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EFFECT OF STRUCTURE-FORMING AGENTS AND SPONTANEOUSLY FERMENTED BUCKWHEAT SOURDOUGH ON THE QUALITY OF GLUTEN-FREE BREAD

L. Mykhonik, PhD, associate professor[1]
I. Hetman, postgraduatestudent[1], researcher [2]
O. Naumenko, Dr.Sc., head of the department[2]
[1]Department of bakery and confectionery goods technologies
National University of Food Technologies
Volodymyrska St., 68, Kyiv, Ukraine, 01601
[2]Department of bread technologies and biotransformation of grain products
Institute of Food Resources of the National Academy of Agrarian Sciences of Ukraine
Evgeny Sverstyuk St., 4A, Kyiv, Ukraine, 02002

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Correspondence:

O. Naumenko
E-mail: ovnaumenko1@gmail.com

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Abstract. Gluten-free bread is a product with reduced nutritional value, since the amount of starch in its recipes ranges 50–90% of the mass of loose raw materials. A topical task is to improve the nutritional value of gluten-free products by including flour of cereal crops in the recipe as part of a growth medium of baking sourdoughs. Among the entire assortment of structure-forming additives, hydroxypropyl methylcellulose (HPMC) and xanthan gum still remain understudied as to their optimal dosage and effect on the technological process, whether separately or as a composition. Neither is there enough information on using cereal flours, structure-forming agents, and their combinations to manufacture bread with the minimum starch content. Baking tests in the laboratory have shown that in the technology of gluten-free bread with a high cereal flour content, it is advisable to use a combination of the structuring agents HPMC and xanthan gum in the amounts, respectively, 0.75% and 0.25% of the weight of the flour/starch mixture. This technological approach will allow achieving a high volume of bread, a smooth surface, and a well-developed, uniform, and thin-walled porosity of the crumb. Schemes of the dilution and production cycles of spontaneously fermented sourdough made from green buckwheat flour have been developed, and the specific features of preparation and the process parameters have been indicated. The sensory, biotechnological, and physicochemical characteristics of the quality of the finished sourdough have been investigated. Following the technological regulations developed, a high-quality semi-finished product was obtained, which could be further used in the production process. Laboratory tests in baking bread with the addition of the newly created spontaneously fermented buckwheat sourdough have shown results proving that it can be effectively used in the technology of gluten-free products. It has been established that the optimal percentage of sourdough in the recipe of buckwheat-rice gluten-free bread is 10–20% by weight of the flour/starch mixture. It has been proved that the sourdough can intensify acid accumulation processes in the dough and accelerate its maturation. The finished products had a pronounced taste and aroma as a result of the activity of lactic acid bacteria.

Key words: coeliac disease, gluten-free bread, nutritional value, structure formers, green buckwheat flour, spontaneous fermentation, intensification of processes, quality indicators.

Introduction. Formulation of the problem

Among the current trends in healthy nutrition, gluten-free products continue to occupy the leading positions in the category of bakery products, since the deterioration of the environment and unhealthy nutrition cause an increase in the number of coeliac patients.

Besides, information on the benefits of a gluten-free diet is greatly popularised among people who do not have this disease. There are different opinions on this issue, but the number of supporters of gluten-free food products is constantly increasing, that is why it is so important to expand the range of dietary types of bread products [1-3].

To manufacture gluten-free bread products, it is allowed to use processed products of such crops as rice, buckwheat, maize, millet, sorghum, amaranth. In small quantities, the products of the processing of leguminous (soya, peas, beans, lupin) and oil (sunflower, flax, sesame, rape) crops are used, as well as nut raw materials. The recipes of bread products often include starches from maize, potatoes, rice, tapioca, or their mixtures. The amount of starch in the recipe is 50–90% of the weight of loose raw materials. This allows obtaining bread with a high volume and porosity of the crumb structure, but significantly reduces its nutritional value.

Unlike wheat flour, the above-mentioned types of raw materials do not contain gluten proteins. That is why structure-forming agents (like various hydrocolloids) are added to the dough: gums of plant and microbial origin, pectin, gelatine, agar-agar, alginates, modified cellulose (carboxymethyl cellulose and hydroxypropyl methylcellulose), carrageenans, β-glucan, psyllium, etc. [1,4,5].

