

FUNCTIONAL PROPERTIES OF RICE FLOUR AND ITS EFFECT ON CONFORMATION CHANGES IN THE STRUCTURE OF WHEAT DOUGH AND BREAD

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ABSTRACT

Situation in food industry in Ukraine and in the world has undergone significant changes during the last decade, especially the last year, which was caused by the military aggression of the Russian Federation. Diseases, particularly of the gastrointestinal tract, such as inflammatory bowel disease, have developed rapidly. In this regard, it is worth looking for approaches to diet therapy, which involves reducing dietary fiber in the diet. A promising raw material for inclusion in the recipe of bakery products is rice flour.

The water absorbing capacity of rice flour was 60% higher compared to wheat flour. The study of the water holding capacity indicator showed the redistribution in the interaction of flours with water. For rice flour, this indicator increased by 27% compared to wheat flour. Fat absorbing capacity is higher for wheat flour than for rice flour by 7%, the increase in the ability to hold fat was by 35% for rice flour.

The advantages of wheat flour over rice flour in terms of the ability to form constant emulsions were shown: the emulsifying ability index of wheat flour was higher by 80% than of rice flour, emulsifying stability — by 210%.

The analysis of the spectra of the control sample of dough and the dough samples with 10% and 20% replacement of wheat flour with rice flour showed that the control sample of the dough and sample with 10% and 20% rice flour after kneading have practically the same spectra. The spectra of the dough control sample after 3.5 hours of fermentation and sample with 10% and 20% replacement have lower value of the relative reflection coefficient. But dependence that spectra of control samples are lower persists. Spectra of bread samples regardless of the presence of rice flour overlap but aspire to the spectrum of control sample of the dough after 3.5 hours of fermentation.

ФУНКЦІОНАЛЬНІ ВЛАСТИВОСТІ РИСОВОГО БОРОШНА ТА ЙОГО ВПЛИВ НА КОНФОРМАЦІЙНІ ЗМІНИ В СТРУКТУРІ ПШЕНИЧНОГО ТІСТА І ХЛІБА

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Продовольча ситуація в Україні та світі зазнала значних змін протягом останнього десятиліття, особливо за останній рік, що спричинено військовою агресією російської федерації. Стрімкого розвитку набули хвороби, зокрема шлунково-кишкового тракту, такі як запальні захворювання кишечника. У зв'язку з цим варто шукати підходи до дієтотерапії, що передбачає зменшення в раціоні харчових волокон. Перспективною сировиною для включення в рецептуру хлібобулочних виробів є рисове борошно.

Встановлено, що водопоглинальна здатність рисового борошна на 60% вища порівняно з пшеничним борошном. Дослідження показника вологоутримувальної здатності показало перерозподіл при взаємодії досліджуваних видів борошна з водою. Для рисового борошна цей показник збільшився на 27% порівняно з пшеничним. Жиропоглинальна здатність пшеничного борошна вища, ніж рисового на 7%, збільшення жирутримувальної здатності рисового борошна встановлено на рівні 35%.

Показано переваги пшеничного борошна перед рисовим за здатністю утворювати стійкі емульсії: показник емульгуючої здатності пшеничного борошна був вищим на 80%, ніж рисового, стабільності емульсії — на 210%.

Аналіз спектрів контрольного зразка тіста та зразків тіста із заміною 10% та 20% пшеничного борошна рисовим показав, що контрольний зразок тіста та зразки з 10% та 20% рисового борошна після змішування мають практично однакові спектри. Спектри контрольного зразка тіста після 3,5 год бродіння та зразків з 10% і 20% заміною мають менші значення відносного коефіцієнта відбиття. Але зберігається залежність нижчого розташування спектрів контрольних зразків. Спектри зразків хліба незалежно від наявності рисового борошна перекриваються, але прагнуть до спектра контрольного зразка тіста після 3,5 год бродіння.

Ключові слова: хліб, рисове борошно, запальні захворювання кишечника, інфрачервона спектроскопія, функціональні властивості.

Formulation of the problem. Situation in food industry in Ukraine and in the world has undergone significant changes during the last decade, especially the last year, which was caused by the military aggression of the russian federation. In this regard, nutrition deteriorated, the quality of products decreased, the unfavorable ecological and economic situation also affected the state of food security (Ivanov et. al., 2021). Diseases of the gastrointestinal tract, such as inflammatory bowel disease (IBD), have developed rapidly. Diet therapy is an approach to maintaining health in today's unfavorable conditions. The development of these diseases among the young working population is of particular concern, because the age peak of morbidity falls on 20—40

years. This affects the economic situation in the world (Burisch, & Munkholm, 2013; Stepanov, Skyrda, & Petishko, 2017). Therefore, an important task is to develop approaches to diet therapy for diseases of the gastrointestinal tract, in particular, when using bakery products, as one of the main ones in the diet.

