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DEVELOPMENT OF THE TECHNOLOGY OF SAUSAGE PRODUCTS FROM AFRICAN CATFISH

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Abstract. *The work substantiates the feasibility of developing the technology of fish sausages from African catfish. On the basis of the analysis of literary sources, the priority directions of processing fish raw materials and expanding the range of fish products are determined. An analysis of the existing technologies of fish sausage products was carried out. The prospects for the production of fish sausages have been established. The expediency of using African clary catfish (Clarias gariepinus Burchell, 1822) as a raw material for the production of sausage products has been theoretically substantiated and experimentally confirmed. The effectiveness of combining catfish meat with other hydrobionts and animal raw materials is shown. New recipes of raw-smoked sausages based on African catfish with the addition of mackerel, sea scallop and lard have been developed. A study of organoleptic, physico-chemical indicators of quality and nutritional value of finished products was conducted. According to the results of the research, the compliance of the indicators with the requirements of the standard was established. The results of the chemical composition study indicate the high nutritional value of the developed sausage products. On the basis of theoretical and experimental studies, a technological scheme for the production of raw-smoked sausages from African catfish was developed.*

Keywords: *African catfish, fish sausage, recipe, technological scheme, nutritional value.*

I. INTRODUCTION

Today, fish and its processed products occupy an increasing share in the human diet, primarily due to the high nutritional benefits associated with the chemical composition. The range of products produced by fish processing enterprises of Ukraine is almost constant, which does not ensure the growth of demand and high demands of consumers.

Technologies for sausage products made from hydrobionts are being successfully developed and implemented in many countries of the world, but the production of these products is limited in Ukraine. Therefore, developments aimed at the use of new types of raw materials, improvement of the technological process of production and recipe composition are gaining special relevance.

The classification of sausage products opens up the possibility of production of a wide range of products - sausages, sausages, sausages, combining the recipe components of which (inclusion of additional raw materials) solves the problem of expanding the range of sausage products.

Recently, African catfish (*Clarias gariepinus*), as a promising object of cultivation and processing, has received a lot of attention. It has valuable meat, is characterized by high growth rates, uses low-cost feed for feeding, and is unpretentious

to the conditions of keeping [1, 2].

The meat of clary catfish has high nutritional and culinary properties. Due to the optimal combination of proteins, fat and amino acids, fish is ideal for children's and dietary food, and the absence of small bones makes it convenient for cooking and eating. The high content of Omega-3 polyunsaturated fatty acids helps to reduce the level of cholesterol in the blood, prevents blood clots, and also has a beneficial effect on strengthening the vessels of the brain. The product is hypoallergenic. Even people with pronounced allergies to fish and seafood can eat meat. African catfish tastes more like animal meat than fish [3].

The development of sausage products from African catfish for further introduction into production at domestic enterprises is relevant.

II. LITERATURE ANALYSIS

Modern principles of creating high-quality sausage products are based on the selection and justification of certain types of raw materials in such ratios that would ensure the achievement of the predicted product quality, high organoleptic indicators and certain technological food characteristics.

The technology of making sausage products includes preliminary processing of raw materials and materials, assembly of sausage mixtures, injection of mixtures, heat treatment and storage of products. The quality of food products is assessed mainly by organoleptic indicators. The properties of sausage products, even of one type, vary widely, which is caused by the difference in the chemical composition of the raw material and the different degree of its processing.

Fish raw materials are used in the recipe of meat-rich sausage cooked from waterfowl meat, which includes ingredients in the following ratio: ground duck meat (muscovy duck) - 30-40%, minced fish (silver crucian carp) - 40-50%, lard - 10%, dry whey - 5%, wheat flour - 1%, eggs or melange - 4% and spices. Samples were made according to the technology of cooking minced meat for cooked sausages [4].

According to the patent (CN №104116091A), the technology of obtaining fish sausage by air drying is known. It involves thawing the fish, cutting the raw material into small pieces of 1-1.5 cm, marinating at a temperature of 0-5 degrees for 2-4 hours, fermentation for 1-3 hours at a temperature of 25-35 degrees, drying for 5-8 hours at a temperature of 10-20 degrees by drying, weighing, packing, vacuum sealing; sterilization at 115-121 degrees for 10-25 minutes, air drying, packaging. Fish sausage made in this way has a good taste and consistency, can be stored at room temperature and is ready for consumption.

In Japan, a sausage made of fish raw materials and spices has been developed, which is stuffed into a thin casing and eaten fried or boiled (JP №2008182897A). The sausage is prepared exclusively from fish and spices, it can be consumed within five days after production and has good organoleptic properties.

According to the method of making sausage from fish meat (KR № 102286395B1), not only a wonderful texture is provided without the use of pork or pork fat, but also the shelf life is increased. A mixture of pollock and sea bream in the ratio of 6:4 is mainly used as raw material. The method of production of sausage from fish meat includes the stages of grinding fish meat, emulsification, mixing minced meat with all ingredients,

injection of casings and heat treatment. Potato starch, which is most often used as a thickener in the technology of making sausages, is the reason for the deterioration of the existing quality of fish sausages. Therefore, potato starch, modified potato starch and tapioca starch are used as a stabilizer in this recipe in a ratio of 7:2:1. Carrageenan is also added to the minced meat mixture as a thickener. The following seasonings are used in the recipe: table salt, granulated sugar, soy sauce, a mixture of peppers, cheese and beetroot powder. The developed technology solves the problem of short shelf life caused by the use of natural starch in existing fish sausages. It is a technology with a very high industrial impact, as it can contribute to increased sales and increased profits.

