Developing the technology of foodstuffs using ingredients rich in $\omega$-3 PUFA

V Volchenko, V Grokhovsky, A Glukharev and S Nesvyashchenko

Murmansk State Technical University, Murmansk, Russia
daesher@mail.ru

Abstract. The problems of developing functional foods enriched with $\omega$-3-polyunsaturated fatty acids are discussed in this article. Cod liver is chosen as a source of such valuable substances. The problems of processing and using the cod liver are reviewed. A method of using of microwave-cooked cod liver without sterilization as a base of a series of production is proposed. The results of experimental researches of developing and choosing an optimal composition of different products (meat and fish sausages with addition the cod liver or its oil with microwave-cooked cod liver, bakery products) are shown. The composition of frankfurters with fish mince, meat and cod liver oil has been optimized. Basic composition of frankfurters with meat, fish protein isolate (FPI), and cod liver has been chosen and then optimized both for main ingredients (meat, fish, and cod liver) and for additives (fermented rice, guar gum). The technology of bakery products using fish oil as a bakery agent (combining with glutathione from inactivated yeasts) has been developed. The characteristics of the gluten with such bakery agents has been studied. Test bakings have been carried out for such bread with addition of algae, bran, and milk thistle. All samples have been evaluated for sensory and structural characteristics.

1. Introduction.

A codfish is one of the main commercial fish of the Northern basin and one of the most important natural resources of the Arctic region. Catch and processing of cod on an industrial scale makes a significant contribution to the economy of the Northern region. Two priority areas can be identified for ensuring sustainable development of the Arctic region. In economic sphere, the most needed are strengthening of coherency and reliability of the transportation system, energy supplies to distant consumers, and stimulating of investment and industrial activities of the industrial enterprises. In social (socio-economic) sphere, it is necessary to maintain and improve the public health [1]. The potential increase in the share of fish and fish product’s consumption (in particular, cod, cod liver oil and oil-containing products) can have a positive impact on the health of the population of the Arctic zone of the Russian Federation.

One of the important problems of developing functional foods is improving the fatty component of foodstuffs adding polyunsaturated fatty acids (PUFA), especially $\omega$-3 [2]. $\omega$-3 PUFA have a very high nutritional value, therapeutic and prophylactic action against a series of diseases, especially against cardio-vascular diseases [3]. Fish [4] and seafoods [5] are traditional and very common source of $\omega$-3 PUFA.
It is reasonable to point out the liver of Gadidae family fishes among these kinds of raw materials. By the way, traditional methods of cod liver processing have some disadvantages. Firstly, it is very difficult to use frozen cod liver for producing high quality foods. Secondly, using very fatty liver, and frozen raw material for canned foods results in high amount of free oil in the can [6]. Authors propose not to use raw cod liver for producing foodstuffs, but to use semi-finished product of cod liver which is microwave processed. It is also possible to use fish oil separated during such processing.

One of the ways of cod liver processing is producing the sterilized canned foods, but this method is not the only possible way. The direct addition of microwave-cooked cod liver and extracted oil might be of a special interest for producing a series of the combined foodstuffs (including culinary) which are analogues of traditional foods, for example, sausages. Using fish raw material in the technology of sausages is not a brand-new method, but it seems to be quite prospective. Unlike traditional meat sausages, meat and fish products make it possible to use highly valuable fish raw materials, and compared to fish products they have more traditional sensory characteristics [7].

Another direction of researches includes using cod liver oil as a bakery agent. The quality of final product is highly dependent on the quality of the main raw material – wheat flour, which properties are not always constant. The bakery agents are needed for providing define characteristics (rheological, colloidal, sensory) to the dough and bakery production. They make possible to produce the bread and bakery products of a stable quality even in case of instable quality of the flour. One of the wide spread groups of bakery agents includes agents of oxidative and reductive actions. Fats and oils including extracted fish oil are agents of oxidative action. The complex usage of both oxidative and reductive agents is practiced for making the best technological effect [8].

