The use of secondary raw materials of food production for bakery flour mixtures

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Abstract. Secondary raw materials formed in the technological process of production of such products as pumpkin juice, beet sugar, etc. is a promising source of useful components, including fiber, pectin substances, macro- and microelements in bioavailability form, etc. It was determined that the water-binding capacity of powders from pumpkin pomace and sugar beet pulp, as well as oat flour, is higher than that of wheat and rye flour by 20.9-22.8%. The study developed the composition of a flour mixture including, %: peeled rye flour - 60, second grade wheat flour - 20, pumpkin pomace powder - 6.3, sugar beet pulp powder - 5.7, oat flour - 8. It is determined that preliminary soaking of powders of pumpkin pomace and sugar beet pulp, as well as oat flour has a positive effect on the physical and chemical properties of bakery products, as well as the content of aromatic compounds in them. The content of dietary fiber in the developed products is 20% of the daily requirement, which makes it possible to classify the developed bread as functional food products.

1. Introduction

Increasing the share of mass consumption products for functional and prophylactic purposes to improve the health of the population is the main task of the development of the food industry [1-14]. The most promising types of fortified food products are bread and bakery products that are consumed daily [2]. At the same time, the expansion of the varieties of raw materials from secondary food sources that could be used for food is associated with a decrease in environmental and economic damage from unused food resources [3].

A promising source of useful substances can be pumpkin pomace powder, which is a waste in the production of pumpkin juice. An equally rich source of biologically active substances is sugar beet pulp powder.

In pumpkin pomace, when juice is obtained, such components as fiber, pectins, minerals, mono and disaccharides are transferred [4]. Known useful properties of pumpkin pulp in diseases of the kidneys, liver, diabetes mellitus, the presence of diuretic, choleretic properties and increased peristalsis [5].
Beet pulp is a secondary raw material in the production of beet sugar. In connection with the industrial production of sugar, beet pulp in sugar factories accumulates in significant quantities. In Russia, this secondary raw material is mainly included in livestock feed rations. However, the presence in it of such important food components [6] as fiber, pectins, vitamins, high-grade proteins shows the need for development involving its use as a food ingredient.

The development of formulations using new types of raw materials is always associated with a large number of experiments. The use of mathematical methods in the selection of raw materials makes it possible to simplify and optimize the development process. This also allows you to reveal the entire technological potential of new raw ingredients, to see the dynamics of the impact on the quality of the finished product.

2. Materials and methods

For flour mixtures, the following raw materials were used in the work: baking wheat flour of the second grade, peeled rye flour, oat flour, powders from pumpkin pomace and sugar beet pulp. Powders from pumpkin pomace and sugar beet pulp were obtained by grinding plant raw materials, distilling the juice and subsequent drying of the obtained pomace in laboratory conditions, grinding the dried pomace in a laboratory mill and sieving.

The study of the properties of raw materials was carried out in terms of the mass fraction of moisture, titratable acidity according to conventional techniques, the content of fiber and hemicellulose of the Kurscher-Hoffher approach and Chlorite Method (table 1).

| Name of raw materials        | Humidity, % | Acidity, degree | Fiber + hemicellulose, g / 100g |
|------------------------------|-------------|----------------|---------------------------------|
| rye flour                    | 13.5±1.0    | 1.0±0.5        | 4.2±0.5                         |
| wheat flour                  | 13.0±1.0    | 1.0±0.5        | 7.1±0.5                         |
| oat flour                    | 9.0±1.0     | 6.5±0.5        | 7.7±0.5                         |
| pumpkin pomace powder        | 7.5±1.0     | 12.5±0.5       | 15.3±0.5                        |
| sugar beet pulp powder       | 7.0±1.0     | 6.0±0.5        | 8.4±0.5                         |

The design of the composition of flour mixtures for rye-wheat bakery products was carried out by the method of simplex-lattice experiment planning [8]. To draw up a simplex-lattice plan, it is necessary to set the step of the levels of the components and write down all possible combinations of the levels of all components (remembering that the sum of the components is always equal to 1).

Table 2 shows a simplex – lattice design of the second order (step h = 1/2) for a four-component mixture (q = 4). The composition of the designed mixtures included the following types of flour: wheat flour (×1), pumpkin pomace powder (×2), sugar beet pulp powder (×3) and oat flour (×4). The amount of rye flour in the mixture was at least 60%, oat flour, pumpkin pomace powder and sugar beet pulp were introduced instead of wheat flour, because it contains the least amount of dietary fiber.