A cheese fish sausage with a high calcium content and a method of its preparation have been developed in China (CN №107095204A). Fish bones are turned into ultra-thin fish bone paste and added to fish sausage. This technology reduces the cost of sausage products. Fish sausage with a high calcium content is rich in nutrients and is especially suitable for consumption by children and the elderly.

The technology was developed and textural and sensory properties of fish sausage made from chilled and frozen rainbow trout (Onchorynchus mykiss) and stored for 14 days at 0–4 °C were determined [5].

A variety of fish sausage is sausage with fruit and vegetable compound (CN № 106333278A). When properly dissolved and joined, the resulting composite fish sausage has a more elastic texture, moderate hardness, and uniform texture than fish sausage made by prior techniques. Fruits and vegetables are added in the form of granules. After adding to fish sausage, the granules can retain the original taste and color of fruits and vegetables, and its elasticity is similar to that of fish sausage. Pectin, sodium alginate, agar, carrageenan can be used as a coagulant.

Developed fish sausage containing fish meat, surimi, potato starch, soy protein, modified tapioca starch, soy fiber, salt, sugar, garlic powder, vegetable oil, chicken eggs (TH №11885C3). The technology was developed and the physico-chemical and sensory properties of sausages made from washed and unwashed Nile tilapia by-products were evaluated [6].

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In Brazil development and evaluation of fresh sausage type of marine catfish stored under low temperatures. The sausages of marine catfish featured good nutritional quality, sensory, and shelf life between 21 to 25 days when kept under refrigeration and four months under freezing [7].

Three types of fresh fish sausage were prepared, one from Clarias lazera, the other from Tetradon fahaka while the third from a mixture of the two species. Nutritional composition, sensory evaluation and microbiological detection of fish sausage made from mince of the two species and a mix were determined [8].

According to patent US20120294982A1, the use of clary catfish in the production of fitness cooked sausage and sausage made of fish, soybean and pork is known. The object of the invention is to provide a meat-mix based foodstuff that altogether omits the admixing of usual empty fats, which is compensated by the addition of lean fish meat having a high content of natural marine omega-3 fatty acids present in fish meat, from particular fish species and, if needed, the admixture of essential vegetable and marine

omega-3 fatty acids in the form of triglycerides and/or ethyl esters thereof as well as plant protein isolates, water-soluble and/or oil-based antioxidants, in order that four objects are achieved: optimum taste; avoiding lifestyle diseases even; continuous metabolization; significant improvement of the taste properties during the storage period, especially of sliced sausages.

Fish sausages are made in Germany (DE №102007025847A1) based on the meat of clary catfish (*Clarias gariepinus*) and freshwater catfish (*Heterobranchus longifillis*). Fish meat with a fat content of less than 7% is used to prepare minced meat. According to the recipe, salt and/or nitrite for marinating and spices are added to the minced fish. The technology of this sausage differs in that carbohydrate-based hydrocolloids are added to the meat base during the cutting process.

The well-known technology and recipe of Chinese-style fish sausage, made from the clarias catfish hybrid. The variations studied were kinds of lipids, i.e., pork fat or palm oil; amount of palm oil between 5 and 10 % (w/w) of fish meat; amount of spices between 1.2 and 1.6 % white pepper or 1.2 % white pepper plus 1.5 % mixed 5 spices powder (cinnamon, cardamom, coriander, star anise, fennel); drying time at 50◦C for 28 or 48 hours [9].

In Turkey production of a dry sausage from African catfish and determination of its microbial, chemical and sensory properties during a 70-day storage at both 4 and 22◦C were prompted [10].

The successful foreign experience of manufacturing various fish sausage products, including those based on clary catfish, testifies to the expediency of this direction of the domestic fish processing industry.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of research is the technology of sausage products based on the meat of the African clary catfish.

The subject of the study is quality indicators of fish raw materials; sausages made from African catfish meat; indicators of quality and safety of fish sausages during storage.

Studies of the chemical composition have been performed according to the following methods: mass fraction of moisture – by drying the product sample to a constant weight in an oven SNOL (Labimpex LTD, Ukraine) at a temperature of 100-105ºC according to DSTU 8029:2015; mass fraction of ash – by a weightning method, after the mineralization of a portion of the product in a muffle furnace SNOL (Labimpex LTD, Ukraine) at a temperature of 500−600°C according to DSTU 8718:2017; mass fraction of lipids – by the Soxhlet extraction-weight method according to DSTU 8718:2017 on the SOX 406 Fat Analyzer (Hanon Instruments, China); mass fraction of protein – by Kjeldahl method of the determination of a total nitrogen, which is based on the ability of organic matter of the product sample to be oxidized with concentrated sulfuric acid in the presence of a catalyst according to DSTU 8030:2015, while samples ashing has been performed on a DK6 digester (Velp Scientifica, Italy), with a vacuum pump JP, distillation has been carried out on a steam distillation apparatus UDK 129 (Velp Scientifica, Italy).

