UDC 664.664.9

EFFICIENCY OF SOURDOUGHS OF SPONTANEOUS FERMENTATION FROM CEREAL FLOUR IN BAKERY TECHNOLOGIES

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https://doi.org/10.31073/foodresources2023-20-03

Subject. *Sourdoughs of spontaneous fermentation from buckwheat, oat and rice flour, as well as dough and bread with the addition of the above-mentioned sourdoughs. The goal is to investigate the effectiveness of the use of oat, buckwheat and rice sourdoughs of spontaneous fermentation in the technology of bread products of various assortments.* ***Methods.*** *When conducting research, generally accepted methods were used, as well as cause-and-effect analysis, experimental, calculation and logical generalization.* ***Results.*** *In the conditions of the development of discrete production and the popularity of sourdough products, it is effective to use spontaneous fermentation. At the same time, it is worth paying special attention to the search for non–traditional ingredients to improve the nutritional value of wheat flour products and dietary types of bread. The scientific novelty of the results consists in the development and description of the cycles of conducting spontaneous fermentation starters with non-traditional fermentation substrate – green buckwheat, oat and rice flour with further modeling of recipes of bread products of various assortments: wheat, wheat-rye and gluten-free. As a result of the developed management schemes, buckwheat, oat and rice sourdough of spontaneous fermentation was created and the effectiveness of their use in the technology of a wide range of bread products was proven. The feasibility of using buckwheat and oat sourdough in the recipes of wheat and wheat-rye bread, and rice and buckwheat sourdough in the recipe of gluten-free bread is justified. Using the method of trial laboratory baking, the optimal dosages of each leaven were selected and the specifics of using each of them were described, depending on the recipe of the bread. It has been established that the addition of leavens contributes to the improvement of the taste–aromatic properties of the products and more intensive acid accumulation in the dough.* ***Scope of results.*** *The obtained results can be used by manufacturers in the modeling of new and correction of already existing recipes of health and dietary bread.*

Key words*: sourdough of spontaneous fermentation, flour of cereal crops, quality indicators, wheat bread, wheat-rye bread, gluten-free bread.*

ЕФЕКТИВНІСТЬ ЗАКВАСОК СПОНТАННОГО БРОДІННЯ З БОРОШНА КРУПЯНИХ КУЛЬТУР В ТЕХНОЛОГІЯХ ХЛІБНИХ ВИРОБІВ

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https://doi.org/10.31073/foodresources2023-20-03

Предмет. *Закваски спонтанного бродіння з гречаного, вівсяного та рисового борошна, а також тісто та хліб з додаванням вищезазначених заквасок.* ***Мета.*** *Дослідити ефективність використання вівсяної, гречаної та рисової заквасок спонтанного бродіння в технології хлібних*

*виробів різного асортименту. **Методи.** При проведенні досліджень використані загальноприйняті методи, а також методи причинно-наслідкового аналізу, експериментальні, розрахункові та логічного узагальнення. **Результати.** В умовах розвитку дискретного виробництва та популярності виробів на заквасках, ефективно використовувати спонтанне зброджування. Водночас варто приділити окрему увагу пошуку нетрадиційних інгредієнтів для покращення харчової цінності виробів з пшеничного сортового борошна та дієтичних видів хліба. Наукова новизна результатів полягає в розробці та описі циклів ведення заквасок спонтанного бродіння з нетрадиційним заквашувальним субстратом – борошном зеленої гречки, вівсяним та рисовим з подальшим моделюванням рецептур хлібних виробів різного асортименту: пшеничного, пшенично-житнього та безглютенового. В результаті розроблених схем уведення було створено гречану, вівсяну та рисову закваску спонтанного бродіння та доведено ефективність їх використання в технології широкого асортименту хлібних виробів. Обґрунтовано доцільність використання гречаної та вівсяної закваски в рецептурах пшеничного та пшенично-житнього хліба, а рисової, гречаної закваски – в рецептурі безглютенового хліба. Методом пробних лабораторних випікань підібрано оптимальні дозування кожної закваски та описано особливості використання кожної з них, залежно від рецептури хліба. Встановлено, що додавання заквасок сприяє покращенню смако-ароматичних властивостей виробів та інтенсивнішому кислотонакопиченню в тісті. **Сфера застосування результатів.** Отримані результати можуть бути використані виробниками при моделюванні нових та коригуванні уже існуючих рецептур хліба оздоровчого та дієтичного призначення.*

