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INFLUENCE OF RICE FLOUR ON CONFORMATIONAL CHANGES IN THE STRUCTURE OF WHEAT BREAD AND ITS NUTRITIONAL VALUE

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Abstract: *The purpose of this paper is determination of the effect of rice flour on the conformational transformations in the structure of wheat bread, which contains lecithin, and its quality indicators. In the last decade, inflammatory bowel diseases, which became a global problem in the world, are a serious threat to human health. In the diet therapy of these diseases, it is recommended not to use a large quantity of dietary fiber. Rice flour is a perspective raw material for production of bakery products for people with this disease, as it contains 8.5 times less dietary fiber than premium wheat flour. Analysis of the chemical composition of bread without rice flour and with its addition showed a slight decrease in protein content by 4.4-10.5%, depending on the dosage (10-40% of wheat flour replacement), and fiber content – by 8.7-35.5%. It was confirmed that conformational changes occur in the structure of proteins and other nutrients of the product in bread making process. The changes of structural groups and their redistribution in the dough after kneading at once and after 3.5 hours of its fermentation and in bread when part of the wheat flour is replaced with rice flour were analyzed. The utilitarian coefficient, redundancy coefficient, DKAS and the indicator of biological value indicated that it is rational to make a replacement of wheat flour with 10% or 20% of rice flour.*

Keywords*: IR-spectroscopy, wheat bread, rice flour, biological value, inflammatory bowel disease.*

1. Introduction

Food industry is structured into some branches and bread-making industry is one of the main ones. Bread contains useful nutrients but it is mostly devoid of high nutritional value. Nowadays in view of the unstable economic, ecological and political situation in the world the structure of nutrition changed. There is occurrence of alimentary and non-alimentary diseases and their amount increase. The rapid development of diseases of the gastrointestinal tract takes place and causes great concern [1].

In the last decade, inflammatory bowel diseases (IBD), which became a global problem in the world, are a serious threat to human health [2]. Some studies indicate connection between the occurrence of IBD and the excess or deficiency of certain nutrients. If the special diet is not followed, the intestinal mucosa may become thinner and more permeable to pathogens and antigens, which leads to persistent inflammation. IBD is associated with intestinal dysbacteriosis, which is characterized by a generalized change in the diversity and abundance of bacterial species [3-4].

Scientists who study the course and methods of treatment of IBD prevent from using a large number of dietary fibers in patients' diet [5]. In view of this, it is

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necessary to develop approaches to diet therapy in context consuming the main groups of food products, such as bakery products. Rice processing products, in particular rice flour, is a perspective raw material for production of bakery products for people with this disease as it contains a low amount of dietary fiber.

Rice flour is widely used in the technological process of making gluten-free bread. The effect of substitution wheat flour with rice flour on the change in structural characteristics and *in vitro* digestibility of low-gluten pretzels was studied [6]. After addition of rice flour, there was an increase in the swelling capacity (18.33±0.51) and bulk density (0.58±0.04 g/cm^3), and a considerable decrease in the moisture absorption capacity (0.62±0.09 mL/g) and solubility index (6,72±0.17 %). Infrared spectroscopy studies did not reveal differences in the main functional groups after the inclusion of rice flour, but its addition had a pronounced effect on the modulus of elasticity. Characteristics of starch digestion *in vitro* showed an increase in starch digestibility by 7.23%. The content of amylose increased (27.3±1.45), as well as the content of resistant starch (6.12±0.97). The low-gluten pretzels have much higher mineral profile. The study showed that including rice flour for replacing wheat flour in an amount of up to 35% affected the quality characteristics of the developed pretzels with a low gluten content.

Water has a significant influence on the functional characteristics of raw materials and products [7]. Scientists studied the influence of adding high-temperature water to different varieties of rice flour to evaluate the quality of bread. The rice flour had an amylose content of 12.1% to 24.5%, a damaged starch content – 2.4% to 5.5%, a protein content – 5.4% to 6.1%, and humidity in the range of 12.0%–15.0%. The obtained results showed that regardless of the characteristics of the rice, bread made with the addition of warm water was fluffier and softer than bread made with cold water (5°C). The optimal water temperature and the degree of starch gelatinization increased for the variety of ror rice flour with a lower amylose content in case of the similar particle size [8]. In addition, in food production technologies, the use of activated water is becoming widespread to increase their efficiency [9].

