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Enhancing fish pâté with non-traditional ingredients: maca root, broccoli, and beetroot

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ABSTRACT

The article substantiates the feasibility of using and combining freshwater fish with non-traditional raw materials (maca root, broccoli, beetroot). Positive results of sensory, organoleptic, colorimetric analysis of fish pâtés using the flavor profile method and establishing their compliance with a hypothetical standard are presented. The feasibility of using the flavor profile method and colorimetric methods to assess the overall impression of fish pâtés for expanding biologically significant food products was shown. Based on the results of consumer preferences, the authors used 10 descriptors of the flavor method to describe flavor. Sensory analysis and colorimetric studies were carried out using current standards. DSTU ISO 6564:2005 "Sensory research. Methodology. Methods for creating a flavor spectrum" was used to create descriptors. It was found that the preliminary heat treatment of pâtés affects the color formation of the finished product. Positive results of organoleptic and colorimetric studies showed the feasibility of using maca root, broccoli, and beetroot in pâté technology.

Keywords: fish pâtés, maca root, broccoli, beetroot

INTRODUCTION

Freshwater fish contain complete proteins, biologically significant fats, and fat-soluble vitamins, but they do not contain important trace elements such as iodine, bromine, and selenium, which are necessary components of functional diets in conditions of constant development of society. That is why, improving the sensory qualities and functional properties of products made from freshwater fish is considered possible by adding plant ingredients, as a source of fiber, vitamins, minerals **[1]**, **[2]**.

The level of consumption of pâtés is increasing **[3]**. Fish pâtés are one of the most relevant food products due to their readiness for consumption, especially nowadays, when the rhythm of life of modern people is accelerating **[4]**, and **[5]**. At the same time, the Ukrainian market is represented to a greater extent by pâtés, which consist exclusively of raw fish materials **[6]**. Given this, improving the technology of pâtés and improving the technology of the production of pâtés from freshwater fish acquires scientific justification **[7]**.

The flavor method is used to describe sensory characteristics, which is a group of methods fundamental to other descriptive methods **[8]**, and **[9]**. This method is recommended for development and modification of food products **[10]**. A.D. Little Inc. developed the flavor profile method to make it possible to obtain the aromatic and taste properties of a product. The concept of flavor refers to the overall sensation in the mouth, which is determined by the taste, texture and smell of a food product **[11]**. An attempt to characterize flavor is the flavor profile method, which takes into account all the descriptors that in turn form the impression of the product. The advantages of tasting analysis compared to instrumental analysis are especially noticeable. Only a person can perceive and analyze a set of organoleptic characteristics within one dimension **[12]**.

The intensity of descriptors, their nature, order of manifestation, completeness, and aftertaste are descriptors that form a holistic impression of the product, and taking them into account makes it possible to characterize the flavor with their help **[13]**, **[14]**, and **[15]**.

Scientific Hypothesis

The scientific hypothesis states that adding 5% of maca root, beetroot, and broccoli, respectively, increases the attractiveness, improves the appearance, and overall organoleptic characteristics of minced meat and ready-made freshwater fish pâtés.

Objectives

Primary objectives: Determine the effect of maca root, beetroot, and broccoli on ready-made pâtés.

MATERIAL AND METHODS

Samples

Samples description: The following materials were used to produce minced meat samples and ready-made pâtés: crucian carp grown in the Khmelnytskyi region, salmon trimmings grown in the Volyn region, maca root, beets, and broccoli.

Samples collection: Crucian carp, salmon trimmings, beetroot, and broccoli were purchased from a supermarket chain. The pond where the crucian carp was caught is in an ecologically clean zone of the Khmelnytskyi region, guaranteeing its ecological purity. As well as salmon trimmings. Maca root was purchased in a 28-gram package. Crucian carp and salmon trimmings were stored at +5 degrees Celsius in a refrigerator for one day until the time of the experiment. Beetroot, broccoli, and maca root were stored in a dry, ventilated room at 20 degrees Celsius.

Samples preparation: To obtain minced meat and pâtés, crucian carp, salmon trimmings, beets, broccoli, maca root, onion, carrots, oil, salt, and ground black pepper were used. In experimental studies, 5% of beetroot, broccoli, and maca root were added to the samples.

