Original Research Article:
full paper

(2022), «EUREKA: Life Sciences»
Number 6

USE OF RICE FLOUR IN WHEAT BREAD TECHNOLOGY

Anastasiia Shevchenko✉
Department of Bakery and Confectionery Goods Technologies[1]
nastyusha8@ukr.net

Vira Drobot
Department of Bakery and Confectionery Goods Technologies[1]

[1]*National University of Food Technologies*
68 Volodymyrska str., Kyiv, Ukraine, 01601

✉**Corresponding author**

Abstract

Last decade is characterized by the increase in the incidence of inflammatory bowel diseases all over the world. Diet therapy, which includes reducing the amount of dietary fiber and including phospholipids in it, is effective in maintaining a stable condition in case of these diseases. A promising raw material with a low dietary fiber content is rice flour, which may be added to the recipe of bakery products to replace part of wheat flour. The aim of the work was to determine the influence of rice flour on the course of the technological process and the characteristics of the dough in bakery products manufacturing, as well as on the quality indicators of bread made from wheat flour, which contains lecithin. Rice flour contains 1.8 times less protein than wheat flour, but this protein is more complete in amino acid composition. The content of dietary fibers in rice flour is 8.5 times lower. The gas-forming capacity of the dough with lecithin separately and in a mixture with rice flour increases by 8.4–18.7 % when replacing 10–40 % of wheat flour. It was established that in the dough sample with lecithin, the amount of formed and fermented sugars increased by 1.2 % and 12.1 %, respectively, compared to the control sample without additives. With an increase in the percentage of replacement of wheat flour with rice flour, the amount of formed sugars increased by 35.2–39.0 %. The amount of fermented sugars also increased by 19.6–31.8 % with an increase in the percentage of replacement. The shape stability of bread slightly improved with the addition of lecithin. However, when adding rice flour, the shape stability of the products decreased by 7.1–26.8 %, as well as the specific volume and porosity of bread.

Keywords: bread, rice flour, lecithin, gas formation capacity, dough, kinetics of sugars.

DOI: 10.21303/2504-5695.2022.002677

1. Introduction

Bakery industry is one of the main ones in the structure of food production in the world. It provides a significant part of the population's diet with useful nutrients contained in bread. However, in view of the change in the environmental situation in the world, the increase in the incidence of alimentary and non-alimentary diseases, the production of food products requires significant revision and improvement in order to meet the needs of all segments of the population who have intolerance to certain ingredients or special requirements for the consumption of certain groups of products. In this aspect, the rapid development of diseases of the gastrointestinal tract causes great concern [1].

Inflammatory bowel diseases (IBD) incidence increased worldwide over the past decade. The prevalence of IBD ranges from 28 to 146 patients per 100 000 population. The beginning of the twenty-first century became a period of rapid growth of morbidity in industrialized countries [2]. The peculiarity of these diseases is their prevalence among the young working population aged 20–40. This negatively affects the economic situation in the world [3, 4]. The etiology of these diseases is unknown, but the most probable is the immunogenetic theory of the occurrence of IBD. Their etiopathology is multifactorial, including genetic predisposition, mucosal barrier dysfunction, disruption of the gastrointestinal microbiota, dysregulation of the immune response, environmental factors and lifestyle [5].

The course of these diseases depends mostly on nutrition, because the main approach to reducing the incidence is diet therapy. The main nutrients contained in food products – proteins, fats, carbohydrates, minerals and vitamins are important for proper nutrition [6]. However, there is still no consensus in the literature regarding the relationship between dietary fiber and the development of IBD. Some researchers demonstrate the positive effect of dietary fiber consumption [7], however, most medical scientists warn against using a large amount of dietary fiber in the diet of patients with IBD [8, 9]. This is because most people with IBD do not have the proper microorganisms to digest fiber. The researchers concluded that while fiber is beneficial for those with adequate levels of special microbes (the microbiome), some dietary fibers may be harmful to patients with active IBD who have lack the appropriate microbes to digest them [10].

In this regard, an urgent task is to develop approaches to diet therapy when consuming the main groups of food products, in particular bakery products, by persons suffering from IBD. For this purpose, promising raw materials with a low dietary fiber content are rice processing products, in particular rice flour [11].

Rice flour is gluten-free starch-containing raw material, which is characterized by a high content of vitamins B, tocopherol, biotin, zinc, iron, magnesium, potassium, calcium and phosphorus. This flour is not used as the main raw material in bread baking, but it is widely used for the production of gluten-free types of bread. The influence of rice flour on the indicators of the technological process and the quality of products in the production of bread from a mixture of potato and corn starch was studied. It was established that it is advisable to add rice flour to the recipe of products in the amount of up to 30 % to replace starch. At the same time, the content of aroma-forming substances in gluten-free bread with rice flour was increased by 12.7 % compared to bread made from a mixture of starches. The nutritional value of bread also increases significantly, in particular, the content of proteins increases by 2.5 times, the content of potassium, magnesium, iron and vitamins increases too [12].

