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Quality characteristics of fish sausages made from African catfish (*Clarias gariepinus*)

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Abstract. In the context of the problem of insufficient consumption of fish products, the possibility of creating high-quality sausage products based on new types of raw materials is considered. The development of high-quality fish sausages from new raw materials will expand the range of sausage products and provide the population with seafood products. The purpose of the study is to establish the feasibility of using African sharptooth catfish in the technology of fish sausage products. The study used a complex of generally accepted organoleptic, chemical, physico-chemical methods of research: moisture content – by drying the sample to a constant weight; fat content – by the Soxhlet method; protein content – by the Kjeldahl method; ash – by burning the sample. The penetration stress was determined using a penetrometer; water activity index – using a hygrometer; the hydrogen index – using a pH meter. As a result of research, the feasibility of using the African sharptooth catfish as a raw material for making fish sausages is theoretically substantiated and experimentally confirmed (*Clarias gariepinus Burchell, 1822*). The effectiveness of combining catfish meat with other hydrobionts and animal raw materials is shown. New recipes for raw smoked sausages based on African catfish with the addition of mackerel, scallop, and lard have been developed. Organoleptic and physico-chemical indicators of quality and nutritional value of finished products were studied. The results of organoleptic evaluation showed the similarity of catfish sausages to conventional meat sausages. Fish flavour and aroma were poorly expressed in sample 2, which included only African catfish meat from fish raw materials, which determined its consumer preferences. Sample 3 obtained by combining African catfish meat with mackerel and scallop received high organoleptic scores. The results of a study of the chemical composition show a high nutritional value of sausage products based on the improved recipe. The moisture content in all samples did not exceed 50%, which is the standard for raw smoked sausages. The highest protein content (26.19%) was observed in sample 2, the amount of protein in other sausage samples exceeded the minimum recommended value of 19%. The fat content in all samples was in the range of 18.93-21.41%, which does not exceed the recommended standard of 25%. Based on the results of physical and chemical studies, the indicators were found to be in line with the established standards. Studies of changes in quality and safety indicators during storage determined the permissible shelf life of raw smoked fish sausages at temperatures from 0 to +5°C for no more than 15 days

Keywords: fish; sausage products; recipe; technology; organoleptic indicators; nutritional value

Introduction

Modern principles of creating high-quality sausage products are based on the choice of raw materials, substantiation of the ratio of ingredients to ensure the appropriate quality of products, high organoleptic parameters and certain technological food characteristics (Rahayu *et al*., 2022). A valuable raw material for food production is fish, due to the high nutritional benefits associated with chemical composition. Fish meat is at the heart of current dietary trends and is recommended for consumption, as it is a source of easily digestible protein, polyunsaturated fatty acids, vitamins and minerals. Fish processing enterprises in Ukraine face a limited range of products that do not meet the growth of demand and high requirements of consumers. However, with the help of classification of sausage products and the possibility of combining different components and additional raw materials, fish processing enterprises have a chance to expand their range of goods (Vieira *et al*., 2019). The advantage of sausage products is that they are made based on minced fish, which solves the

issue of rational use of raw materials, creating products accessible to all segments of the population, with specified taste properties, biological and structural characteristics. Due to the use of fish meat in the technology of sausage products as a structural component of the minced meat system, it is possible to increase its water binding capacity and juiciness of finished products.

Technologies for sausage products made from aquatic organisms are being successfully developed and implemented in many countries around the world. Despite the world experience, the production of fish sausages in Ukraine is limited. Therefore, the necessary developments are aimed at using new types of raw materials, improving technology for further introduction into production at Ukrainian enterprises.

N. Bozhko *et al*. (2021) investigated the use of freshwater fish in sausage technology. Researchers have proven the positive effect of combining duck meat (*Anas platyrhynchos*) and freshwater fish (*Hypophthalmichthys molitrix*) in semi-smoked meat sausages. An increase in protein content by 17.90-21.34% was observed in semi-smoked sausages with a different ratio of duck and fish meat, compared to the analogue. A sample containing 50% duck and 30% fish showed an ideal protein-fat ratio. It is proved that the addition of silver carp improves the elasticity of minced meat and increases the stability of the emulsion. The expediency of combining meat and fish raw materials is proved by the high organoleptic characteristics of sausage products.

The above-mentioned researchers, together with other scientists, also developed meat-containing boiled sausage with duck meat and freshwater silver carp (*Carassius gibelio*) and meat-containing semi-smoked sausages with musk duck and grass carp meat (*Hypophthalmichthys molitrix*). It is established that the use of freshwater fish with duck meat increases organoleptic, functional, and technological properties, does not have a negative impact on the physical and chemical parameters of finished sausage products, and allows obtaining products that meet the requirements of the standard. The results obtained indicate an increase in the consumer value of sausages and confirm the effectiveness of using freshwater fish raw materials with waterfowl meat in the technology of sausage products (Bozhko *et al*., 2018). Meat from various types of fish can be used to make fish sausages, but it is not recommended to use dark meat from mackerel and tuna species, as blackish-red spots appear after heat treatment. Known technologies of fish sausages made from cod, pollock, horse mackerel, rainbow trout, carp, silver carp, sea catfish (Coban *et al*., 2018). Sausages made from washed minced fish surimi are also popular (Liu *et al*., 2019).