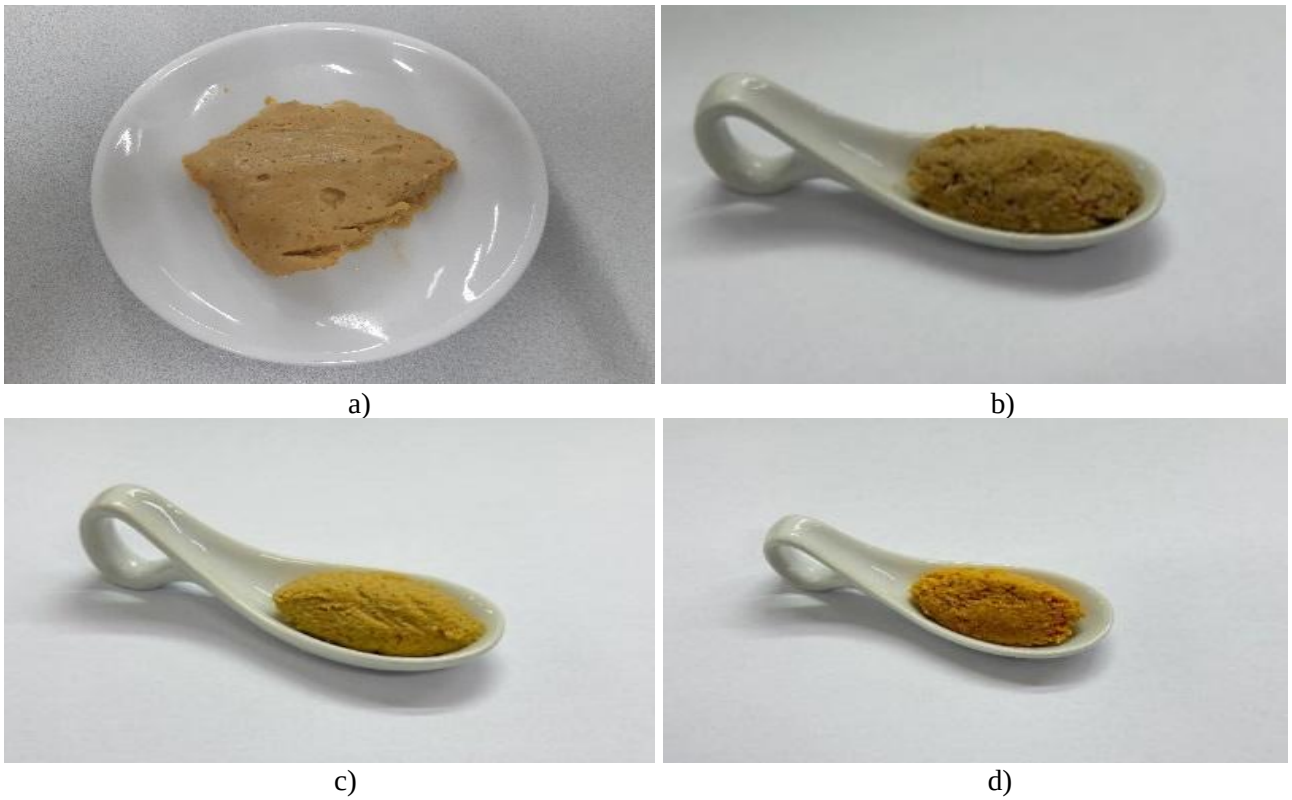


Figure 1 Finished products.
Note:
a) Fish pâté control
b) Fish pâté with maca root
c) Fish pâté with broccoli
d) Fish pâté with beetroot

Number of samples analysed: 20

Chemicals

No chemicals were used for the study.

Animals, Plants and Biological Materials

Maca root was purchased from Purella Sp. Z o.o., Warszawa, Poland.

Instruments

YL4560 Series Non-contact Benchtop Spectrophotometer (Shenzhen Threenh Technology Co., Ltd., China).
Grinder (Model SM–3, Hsiangtai, Taiwan).
Sous vide 225 448 system (Hendi, Hamburg, Germany).
Scale (Axis A6000, Poland, accuracy 0.1g).

Laboratory Methods

According to the evaluation of the descriptors, their weight significance was determined concerning the overall assessment of the samples. They were determined in relation to the significance of the descriptors for consumers. Tasting evaluation of paté samples was carried out on a scale of desirability and intensity of the sensation of taste and aromatic qualities of the product: 0 points - no sign; 1 point - barely perceptible; 2 points - weak intensity; 3 points - medium intensity; 4 points - strong intensity; 5 points - very strong intensity.

Descriptors reflect three dimensions of the sensation of flavor: taste, aroma, consistency, overall impression.

Among the taste descriptors, harmonious was highlighted, which is an equivalent concept of product balance. The descriptors "harmonious," "slightly pronounced fishy," "pronounced," "typical," "sweet," and "salty" characterize the fullness of the pâté's taste. The tasters first revealed the aroma, after which they determined the intensity of each component's manifestation on the taste.

To create flavor profiles, the method described in DSTU ISO 6564:2005 "Sensory research. Methodology. Methods for creating a flavor spectrum" (ISO 6564, 2005) was used.

Chromaticity studies were conducted on control and experimental samples using white light, and its red-orange, yellow-green-blue, and blue-light blue-violet illuminant components using a non-contact spectrophotometer YL 4560-3nh (Shenzhen Threenh Technology Co., Ltd., China) and presented in RGB (Red, Blue, and Green) coordinates.

Description of the Experiment

Study flow: At the very beginning, all the necessary ingredients were prepared, including crucian carp, salmon trimmings, maca root, beetroot, broccoli, carrots, onions, oil, salt, and ground black pepper. The crucian carp were processed to a carcass, the salmon was not subjected to processing because trimmings were used. Beetroots, broccoli, and carrots were peeled. For the experiment, 5% of maca root, beetroots, broccoli, respectively, were added to the sample recipes. All ingredients were weighed and homogenized to obtain a homogeneous consistency of the samples. After that, the samples were treated in boiling water (100 degrees Celsius) in a sous vide apparatus for 60 minutes. The pâté production process consists of the following operations: receiving raw materials, sorting, washing, grinding, preparing minced meat, forming, cooking, packing in consumer containers, packaging in transport containers and storage.

Quality Assurance

Number of repeated analyses: 5

Number of experiment replication: 5

Reference materials: The equipment manufacturer provided instructions to check the equipment's performance.

Calibration: Each instrument was calibrated before each experiment, and calibration checks were performed regularly to maintain measurement accuracy. Each instrument was calibrated before each experiment, and calibration checks were performed periodically to maintain measurement accuracy.

Laboratory accreditation: The experiments were conducted at the "Ukrainian Laboratory of Quality and Safety of Agricultural and Industrial Complex Products", the management of which is carried out through the implementation of a management system built (since 2007) bythe requirements of DSTU EN ISO/IEC 17025:2019 (EN ISO/IEC 17025:2017, IDT; ISO/IEC 17025:2017, IDT) and confirmed by the Accreditation Certificate of the National Accreditation Agency of Ukraine.

Data Access

The data supporting the findings of this study are not publicly available.

Statistical Analysis

The results of the experimental studies were processed using mathematical statistics. The experimental data was analysed using the Data Analysis in Microsoft Excel. Each experiment was performed with a minimum of three to five repetitions. The acquired results were subjected to standard processing methods and are presented

as average values and standard errors of the mean (± SEM). Statistical results were assessed using the Student's t-test, with differences considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

An expert commission of 20 people conducted the sensory analysis. At the same time, such descriptors were evaluated as significant for consumers and included in the hypothetical standard's complex flavor profile **[16]**.

The survey participants were offered 10 descriptors to evaluate fish pâtés on the scale given above, which were arranged in descending order of significance.

According to the tasting results and after mathematical processing of the obtained data, flavor profiles of fish pâté samples with the addition of maca root, broccoli, and beetroot, and a control sample without adding plant raw materials were compiled.

Based on the results of consumer preference studies, a set of 10 descriptors for flavor characteristics was defined (Table 1).

Table 1 Sensory evaluation of fish pâtés using the flavor profile method.

Descriptors	**Intensity of characteristics, score**				
		Fish pâté			
	Standard	**Fish pâté control**	**Fish pâté with maca root**	**Fish pâté with broccoli**	**Fish pâté with beetroot**
Aroma and taste characteristics **[17]:**	5.0	4.1	4.7	4.7	4.6
harmonious					
typical	4.5	4.1	4.3	4.4	4.3
slightly pronounced fishy	4.5	3.9	4.5	4.2	4.3
pronounced	3.5	2.9	3.3	3.1	3.4
sweet	3.0	2.2	2.1	2.5	2.2
salty	3.0	2.0	2.1	2.6	2.4
Consistency characteristics **[18]**:	3.0	2.5	2.7	2.8	2.8
tender					
juicy	3.5	3.1	3.1	3.4	3.2
spreadable	3.0	2.4	2.7	2.4	2.1
Overall impression	5.0	4.1	4.8	4.8	4.5
Total points	38.0	31.3	34.3	36.9	34.5

The experimental studies conducted found that the samples are unique in their organoleptic indicators. In most indicators, the experimental samples outperform the control samples. At the same time, it is worth noting that the experimental samples surpassed the control sample in their ratings but still did not reach the absolute indicators of the standard. Samples with maca root in the sweet aroma and taste category showed the most significant differences, with beetroot in the spreadable consistency category.