The glutathione has been chosen as a reductive agent. It is a tripeptide containing cysteine residue with –SH group. It can break disulfide bonds in the gluten molecule, changing the structural and mechanical characteristics of the dough. The yeasts can be used as the source of glutathione. It is also reasonable to use accelerated kneading of the dough and to reduce the time of dough fermentation [9]. The inactivated yeast cells have been used as a source of glutathione.

2. Materials and methods
2.1. Materials
The chilled liver of Atlantic cod (Gadus morhua), shipped by fishing companies (Sevros LLC and Bionord LLC, Murmansk, Russia) all the year round, and was used as the source of ω-3 PUFA. The cod liver was preliminary cooked using microwave heating followed by freezing and storing at the temperature minus 18 °C. Fish oil extracted during microwave treatment was purified by sedimentation and decantation methods. These semi-finished products have been used for producing the new kinds of foodstuffs. Other raw materials (meat, salt, spices etc.) have been obtained from the local market.

Fish protein isolate (FPI) was produced using the method of dissolving of muscle tissue of fish raw material in the alkaline medium followed by the protein sedimentation at the isoelectric point (slightly acidic medium) [10]. Blue whiting was used as a fish raw material.

2.2. Experimental and data processing methods
The Kjeldahl method [11] is using Selecta Bloc Digest and Selecta Pro-Nitro modules (Spain). The obtained nitrogen content was recalculated to the raw protein (P) using the following formula:

\[ P = N \times K_p \]  

where: \( N \) – total nitrogen content; \( K_p \) – recalculation coefficient.

The lipid content in the samples of raw material, FPI and foodstuffs produced from them (canned foods) was determined using extractor Selecta DET/GRAS (Spain) by the Soxhlet method.

Fatty acids composition of lipids was determined using the high-performance liquid chromatography method (HPLC) with Agilent 1100 (USA) after saponification of lipids with alcohol
solution of 2 N KOH and pre-column derivatization with bromophenacyl bromide and triethylamine [12].

The penetration strength was used for estimating the structural and mechanical characteristics. Food Checker (Japan) with spherical indenter (diameter 8 mm) immersing at the depth of 10 mm at the constant speed and at the temperature of 20 °C was used to obtain this characteristic.

Acid number of the oil was determined after oil extraction using the mixture of chloroform and ethyl alcohol by titration with 0.1 M sodium hydroxide with phenolphthalein. Peroxide number of the oil was determined by titration of iodine displaced from potassium iodide by peroxides and hydroperoxides with sodium thiosulfate [13].

Sensory methods have been carried out using estimation scales [14]. The generalized sensory score (%) has been calculated by this method.

Determining of water and fat holding capacity, and stability of mince emulsion has been carried out using Salavatulina method which includes determining the losses of water and fat, and also the emulsion characteristics after heating the mince in the can [15].

The porosity of bakery products has been determined using Zhuravlyov device, water content has been found using drying, and raw gluten quantity has been determined after washing the dough ball [16].

Methods of experimental design (in particular, central composite rotatable design) have been used in this research. Choosing and evaluating the regression equation, and regression analysis at whole have been carried out using Oakdale Datafit 9.1.

3. Results and discussion
3.1. Using FPI and microwave-cooked cod liver in the technology of meat and fish sausages

Producing meat and fish sausages may be one of the directions of using of semi-finished cod liver. Two variants of the composition have been used for studies of meat and fish products. First composition includes meat, chicken egg yolk, starch, tomato paste, spices, washed and dried fish mince, and cod liver oil. Second composition in addition to the first one includes FPI from blue whiting, and microwave-cooked cod liver.

The problem is it is not possible to estimate the optimality of the texture by the penetration strength: the same inacceptable would be both extremely hard texture of the product and extremely soft, spreadable product (if it is not a paste). So, experiments have been directed to find a regression dependency of texture estimation (acceptability) on the penetration strength. The first series of experiments have been carried out to develop the technology of analogues of frankfurters colored by adding the tomato paste and acidity regulation. The regression equation is the followed:

\[ Y = a + b \cdot X^2 + c \cdot X^3 \]  

where \( a = 2.260, b = 5.174 \cdot 10^{-3}, c = -9.547 \cdot 10^{-5} \) – regression coefficients;

\( X \) – penetration strength, kPa;

\( Y \) – texture estimation (from 0 to 5, higher is better).

