Development of a fish loaf technology for dietary purposes

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Abstract. The work studied the effect of two polysaccharides (PS), xanthan and guaran, on the quality of fish loaves. Optimal concentrations of the polysaccharides (0.1% and 0.3%, respectively) were selected on the basis of sensory analysis. In the process of our research, a positive effect of all the studied PS on the quality of fish loaves was revealed, namely: the dry matter content increased by an average of 6.7%, the acidity decreased by an average of 20.55%, and a decrease in the fat weight fraction by an average of 15.35% was observed as compared with the reference sample. The addition of the polysaccharides was found to have a positive effect on taste, to reduce the growth of mesophilic aerobic and facultative anaerobic microorganisms, as well as bacteria of the Escherichia coli group and to contribute to an increased shelf life. The addition of PS reduced the prime cost of the samples under study by an average of 3.9%. As a result of our sensory analysis, physicochemical and microbiological studies, guaran in a concentration of 0.3% was recommended as a food additive to fish loaves.

1. Introduction

People have always thought about healthy eating. Even in ancient times, the famous physician Hippocrates said: “Let food be thy medicine and medicine be thy food,” it is a simple truth that means that food is, in fact, the best medicine, as well as the enemy of human health. That is why many progressive states of the world have long been concerned about nutritional problems. Scientists from many countries have come to the conclusion that the daily use of food products which suit the body’s differentiated needs for nutrients and energy (depending on the age, sex and physical activity of a person) and have beneficial properties, could prevent the development of various kinds of diseases or reduce their clinical manifestation in adulthood.

According to the modern concept of healthy nutrition, formulated in the Russian Federation (October 25, 2010), food products should not only satisfy the human body’s needs for basic nutrients and energy, but also provide it with all the necessary spectrum of macro-ingredients and micro-ingredients, contributing to the prevention of alimentary-dependent diseases. At the same time, food should be various, tasty and, of course, safe. It should also correspond to national traditions and habits. According to experts from the Institute of Nutrition of the Russian Academy of Sciences, a distinctive feature of food products of the 21st century is a set of criteria “health” and “taste” [1].

This concept is reflected in the development of a new Foodnet market within the national technology initiative, whose goal is to create by 2035 “smart” services and products that will become leaders in
world markets through the best technological solutions for human food security. The share of Russian companies developing such services and products in the future will reach from 5% to 15% of the world market [2].

As a result of the above, the development of a technology for dietary fish loaves is an urgent task. The aim of the study was to develop a technology for dietary fish loaves.

To achieve this aim, the following tasks were set:

- to study the physical and chemical characteristics of fish loaves;
- to evaluate the nutritional and energy value of fish loaves;
- to estimate the biological value of fish loaves;
- to explore the structural and mechanical characteristics of fish loaves;
- to reveal the microflora of fish loaves; and
- to assess the economic efficiency of fish loaves.

2. Materials and methods

The object of our study was fish loaves prepared according to the recipe from Ref. [3].

Polysaccharides (PS) were also used, namely: xanthan (Deosen, China) and guaran (Guarsar, India).

Sampling for organoleptic analysis was carried out in accordance with GOST No. 31986-2012 “Catering services. The method of organoleptic assessment of the quality of public catering products” on a five-point scale [4, 5].

The weight fraction of fat was measured by the accelerated extraction–weight method according to GOST 23042-86 “Meat and meat products. Fat analysis methods” [6–9].

The weight fraction of dry substances was estimated in a Chizhov apparatus at a temperature of 152–154°C for seven min in accordance with GOST R 54607.2-2012 [7–9].

Total acidity was measured by titration in accordance with the guidelines for laboratory quality control of public catering products [8, 9].

The number of mesophilic aerobic and facultative anaerobic microorganisms (MAFAM) was evaluated in accordance with GOST 10444.15-94 “Food products. Methods for counting mesophilic aerobic and facultative anaerobic microorganisms” [10].

