High-protein sublimated fish and vegetable based snacks

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Abstract. The paper presents research data justifying the relevance of developing a ready-to-eat food product in the form of freeze-dried snacks based on a homogenized fish-vegetable system. Recipe formulations are substantiated and the technology of four freeze-dried snacks using fish and vegetable raw materials is developed, which allows to obtain a high-protein product containing polyunsaturated fatty acids, dietary fiber and minerals. Studies of the quality indicators of the developed finished products made it possible to establish its high nutritional, in particular biological value: snacks in their composition contain dietary fiber, in particular fiber (7.05-23.77%) and inulin (4.35%), polyunsaturated fatty acids of the omega -3.6 group (ω-3: 45.52-49.43% and ω-6: 5.48-6.98% of the total fatty acids), as well as trace elements such as iodine (0.021%), which allows us to recommend them as functional foods for the diet of the population.

1. Introduction
Given that modern society is characterized by an accelerated pace of life and at the same time monitors its diet, eating healthy food, the development of “fast food” products containing the necessary nutrients, including proteins and functional plant components, is relevant.

Fish-based sublimated snacks are less available on the Russian food market. Therefore, the use of aquatic biological resources as part of ready-to-eat foods or products of a high degree of readiness is an important area of modern scientific research and allows the rational use of the edible part of raw materials when cutting it [1, 2, 3].

The use of plant materials in the recipe for snacks will enrich them with dietary fiber, polyunsaturated fatty acids of the omega-3.6 group (PUFA ω -3.6), as well as additional mineral substances and thereby create a functional food product [1, 4, 5].

In this regard, the main goal of the research was to develop the recipe composition and technology of multicomponent high-protein snacks of long-term storage from fish raw materials using functional plant components.

2. Objects and research methods
In this work, pollock (Theragra chalcogramma), cod (Gadus morhua) and macrourus (Macrourus), which are a source of high-grade protein (15.0 -17.0%), are used as a fish base for prescription compositions of the fish-vegetable system (RCC) for snacks. and have a low fat content (0.6-1.0%).

The following plant components were used as plant components: Jerusalem artichoke, pumpkin, zucchini, broccoli, spinach, celery, dill, carrots, flax and chia seeds, as well as the algae residue obtained by complex processing of kelp (Saccharina japonica) [6, 7, 8]. Jerusalem artichoke is a
source of prebiotic fiber - inulin (17.0 - 20.5%), and algae, zucchini, pumpkin, carrots and broccoli are sources of fiber (2.0-15%) [1, 2, 4, 6, 7, 8]. It should be noted that the algal residue is also a source of trace elements, especially iodine. The use of algal fiber can improve the rheological properties of snacks and at the same time enriches this type of product with fiber and alginate [7, 8]. Flax and chia seeds were selected as components that will contribute to the enrichment of the product not only with vegetable protein (16.0 - 22, 0%), but also PUFA \( \omega -3.6 \) (\( \omega -3: 17.0 -23.0\% \) and \( \omega -3: 5.0 -7.0\% \) per 100g of product) [9].

2.1. Mathematical data processing
Processing of experimental data and prescription optimization was carried out using mathematical statistics using Microsoft Excel 365 programs [2, 10, 11].

2.2. Technological process
In order to obtain homogeneous PPC, a three-stage cooking of raw materials in water was carried out at high temperatures (95-97 °C).

At the first stage, vegetable raw materials were cooked according to the developed recipe formulations in water (95-97 °C) for 20-25 minutes. The laying in the digester was carried out in stages according to the time of their cooking until ready. The algal residue was added at the end of the second cooking stage, due to the fact that it has a high degree of readiness and does not require a long heat treatment [15].

At the second stage, the muscle tissue of fish raw materials (pollock, cod and macrourus), crushed on a top (diameter of the holes of the lattice 3 mm), was cooked in a previously prepared plant system. The cooking process lasts 10 minutes.

