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PROTEIN SUBSTANCES OF RICE FLOUR AND ITS USE IN WHEAT BREAD TECHNOLOGY

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ABSTRACT

The protein substances of the recipe components of bread determine not only its biological value, but also the structural characteristics of the dough for bakery products. In connection with the military aggression of the russian federation, the ecological, economic and food situation in the world has significantly worsened. This caused exacerbation of diseases, including those of the gastrointestinal tract, such as inflammatory bowel disease.

According to the recommendations of nutritionists, it is necessary to increase the content of complete protein with the maximum limitation of fiber in the diet of such patients. For this purpose, rice flour is a promising raw material with a low dietary fiber content.

Rice flour contains less amount of total protein than wheat flour, but it is more complete. It was established that the limiting amino acid of wheat flour is lysine, the amino acid score of which is 0.44, in rice flour it is 6.92. The limiting amino acid of rice flour is tryptophan, the amino acid score of which is 1.61. This indicates that rice flour is complete in terms of amino acid composition, since the amino acid score of the limiting amino acid is more than 1.

The difference in the protein composition of wheat and rice flour affects the structure of the dough. The content of raw gluten decreased when replacing part of the wheat flour with rice flour by 21.6—55.6% with an increase in the percentage of replacement. The elasticity, hydration capacity of gluten and its extensibility also decreased.

The limiting amino acid in all bread samples is lysine, but in the control sample its amino acid score is 0.46, while with an increase in the percentage of replacement of wheat flour with rice flour, it increased to 0.82—2.10. In the sample with the replacement of 20% flour and more, the amino acid score for lysine exceeds 1, which means that the protein of these samples is complete.

Considering the obtained results, it is worth replacing about 20% of wheat flour with rice flour.

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БІЛКОВІ РЕЧОВИНИ РИСОВОГО БОРОШНА ТА ЙОГО ВИКОРИСТАННЯ В ТЕХНОЛОГІЇ ПШЕНИЧНОГО ХЛІБА

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Білкові речовини рецептурних компонентів хліба значною мірою визначають не лише його біологічну цінність, а й структурні характеристики тіста для цих виробів. У зв'язку з військовою агресією російської федерації у світі значно погіршилась екологічна, економічна та продовольча ситуації. Це спричинило загострення захворювань, в тому числі шлунково-кишкового тракту, таких як запальні захворювання кишечника.

Згідно з рекомендаціями дієтологів у раціоні таких хворих варто підвищувати вміст повноцінного білка при максимальному обмеженні клітковини. З цією метою перспективною сировиною з низьким вмістом харчових волокон є рисове борошно.

Рисове борошно містить менше білка, ніж пшеничне, але він більш повноцінний. Встановлено, що лімітуючою амінокислотою пшеничного борошна є лізин, амінокислотний скор якої 0,44, у рисовому борошні — 6,92. Лімітуючою амінокислотою рисового борошна є триптофан, амінокислотний скор — 1,61. Це свідчить про те, що рисове борошно є повноцінним за амінокислотним складом, оскільки амінокислотний скор лімітуючої амінокислоти більше 1.

Різниця в білковому складі пшеничного і рисового борошна впливає на структуру тіста. Встановлено тенденцію зменшення вмісту сирої клейковини при заміні частини борошна пшеничного рисовим на 21,6—55,6% зі збільшенням відсотка заміни. Знижується також пружність, гідратаційна здатність клейковини та її розтяжність.

Лімітуючою амінокислотою в усіх зразках хліба є лізин, однак у контролі його амінокислотний скор 0,46, в той час як зі збільшенням відсотка заміни пшеничного борошна рисовим, він збільшується до 0,82—2,10. У зразку з заміною 20% борошна і більше амінокислотний скор за лізином перевищує 1. Це означає, що білок цих зразків є повноцінним.

Зважаючи на отримані результати, варто проводити заміну близько 20% пшеничного борошна рисовим.