***Ключові слова:** закваска спонтанного бродіння, борошно круп'яних культур, показники якості, пшеничний хліб, пшенично-житній хліб, безглютеновий хліб.*

Formulation of the problem. Sourdoughs of spontaneous fermentation are sourdoughs in which the driving force of the fermentation of the water–flour mixture is the natural microflora of the raw material – fermentation substrate. Today, there is a growing demand for national bakery products made using authentic technologies. National bread baking is characterized by the spontaneous fermentation of a nutritious mixture of flour and water, with the addition of straw, hops, etc. On the other hand, the popularity of spontaneous leavened products is facilitated by the spread of mini–productions, both individually and at bakeries, hotel, restaurant and tourist complexes with their own baking. Such establishments usually have small volumes of production, minimal areas and limited resources, under such conditions the use of spontaneous starters is particularly convenient and effective [1,2].

The main advantages of using sourdoughs in bread products are:

– increasing the acidity and accelerating the ripening of the dough;

– properties of a preservative, as the sourdough produces bacteriocins (peptides with a bacterial effect), antifungal and other antimicrobial substances that inhibit pathogenic microflora;

– strengthening of the taste–aromatic properties of ready-made bread;

– long–term preservation of freshness of products and extension of storage terms;

– raising the dough (if there is no commercial baking yeast);

– improving the digestion of bread by the human body;

– higher digestibility of mineral substances, due to the ability to inhibit the formation of salts of macro- and micronutrients [3,4].

At the same time, the technologies of sourdough bread are quite complex, since sourdough is a semi-finished product with complex, multi-stage, interrelated processes. The lack of systematized data on the patterns of development of fermentation microflora in breeding and production cycles of various starter cultures makes it necessary to deepen research in this direction [1, 5]. It is worth noting that in Ukraine, the interest of scientists in the problems of bread production on spontaneous sourdough is at the stage of development, while abroad such research has been relevant for a long time.

The use of non-traditional nutrient media for fermentation or their partial replacement of wheat or rye flour is growing in popularity. In Ukraine, the vast majority of research is devoted to traditional rye and wheat sourdoughs of spontaneous fermentation [1, 2, 6] and there is not enough research, in particular, on the use of cereal flour as a nutrient medium for sourdoughs. In

view of the peculiarities of the chemical composition and a more balanced composition of nutrients, in comparison with wheat flour, green buckwheat, oat and rice flour was chosen.

Oat flour, compared to wheat flour, is characterized by a reduced content of starch and an increased content of fat, contains all essential amino acids, vitamins E, A, H, group B, micro- and macroelements (K, Mg and Fe), which play an important role in metabolism [7, 8].

Features of the carbohydrate composition of oat flour, as is known, are the presence of soluble polysaccharides: pentosans, levulesan, as well as prebiotic and immunostimulant β-glucan, which makes up most of the hemicellulose of flour.

Green buckwheat flour preserves the entire complex of useful substances to a greater extent than buckwheat flour made from heat-treated (brown) buckwheat groats. It has a high protein content (13–15%) with a balanced amino acid composition. Buckwheat flour contains more calcium and iron than flour of other cultures, it contains vitamins B1, B2, PP and E. Fiber in buckwheat flour is 1.5–2 times more than in oat flour [7, 9].

Rice flour is a traditional raw material for gluten-free products due to the absence of gluten protein fractions in its composition. The technological properties of flour make it possible to obtain high-quality products with a more valuable chemical composition and better organoleptic indicators, compared to products based only on starch. Proteins in flour are 7–8%, but in terms of amino acid composition, they are close to the proteins of human milk [8, 10].

The purpose of our work was to investigate the effectiveness of the use of oat, buckwheat and rice leavens of spontaneous fermentation in the technology of bread products of various assortments.