The third cooking stage (5 min with constant stirring) was carried out after homogenization and addition of flax and chia seeds in a roasted and crushed form (speed - 4000 min-1, duration of the process - 10 min). After that, food additives (salt, sodium alginate) were added and the system was cooled and sent to freeze-drying, followed by the formation of snack products in the form of plates.

2.3. Determination of chemical composition
The mass fraction of water was determined by drying at a temperature of 103 ± °C to constant mass [12].

The mass fraction of ash was determined by burning the dried sample in a muffle furnace at t = 500–700 °C to constant mass [12].

The mass fraction of protein was determined according to the Kjeldahl method using an autoanalyzer of the Swedish company FOSS Analitical AB, model FOSS 2300, calculated by the total nitrogen content using a coefficient of 6.25 [13].

The mass fraction of fat was determined by the extraction method using the Soxhlet apparatus [2].

The mass fraction of carbohydrates was determined by extraction of soluble carbohydrates (sugars) from the product with distilled water at a temperature of 50-60 °C, subsequent hydrolysis of 1% sulfuric acid with easily hydrolyzable carbohydrates (starch) in the residue, sugar dehydration of the extract and hydrolyzate, staining of solutions with an anthrone reagent and photometric determination optical density of solutions [12].

The mass fraction of inulin was determined spectrophotometrically, based on the ability of sugars like fructose and sucrose to form products with maximum absorption at a wavelength of 200–380 nm when heated with concentrated acids [6].

The mass fraction of fiber was determined by the method of sequential processing of a sample of the test sample with solutions of acid and alkali, ashing and quantitative determination of the organic residue by the gravimetric method [12].

The mass fraction of iodine was determined by the titrimetric method based on the oxidation of iodide to iodate and the liberation of free iodine titrated with sodium sulfate, from which iodine content was determined by calculation by calculation [12].
The mass fraction of solids was determined by the calculation method using indicators of chemical composition [12].

The recommended daily intake of nutrients was calculated in accordance with the norms of use established in the Russian Federation [10, 11, 14].

2.4. Determination of energy value

Energy value was determined by the calculation method, using data on the chemical composition and conversion factors for protein: fat: carbohydrates 4: 9: 4 [11, 12].

2.5. Determination of amino acid and fatty acid composition

The amino acid and fatty acid composition of the product was determined by gas-liquid chromatography. Amino acid scores were determined by the calculation method using the amino acid scale and daily requirement for essential amino acids [12].

2.6. Determination of organoleptic indicators

Organoleptic indices were determined by visual, olfactory, and taste methods using verbal characterization of properties and a point scale [10, 12].

3. Results and discussion

The calculation of the mass fractions of the components included in the formulation of the homogenized PPC for snacks was carried out using mathematical modeling methods [2, 10, 11]. Table 1 presents the main criteria for calculating the recipe by the example of one homogenized PPC for high-protein freeze-dried snacks (CHD).

| Ingredients           | X     | Protein | Fat | Carbohydrate | Dietary fiber | Inulin |
|-----------------------|-------|---------|-----|--------------|---------------|--------|
| Water                 | X0    | 0       | 0   | 0            | 0             | 0      |
| Pollock               | X1    | 15.91   | 0.63| 0            | 0             | 0      |
| Jerusalem artichoke   | X2    | 1.77    | 0.23| 13.72        | 4.59          | 12.43  |
| Broccoli              | X3    | 2.67    | 0.43| 4.51         | 2.79          | 0      |
| Carrot                | X4    | 1.43    | 0.15| 7.38         | 2.63          | 0      |
| Dried dill            | X5    | 21.32   | 4.65| 43.51        | 14.03         | 0      |
| Flax seeds            | X6    | 19.09   | 40.55| 1.63        | 26.33         | 0      |
| PPC (estimated)       | 100   | 11.54   | 1.99| 2.26         | 1.55          | 0.96   |
| With the removal of 95% moisture by freeze-drying | 100 | 50.38 | 8.16| 9.45 | 6.68 | 4.58 |