Determination of organoleptic parameters has been carried out by the profile

method using a 5-point scale, according to the recommendations of T.M. Safronova.

The acid number of lipids was determined according to DSTU EN ISO 660:2019. Peroxide number of lipids, according to DSTU EN ISO 3960:2019. The total volatile basic nitrogen according to GOST 7636– 85.

The number of mesophilic aerobic and facultative anaerobic microorganisms was determined in accordance with DSTU 8446: 2015; bacteria of the Escherichia coli group, according to DSTU GOST 30726: 2002; Staphylococcus aureus, according to GOST 10444.2-94; pathogenic microorganisms, including genus Salmonella, according to DSTU ISO 11290-1, DSTU ISO 11290-2.

Shelf life was determined by the dynamics of changes in the complex of organoleptic, physicochemical and microbiological indicators.

IV. RESULTS

At the first stage of research, the size and mass composition of the African catfish was determined (fig. 1).

Fig. 1. Determination of size composition of African catfish

Dimensional characteristics are given in tabl. 1.

According to GOST 1368-2003, a catfish is a large fish with a length of 53 cm or more, a small fish is a fish with a length of less than 53 cm, therefore, the studied samples of African catfish are small fish.

Table 1. Size composition of African catfish

Indicators	**L, sm**
Length:	
- absolute	50,1± 0,5
- industrial	44,3± 0,3
- head	10,3± 0,1
- tail fin	6,2± 0,2
- carcass	33,2± 0,3
Body height	7,9± 0,2
Body thickness	7,3± 0,2

The mass composition of fish depends on its sex, physiological state, season and other factors. The dependence of the mass composition on the sex of the fish is due to the different sizes and mass of mature sexual products in males and females, and seasonal differences are associated with changes in the size of sexual products during

their development and spawning, as well as with uneven nutrition and different fatness of fish. As the fish ages, the mass of edible parts increases due to the development of fat and muscle tissue. The results of the study of the mass composition of clary catfish are presented in tabl. 2.

Table 2. Mass composition of African catfish

Fish body parts	**The mass fraction**	
	grams	**%**
Whole fish	758± 0,2	100
Fish without fins	747±0,3	98,5
Fish without bowels	731±0,9	96,4
Headless fish with shoulder bones	524± 0,3	69,1
Fillet with skin	440± 1,4	58,0
Fillet without skin	390± 0,5	51,4
Head	207± 0,3	27,3
Bowels	16± 0,9	2,1
Fins	11±0,3	1,4
Bones	84± 0,6	11,1
Skin	50± 0,5	6,5
Output	390± 0,5	51,4
Waste	368± 0,5	48,6

Analysis of the data in table 2 showed that the yield of clean fillet is 51.4%. The internal organs of catfish occupy a small volume - 2.1% of the weight of the fish. The practical absence of intercostal bones, a large content of muscle tissue makes the clary catfish a valuable object for processing.

The consumer properties of clary catfish meat are largely determined by its chemical composition. The results of the study of the content of moisture, protein, fat and ash are shown in fig. 2.

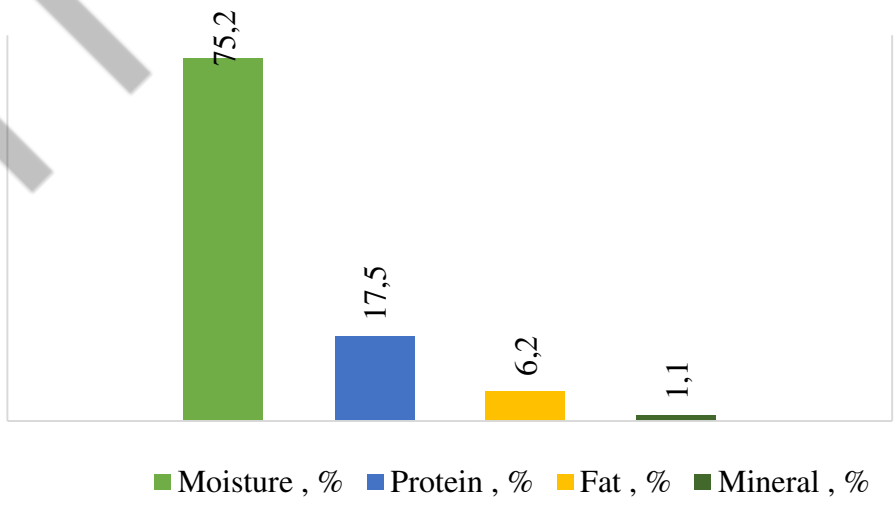

Fig. 2. Chemical composition of African catfish meat

According to the results of the chemical composition study, African catfish is a protein, medium-fatty fish. The research results are consistent with literature data [10].

One of the indicators of the quality of muscle tissue is the water-holding capacity. The study of the water-holding capacity of fresh (sample 2), chilled (sample 3) and frozen (sample 1) meat is presented in fig. 3.

