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Use of Marine Biological Resources of the Arctic Region for Creation of Combined Fish and Vegetable Canned Pastes

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Abstract

The article discusses the possibility of expanding the species composition of sterilized food products through harvesting and processing of fucus algae growing in the Arctic littoral. Their rich chemical composition is shown, having a high content of such essential nutrients as polysaccharides, iodine, and water-soluble vitamins. Microbiological and toxicological studies of fucus algae *F. vesiculosus* and *A. nodosum* conducted by the authors have proved the safety and possibility of using fucus algae in food production. The article presents the results of the newly-developed manufacturing technology for canned fish pastes with vegetable components on the example of Northern blue whiting (*Micromesistius poutassou)* and the Barents Sea algae (*Fucus vesiculosus)*. The authors worked out the technological scheme, optimized the product formulation, provided the scientific substantiation for the product sterilization regime, and evaluated the quality of the finished product. The combination of fucus properties with fish tissues enabled the authors to bring closer the solution to the problem of developing food products with a balanced nutrition formula. The functionality of the developed sterilized product based on the content of iodine, calcium, magnesium and phosphorus is shown.

Keywords: fucus algae, food products, canned pastes, formulation, sterilization, functionality.

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1. Introduction

The expansion of the domestic production of fish food products is an important area of the Russian Federation state policy for the period until 2020. An urgent task for the Arctic basin is the rational use of its raw material base, which includes processing of fish raw materials and seaweed. The combination of fish and vegetable raw materials is a promising one from the standpoint of a healthy diet. The development and production of combined fish and vegetable foods containing a high amount of essential nutrients is an effective and affordable way to eliminate the current shortage of essential nutrients, especially for the population living in the Arctic region. The creation of sterilized products

capable of preserving all useful properties for a long time without additional energy costs, such as freezing storage is also of great importance [2].

2. Purpose of the Study

In order to solve the problem, it was proposed to expand the species composition of sterilized food products through the use of brown fucus algae, which is widely distributed in the Arctic littoral.

The combination of Fucus properties with fish tissues makes it possible to approach the solution to the problem of creating balanced products that correspond to the optimal nutrition formula.

The novelty of the task lies in a new approach to the formation of properties of protein-polysaccharide food compositions under development, and the solution of the problem of achieving the specified products quality indicators.

2.1. Properties of raw materials

The following representatives of the fukus algae can be found in the Barents and the White Seas: *Ascophyllum nodosum, Fucus distichus, F. serratus, F. spiralis, F. vesiculosus, F. inflatus, Pelvetia canaliculata,* and *Halidrys siliquosa*. Ascophyllum *(A. nodosum)* and fucus (*F. vesiculosus, F. distichus, F. serratus*) are large commercial algae. Reserves of fukus algae in the Barents Sea are estimated at 200-250 thousand tons [3].

Brown algae produce a large number of different chemical compounds which have a pronounced biological and pharmacological effect on various tissues, organ systems, and functions of animal organisms [4].

Fucus algae are a valuable raw material for the production of polysaccharides (alginates, fucoidan, laminaran), having a balanced macro- and microelement composition [5--7]. They are also enriched with vitamins in the amounts 100-1000 times higher than terrestrial plants, and they synthesize a large number of biologically active substances that terrestrial plants do not contain [8]. The chemical composition of brown algae is very diverse. In addition to protein substances and fat, they contain a complex of polysaccharides described below.

– Fucoidan is a polysaccharide consisting of fructose blocks. It enhances the processes of phagocytosis (destruction of bacteria and foreign particles), increases the number of white blood cells in the body and stimulates the production of vital immune

cells. Fucoidan's ability to destroy cancer cells makes it one of the most promising remedies in oncology.

– Alginates are heteropolymers which are formed by two polyuronic acid residues (D-mannuronic and L-guluronic). They sorb and remove not only radionuclides and heavy metals from the body, but also toxins of organic origin. Alginates are able to stimulate regeneration processes and enhance epithelization of tissues.

– Mannitol is a hexatomic alcohol. It is used as a sugar substitute for patients with diabetes, as well as an additive that prevents the formation of lumps in dairy and other types of products.

– Lamaran is a biopolymer whose main chain is built from glucopyranose residues connected by glycosidic bonds.