Materials and methods. The raw materials for making bread were: wheat flour of the highest grade, de–hulled rye flour (TM "Zernari", Ukraine), green buckwheat flour (TM "Organik Eco Product", Ukraine), oat flour (TM "Alta Vista", Ukraine), flour rice (Organic Eco Product LLP, Ukraine), corn starch (Sto Pudov, Ukraine), pressed baker's yeast (Kryvorizky Yeast TM, Ukraine), table salt (Artemsil SE, Ukraine), sunflower oil (Kama LLC, Ukraine), corn oil (Kama LLC, Ukraine), white crystalline sugar (Sarkara-Group LLC, Ukraine), HPMC (Himsale LLC, Ukraine), xanthan gum (Khimprodukt LLC ,Ukraine), drinking water.

The fermentation process consists of a dilution cycle and a production cycle. In the dilution cycle, sourdough is prepared from grain flour (oatmeal, green buckwheat, rice flour) and water (temperature 30±2 °C) according to schemes developed in previous studies [5, 11]. The duration of the breeding cycle, during which the sourdough acquires consistently high quality indicators, is 120 hours for buckwheat and rice sourdough, 96 hours for oat sourdough, that is, it includes 4–5 phases. A nutritious mixture of flour and water is added to the ripe sourdough of preliminary preparation in the following ratio: for rice – 1:1; buckwheat – 1:1.5, oat – 1:2. The duration of fermentation of each phase is 22–24 hours, the temperature is 26–28ºC.

In the production cycle, the sourdough is maintained by introducing a nutrient mixture of flour and water, followed by fermentation for 10–12 hours until the acidity is 16–18 degrees. The ratio of starter and nutrient mixture is 30:70 for buckwheat and oat, 50:50 for rice [5, 11].

The dough for wheat bread was prepared by steamless accelerated method using oat and buckwheat sourdough, for wheat and rye bread – on buckwheat and oat sourdough. Rice and buckwheat sourdoughs were used for gluten-free bread. It was prepared as follows: flour, starch and structure formers were pre-mixed in dry form. In each technology, sugar and salt were dissolved in water with a temperature of (35±2) °C, yeast was added in the form of a yeast suspension in a ratio of 1:3 with water, and appropriate sourdoughs were added.

Kneading was carried out using a dough mixer ("KVL4100S", China) for (10±2) minutes, for gluten–free bread – (5±2) min. The duration of fermentation of wheat and wheat-rye dough was (90±2) min at a temperature of (32±2) °C until the volume increased by 1.5 times. The gluten-free dough was immediately divided into dough blanks by hand weighing (225±5) g, which were left in molds (without the fermentation process) in the «XLT 133-UNOX» proofing cabinet at a temperature of (35±2)ºC until ready. Wheat and wheat-rye dough was manually divided into dough blanks weighing (290±10) g.

Next, the dough blanks for wheat and wheat–rye bread were formed manually and proofed. Proofing of dough blanks for wheat bread took place for (30±5) min, for wheat–rye bread – for (40±5) min at a temperature of (35±2)ºС in a proofing cabinet («XLT 133–UNOX», Italy). The readiness of dough blanks during proofing was determined by sensorial evaluation. Next, the dough blanks were sent to the oven («Unox XFT133», Italy), where they were baked at a temperature of 180–200ºС for (30±2) min. The control for wheat bread was bread with wheat sourdough of spontaneous fermentation, for wheat–rye bread – with rye sourdough of spontaneous fermentation, for gluten-free bread – without sourdough.

In the starters, the mass fraction of moisture was determined using the Chyzhov apparatus, the titrated acidity was determined by the titration method, and the activity of lactic acid bacteria was determined by the intensity of restoration of the blue color of methylene blue [12]. Cell densities of lactic acid bacteria, yeasts were determined by plating serially diluted sourdoughs, accordingly, on Sourdough MRS agar media, on Sabouraud Dextrose agar medium, supplemented with chloramphenicol (0.1 g/l), at 30 °C for 48 h [13].

Determination of sensorial indicators of the quality of finished products was carried out according to the methods [10].

The moisture content of bread was determined by the standard method of drying a sample in a SESH-3M drying cabinet at a temperature of 130ºС , acidity – by an accelerated method [12].

The specific volume of the products, the porosity, and the dimensional stability of the bread were determined according to generally accepted methods [10, 13].

Results and discussion.

According to the schemes developed in previous researches, sourdoughs of spontaneous fermentation were derived from oat, rice flour and green buckwheat flour, the quality indicators of which are listed in Table 1.