It is important to include phospholipids in the nutrition of patients with IBD along with reducing the use of dietary fiber. Phosphatidylcholine is a membrane phospholipid, which is one of the main ones, it takes part in the formation of tstructure of the protective layer of intestinal mucin [10]. Phospholipids participate in biological processes in the body, maintaining cell membrane integrity, preventing neurological diseases, and regulating basic biological processes such as transmission of signals between cells. In human body phospholipids are concentrated in vital organs, such as the brain, liver, and kidneys [11]. phosphatidylcholine is found in large quantities in lecithin. Soy lecithin became widely used in the food industry. Sunflower lecithin is a promising alternative to soy lecithin, as it is a product without genetically modified organisms [12-13].

The effectiveness of using defatted sunflower lecithin for the production of gluten-free bakery products from rice flour with the use of flour starch modified with enzymes was studied [14]. There was determined that 1.0% of lecithin by mass of flour leads to the improvement of gas formation in rice dough and increases the porosity by 12.7% and the specific volume of ready bread by 16.2%. Due to the presence of a hydrophobic group in the lecithin molecule, the addition of this raw matherial to the dough is compatible with adding sunflower oil in the amount of 3%

to the mass of flour. In addition, the compatible use of vegetable oil and lecithin in rice bread tproduction allows to extend the freshness and shelf life of the products.

However, there were not found studies of the effect of rice flour on the process of manufacturing bakery products from wheat flour in combination with lecithin, so this direction is relevant.

Previous studies established that the use of rice flour reduces gas retention by 3.7-20.4%, the viscosity of the dough system increases by 3.7-18.5%, and the specific volume and porosity of the samples decrease. The dimensional stability of bread is significantly reduced, which is associated with the features of the formation of the gluten framework in the dough samples with the addition of rice raw materials. The crumb acidity of the studied products is practically the same as in the control sample [15].

The aim of the work is to determine the effect of rice flour on the conformational transformations in the structure of wheat bread, which contains lecithin, and its quality indicators.

2. Matherials and methods

The main objectives of this study:

1. To determine the content of the main nutrients in raw materials;
2. To study the process of changing the structural components of bread with different dosage of additives;
3. To determine the chemical composition of bread with different dosages of additives;
4. To calculate indicators which characterize the biological value of bread with different dosages of additives.

Matherials

Premium wheat flour, rice flour and sunflower lecithin were used for research.

Samples of dough were prepared with the addition of salt (1.5% by weight of flour) and pressed baker's yeast (3% by weight of flour). Lecithin was added in the amount of 3% to the mass of flour. This dosage was chosen due to the recommendations for the daily norm of lecithin for people with IBD [16]. Wheat flour was replaced with rice in the amount of 10%, 20%, 30%, 40%. A sample without rice flour and lethitin was control sample.

Methods

Total protein content

For determination total protein content there was used Kjeldahl method. After mineralization of the sample titration technique was used. 1 g of the sample was hydrolyzed with 15 ml concentrated sulfuric acid in a heat block at 420°C for 2 h with two copper catalyst tablets. Then the sample was cooled. After cooling distilled H_2O was added using pipette to the hydrolysates before neutralization of the sample and its titration. The amount of protein was calculated taking into account the concentration of nitrogen in the product (g of proteins / 100 g of flour) [17].

Fat

The sample of the product is put in a thimble. During heating flask, the solvent (petroleum ether) is evaporated and moved to the condenser. It is reformed there into a liquid and collected in the extraction chamber where the sample is. In the process of passing solvent through the sample, the fats are extracted and carried into the flask. This continues from 6 to 24 hours. After finishing the extraction and evaporation of the solvent, the remained amount of lipid is measured [18].

Fiber

Determination the content of total dietary fiber (TDF) in products was conducted using collaborative enzymatic-gravimetric method.

Amount of fiber was calculated as the difference between the mass of the residue and the mass of protein and ash [19].