To prepare dough from model mixtures, water, a solution of salt, citric acid, and a yeast suspension were added to them. The amount of water for kneading was calculated based on a given dough moisture content of 50%. A proofing cabinet Voskhod Briz-33 (ZAO NPP Voskhod, Russia) was prepared with a temperature of 35-38 °C and an air humidification of 70-80%. The dough was kneaded on a U1-ETB laboratory kneading machine (Analitprompribor, Russia) and placed in a prepared proofing cabinet for fermentation.

The test was used to determine the mass fraction of moisture, the initial and final titratable acidity by conventional methods [9]. The fermented dough was placed in oiled molds and proofed in a proofer with humidification at a temperature of 35-38 °C. The readiness of the dough for baking was determined organoleptically. The baked goods were produced in a Monsoon-rotor electric oven (ZAO NPP Voskhod, Russia) at a temperature of 220 °C for 30-45 minutes. The finished products were analyzed in terms of specific volume, porosity and titratable acidity in accordance with the methods given in [9] not earlier than 3 hours and not later than 24 hours after baking.
Table 2. Simplex-lattice design of the 2nd order (Q = 4) and composition of mixtures.

| Coded designation | Coded values | Natural values |
|-------------------|-------------|---------------|
|                   | x1          | x2           | x3          | x4          | Rye flour | wheat flour | pumpkin pomace powder | sugar beet pulp powder | oat flour |
| Z1                | 1           | 0            | 0           | 0           | 60        | 40          | 0               | 0            | 0       |
| Z2                | 0           | 1            | 0           | 0           | 60        | 0           | 40              | 0            | 0       |
| Z3                | 0           | 0            | 1           | 0           | 60        | 0           | 0               | 40           | 0       |
| Z4                | 0           | 0            | 0           | 1           | 60        | 0           | 0               | 0            | 40      |
| Z12               | ½           | ½            | 0           | 0           | 60        | 20          | 20              | 0            | 0       |
| Z13               | ½           | 0            | ½           | 0           | 60        | 20          | 0               | 20           | 0       |
| Z14               | ½           | 0            | 0           | ½           | 60        | 20          | 0               | 0            | 20      |
| Z23               | 0           | ½            | ½           | 0           | 60        | 0           | 20              | 20           | 0       |
| Z24               | 0           | ½            | 0           | ½           | 60        | 0           | 20              | 0            | 20      |
| Z34               | 0           | 0            | ½           | ½           | 60        | 0           | 0               | 20           | 20      |

Dough and bakery products were prepared from model compositions in accordance with table 3. Humidity, initial acidity, fermentation duration, final acidity, and proofing duration were determined as output parameters (responses). In finished products, the mass of cooled bread, specific volume, acidity and moisture were determined.

Table 3. Dough recipes from model flour mixtures.

| Coded designation | Rye flour, g | wheat flour, g | Pumpkin powder, g | Sugar beet powder, g | Oat flour, g | Salt, g | Yeast, g | Water, g | Citric acid, g |
|-------------------|--------------|---------------|-------------------|----------------------|--------------|---------|----------|----------|---------------|
| Z1                | 120          | 80            | 0                 | 0                    | 142          | 1.41    |          |          |               |
| Z2                | 120          | 0             | 80                | 0                    | 4            | 4       | 150      | 0        |               |
| Z3                | 120          | 0             | 0                 | 80                   | 4            | 4       | 150      | 0.218    |               |
| Z4                | 120          | 0             | 0                 | 0                    | 80           | 4       | 4        | 150      | 1.5          |
| Z12               | 120          | 40            | 40                | 0                    | 4            | 4       | 150      | 0        |               |
| Z13               | 120          | 40            | 0                 | 40                   | 4            | 4       | 150      | 0.801    |               |
| Z14               | 120          | 40            | 0                 | 0                    | 4            | 4       | 150      | 0.884    |               |
| Z23               | 120          | 0             | 40                | 40                   | 4            | 4       | 150      | 0        |               |
| Z24               | 120          | 0             | 40                | 0                    | 4            | 4       | 150      | 0        |               |
| Z34               | 120          | 0             | 0                 | 40                   | 4            | 4       | 150      | 0        |               |

When determining the optimal method of dough preparation, the content of bisulfite-binding compounds in bakery products was additionally investigated according to the method developed by R.Tokareva and V.Kretovich for the determination of flavoring substances in bread, and was expressed in meq of sodium bisulfite solution per 100 g of dry crumb substance [10].

All analyzes were performed in triplicate. For an objective judgment about the degree of reliability of the results obtained, mathematical processing was carried out to find the average interval value of the measured value at a 95% reliability factor.
3. Results and Discussion

It was determined that the water-binding capacity of wheat, rye and oat flour, as well as powders from pumpkin pomace and sugar beet pulp, largely depends on pH and temperature.