Table 1

Indicators of the quality of sourdoughs in the production cycle

Indicators*	Sourdough		
	Buckwheat	Rice	Oat
Mass fraction of moisture,%	57.5±0.2	53.5±0.2	62.0±0.2
Acidity, degrees	16.2±0.2	12.4±0.2	16.8±0.2
Activity of lactic acid bacteria, min	60±1.0	75±1.0	62±1.0
The number of lactic acid bacteria, CFU/g	$(3.1\pm0.2)\times10^9$	$(1.6\pm0.2)\times10^9$	$(3.9\pm0.2)\times10^9$
Amount of yeast, CFU/g	$(1.5\pm0.2)\times10^9$	$(5.5\pm0.2)\times10^8$	$(1.7\pm0.2)\times10^8$

*average arithmetic values, n=5; $p\leq0.05$.

According to the selected management parameters, buckwheat and oat leavens are characterized by high acidity. The values are in the same range, 16–18 degrees, the values of indicators of activity of lactic acid bacteria are characterized as high. Rice sourdough has a lower mass fraction of moisture than other sourdoughs and is able to accumulate 3.8–4.4 degrees lower acidity than buckwheat and oats. At the same time, the microbiological composition of each of the starters differs by a sufficient number of colony-forming units of lactic acid bacteria and yeast, being within the same order. It is worth noting that rice sourdough has a greater number of yeasts, which is explained by lower humidity and acidity, which create favorable conditions for their development.

These sourdoughs are proposed to be used for the purpose of enriching bread products and intensifying the technological process during the production of gluten–free, wheat and wheat–rye bread.

The following recipe was used for wheat bread, g per 100 g of flour: wheat flour of the first grade – 100; pressed baker's yeast – 2.0; table salt – 1.5; white crystalline sugar – 2.0; sunflower oil – 2.0; water – by calculation.

The control was bread with wheat sourdough of spontaneous fermentation with the following quality indicators: acidity – 14.5 degrees, mass fraction of moisture – 58.0%, activity of lactic acid bacteria – 40 min, lifting force – 35 min. It has been established that for wheat bread it is advisable to use buckwheat and oat sourdough in the amount of 15% to the mass of flour. In the case of the specified dosage, the amount of flour that is introduced with leaven is about 9%, thus, the corresponding amount of wheat flour is replaced by the corresponding flour of cereal culture. The summarized results are given in the table. 2.

Table 2

Wheat bread quality indicators

Indicators*	With the addition of sourdough		
	Wheat (15%)	Buckwheat (15%)	Oat (15%)
Specific volume, cm^3/g	2.62	2.54	2.46
H/D field bread	0.46	0.44	0.45
Porosity,%	73.0	72.0	72.0
Mass fraction of moisture,%	40.6	42.4	41.9
Acidity, degrees	3.2	4.0	4.4

*average arithmetic values, n=5; $p \leq 0.05$.

Addition of cereal flour with sourdough instead of wheat up to 20% worsens shape stability and leads to an increase in the acidity of bread above standard values, which is also felt during sensorial evaluation.

At a dosage of 15% of sourdough to the mass of flour, the acidity value does not exceed the normative value, the volume, porosity and dimensional stability do not significantly differ from the control, the products have a pleasant slightly acidic taste with a hint of buckwheat or oats.

For wheat–rye bread, a unified recipe was used, g per 100 g of flour: high–grade wheat flour – 70; peeled rye flour – 30; pressed baker's yeast – 1.5; table salt – 1.5. For wheat and rye bread, we recommend dosing 30% of buckwheat or oat sourdough to the total mass of flour. In the case of the specified dosage, the amount of cereal flour, which is added with leaven, is 11–13%. Bread with rye sourdough of spontaneous fermentation with quality indicators was used as a control: acidity – 16.8 degrees, mass fraction of moisture – 60.3%, activity of lactic acid bacteria – 73 min, lifting force – 45 min. The summarized results are given in the table. 3.