A.M.T. Lago *et al.* (2019) developed and investigated the quality of fish sausages made from filleting waste of Nile tilapia (*Oreochromis niloticus*), which were stored frozen at a temperature of -10°C. It was found that the food and microbiological quality of tilapia sausage was maintained within the recommended standards during the established shelf life. A comparative analysis of the quality of sausage from Nile tilapia (*Oreochromis niloticus*) is covered by P.C. Alda *et al.* (2019). Researchers have established the advantages of sausage made from this type of raw fish compared to chicken sausage and pork sausage. Fish sausage had higher levels of moisture, ash, calcium, and collagen compared to other species. Tilapia sausage had a higher pH value and lower water activity. The texture of the fish sausage was better in terms of hardness, stickiness, and chewiness.

A decrease in the volume of fish and seafood production, changes in the species composition of raw materials, make it necessary to use new aquaculture facilities. Recently, African catfish (*Clarias gariepinus*) has been receiving a lot of attention as a promising object of cultivation and processing. It is characterised by high growth rates, the use of inexpensive feed, and is undemanding to keeping conditions (Olopade *et al*., 2023). African catfish

has high-quality meat rich in essential amino acids, biologically effective lipids, vitamins and minerals (Adebisi & Oshibanjo, 2019), therefore, the issue of developing sausage products from African catfish using an improved recipe and technology to expand the range and provide the population with fish products is becoming particularly relevant.

The purpose of the study was to determine the quality indicators of sausage products made from African catfish and establish the feasibility of using this type of raw material in the technology of raw smoked fish sausages.

To achieve this goal, the following tasks were defined:

- study organoleptic parameters;
- investigate chemical composition and energy value;
- determine physico-chemical parameters and establish their compliance with the standards;
- investigate changes in organoleptic and physico-chemical parameters during storage.

Literature Review

Fish sausages are products that are increasingly common on the global market. These products have high potential due to their convenience (ready to eat), lack of bones, good sensory properties, and they are often used as a model for testing new ingredients and/or additives (Rahmanifarah *et al.,* 2023). Therefore, the research by many foreign researchers is devoted to the development and improvement of the technology of sausage products made from hydrobionts, including African catfish.

To increase organoleptic parameters and nutritional value, the recipe for fish sausages includes pork fat, seafood, seaweed, vegetable components, and spices. The technology of fish sausages made from sea catfish with the addition of 30% smoked pork fat was developed, which improved the sensory properties of smell, taste, and general perception, increased fat content, ash content, energy value, and reduced moisture content and water activity (Vieira *et al*., 2019). Fresh sea catfish sausages stored at low temperatures were manufactured and evaluated. Sea catfish sausages had good nutritional quality, sensory properties, and a shelf life of 21 to 25 days when stored in the refrigerator and four months when frozen (Veloso *et al.,* 2019*)*. Smoked catfish sausages are made both by traditional smoking and using liquid smoking. The results show that both methods provide products with good physico-chemical, microbial, and biochemical parameters during storage (Filho *et al*., 2021). It is important to ensure the appropriate texture and consistency of the finished product (Chattopadhyay *et al*., 2019). For this purpose, various types of raw materials and variations of components are used, protein-fat emulsions and hydrocolloids are introduced.

In modern technologies of sausage production, including those made from hydrobionts, considerable attention is paid to the quality and safety of finished products. Researchers (Estevez *et al*., 2021) proposed a partial replacement in the NaCl formulation with KCl, which are suitable solutions for reducing Na levels while maintaining the quality of sausage products and allowing for a K-rich product, which can help protect the cardiovascular system. In order to extend the shelf life of smoked carp sausages (*Cyprinus carpio* it is suggested to use propolis extract (Coban *et al*., 2018). According to the results of studies, treatment with 1% propolis increased the shelf life of sausage by 3 weeks compared to control samples. Researchers have also proven the antioxidant and bactericidal effect of using goji berries in smoked carp sausage recipe (Fadiloglu & Coban, 2019).

Due to the high content of polyunsaturated fatty acids, fish sausages are a healthier alternative to conventional meat sausages. However, hydrobiont sausages can quickly become rancid due to oxidation, which leads to a loss of quality. To reduce the oxidative effects and preserve the quality of the lipid component, researchers suggest using natural antioxidants such as

polyphenols from spices, herbs, green tea, as well as tocopherol nanoemulsion. The existing range and innovations in the technology of fish sausage products determine the feasibility and prospects of producing high-quality products based on global trends (Nikoo *et al*., 2021).

Materials and Methods

Materials of the study included raw smoked sausages based on African catfish meat. In the production of sausages, the following raw materials were used: live African catfish (*Clarias gariepinus*), autumn catch, grown on a farm in the Hrebinki village, Kiev oblast, according to DSTU 2284:2010 (2010); frozen Alaska pollock (*Theragra chalcogramma*) and Atlantic mackerel (*Scomber scombrus*) according to DSTU 4868:2007 (2007); frozen scallop (*Mizuhopecten yessoensis*) according to DSTU GOST 30314:2009 (2009); chilled pork fat, unsalted according to DSTU 4590:2006 (2006). Table salt and spices were used as additional raw materials. The recipe composition of sausages is shown in Table 1.

