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MACHINE-HARDWARE DIAGRAM OF COMPLEX BIOTECHNOLOGICAL PROCESSING OF AQUACULTURE OBJECTS

Abstract. Currently, a number of fish farms operate in the Kaliningrad region, which specialize in breeding aquaculture objects, including common carp (*Cyprinus carpio* Linnaeus, 1758) and clariid catfish (*Clarias gariepinus* Linnaeus, 1758) and their further sale in live or chilled whole form. There is not complex processing, as a rule. The paper shows the need for biotechnological processing of aquaculture and ways to use the waste obtained during filleting for production of minced fish and, later, minced semi-finished products. The lack of integrated use of waste from fish processing industries is a common problem in the fishing industry, so the need to solve this problem is obvious. For the efficient processing of fish raw materials, it is necessary to create a technology that will make it possible to maximize the use of waste from fish production, including the use of biotechnological methods, but at the same time ensure high quality of finished products. The paper presents the mass composition of common carp (*Cyprinus carpio* Linnaeus, 1758) and clariid catfish (*Clarias gariepinus* Linnaeus, 1758), developed a technological diagram for the complex biotechnological processing of aquaculture objects in the conditions of small enterprises of fish processing farms, proposed a description of technological processes and a machine-hardware diagram. Integrated technology implies the presence of the main and additional production. An additional diagram is associated with the production of imitation fat, the basis for which can be ground fat-containing components pre-treated with enzymes, such as tioshka and milk, as well as fish broths obtained by cooking collagen-containing components (heads, fins, tails). This technological approach can be used in the conditions of “Belvodkhoz” enterprises engaged in the cultivation and subsequent processing of aquaculture objects, for example, Fish Farm “Volma”.

Keywords: aquaculture, clariid catfish, common carp, imitation fat, machine-hardware diagram, complex processing

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МАШИННО-АППАРАТУРНАЯ СХЕМА КОМПЛЕКСНОЙ БИОТЕХНОЛОГИЧЕСКОЙ ПЕРЕРАБОТКИ ОБЪЕКТОВ АКВАКУЛЬТУРЫ

Аннотация. В настоящее время в Калининградской области функционирует ряд рыбоводческих хозяйств, которые специализируются на разведении объектов аквакультуры, в том числе карпа обыкновенного (*Cyprinus carpio* Linnaeus, 1758) и клариевого сома (*Clarias gariepinus* Linnaeus, 1758), и их дальнейшей реализации в живом или охлажденном неразделанном виде. Комплексная переработка, как правило, отсутствует. Показана необходимость биотехнологической переработки аквакультуры и пути использования отходов, полученных при разделке на филе, для производства рыбных фаршей и в дальнейшем фаршевых полуфабрикатов. Отсутствие комплексного использования отходов рыбоперерабатывающих производств является распространенной проблемой рыбной отрасли, ввиду чего необходимость ее решения очевидна. Для эффективной переработки рыбного сырья требуется создать технологию, которая позволит максимально использовать отходы рыбного производства, в том числе с применением биотехнологических методов, но при этом обеспечить высокое качество готовой продукции. Представлен массовый состав карпа обыкновенного (*Cyprinus carpio* Linnaeus, 1758) и клариевого сома (*Clarias gariepinus* Linnaeus, 1758), разработана технологическая схема комплексной биотехнологической переработки объектов аквакультуры в условиях малых предприятий рыбоперерабатывающих хозяйств, предложены описание технологических процессов и машинно-аппаратурная схема. Комплексная технология предполагает наличие основного и дополнительного производства. Дополнительная схема связана с производством имитационного шпика, основой для которого могут послужить предварительно обработанные ферментами измельченные жиросодержащие компоненты, такие как теша и молоки, а также рыбные бульоны, полученные при варке коллагенсодержащих компонентов (головы, плавники, хвосты). Данный технологический подход может быть использован в условиях предприятий ГО «Белводхоз», занимающихся выращиванием и последующей переработкой объектов аквакультуры, например ОАО «Рыбхоз “Волма”».

Ключевые слова: аквакультура, клариевый сом, карп обыкновенный, имитационный шпик, машинно-аппаратурная схема, комплексная переработка

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Introduction. Currently, aquaculture is one of the main areas that ensure food security of the country, since its development is aimed at solving the most important national tasks, such as: providing the population with fish and other aquatic organisms, reducing import dependence, and conserving aquatic biological resources [1]. At the moment, the Russian market has nearly suspended the supply of fish due to the closure of seaports, which creates the conditions for a significant growth of aquaculture, as fishing is increasingly becoming unprofitable in the face of depletion of the main commercial fish stocks.