All samples surpassed the experimental control in terms of aroma. Some, such as the sample with maca root, came close to the standard in terms of the indicator. Like in the "typical" category, the "slightly pronounced fishy" is a positive characteristic. There were no sharply harmful components of the aroma or taste described.

For a visual perception of the results, detailed flavor profiles of the developed fish pâté samples were constructed (Figure 2, Figure 3, and Figure 4). Profile analysis makes it possible to identify which characteristic of taste and aroma one sample under study (in our case, the control, the standard) differs from another (samples with maca root, beetroot, broccoli). It is worth stating that with the help of profile analysis, a more objective assessment of the organoleptic indicators of fish pâtés was obtained.

Organoleptic studies established that it is appropriate to combine maca root with freshwater fish, as evidenced by a pleasant, non-offensive, slightly fishy taste and a tender, juicy consistency.

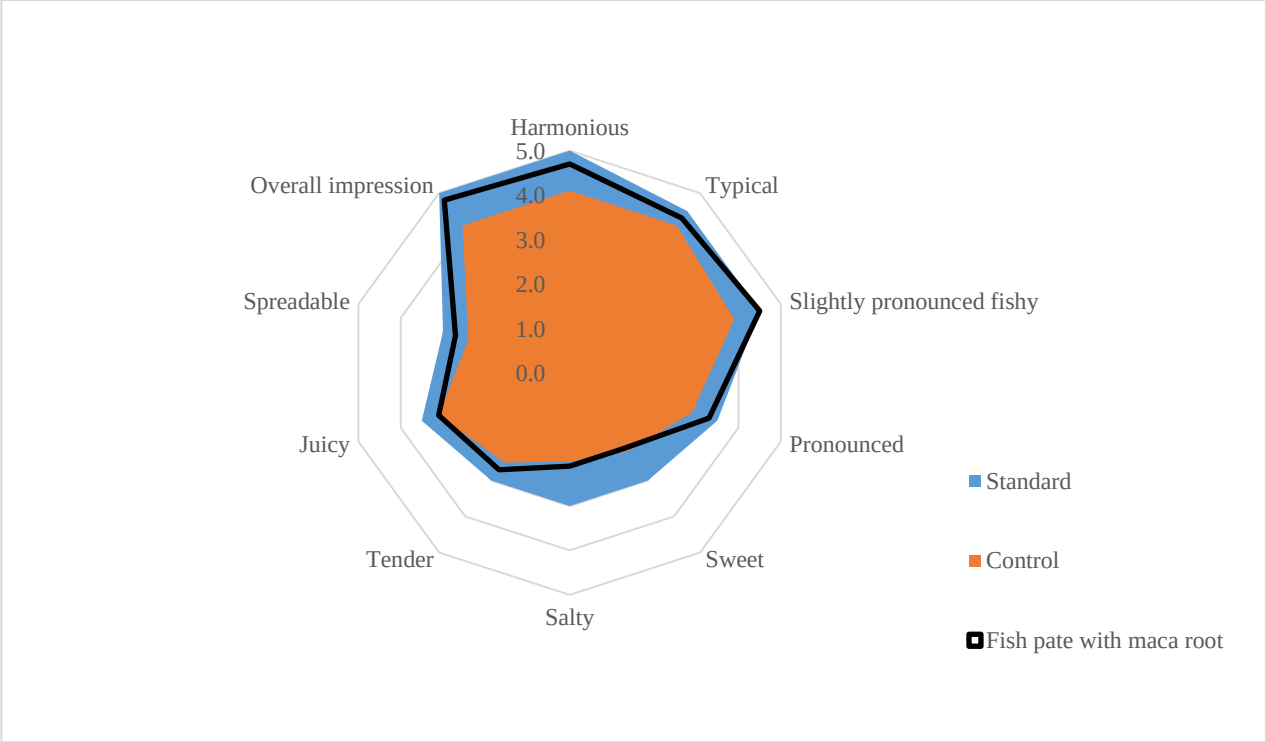


Figure 2 Flavor profile of fish pâté with maca root.

The pâté with the addition of maca root is characterized by high ratings for descriptors such as slightly pronounced fishy, overall impression, pronounced, and harmonious. In terms of consistency, the fish pâté is tender and quite juicy when cut.

When comparing the calculated overall score, the sample of fish pâté with added broccoli was the closest to the standard, with a score of 36.9 (Figure 3).