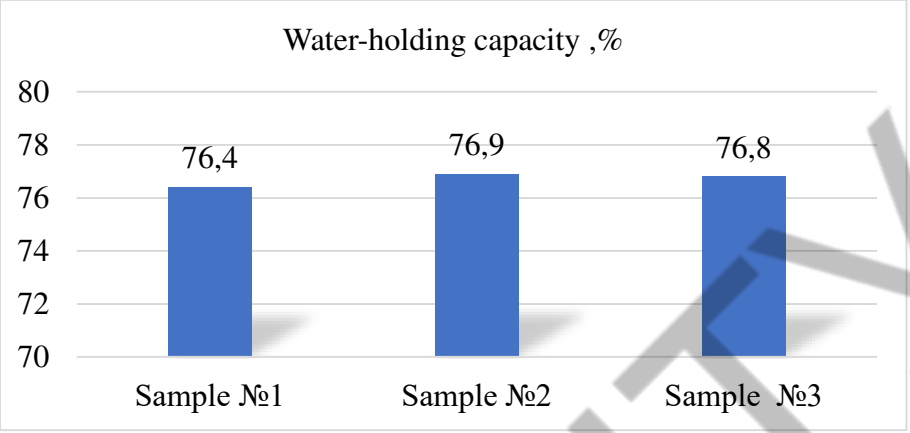

Fig. 3. Water-holding capacity of minced African catfish

The analysis of the data in Figure 3 shows the high water-holding capacity of the minced meat, so products made of African catfish will perfectly retain their shape, be juicy and tender.

Samples of sausages based on African catfish were developed with the addition of such ingredients as: Atlantic mackerel, sea scallop, pork lard and spices, which improve the organoleptic indicators of finished sausage products, increase their nutritional and biological value. Comparative characteristics of control and experimental samples of sausage products are presented in tabl. 3.

Table 3. Comparative characteristics of the recipe composition of control and experimental samples of African catfish sausages.

The name of the raw material	**Consumption of raw materials per 100 g**			
	Control	**Experimental samples**		
		№1	**№2**	**№3**
Pollack (pieces)	30	-	-	-
Pollack (minced)	30	-	-	-
African catfish (pieces)		30	40	30
African catfish (minced)		45	50	30
Atlantic mackerel (minced)	10	15	-	10
Sea scallop muscle	20	-	10	20
Pork lard is unsalted	10	10	-	10
Salt	2,0	2,0	1,2	1,5
Ground black pepper	0,1	0,1	0,1	0,1
Whole coriander	0,1	0,1	0,1	0,1
Ground nutmeg	0,1	0,1	0,1	0,1
Dried ground red hot pepper	0,05	0,05	-	0,05
Dried minced garlic	-	0,2	-	0,2
Ground paprika	-	-	0,1	0,2
Cumin seeds	-	0,05	0,1	0,05
Dried ground ginger	-	0,1	-	0,1

The technical result of the developed recipe consists in obtaining high-quality raw-smoked fish sausage from African catfish, which has a high nutritional value due to the combination of pre-salted fish raw materials and raw non-fish raw materials. At the same time, the quantitative ratio of the selected components makes it possible to obtain a high-quality finished product.

For the production of fish sausages, fresh and frozen fish raw materials of a quality not lower than the first grade were used. After thawing, the fish was washed in running water, the temperature of which does not exceed 15 °C, to remove mucus and other impurities from the surface of the fish, and it was cut into fillets. Lard was chopped into 5×5 mm pieces. The fish fillet was salted and kept at a temperature from 0°C to 10°C for 6-12 hours until the salt content was 3%.

Part of the fish raw material was ground into pieces, and the other part of the fish raw material was added to the minced meat mixture in the form of pieces with geometric dimensions equal to 1.0-2.0×10-2 m, in order to obtain the fibrous structure of the finished sausage products. Food and flavor additives were added to the minced meat mixture.

Prepared natural casings (pork bellies) were filled with ready minced meat and loaves were formed. The obtained loaves were kept in a ripening chamber at a temperature from 0°C to 10°C and a relative humidity of no more than 75% for 12...36 hours until the average value of the buffering index is at least 70°.

Smoking was carried out by the convective method at an air temperature of 45-60°C until a homogeneous state and reaching an average water content of no more than 55%. After smoking, the obtained sausage products were dried by the convective method at an air temperature of 19°C to 25°C and a relative air humidity of 75...85% to an average value of the mass fraction of water no more than 50%.

A developed sample of African catfish sausage is presented in Fig. 4.

Fig. 4. Fish sausage from African catfish

In order to substantiate the expediency of combining clary catfish meat with Atlantic mackerel meat, sea scallop meat and raw materials of plant origin, an organoleptic evaluation of the compatibility of these ingredients in fish sausages was carried out using the flavor profile method.

To characterize the taste of African catfish sausages, a profile analysis has been performed by the method of flavor based on selected descriptors. In order to better visualize the results for each of the samples, detailed organoleptic profiles of the flavor have been developed, and a comparison with the "ideal" profile have been performed (fig. 5).