According to the recommendations of nutritionists, the protein content in the diet should be increased with the maximum limitation of fiber (Forbes et al., 2017). For this purpose, promising raw materials with a low dietary fiber content are rice by-products, in particular rice flour.

Analysis of recent research and publications. Epidemiological studies have shown an association of IBD with environmental risk factors such as smoking, hygiene, antibiotic use, and diet (Andersen et. al., 2018). When developing approaches to diet therapy for patients with IBD, nutritionists pay attention to the main aspect — reducing the consumption of dietary fiber. However, it is commonly observed that patients with IBD consistently adhere to a low-fiber diet, regardless of disease activity (Zallot et. al., 2013).

It was shown that dietary fiber in patients with IBD is related to population aspects and is not necessarily related to the clinical characteristics of the disease, however, such individuals do not have the appropriate microorganisms to digest fiber (Oliveira et. al., 2014).

One of the effective ways to reduce the amount of dietary fiber in the diet is to replace recipe components with a high fiber content by raw materials with a reduced amount. Rice and its by-products contain little dietary fiber and are widely used in the technology of gluten-free bakery products.

Gluten-free bakery products have nutritional and technological disadvantages. Sprouted rice flour has become a promising alternative due to its difference in composition. Sprouting improves the nutritional, processability and sensory aspects of bread and increases protein content and starch digestibility. Bread made from rice flour with a 24-hour germination period had a higher specific volume, and with a 48-hour germination period, had better chewiness values (Heberle, Ávila, do Nascimento, & Gularte, 2022).

By-products of various types of rice are used in food production. Red rice flour is a promising grain ingredient for the preparation of gluten-free products, which replaces wheat flour due to its advantages in naturalness, hypoallergenicity and mild taste. Since rice usually contains a small amount of prolamin, appropriate additives such as gums, emulsifiers, and dairy products must be used to increase the consistency or viscosity of the system (Das, & Bhattacharya, 2019). Addition of transglutaminase to rice bread increased bread volume, firmness, and chewiness. However, elasticity remained unchanged. A formulation with 1% transglutaminase showed the best sensory properties (Gusmão et. al., 2019).

Water- and fat-absorbing capacity, emulsifying and foaming capacity allow the use of rice by-products in bakery and confectionery industries. Defatted rice bran can be used to replace up to 10—20% of wheat flour in recipes of biscuits without adversely affecting their quality (Ashraf et. al, 2012).

Rice germ contains lipophilic antioxidants (tocopherols, tocotrienols and γ -oryzanol) and phenolic compounds. These substances protect from free radicals and extend the shelf life of products (Esa, Ling, & Peng, 2013; Min, McClung, & Chen, 2011).

Since it is not recommended to completely exclude gluten from the diet during diet therapy for people with IBD, a promising direction is to replace wheat flour with other types with a low dietary fiber content. The relationship between the properties of rice flour with different degrees of damage of starch grains and the specific volume of bread made from a mixture of rice and wheat flour was studied. A lower degree of starch damage and a finer grain structure is crucial for obtaining better flour for making high quality bread (Araki et. al., 2009).

The purpose of the research is to determine the functional characteristics of rice flour and evaluate its influence on conformational transformations in semi-finished and finished bakery products.

Materials and methods. *Sample preparation.* Dough samples were prepared with the addition of pressed baker's yeast (3% by weight of flour) and salt (1.5% by weight of flour). Wheat flour was replaced with rice flour in the recipe in the amount of 10% and 20%. The control was a sample without rice flour.

Moisture Binding and Retaining Capacity. Moisture binding capacity was determined by the centrifugation method, and was calculated as follows:

$$\text{moisture binding capacity (\%)} = (\text{weight of precipitate/weight of original flour}) \times 100.$$

The determination of the moisture retaining capacity was carried out by mixing the sample with water and determining the amount of separated liquid after a centrifugation, and was calculated as follows:

$$\text{moisture retaining capacity (\%)} = [(\text{weight of tube with flour and water retained} - \text{weight of tube with flour})/(\text{weight of flour})] \times 100 \text{ (Litvynchuk et. al., 2022).}$$

Fat Binding and Retaining Capacity. Fat binding capacity (*FBC*) was determined as the difference between the fat content in the flour suspension (F_1) and the amount of fat released after centrifugation (F_2):

$$FRC = F_1 - F_2.$$

Fat retention capacity (*FRC*) was determined as the difference between the fat content in the flour suspension (F_1) and the amount of fat released during heat treatment ($F_{rel.}$):

$$FRC = F_1 - F_{rel.} \tag{1}$$

Stability of flour emulsion. The stability is determined by heating emulsion, cooling with water. Then 4 calibrated centrifuge tubes with a capacity of 50 cm³ are filled with the emulsion and centrifuged at a frequency of 500 rpm for 5 minutes. Then the volume of the emulsified layer is determined.