The coefficient of water-binding capacity of rye flour increases with increasing temperature, the maximum water-holding capacity is observed at temperatures of 50 and 60 °C.

The coefficient of water-binding capacity of wheat flour has a more complex dependence on temperature than rye flour. At pH 3, a decrease in water-binding capacity was observed at temperatures of 40 and 60 °C, at pH 4 - at a temperature of 40 °C, at pH 5 - at a temperature of 50 °C, at pH 6 there was an increase in water-binding capacity in direct proportion to an increase in temperature.

The coefficient of water-binding capacity of oat flour increases with increasing temperature and pH. The maximum water-binding capacity of oat flour is observed at a temperature of 60 °C and pH 6.

The coefficient of water-binding capacity of sugar beet and pumpkin pulp increased with increasing temperature and pH. At the same time, the maximum water-binding capacity of sugar beet pulp was observed at a temperature of 60 °C and pH 6, pumpkin pulp - at a temperature of 60 °C and pH 5.

Thus, the water-binding capacity of powders from pomace of pumpkin and pomace of sugar beet and pumpkin and oat flour is higher than that of wheat and rye flour by 20.9-22.8%. This will have a positive effect on the yield of baked goods.

It is known that dietary fiber raw materials have the sorption capacity of various harmful substances [11], including nitrates, urea. In this regard, the ability of the components of the flour mixture to sorb nitrates and urea from aqueous solutions was experimentally studied.

It was determined that the maximum sorption capacity of nitrates by components of the flour mixture was observed at a concentration of 0.1 mol / dm$^3$, urea - 0.5 mol / dm$^3$. It was found that the highest sorption capacity is possessed by the powder from pumpkin pomace and sugar beet pulp. The average sorption capacity of nitrates by the components of the mixture can be arranged in the following order: wheat flour < rye flour < oat flour < sugar beet pulp powder < pumpkin pomace powder, i.e. according to the obtained experimental data, respectively, mol / dm$^3$: 0.190<0.212<0.218<0.220<0.260.

Thus, oat flour, powders from pumpkin pomace and sugar beet pulp, in comparison with rye and wheat flour, have a greater ability to sorb nitrates from aqueous solutions by 34-36%, urea - by 12.5-12.8%.

Dough and bakery products were prepared from model rye-wheat flour mixtures with oat flour, powders from pumpkin pomace and sugar beet pulp.

It was determined that the initial acidity of dough samples from model flour mixtures practically coincides with the calculated data (7 degrees), the moisture content of the dough is 49.8 ± 3.2 degrees. The duration of fermentation and proofing in samples from model flour mixtures was in the range of 60-70 and 45-50 minutes, respectively. The acidity of finished products is within acceptable limits for such types of bakery products - no more than 10 degrees [15-17].

For the specific volume ($V_1$) and porosity ($V_2$) of bakery products from model flour mixtures, the equations of the second order are obtained:

1) specific volume:

\[
Y_1 = 1,69x_1 + 1,29x_2 + 1,12x_3 + 1,6x_4 - 1,16x_1x_2 - 1,14x_1x_3 + 0,02x_1x_4 - 0,7x_2x_3 - 1,42x_2x_4 - 1,04x_3x_4 \quad (1)
\]

2) porosity:

\[
Y_2 = 66,5x_1 + 29,3x_2 + 29,5x_3 + 58,7x_4 - 34,82x_1x_2 - 34x_1x_3 + 24x_1x_4 - 4,8x_2x_3 - 40,4x_2x_4 - 25,2x_3x_4 \quad (2)
\]

Calculation of the chemical composition [12] of the developed bakery product showed that the content of dietary fiber in it is 4 g per 100 g of the finished product. This makes it possible to classify this type of bread as a functional product, since with a daily requirement for dietary fiber of 20 g, their content in this bread is 20%.
4. Conclusion
Thus, using the methods of mathematical planning of the experiment, a rye-wheat bakery product was developed, enriched with sources of dietary fiber from secondary raw materials - powder from pumpkin pomace and sugar beet. The additional introduction of oat flour into the flour mixture for bread made it possible to enrich it with water-soluble dietary fibers, such as β-glucans. It has been determined that these types of raw materials have an increased water-binding capacity, which will have a positive effect on the yield of bakery products. The increased sorption capacity of raw materials from secondary sources to nitrates and urea in comparison with wheat flour has been established, which, when these raw materials are included in the bread recipe, give it additional preventive properties associated with the elimination of harmful substances from the body.

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