Table 1. *Recipe composition of fish sausages*

Raw material name	Content of ingredients required for sausage production, %			
	Control	Experimental samples		
		No. 1	No. 2	No. 3
Alaska pollock (pieces)	30	-	-	-
Alaska pollock (minced meat)	30	-	-	-
African catfish (pieces)		30	40	30
African catfish (minced meat)		45	50	30
Atlantic mackerel (minced)	10	15	-	10
Scallop muscle (pieces)	20	-	-	20
Unsalted pork fat	10	10	10	10
Auxiliary raw materials, g/100 g of raw materials				
Boiled table salt “Extra” grade	2.0	2.0	2.0	2.0
Ground black pepper	0.1	0.1	0.1	0.1
Whole coriander	0.1	0.1	0.1	0.05
Ground nutmeg	0.1	0.1	0.1	0.05
Dried ground red pepper	0.05	0.05	-	0.05
Dried ground garlic	-	0.1	-	0.1
Ground paprika	-	-	0.1	0.1
Cumin seeds	-	0.05	0.05	0.05
Dried ground ginger	-	0.1	-	0.1

Source: developed by the authors

The sausage without African catfish meat was used as a control, the recipe of which is given in Table 1. The technology of fish sausages included preliminary preparation of raw materials (defrosting, washing, cutting into fillets), dry salting to a salt content of 3%. Part of the fish raw material was crushed in a grinder, and the other part was added to the minced meat in the form of pieces of 1.0-2.0×10-2 mm in size to obtain a fibrous structure of the finished sausage products. Unsalted pork fat was cut into 5×5 mm pieces. Food and flavouring additives were added to the minced meat mixture. Prepared natural shells (salted pork stomachs)

were filled with ready-made minced meat and loaves were formed. The resulting loaves were kept in the maturation chamber at a temperature of 0°C to 10°C and a relative humidity of not more than 75% for 12-36 hours to an average buffering value of at least 70°. Smoking was carried out by convective method at an air temperature of 45-60°C until a homogeneous state and an average humidity of no more than 55% was reached. After smoking, the resulting sausage products were dried convectively at an air temperature of 19°C-25°C and a relative humidity of 75-85% to an average moisture content of no more than 50%.

Determination of organoleptic parameters was carried out by the profile method using a 5-point scale (Tkachenko *et al.*, 2020). The chemical composition of the sausages was studied using the following methods: mass fraction of moisture – by drying the product sample to a constant weight in a SNOL drying oven (Labimpeks LTD, Ukraine) at a temperature of 100-105°C, according to DSTU 8029:2015 (2015); mass fraction of ash – by weighting, after mineralisation of the product sample in a SNOL muffle furnace (Labimpeks LTD, Ukraine) at a temperature of 500-600°C, according to DSTU 8718:2017 (2017); mass fraction of lipids – by the Soxhlet extraction-weight method, according to DSTU 8717:2017 (2017) on the SOX 406 Fat Analyser (Hanon Instruments, China); mass fraction of protein – by the determination of total nitrogen by the Kjeldahl method, which is based on the ability of the organic matter of the product sample to be oxidised by concentrated sulphuric acid in the presence of a catalyst, according to DSTU 8030:2015 (2015), the ashing of the samples was carried out on a DK6 digester (Velp Scientifica, Italy) with a JP vacuum pump, distillation was carried out on a UDK 129 steam distillation apparatus (Velp Scientifica, Italy). The penetration stress was determined using an Ulab 3-31 M penetrometer, using a needle indenter at a sample temperature of (20±0.5)°C, converting the indenter penetration value to stress, in Pa. The active acidity (pH) was measured using a portable pH meter. The water activity index was determined using a highly sensitive Hygro Palm HP23-AW device (Great Britain). The acid value of lipids was determined by titration (neutralisation) of free fatty acids with alkali in the presence of an indicator, and the peroxide value of lipids was determined by titration with a solution of sodium thiosulphate. This process was based on the interaction of fat oxidation products with potassium iodide in a solution of acetic acid and chloroform, followed by the determination of the amount of iodine. The mass fraction of volatile basic nitrogen (VBN) was studied by the titrometric method, according to which free and bound volatile bases were distilled with steam, the resulting ammonia interacted with sulphuric acid, and the excess sulphuric acid was titrated with alkali (Slobodyanyuk *et al.*, 2018).