Near-Infrared Reflection Spectroscopy

To research the reflection spectra from shredded samples and a smooth surface in near infrared area in the range 1330 to 2370 nm infrapid spectrometer (Labor-Mim, Hungary) was used. Reference I0 is used to record the reflectance spectrum from it, then the spectrum is recorded from the researched sample. Reflectivity of R characterizes the spectra, it is represented in relative units (I/I0 = R), depending on the wavelength in nm [20-21]. Samples of dough immediately after kneading and after 3.5 hours of fermentation, raw matherials – rice and wheat flours, lecithin, and ready bread were researched and the intensity of reflection was measured in them. Relative reflection coefficient was used to express the reflection intensity [22].

Biological value of bread

To characterizes the balance of all essential amino acids of proteins with respect to physiological norm utilitarian coefficient is used. It compares the protein composition of any food product based on its amino acid composition and inadequacy of the use in the body. It was calculated by the formula:

$$U = \frac{C_{min} \cdot \sum_{j=1}^{8} A_{ej}}{\sum_{j=1}^{8} A_j}$$

where C_{min} is score of the first limited acid essential amino acid, units; A_j is the mass fraction of the j-th of essential amino acid in the product, mg/g protein; A_{ej} is the mass fraction of the j-th of essential amino acid in the protein model, mg/g protein (FAO/WHO scale, 2011).

To determine the mass fraction of essential amino acids in 100 g product, which are not fully used by the body redundancy coefficient is determined. It was calculated by the formula:

$$\sigma_{red} = \frac{\sum_{j=1}^{k}(A_j - C_{min}A_{ej})}{C_{min}}$$

DCAS is the average excess of essential amino acids compared to the least amino acid score of the limiting amino acid. DCAS is calculated by the formula:

$$DCAS = \frac{\sum \Delta DAS}{n}$$

where DAS is the difference in amino acid score for each essential amino acid compared to the amino acid score of a limiting amino acid, %; n – the number of essential amino acids.

Biological value was calculated by the formula:

$$BV = 100 - DCAS$$

where, BV – Biological value of the protein, % [23].

Statistical analysis

Three parallel experiments were provided for each parameter to ensure the precision of the obtained results. Standard deviation was taken into account for obtained and presented results. For performing graphical presentation of experimental data there was used standard statistical processing program – Microsoft Excel 2010.

3. Results and discussion

The properties of the dough system and the quality of bakery products are largely determined by the recipe components, especially peculiarities of their chemical composition. Composition of main nutrients of rice flour and lecithin differs from wheat flour (Table 1).

Protein content in rice flour is 1.8 times less than in wheat flour, but its amino acid composition is more complete. Dietary fibers content in in rice flour is 8.5 times lower than wheat. It makes it a perspective raw material for the manufacturing bread for patients with IBD. Almost the entire chemical composition of lecithin is represented by fat.

The difference in the chemical composition of lecithin, rice flour, and wheat flour should affect the change in the basic structural units of the chemical composition of bread with these components in the recipe. To identify and estimate these components, it is recommended to use the reflection spectrum in the near infrared region [24].

Table 1.

Chemical composition of rice flour and wheat flour of the highest grade

Indicator	Rice flour	Lecithin	Wheat flour of the highest grade
Protein, %	6.0±0.21	0.5±0.001	11.3±0.24
Fat, %	1.4±0.01	95.3±1.1	1.1±0.01
Carbohydrates, %	70.1±1.14	2.0±0.01	69.8±1.14
Fiber, %	0.4±0.01	-	3.5±0.06

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

In the process of baking high temperatures (220°C) are applied, under such conditions changes in the structure of protein composition and other substances of the product occur, which affects the intensity of reflection of product samples (Figure 1).