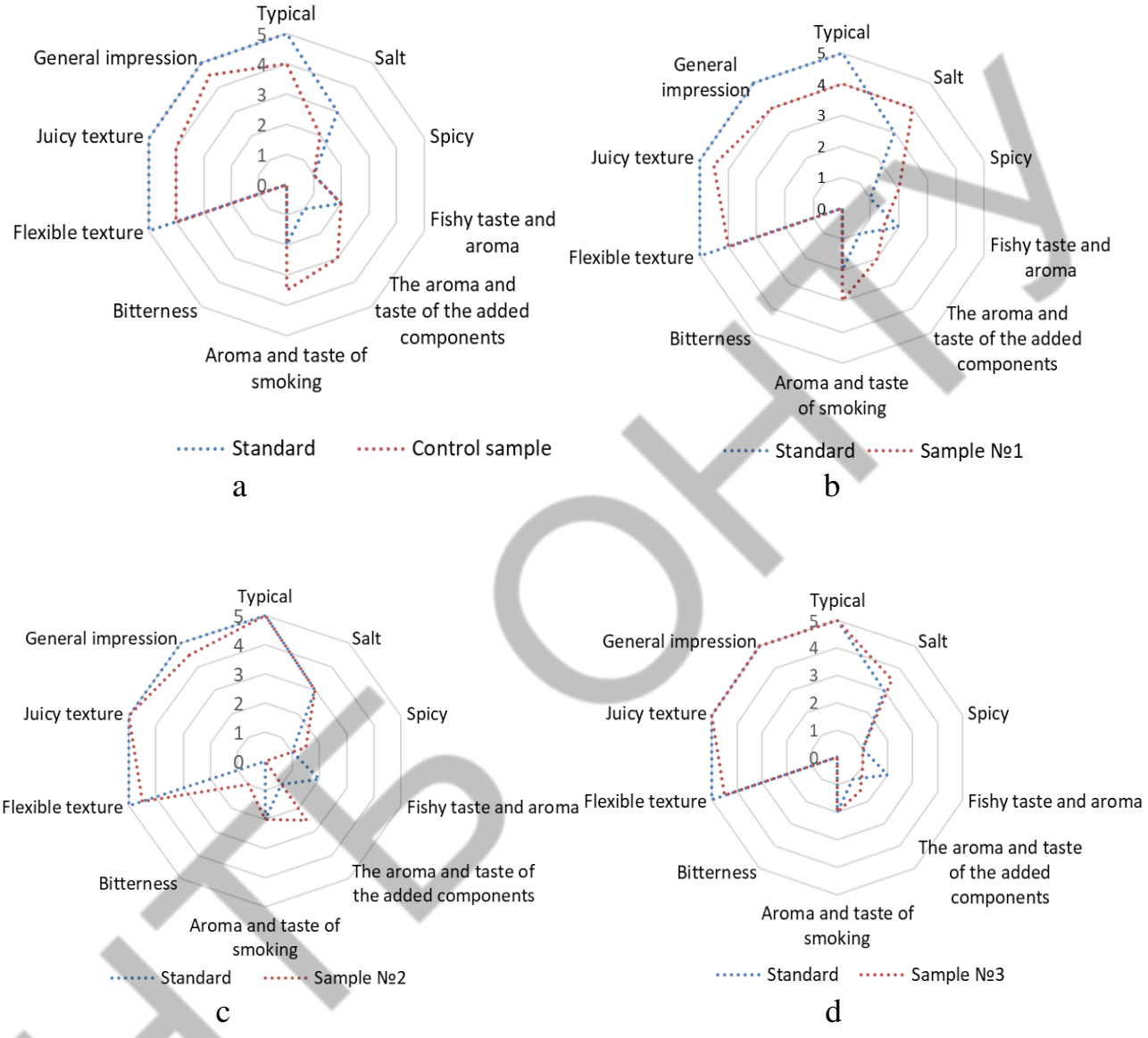

Fig. 5. Fish sausage flavor profiles: a – control sample, b – sample №1, c – sample №2, d – sample №3

According to organoleptic profiles, the most similar to the "ideal" is the profile of fish sausage made according to recipe № 3.

As a result of the assessment of the compatibility of the ingredients in fish sausages using the flavor profile method, it was established that the addition of minced fatty fish, namely mackerel, and pieces of lard and sea scallop to mincemeat made from lean fish increases the taste properties, appearance and creates an elastic consistency and a whole sausage structure. Flavor and aroma indicators are improved by spices and seasonings, which were added by us according to the recipes. The addition of cumin,

paprika, ginger and garlic gives piquancy and original taste to the sausages.

The organoleptic evaluation of fish sausage products was carried out according to the following indicators: appearance, color, taste, smell, consistency. A comparison of the received samples of fish sausages with each other using the "Quality Polygon" is shown in fig. 6.