Results and Discussion

Organoleptic characteristics of food are an important criterion for assessing consumer perception of finished products. They depend on the type of raw material and manufacturing technology. As a result of organoleptic evaluation, it was found that the addition of minced meat of fatty varieties, namely mackerel, lard pieces, and scallop, to minced meat from low-fat fish increases the taste properties and appearance, and creates an elastic consistency and integral structure of the sausage. Taste and aroma indicators are improved by spices and seasonings, the addition of cumin, paprika, ginger, and garlic the sausages a spicy and original taste. The colour of the experimental samples had a pinkish tint caused by the natural colour of the catfish, which was their advantage over the control. Due to the natural colour of African catfish, there is no need to use natural or artificial colourings in sausages, which makes the product healthier. A special feature of the prototypes was the weakly expressed taste and aroma of fish, which is due

to the practical absence of taste and aroma characteristics in African catfish. For the purpose of better visual perception of the results of organoleptic evaluation of samples, in comparison with the control, a quality polygon was constructed (Fig. 1).

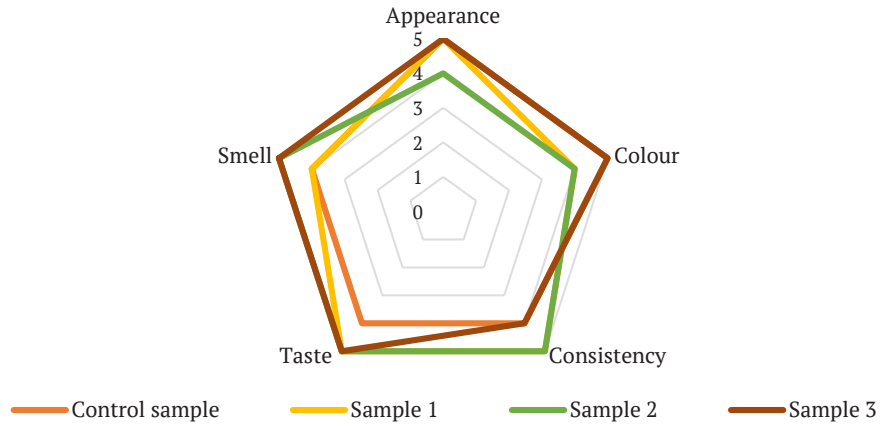

Figure 1. Organoleptic evaluation of fish sausage samples

Source: developed by the authors

According to the results of the organoleptic evaluation, sample 1 received maximum points for the appearance and taste of the product. Fish taste and aroma were poorly expressed in sample 2, which included only African catfish meat from fish raw materials, which determined its consumer preferences. The maximum score was also estimated for the consistency of sample 2, which is due to the high functional and technological properties of African catfish meat. Sample 3, made by combining African catfish meat with mackerel and scallop, received high organoleptic scores for taste and aroma characteristics, appearance, and colour. O.F. Adebisi & O.D. Oshibanjo (2019) also proved that smoked African catfish sausages are characterised by high sensory characteristics. R.R. Veloso *et al*. (2019) showed the colour preferences of African catfish sausages compared to small carp sausages and minced meat sausages from Nile tilapia fillet waste.

Nutritional value is one of the main indicators of food quality, which is determined by their chemical composition. The chemical composition and energy value of fish sausages are shown in Table 2.

Table 2. *Chemical composition of fish sausages*

Sample name	Content, %				Energy value, kcal/100 g
	moisture	fat	protein	ash	
Control sample	49.92±0.7	21.41±0.3	23.72±0.2	4.95±0.1	287.57
Sample 1	49.83±0.6	21.33±0.2	24.11±0.2	4.73±0.1	288.41
Sample 2	49.95±0.4	18.93±0.5	26.19±0.1	4.93±0.2	275.13
Sample 3	49.84±0.5	20.04±0.2	25.24±0.1	4.88±0.1	281.32

Source: developed by the authors

Analysis of the results shows that the chemical composition of the experimental formulations does not significantly differ from the control sample. The moisture content in the experimental samples and control did not exceed 50%. In terms of protein content, all study samples exceeded the control. The highest protein content (26.19%) was observed in sample 2. Sufficient protein intake is crucial for health and development. Due to its amino acid composition and good digestibility, hydrobiont proteins are valuable and necessary for the human body. The developed sausage samples will complement the human diet with high-quality easily digestible protein. The fat content in all samples was in the range of 18.93-21.41%, which does not exceed the recommended norm. High protein and lipid content was found due to the inverse relationship between humidity and lipid content, as well as moisture and protein. As a result of the smoking process, the moisture content of sausages decreased, thereby increasing the fat and protein content. The addition of seasonings, mainly salt, resulted in the corresponding ash content in sausages from 4.73% to 4.95%.

The obtained chemical composition values meet the requirements for commercial raw smoked sausages and are consistent with the results of previous studies by other researchers. According to global recommendations, the minimum protein content in smoked fish sausages is 19%, the recommended fat rate is no more than 25%. The amount of ash is not regulated by Ukrainian and international standards for fish sausages, so it is not possible to compare its content with any established regulations. However, ash is made up of minerals such as iron, zinc, and phosphorus, which are important for achieving a balanced diet (Veloso *et al.*, 2019; Ernawati *et al.*, 2021).