Based on the information data matrix (table 1), a system of balance linear equations is compiled (table 2).

| Balance | Equations and Constraints |
|---------|--------------------------|
| In relation to 1: 1: 4 | 15.91x1 + 1.77x2 + 2.67x3 + 4.51x5 + 1.63x6 = 100 |
| Fats: Protein | 0.63x1 + 0.23x2 + 0.43x3 + 0.15x4 + 4.65x5 + 40.55x6 = 100 |
| Fats: Carbohydrates | 13.72x2 + 7.38x4 + 43.51x5 + 1.63x6 = 100 |
| For carbohydrates | 4.59x2 + 2.79x3 + 2.63x4 + 14.03x5 + 26.33x6 = 100 |
| Dietary fiber | 12.43x2 = 100 |
| Inulin | 60 < water < 70; 30 < pollock < 40; 20 < Jerusalem artichoke < 30; 5 < broccoli < 10; 1 < carrot < 5; 0.01 < dried dill < 0.05; 1 < flax seeds < 5. |
| Technological restrictions (kg) on the use | x0 + x1 + x2 + x3 + x4 + x5 + x6 = 100 |
of certain types of ingredients of the formulation

Thus, on the basis of mathematical modeling for the experimental studies, formulations of high-protein sublimated snacks (VBS) based on PPC were developed (table 3).

Table 3. Prescription composition of VBS based on PPC

| Prescription Ingredients | Component Content |
|--------------------------|-------------------|
|                          | VBS 1  | VBS 2  | VBS 3  | VBS 4  |
|                          | Mass   | Mass   | Mass   | Mass   |
|                          | g/100 g system | %     | g/100 g system | %     | g/100 g system | %     | g/100 g system | %     |
| Water                    | 65.13  | 44.65  | 78.00  | 55.58  | 60.40  | 45.88  | 40.00  | 28.47  |
| Pollock                  | 36.92  | 27.37  | -      | -      | -      | -      | -      | -      |
| Cod                      | -      | -      | 32.00  | 22.80  | -      | -      | 25.00  | 17.86  |
| Macrourus                | -      | -      | -      | 36.80  | 27.96  | -      | 50.00  | 35.71  |
| Algal residue            | 26.85  | 18.41  | -      | -      | -      | -      | -      | -      |
| Jerusalem artichoke      | -      | -      | -      | 22.00  | 15.70  | -      | -      | -      |
| Pumpkin                  | -      | -      | -      | 2.00   | 1.40   | -      | -      | -      |
| Squash                   | 6.71   | 4.60   | -      | -      | -      | -      | -      | -      |
| Broccoli                 | -      | -      | -      | 0.30   | 0.23   | -      | -      | -      |
| Celery                   | 4.03   | 2.76   | 2.80   | 2.00   | 3.80   | 2.89   | 15.00  | 10.71  |
| Spinach                  | 0.03   | 0.02   | 0.04   | 0.04   | 0.03   | 0.02   | -      | -      |
| Carrot                   | 3.01   | 2.06   | 3.20   | 2.43   | 2.94   | 2.22   | 2.80   | 2.00   |
| Dried dill               | -      | -      | -      | -      | 6.70   | 4.79   | -      | -      |
| Flax seeds               | 0.01   | 0.01   | 0.01   | 0.01   | 0.13   | 0.08   | -      | -      |
| Chia seeds               | 0.17   | 0.12   | 0.19   | 0.14   | 0.16   | 0.13   | 0.5    | 0.36   |

The development of the technology of “fast food” products based on homogenized PPC consists not only in modeling the formulation (varying the type and ratio of the main components), but also in optimizing the parameters of the main technological operations: cooking, homogenizing and drying. These operations made it possible to disperse, with different strength structures of the components of the formulation.