So, it is not difficult to calculate an optimal value of penetration strength which is of 36.1 kPa.

According to this result, using the relative structural and mechanical characteristic (\( Y_{RI} \), %) was proposed. It can be calculated by the followed equation:

\[ Y_{RI} = \exp\left(-\frac{Y_f - Y_{opt}}{\Delta Y_f}\right) \]  

where \( Y_f \) – penetration strength, kPa;

\( Y_{opt} \) – optimal penetration strength, kPa (36.1);

\( \Delta Y_f \) – critical growth of penetration strength; this or higher growth of this parameter results in significant changing the texture, kPa (4).

This characteristic will be changed in the range from 0 (worst) to 100 (best), so, it is possible to join it with the generalized sensory score.
The generalized quality level has been calculated by the followed equation

\[ Y_0 = Y_R \cdot K_f + q \cdot K_2 \]  \hspace{1cm} (4)

where \( K_f \) and \( K_2 \) – significance coefficients (0.3 and 0.7);

\( q \) – generalized sensory score, %.

The central composition rotatable design has been used for providing the followed studies. Factors are: \( X_1 \) – meat to fish ratio, \( X_2 \) – quantity of cod liver oil added. The results are shown in Table 1.

**Table 1. Experimental design and results of producing analogue frankfurters with cod liver oil**

| Meat to fish ratio \( (X_1) \) | Quantity of cod liver oil added \( (X_2) \) | Relative structural and mechanical characteristic, % \( (Y_{X1}) \) | Generalized sensory score \( q \), % | Generalized quality level \( Y_0 \), % |
|---|---|---|---|---|
| 2 | 7 | 95.7 | 83 | 86.8 |
| 6 | 7 | 91.7 | 89.8 | 90.4 |
| 2 | 13 | 50.1 | 88.8 | 77.2 |
| 6 | 13 | 46.3 | 86.6 | 74.5 |
| 1.72 | 10 | 78.7 | 84 | 82.4 |
| 6.83 | 10 | 17.5 | 85.5 | 65.1 |
| 4 | 14.24 | 35.1 | 83.3 | 68.8 |
| 4 | 5.76 | 0.000433 | 71 | 49.7 |
| 4 | 10 | 0.000220 | 71.75 | 50.2 |

The response surface is shown at the Figure 1.

The regression equation is followed:

\[ Y_0 = a + \frac{b}{X_1} + \frac{c}{X_1^2} + \frac{d}{X_2} + \frac{e}{X_2^2} + \frac{f}{X_2^3} \]  \hspace{1cm} (5)

where \( a = 690.7; b = -414.9; c = 623.4; d = -15473; e = 133860; f = -367760 \)

The regression equation doesn’t make it possible to find an optimum at the factors changing range, but it can be noted that going outside this range is very undesirable due to coming to another assortment group. Thus, the specimen no.2 has been chosen to be a near-to-optimal point. It has been evaluated for different characteristics shown in Table 2.

According to the second way of experiment, the formulation included non-fatty pork, microwave-cooked cod liver, FPI, eggs, potato starch, salt, spices and some other additional ingredients. It was reasonable to balance both basic and additional ingredients.

**Figure 1. Response surface of an experiment of producing analogue frankfurters with cod liver oil**

**Table 2. Result of evaluation of the chosen specimen**

| Characteristic | Results, % |
|---|---|
| Lipid content | 15.5 |
| Protein content | 14 |
| Water content | 59 |
| Mineral (ash) content | 3.5 |
| Generalized sensory score | 89.8 |
The following optimization parameters have been chosen for basic ingredients optimizing: 
generalized sensory score of the product, %; penetration strength, kPa; raw material composition costs, 
P/kg. Authors have chosen the following factors most significant influencing the quality of the 
resultant product: non-fatty pork to microwave-cooked cod liver ratio (X1); FPI dosage, kg (X2). 