Green buckwheat groats and its processing products, in particular, flour, are promising raw materials for gluten-free bakery products. Producing green buckwheat flour involves no heat treatment. This allows preserving, to the maximum degree possible, the entire range of vitamins, macro- and micronutrients, the enzyme complex, and powerful antioxidant properties, since it includes flavonoids: orientin, quercetin, vitexin, rutin, etc. A feature of green buckwheat is its high content of high-quality protein, which averages up to 13–15%. It is well assimilated and retains a valuable amino acid base [6]. Besides, the protein composition shows no gluten and the predominant amount of albumins and globulins, which allows using this flour in the technology of gluten-free products. It contains 62–68% of carbohydrates, including those with a low glycaemic index (about 15%), which gives the flour dietetic properties. Fats (3.0–3.5%) are represented by essential polyunsaturated fatty acids (ω-3, ω-6), which are not synthesised by the human body, but must be present in food to ensure the normal functioning of the body. Buckwheat flour contains about 6–12% of fibre. It helps to remove toxins and improve the work of the gastrointestinal tract by speeding up metabolism [7,8].

Green buckwheat flour is rich in vitamins of the B group (B_1, B_2, B_6, B_9), E, PP. Along with phosphorus, they participate in the synthesis and maintenance of nerve cells. This flour also contains a number of macroelements, such as potassium, magnesium, phosphorus, and trace elements: iron, copper, zinc, chromium, molybdenum, manganese [9,10].

Thus, the high nutritional value of buckwheat flour makes it possible to use it as a growth medium for spontaneously fermenting leavens.

The technology of gluten-free bread (unlike traditional bread from wheat and rye flour) only involves resting the dough pieces without the process of dough fermentation. That is why the products taste bland and have a dull aroma. One of the ways to improve the quality of gluten-free bread is the use of sourdoughs, as well as physiologically functional ingredients which increase the nutritional value of products and balance their chemical composition [11].

Analysis of recent research and publications

Creating gluten-free bakery products remains a topical issue for scientists developments.

The scientists developed recipes for protein-free bread from cereal starch and gluten-free bread from cereal flour, and proved the effectiveness of using guar and xanthan gums to ensure the structural and mechanical properties of gluten-free dough [1].

There was also a study of how to correct the mechanostructural properties of gluten-free dough from rice flour by using hydroxypropyl methylcellulose (HPMC) and lecithin [12].

The researchers developed and scientifically substantiated an innovative technology of gluten-free bakery products based on flour mixtures with collagen-containing proteins and the enzyme transglutaminase used as structure-forming agents. The patented new method of gluten-free bread production involves additional processes: suspending of yeast and dissolution of an enzyme preparation of transglutaminase in water [13].

It was proved that psyllium and HPMC, psyllium and guar and xanthan gums synergistically interact in the technology of gluten-free bread based on a starch/flour mixture from maize and potato starch and maize, rice, and millet flour. It was determined what ratios of the ingredients were optimal to obtain high-quality products with improved nutritional value [14].

It was studied how sodium alginate, sodium carboxymethyl cellulose, modified starch, citrus pectin, and xanthan and guar gums affected the quality of protein-free bread. It was established that the best organoleptic and physicochemical indicators were in the bread samples with the addition of 0.5% of xanthan gum to the mass of starch [15].

It was studied what effect sorghum flour, oat bran, and flaxseed flour produced on the technological characteristics of gluten-free steamed-baked bread from maize flour. The positive influence of the selected additives on the organoleptic and physicochemical quality indicators and the nutritional value of finished products were proved [16].

It was established that addition of 2% of pectin, 1% of carboxymethyl cellulose and 1% of β-glucans improved the porosity of gluten-free bread based on rice flour, maize starch, and sodium caseinate and extended the period of the product's freshness [5].

Scientists established the effectiveness of using spontaneous fermentation to develop gluten-free products. The effect of spontaneously fermented rice sourdough on dough's rheological properties was studied, and the indicators of the technological process of making bread from rice flour were analysed and showed that the maturation of dough accelerated and the intensity of acid accumulation increased [17,18].