As a rule, the main objects of breeding in pond aquaculture are cyprinid fish species. Sturgeon and other species are also cultivated. Recently, there has been an active cultivation of catfish. Among the advantages of their cultivation are a fairly fast period of growth to marketable fish (six months), disease-resistance and a possibility of growing even with limited water space. The commodity advantages of catfish are obvious – absence of scales and small bones, tasty meat and a low selling price [2–7]. Sharptooth catfish is a heat-loving species with an optimal average growing temperature of 25 to 28 °C. During the summer period, it grows from a fry to an individual weighing about 600 g. However, if it is grown in open water bodies, it must be caught and sent for processing.

Growing raw materials involves their further use, therefore, small workshops are built near fish farms or on their territory, which allows increasing the output of finished products. As a rule, aquaculture objects are sold in a live or chilled whole form, which is associated with the peculiarities of the anatomical structure and a large number of bones in some species, such as cyprinids, or they are cut into fillets (yield is 40–50 % of the total mass) or sent to production of hot smoked products. In order to maximize the use of the edible part, it is advisable, after cutting the fish into fillets, to use food fish waste, namely the remaining muscle part on the bone for the production of minced meat from freshly caught or chilled raw materials. Minced meat can be sold in a chilled or frozen form, as well as molded semi-finished products can be produced based on it. This will not only introduce waste-free technology, but also generate additional income for fish processing enterprises. For the complex biotechnological processing of fish raw materials, which ensures a high degree of use of food waste obtained during cutting, it is necessary to create new technologies for enterprises for processing and developing competitive fish products from aquaculture objects [8].

Recently, the range of semi-finished products is constantly changing and growing. The pace of life of a modern person and his or her employment increases the demand for products that require a minimum investment of time. Preparation of semi-finished products allows increasing the range of fish products [9].

Fish semi-finished products include molded fish products from cutlet mass (cutlets, meatballs) and minced meat intended for the production of fish sausages, including grilled sausages. Production of molded minced products allows using food waste, improving the taste of the product from cutting and expanding the range. Semi-finished products, namely fish sausages, pre-prepared for frying, are popular with the population, since they are most convenient both for picnics and for everyday use due to ease of preparation and relatively low cost.

The key issue of the complex processing of aquaculture objects, such as common catfish (*Cyprinus carpio* Linnaeus, 1758) and sharptooth catfish (*Clarias gariepinus* Linnaeus, 1758) is the lack of practical application of waste-free machine-hardware diagrams and the full use of valuable food waste, of which only a small part is used further for feed purposes [10–14].

In the published literature, there are no machine-hardware diagrams for the complex processing of fish raw materials, including the processes of using food waste from cutting. At present, the state program of the Russian Federation “Development of the fishery complex”[1] has been adopted, which in-

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cludes a number of subprograms (for example, "Organization of fishing", "Development of aquaculture"), the "Strategy for the development of the fishery complex until 2030"[1] is in force. The use of waste-free technologies for extraction (catch), transportation and processing is an important task.

The purpose of the research is to develop a machine-hardware diagram for the complex biotechnological processing of aquaculture objects in the conditions of small enterprises of fish processing farms.

The tasks are as follows:

1. Development of principles and technological methods for the integrated biotechnological use of edible fish waste for production of fish fillets and fish semi-finished products (grilled sausages).

2. Selection of equipment for complex processing of aquaculture objects.

Objects and Methods of the Research. The object of the study is such aquaculture objects as common carp (*Cyprinus carpio* Linnaeus, 1758) and sharptooth catfish (*Clarias gariepinus* Linnaeus, 1758), grown at fish farms of the Kaliningrad region.

Results and Discussion. At the initial stage of the research, the weight composition of common carp (*Cyprinus carpio* Linnaeus, 1758) and sharptooth catfish (*Clarias gariepinus* Linnaeus, 1758) was studied. The data are presented in Table.

