Study of the functional properties of dough

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Abstract. The paper presents the studies of gluten-free types of unleavened dough, it shows the effect of hydrocolloids on the structure of the dough. The aim of the work is to study the functional and technological properties of the dough depending on the type and concentration of the flour and hydrocolloids. The tasks of the research are the following: to determine the concentration of colloids that makes dough plastic and strong dough; to identify the dependence of the concentration of flour on the type and properties of hydrocolloids; to study organoleptic quality indicators. The dynamic viscosity of the dough was determined by using a Brookfield viscometer. The methods of mathematical experiment planning were used to design the recipes of the unleavened dough. To define the reference dependency of viscosity on shear rate, the coefficients of nonlinear model equations have been estimated by using the methods of regression analysis in the program Statistica v6. For the experimental samples, the equation of the viscosity dependence is determined as a model of non-linear multiple regression. The graphs of the viscosity dependence on the shear rate compared to the reference rate are made. The methods of mathematical programming have been used to find the optimal ratio of flour and each type of structure-forming agents (soy protein isolate, xanthan gum, and potato starch) in the dough to maximize the approximation of the viscosity curve to the reference one. For this purpose, an objective function with limits on the shear rate is compiled. Using the MathCAD v15, the optimal values of the content of the components such as rice flour - 27.78%, soy protein isolate - 7.22%, potato starch - 32.22%, xanthan gum - 0.28 % are found. The results of the control measurement of the viscosity of the sample with the optimal composition indicate that the selected mathematical model corresponds to the elastoviscoplastic properties of this dough and the curve changes depending on the composition of the dry dough mixture. The description of the mathematical model and the regression analysis make it possible to select the ratio of the prescription components so that the resulting product has rheological characteristics close to the control sample.

1. Introduction

Nowadays, the range of rice flour products is not sufficiently represented on the market and is mainly limited to the products in which rice flour is used as a mixture with wheat flour [1].

Most of the published recipes for gluten-free products relate to bread and bakery products, the range of which is determined by national traditions, purpose in diets and menus, and special requirements for nutritional value. The flour mixtures for making gluten-free macaroni and pasta are widely spread. The gluten-free flour mixtures for a wide range of flour confectionery products can be various.
Such products, based on rice flour, as rice porridge, jelly, flour mixtures for baking can be met at the market. However, there are practically no recipes for flour dishes, such as meat dumplings, dumplings, pancakes, etc.

The development of the recipes for such specialized dishes and products for cafes, restaurants and other public catering establishments is becoming more and more relevant in connection with the development of tourist service.

Rice flour does not form gluten, which gives the dough necessary viscoelastic properties, while at the same time it contains a large amount of starch, which is manifested in the production of sticky dough that does not retain its shape. It is found that when rice flour is brewed, the starch is gelatinized, while the dough becomes elastic and less sticky [2].

It is known that water significantly affects the rheological properties of rice flour dough, its elasticity and resistance to deformation, and its ability to retain gas. In addition, the water-holding capacity of the dough affects the quality of products, namely, its texture, appearance, taste, and shelf life. This makes it possible to study the physical and chemical properties of the main structural components in the feedstock.

So, one can make a conclusion that in the production of rice flour products, it is necessary to use a mixture of various hydrocolloids, the combination of which provides the required technological properties of the dough and the quality of the finished products. Soy protein isolate and natural polysaccharide xanthan gum are selected as a system of such hydrocolloids.

Xanthan gum is a common thickener and one of the most trouble-free hydrocolloids to use. It is active in a wide range of temperatures, in alkaline, acidic and even salty solutions.

Xanthan gum is formed by the breakdown of glucose by specially grown bacteria. In the process of their vital activity, the gum precipitates and is subjected to drying, and then – grinding. After that, it can be considered to be ready for further processing.

Xanthan gum was first produced at the research center at the USDA in the 50s, its commercial production began in the 60s, and in 1969 it was included in the register of permitted additives for food use.

Xanthan gum reveals its potential when interacting with other textures. By increasing the viscosity of liquids, it prevents the separation of liquids in gels and stabilizes emulsions and foams. It is also used in the production of gluten-free products, because it can partially replace gluten, preserving its properties.

Xanthan gum is recognized worldwide as the best natural gelling agent. It has a high viscosity and an excellent stabilizing activity. Moreover, these qualities are retained even after freezing. Food stabilizer E415 can be successfully combined with gelatin, pectin, starch and other thickeners. This quality has made it indispensable in the modern food industry.

In the production of flour products, the recommended dosage of xanthan gum is 0.1-0.2% by weight of flour [3].

The products made from soy seeds are divided into three groups that differ in protein content: full-fat flour with a protein content of 40-50%, protein concentrate with a protein content of 65-70% and protein isolate containing at least 90% protein [4].