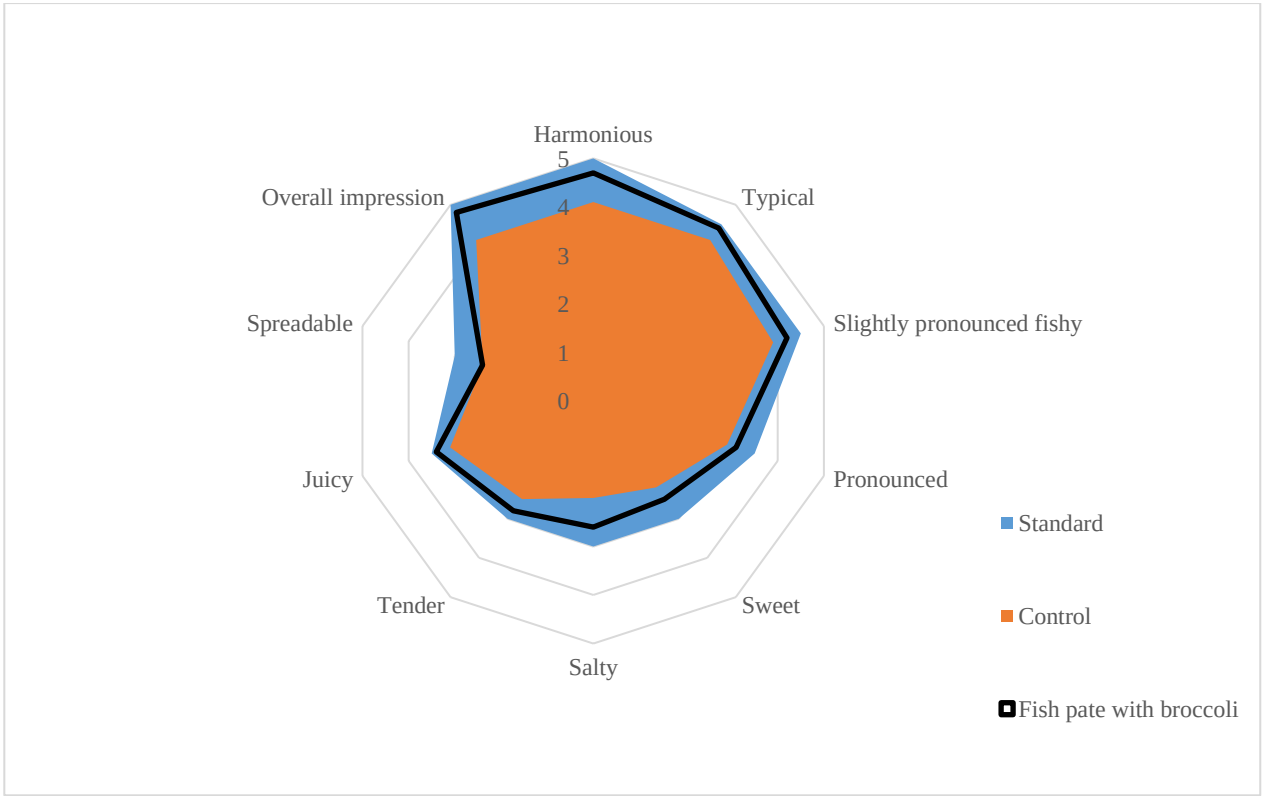


Figure 3 Flavor profile of fish pâté with added broccoli.

The most significant difference between the control sample and the sample with the addition of broccoli compared to the standard was the descriptor called "spreadable". There is a need to assert the rationale for improving the technology to enhance this indicator.

Organoleptic studies' results established the feasibility of combining beetroot with freshwater fish, as evidenced by the typical, pleasant taste without any off-flavors, a slightly pronounced fish taste, and a tender, firm consistency.

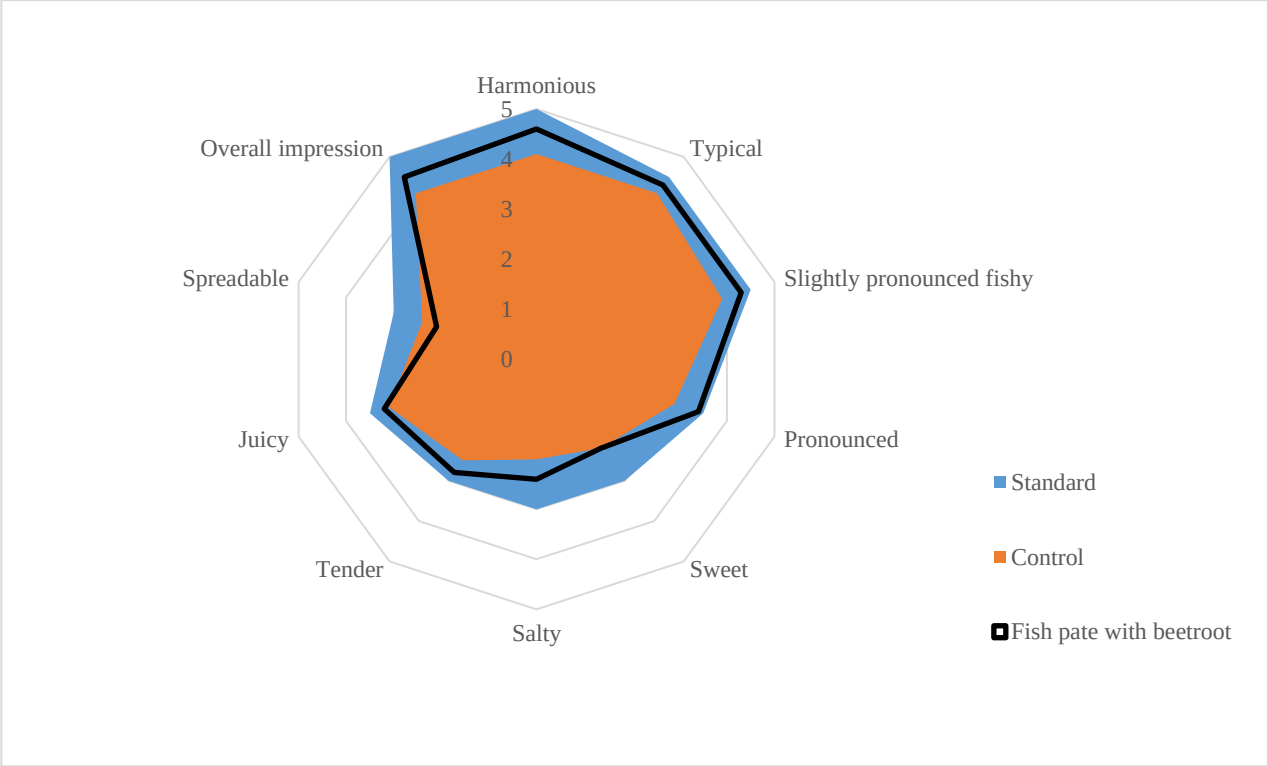


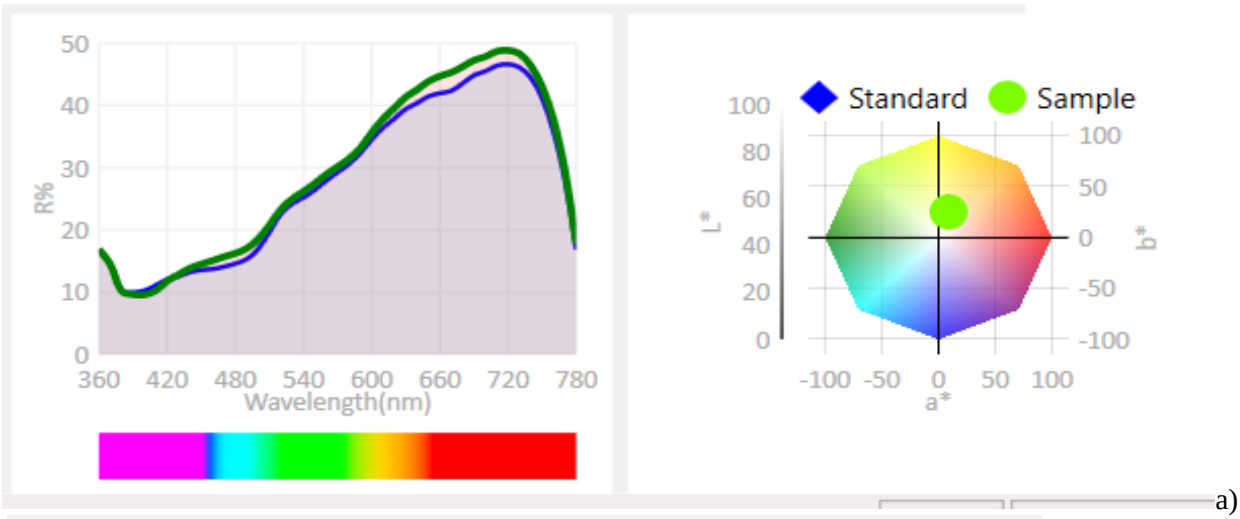
Figure 4 Flavor profile of fish pâté with added beetroot.