Weight composition of common carp (*Cyprinus carpio* Linnaeus, 1758) and sharptooth catfish (*Clarias gariepinus* Linnaeus, 1758), %

Type of cutting	Waste	Fish type, weight fraction of the different parts of fish, % from the weight of the whole fish	
		Common carp (*Cyprinus carpio* Linnaeus, 1758)	Sharptooth catfish (*Clarias gariepinus* Linnaeus, 1758)
Fillet	–	50.7	41.5
–	Tail, fins	4.4 ± 0.4	3.1 ± 0.4
–	Head	26.1 ± 0.6	30.7 ± 0.5
–	Bones left from fish filleting	16.9 ± 0.9	15.6 ± 0.6
–	Fat-containing food waste (tioshka, milt)	10.2 ± 0.4	8.4 ± 0.5
–	Guts	12.3 ± 0.5	2.3 ± 0.4
–	Scale	2.2 ± 0.4	–
–	Skin	3.6 ± 0.4	2.3 ± 0.5

The presented data shows that the percentage of fat-containing fish waste (tioshka, milk) is significant and amounts to about 10 % of the total mass of raw materials. This shows the feasibility of their further processing, which is due to the biological effectiveness of fish oil, the composition of which is mainly represented by unsaturated fatty acids. Being dense in structure, tioshka should be a homogeneous mass in the manufacture of imitation fat, in order to soften and increase the yield before grinding. Because of that the authors proposed a preliminary biotechnological treatment of fat-containing fish waste, including two stages: I – fermentation, II – temperature treatment (cooking).

The water-holding capacity and rheological characteristics of meat raw materials are important indicators that have a significant impact on the technological process, resource and energy efficiency of production and the quality of finished products. High-molecular compounds of meat raw materials – proteins – are the main structural components that bind moisture in food raw materials and products. It is evident that regulation of functional, technological and organoleptic properties of meat (fish) raw materials is possible by forming certain spatial structures of proteins and peptides that have various radicals and functional groups on their surface that have hydrophilic properties. Undoubtedly, the functional state of these groups is determined by the environmental conditions (temperature, ionic strength of the solution, pH, chemical components, etc.) [15–17]. In recent years, enzyme preparations (a complex containing one (or several) enzymes and auxiliary components) have been actively used in order to accelerate

[1] [Об утверждении Стратегии развития рыбохозяйственного комплекса Российской Федерации на период до 2030 года и плана мероприятий по ее реализации] [Электронный ресурс]: распоряжение Правительства РФ, 26 нояб. 2019 г., № 2798-р (в ред. от 12.05.2022 г.) // КонсультантПлюс: [сайт]. 2022. URL: https://www.consultant.ru/document/cons_doc_LAW_338713/ (дата обращения: 12.04.2023).

specific reactions in the biotechnological processes of production, storage and processing of food raw materials and products. In the present work, fermentation was carried out using the Enzy-Mix U enzyme preparation, which includes a complex of acid proteinases (chymosin: pepsin, mass ratio 1 : 9). In the course of previous studies, the technological parameters of fermentation were substantiated, which made it possible to obtain the maximum yield of fat-containing raw materials (the fermentation time was 12 hours at a temperature of (20 ± 5) °C). To reduce economic costs and rational use of the biocatalyst, we justified the mass fraction of the introduced enzyme preparation, which was 0.1 % of the mass of raw materials. The enzymatic hydrolysis of the peptide bonds of the protein components of raw meat contributed to the fact that the samples obtained after fermentation had a loose texture and were easily grindable. Obviously, the hydrolysis of peptide bonds of macromolecular compounds – proteins with the participation of an enzyme preparation led to the formation of peptides, which affected the rheological characteristics of mince products, product yield and the speed of technological processes.

To inactivate enzymes and simplify the separation of the fat-containing part, the cooking modes (temperature (70 ± 1) °C, time 20 min) have been substantiated [18]. The output of the semi-finished product after tioshka fermentation is about 80 %. The technology for obtaining imitation fat is described below.

Bones from fish filleting from the mass of raw materials range from 15 to 18 %. Their separation makes it possible to obtain minced meat with the mass varied in the range from 8 to 10 % of the body weight of fish, which shows the feasibility of processing food waste obtained from cutting aquaculture objects into fillets.

The planned work shop for production of fish fillets and fish semi-finished products (grilled sausages) is located near fish farms, which makes it possible to use high-quality raw materials immediately after being caught. Figure 1 shows the flow diagram of complex processing.