Under different fermentation conditions, spontaneously fermenting sourdoughs were derived from buckwheat flour. They contained a wide range of well-developed microflora: various types of lactic acid bacteria (LAC) and yeast, sone of which were traditional for wheat and rye sourdoughs, and some were not (the species *Pediococcus pentosaceus, Leuconostoc holzapfelii, Lactobacillus gallinarum, Lactobacillus vaginalis, Lactobacillus sakei, Lactobacillus graminis, Weissella cibaria,*and *Lactobacillus plantarum*). It was proved that the composition of stable microflora mostly depends on the fermentation conditions [19,20].

Spontaneously fermenting sourdough from maize flour was developed, and the microflora was studied at different pH values. It was shown that the optimal pH value was 3.65–3.90 units of the instrument. At this value, strains of LAB, highly active, fast-rising yeast were detected [21,22].

However, there are almost no studies on the use of structuring agents and their combinations for the production of gluten-free bread from cereal flour without the addition of starch. There are also quite few experimental studies on the use of spontaneously fermented sourdoughs in the technology of gluten-free products. This makes scientific research in this direction necessary and topical.

The purpose of the work is to study how structuring agents (xanthan gum, hydroxypropyl methylcellulose) and spontaneously fermented sourdough from green buckwheat flour affect the technological process and quality indicators of buckwheat/rice gluten-free bread. The main research **objectives** are:

– to determine the effective ratio of the structuring agents (HPMC and xanthan gum);

– to develop a scheme for obtaining spontaneously fermented buckwheat sourdough and investigate its properties;

– to establish the amount of buckwheat sourdough in the gluten-free bread recipe;

– to develop the technology of gluten-free bread based on the sourdough with the use of the structuring agents HPMC and xanthan gum.

Research materials and methods

For the baking tests in the laboratory, the following raw materials were used: green buckwheat flour (Organic Eco Product, Ukraine), rice flour (Organic Eco Product, Ukraine), maize starch (Sto Pudov, Ukraine), pressed baker’s yeast TM *Kryvorizki drizhdzhi*(Nadezhda, Ukraine), white crystalline sugar (Sarkara-Group, Ukraine), table salt (Artemsil, Ukraine), maize oil (Kama, Ukraine), HPMC (Chemsale, Ukraine), xanthan gum (Khimprodukt, Ukraine).

The following reagents were used in the research: sodium hydroxide (standard titre (0.1N) 0.1 mol/dm^3) from Alfarus, Ukraine, phenolphthalein (China), methylene blue (India).

All raw materials and reagents complied with regulatory documentation and were stored under the conditions specified on the label.

The following parameters have been determined in the sourdoughs: the mass fraction of moisture (using a Chyzhov machine), titratable and active acidity (using a pH meter), LAB activity (by the intensity of recovery of the blue colour of methylene blue) [23].

Laboratory baking of bread with the addition of structure formers and buckwheat sourdoughs was carried out according to the recipe given in Table 1.

The bread recipe used as the control was based on the one described in patent No. 120726 UA, IPC A21D 13/066 (2017) Gluten-free bread *Smachyy*. HPMC hydrocolloids and xanthan gum were added separately (samples 1 and 2 respectively) and together in the ratios 3:1 (sample 3), 1:1 (sample 4), 1:3 (sample 5). The amount of the structure former added was 1% by weight of the flour/starch mixture.

Flour, starch, and structuring agents had been pre-mixed in dry form. Sugar and salt were dissolved in water with a temperature of 37±2°C, yeast was introduced in the form of a yeast suspension with water (in the ratio 1:3). Spontaneously fermenting sourdough was previously prepared from buckwheat flour, its scheme of preparation and amount are given in Table 3. Buckwheat sourdough and oil were added to the dough without prior preparation. The dough was mixed according to the recipe for 2 minutes using a mixer KVL4100S (China) at the mixing speed 200 rpm. Then the dough was divided into dough pieces weighing 0.22–0.23 kg each, which were placed into moulds and rested until ready (without the fermentation process) in a proofing cabinet XLT 133-UNOX at 36–38°C and a relative humidity of at least 75%. The dough pieces were baked in a steam-humidified oven at 210–220°C for 20–25 min. The piece without no fermentation starter added was the control sample.