The correlation between the properties of rice flour and the specific volume of bread made from a mixture of rice flour and wheat flour was studied. Rice flour mainly consisted of polyhedral single starch granules and smooth surface cells surrounded by a cell wall. Rice flour with a high content of damaged starch consisted only of small irregular particles with no visible structure. A lower degree of damage of starch and cellular structures with a smaller particle size is crucial for obtaining better flour for making high-quality bread [13].

The use of phospholipids, in particular phosphatidylcholine, is important in the diet of patients with IBD. It is one of the main membrane phospholipids, which prevents damage of the upper and lower parts of the gastrointestinal tract, and participates in the formation of the protective layer of intestinal mucin [14]. One of the sources rich in phosphatidylcholine is lecithin.

However, there are few studies on the influence of rice flour on the technological process of making bakery products from wheat flour when it is combined with lecithin, so this direction is relevant and actual.

The purpose of the work is to determine the influence of rice flour on the course of the technological process and the characteristics of the dough in the manufacture of bakery products, as well as on the quality indicators of bread made from wheat flour, which contains lecithin.

2. Materials and Methods

2. 1. Object of research

Premium grade wheat flour, sunflower lecithin with 95.3 % phosphatidylcholine, and rice flour were used for research.

Dough samples were prepared with the addition of pressed baker's yeast and salt. Lecithin was added in the amount of 3 % to the mass of flour. This dosage was chosen based on the recommendations of the daily lecithin norm for people with IBD [15]. To determine the rational dosage of rice flour, wheat flour in the amount of 10 %, 20 %, 30 %, 40 % was replaced with rice flour in the recipe. A sample without additional raw materials was a control sample.

2. 2. Total protein content

Kjeldahl method was used for determination followed by titration technique. An amount of 1 g of raw material was hydrolyzed with 15 mL concentrated sulfuric acid containing two copper catalyst tablets for 2 h in a heat block at 420 °C. After cooling, distilled H_2O was added to the hydrolysates before neutralization and titration. The amount of present protein was calculated from the nitrogen concentration in the product. Total *N* was expressed as g proteins per 100 g of flour [16].

2. 3. Fat

The sample is placed in a thimble; once the flask is heated, the solvent is evaporated and moved up to the condenser, where it is converted into a liquid and collected into the extraction chamber containing the sample. When the solvent passes through the sample, it extracts the fats and carries them into the flask. This extraction process typically lasts several hours (6–24 h). After completion of the extraction, the solvent is evaporated, and the mass of lipid remaining is measured [17].

2. 4. Fiber

A collaborative study was conducted to determine the total dietary fiber (TDF) content in products, using enzymatic-gravimetric method. TDF was calculated as the weight of the residue minus the weight of protein and ash [18].

2. 5. Gas-forming ability of the dough

The indicator of gas-forming ability is the amount of cm^3 of carbon dioxide (CO_2) emitted during the fermentation and keeping of the dough from 100 g of flour at a temperature of 30 °C. This indicator was determined by the volumetric method, namely the volume of CO_2 emitted at constant temperature and pressure [19].

2. 6. Kinetics of accumulation of sugars in the dough

The amount of sugars formed during the fermentation of the dough was determined by the difference between their content in the dough without yeast immediately after kneading and after 180 minutes of fermentation. The amount of fermented sugars was determined by the difference between the sum of the amount of sugars at the beginning of fermentation of yeast dough and the amount of sugars formed in yeast-free dough and the amount of sugars contained in yeast dough after 180 minutes of fermentation. The kinetics of sugar accumulation in the dough was determined by the accelerated iodometric method [20].

2. 7. The size of the flour particles

The size of the flour particles was determined by sieving on sieves. Sieves of different sieve fabric and different hole sizes were used: N 33/36 (35) (220 μm), N 27 (260 μm), N-067 (670), N 49/52 PA (43) (132 μm), N 41/43 (38) (160 μm) [21].

2. 8. Specific volume of bread

The specific volume of bread is determined by dividing the volume of bread by its weight and expressed to the nearest 0.01 cm^3/g [22].

2. 9. Porosity of bread

The porosity of bread reflects the volume of the pores in a certain volume of the crumb, expressed as a percentage to the total volume [17].

2. 10. Statistical analysis

The accuracy of the obtained results was ensured by repeating the experiments 3 times. The obtained and presented results take into account the standard deviation; graphical presentation of experimental data was performed using standard statistical processing programs – Microsoft Excel 2010.

3. Results and Discussion

The chemical composition of the components of the recipe of bakery products mainly determines the properties of the dough system and affects the quality of the finished products.