Isolates have a neutral taste, smell and color - white or cream, they are well soluble in water, forming proteinates, in salt and alkaline solutions. When solutions and concentrated suspensions are heated, the isolates form strong non-regenerating jellies with a high water content. They have fiber-forming properties and stabilize fat emulsions in water, foams, and starch suspensions [4].

The expediency of using protein products from soy seeds in the production of pasta, confectionery and flour products is associated with the need to increase the biological value and improve the technological and taste qualities of the resulting products.

In the production of bakery products, the addition of protein isolates positively affects the hydrodynamic properties of the dough. In an alkaline environment, the water absorption capacity increased significantly, and the consistency of the dough is improved, although the degree of loosening, on the contrary, becomes worse.
Adding an isolate to pasta [5] reduces the duration of their drying as a result of the redistribution of moisture between the proteins and starch of flour and the protein of the enricher, due to this water passes from a stronger state to a less strongly bound one and is easily removed.

It is known that the production of high-quality pasta requires flour made from durum wheat. When using additives of protein products from oilseeds, it becomes possible to use soft wheat flour.

In the confectionery industry, soy isolate is used as an additive that make it possible to design and produce confectionery masses with specified rheological characteristics, as well as a protein concentrator. Even a small amount of protein isolate in the recipe of a confectionery product helps manipulate with such functional and technological indicators as the viscosity, foam- and gel formation, emulsifying, water and fat-absorbing abilities [6-12, 15].

Soy protein has a high biological value. 100 g of isolate contains at least 90% of protein. Fat is about 0.5%, raw fiber no more than 6.0%. In addition, the food supplement is rich in micro and macro elements.

It actively stabilizes metabolism, affects the proper functioning of hormones and the thyroid gland, and it is an excellent antioxidant.

Protein concentrates and isolates from soybeans stimulate the elimination of heavy metal salts and radionuclides from the body, which reduces the risk of cancer.

The purpose of the work is to study the functional and technological properties of the dough depending on the type and concentration of flour and hydrocolloids.

In accordance with this goal, the following tasks must be solved:

- determine the concentration of colloids, which makes the dough plastic and strong;
- identify the dependence of the flour concentration on the type and properties of hydrocolloids;
- study organoleptic quality indicators.

2. Materials and methods

The objects of the study are four types of unleavened dough prepared with various structure-forming agents to improve hydrocolloid properties, and a control sample made according to recipe No. 412 of the collection of recipes [1].

Wheat flour with humidity of 13% and gluten of the 1st group-quality and rice flour with a moisture content of 14% were used in the study.

These samples were examined using organoleptic and physico-chemical methods. The quality of flour was determined according to GOST 26574-2017 with the establishment of a transition period for GOST 26574-85 up to 01.01.2021. The dynamic viscosity of the dough was determined using a Brookfield viscometer. The methods of mathematical experiment planning were used to design the recipes of the unleavened dough. To define the reference dependence of viscosity on shear rate, the coefficients of nonlinear model equations were estimated by using the methods of regression analysis in Statistica v6. For the experimental samples, the equation of the viscosity dependence was determined as a model of non-linear multiple regression. The graphs of the viscosity dependence on the shear rate compared to the reference rate were made. The methods of mathematical programming were used to find the optimal ratio of flour and each type of structure-forming agents (soy protein isolate, xanthan gum, and potato starch) in the dough to maximize the approximation of the viscosity curve to the reference one. For this purpose, an objective function with limits on the shear rate was compiled. Using the MathCAD v15, the optimal values of the content of the components such as rice flour - 27.78%, soy protein isolate - 7.22%, potato starch - 32.22%, xanthan gum - 0.28 % were found. the Nutritional value of the samples was determined by the calculation method.

3. Results and discussion

To study the influence of structure-forming agents on the quality of unleavened dough, it was prepared according to the recipe presented in table 1.
Table 1. The recipe for the production of unleavened pizza dough (net, g).

| Raw materials      | Control | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|-------------------|---------|-----------|-----------|-----------|-----------|
| Wheat flour       | 240     | -         | -         | -         | -         |
| Rice flour        | -       | 100       | 126       | 100       | 246       |
| Soy protein isolate | -      | 26        | -         | 26        | 26        |
| Xanthan gum       | -       | 1         | 1         | -         | 1         |
| Potato starch     | -       | 116       | 116       | 116       | -         |
| Water             | 100     | 100       | 100       | 100       | 100       |
| Olive oil         | 15      | 15        | 15        | 15        | 15        |
| Salt              | 5       | 5         | 5         | 5         | 5         |
| Output            | 360     | 360       | 360       | 360       | 360       |

Flour was poured into a kneading machine, then water heated to 30-35°, soy protein isolate, xanthan gum and potato starch were added in accordance with the recipe, then olive oil and salt were also added, the dough was kneaded until it had a uniform consistency. The prepared dough has been kept for 30-40 minutes to swell the gluten and become elastic, afterwards it can be used for cooking pizza.