Previous research has shown that the use of vegetable raw materials **[18]**, **[19]**, **[20]**, **[21]**, and **[22]** in the technology of freshwater aquatic organisms contribute to the harmonization of organoleptic characteristics

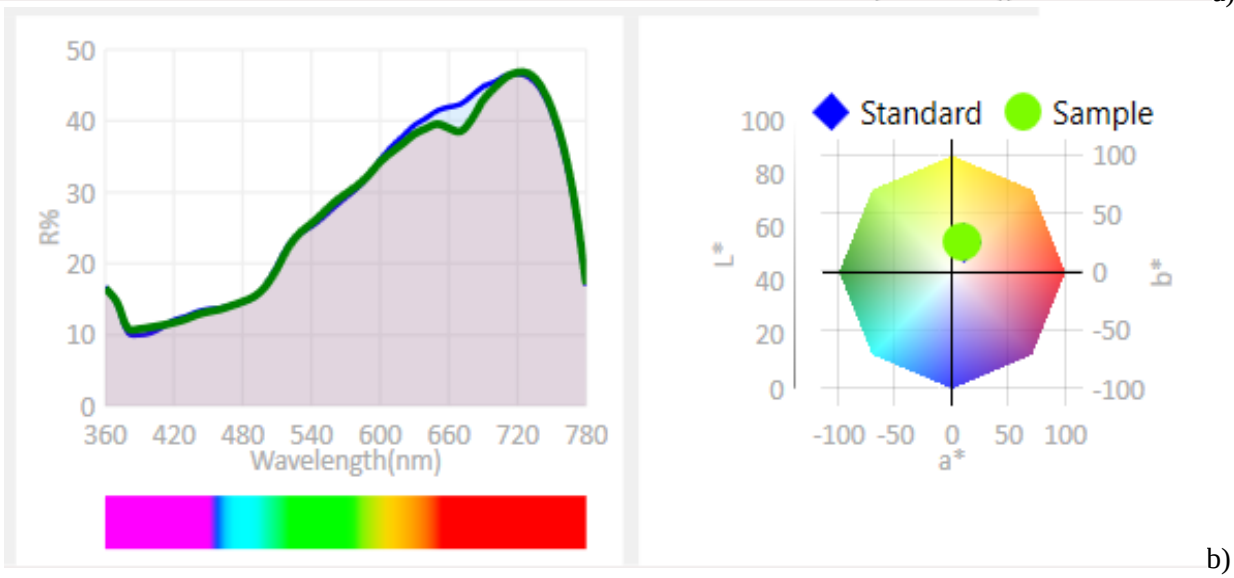
The pâté, with the addition of beetroot, is characterized by high ratings for descriptors such as typical, pronounced, and slightly pronounced fish taste and aroma. In terms of consistency, the fish pâté is tender and juicy when cut.

The general analysis and comparison allow us to state that all samples of fish pâtés have a harmonious and fishy taste and a positive overall impression.

As we can see, the sample with the addition of maca root practically does not differ on the a*, b*, and L* axes; the control sample and the sample with maca root completely overlap each other in this dimension. What cannot be said about the sample with the addition of broccoli, we see a deviation along the a* axis towards green **[23]**. At the same time, the sample with the addition of beetroot significantly differs from the control sample with a deviation along the a* axis towards green and the b* axis towards blue. Regarding the L* value from black to white, it can be said that all samples have approximately the same values on this axis.



a)



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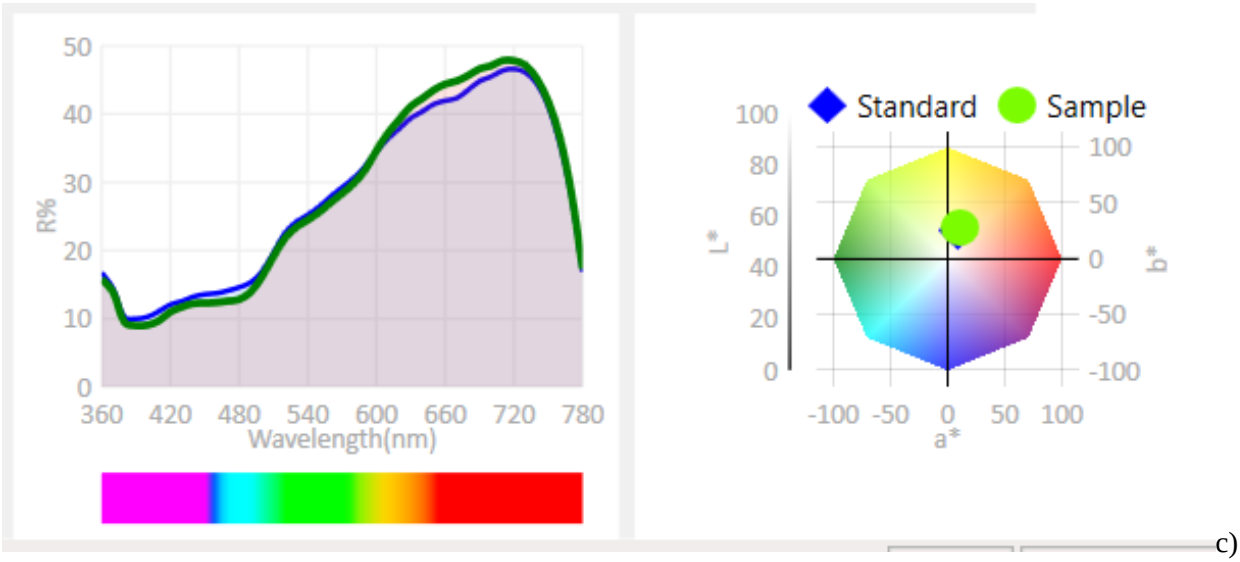

c)

Figure 5 Comparison of color characteristics of samples with control.
Note:
a) Standart - fish pâté control, Sample - fish pâté with maca root,
b) Standart - fish pâté control, Sample - fish pâté with broccoli,
c) Standart - fish pâté control, Sample - fish pâté with beetroot.