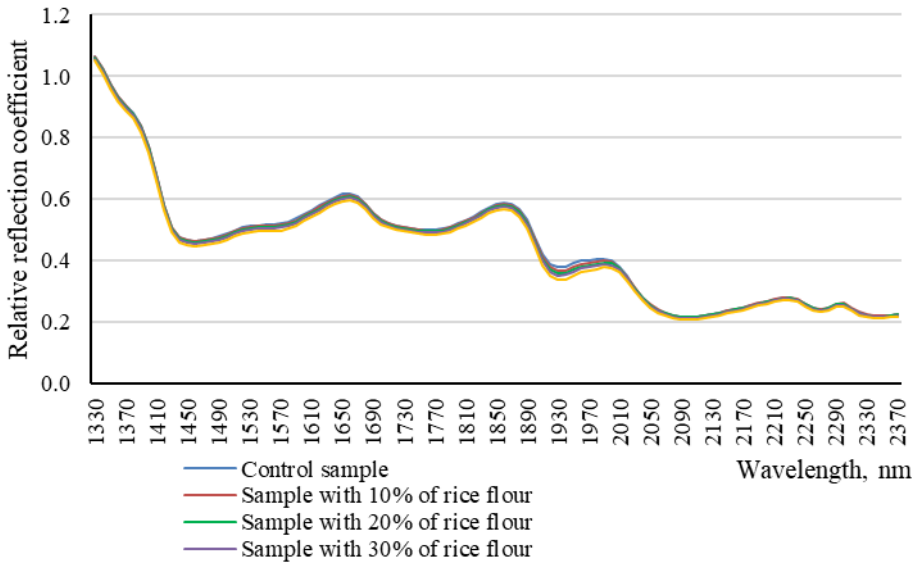

Fig. 1. Reflection spectra of bread with rice flour at different concentrations (10, 20, 30 and 40%).

The reflectance spectrum of bread samples with different percentages of rice flour for replacement wheat flour showed peaks associated with protein functional groups at wavelengths of 1430, 1982, 2052 and 2292 nm. The peak at a wavelength of 1430 nm correlates with the absorption-stretching band of N-H groups. Peaks at wavelengths of 1980 and 2052 nm can be correlated with the combined absorption band of N-H asymmetric stretching. Peak at a wavelength of 2294 nm can be correlated with the combined absorption band of the stretching of the N-H and C=O groups corresponding to the wavelength of 2294 nm, which characterizes amino acids.

In the entire analyzed range of wavelengths, the reflection spectra of the sample of bread without additives and samples with different dosages of rice flour turned out to be very similar. But the control sample had a bit higher reflectance intensity across the entire spectrum in comparison with the bread samples with the additive. This may be due to the greater presence of α-helical structures in the control sample than in the replacement samples. They are one of the structural elements which are responsible for dough viscosity.

The differences and redistribution of structural groups in the dough immediately after kneading and after 3.5 hours of its fermentation and in bread with 40% wheat flour replaced with rice were analyzed. The reflection coefficient was converted to the spectral index, which is lg(1/R) and the spectra were obtained (Figure 2). The functional groups O-H, N-H, S-H present in the studied samples were determined.