Therefore, the content of the main nutrients in rice flour was determined in comparison with premium grade wheat flour (**Table 1**).

Rice flour contains 1.8 times less protein than wheat flour, but this protein is more complete in amino acid composition. The content of dietary fibers in rice flour is 8.5 times lower, which makes it a valuable raw material for the production of bread for patients with IBD.

Table 1

Chemical composition of rice flour in comparison with premium grade wheat flour

Indicator, content per 100 g of product	Premium grade wheat flour	Rice flour
Protein, %	11.3±0.24	6.0±0.21
Fat, %	1.1±0.01	1.4±0.01
Carbohydrates, %	69.8±1.14	70.1±1.14
Fiber, %	3.5±0.06	0.4±0.01

Note: Results given as M±SD (mean±standard deviation) of triplicate trials.

The size of the particles of ingredients in the recipe has a significant influence on the process of making bread and the characteristics of dough systems. The raw material, which differs in particle size from wheat flour, can significantly affect the properties of the dough and the quality of the finished products. The evaluation of the granulometric composition of the raw material showed (**Table 2**) that rice flour is more dispersed than wheat flour of the second grade, since the residue on sieve N 27 is less than the limit normalized value for wheat flour of the second grade. But it is more coarsely dispersed than wheat flour of the first grade, which is evidenced by a larger residue on the sieve N 33/36 (35) than the limit standardized value for wheat flour of the first grade. The weighted average particle size was for rice flour is 0.25 mm.

Table 2

Particle size of rice flour compared to wheat flour

Size indicators, *N* of sieve	The size of the hole, µm	Wheat flour, variety			Rice flour
		first	second	whole-meal	
The residue on the sieve %, no more: N 33/36 (35)	220	2	–	–	21.16
N 27	260	–	2	–	1.92
N 067	670	–	–	2	0.34
Passage through a sieve, % no less: N 49/52 PA (43)	132	80	–	–	3.76
N 41/43 (38)	160	–	65	35	11.86

Microbiological processes in dough play an important role in bread technology. During the ripening of the dough, biotransformation of its polymers takes place. The intensity of the processes in the dough system is influenced by the chemical composition of the recipe components. Microbiological processes in the dough with the replacement of part of the wheat flour with rice flour were evaluated by the amount of carbon dioxide released during the fermentation and keeping of the dough (**Fig. 1**).

Total gas formation in the dough with lecithin increased, compared to the control sample, which contributes to the improvement of the fermentation capacity of yeast due to its plasticization and the presence of choline, which positively affects the yeast cells [23]. When replacing part of the wheat flour with rice flour, gas formation increased by 8.4–18.7 % with an increase in the replacement percentage. The gas-forming capacity largely depends on the dispersion of particles, which affects the availability of sugars for the action of yeast enzymes and the availability of starch for the action of amylolytic enzymes. The particle size of rice flour is smaller than of wheat flour, which is confirmed by research (**Table 2**). The increase in gas formation with rice flour is observed as a result of improving the yeast nutrition with nitrogenous substances of rice flour due to the greater susceptibility of rice flour starch to amylolysis than that of wheat flour [24].

Biochemical processes which take place in the dough mean breakdown of the components of flour, mainly proteins and starch under the action of the flour's own enzymes, as well as the enzymes of yeast and other microorganisms. Sugars and nitrogenous substances accumulate in the dough. The content of sugars depends on the ratio between the intensity of the accumulation of sugars in the dough and their fermentation by microorganisms [25]. The depth of this process was characterized by the kinetics of accumulation and fermentation of sugars (**Table 3**).

It was found that in the sample of dough with lecithin, the amount of formed and fermented sugars increased by 1.2 % and 12.1 %, respectively, compared to the control sample, which is associated with the action of the phospholipid component, which promotes more effective access of nutrients to the yeast cell. The amount of formed sugars increased by 35.2–39.0 % with an increase in the percentage of replacement of wheat flour with rice flour. The amount of fermented sugars also increased by 19.6–31.8 %. This is explained by the better susceptibility of rice flour starch to amylolysis, which contributes to improved access of enzymes to starch grains and correlates with the obtained values of gas formation in the dough.