Paying attention to the highest reflectance depending on the length of a certain wavelength **[24]**, it is worth noting that in the sample with the addition of maca root in the range from 600 nm to 730 nm, the reflectance is higher than the control. In the range from 630 nm to 690 nm, the control sample is higher on the reflectance axis than the sample with the addition of broccoli. The wavelength range from 620 to 720 nm on the graph comparing the sample with beetroot addition to the control indicates the dominance of the sample's reflectance with broccoli addition over the control sample. A generalized comparison of the samples with each other and the control taken as the origin of the coordinates along the axes Δa*, Δb*, ΔL* is shown in Figure 6.

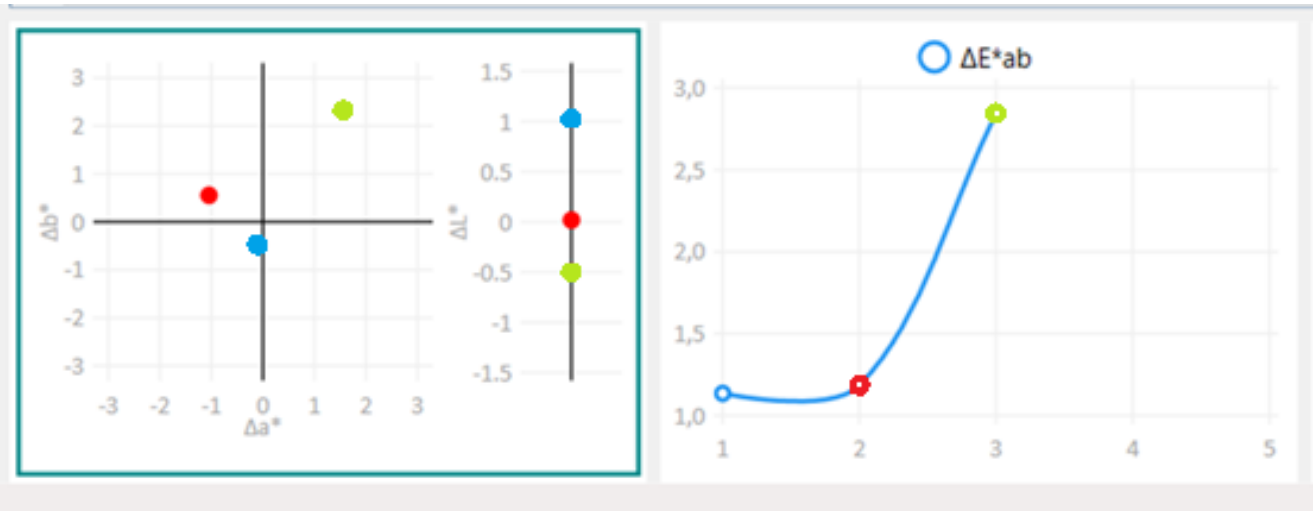

Figure 6 Comparison of sample data Δa*, Δb*, ΔL* with the control.
Note:
a) Blue - sample fish pâté with added maca root,
b) Red - sample fish pâté with broccoli,
c) Green - sample fish pâté with beetroot.

Based on the data of previous researchers **[25]**, it can be concluded that the samples with the addition of maca root and broccoli barely differ from the control; only an experienced observer will notice the difference. Meanwhile, the sample with the addition of beetroot has quite profound differences in color, which can be seen even by an inexperienced observer.

Table 2 Chromaticity indicators under incandescent light.

Indicator	Fish pâté control	Fish pâté with maca root	Fish pâté with broccoli	Fish pâté with beetroot
L*	61.56	62.54	61.48	61.35
a*	13.31	13.74	11.82	15.41
b*	29.05	28.16	29.35	31.81

Describing the colorimetric data of the samples under the light of an incandescent lamp **[26]**, it is worth noting that the sample with the addition of maca root will be lighter than other samples. The sample with the addition of beetroot will show a significantly higher value of the a* indicator under the same conditions, from which we can conclude that this sample is redder than the others. As for the b* indicator, the sample with the addition of maca root is the one that approaches the blue shade, while the sample with the addition of beetroot shows a shift toward the yellow color (Table 2).

Table 3 Chromaticity indicators under cool white fluorescent lighting.

Indicator	Fish pâté control	Fish pâté with maca root	Fish pâté with broccoli	Fish pâté with beetroot
L*	60.59	61.50	60.73	60.12
a*	5.36	5.44	4.31	6.55
b*	28.96	28.38	29.81	31.11

The brightest sample among all tested under the light of a cold white fluorescent lamp was the sample with the addition of maca root (Table 3). The sample with the addition of beetroot is closer to red, while the sample with broccoli is closer to green. The sample with the addition of beetroot has the most significant addition of yellow, and the sample with the addition of maca root tends to be blue.

The obtained research data showed that adding beetroot, broccoli, and maca root to fish pâtés improved their organoleptic properties, such as a pronounced, harmonious taste and aroma and spreadable consistency. These results are supported by similar studies, where adding natural additives also improved the quality of fish pâtés. For example, the effect of adding different levels of potato inclusions in the amount of 5, 10, 15, and 20% was investigated, and the effect of additives on the physicochemical and sensory properties of pâtés **[23]**. In some studies, for example, adding oregano oil to pâtés also improved the product's taste properties and chemical and fatty acid composition **[27]**.

The effect of adding various plant materials and their compositions, such as chili pepper microcapsules, aquafaba to pâtés has been investigated **[28]**, and **[29]**. Partial replacement of 10-20% of animal fat with vegetable, hemp oil positively reduces cholesterol levels, improving the level of polyunsaturated fatty acids in pâtés **[30]**. Adding guabiroba peel extract reduces lipid oxidation during storage **[31]**, and **[32]**. Addition of caviar, liver improves the product's protein content and perception **[33]**, and **[34]**.

The addition of beetroot, broccoli, and maca root increased the organoleptic properties of the finished product compared to the control, confirming the effectiveness of using these ingredients. This shows the prospects for using beetroot, broccoli, maca root, and other natural additives to improve the organoleptic properties of fish pâtés.

Studies of the finished pâtés' chemical composition were conducted to assess their quality. The results are presented in Table 4.

The highest moisture content is found in broccoli pâté – 62.20±2.3%, while the control sample has only 58.80±2.4%. Beetroot pâté has 60.60±2.3%, and maca root pâté – 60.04±2.7%. The control sample contains the most protein – 20.50±0.7%, broccoli pâté has 18.90±0.21%, maca root – 18.60±0.23%, and the lowest protein content is observed in the beetroot sample – 18.10±0.25%. The beetroot pâté contains the most minerals — 3.30±0.17%, the control sample has 1.28±0.14%, the maca root pâté contains 2.56±0.16%, and the least minerals among the experimental samples with the addition of broccoli — 1.31±0.16%.

