Effect of addition corn flour, millet flour and pumpkin seed flour on the properties of gluten-free gingerbread

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Abstract. This article presents the development of a recipe for gluten-free gingerbread using secondary raw materials and cereals that normalize the intestinal micro flora. The gluten-free gingerbread recipes included the following gluten-free raw materials: corn flour (CF), millet flour (MF), pumpkin seed flour (PSF). The formulation was used as gingerbread «Limon» of wheat dough as a control sample. Prescription gluten-free components and their ratio were selected based on the analysis of data from domestic and foreign sources, taking into account the functional orientation and consumer properties. Laboratory baking of gingerbread was carried out with a complete replacement of wheat flour in the recipe for a different ratio of gluten-free flour mixture CF:MF:PSF - 40:40:20 and 35:35:30. To evaluate the obtained gingerbread, organoleptic and physicochemical methods of analysis were used. The organoleptic properties and physicochemical properties of the control sample and samples of gluten-free mixtures were compared. It has been found that replacing wheat flour with a gluten-free flour mixture generally improves the properties of gingerbread. We determined the rational ratio of gluten-free flour ingredients for the production of gingerbread CF:MF:PSF - 35:35:30.

1. Introduction
Consumers in the Russian Federation have recently increased their attention to the so-called “proper nutrition”. As a result, the demand for functional food products and products with reduced energy value is increasing. The priority tasks in the field of food production include the development of technologies for flour confectionery products for specialized and medical purposes.

Wheat flour, used in most bakery and flour confectionery products, contains proteins that form a protein complex called gluten. Gluten provides the viscoelastic properties of the dough necessary for the preparation of various products. Unfortunately, some people have allergic reactions to gluten. These reactions are a manifestation of celiac disease. Celiac disease is a disease that occurs as a result of the immune response to the consumption of foods containing gluten due to insufficient activity of a specific enzyme in the body [1]. Gluten is a cereal protein, hence celiac disease is caused by gluten intolerance. Treatment and prevention of a disease such as celiac disease can be carried out with a gluten-free diet.

In the last 20-25 years, the number of diseases of the gastrointestinal tract has increased, to which gluten enteropathy (celiac disease) belongs. The number of consumers of gluten-free flour confectionery products is small, however, it is important to provide this category of people with specialized food products.

Specialized food products with a low gluten content include food products containing 20-100 mg of
gluten per 1 kg of product. Gluten-free foods should contain no more than 20 mg/kg gluten and be labeled gluten-free [2]. Gluten-free food products include cereals and their processed products (rice, buckwheat, corn, soybeans), potatoes and vegetables (carrots, cabbage, zucchini, pumpkin), fruits (apples, pears, bananas), fruit juices, large meat cattle, pork, poultry, low-fat fish, vegetable oils, honey, preserves, jams [3, 4, 5].

As a result of research [6], we optimized the process parameters for formulation of gluten-free cookies from quinoa flour.

The most accessible and palatable raw material for the consumer is flour obtained from various grains: corn, rice, buckwheat, rye [7].

Researchers are actively conducting research to assess the possibility of using flour from millet and buckwheat in the technology of bakery and flour confectionery for celiac patients [8, 9]. The specified plant raw materials have a significant potential of biologically active substances that are important for human health and full-fledged life.

Products prepared using 25% and 50% millet flour were characterized by almost the same quality indicators as products made from 100% wheat flour, which confirms the advisability of using millet [10].

The functional and technological properties of extruded buckwheat have been investigated, since they determine the advisability of using non-traditional types of raw materials in the technology of bakery and flour confectionery products [11].

Cereals containing gluten are a good source of B vitamins. Therefore, celiac disease patients may be deficient in these vitamins and other food ingredients - protein, polyunsaturated fatty acids, mineral components, etc. To prevent this, amaranth, buckwheat porridge and millet should be included in the diet, as well as nuts, sunflower seeds, sesame seeds or pumpkin seeds.

The aim of the work was to develop a recipe for gluten-free gingerbread using secondary raw materials, cereals, normalizing the intestinal micro flora.

2. Materials and methods
The following types of gluten-free raw materials were used as ingredients to replace wheat flour: corn flour (CF), millet flour (MF), pumpkin seed meal (PSF).

Millet flour was obtained by grinding cereals. Pumpkin seed meal was prepared as follows. The pumpkin seeds were washed, distributed evenly on a mesh tray. Then the pumpkin seeds were dried at 70 °C for 12 hours. The dried seeds were ground using a laboratory mill. The resulting powder was sieved.

The objects of research were: a control sample of gingerbread made from wheat dough and experimental samples of gingerbread based on a gluten-free flour mixture with different ratios of ingredients.

Prescription gluten-free components and their ratio were selected based on the analysis of data from domestic and foreign sources, taking into account the functional orientation and consumer properties.

2.1. Organoleptic research methods
The taste and smell, structure, color, surface, shape of the gingerbread products were evaluated by 25 points in accordance with GOST 5897.