E. Ernawati *et al.* (2021) highlighted the chemical composition of smoked African catfish sausages made using smoking liquid. It was found that depending on the concentration of liquid smoke and the duration of immersion, the protein content ranged from 42.96% to 43.88%, the fat content from 11.34% to 12.89%, and the average moisture content was 20%. It is confirmed that the chemical composition of smoked sausages does not depend on the concentration of liquid smoke and the duration of immersion, and the protein and fat content changes due to heat treatment and dehydration. Energy value reflects the amount of energy provided to the body by the proteins and fats found in the product. Sample 2 had the lowest energy value due to its lower lipid content. This is due to the recipe composition, namely, the absence of fatty mackerel fish in sample 2. The physical and chemical characteristics of fish sausages, which are shown in Table 3, indicate that the products meet the standards and are stable during storage.

Table 3. *Physical and chemical parameters of fish sausages*

Indicators	Control	Sample 1	Sample 2	Sample 3
pH	6.68±0.09	6.40±0.10	6.37±0.09	6.50±0.08
Water activity indicator	0.88±0.01	0.87±0.01	0.85±0.01	0.83±0.01
Penetration stress, Pa	1.910±0.19	1.670±0.16	1.860±0.17	2.020±0.19

Source: developed by the authors

The results of the pH test are in the range of 6.37-6.68, which is below the established value of 6.8 and indicates that the products are of good quality. The obtained pH values will be consistent with the results obtained in the study of fish sausage products from other raw materials highlighted in the paper by R.R. Veloso *et al.* (2019). Thus, the pH of

chilled catfish sausages during storage for four days was 6.40. In Japanese bream sausages, the initial pH value was 6.75.

Water activity (a_w) indicates the microbiological stability and shelf life of food products. This indicator interacts well with the rate of various destructive processes and can be used to assess the quality of water in food and its suitability for chemical and biological changes. The values of the water activity index for fish sausages range from 0.83 to 0.88, which is less than the optimal level of water activity for most microorganisms (from 0.90 to 0.98). This indicates that sausages are resistant to the development of many types of bacteria, but can promote the growth of mould and yeast.

The obtained values are consistent with the water activity indicators of African catfish fish sausages obtained using industrial liquid smoke and improved technology by treating with a liquid concentration of 20% for 30 minutes (Ergawati *et al*., 2021). Other researchers (Fasuan *et al*., 2022) also noted the influence of the water activity index on the microbiological stability of smoked products. Thus, in the samples of smoked catfish obtained in the conventional and improved way contained traces of *Aspergillus fumigatus, Aspergillus niger, Aspergillus flavus and Penicillium*. This is due to the water activity values of these samples of 0.85 and 0.81, which is higher than the Codex standard for smoked fish, which is 0.75.

The values of the stress penetration index indicate the texture density of sausage products due to dehydration of the semi-finished product during smoking. Sample 3 and control have higher penetration stress values, which is explained by the presence of scallop muscle pieces in their composition, which have a dense consistency even after heat treatment. The lower indenter penetration limit of sample 2 compared to sample 1 indicates a denser consistency of African catfish sausage without the addition of mackerel meat. The results of rheological studies confirm the organoleptic evaluation of consistency. Preservation of quality and safety of sausage products during storage is determined by the chemical composition of raw materials, quantitative and qualitative composition of microflora, pH level, humidity and surface condition of the product, type of packaging, presence of bactericidal agents, and environmental conditions. In the technology of raw smoked fish sausages, the preservative effect is due to salting, dehydration, and exposure to smoke compounds that exhibit bactericidal properties (Filho *et al*., 2021). Dynamics of changes in organoleptic parameters of manufactured sausage samples during storage at a temperature of 5-6°C for 15 days is shown in Figure 2.

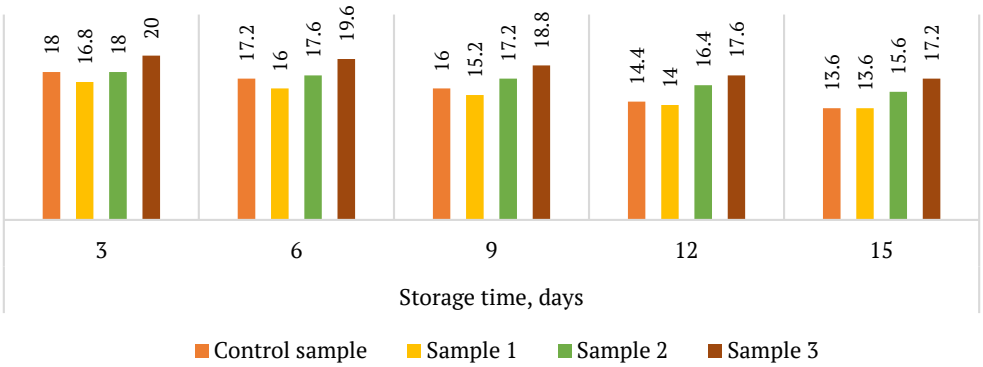

Figure 2. Organoleptic evaluation of fish sausages during storage

Source: developed by the authors

During storage, the highest scores of organoleptic parameters were observed in experimental samples that were stored for 3-6 days. The overall rating of sausage products after the 6th day decreased with an increase in the shelf life. The decrease in sensory parameters during storage is conditioned by the processes of proteolysis and denaturation changes in proteins, hydrolysis and oxidation of lipids, and the development of microorganisms. The discolouration of fish sausages during storage may be due to lipid oxidation and changes in blood pigments and heme and sarcoplasmic proteins (Sadeghinejad *et al.*, 2019).