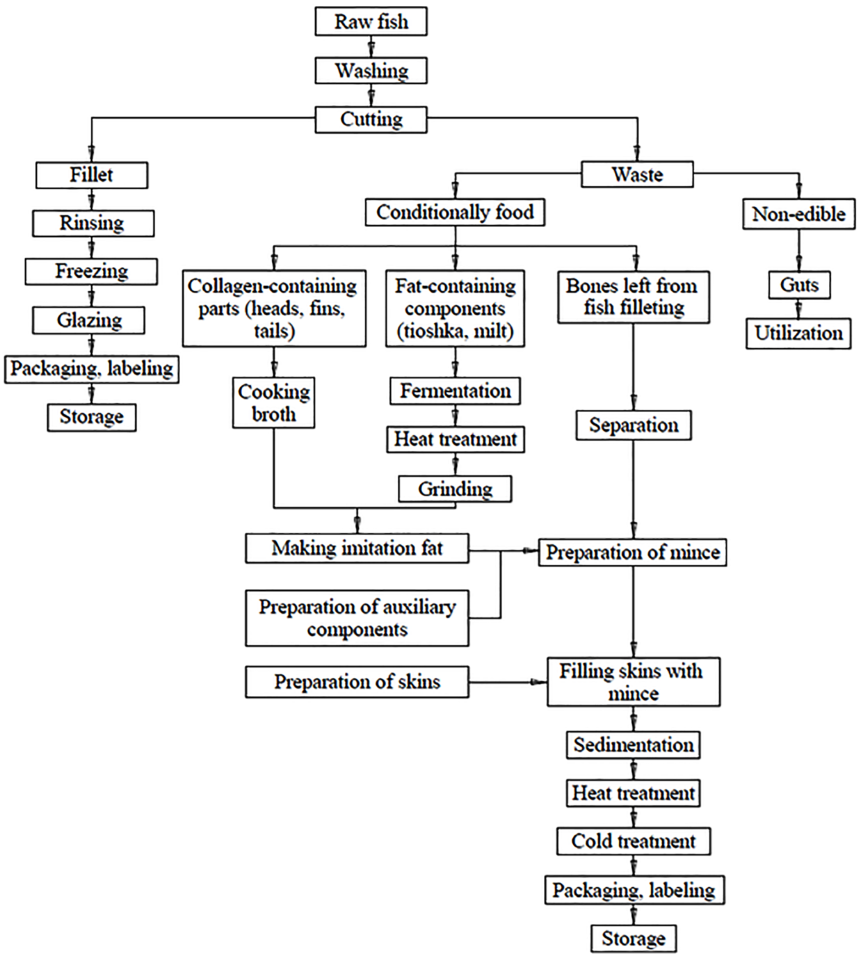

Figure 1. Complex processing flow diagram

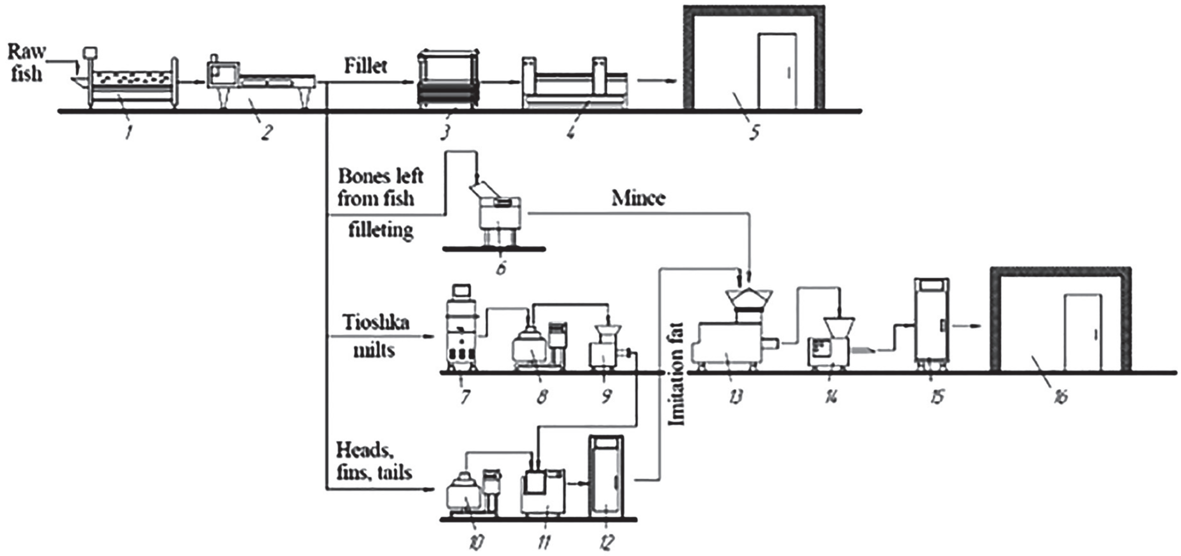

Figure 2. Machine-hardware diagram for the complex processing of aquaculture objects: *1* – preparation of fish, including washing, if necessary – removal of scales; *2* – cutting into fillets; *3* – freezing; *4* – glazing; *5* – packaging, storage; *6* – obtaining mince on a neopress; *7* – fermentation; *8* – heat treatment; *9* – grinding; *10* – cooking and filtering of the broth; *11, 12* – preparation of imitation fat; *13* – preparation of mince; *14* – filling skins with mince, sedimentation; *15* – heat treatment; *16* – packaging, labeling, storage