Table 1 – Recipe compositions for gluten-free bread

Raw material	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Green buckwheat flour, g	40.0	40.0	40.0	40.0	40.0
Rice flour, g	30.0	30.0	30.0	30.0	30.0
Maize starch, g	30.0	30.0	30.0	30.0	30.0
Pressed yeast, g	3.0	3.0	3.0	3.0	3.0
Table salt, g	2.0	2.0	2.0	2.0	2.0
Sugar, g	4.0	4.0	4.0	4.0	4.0
Maize oil, g	5.0	5.0	5.0	5.0	5.0
Xanthan gum, g	-	1.0	0.25	0.5	0.75
HPMC, g	1.0	-	0.75	0.5	0.25

The organoleptic indicators of the quality of the finished products were determined according to DSTU 7044:2009, and the physicochemical ones according to DSTU 7045:2009 four hours after baking. The specific volume of the products was determined according to the method [Tekhnokhimichnyi kontrol syrovyny ta khlibobulochnykh i makaronnykh vyrobiv, za red. chl.-kor. V. I. Drobot, 2015].

Results of the research and their discussion

Determination of the effective composition and ratio of structure-forming agents.

It has been found in literature sources that the following structure-forming additives are most widely used in gluten-free bread technologies: sodium alginate, sodium carboxymethyl cellulose, modified starch, citrus pectin, xanthan gum, guar gum. Most starch-based mixtures included HPMC separately or in combination with other structure-forming agents, in particular, xanthan gum [1,14,15]. However, the data on how they affect the dough system are insufficient. So, we have studied the effect of HPMC and xanthan gum on the technological process and the quality of gluten-free bread based on cereal flour. The findings are shown in Table 2.

As a result of the laboratory baking of bread according to the recipes developed (see Table 1), it has been established that the HPMC-containing products (sample 1) had a volume larger by 18.4% and a uniform, thin-walled structure of porosity, as compared with the xanthan gum-containing products (sample 2), but a worse surface, with cracks and irregularities (Table 2). These results are confirmed by other scientists' research: they found that increasing the HPMC amounts 1.0% and more are ineffective, because this results in thickening of the crumb and in cracks appear on the surface of products [14].

The addition of HPMC and xanthan gum in equal amounts (1:1) allowed improving the condition of the surface of the products (sample 4), but no positive changes in the volume and porosity indicators were observed, and the pore structure was uneven and thick-walled. The authors [15] observed that adding up to 0.5% of xanthan gum had a positive effect on the mechanostructural parameters of the dough.

The addition of a combination of HPMC and xanthan gum, with the predominance of the latter (sample 5) led to a decrease in the volume and porosity of bread by 4–12% and 19.6–22.0% respectively, compared with the other samples. The surface of the products was smooth, without cracks, and the porosity structure was uneven, thick-walled. The scientists [5] also reported that an increase in xanthan gum had no positive effect on the volume and porosity of the products, although the bread crumb was characterised by high elasticity.

We have established that the quality of the finished bread increased by all the indicators when both structure-forming agents were introduced in combination where the amount of HPMC was higher. The products containing HPMC and xanthan gum in the ratio 3:1 (sample 3) had well-developed, thin-walled, fine crumb porosity (by 9.7–37.0% higher than in other samples) and a bigger volume (by 6.2–20.8%).

Preparation of spontaneously fermented sourdough from green buckwheat flour.

Usually, spontaneously fermented sourdough is made in 2 cycles: dilution cycle and production cycle [11,24,25]. That is why first the scheme of the dilution cycle for the preparation of spontaneously fermented sourdough in a laboratory environment was developed (Table 3).

Table 2 – Effect of xanthan gum and HMPC on the quality indicators of gluten-free bread

Indicator	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Specific volume, $cm^3/100g^{1)}$	225	190	240	212	198
Porosity, %$^{2)}$	65	45	72	63	56
Colour of the crust	Light yellow				
Surface condition	Uneven, flat, with small cracks on the surface	Smooth, without cracks	Smooth, convex, without cracks	Smooth, without cracks	Smooth, convex, without cracks
Colour of the crumb	Creamy yellow				
Porosity structure of the crumb	Small, uniform, thin-walled	Large, thick-walled	Small, uniform, thin-walled	Large, uneven thick-walled	Large, uneven thick-walled
Taste and smell	Pleasant, characteristic of this type of products, with a slight aftertaste and aroma of buckwheat				

$^{1,2)}$ – arithmetic mean value, *n*=5; confidence intervals: $^{1)}$ ±0.5; $^{2)}$ ±0.1; p≤0.05