The developed samples of sausage products contain an increased content of fish and animal fats. Therefore, an important indicator is the evaluation 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 values. The acid value of fat characterises the presence of primary products of fat hydrolysis. The dynamics of free fatty acid accumulation is shown in Figure 3.

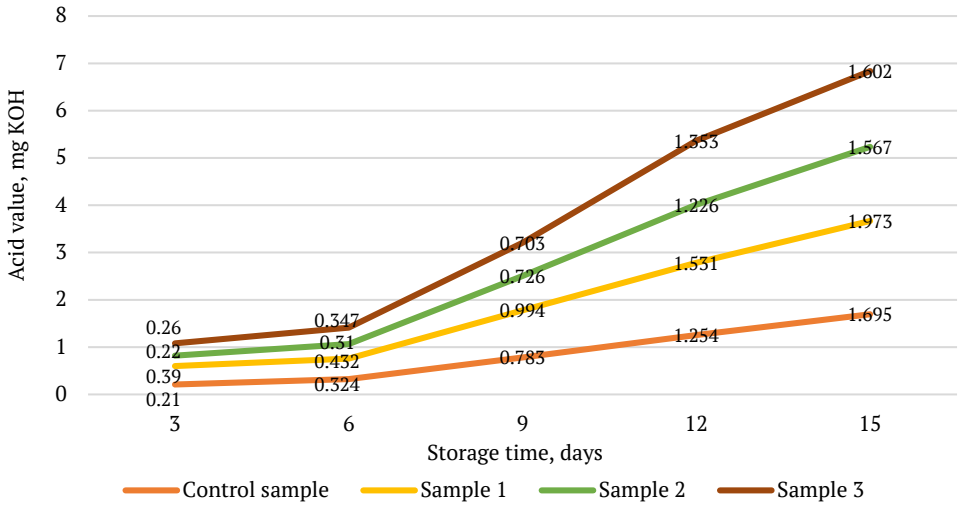

Figure 3. Changes in the acid value of fat during storage of fish sausages

Source: developed by the authors

During the storage of fish sausages, there is a linear trend of increasing the acid value of fat, which is due to the processes of hydrolysis of triglycerides. It was noted that from day 6, the breakdown of complex lipid compounds to simple ones occurred more intensively. The accumulation of free fatty acids during the storage of fish products is associated with enzymatic activity. During the entire shelf life of fish sausages, the acidic number of lipids in all samples did not exceed the established values for fish fats for food production – 4 mg KOH/1 g of fat.

K. Rahmanifarah *et al.* (2023) noted a similar trend towards an increase in the acid value levels during the storage of sausages from washed minced silver carp in a frozen state. Along with the lipidhydrolysis, oxidation processes also occur. Lipid oxidation negatively affects not only the sensory, but also the functional characteristics of products. Various primary and secondary byproducts are formed during the process, depending on the types of fatty acids, the presence of oxygen, and the presence of pro- and antioxidants. Some of the lipid oxidation products only affect product quality, while others affect human health. Therefore, the study of lipid oxidation processes in fish sausages is important for assessing

their quality, as well as for human health. As a result of fat oxidation, peroxide compounds, aldehydes, and ketones are formed. The presence of lipid oxidation processes in the initial stages characterises the peroxide value. This constant indicates the content of peroxide compounds in fat, and allows detecting the presence of spoilage products much earlier than it can be determined organoleptically. According to R.R. Veloso *et al.* (2019), lipid oxidation in fish sausages may be related to the amount of lipids, the type of fatty acids, the degree of fillet grinding, and the presence of oxygen. Thus, the inclusion of minced mackerel, lard, and shredded catfish fillets may have contributed to the lipid oxidation of sausages in this study. The dynamics of accumulation of peroxides and hydroperoxides during storage of fish sausages is shown in Figure 4.