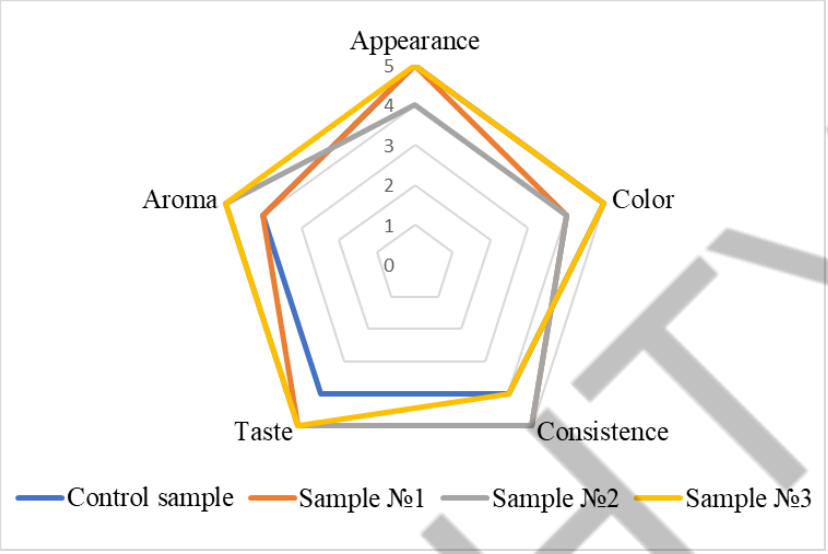

Fig. 6. Organoleptic evaluation of samples of fish sausages using the "Quality Polygon"

According to the organoleptic evaluation, sample № 3 is the best.

The main indicator of nutritional value is the chemical composition. The results of studies of the general chemical composition of formulations are given in tabl. 4.

Table 4. General chemical composition of recipes

Name of samples	**Chemical composition, %**			
	moisture	**fat**	**protein**	**ash**
Control sample	49,92±0,7	21,41±0,3	23,72±0,2	4,95±0,1
Sample №1	49,83±0,6	21,33±0,2	24,11±0,2	4,73±0,1
Sample №2	49,95±0,4	18,93±0,5	26,19±0,1	4,93±0,2
Sample №3	49,84±0,5	20,04±0,2	25,24±0,1	4,88±0,1

The results of the study of the chemical composition of the developed samples indicate a high nutritional value. The moisture content does not exceed 50%, which corresponds to the norm for raw smoked sausages.

The stability of fish products during storage is determined by the level of initial microbiological insemination, the qualitative composition of microflora, the type of raw materials, the pH level, the moisture content, the condition of the surface of the product, the temperature, the humidity of the environment and the speed of air circulation, non-compliance with the temperature conditions of storage, the type of packaging, the presence of bactericidal and bacteriostatic means, shells.

The results of studies of the organoleptic indicators of the manufactured sausage samples during storage at a temperature of 5-6 °C for 15 days are shown in fig. 7.

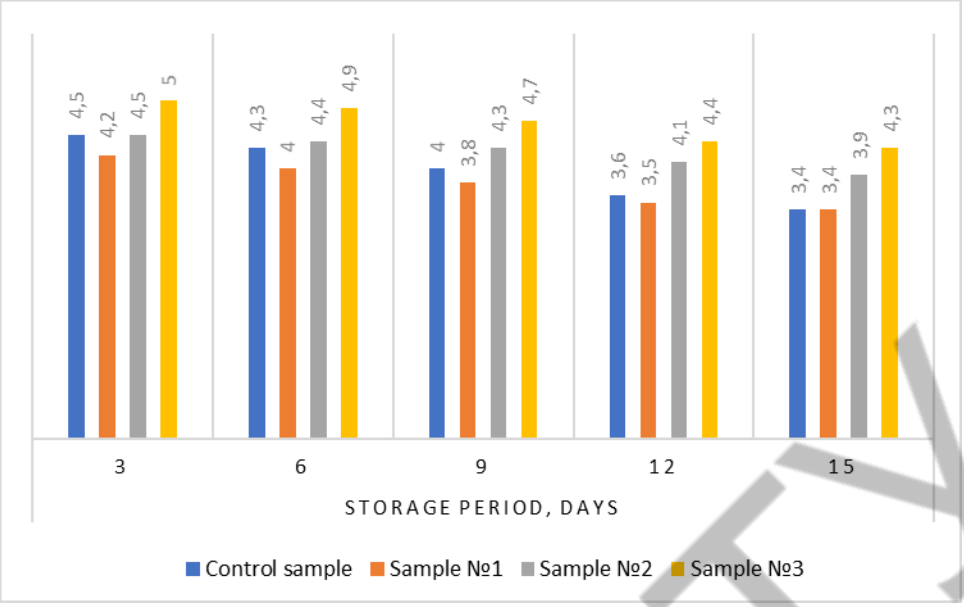

Fig. 7. Organoleptic evaluation of fish sausages during storage

It can be seen from Figure 6 that gradually during storage sausage products reduce their organoleptic indicators.

The developed samples of sausages have a high content of fish and animal fats in their composition. An important indicator is the assessment of the quality of the lipid component of products during storage. The course of hydrolysis and oxidation of fats in fish sausages was evaluated by acid and peroxide numbers.

The acid number of fat characterizes the presence of primary products of fat hydrolysis. The dynamics of accumulation of free fatty acids is shown in fig. 8.