To estimate the coefficients of the reference dependence of viscosity on the shear rate, a coupling equation was obtained using regression analysis in Statistica v6 program. For example,

\[
v = \frac{260.034}{w^{0.603}},
\]

where \(v\) – viscosity, Pa·s; \(w\) – shear rate, c/s.

The calculated coefficients of the regression equation are significant at the level of 0.05, the share of variance of the initial data explained by the model (the coefficient of determination \(R^2\)) is 0.99 [13]. Such a high value of this coefficient indicates the high practical significance and adequacy of the equation. For the other samples, the equation of viscosity dependence was found in the form of the following model:

\[
v = \frac{a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4}{w^{b_1x_1+b_2x_2+b_3x_3+b_4x_4}}
\]

where \(w\) – shear rate, c/s; \(a_1, a_2, a_3, a_4, b_1, b_2, b_3, b_4\) – coefficient estimations; \(x_1\) – rice flour portion; \(x_2\) – starch portion; \(x_3\) – xanthan gum portion; \(x_4\) – soy protein isolate portion.

![Figure 1. Dependence of dough viscosity on shear rate in the reference composition.](image-url)
Figure 1 shows a graphical representation of the dependence of the dough viscosity on the shear rate in the reference composition.

The obtained coefficients are significant at the level of 0.05, the share of variance of the initial data explained by the model (the coefficient of determination $R^2$) is 0.9952 [14].

Table 2 presents the results of measuring the dynamic viscosity of the experimental samples of fresh dough depending on the shear rate.

**Table 2.** Dependence of dynamic viscosity of the experimental samples of fresh dough on the shear rate.

| Shear rate, c/s | Sample Number |
|----------------|---------------|
|                | 1  | 2  | 3  | 4  |
| 0.015          | 11850 | 6260 | 4480 | 2115 |
| 0.035          | 4390  | 2680 | 2520 | 1949 |
| 0.045          | 3485  | 2055 | 2230 | 1558 |
| 0.050          | 2715  | 1925 | 1560 | 1562 |
| 0.065          | 2130  | 1515 | 1265 | 1313 |
| 0.125          | 1245  | 1165 | 818  | 679  |
| 0.250          | 615   | 610  | 379  | 356  |
| 2.000          | 114   | 118  | 84   | 78   |
| 3.000          | 73    | 39   | 58   | 52   |
| 3.450          | 66    | 33   | 51   | 47   |

The results of the control measurement of the viscosity of the sample with the optimal composition indicate that the selected mathematical model corresponds to the elastoviscoplastic properties of this dough and the curve changes depending on the composition of the dry dough mixture. To find the optimal ratio of each type of flour and tapioca starch in the dough for the maximum approximation of the viscosity curve to the reference one, the numerical methods for finding optimal solutions to multidimensional problems—mathematical programming methods were used. To do this, the target function was created. For example,

$$F(x_1; x_2; x_3; x_4) = \int_{0.017}^{3.33} (\nu(w, x_{(1)} x_{(2)} x_{(3)} x_{(4)}, \nu(w))^{2} dw, \ (3)$$

where the shear rate is limited from 0.017 c/s to 3.33 c/s.

Using the operation Minimize in MathCAD v15, the optimal values of variables $x_1$, $x_2$, $x_3$, $x_4$ that deliver the minimum of the objective function, are found. The obtained values are the following: $x_1 = 27.78\%; x_2 = 7.22\%; x_3 = 32.22\%; x_4 = 0.28\%$. The obtained viscosity dependences in the optimal dough composition (opti) and the reference one ($\nu(w)$) is shown in figure 2.

Curve 1— the reference dependence, obtained analytically; curve 2 – the experimental dependence, curve 3 – the function, approached to the reference; curve 4 – the result of the experiment of optimal composition.

As a result of the study of the influence of viscosity on the shear rate, it can be noted that by means of the mathematical model and regression analysis, it was possible to select such a ratio of raw materials when the technological properties of the fresh dough are almost as good as the control one. The results show that the optimal ratio of dry components in the recipe of fresh gluten-free dough will be rice flour 27.78%, soy protein isolate 7.22%, potato starch 32.22%, xanthan gum 0.28%.
4. Conclusions and recommendations

The results of the control measurement of the viscosity of the sample with the optimal composition indicate that the selected mathematical model corresponds to the elastoviscoplastic properties of this dough and the curve changes depending on the composition of the dry dough mixture. It can be noted that the application of the mathematical model and the regression analysis make it possible to select the ratio of the prescription components so that the resulting product has rheological characteristics approximate to the control sample.

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