2.2. Physicochemical research methods
The dimensions of the gingerbread products were determined using a metal measuring ruler in accordance with GOST 427. The mass fraction of moisture in wheat flour of the highest grade, corn, millet flour was determined in accordance with GOST 9404-88. The mass fraction of moisture in gingerbread was determined in the crumb by drying a sample in an oven at 130 °C in accordance with GOST 5900-2014. The determination of the mass fraction of total sugar was carried out refractometric. The specific volume of finished products was determined by the ratio of the volume of
millet displaced by a certain mass of gingerbread. The calculation of the chemical composition, nutritional and energy value of gingerbread was carried out using a methodology based on reference data in accordance with the industry and the use of an energy coefficient of 4 kcal/g for calculating the value of proteins and carbohydrates, 9 kcal/g for calculating the energy value of fats. The pH value was assessed using an LCD digital pH meter.

The total amount of water-soluble substances in the gingerbread crumb was determined as follows. To 10 g of crushed gingerbread crumb was added 100 ml of distilled water, shaken for 30 minutes and left alone for 10 minutes. The amount of water-soluble substances was determined using an optical refractometer. All indicators were determined in triplicate.

3. Results and discussion

To develop a recipe for gluten-free gingerbread, products were baked with a complete replacement of wheat flour with a gluten-free flour mixture. We selected mixtures of corn flour (CF), millet flour (MF) and pumpkin seed meal (PSF) in the ratio of 45:45:10, 40:40:20, 35:35:30, 30:30:40 and 25:25:50.

Pre-baked gingerbread test variants showed a deterioration in sensory performance when using a mix ratio of 25:25:50 and 30:30:40. The appearance of the products and the texture of the crumb have significantly deteriorated. Low textural performance of the test was noted using a 45:45:10 ratio.

The sensory evaluation of gingerbread based on a gluten-free mixture in the ratio of 40:40:20 and 35:35:30 indicates the elimination of cracks on the surface, an increase in porosity, and a weakening of the cereal taste and smell.

In further experiments, the ratios of a gluten-free flour mixture of 40:40:20, 35:35:30 were selected, which made it possible to obtain organoleptic characteristics similar to the control sample.

The nutrients from wheat flour and mixtures for gluten-free gingerbread are shown in Table 1.

**Table 1.** Nutrients of wheat flour and mixtures for gluten-free gingerbread, g/100 g

| Nutrients              | Wheat flour | Gluten-free flour mixture ratio CF:MF:PSF, % |
|------------------------|-------------|---------------------------------------------|
|                        |             | 40:40:20                                   | 35:35:30                                   |
| Moisture               | 14.0        | 12.6                                       | 11.9                                       |
| Protein                | 10.3        | 14.2                                       | 16.4                                       |
| Fats                   | 1.2         | 8.5                                        | 11.3                                       |
| Fatty acid             | 0.77        | 7.2                                        | 9.8                                        |
| NLC                    | 0.15        | 1.0                                        | 1.4                                        |
| MNZhK                  | 0.11        | 1.9                                        | 2.6                                        |
| PUFA                   | 0.51        | 4.2                                        | 5.7                                        |
| ω-3 (α-linolenic)      | 0.03        | 0.04                                       | 0.05                                       |
| ω-6 (linoleic)         | 0.48        | 4.2                                        | 5.7                                        |
| Mono- and disaccharides| 1.5         | 3.0                                        | 3.7                                        |
| Starch                 | 68.0        | 54.2                                       | 47.4                                       |
| Alimentary fiber       | 1.5         | 4.8                                        | 5.0                                        |
| Ash                    | 0.5         | 1.6                                        | 1.9                                        |
| Potassium, mg          | 122         | 348.2                                      | 432.8                                      |
| Calcium, mg            | 18.0        | 86.8                                       | 118.5                                      |
| Phosphorus, mg         | 86.0        | 368.8                                      | 467.7                                      |
| Magnesium, mg          | 16.0        | 151.4                                      | 198.9                                      |
| B1 (thiamine), mg      | 0.17        | 0.4                                        | 0.3                                        |
| B2 (riboflavin), mg    | 0.04        | 0.1                                        | 0.1                                        |
| PP (niacin), mg        | 1.2         | 1.9                                        | 2.2                                        |
| Energy value, kcal     | 330.0       | 362.1                                      | 371.6                                      |
The effect of the gluten-free ingredients on the quality characteristics of the gingerbread was investigated. Gingerbread with a recipe in which wheat flour was completely replaced by various ratios of gluten-free flour mixture CF: MF: PSF - 40:40:20, 35:35:30 were baked.