Table 3 – Dilution cycle of spontaneously fermented sourdough from green buckwheat flour in a laboratory environment

Dilution cycle stage	Biotechnological indicators of sourdough at the end of the stage
1 stage. Mixing the components: Flour– 0.05 kg; Water – 0.075 l. Fermentation*	Acidity – 3.2 degrees Activity of LAB > 120 min
2 stage. First refreshment: 1st stage sourdough – 0.125 kg; Flour – 0.05 kg; Water – 0.075 l. Fermentation*	Acidity – 6.4 degrees Coefficient of volume increase – 1.1 Activity of LAB - 115 min
3 stage. Second refreshment: 2nd stage sourdough – 0.25 kg; Flour – 0.1 kg; Water – 0.15 l. Fermentation*	Acidity – 10.4 degrees Coefficient of volume increase – 1.21 Activity of LAB – 92 min
4 stage. Third refreshment: 3rd stage sourdough – 0.5 kg; Flour – 0.2 kg; Water – 0.3 l. Fermentation*	Acidity – 14.6 degrees Coefficient of volume increase – 1.3 Activity of LAB – 74 min
5 stage. Fourth refreshment: 4th stage sourdough – 1.0 kg; Flour – 0.4 kg; Water – 0.6 l. Fermentation*	Acidity – 16.0 degrees Coefficient of volume increase – 1.35 Activity of LAB – 70 min
6 stage. Fifth refreshment: 5th stage sourdough – 2.0 kg; Flour – 0.8 kg; Water – 1.2 l. Fermentation*	Acidity – 16.6 degrees pH – 3.79 units of device Mass fraction of moisture – 60.5% Coefficient of volume increase – 1.3 Activity of LAB – 45 min

Note: *Conditions for sourdough fermentation at each stage: duration 24 hours, temperature 26–28°C

At the beginning of the 1st stage, green buckwheat flour was mixed with water in the ratio 1:(1–1.25). The dilution cycle consisted of 6 consecutive stages lasting 120 hours. Every 24 hours, a nutrient mixture of flour and water was added to the mature sourdough from the previous stage in the ratio 1:(1–1.25) and cultured at 28–30°C. At the end of the 6th stage, by the sensory and physicochemical indicators, the quality of the sourdough stabilised. It now had a pleasant, mildly pronounced acid-alcohol smell reminding of buckwheat. The activity of LAB was high – 45 min, which meant maturity of the sourdough obtained. Bakery microorganisms dominated in its microbiota. Based on the properties investigated, it has been shown that the sourdough obtained from the 6th stage can be further used in the production cycle to make bread.

The production cycle involved the selection of the ready sourdough from the 6th stage of the dilution cycle in a laboratory environment every 12 hours. Three parts of the nutrient mixture of flour and water (1:1.25) were added to one part of the remaining sourdough.

The acidity of the production sourdough obtained was 16.0–18.0 degrees, pH 3.66–3.79 units of device, activity of LAB 55–65 min.

The influence of spontaneously fermented sourdough on the technological process and the quality of finished products.

It has been studied how effective it is to use the obtained sourdough in the gluten-free bread technology to accelerate the dough-resting process and improve its consumer properties.

In order to determine the dose of sourdough added, laboratory baking of bread was carried out according to the recipe developed (see Table 1, sample 3). The structure formers HPMC and xanthan gum were used in the selected ratio 3:1 (see Table 2, sample 3). Sourdough was dosed in the amount 10–30% of the weight of the flour/starch mixture. The results of the research are presented in Table 4.

It has been established that sourdough intensified the accumulation of acids in the dough, causing an increase in the acidity by 0.8–1.6 degrees, depending on the dosage. Since a part of the “fermented” flour was added together with sourdough, the dough matured faster, and the duration of rest was reduced by 5–10 min, compared with the control sample without sourdough.

It has been shown that the addition of sourdough activated microbiological and biochemical processes in the dough, which had a positive effect on the quality indicators of the finished products (Table 5). Thus, the specific volume and porosity significantly increased with the addition of 20% of sourdough, the correlation coefficient being, respectively, r = 0.81 and 0.64 (n = 10, p < 0.05).