Based on simulated PPC prescription compositions and established rational parameters of cooking processes (process duration - 40-45 min), homogenization (speed - 4000 min⁻¹, process duration - 10 min) and drying (temperature minus 30°C and pressure 0.25 atm.) developed technology for the process of obtaining snacks based on homogenized RRS. Pilot development of the developed product was carried out and its research was carried out to determine quality indicators, as well as amino acid and fatty acid composition (tables 4-7).

Table 4. Chemical composition and energy of PFS based on PPC.

| Indicators                 | VBS 1 | VBS 2 | VBS 3 | VBS 4 | Recommended Daily Allowance | The share of the recommended daily allowance, % (in 100 finished products) |
|----------------------------|-------|-------|-------|-------|-----------------------------|-----------------------------------------------------------------------------|
| mass fraction of water,%   | 3.78±0.07 | 4.25±0.09 | 3.42±0.05 | 5.38±0.08 | -                           | -                                                                            |
Having analyzed the chemical composition of PBC based on RRS, we can conclude that all 4 types of snacks have a high protein content, varying within 30.34-56.64%, which is 37.9-70.8% of the daily norm and confirms that this type of product is high protein. The fat content in all types of snacks is more than 8.0%, which will affect the calorie content of the product. All types of snacks contain fiber from 8.73 to 13.68% (32.3-67.3% of the daily norm). VBS 1 contains inulin in the amount of 4.35%, which is associated with the introduction of Jerusalem artichoke in its formulation. Snacks of all recipes are rich in minerals, their content in samples is more than 8.5%. At the same time, VBS 4 contains in its composition iodine 0.021%, due to the use of algal residue in the formulation. The energy value of the products was 332.87-426.00 kcal.

Table 5. The content of essential amino acids (NAC) in the total VBS protein based on PPC g/100 g protein*

| Name amino acids | VBS 1 | VBS 2 | VBS 3 | VBS 4 | Data FAO / WHO |
|------------------|-------|-------|-------|-------|----------------|
|                  | A     | C     | A     | C     | A              | A | C | Essential Amino Acids (NAC) |
|                  |       |       |       |       | 0.021±0.002    |   | 150 mkg | more 100.0 |
| energy value, kcal | 335.10±5.38 | 332.87±5.21 | 352.81±5.68 | 426.00±7.68 | 2500 kcal | 13.3-18.1 |
After analyzing the fatty acid composition of the obtained WBC samples, we can conclude that there is some difference in the content of saturated and unsaturated acids in them. Moreover, the total content of polyunsaturated fatty acids prevails over the total content of saturated and monounsaturated acids, which is also explained by the high content of PUFA ω-3 (45.52-49.43%). In all WBC samples, ω-6 PUFA content ranged from 5.48 to 6.96%. The high content of PUFA in the composition of VBS lipids is explained by the use of flax and chia seeds in the prescription composition of RCC.

Table 7 presents the organoleptic characteristics of high-protein freeze-dried snacks based on fish-vegetable systems.
The obtained PPC-based snacks are porous plates with a crispy and strong structure with various shades of yellow and green. They have a pleasant, rich taste and aroma of fish and vegetable raw materials used in these formulations (table 7).

4. Conclusion

Thus, sublimated high-protein snacks based on a fish-vegetable system can be attributed to functional foods that are a source of protein (30.34-56.64%), PUFA ω-3 (45.52-49.43% of total fat acids), dietary fiber, including inulin (VBS 1 - 4.35%) and fiber (VBS 4 - 23.77%), as well as minerals, in particular iodine (VBS 4 - 0.021%), which makes it possible recommend them for use in the diets of people leading a healthy lifestyle to meet the physiological needs for nutrients.

Moreover, the use of freeze-drying in the technology of these products, according to studies [15], will allow maintaining quality indicators for a long time storage in a sealed package at uncontrolled temperatures.

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