Adding broccoli and beetroot increases moisture, which positively affects the juiciness of the product but reduces the protein content. Adding vegetables has a slight effect on the fat content of the product, keeping the calorie content at about the same level.

Table 4 General chemical composition of fish pâtés.

Indicator	Samples of pâtés			
	Fish pâté control	**Fish pâté with maca root**	**Fish pâté with broccoli**	**Fish pâté with beetroot**
Moisture content	58.80±2.4	60.04±2.7	62.20±2.3	60.60±2.3
Protein content	20.50±0.7	18.80±0.8	16.40±0.9	18.00±0.9
Fat content	19.42±0.22	18.60±0.23	18.90±0.21	18.10±0.25
Mineral content	1.28±0.14	2.56±0.16	2.50±0.16	3.30±0.17

Note: results are in %, (n=5, p≤0.05).

These results indicate that adding vegetables to the fish pâté recipe affects its chemical composition, allowing individual parameters to be adjusted depending on the desired product properties.

Kamsulina and Ildirova use herbal supplements in their work and substantiate their effect on increasing moisture retention capacity, dry matter content, and protein **[35]**.

A study of water activity in finished pâtés was also conducted. The data are presented in Table 5.

Table 5 Water activity in pâtés.

Water activity	**Fish pâté control**			
	Fish pâté control	**Fish pâté with maca root**	**Fish pâté with broccoli**	**Fish pâté with beetroot**
A_w	0.937	0.914	0.935	0.960

Water activity characterizes the effect of moisture on product spoilage and is a key physicochemical indicator that determines the resistance of fish products, particularly pâtés, to spoilage. It correlates well with the rate of many destructive reactions and can be measured and used to assess the state of water in food products and its involvement in chemical and biological changes. Thus, analyzing the data in the table, we observe that beetroot increases water activity the most, which may indicate a potentially shorter shelf life of this option due to a higher risk of microbiological spoilage. On the contrary, maca reduces Aw, which may contribute to better resistance to spoilage.

The influence of the water activity index on the quality and microbiological stability of food products has been highlighted in the works of many domestic scientists **[36]**, and **[37]**. The works of foreign authors also provide the results of research on the Aw index in the manufacture of fish products, including those based on fish caviar **[38]**, **[39]**, and **[40]**. Given the significant informativeness, importance, and world experience in using the Aw index in the manufacture of fish products, it is advisable to use this indicator as a quality and safety criterion in the fish pâtés technology with the addition of vegetable raw materials.

Menchynska and other authors provide data on water activity in shrimp mousses. The water activity is 0.967, which is a high indicator and indicates rapid spoilage of the product **[41]**.

The acid and peroxide values were examined during storage. Figure 7 shows the dynamics of the accumulation of fat hydrolysis products in pâtés.

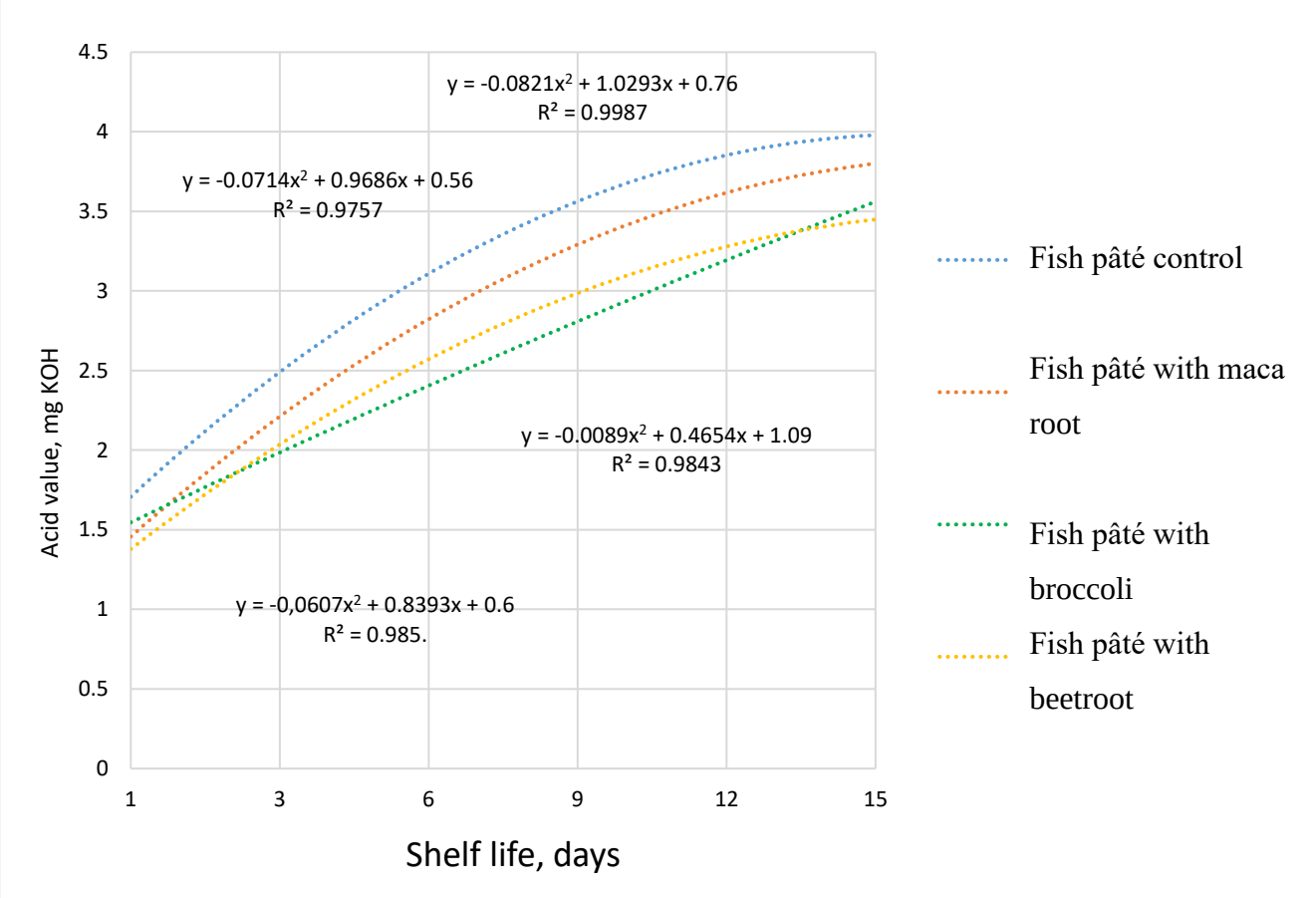

Figure 7 Changes in the acid value of fat during storage of pâtés.