The data obtained are consistent with the studies of other scientists, who also observed a positive technological effect from the addition of rice sourdough (no more than 20% by weight of flour) in the technology of makinggluten-free bread from rice and chestnut flour [18].

The products of the activity of the sourdough microbiota had a positive effect on the organoleptic and physicochemical parameters of bread quality. Thus, the sourdough-based products had an obvious advantage over the control sample due to their more pronounced acid-alcohol, "buckwheaty" taste and aroma, well-developed, uniform, thin-walled porosity structure, and elastic crumb. The addition of sourdough improved the colour of the crust. Conversely, the bread without no sourdough added had a bland taste and paler crust (Fig. 1).

It is known that the addition of sourdough resulted in better accumulation of low-molecular-weight compounds in the dough and, accordingly, in a more intensive course of the melanoidin-formation reaction [24,25].

It has been recorded that bread with the addition of 30% of sourdough had higher acidity, which worsened its sensory properties. Based on the results obtained, the recommended dose of adding sourdough is 10–20% of the weight of buckwheat flour.

Field testing of the research results. The research results can be used in manufacture to model new and improve the existing recipes of gluten-free bread products, thus expanding their range on the market. Testing the newly developed recipe of gluten-free bread based on sourdough with the use of the structure formers HPMC and xanthan gum is the objective for further research.

Table 4 – Technological process parameters and dough quality indicators

Indicator		Control sample (without sourdough)	Sample 1	Sample 2	Sample 3
			(10% of sourdough)	(20% of sourdough)	(30% of sourdough)
Mass fraction of moisture, %$^{1)}$		50.2	50.2	50.4	50.5
Acidity, degrees$^{2)}$	Initial	1.6	2.4	2.6	3.0
	Final	2.2	3.2	4.0	4,6
Duration of resting, min$^{3)}$		55	50	45	45

$^{1, 2, 3)}$ arithmetic mean value, *n*=5; confidence intervals: $^{1)}$ ±0.01; $^{2)}$ ±0.1; $^{3)}$ ±1.0; p≤0.05

Table 5 – Quality indicators of finished products

Indicators	Control sample (without sourdough)	Sample 1	Sample 2	Sample 3
		(10% of sourdough)	(20% of sourdough)	(30% of sourdough)
Specific volume, cm^3/100g$^{1)}$	248	262	260	258
Porosity, %$^{2)}$	64	66	68	67
Mass fraction of moisture, %$^{3)}$	49.6	49.5	49.6	49.8
Acidity, degrees $^{4)}$	1.8	2.5	3.2	3.8

$^{1, 2, 3, 4)}$ arithmetic mean value, *n*=5; confidence intervals: $^{1)}$ ±0.5; $^{2)}$ ±0.1; $^{3)}$ ±0.01; $^{4)}$ ±1.0; p≤0.05

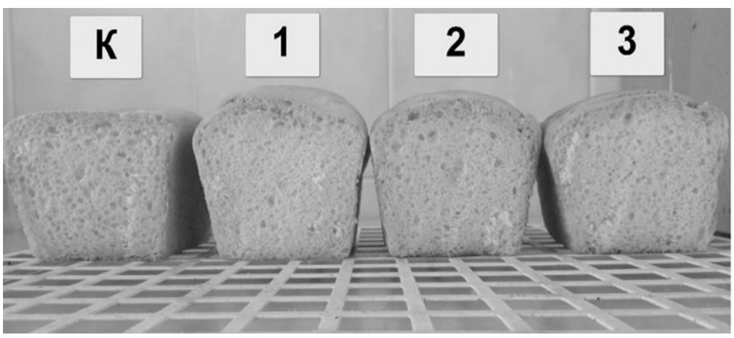

Fig. 1. Products with the addition of buckwheat sourdough:
C – control sample; 1 – 10% of sourdough; 2 – 20% of sourdough; 3 – 30% of sourdough

Conclusion

As the number of coeliac patients is increasing and the trend of preventive healthy nutrition spreading, it is necessary to develop competitive technologies for the production of gluten-free bread to provide people with dietetic products.

This research, have allowed establishing effective technological solutions for the use of structure-forming agents (HPMC and xanthan gum) and spontaneously fermented sourdough from green buckwheat flour in the gluten-free bread technology.