A specific feature of fucus cells is the ability to accumulate iodine. The iodine content in fucus can reach from 0.03% to 0.3% by wet weight of the algae. Iodine is presented in various forms: in the form of iodides and iodates, as well as in the organically bound form, mainly with algae proteins. Iodine is involved in the functioning of the thyroid body and provides the formation of hormones (thyroxine and triiodothyronine). Iodine improves the assimilation of protein, the absorption of phosphorus, calcium and iron, and activates a number of enzymes. Iodine reduces blood viscosity and reduces vascular tone. Brown algae products are recommended as antizobic drugs since iodine, being combined with amino acids, is effectively absorbed by the body.

Brown algae are a rich source of water-soluble vitamins, such as vitamins C and B2. Vitamin C is found mainly in brown algae, e. g. *Fucus vesiculosus* (414 mg%) and *Fucus serratus* (495 mg%).

3. Study Results

3.1. Investigation of raw materials safety

In order to determine the possibility of using Fucus algae in food production, we carried out microbiological and toxicological studies of dry algae for compliance with the TR EAEU 040/2016 requirements. The results are presented in tables 1 and 2.

As it can be seen from the results, QMAFAnM is $1{,}5x10^2$ CFU in 1 g, which does not exceed the standard values (the norm is 5×10^4 CFU in 1 g). Pathogenic and opportunistic microorganisms (Coliforms and Salmonella) were not detected; the quantity of molds in 1 g of algae is less than 10. Thus, the quality of dry fucus according to the microbiological indicators meets the requirements to raw materials used for food production. Dry algae

Table 1: Microbiological characteristics of dry focus.

Name of indicator	Value of indicator [9]	Test results
Mesophilic aerobic and facultative anaerobic microorganisms (QMAFAnM, CFU/G, not exceeding)	$5\ 10^4$	1.2×10^2
Coliforms, in 0.01 g	Not allowed	Not found
Pathogenic including salmonella	Not allowed	Not found
Moulds, CFU, in g, no more	100	4

Table 2: Content of toxic elements in dry algae.

Name of algae	The content of toxic elements, mg / kg		
	cadmium	arsenic	mercury
F. vesiculosus	0,338	3,300	traces
A. nodosum	0,211	3,100	traces
Accepted levels [9]	1,0	5,0	0,1

(*F. Vesiculosus* and *A. nodosum)* have been found to contain a small amount of toxic elements, which do not exceed the standard values for raw algae, according to the safety indicators positioned in table 2.

The authors developed a new type of canned pastes made of cod fish with vegetables and focus [10]. One of the main stages of dry algae processing is their restoration. In order to improve the fucus organoleptic properties and increase their assimilation by the human body, the algae must be subjected to thermal treatment. As a result of the previous work, pre-treatment schemes of dry fucus ware developed: swelling in water with a temperature of (20 ± 5) °C during 1-1.5 hours, followed by cooking at a temperature of (95 ± 5) °C during 1 hour.

3.2. Development of multicomponent canned paste with fucus

To make the paste, we used frozen blue whiting, which is one of the dominant Northern Basin aquatic biological resources, and is not inferior in biological value to the other cod species, to which it belongs. The high protein content with minimum lipid content, the blue-and-white color of meat, as well as perfect rheological properties allow it being used as an ideal raw material for the production of various food products. The possibility of using mince from low-value blue whiting in the production of canned pastes would give a new impulse to the development and improvement of canned products technologies from low-value fish species of the Northern Basin.

The technology of food products prepared on the basis of crushed blue whiting meat is relevant because it is considered to be the most rational in terms of the final edible

portion. The possibility of various combinations of animal and vegetable components allows planning and calculating the nutritional and biological value of the produced canned pastes, as well as evaluating their compliance with the principle of balanced nutrition.

Fucus algae, carrots and onions were considered as vegetable ingredients for the production of fish pastes. Flour, vegetable oil, and spices were also used in the paste recipe.

The combination of food components allows creating a product that contributes to the stabilization of nutrition according to the main ingredients and meets the differentiated requirements of a balanced diet. The introduction of vegetable additives and their mixtures in the formulation of minced fish products can improve their nutritional quality and increase their nutritional value; the introduction of fucus in the formulation allows assigning functional properties to the products.

The main stages of the technological process were as follows: defrosting, washing, cutting, blanching in water. Fish cutting or fillet was used after draining. The blanched fish was mixed with prepared vegetables and other ingredients (sautéed carrots and onions, flour, chopped boiled fukus, vegetable oil, salt, spices) using a cutter. The prepared paste mass was packed into tin cans No 3. The seamed cans were sealed and sterilized.