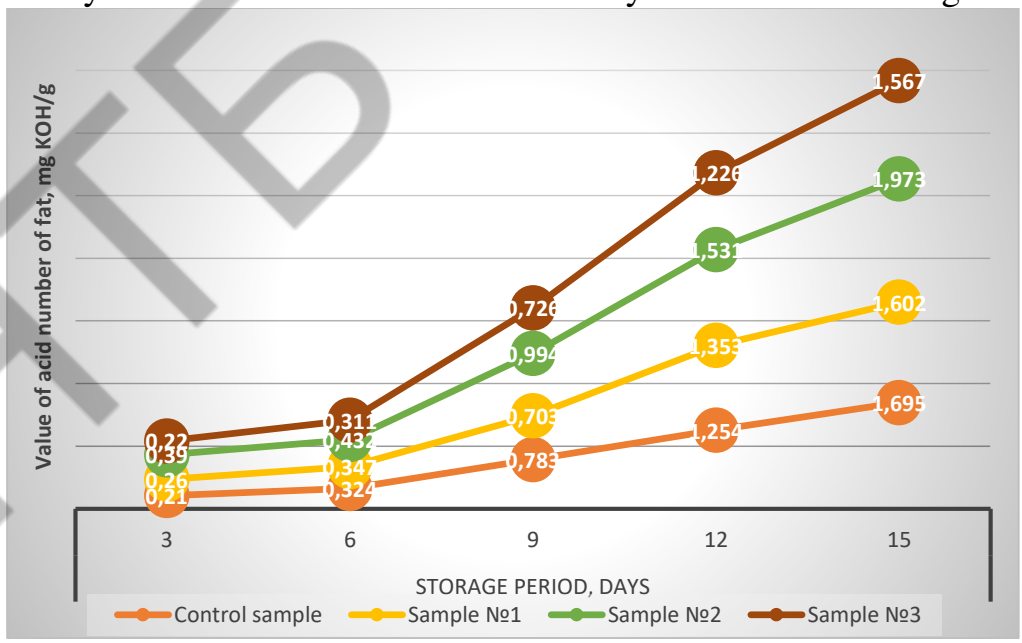

Fig. 8. Dynamics of acid number indicators in sausages

An increase in the acid value of fat during storage of fish sausages occurs due to the hydrolysis of triglycerides. During the entire storage period, the acid number of lipids in both samples does not exceed the norm established for fish fats for the

production of food products (4.0 mg KOH/1 g of fat).

The course of lipid oxidation processes in the initial stages is characterized by the peroxide number. The dynamics of the accumulation of peroxides and hydroperoxides during the storage of sausages is shown in fig. 9.

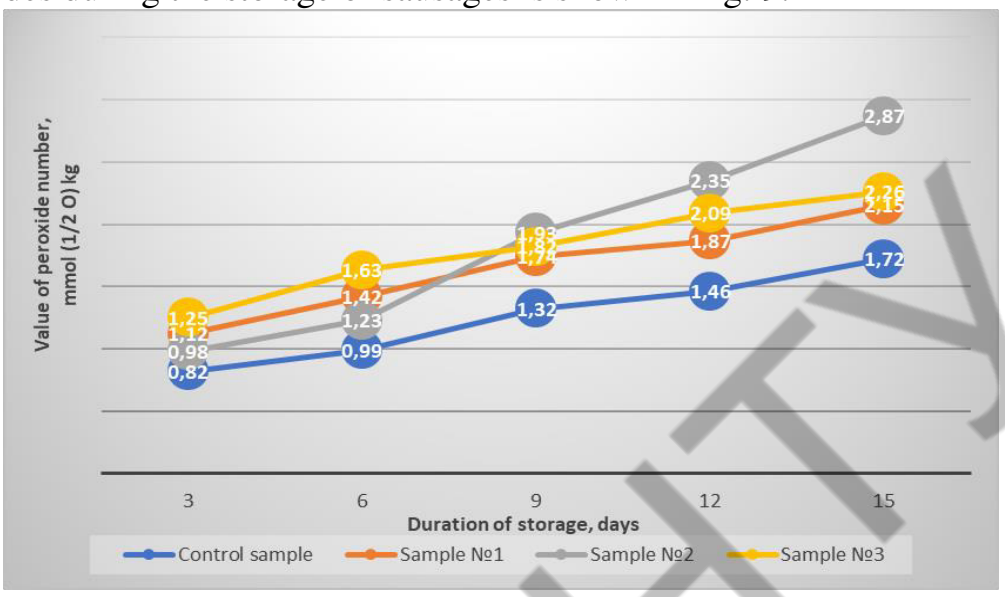

Fig. 9. Dynamics of peroxide number values in sausages

From fig. 8 it can be seen that the processes of fat oxidation occur more intensively in sample № 2, which is explained by the presence of hydrobionts in the lipid composition. On the 15th day of storage, the indicators of the fat peroxide number of all samples are significantly below the established norm of 10 mmol (1/2 O)/kg of fat.

The degree of microbiological processes and proteolysis was studied by changes in the total nitrogen content of volatile bases (fig. 10).