The presence of coliform bacteria was detected according to GOST 31747-2012 “Food products. Methods for detecting and counting bacteria of the E. coli group (coliform bacteria)” [11, 13].

The presence of yeast and molds was detected according to GOST 10444.12-2013 “Microbiology of food and animal feed. Methods for detecting and counting yeast and molds” [12, 13].

Research was carried out at the chairs “Food Technologies” and “Microbiology, Biotechnology and Chemistry.”

Research results were statistically processed using Microsoft Office Excel 2007 and MathCAD 14 [14].

3. Results and discussion

When developing fish loaves for dietary use, a reference sample recipe was taken from the recipe collection for students of all educational institutions [3], where butter was replaced by the polysaccharides (PS) xanthan and guaran in concentrations from 0.1 to 1.0%.

It is known from the literature that these gums have a number of features and advantages, namely, a wide viscosity range, high thermal stability, lack of syneresis, antioxidant effect, real origin, economic efficiency, and the possibility of using in dietary nutrition [15].

In the course of our work, samples 1.1–1.10 of fish loaves with the addition of xanthan in concentrations of 0.1–1.0% and samples 2.1–2.10 of fish loaves with the addition of guaran in concentrations of 0.1–1.0% were prepared and studied.

Figure 1 shows that, as a result of our organoleptic analysis, the best concentration was 0.1% (34 points) and 0.3% (35 points) for the samples of group 1 and group 2, respectively.
Figure 1. Organoleptic analysis of the studied samples of fish loaves.

As a result of our sensory evaluation, samples from groups 1.1 and 2.3 with the best organoleptic properties were selected for further physicochemical studies (table 1).

Table 1. Physicochemical indicators of the studied samples.

| Indicator                      | Reference sample | Test samples          |
|-------------------------------|------------------|-----------------------|
|                               |                  | group 1.1             |
|                               |                  | 0.1 % xanthan         |
|                               |                  | group 2.3             |
|                               |                  | 0.3 % guaran          |
| Dry matter content, %        | 54.55±0.01       | 58.66±0.05            |
| Weight fraction of fat, %    | 7.50±0.05        | 6.70±0.02             |
| Acidity, deg.                | 2.26±0.02        | 1.74±0.01             |

From table 1 it can be seen that the dry matter content in the test samples increased in comparison with the reference sample by an average of 6.7%. Possibly, this increase was influenced by the addition of the polysaccharide, as well as its nature. In addition, the changes we made to the recipe of the dish (butter replacement with PS) reduced the weight fraction of fat by an average of 15.35% as compared to the reference. Also from table 1 it can be seen that the acidity of the test samples decreased by an average of 20.55%. The decrease in acidity in the test samples is due to the decrease in the butter content, as well as to the properties of PS to influence the pH level of the product [16].

Using the data given in the reference book “Chemical composition and calorie content of Russian food products” [17], we calculated the nutritional and energy value of the products under study, which are presented in table 2.

Table 2. Nutritional and energy value of fish loaves.

| Indicator         | Reference sample | Test samples          |
|-------------------|------------------|-----------------------|
|                   |                  | group 1.1             |
|                   |                  | 0.1 % xanthan         |
|                   |                  | group 2.3             |
|                   |                  | 0.3 % guaran          |
| Proteins, g       | 16.010           | 15.980                |
| Fat, g            | 4.090            | 1.700                 |
| Carbohydrates, g  | 7.700            | 7.660                 |
| **Dietary fiber, g** | 0.350        | 0.450                 |
| Retinol, mcg      | 38.30            | 30.300                |
| Thiamine, mg      | 0.199            | 0.196                 |
| Riboflavin, mg    | 0.214            | 0.201                 |
| Niacin, mg        | 3.101            | 3.092                 |
As can be seen from table 2, the addition of PS to fish loaves did not have a significant effect on the protein content (decreased by 0.2%) and the content of carbohydrates (decreased by 0.5%). At the same time, replacing butter with PS reduced the total fat content and calorie content significantly – by 58.4 and 15.5%, respectively. The content of dietary fiber increased in sample 1 by 28.6% and in sample 2 by 85.7%. In addition, due to our changes in the food composition, there was also a slight decrease in the content of vitamins and minerals (by 4.8% on average).