Table 3

Quality indicators of wheat–rye bread

Indicators*	A sample with the addition of sourdough		
	Rye (30%)	Buckwheat (30%)	Oat (30%)
Specific volume, cm^3/g	2.35±0.5	2.32±0.5	2.28±0.5
Porosity,%	65±0.2	64±0.2	63±0.2
H/D field bread	0.42±0.3	0.40±0.3	0.39±0.3
Mass fraction of moisture,%	46.4±0.2	46.1±0.2	46.9±0.2
Acidity, degrees	7.2±0.2	6.5±0.2	7.0±0.2

*average arithmetic values, n=5; $p \leq 0.05$.

When the sourdough was dosed in the amount of 30% to the mass of flour, the products were characterized by a pronounced aroma characteristic of a certain type of flour with an acidic aftertaste, while the control had a characteristic acetic acid aroma. The sensorial indicators did not differ either.

The positive influence of sourdoughs on dough ripening processes has been established. The absence of gluten proteins in the added buckwheat and oat flour leads to a decrease in the shape and gas retention capacity, but if the leaven is not more than 30%, it does not significantly affect the quality of the finished products. According to physical and chemical parameters, the

products met the requirements of regulatory documentation. They did not significantly differ from the control in terms of acidity.

To determine the influence of sourdough on the quality indicators of gluten–free products, the recipe *«Khlib bezghliutenovyi smachnyi»* [14] was used. Rice sourdough in the amount of 30% and buckwheat sourdough in the amount of 20% to the weight of the flour–starch mixture were used for research (the mass of flour in sourdough is 5–15%, depending on the type of sourdough). Unleavened bread served as a control. The summarized results are given in the table. 4.

Table 4

Quality indicators of gluten–free bread

Indicators*	Control (without sourdough)	With the addition of sourdough	
		Buckwheat (20%)	Rice (30%)
Specific volume, cm^3/g	3.20±0.5	3.62±0.5	3.44±0.5
Porosity,%	62±0.2	67±0.2	65±0.2
Mass fraction of moisture,%	50.0±0.2	50.0±0.2	49.2±0.2
Acidity, degrees	1.5±0.2	2.8±0.2	2.6±0.2

*average arithmetic values, n=5; p≤0.05.

It was established that the addition of leavens intensifies the accumulation of acids, leading to an increase in the acidity of bread by 1.3–1.6 degrees, depending on their dosage. The duration of standing was reduced by 6–10 minutes compared to the control. The activation of microbiological and biochemical processes in sourdough dough has a positive effect on the volume of products and porosity, which increase with an increase in the dosage of sourdough.

The addition of sourdough improves the sensorial indicators of the products, which are characterized by a pronounced acid–alcohol, in the sample with buckwheat flour – a "buckwheat" taste and aroma and a developed even thin-walled structure of porosity, as well as an elastic crumb, the color of the crust for the product with buckwheat sourdough also improves. This can be explained by the better accumulation of low-molecular-weight compounds in the dough with buckwheat sourdough, and, accordingly, the more intensive course of the reaction of melanoid formation, as scientists found out [8]. Bread without adding sourdoughs had insipid taste and a paler crust.

Conclusions. It was found that the peculiarities of the chemical composition of the flour of cereal crops create prospects for conducting research on their use as leavening substrates during spontaneous fermentation.

The effectiveness of the use of sourdoughs of spontaneous fermentation from the flour of cereal crops in the technologies of products of the following assortment has been proven: wheat bread, wheat-rye and gluten-free bread.

We have researched that the use of such sourdoughs has a positive effect on the taste-aromatic indicators of bread: the characteristic acetic acid aroma of wheat-rye, the slightly pronounced acid aroma of wheat and the fresh taste of gluten-free bread have changed to a pronounced acid–alcohol taste and aroma characteristic of the corresponding wholemeal flour cultures.

The research showed that the use of sourdoughs can level the insignificant decrease in some physico-chemical indicators of bread quality, in particular, volume, dimensional stability, porosity when "gluten-free" types of flour (buckwheat and oat) are included in the recipes of wheat and wheat-rye bread. Provided that the correct dosage of leaven is selected in the recipe, the products meet the regulatory indicators.

It was also researched that the microflora of sourdoughs significantly affects gluten–free dough: the ripening of the dough and the accumulation of acid in it during fermentation are intensified, which also improves the organoleptic indicators of the quality of the products.

The use of sourdoughs of spontaneous fermentation from the flour of cereal crops for a variety of bread products is promising in the conditions of small and medium-sized enterprises.

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