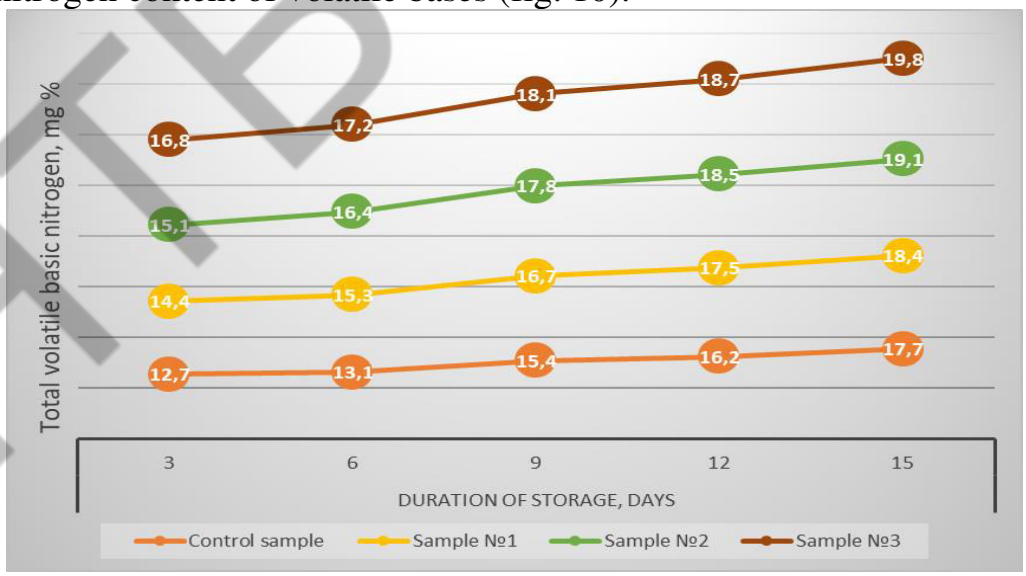

Fig. 10. Changes in indicators of total nitrogen of volatile bases in the process of storing sausages

In fig. 9, we can see that at the maximum product storage period of 15 days, the total nitrogen content of volatile bases does not exceed the permissible level of 30 mg%.

The safety of fish sausages was studied by microbiological quality indicators. On the 15th day of sausage storage, the number of mesophilic aerobic and facultatively anaerobic microorganisms is acceptable for product suitability, but close to the limit $5 \cdot 10^3$ CFU/g. Bacteria of the Escherichia coli group, Staphylococcus aureus, and Proteus were not detected in 0.1 g of the studied samples. Pathogenic microorganisms, including Salmonella and L. monocytogenes, were absent in 25 g of all sausage samples.

V. CONCLUSIONS

Based on the analysis of theoretical and experimental studies, the technology for the production of sausage products from African catfish was developed.

Based on the techno-chemical characteristics of African catfish, the expediency of using this raw material in the technology of sausage products has been confirmed.

Recipes of raw-smoked African catfish sausages with the addition of such components as mackerel, sea scallop, lard have been developed.

Organoleptic, physico-chemical, chemical, microbiological, studies of quality indicators of finished products were conducted. Based on the research results, the compliance of the indicators with the requirements of the standard was established.

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INTEGRATION OF TECHNOLOGY IN THE MECHATRON MODULE OF LIQUID DOSING

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Abstract. *The influence of individual parameters on the accuracy of product dose formation was determined during physical and mathematical modeling. We have found ways to ensure the necessary distribution of compressed air pressure, subject to compliance with the specified performance of the dispenser. Research results make it possible to improve the operation of dosing systems for liquid products with high dosing accuracy. The control system is formed on the basis of electro-pneumatic complexes. The control model with dosing operating modes is substantiated. It was established that the consumption of compressed air will depend on the value of the input main pressure P (0.05... 0.4 MPa).*

The consumption of the product was in the range of 1 ml to 50 ml with a feeder volume of 2.25 l. A mathematical model of the dosing process of liquid products (non-carbonated drinking water, milk, juice) has been developed. Boundary conditions took into account the influence on the formation of the product dose from the programmed current values in mA (with an accuracy of 0.001 mA) in relation to the standard scale Imin, Imax=4..20 mA.

An analytical description of individual stages of the dosing process with further analysis of individual stages and accepted assumptions was formed. Tests of the experimental sample of the dispenser showed the accuracy of the repetitions of the dose extrusion (limits ± 0.035% and 0.8%) from the set value of the dose mass up to 50 ml during the change and the initial liquid level in the reservoir of the dispenser feeder.

Keywords: *dosing, air lift system, excess pressure, feedback, dosing accuracy.*

I. INTRODUCTION

A number of small and medium-sized enterprises are now engaged in the production and packaging of liquid products in containers. In this regard, the problem of creating inexpensive and compact import-substitutable dosing and packaging equipment, taking into account the specific working conditions for small productions, becomes extremely urgent [10-27].

The systems of dosing and packaging modules for liquid products in containers, in the conditions of small productions, have specific requirements: high operational reliability, a wide range and high accuracy of dosing in combination with the possibility of rapid reconfiguration of the equipment for different types of liquids and dosing ranges; the possibility of smooth adjustment of the dose in a wide range; the possibility of prompt flushing or replacement of the product line; the possibility of installing the dispenser in the conveyor line; construction of multi-channel dosing systems; absence of intraoperative drop formation; compactness, simplicity and safety of maintenance; fire and explosion safety, etc.

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