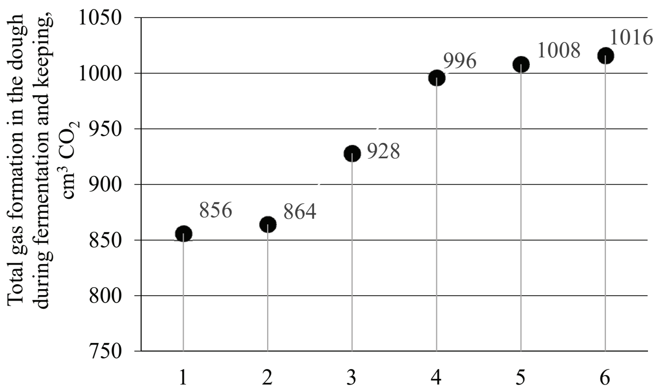

Fig. 1. Total gas formation in the dough during fermentation and keeping time: 1 – control sample; 2 – sample with lecithin; 3 – sample with lecithin and 10 % rice flour to replace wheat flour; 4 – sample with lecithin and 20 % rice flour to replace wheat flour; 5 – sample with lecithin and 30 % rice flour to replace wheat flour; 6 – sample with lecithin and 40 % rice flour to replace wheat flour

Table 3

Accumulation and fermentation of sugars during the fermentation of the dough (in terms of maltose), % to dry matter

Indicators	Control sample	Sample with lecithin	Rice flour to replace wheat flour, %			
			10	20	30	40
Yeast–free dough						
After kneading	2.10±0.10	2.10±0.10	1.99±0.09	1.98±0.09	1.96±0.09	1.95±0.09
After 3 hours of fermentation	3.15±0.13	3.39±0.17	3.41±0.18	3.41±0.18	3.41±0.18	3.41±0.18
Formed sugars	1.05±0.01	1.29±0.03	1.42±0.05	1.43±0.05	1.45±0.05	1.46±0.08
Yeast dough						
After kneading	2.12±0.10	2.15±0.12	2.06±0.10	2.02±0.10	2.02±0.10	2.02±0.10
After 3 hours of fermentation	1.69±0.06	1.78±0.08	1.71±0.07	1.66±0.06	1.59±0.07	1.53±0.07
Fermented sugars	1.48±0.05	1.66±0.06	1.77±0.08	1.79±0.08	1.88±0.08	1.95±0.09

Note: Results given as: M±SD (mean ± standard deviation) of triplicate trials.

The patterns of changes in the technological characteristics of semi-finished dough and the influence of raw materials on the quality of bread were determined by trial baking, since the dough, in case of replacing part of the wheat flour with rice, has a greater gas-forming capacity. The dough needs less time to reach the necessary volume, so the duration of keeping the dough is reduced by 2–6 minutes depending on the replacement percentage.

The shape stability of bread slightly improved with the addition of lecithin, and in case of the addition of rice flour, it decreased by 7.1–26.8 %, which is due to the peculiarities of the formation of the gluten framework in the dough with the addition of rice flour which is gluten-free. The specific volume and porosity of bread samples also decreased. This can be explained by the fact that rice flour has a low activity of amylolytic enzymes, so the intensity of fermentation process in the dough decreases, as a result of which it does not rise well, and the finished products have a small volume and a pale crust, on the surface of which cracks appear. Therefore, the rational amount of replacing wheat flour with rice flour is no more than 20 %.

The obtained results make it possible to follow changes during the technological process of manufacturing bakery products with dietary properties. They can be used in the development of recipes of products with rice flour for special purpose. The direction of providing future studies is conducting research on conformational transformations and rheological characteristics in dough systems with rice flour and indicators of bread quality.

4. Conclusions

The expediency of replacing part of the wheat flour with rice flour in the recipe of the products, as well as its introduction in the mixture with lecithin, was established in order to expand the range of bakery products for patients with IBD and in view of the need to reduce the fiber content in their diet, since the content of dietary fibers in rice flour is 8.5 times lower.

Rice flour has a greater dispersity than wheat flour of the second grade, but it is coarser than wheat flour of the first grade.

There is an increase in gas formation in the dough by 8.4–18.7 % both with lecithin and when replacing part of the wheat flour with rice flour, which indicates a greater availability of sugars to the action of yeast enzymes and the availability of starch to the action of amylolytic enzymes.

It was established that in the dough sample with lecithin, the amount of formed and fermented sugars increased by 1.2 % and 12.1 %, respectively, compared to the control sample. The amount of formed sugars increased by 35.2–39.0 % and the amount of fermented sugars also increased by 19.6–31.8 % in case of the increase in the percentage of replacement of wheat flour with rice flour.

However, when adding rice flour, the shape stability of bread decreased by 7.1–26.8 %, as well as its specific volume and porosity.

Therefore, the rational amount of replacing wheat flour with rice flour is no more than 20 %.

Conflict of interest

The authors declare that there is no conflict of interest in relation to this paper, as well as the published research results, including the financial aspects of conducting the research, obtaining and using its results, as well as any non-financial personal relationships.

Financing

The study was performed without financial support.

Data availability

Manuscript has no associated data.

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Received date 01.10.2022
Accepted date 13.11.2022
Published date 30.11.2022

How to cite: *Shevchenko, A., Drobot, V. (2022). Use of rice flour in wheat bread technology. EUREKA: Life Sciences, 6, 44–51. doi: https://doi.org/10.21303/2504-5695.2022.002677*