The stability of the emulsion is calculated by the formula:

$$SE = \frac{V_1}{V_2} \cdot 100, \tag{2}$$

where *SE* — stability of the emulsion, %; V_1 — volume of emulsified oil, cm³; V_2 — total emulsion volume, cm³.

Emulsifying ability. A portion of flour weighing 7 g is suspended in 100 cm³ of water in a homogenizer (or mixer) at a frequency of 66.6 rpm for 60 s. Then 100 cm³ of unrefined sunflower oil is added and the mixture is emulsified in a homogenizer or mixer at a frequency of 1500 rpm for 5 minutes. After that, the emulsion is poured into

4 calibrated centrifuge tubes with a capacity of 50 cm³ and centrifuged at 500 rpm for 10 minutes. Then the volume of emulsified oil in the layer is determined.

Emulsifying ability is calculated by the formula, %:

$$EA = \frac{V_1}{V} 100, \quad (3)$$

where *EA* — emulsifying ability, %; *V*₁ — volume of emulsified oil, cm³; *V* — total emulsion volume, cm³ (Silva, Barreira, & Oliveira, 2016).

Near-infrared reflection spectroscopy. The reflection spectra from shredded samples and a smooth surface were determined using infrared spectrometer (Labor-Mim, Hungary) in near infrared range from 1330 to 2370 nm. Firstly, the spectrometer recorded the reflectance spectrum from reference I0, secondly a reflection spectrum from the researched sample. The spectra are represented as the reflectivity of R in relative units (the ratio of the intensities *I/I0 = R*), depending on the wavelength in nm (Niewitzki, Tillmann, Becker, & Mollers, 2010; Yip, Gausemel, Sande, & Dyrstad, 2012). The intensity of reflection was measured in rice and wheat flours, in lecithin, in dough after kneading and after 3.5 hours of fermentation and in bread. The reflection intensity was expressed through the relative reflection coefficient (Shevchenko, & Litvynchuk, 2022).

Results and discussion. Rice flour significantly differs from wheat flour in terms of its chemical composition and technological properties. Therefore, when using it to partially replace wheat flour, it is necessary to study its functional characteristics.

Main functional properties of rice flour, namely the ability to interact with water and fat molecules and stabilize dispersed systems were studied to determine the possibility of its use for replacement part of wheat flour. The most important characteristics, which allow to assess their functional properties, are water absorbing, water holding, fat absorbing, and fat holding capacities, as well as emulsifying ability (*EA*) and emulsion stability (*ES*). In order to determine the ability of rice flour to bind and hold water and fat, which are present in most food products, namely bread, water absorbing capacity (*WAC*), water holding capacity (*WHC*), fat absorbing capacity (*FAC*) and fat holding capacity (*FHC*) were studied (Fig. 1).

Setting limits for these parameters allow to determine the required amount of water and fat, which is an important factor that must be taken into account when developing product recipes.

The *WAC* of rice flour was 60% higher compared to wheat flour. This is explained by the difference in the granulometric composition of the experimental samples. Rice flour has smaller particle size than wheat flour, which makes the system more porous and leads to increase in the water absorption rate (Shevchenko, & Drobot, 2022). The study of the *WHC* indicator, which characterizes the ability of system to retain moisture in the formed structure after heat treatment, showed the redistribution in the interaction of flours with water. For rice flour, this indicator increased by 27% compared to wheat flour. Heat treatment contributed to the release of side polar groups of protein, soluble molecules of carbohydrates which have hydrophilic properties, which led to increase in the amount of retained moisture. There is radical redistribution for *FAC*. This indicator is higher for wheat flour than for rice flour by 7%, which may be due to the higher content of hydrophobic polysaccharides contained in wheat flour. The increase in the

ability to hold fat was by 35% for rice flour. The different distribution of the studied properties for the studied flours in relation to water and fat molecules is explained by the difference in the ratio of hydrophilic and hydrophobic particles in the composition of the samples (Wang et al., 2017).