Schemes have been developed, technological parameters of dilution and production cycles of spontaneously fermentated buckwheat sourdough have been established, and quality indicators of finished sourdough have been determined. According to the technological regulations developed, a high-quality semi-finished product suitable for use in the further production process has been obtained.

It has been shown that in the technology of rice-buckwheat gluten-free bread, it is practical to use a combination of the structuring agents HPMC and xanthan gum in the ratio 3:1 (0.75% of HPMC and 0.25% of gum) to the weight of the flour-starch mixture. This ensures obtaining high-volume products with a smooth surface without cracks and a well-developed, uniform, and thin-walled structure of the crumb porosity.

The optimal amount of buckwheat sourdough in the recipe of rice-buckwheat gluten-free bread has been established: 10–20% of the weight of the flour/starch mixture. The sourdough created has made it possible to intensify acid accumulation in the dough, accelerate its maturing processes, and improve the taste and aroma of the finished bread.

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ВПЛИВ СТРУКТУРОУТВОРЮВАЧІВ ТА ГРЕЧАНОЇ ЗАКВАСКИ СПОНТАННОГО БРОДІННЯ НА ЯКІСТЬ БЕЗГЛЮТЕНОВОГО ХЛІБА

Л.А. Михонік, к.т.н., доцент[1], *E-mail*: gm_lora@i.ua
І.А. Гетьман, аспірант[1], науковий співробітник[2], *E-mail*: getmaninna7@gmail.com
О.В. Науменко, д.т.н., зав. відділу[2], *E-mail*: ovnaumenko1@gmail.com
[1]Кафедра технології хлібопекарських і кондитерських виробів
Національний університет харчових технологій, вул. Володимирська, 68, м. Київ-33, Україна, 01601
[2]Відділ технологій хліба та біотрансформації зернових продуктів
Інститут продовольчих ресурсів Національної академії аграрних наук України
вул. Євгена Сверстюка, 4А, м. Київ, Україна, 02002

Анотація. Безглютеновий хліб належить до виробів зі зниженою харчовою цінністю, оскільки кількість крохмалю в рецептурах коливається в межах 50–90 % від маси сипкої сировини. Актуальним завданням є покращення харчової цінності безглютенових виробів за рахунок включення в рецептуру борошна круп'яних культур у складі живильного середовища для хлібопекарських заквасок. Серед усього асортименту структуроутворюючих добавок мало вивченими, з точки зору оптимального дозування та впливу на технологічний процес, залишаються гідроксипропілметилцелюлоза (ГПМЦ) та камедь ксантану, окремо або в композиції. Даних щодо використання борошна круп'яних культур, структуроутворювачів та їх комбінацій для виробництва хліба з мінімальним вмістом крохмалю також обмаль. У результаті пробних лабораторних випікань встановлено, що в технології безглютенового хліба з високим вмістом борошна круп'яних культур доцільно використовувати комбінацію структуроутворювачів ГПМЦ та камеді ксантану в кількості, відповідно, 0,75% та 0,25% до маси борошняно-крохмальної суміші. Такий технологічний підхід дозволить отримати хліб високого об'єму, з гладенькою поверхнею, добре розвинутою, рівномірною та тонкостінною структурою пористості м'якушки. Розроблено схеми розвідного та виробничого циклів ведення закваски спонтанного бродіння з борошна зеленої гречки зі зазначенням специфічних особливостей приготування та параметрів процесу; досліджено органолептичні, біотехнологічні та фізико-хімічні показники якості готової закваски. Згідно з розробленим технологічним регламентом отримано напівфабрикат високої якості, придатний для використання у виробничому процесі. Результати пробних лабораторних випікань хліба з додаванням створеної гречаної закваски спонтанного бродіння засвідчили ефективність її використання в технології безглютенових виробів. Було визначено оптимальне дозування закваски в рецептурі гречано-рисового безглютенового хліба, яке становило 10–20% до маси борошняно-крохмальної суміші. Доведено, що закваска здатна інтенсифікувати процеси кислотонакопичення в тісті та прискорити процеси його дозрівання, а готові вироби в результаті життєдіяльності молочнокислих бактерій мали яскраво виражений смак і аромат.

Ключові слова: целіакія, безглютеновий хліб, харчова цінність, структуроутворювач, борошно зеленої гречки, закваска спонтанного бродіння, інтенсифікація процесів, показники якості.