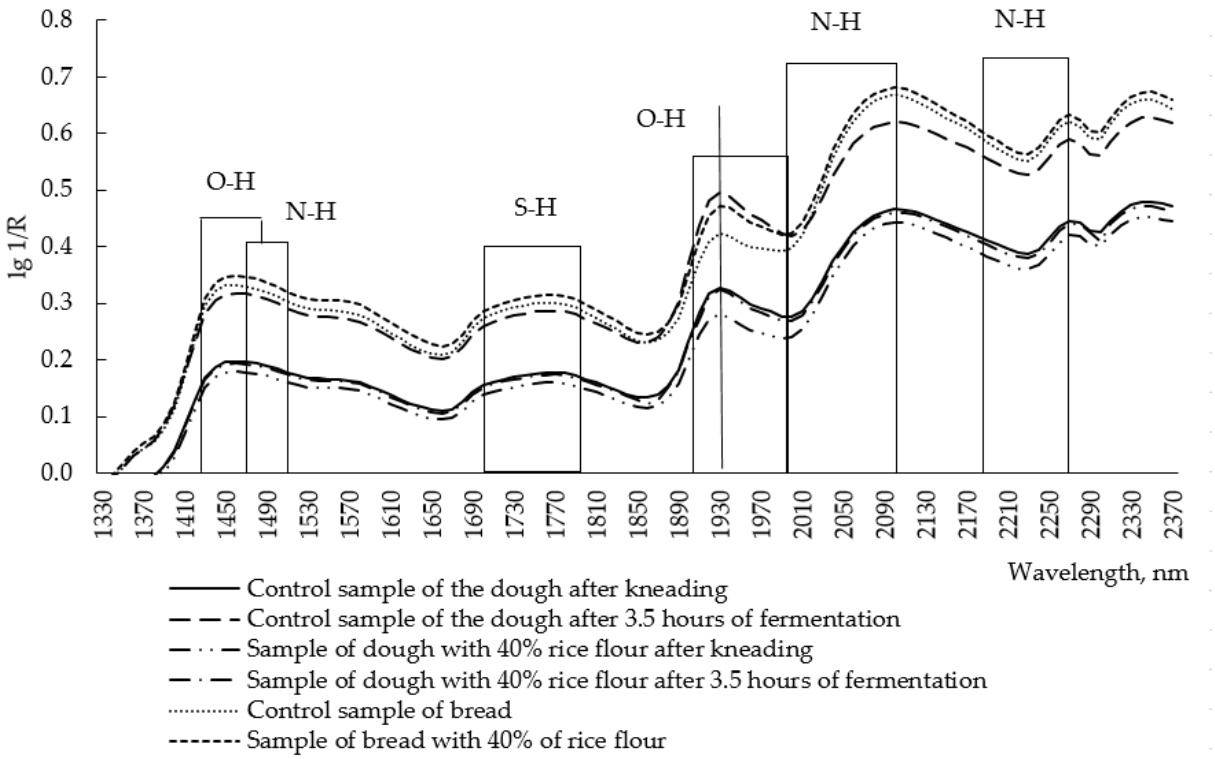

Fig. 2. Changes and redistribution of structural groups in dough after kneading and after 3.5 hours of fermentation and in bread

Analyzing the spectra of the dough obtained after kneading, after 3.5 hours of fermentation and finished bread (control sample and with the maximum researched dosage of rice flour) the following reflectance maxima can be noted: 1460 nm, 1770 nm, 1930 nm, 2100 nm, 2270 nm and 2350 nm. The extremum at a wavelength of 1460 nm corresponds to the valence vibrations of the OH group, the first overtone (it is observed in all tested samples of dough and bread). The functional group of the first overtone of the S-H group appears at a wavelength of 1770 nm. At a wavelength of 1930 nm, it is possible to determine the moisture content

in the samples, i.e. the presence of water (the second overtone of O-H deformation oscillations). At a wavelength of 2100 nm, conformational changes of gluten proteins can be observed, the specified wavelength corresponds to the deformation vibrations of N-H, the second overtone. It was established that to a greater extent these transformations take place in the sample of bread with rice flour and the control sample of bread, which indicates that the protein structure changes significantly under the influence of high temperatures and to a greater extent in the sample with rice flour. Dough samples during the fermentation process also undergo changes in the protein structure compared to samples immediately after kneading.

The nutritional value of bread and provision of daily needs, when part of wheat flour is replaced with rice flour, was determined (Table 2). The daily need for protein was taken at the level of 59.0 g, for fat – 60.0 g, for carbohydrates – 344.0 g, and for fiber – 25.0 g.

Table 2.

Nutritional value of bread samples with the replacement of part of wheat flour with rice flour

Indicators	Control sample	Sample with lecithin	Rice flour to replace wheat flour, %			
			10	20	30	40
Protein, %	8.10±0.22	8.10±0.22	8.46±0.22	8.06±0.22	7.66±0.22	7.25±0.22
Fat, %	1.09±0.01	3.06±0.02	3.08±0.02	3.11±0.02	3.13±0.02	3.15±0.02
Carbohydrates, %	52.97±1.07	52.97±1.07	52.99±1.08	53.00±1.08	53.02±1.08	53.03±1.08
Fiber, %	2.65±0.04	2.65±0.04	2.42±0.04	2.18±0.04	1.95±0.03	1.71±0.03

Analysis of the chemical composition of bread without rice flour and with its addition showed a slight decrease in protein content by 4.4-10.5%, depending on the dosage, and fiber content by 8.7-35.5%. This is a positive factor due to the use of rice flour in dietary therapy for IBD.