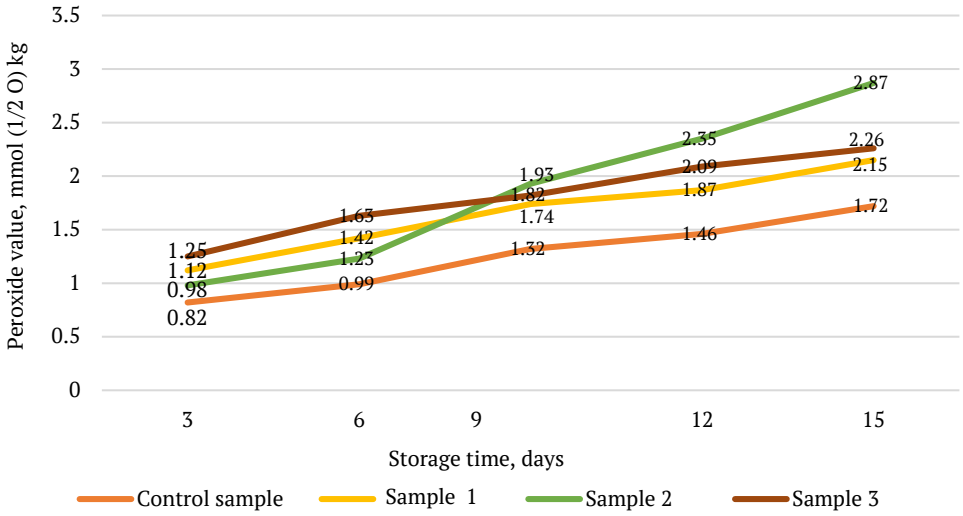

Figure 4. Changes in the peroxide value of fat during storage of fish sausages

Source: developed by the authors

Lipid oxidation processes were more intense in sample 1, which included the maximum amount of mackerel meat, compared to other fish sausage samples. This is due to the high lipid lability of aquatic organisms. The obtained peroxide values of fat in sausages on the 15th day of storage are significantly lower than the established norm – 10 mmol (1/2 O)/kg of fat and below the threshold value for detecting rancid taste, which indicates the good quality of the lipid component. Fish oil, especially marine and oceanic fish, is a source of omega-3 fatty acids, especially eicosapentaenoic and docosahexaenoic, which are polyunsaturated and very susceptible to oxidative changes (Nikoo *et al.*, 2021). A significant amount of saturated fatty acids present in the fat added to all fish sausage samples contributed to the inhibition of lipid oxidation processes, which is consistent with the conclusions of S. You *et al.* (2022). The low content of fat oxidation products in smoked sausages is also explained by the presence of antioxidants in the smoke, in particular phenols, which can inhibit the oxidation process (Abeyrathne *et al.*, 2021; Ernawati *et al.*, 2021)

The degree of proteolysis and microbiological processes was studied by changes in the volatile basic nitrogen content (VBN). The nitrogen content of volatile bases increases during storage under the influence of enzymatic processes and the vital activity of microorganisms

and is accompanied by the breakdown of amino acids to form ammonia, mono-, di-, and trimethylamines. The dynamics of VBN content during storage is shown in Figure 5.

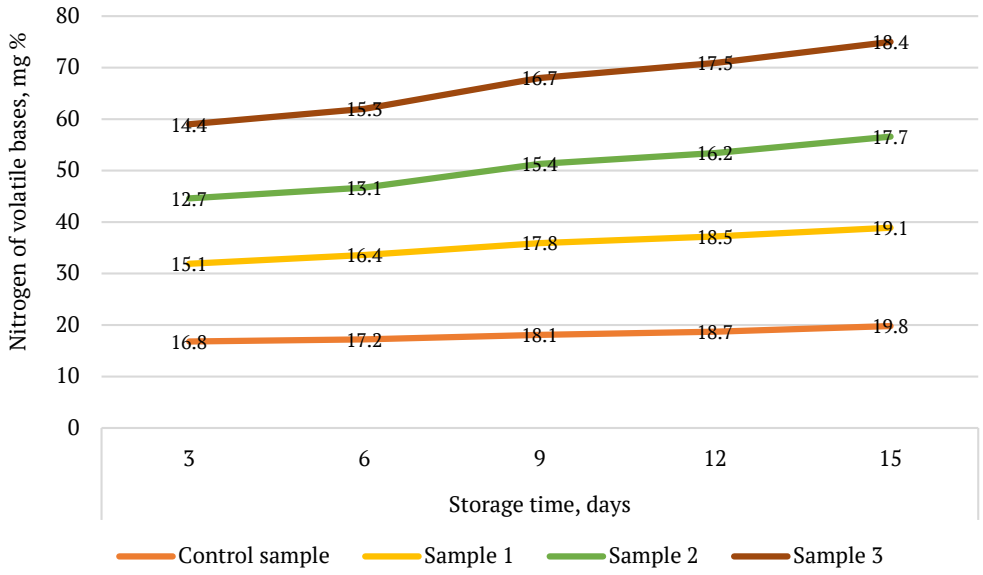

Figure 5. Changes in volatile basic nitrogen during storage of fish sausages

Source: developed by the authors

The study results show that fresh fish sausages had the lowest VBN values, which increased during storage. At the maximum storage period of the product, after 15 days, the content of volatile basic nitrogen in the control sample is 19.8 mg%, in sample 1 – 19.1 mg%, in sample 2 – 17.7 mg%, in sample 3 – 18.4 mg%, with an acceptable level of 30 mg%. The highest content of volatile basic nitrogen in the control is explained by the presence of trimethylamine, which is formed as a result of the breakdown of trimethylamine oxide, which is found mainly in marine aquatic organisms.