For animal products, their biological value, namely, the amino acid composition, is an important indicator. The biological value is understood as the degree of food nitrogen retention in the body or the efficiency of its utilization to maintain nitrogen balance in adults, which depends on the amino acid composition of a particular protein and its structural features. Proteins with high contents of essential amino acids are considered particularly nutritious in terms of nutritional physiology. To assess the balance of the amino acid composition of our fish loaves, we used N.N. Lipatov’s technique (1987). It provides for the calculation of a set of indicators, namely, the minimum amino acid score, the difference coefficient of amino acid scores, the biological value of the food product, and the utilitarian coefficient [18].

Table 3. Indicators of the amino acid composition of proteins.

| Amino acid | Protein content, mg/g | Amino acid score, % | Difference coefficient between amino acid scores, % | Biological value of food protein, % | Limiting amino acid | Utilitarian coefficient, fractions of unit |
|------------|-----------------------|--------------------|-----------------------------------------------|---------------------------------|------------------|---------------------------------|
|            | Standard | Test  |            |                                      |                          |                  |                                  |
| Valine     | 50       | 71.35 | 142.70     | -                                 | -                | -     |                                |
| Isoleucine | 40       | 69.64 | 174.10     | -                                 | -                | -     |                                |
| Leucine    | 70       | 104.91| 149.90     | -                                 | -                | -     |                                |
| Lysine     | 55       | 113.80| 206.90     | -                                 | -                | -     |                                |
| Methionine + Cysteine | 70       | -     | -          | 30                               | Leucine | 104.01 | 0.83                              |
| Threonine  | 40       | 65.72 | 164.30     | Valine 71.35                     | -                | -     |                                |
| Tryptophan | 10       | 16.78 | 167.80     | -                                 | -                | -     |                                |
| Phenylalanine + Tyrosine | 60       | 112.39| 187.30     | -                                 | -                | -     |                                |
| Total      | 360      | 620.6 | -          | -                                 | -                | -     |                                |

Our calculation of the amino acid score (AAS) is based on a comparison of the amino acid composition of the protein of food products with the amino acid composition of the standard (“ideal”) protein. The standard protein reflects the composition of a hypothetical protein of high nutritional value, ideally satisfying the body’s physiological need for essential amino acids. The amino acid composition of such a protein was proposed by the FAO/WHO Committee in 1985 and shows the content of each essential amino acid (EAA) in 1 g of protein [19–22].

The results of our calculation of amino acid scores of essential amino acids in the products studied are presented in table 3. As can be seen from it, the minimum amino acid score is observed for valine...
(142.7%), therefore, it is the main (first) limiting amino acid of the test product. The second limiting acid is leucine (149.9%). These EAA data are responsible for the coordination of human movements, as well as for the full functioning of the thyroid gland and kidneys.

The difference coefficient of amino acid scores (DCAAS) shows the excess amount of essential amino acids not used for plastic needs. It is known from the literature that the lower the DCAAS value, the higher the quality of the protein under study [23]. In the course of our research, the difference coefficient of amino acid scores was 30% and the biological value of food protein was 70%, which indicates the high quality of our finished product.

The utilitarian coefficient (U) is an indicator to characterize a protein in terms of the degree of its assimilation, consumption with benefit; it considers the balance of the amino acid composition not only in the limiting amino acids, but also in their excess [23]. Therefore, as can be seen from table 3, the utilitarian coefficient is 0.83, which indicates a high degree of digestibility of the proteins in the test product.