The machine-hardware diagram is shown in Figure 2. The proposed diagram of the complex processing of aquaculture objects provides for cutting fish raw materials into fillets, subsequent separation of meat from bones in a neopress, production of imitation fat based on fish edible waste and further production of fish semi-finished products (grilled sausages). This technological line is unified and allows the production of assorted fish semi-finished products on a mince basis.

Filleting of aquaculture objects is mechanized and carried out on filleting machines (*2*). Before cutting, the raw material undergoes additional (*1*) treatment (washing, if necessary, removal of scales). The use of equipment, in comparison with cutting by hand, allows increasing the yield of the finished product. Belly bones of common carp (*Cyprinus carpio* Linnaeus, 1758) are removed using a deboning machine, where the fillets are cut up to 300 mm wide. The fillet is further sent for freezing (*3*) followed by glazing (*4*), storage and sale (*5*). The remaining muscle tissue on the bone is processed using a neopress (*6*). The fish passes between the pressing drum and the milling belt, where the meat is squeezed out through the small holes of the drum and minced. All by-components of minced fish, such as skin, bones, scales, exit through a special hole.

Collagen-containing food waste, such as fish heads, is proposed to be used for production of fish broths, which can later be sold either to catering establishments in a chilled or frozen form, or as a liquid base for manufacture of fish imitation fat, which serves as a semi-finished product for a number of sausage-based fish products. The broths are produced in vacuum cookers (*10*). As a fat-containing component, pre-prepared crushed fat-containing wastes (tioshka, milk) are added to the imitation fish fat. Subsequently, the filtered fish broth is mixed with a multifunctional mixture and crushed fat-containing fish components until a stable emulsion is obtained, which is then aged until completely solidified.

The stage of preparation of mince is to mix it with the rest of the ingredients. Mince is prepared on a mince meat mixer (*13*). Among the advantages of mince preparation using a mince meat mixer are that this equipment is relatively inexpensive and does not require high qualification of the operator [13, 19]. According to the recipe, spices and imitation fat (may be pre-crushed) are added to the mince. Filling the skins with mince is carried out with a stuffer using vacuum of periodic action (*14*). The sausage loaves are further hung on sticks, which are then placed on frames, sent to the sediment and then to the heat chamber (*15*), where saturated steam cooking is carried out. Cooling can be carried out in water or air in a heat chamber. At the end of the technological process, ready-made fish sausages are packed, labeled and sent for sale.

The machine-hardware diagram for the complex biotechnological processing of aquaculture objects in conditions of small fish processing enterprises, additionally includes a line for the production of imitation fat, which allows for the complex use of edible fish waste obtained during cutting.

An important issue of ensuring the economic efficiency of the line for the complex processing of aquaculture objects is a high level of automation at all stages of production (including complex automation, including aquaculture processes). Introduction of integrated automation allows minimizing human participation in the management process, ensuring control and regulation of the main technological parameters, including food safety, creating flexible production that implements the most rational use of raw materials.

With the right organization of technological and complementary processes, waste recycling can significantly increase profitability and allow enterprises to generate additional income. The integrated use of aquatic bioresources is an important area of research, which allows to reduce economic costs, expand the range of products and allow rational use of raw materials. The proposed technology for the complex processing of aquaculture objects in the conditions of small enterprises makes it possible to overcome the above problems associated with waste disposal and range expansion.

Conclusion. 1. As a result of the research, the principles of technological (including biotechnological) methods for the integrated use of fish food waste from cutting, aimed at the production of semi-finished fish products (grilled sausages) have been developed.

2. The modes of two-stage biotechnological processing of fat-containing fish waste (tioshka) have been substantiated: fermentation time and temperature (12 h, (20 ± 5) °C), mass fraction of the introduced enzyme preparation (0.1 %). A recipe for imitation fat and a technology for its production have been developed.

3. A unified machine-hardware diagram for the complex biotechnological processing of aquaculture objects in conditions of small fish processing enterprises has been developed. This diagram includes biotechnological processing of fat-containing fish waste and an additional line for production of imitation fat, aimed at the production of fish fillets and semi-finished fish products (grilled sausages). All this allows for the complex use of edible fish waste obtained during cutting.

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