Fat hydrolysis products accumulate more intensively in the control sample than in the experimental sample. The same trend is observed when determining changes in the peroxide value, which reflects the accumulation of primary fat oxidation products. Changes in the peroxide value during sample storage are presented in Figure 8.

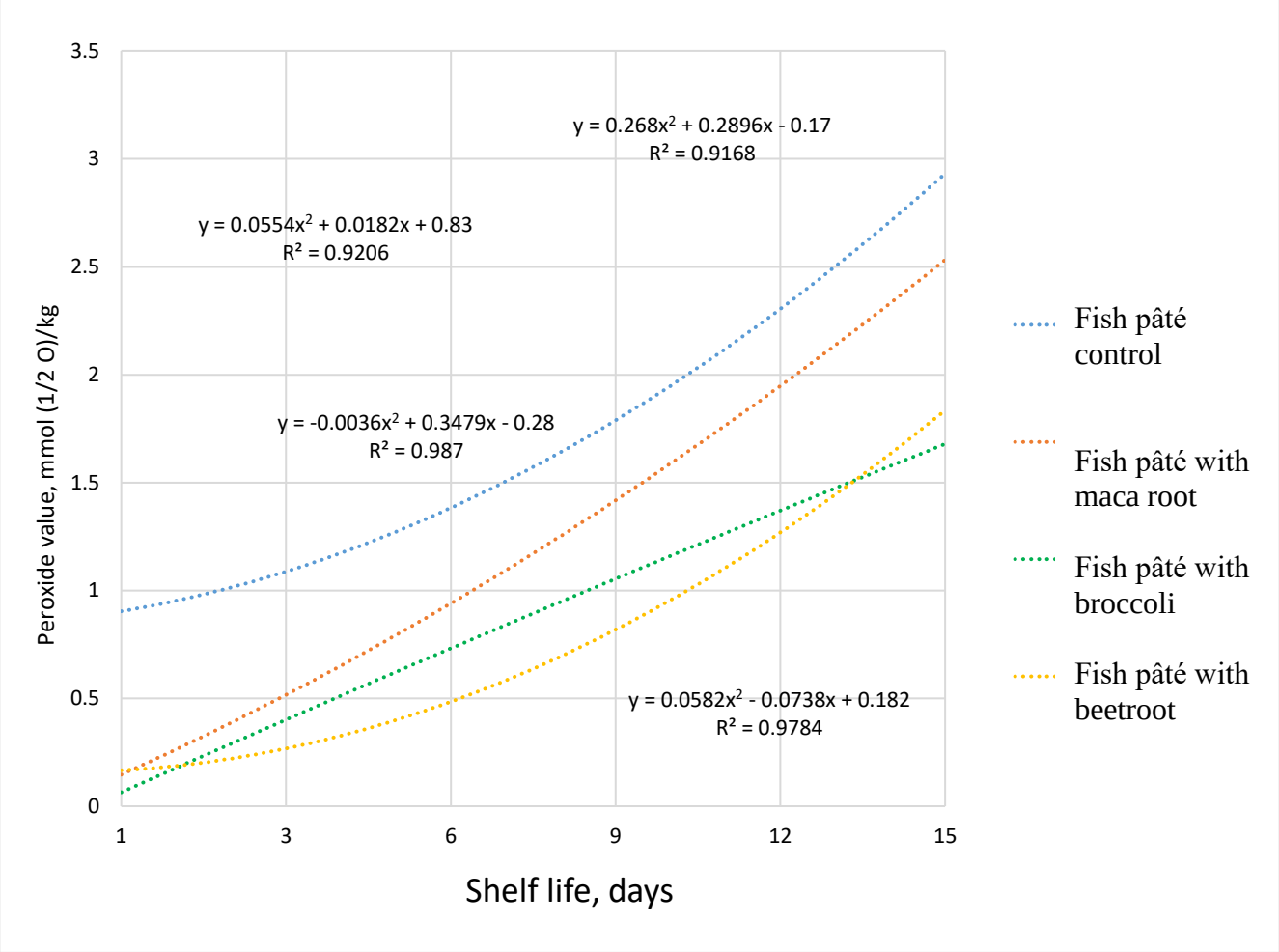

Figure 8 Changes in peroxide value during storage of pâtés.

Analyzing the data in the figure, it can be noted that the optimal value of the quality indicators of pâtés is their storage period of 9 days, which corresponds to good-quality, fresh fat in the product.

One of the major weaknesses of this article is the superficial and overly formal discussion, which lacks depth, critical analysis, and meaningful scientific interpretation. The discussion should summarize the findings and critically analyze their implications, compare them with existing research, and provide possible explanations for observed trends. However, in its current form, the discussion remains generic and lacks deeper insight into the significance of the results.

CONCLUSION

The study showed that beetroot, broccoli, and maca root significantly improved the product characteristics, including organoleptic characteristics. Adding 5 percent of beetroot, broccoli, and maca root optimized and improved the finished product's color, taste, appearance, and texture. According to the results, the sample with the addition of broccoli showed the highest results.

The color indicators also showed positive results in the pâté sample with added beetroot, in which the color difference would be noticeable to an inexperienced observer.

Studies of the chemical composition of fish pâtés yielded positive results. It was substantiated that the addition of plant raw materials increases the mineral content compared to the control sample, which indicates the feasibility of their addition.

Based on the research, it was found that adding broccoli and beetroot to the composition of pâtés increases the moisture content of the product, which has a positive effect on its juiciness. The highest moisture content was recorded in the broccoli pâté —62.20±2.3%, while the control sample had only 58.80±2.4%. The pâté with beetroot showed a moisture content of 60.60±2.3%, and with maca root—60.04±2.7%.

A slight decrease in protein content accompanied the addition of vegetable components. The control sample had the highest protein content — 20.50±0.7%, while the broccoli, maca root, and beetroot pâtés had values of 18.90±0.21%, 18.60±0.23% and 18.10±0.25%, respectively.

Regarding the mineral content, the highest value was found in the beetroot pâté — 3.30±0.17%, while the control sample contained only 1.28±0.14%. In the maca root pâté, this value was 2.56±0.16%, and the lowest mineral content was recorded in the broccoli sample — 1.31±0.16%.

At the same time, the addition of vegetables had practically no effect on the product's fat content, which allowed the calorie content to be kept at approximately the same level for all samples. In general, using vegetable components in the recipe of pâtés allows for an increase in the juiciness and enrichment of the product with minerals, while maintaining a sufficient level of protein and calorie content.

The developed technology of fish pâtés will significantly expand the scope of functional products based on natural components, which allow, to a certain extent, to expand the ways of solving the problem of using and processing freshwater fish.

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