Thus, as a result of our calculations, it has been established that the tested product is balanced in terms of the EAA content. These calculations were carried out ignoring heat treatment losses, which may amount to 14% [17], which, in general, would insignificantly affect the content of essential amino acids. Compared to the standard, the content of essential amino acids in the dish under study before heat treatment is higher by 70%, and after heat treatment it will be higher by 56%.

Figure 2. Volumetric mass of the tested fish loaves with reduced calorie content.

Figure 2 shows that the sample of group 1 has a slight decrease in its volumetric weight relative to the reference one. Also, during our study, we noted that the sample of group 2 had the lowest volumetric mass in comparison with the reference one. In addition, we observed the same effect of PS after heat treatment also. These changes are possible due to the nature of the polysaccharides introduced into the product.

Figure 3. Height of the test fish loaves with reduced calorie content. Note: a – reference sample; b – sample No. 1 with the addition of xanthan at a concentration of 0.1%; c – sample No. 2 with the addition of guaran at a concentration of 0.3%.
Figure 3 shows that the height of the studied samples of groups of 1.2 is less by 4 mm and 3 mm in comparison with the reference sample, respectively. As a result of our study, it can be concluded that the addition of PS affects the structure and density of the final product.

In order to assess microbiological safety and shelf life, we carried out microbiological studies, whose results are presented in table 4.

| Polysaccharides | MAFAM, CFU/g 1 hour | MAFAM, CFU/g 24 hours | Coliform bacteria 1 hour | Coliform bacteria 24 hours |
|-----------------|---------------------|-----------------------|---------------------------|---------------------------|
| TR 021/2011     | 1.0·10^4            | 1.0·10^4              | 1.0                       | 1.0                       |
| Reference       | not found           | not found             | 0.2·10^3±0.03             | not found                 |
| Xanthan         | not found           | not found             | 0.1·10^3±0.03             | not found                 |
| Guaran          | not found           | not found             | not found                 | not found                 |

Table 4 shows that in the fish loaves with the addition of xanthan, a 2-fold decrease in the number of mesophilic aerobic and facultative anaerobic bacteria was revealed in comparison with the reference sample, at the same time, it meets the technical regulation requirements.

In the fish loaves with the addition of guaran, after a day, the content of microorganisms was not detected in comparison with the reference sample, which also corresponds to the permissible values of the technical regulations.

No Escherichia coli bacteria were detected in the samples with the addition of all the polysaccharides. As a result, it can be concluded that replacing butter with polysaccharides in fish bread reduces the number of microorganisms, which leads to an increase in the shelf life of the product.

As a result of our preliminary economic calculations, the prime cost of finished products of the reference and test samples was evaluated, which is presented in figure 4.

**Figure 4.** Prime cost of finished products of the reference and test samples of fish loaves (pricing as of September 01.2020).

Figure 4 shows that our change in the component composition of fish loaves has led to a decrease in the prime cost by an average of 3.9%. This is due to the replacement of butter, which was in the reference sample recipe.

4. **Conclusions**

Thus, the results of our studies allow us to draw the following conclusions:

- from the test samples with PS for fish loaves we recommend the PS guaran in a concentration of 0.3%;
• for the selected sample, the dry matter content was 57.75 ± 0.01%, fat weight fraction was 6.00 ± 0.05%, acidity was 1.85 ± 0.02 deg; in 100 g of the product, the protein content was 15.98 g, fat – 1.70 g, carbohydrates – 7.66 g, dietary fiber – 0.65 g, and energy value was 113 kcal;
• the content of EAA is 1.7 times higher than the required content of essential amino acids in protein according to the FAO/WHO requirements;
• the addition of guaran to fish loaves had a positive effect, since it reduced the content of MAFAM and contributed to an increase in shelf life up to 24 h;
• replacing butter in the reference sample with guaran reduced the prime cost of the samples by an average of 3.9%;
• our developed dish of fish loaves with the addition of guaran (0.8%) is recommended for introduction into the food industry (catering) as a dietary product.

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