Ключові слова: *хліб, рисове борошно, запальні захворювання кишечника, амінокислота, клейковина.*

Formulation of the problem. The protein substances of the recipe components of bread determine not only its biological value, but also the structural characteristics of the dough for bakery products (Sivam, Sun-Waterhouse, & Quek, Perera, 2010). In connection with the military aggression of the russian federation, the ecological, economic and food situation in the world has significantly worsened. This caused exacerbation of diseases, including those of the gastrointestinal tract, such as inflammatory bowel disease (IBD).To slow down the development of these diseases and maintain he-

alth, it is recommended to follow diet therapy (Burisch, & Munkholm, 2013; Stepanov, Skyrda, & Petishko, 2017).

According to the recommendations of nutritionists, it is necessary to increase the content of complete protein with the maximum limitation of fiber in the diet of such patients (Forbes та ін., 2017). For this purpose, rice flour is a promising raw material with a low dietary fiber content.

Analysis of recent research and publications. 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 for raw materials with a reduced amount. Rice and its processed products contain little dietary fiber, but at the same time their protein is complete.

In addition, rice germ contains phenolic compounds and tocopherols, tocotrienols and γ-oryzanol which are lipophilic antioxidants. These substances extend the shelf life of products and protect from free radicals (Esa, Ling, & Peng, 2013).

Rice flour is widely used in gluten-free bread technologies. Protein, fat and fiber content was determined in bread made from traditional rice flour and high-proteinflour. An organoleptic evaluation of gluten-free bread was carried out. Sensory evaluation included the analysis of appearance, aroma, texture and taste of bread. The protein content of bread made from traditional rice flour was 9.25%, with increased content — 10.1%. According to organoleptic indicators, both types satisfied the needs of consumers (Paz, King, & Prinyawiwatkul, 2021).

Studies evaluating the influence of rice nutritional compounds on consumer characteristics and sensory evaluation of bread showed that the content of arginine in different types of rice flour (from long-grain rice, polished round-grain rice and black rice) was higher by 44.19, 21.74 and 34.78% respectively, than in wheat flour. When the added amount of rice flour exceeds 15%, the prepared bread gradually loses its elasticity and has a lower specific volume (Tian, Wei, & Chen, 2022).

The main nutrients (crude protein, fat and carbohydrates) and nutritional components (vitamins A, C, E, minerals, amino acids and fatty acids) of rice flour were analyzed. The content of crude protein, fat, and carbohydrates in rice flour was 6.80 g, 0.14 g, and 84.43 g, respectively. No vitamin A was detected, and vitamin C and E were 8.30 and 0.3467 mg/100 g, respectively. The content of calcium, potassium, magnesium, iron and sodium was 6.23, 65.05, 9.78, 0.17 and 2.84 mg/100 g. A large amount of potassium contributes to the excretion of sodium. Rice flour contains eight essential amino acids. As for essential fatty acids, the content of linoleic acid was 41.01 mg/100 g, and linolenic acid was 2.20 mg/100 g (Lee, Jung, Jo, Back, Kim, & Park, 2018).

The effect of replacing wheat flour with 5%, 10% and 15% protein concentrates from natural and yeast-fermented rice bran on the rheological properties of dough and bread was studied. The specific volume of bread from 100% wheat flour did not differ significantly from bread with up to 10% protein concentrate replacement. The optimized composite bread contained higher total amino acid content, radical scavenging activity and iron reducing capacity than the control sample. The springy indicators of wheat bread did not differ significantly from composite bread. Scanning electron microscopy revealed that the composite bread has a surface with embedded granules similar to protein deposits with small pores (Chinma, Ilowefah, Shammugasamy, Mohammed, & Muhammad, 2015).

Since it is not recommended to completely exclude gluten from the diet during diet therapy for people with IBD, replacing wheat flour with rice flour is a promising direction. The relationship between the properties of rice flour with different degree of damage of starch grains and the specific volume of bread made from a mixture of rice and wheat flour was studied. The best quality flour was obtained by fine grinding and the absence of a large number of damaged starch grains to make high quality bread (Araki, 2009).

The purpose of the research is to determine the content and completeness of protein substances of wheat bread with rice flour and their influence on structural properties of dough and sensory characteristics of bread.

Materials and methods. *Sample preparation.* Dough samples were prepared from wheat flour 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.