The generalized numeric quality characteristic of the meat and fish frankfurters has been composed 
to be a response. It includes generalized sensory score (Y1), value of the relative structural and 
mechanical characteristic Y_{R2}, and relative raw material cost Y_{C3}. Response Y_0 can be calculated 
according to the following equation:

\[ Y_0 = Y_1 \cdot K_1 + Y_{R2} \cdot K_2 + Y_{C3} \cdot K_3 \] (6)

where \( Y_1 \) – generalized sensory score, %; \( Y_{R2} \) – the relative structural and mechanical characteristic, 
%, \( Y_{C3} \) – relative raw material cost, %; 
\( K_1, K_2, K_3 \) – significance coefficients determined by expert method.

The most significant parameter was considered to be the generalized sensory score (\( K_1 = 0.45 \)); other 
parameters considered to be less significant (\( K_2 = 0.37; K_3 = 0.18 \)).

The relative structural and mechanical characteristic \( Y_{R2} \), %, was calculated according to following 
equation in this series of experiments:

\[ Y_{R2} = 100 - \frac{y_2 - y_{2opt}}{y_{2opt}} \cdot 100 \] (7)

where \( y_2 \) – penetration strength, kPa; \( y_{2opt} \) – optimal value of the penetration strength, kPa.

As it was done in previous series of experiments, the optimal value of the penetration strength was 
determined by using the regression method; the followed equation has been found:

\[ Y = -1.88 \cdot 10^{-12} \cdot x^3 + 2.78 \cdot 10^{-7} \cdot x^2 - 1.34 \cdot 10^{-2} \cdot x + 216.35 \] (8)

F-ratio is 5.46 which means the adequacy of the regression equation with the confidence level of 0.95. Analysis of the regression equation made it possible to determine an optimal value of penetration 
strength which is 56.62 kPa.

Relative raw material costs \( Y_3 \) (%) is calculated according the following equation:

\[ Y_{C3} = \frac{300}{y_3} \] (9)

where \( y_3 \) – cost of all raw materials needed to produce 1 kg of finished product, P; 
300 – practically minimal possible cost of raw materials for 1 kg of product, P.

The central composite rotatable design for optimizing the composition of meat and fish frankfurters 
has been developed using experimental design theory, it is shown in Table 3.

| № | \( X_1 \) | \( X_2 \) | \( Y_1 \) | \( y_2 \) | \( y_3 \) | \% | \( Y_{C3} \) | \% | \( Y_3 \) | \% |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.00 | 2.00 | 79.38 | 29274.53 | 339.28 | 51.70 | 88.42 | 70.70 |
| 2 | 2.00 | 4.00 | 80.52 | 57085.34 | 352.48 | 99.18 | 85.11 | 88.31 |
| 3 | 3.00 | 2.00 | 82.50 | 48790.89 | 350.70 | 86.17 | 85.54 | 84.42 |
| 4 | 3.00 | 4.00 | 87.50 | 49766.70 | 363.61 | 87.90 | 82.50 | 86.74 |
| 5 | 2.51 | 3.00 | 85.00 | 33665.71 | 352.37 | 59.46 | 85.14 | 75.50 |
| 6 | 1.80 | 3.00 | 85.63 | 29762.44 | 342.66 | 52.57 | 87.55 | 73.65 |
| 7 | 3.20 | 3.00 | 90.73 | 32689.89 | 358.80 | 57.74 | 83.61 | 77.14 |
| 8 | 2.51 | 1.60 | 88.54 | 32201.99 | 343.63 | 56.88 | 87.30 | 76.51 |
| 9 | 2.51 | 4.40 | 84.58 | 39032.71 | 361.49 | 68.94 | 82.99 | 78.46 |
| 10 | 3.20 | 4.40 | 83.65 | 37681.81 | 363.84 | 63.84 | 81.56 | 75.89 |
| 11 | 2.75 | 3.00 | 79.90 | 35490.90 | 354.90 | 94.79 | 84.53 | 86.29 |
| 12 | 2.25 | 1.60 | 83.23 | 45.86 | 345.82 | 81.00 | 86.75 | 83.04 |
where recalculated, other parameters have been recalculated to the same range according to (7).