For the manufacture of sterilized canned food and in order to enrich the product with minerals, it was decided to use fish cutting.

3.2.1. Optimization of fish heat pre-treatment

During the experiment, we carried out the work to find out the optimal time for blanching the fish in water. The cutting was blanched in water during 10, 15 and 20 minutes. The ratio of fish and water was 1:2. The results of the organoleptic evaluation of pastes from semi-finished blanched fish are presented in picture 1.

The results showed that an increase in the duration of blanching after water boiling for more than 10 minutes has virtually no effect on softening of the bones and improvement of the pastes consistency.

Fucus reconstituted in water was washed to remove sand, mucus and other impurities, crushed in a top (lattice diameter 3 mm), and boiled in water for 1 hour (ratio of fucus and water 1:1). The resulting pulp - a smooth water boiled mass of fucus (boiled fucus) - was used to prepare the paste mass.

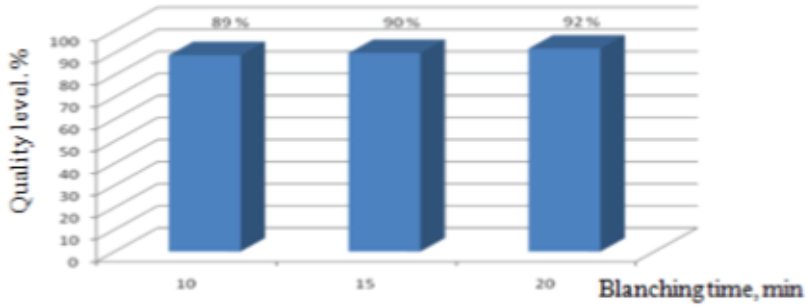

Figure 1: Organoleptic evaluation of pastes depending on the fish blanching time.

3.2.2. Optimization of paste mix recipe

During the research, the formulation of canned pastes was optimized on the basis of organoleptic evaluation of the finished product quality. The organoleptic evaluation of canned fish was carried out according to a five-point scale developed for this type of canned food with the introduction of significance coefficients and the followingt calculation of the product quality level. Optimization results are presented in table 3.

TABLE 3: Paste mass recipe for 1000 grams of paste.

Components and total assessment of product quality (level of quality, %)	Mass of components, g					
	1	2	3	4	5	6
Blanched fish	500	500	500	500	500	500
Fucus	60	100	120	140	180	260
Onion	84	84	84	84	82	72
Carrot	230	188	174	154	112	70
Sunflower oil	68	70	64	64	68	40
Sauteed flour	42	42	42	42	42	42
Salt	12	12	12	12	12	12
White pepper	2	2	2	2	2	2
Gum	2	2	2	2	2	2
Quality level, %	97	95	94	91	86	77

The paste with the addition of 6% fucus (to the paste mass) had the highest quality level (97%). It was noted that with the addition of fucus no more than 14%, the organoleptic characteristics of the pastes were quite high and the quality level exceeded 90%. Organoleptic characteristics of the product, especially smell and taste, deteriorated with higher fucus content. The addition of fucus in such quantities enriched the product with iodine, calcium, magnesium, phosphorus, potassium, zinc, dietary fiber and alginic acids

while maintaining high organoleptic characteristics. For this reason it was decided to use recipe 3 as the basic one.

The main factor determining the quality characteristics of sterilized products and their shelf life is the sterilisation mode of the canned food. For each type of packaging, which differs in size, material, volume and the sterilization method used, a specific scheme must be developed that reflects the temperature-time parameters of heat treatment.

3.2.3. Development of sterilization scheme for canned paste

The authors also conducted studies on the development and scientific justification of the sterilization shceme for the developed products. The value of the practical lethality was used as a determining factor in the selection of the sterilization scheme; the value should be higher than the standard indicators. According to the "Instructions for the development of sterilization schemes for canned fish and seafood", the value of the regulated sterilizing effect for canned pastes in No. 3 can (net weight 240g) is 5.5 conventional minutes (conv. min.) at the contamination rate with spore mesophilic anaerobic microorganisms of 1 spore in 1 g of product before sterilization.