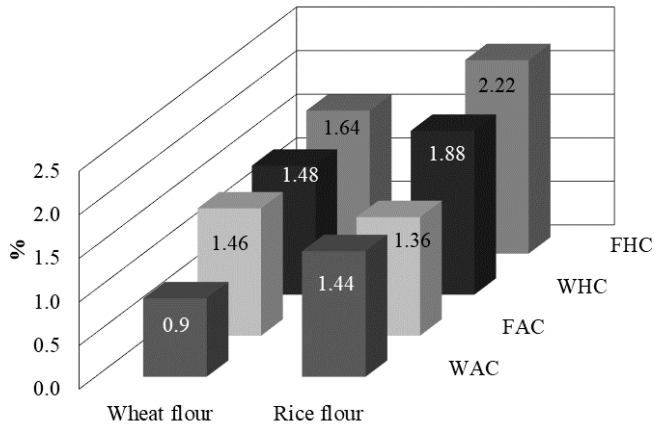


Figure 1. Functional properties of wheat and rice flour

The *ES* and *EA* indicators characterize the ability of multicomponent systems to form constant dispersions of water and fat and to resist their stratification over time and under the influence of external factors. The ability of the formed emulsion to maintain constant structure depends on the nature of the used additives, which act as stabilizers and thickeners. In this regard, the ability of rice and wheat flours to form and stabilize water-fat systems was studied (Fig. 2).

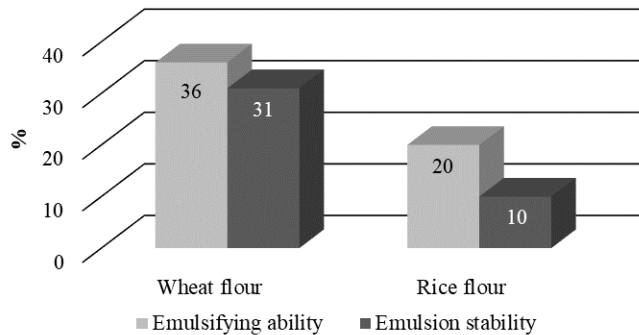


Figure 2. Emulsifying properties of wheat and rice flour

The advantages of wheat flour over rice flour in terms of the ability to form constant emulsions were shown: the *EA* index of wheat flour was higher by 80% than of rice flour, *ES* — by 210%. This may be due to the increasing viscosity of the water system, thereby contributing to a more effective surface coating of fat molecules. The increase in the difference in the manifestation of emulsifying properties after heat treatment between flours is determined by the ability of wheat fibers to promote the forma-

tion of interpolymeric bonds between polysaccharides, which bind protein molecules and creates more tough and impermeable system.

Functional properties of additives have a significant impact on conformational transformations in semi-finished products of bakery production and redistribution of main functional groups in finished products.

It was established in previous studies that taking into account the microbiological, biochemical, and structural-mechanical indicators of the dough, as well as the physico-chemical and organoleptic indicators of the quality of finished products, it is advisable to replace 10—20% of wheat flour with rice flour (Дробот, Шевченко, & Літвинчук, 2021).

Since proteins, fats and carbohydrates are involved in the formation of the dough structure, and the addition of rice flour significantly changes the composition of the dough, the conformational changes of these dough substances were studied by IR spectroscopy. The dough was studied after kneading, at the end of fermentation, as well as the indicators of bread. Replacement of wheat flour with rice flour was carried out at the level of 10% (Figure 3) and 20% (Figure 4).

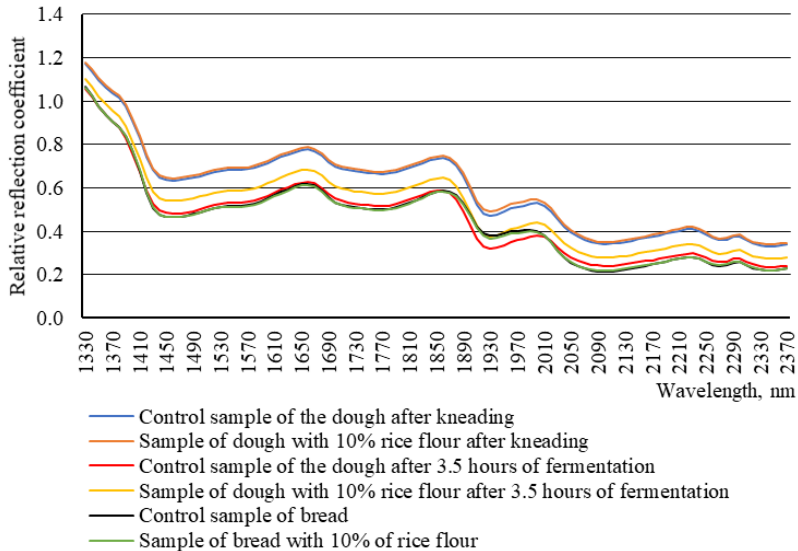


Figure 3. Infrared reflection spectra of dough and bread samples with rice flour (10% replacement)

In the process of fermentation and baking, under the influence of high temperatures, all substances of the dough change, which affects the intensity of the reflection. The analysis of the spectra of the control sample of dough and the dough samples with 10% and 20% replacement of wheat flour with rice flour (after kneading and after 3.5 hours of fermentation), as well as samples of bread, made it possible to trace similar dependencies.