The guar gum has been used to provide the most acceptable structural and mechanical characteristics of the product. It was also decided to drop using tomato paste as a coloring agent and use fermented rice to provide slightly pink color of the product.

F-ratio for this equation is 9.77, the probability of inadequacy is 0.096. This model is quite complex, and includes subjective sensory parameter (which is mostly significant according to experts’ estimations), so confidence level more than 0.9 is not needed and expected. All regression coefficients are significant at the confidence level of not less than 0.95. The response surface which make it possible to analyse factor influence on the generalized quality level is shown at Figure 2.

Optimal factors values are the followed: \( X_1 \) (pork mince to microwave cooked liver ratio) is 2.73; \( X_2 \) (FPI dosage) is 2.09.

In addition to balancing the main ingredients of sausage product, it is important to determine the dosage of additional ingredients which can influence on the yield of the finished product, on structural and mechanical characteristics, on color. So, the next stage of developing the composition of meat and fish product was an optimization of additional ingredients.

The guar gum has been used to provide the most acceptable structural and mechanical characteristics of the product. It was also decided to drop using tomato paste as a coloring agent and use fermented rice to provide slightly pink color of the product.

Objective characteristic of the color of finished product is its additive color model (RGB). Using this model instead of sensory color determination increases the accuracy of the experiment. But the RGB model includes 3 parameters changing it the range from 0 to 255, so it is reasonable to determine summary square deviation from optimal reference. The consequent sampling of colors has been made, and the most acceptable colors for frankfurters have been determined using expert method. The results show that an optimal RGB color is 248.170.168.

So, it is possible to develop the central composition design of two-factor experiment. Generalized optimization parameter includes 5 single parameters: \( Y_1 \) – water holding capacity; \( Y_2 \) – fat holding capacity; \( Y_3 \) – emulsion stability; \( Y_{R4} \) – relative structural and mechanical characteristic calculated according to (7); \( Y_5 \) – deviation from optimal color calculating according to the following equation

\[
Y_5 = 100 - \frac{\sum_{i=1}^{2}\left(X_{ij} - X_{ij, opt}\right)^2}{R^2 + G^2 + B^2}
\]

Parameters \( Y_1 \) - \( Y_3 \) are percentage, and they need to be maximized, so they do not need recalculated, other parameters have been recalculated to the same range.

Generalized optimization parameter is calculated by the equation:

\[
Y_0 = Y_1 \cdot K_1 + Y_2 \cdot K_2 + Y_3 \cdot K_3 + Y_{R4} \cdot K_4 + Y_5 \cdot K_5
\]

where \( K_1, K_2, K_3, K_4, K_5 \) - significance coefficients, they are 0.2; 0.2; 0.1; 0.1; 0.4 respectively.

The design and results of two-factor experiment are shown in Table 4.
Table 4. Design and results of experiment for additional ingredients balancing

