Sodium	0.6E	-
Microelements, mg/kg		
Copper	3.0	3.0
Iodine	1.10	1.10
Iron	60	-
Manganese	1.3	12
Selenium	0.3	0.15
Zink	30	15

Analysis of sturgeon feeding programs. On the next stage of the work we have analyze the experience of leading sturgeon feed producers and their feeding programs. Compound fishfeed for the world market is represented by foreign manufacturers such as Biomar, LikraSkreting, Aller Aquaetc, which occupy the bulk of the market and are popular for both foreign and domestic consumers due to high-quality raw materials used and the latest technologies. A thoughtful feeding program involves taking care of different sizes of different species in their own niches in the pond. Commercial fish feeds from Aller Aqua are the result of comprehensive testing and evaluation, they have own research and development department and trial station in Germany, Aller Aqua Research. Accordin official information Aller Aqua use in sturgeon feeds fish meal, fish oil, grain products, vegetable proteins, vitamins and minerals as ingredients.

The paper considers the feeding programs of such foreign manufacturers as Biomar and AllerAqua, they are presented in table 3, 4, 5. As can be seen from the tables, the nutritional value of compound feed depends on the purpose of the fish, for obtaining caviar or for obtaining fillets from the fish. EFICO Sigma 844 is specially designed for mature sturgeon females as a finishing feed for the final stages of caviar production. In collaboration with top sturgeon farms in France, BioMar's caviar finishing feed is designed to promote high yields of quality caviar.

As can be seen from table 3, sturgeon feeds require higher crude fat compare to feeds for fillet purpose table 4. Also BioMar has aquafeeds for fish in stress

conditions; they have higher crude protein content [22]. BioMar has over 20 years of experience with sturgeon feed production. BioMar's sturgeon feed is produced with high quality raw materials. It is suitable for both recirculation and flow-through systems in a variety of climates for optimum growth performance and cost-effective fish farming.

Table 3. **Feeding program of BioMar company for obtaining caviar from sturgeon [20]**

Indicator	EFICO Sigma 844	EFICO Sigma 844	EFICO Sigma 844
Pellets size, mm	3.0...4.5	6.5... 9.0	12.0...15.0
Crude protein, %	47.0	44.0	43
Crude fat, %	14.0	18.0	18.0
Crude fiber, %	4.0	4.0	3.7
Crude ash, %	8.4	7.9	7.7
Phosphorus %, not less	1.2	1.1	1.1
Gross energy, not less, MJ / kg	20.7	21.4	21.6
Vitamin E, mg/kg, not less Vitamin C, mg/kg, not less	200 300	200 300	200 400

BioMar uses the following ingredients: feather meal, fish meal, hemoglobin, meat bone meal animal fat, rapeseed, rapeseed oil, soybeans, concentrated sunflower protein, triticale, vitamins and minerals, wheat.

Potential alternative include meals and oils from plants (the greatest source of protein and edible oil on earth), fish processing waste, yeast, bugs and other special meals, and even seaweed. Potential alternative ingredients already in use include soybeans, barley, rice, peas, canola, lupine, wheat gluten, corn gluten, other various plant proteins, yeast, insects and algae.

Table 4. **BioMar feeding program for feeding for fillet purpose [22]**

Indicator	EFICO Sigma 811R	EFICO Sigma 811R	EFICO Sigma 811R	INICIO Plus 805 (stress conditions)
Pellets size,mm	3.0...4.5	6.5...9.0	12.0...15.0	12.0...15.0
Crude protein, %	46.0	44.0	44.0	51.0
Crude fat,%	14.0	16.0	16.0	16.0
Crude fiber,%	5.0	5.3	5.3	2.4
Crude ash,%	6.3	6.6	6.6	8.7
Phosphorus %, not less	0.9	1.0	1.0	1.3
Gross energy, MJ / kg	21.8	21.9	21.9	18.0