The control sample of the dough and sample with 10% rice flour after kneading have practically the same spectra. The spectra of the dough control sample after 3.5 hours of fermentation and sample with 10% replacement have lower value of the rela-

tive reflection coefficient. But dependence that spectra of control samples are lower persists.

Spectra of bread samples regardless of the presence of rice flour overlap but aspire to the spectrum of control sample of the dough after 3.5 hours of fermentation.

This means that the conformational transformations in bread have a similar character to transformations in dough based on wheat flour after fermentation and are determined to a greater extent by the properties of wheat flour (Chompoorat, Fasasi, Lavine, & Rayas-Duarte, 2022). It is due to changes in the secondary structure of gluten in bread after exposure to temperature. Available α -helices and β -turns contributed to the formation of disulfide bonds (Xiang, Zou, Liu, & Ruan, 2020).

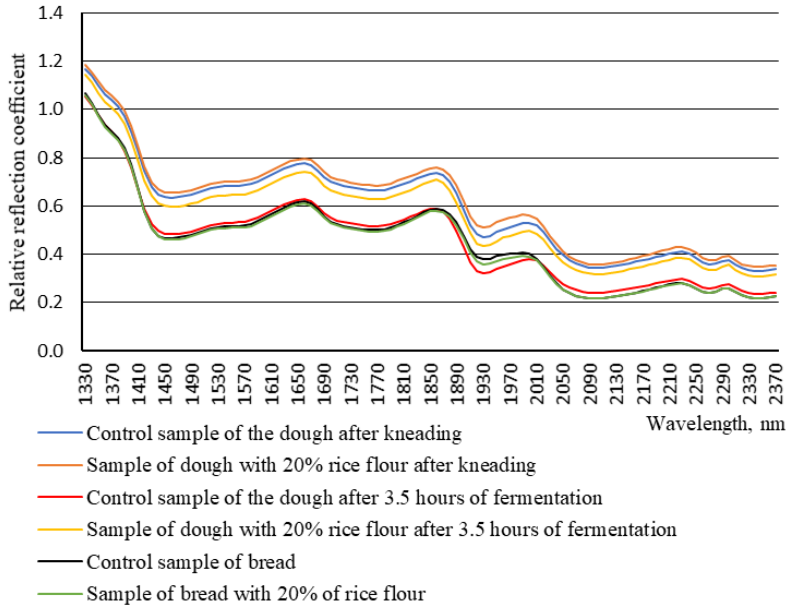


Figure 4. Infrared reflection spectra of dough and bread samples with rice flour (20% replacement)

Dependencies when replacing 20% of wheat flour with rice flour generally remain constant. However, the reflection intensity increases, particularly in the sample of dough with 20% rice flour after 3.5 hours of fermentation. Its spectrum gravitates towards dough samples after kneading.

The conducted studies indicate that functional properties of raw materials affect the redistribution of the main groups in the composition of semi-finished products of bakery production as well as of bread.

Conclusions

A promising raw material for inclusion in the recipe of bakery products is rice flour which differs in chemical composition and technological properties.

The water absorbing capacity of rice flour was 60% higher compared to wheat flour. The study of the water holding capacity indicator showed the redistribution in the interaction of flours with water. For rice flour, this indicator increased by 27% com-

red to wheat flour. Fat absorbing capacity is higher for wheat flour than for rice flour by 7%, the increase in the ability to hold fat was by 35% for rice flour.

The advantages of wheat flour over rice flour in terms of the ability to form constant emulsions were shown: the emulsifying ability index of wheat flour was higher by 80% than of rice flour, emulsifying stability — by 210%.

The analysis of the spectra of the control sample of dough and the dough samples with 10% and 20% replacement of wheat flour with rice flour showed that the control sample of the dough and sample with 10% and 20% rice flour after kneading have practically the same spectra. The spectra of the dough control sample after 3.5 hours of fermentation and sample with 10% and 20% replacement have lower value of the relative reflection coefficient. But dependence that spectra of control samples are lower persists. Spectra of bread samples regardless of the presence of rice flour overlap but aspire to the spectrum of control sample of the dough after 3.5 hours of fermentation.

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