An increase in VBN values in fish products, according to S. You *et al*. (2022), is associated with bacterial metabolism and oxidation of protein and non-protein components. In other studies of fish sausages, an increase in VBN values was also observed during storage. In particular, in chilled catfish sausages, the VBN index increased from 14.9 mg% after four days of storage to 43.1 mg% at the end of 32 days of storage. There was also a significant increase in VBN values from 12.2 mg% to 16.5 mg% during the four months of frozen sausage storage (Veloso *et al.*, 2018). Based on organoleptic evaluation and physico-chemical indicators, the permissible shelf life for raw smoked fish sausages at temperatures from 0 to +5°C was set for no more than 15 days.

Conclusions

Based on the analysis of experimental studies, it was found that fish sausages based on African catfish are characterised by high sensory characteristics, nutritional value, and meet the requirements for raw smoked sausages. Organoleptic parameters indicate the taste and aroma advantages of African catfish sausages in comparison with sausages made from other fish raw materials. This is confirmed by the maximum scores for the taste, aroma, and

consistency characteristics of sample 2, which included only African catfish meat from raw fish. Sample 3, made by combining African catfish meat with mackerel and scallop, received high organoleptic scores for taste and aroma characteristics, appearance and colour.

The results of chemical composition studies indicate a high nutritional and energy value of sausages from African catfish. The moisture, protein and fat content in all samples comply with international regulations for raw smoked sausages. The moisture content in the experimental samples and control did not exceed 50%. In terms of protein content, all the test samples exceeded the control, so the developed sausages can be considered a source of high-quality, easily digestible protein. The fat content in all samples was in the range of 18.93-21.41%. Physical and chemical indicators are within the established standards and indicate the good quality of the finished product. According to the obtained values of the water activity index (0.83-0.88), raw smoked fish sausages are resistant to the development of most bacteria, but mould and yeast can develop in the products. The results of the study of penetration stress indicate the texture density of sausage products due to dehydration of the semi-finished product during smoking.

During the storage of fish sausages for 15 days, a gradual deterioration of sensory characteristics and quality indicators of protein and lipid components was observed. The highest scores of organoleptic parameters were observed in experimental samples that were stored for 3-6 days. During the entire shelf life of raw smoked sausages, the acid and peroxide lipid numbers of the prototypes did not exceed the established values for fish fats for food production, which confirms the quality of the lipid component. The quality of proteins in African catfish sausages was proved by the obtained values of the nitrogen content of volatile bases, which did not exceed the permissible level during the established shelf life. Further studies will focus on the development of regulatory documents and the implementation of the technology at fish processing plants.

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None.

Conflict of Interest

None.

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Якісні характеристики рибних ковбас з африканського сома (*Clarias gariepinus*)

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Анотація. У контексті проблеми недостатнього споживання рибних продуктів розглянуто можливість створення високоякісних ковбасних виробів на основі нових видів сировини. Розроблення високоякісних рибних ковбас з нових видів сировини дозволить розширити асортимент ковбасних виробів та забезпечить населення рибними продуктами. Мета роботи полягає у встановленні доцільності використання африканського кларієвого сома у технології рибних ковбасних виробів. В роботі використовували комплекс загальноприйнятих органолептичних, хімічних, фізико-хімічних методів досліджень: вміст вологи – методом висушування зразка до постійної маси; вміст жиру – методом Сокслета; вміст білка – методом К'єльдаля; золи – спалюванням наважки. Пенетраційну напругу визначали за допомогою пенетрометра; показник активності води вимірювали за допомогою гігрометру; водневий показник – pH-метром. В результаті досліджень теоретично обґрунтовано й експериментально підтверджено доцільність використання африканського кларієвого сома (*Clarias gariepinus Burchell, 1822*) в якості сировини для виготовлення рибних ковбас. Показано ефективність поєднання м'яса сома з іншими гідробіонтами та тваринною сировиною. Розроблено нові рецепти сирокопчених ковбас на основі африканського сома з додаванням скумбрії, морського гребінця та шпику. Досліджено органолептичні,

фізико-хімічні показники якості та харчової цінності готової продукції. Результати органолептичної оцінки показали подібність ковбас із сома до традиційних м'ясних ковбасних виробів. Рибний смак і аромат був слабко виражений у зразку 2, який включав з рибної сировини лише м›ясо африканського сома, що зумовило його споживчі переваги. Високі бали органолептичної оцінки одержав зразок 3, виготовлений шляхом комбінування м'яса африканського сома зі скумбрією та морським гребінцем. Результати дослідження хімічного складу показують високу харчову цінність ковбасних виробів за удосконаленою рецептурою. Вміст вологи в усіх зразках не перевищував 50 %, що відповідає нормі для сирокопчених ковбас. Найвищий вміст білку (26,19 %) відмічено у зразку 2, кількість білка в інших зразках ковбас перевищувала мінімальне рекомендоване значення 19 %. Вміст жиру в усіх зразках перебуває в діапазоні 18,93-21,41 %, що не перевищує рекомендовану норму 25 %. За результатами фізико-хімічних досліджень встановлено відповідність показників встановленим нормам. Дослідження змін показників якості та безпечності в процесі зберігання визначили допустимий термін зберігання рибних сирокопчених ковбас за температури від 0 до +5 °С не більше 15 діб

Ключові слова: риба; ковбасні вироби; рецептура; технологія; органолептичні показники; харчова цінність