It was also calculated the degree of provision of the daily need for nutrients due to the consumption of 100 g of bread and the daily norm of bread in Ukraine - 277 g (according to "Decree of the Cabinet of Ministers of Ukraine" No. 656). The data are shown in Table 3.

Table 3.

Ensuring the daily need for basic nutrients when replacing part of the wheat flour with rice flour

Indicators	Control sample	Sample with lecithin	Rice flour to replace wheat flour, %			
			10	20	30	40
Integral score, % due to consumption of 100 g of bread						
Protein	15.02	15.02	13.66	13.66	12.98	12.30
Fat	1.82	5.10	5.18	5.18	5.21	5.25
Carbohydrates	15.40	15.40	15.41	15.41	15.41	15.42
Fiber	10.61	10.61	8.73	8.73	7.79	6.85
Integral score, % due to consumption of 277 g of bread						
Protein	24.54	24.54	23.43	22.32	21.21	20.10
Fat	5.04	8.48	8.54	8.60	8.67	8.73
Carbohydrates	42.65	42.65	42.67	42.68	42.69	42.70
Fiber	29.38	29.38	26.78	24.17	21.57	18.97

The degree of providing the daily need for protein due to the consumption of 100 g and 277 g of bread in case of partial replacement of wheat flour with rice is lower than control sample by 9.0-18.1% and 4.5-18.1%, respectively. The body's supply of dietary fibers decreased by 17.7-35.4% and 8.8-35.4% when consuming 100 g and 277 g of bread per day, respectively.

The utilitarian coefficient was calculated, which characterizes the balance of essential amino acids (EAA) in relation to the physiologically necessary norm. To characterize the total amount of EAA that the body uses for anabolic needs, the indicator of the comparative excess of essential amino acids (redundancy coefficient) and the amount of the excess amino acid composition of EAA (the coefficient of difference in the amino acid score of DCAS) and the biological value were calculated (Table 4).

Table 4.
Utilitarian coefficient, DCAS, redundancy coefficient and biological value of bread in case of the partial replacement of wheat flour with different percentages of rice flour

Indicators	Control sample	Sample with lecithin	Rice flour to replace wheat flour, %			
			10	20	30	40
Utilitarian coefficient	0.49±0.01	0.49±0.01	0.54±0.01	0.50±0.01	0.39±0.01	0.32±0.01
Redundancy coefficient	37.25±1.11	37.25±1.11	30.28±1.07	35.90±1.17	55.18±1.22	74.91±1.26
DCAS	0.47±0.01	0.47±0.01	0.64±0.01	0.98±0.01	1.61±0.01	2.31±0.01
Biological value (%)	99.53±2.49	99.53±2.49	99.36±2.47	99.02±2.44	98.39±2.43	97.69±2.32

The analysis of the utilitarian coefficient showed that the degree of balance of essential amino acids in relation to the physiologically necessary norm is the highest in the sample with the replacement of 10% of wheat flour with rice. The coefficient of redundancy of samples shows that the protein of bread with 10% replacement is more fully used by the body for anabolic needs. As the replacement percentage increased, the DCAS indicator increased too. This indicates that the amino acids contained in the control sample are more fully used by the body than when the supplement is applied. In general, the biological value of the control sample is slightly higher than the bread samples with rice flour, but this increase is insignificant.

4. Conclusion

In conclusion, rice flour is a perspective raw material for iuse in diet therapy of patients with IBD, as it contains 8.5 times less dietary fiber than wheat flour. Analysis of the chemical composition of bakery products without rice flour and with its addition showed a slight decrease in protein content by 4.4-10.5%, depending on the dosage, and fiber content by 8.7-35.5%. It was confirmed that in the bread making process, conformational changes occur in the structure of proteins and other nutrients of the product. The utilitarian and redundancy coefficients, KRAS and the indicator of biological value indicate that it is rational to replace 10% or 20% of wheat flour with rice flour.

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