Table 5. **Aller Aqua feeding program for sturgeon for fillet purpose [21]**

Indicator	Aller Performa	Sturgeon ALLER IVORY EX, 2 MM Fry feed to 50 g	Sturgeon ALLER BRONZE Grower Feed	Sturgeon ALLER BRONZE Grower Feed
Pellets size, mm	1.5	2.0	5.0	11.0
Crude protein, % not less	48.0	54.0	45.0	45.0
Crude fat, % not less	21.0	20.0	15.0	15.0
Crude fiber, % notmore	1.1	0.9	3.2	3.2
Crude ash, %	8.7	8.2	6.5	6.5
Phosphorus %, not less	1.2	1.1	1.2	1.1

Based on the analysis of the feeding programs (table 4, 5, 6) and recommendations from foreign sources and research, our own sturgeon feeding program was developed, it shown in table 7. The main impotent indicators were chosen: crude protein, crude fat, crude fiber, crude ash, lysine, methionine, phosphorus, gross energy, vitamin E and vitamin C. As can be seen from the table 7, starting sturgeon feeds should have higher crude protein content (minimum 48.0 %) and less crude fiber content (maximum 1.1 %), lysine and methionine content (% of protein) not less 5.4 and 2.0 respectively.

Table 6. **Sturgeon feeding program [22]**

Feeding period	Fish size, mm	Pellets size, mm	Crude protein, %	Crude fat	Crude fiber	Gross energy	Phosphorus
Prestrating	3-15	1.3-1.5	58.0	17.0	0.9	21.6	1.2
Starting	15-50	2.0	54.0	20.0	0.9	22.2	1.1
Grower	50-7000	38.0	45.0	15.0	3.2	21.2	1.1
Finishing	more 7000	11.0	45.0	15.0	6.5	21.2	1.1

After analyzing the feeding programs of the presented manufacturers, it can be noted: the presented feed manufacturers use feeding programs that differ in the growing periods and nutritional value of the compound feed; modern feeding programs mainly divide the period of sturgeon rearing into prestart, starting, growers and productive (finishing); for fish of the same age, within the same manufacturer, compound feeds are produced that differ

in nutritional value, indicating the difference in feed (for example, economy and increased nutritional value); in the programs of different companies, at the beginning of productive cultivation, different weights of fish correspond.

Table 7. **Feeding program for sturgeon (developed)**

Indicator	Feeding period of sturgeon		
	Starting	Grower	Finishing
Pellets size, mm	1.5	1.5	5.0
Crude protein content, % not less	48.0	48.0	45.0
Crude fat content, % not less	21.0	21.0	15.0
Crude fiber, % notmore	1.1	1.1	3.2
Crude ash, %,	8.7	8.7	6.5
Lysine, % of protein, not less	5.4	5.4	5.4
Methionine, % of protein, not less	2.0	2.0	2.0
Phosphorus %, not less	1.2	1.2	1.2
Gross energy, not less, MJ / kg	20.0	20.0	21.2
Vitamin E, mg/kg, not less	200	200	200
Vitamin C, mg/kg, not less	300	300	400

Conclusions. The current state of fish farming and the relevance of the production of compound feed for sturgeon fish have been investigated. In recent years, the new sturgeon farms have been opened in Ukraine. The increase in sturgeon cultivation is partly due to the use of the highly efficient foreign-made compound feeds. In Ukraine, for the effective development of aquaculture, it is necessary to pay close attention to the efficiency and quality of compound feed. Unfortunately, the quality and nutritional value of domestic compound feeds are inferior to foreign ones due to the use of outdated requirements and programs for years of valuable fish species.

The article analyzes the physical properties of compound feed for sturgeon fish and the peculiarities of the formulation of foreign manufacturers. The need of sturgeon fish in micro- and microelements, vitamins is shown. The analysis of existing feeding programs BioMar and Aller Aqua was carried out. Based on the analysis, we have developed our own sturgeon feeding program. The developed sturgeon feeding program will divide the period of fish development into initial, growth and final periods and meets the needs of sturgeon fish according to the latest recommendations.

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