| No | $X_1$, kg | $X_2$, kg | $Y_1$, % | $Y_2$, % | $Y_3$, % | $Y_{res}$, % | $Y_5$, % | $Y_6$, % |
|----|----------|----------|--------|--------|--------|------------|--------|--------|
| 1  | 0.2      | 0.1      | 60.73  | 12.19  | 97.63  | 95.65      | 83.99  | 67.51  |
| 2  | 0.2      | 0.5      | 60.64  | 12.40  | 97.41  | 97.81      | 79.49  | 65.93  |
| 3  | 0.4      | 0.1      | 61.64  | 14.46  | 97.49  | 94.44      | 84.33  | 68.14  |
| 4  | 0.4      | 0.5      | 59.96  | 14.14  | 97.18  | 91.99      | 80.75  | 66.04  |
| 5  | 0.3      | 0.3      | 60.84  | 13.62  | 97.60  | 98.31      | 83.25  | 67.78  |
| 6  | 0.16     | 0.3      | 60.50  | 13.29  | 97.46  | 95.94      | 85.06  | 68.12  |
| 7  | 0.44     | 0.3      | 63.57  | 12.97  | 97.98  | 89.70      | 85.33  | 68.21  |
| 8  | 0.3      | 0.02     | 61.84  | 12.37  | 97.59  | 99.00      | 80.32  | 66.63  |
| 9  | 0.3      | 0.58     | 61.76  | 13.18  | 97.63  | 98.66      | 78.46  | 66.00  |
| 10 | 0        | 0        | 57.27  | 11.12  | 96.13  | 92.78      | 79.01  | 64.17  |

Data processing results in the following regression equation:

$$Y = 64.31 + 14.59 \cdot X_1 - 21.82 \cdot X_1^2 + 13.30 \cdot X_2 - 26.81 \cdot X_2^2$$  \hspace{1cm} (13)

F-ratio for this equation is 11.12, inadequacy probability is 0.01. All regression coefficients are significant at the confidence level not less than 0.99. The response surface is shown at Figure 3.

Using differential method, the local maximum has been found. Optimal factors values are $X_1 = 0.33$, $X_2 = 0.25$.

The optimal composition of meat and fish frankfurters is shown in Table 5.

The physical and chemical experiments have been carried out to prove the functional properties of finished products. The results are shown in Table 6.

Thus, due to additives the monounsaturated acids are dominated in the frankfurters, moreover, a large amount of $\omega$-3 PUFA present there. Low amount of $\omega$-6 PUFA can be compensated by vegetable oils.

Figure 3. Response surface for additional ingredients balancing

Table 5. Optimal composition of meat and fish frankfurters using basic and additional ingredients

| Basic raw materials, kg | Spices and materials, kg |
|------------------------|--------------------------|
| Non-fatty trimmed pork | 70.20                    |
| Microwave-cooked cod liver | 25.71                |
| FPI from blue whiting  | 2.09                     |
| Chicken eggs           | 2.00                     |
| Potato starch          | 3.00                     |
| Common salt            | 2.50                     |
| Sugar                  | 0.10                     |
| White pepper (grounded)| 0.25                     |
| Black pepper (grounded)| 0.25                     |
| Fermented rice         | 0.25                     |
| Guar gum               | 0.33                     |
| Ice and water mixture  | 15.00                    |

Table 6. Results of physical and chemical experiments of meat and fish frankfurters.

| Property                  | Result   |
|---------------------------|----------|
| Water content, %          | 63.36    |
| Protein content, %        | 16.14    |
| Lipid content, %          | 15.85    |
| Sodium content, %         | 2.52     |
| Mineral (ash) content, %  | 2.82     |
| Acid number of the lipids, mg KOH/g | 2.09 |
| Penetration strength, kPa | 59.33    |
Results of table 6 prove the high content of saturated and monounsaturated fatty acids. It could also be said that ω-3 PUFA are dominated among the total PUFA content.

3.2. Producing bakery products using cod liver oil

In this article, marketing research was conducted using a questionnaire to determine the most preferred types of bakery products and the types of the most desirable additives. Survey results showed that consumers prefer traditional types of bread: shaped (baked in the form) and hearth almost equally. The analysis showed that algae (kelp) (68% of the total number of respondents) and additives based on fish lipids (27% of the total number of respondents) were chosen among the additives of marine hydrobionts for including in the bread recipe. Also consumers elect the addition of grain and seeds, for example, oat grains, flax seeds, sunflower seeds (73% of the total number of respondents), and dietary fiber, for example, bran (56% of the total number of respondents).