The sensory evaluation of the products showed that the gingerbread based on the gluten-free flour mixture in the ratio of 40:40:20 and 35:35:30 had the correct shape. The surface of products based on gluten-free flour mixture in different products was characterized by a lower condition than that of gingerbread made with wheat flour. High-quality flour from pumpkin seeds gives a more pronounced nutty taste and smell. With the content of 30% pumpkin seed flour in the mixture, the gingerbread cookies had a pronounced nutty taste and smell.

| Table 2. Sensory evaluation of gingerbread based on gluten-free flour mixtures |
|-------------------------------|---------|---------|---------|---------|
| Flour mixture                | Form    | Surface | Smell   | Taste   | Amount |
| Control sample               | 8.7     | 4.5     | 2.5     | 7       | 28.7   |
| Mixture CF:MF:PSF 40:40:20   | 8       | 4.3     | 2.8     | 7.5     | 28.3   |
| Mixture CF:MF:PSF 35:35:30   | 8.5     | 4.4     | 3       | 7.7     | 29.4   |

The sum of points for the organoleptic assessment of gingerbread based on gluten-free flour mixture was 28.3 and 29.4 points. The sum of points of the organoleptic evaluation of gingerbread on wheat flour was 28.7. The organoleptic assessment characterizes the quality of control and experimental gingerbread samples as excellent. Table 2 shows the results of studies of the physicochemical parameters of gingerbread based on gluten-free flour mixture.

| Table 3. Physical and chemical indicators of the quality of gluten-free gingerbread |
|---------------------------------------------|---------|-------------------|-------------------|
| Properties                          | Control sample | Gluten-free flour mixture ratio CF:MF:PSF, % |
|                                 | 40:40:20 | 35:35:30          |
| Humidity,%                        | 12.5     | 12.7              | 12.8              |
| Sugar content,%                   | 35.0     | 36.5              | 37.0              |
| Product yield,%                   | 100.7    | 101.9             | 102.5             |
| Product thickness, mm             | 15       | 17                | 18                |
| Density of products, g/cm³        | 0.70     | 0.60              | 0.55              |
| Specific volume, cm³/g            | 1.50     | 1.65              | 1.72              |

The results show that the yield of the test gingerbread sample based on the gluten-free flour mixture was highest at a ratio of 35:35:30. This indicates the high water absorption capacity of the gluten-free flour mixture. The dietary fiber content of the flour mixture is known to affect the moisture loss during baking. This explains the increased yield of the products.

The thickness of the gingerbread is greatest in the sample with a high content of pumpkin seed flour. This indicates a more effective loosening of the dough in the experimental variants. The increase in porosity is evidenced by a decrease in the density of the products compared to the control sample (0.65 and 0.55 g/cm³ in the experimental variants and 0.70 g/cm³ in the control).

The specific volume in the experimental samples with 20 % pumpkin seed meal was 10 % higher than in the control. The specific volume in the experimental samples with 30 % pumpkin seed meal was 15 % higher than in the control.

The analysis of the chemical composition of the spice cakes indicates higher moisture content in the experimental spice cakes compared to the control variant. The moisture content of the gingerbread with the ratio of gluten-free ingredients 40:40:20 and 35:35:30 is higher by 1.6 and 1.4% than in the control sample. The moisture content of the 40:40:20 mix is 0.7% higher than the 35:35:30 mix. The higher moisture content of the test gingerbread samples indicates the hygroscopic effect of dietary fibers. The protein content of the gingerbreads baked on a 40:40:20 and 35:35:30 mixture was 8.4 % and 9.6 %. In the spice cakes baked on the basis of a 35:35:30 mixture, the protein content was 14.3 % higher than in the spice cakes baked on the basis of a 40:40:20 mixture. It can be argued that
increasing the proportion of pumpkin seed flour in the total flour mixture contributed to the increased protein content of the experimental gingerbread samples.

The lipid content of the products increased as the proportion of pumpkin seed flour in the total mass of the flour ingredients increased. The lipid content when using a mixture of 40:40:20 and 35:35:30 was 6.4% and 8.0%, respectively. The lipid content using a mixture of 35:35:30 was 25% higher than in a mixture of 40:40:20. The mono- and disaccharide content of the gingerbreads prepared with a 40:40:20 and 35:35:30 mixture was 36.7% and 37.1%, respectively. The starch content of the 35:35:30 mixture is 14% lower than that of the pumpkin seed flour mixture (40:40:20). The experimental gingerbread samples contain considerably more minerals than the control sample. The best ratio of gluten-free ingredients for making gingerbread is considered to be corn flour: millet flour: pumpkin seed flour - 35:35:30.

4. Conclusion
Increasing the proportion of pumpkin seed flour in the total flour mixture helped to increase the protein and fat content of the tested gingerbread samples. Replacing wheat flour with a gluten-free flour mixture generally improves the properties of the gingerbread. The results showed the big potential of using different grains and seeds to create a gluten-free flour mixture. The organoleptic and physico-chemical quality parameters of the gluten-free gingerbread compared to the control sample identified the best sample with an ingredient ratio of 35:35:30.

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