The duration of sterilization stage was varied (from 45 to 55 min) when selecting the sterilization scheme with the constant temperature of the heating medium (120 ˚C). Experimental cans with temperature sensors placed in the center of the can were located in the least warmed zone of the autoclave and sterilized (steam sterilization, back cooling with water) in the autoclaves of AB type. The heating medium temperature in the autoclave and the product temperature in the can were recorded every minute using the automatic control system of the sterilization process "SAUST-E". The practical lethality during sterilization was calculated and recorded using the software device of the TrackSense PRO wireless system (Ellab, Denmark).

It was revealed that the actual sterilization effect was lower than the normative one and varied from 5.2 to 5.4 conv. min. for the canned paste from blue whiting, vegetables and fucus in No. 3 can during the 45 minutes sterilization at the temperature of 120 ˚C. The actual sterilization effect reached the value of 10.6 conv. min. when the product had been steriliezed for 55 minutes, which significantly exceeds the standard. Sterilization within 50 minutes allows obtaining commercially sterile canned food with good organoleptic properties. The value of practical lethality (7.5 conv. min) exceeds the standard by 20-30%, which guarantees microbiological sterility of the product.

4. Assessment of Biological Value and Functional Properties of the Canned Paste

The samples of canned pastes from blue whiting with vegetables and fucus were made according to the developed recipe and the scientifically based sterilization regime. The studies of the product quality indicators were conducted after confirmation of its industrial sterility.

The final product is a smooth finely cut spread mass having juicy consistency and light beige color with brown inclusions. It has a pleasant taste typical for this type of canned foods with a light aftertaste and the aroma of algae and iodine.

The chemical composition of the paste is presented in table 4. Based on the studies, it was found that the paste is balanced in its chemical composition: it contains vegetable and animal proteins, fats, a sufficient amount of carbohydrates, as well as macro- and microelements.

A study of the amino acid composition of the paste (table 5) revealed that the samples are characterized by a complete set of protein amino acids, including the essential ones. At the same time there are no limiting amino acids. The protein of the studied product is well balanced compared to the reference protein [11], which proves the high value of the rationality coefficient (*Rc* = 0,83).

Table 4: Chemical composition of the blue whiting, vegetables and fucus algae paste.

Indicators	Content, %
Mass fraction of water, %	64,4 ± 0,1
Mass fraction of protein, %	9,3± 0,1
Mass fraction of carbohydrates, %	17,0± 0,2
Mass fraction of fat, %	7,1 ± 0,5
Mass fraction of ash, %	2,9 ± 0,1
Energy value for 100 g, kcal	169

The studies of the mineral and carbohydrate composition of the paste determined the presence of functional substances in the final product (table 6).

The comparative analysis of the actual content and the required daily [13] intake of iodine, calcium, magnesium and phosphorus allows classifying the developed product as functional. This type of developed product is protected by a patent of the Russian Federation [14].

Table 5: Amino acid composition of the canned paste.

Amino acid	mg in 100 g of product	mg in 1 g of protein	Score, %
Tryptophan	217	12	120
Lysine	1659	90	163
Histidine	722	39	
Arginine	1071	58	
Aspartic acid	1666	90	
Threonine	959	52	130
Serine	759	41	
Glutamic acid	2423	131	
Proline	961	52	
Glycine	1770	96	
Alanine	1201	65	
Cystine	-	-	102 {cystine + methionine}
Methionine	579	31	
Valine	1013	55	110
Isoleucine	962	52	130
Leucine	1465	80	114
Tyrosine	451	24	108 {tyrosine + phenylalanine}
Phenylalanine	766	41	
Sum of amino acids	18847		
Limiting amino acid, score, %			No

Table 6: Content of functional substances in the blue whiting, vegetables and fucus paste.

Substances	Daily requirement [12]	Content in 100 g of product	% of daily requirement
Calcium, мg	1000	199,79	20
Magnesium, мg	400	41,6	10,4
Potassium, g	3,5	0,216	6,2
Selenium, мg	0,07	less than 0,0001	-
Phosphorus, мg	800	420	50
Zinc, мg	15	0,65	4,3
Iodine, мg	0,15	0,2	133
Alginic acid, g	--	0,36	
Dietary fibers, g	30	1,25	4,2

5. Conclusion

– The possibility and safety of using fucus algae for food production has been established.

– The technology of fish and vegetable sterilized canned paste from blue whiting, vegetables and fucus has been developed and optimized.

– Canned paste from blue whiting, vegetables and fucus are functional according to the content of four minerals: iodine, calcium, magnesium and phosphorus.

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Conflict of Interest

The authors have no conflict of interest to declare.

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