The studies of using the cod liver oil during producing white bread have been carried out. The series of experiments of baking the specimens of bread with the addition of cod liver oil and glutathione have been provided. The best characteristics have been obtained while using the oil dosage of 1 % to flour mass. Table 7 shows the results of studying the gluten characteristics, and Table 8 shows the properties of specimens of finished product.

| No | Ingredients | Raw gluten, g | Raw gluten yield, % | Gluten color | Elasticity | Extensibility, L, cm |
|----|-------------|---------------|---------------------|--------------|------------|---------------------|
| 1  | Reference. Flour+water | 9.2 | 24.2 | Light | elastic | 18 |
| 2  | Flour +water+cod liver oil (1%) | 9.05 | 23.7 | Light | elastic | 10 |
| 3  | Flour+ water+cod liver oil (1%) + inactivated yeast | 10.07 | 26.2 | Light | elastic | 16 |

| Specimen | Oil dosage, % | Fish oil odor intensity ** | Generalized sensory score, % |
|----------|---------------|---------------------------|----------------------------|
| 1        | 0             | 0.25                      | 67.1                       |
| 2        | 1             | 0.94                      | 96.6                       |
| 3        | 1.5           | 1.69                      | 84.4                       |
| 4        | 2             | 4.06                      | 84.2                       |

*– % to flour mass

**– Fish oil odor intensity has been estimated according to the following scale:

0 – absent
1 – hardly perceptible, positive or neutral
2 – weak, positive or neutral
3 – weak, negative
4 – medium, negative
5 – strong, negative

The average result is shown in the table.

Thus, the most acceptable fish oil dosage is 1-1.5 %.

The compositions of bakery products from wheat flour with the addition of algæ, bran, and milk thistle have been developed to expend the assortment of bakery products. The bran is a rich source of dietary fibers which helps to regulate the work of intestine. Algæ is a source of iodine, it also contains natural sorbents (alginates) and sterols which can make a positive effect on human organism. Milk thistle have both dietary fibers and flavonolignans.

The specimens of wheat bread with such additives have been prepared and evaluated; the results are shown in Table 9.

| Characteristic                  | Wheat bread with cod liver oil and inactivated yeast | Wheat bread with cod liver oil, inactivated yeast, and algæ | Wheat bread with cod liver oil, inactivated yeast, and bran | Wheat bread with cod liver oil, inactivated yeast, and milk thistle |
|--------------------------------|-----------------------------------------------------|------------------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------------------|
| Water content, %               | 33.0                                                | 33.5                                                      | 32.0                                                    | 32.0                                                                |
| Porosity, %                    | 76.0                                                | 63.0                                                      | 61.0                                                    | 67.0                                                                |
| Acidity, degrees               | 3.0                                                 | 2.9                                                       | 3.3                                                     | 3.1                                                                 |
| Generalized sensory score, %   | 93.0                                                | 92.3                                                      | 87.2                                                    | 84.0                                                                |

So, quite high quality of the product can be achieved using algæ addition. Using bran also makes it possible to obtain qualitative product.

This technology is patented (RU2579362 and RU2579363).

4. Conclusions

The technology of processing meat and fish frankfurters with FPI and microwave-cooked cod liver is developed; optimal composition is found and proved. Experimental samples are studied.

The relevance of improving the technology of sausage products directed to producing qualitative meat product with enhanced food and nutritional value is proved. A special attention has been paid to the coloring process. It was decided to drop the doubtful traditional ingredient like sodium nitrite and phosphates.

The sensory evaluation of frankfurters has been carried out, the total chemical composition and penetration strength has been determined. The food and nutrition values have been measured. It was proved that frankfurters with cod liver and FPI are rich in ω-3 PUFA.

Using the combination of cod liver oil and glutathione as bakery agents has been proved to enhance both structural and mechanical, and sensory characteristics of bakery products. Adding such components as algæ, bran, and milk thistle could in several ways increase the nutritive value of the product and satisfy consumer demand for bread products with natural additives.

5. Acknowledgements

This work was carried out with the help of the Russian Science Foundation, project 16-16-00076.

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