Essential amino acid (EAA) composition. For determination amino acid composition method of ion exchange chromatography was used (Litvynchuk et. al., 2022). The qualitative determination of amino acids was carried by hydrolysis of proteins. The determination of quantitative estimation of amino acids was held using an automatic analyzer of amino acids, T-339 (Czech Republic), using polystyrene sulfonate ion exchange resins of "Ostion LJ ANB" in Li-citrate buffer one-column mode. The elution of amino acids from the column was conducted, in turn, by Li-citrate buffers from pH 2.75 ± 0.01; pH 2.95 ± 0.01; pH 3.2 ± 0.02; pH 3.8 ± 0.02; pH 5.0 ± 0.2. Amino acids were detected by rectification with a ninhydrin solution using photometer (Unicam SP 800, Britain) at a wavelength of 560 nm. The results of detection in the form of the peaks of absorption of light of ninhydrin positive substances in an eluent that count the direct ratio concentrations of this substance in solution were registered by a variplotter. The correlation of the solution of ninhydrin reagent and eluents was 1:2; the temperature of thermostatic T_1 = 38.5° C; T_2 = 65 °C. The prototype was diluted in Li-citrate buffer by pH 2.2 ± 0.02 and inflicted on an ion exchange column. The quantitative estimation of chromatograms of the pre-production model settled in relation to the Bio-Rad standard mixture of amino acids. The mass of every amino acid in the investigated solution was calculated and expressed as g per 100 g protein. Amino acid score is expected according to the certificate scale of THEO/WHO (Choi et. al., 2012).

Wet gluten content. Wet gluten content of the dough samples was determined according to methods stated in SR ISO 21415-1:2007 and in Manual de gradarepentru seminte de consum (2008) and through GIM (AACC 38-12.02 method) using the Glutomatic 2200 system (Perten Instruments AB). The moisture content was determined according to the SR ISO 712:2005 method, the protein content by the NIR technique (Inframatic, model 8600, Perten Instruments AB), and the gluten deformation according to the SR ISO 90/2007 (Ionescu, Stoenescu, Vasilean, Aprodu, & Banu, 2010).

Gluten deformation index. The gluten deformation index values for all samples were determined using Gluten deformation index device. 4 g of sample of wet gluten was left for keeping for 15 min in distilled water. Then it was put on the table of the device. The rod of the device lowered and the device fixed the value of the deformation (Tamba-Berehoiu, Lambrache, & Popa, 2019).

Statistical analysis. The statistical processing of the result values was performed by sequential regression analysis using the Microsoft Excel XP and Origin Pro8 software calculating correlation coefficients (Hinkle, Wiersma, & Jurs, 2003).

Results and discussion. Rice flour contains less amount of total protein than wheat flour — 6 та 11,3 g/100 g of flour, respectively. However, despite this, the content of the majority of essential amino acids (EAA) is higher (Table. 1).

Table 1. **Amino acid composition of rice and wheat flour**

EAA	EAA content, g/100 g of raw material	
	Wheat flour of premium grade	Rice flour
Valine	0.42	4.21
Isoleucine	0.36	3.31
Leucine	0.71	6.20
Lysine	0.23	2.59
Methionine	0.40	3.00
Threonine	0.28	2.41
Tryptophan	0.13	0.10
Phenylalanine	0.52	6.62

To assess the completeness of protein substances, the amino acid score of each amino acid was calculated. It was established that the limiting amino acid of wheat flour is lysine, the amino acid score of which is 0.44, in rice flour it is 6.92. The limiting amino acid of rice flour is tryptophan, the amino acid score of which is 1.61. This indicates that rice flour is complete in terms of amino acid composition, since the amino acid score of the limiting amino acid is more than 1. The introduction of this raw material into the recipe of wheat bread is not able to increase the total protein content, but an increase in the degree of balance of essential amino acids in relation to the physiologically necessary norm is expected. It is also predicted that protein will be used more fully for anabolic needs by the body.

The fractional composition of the protein of rice flour also differs from that of wheat flour. It was established (Shevchenko, & Litvynchuk, 2022) that the content of glutelins and globulins is higher in rice flour, but the composition of glutelins is different. In wheat flour, it is glutenin which forms the gluten of the dough (Huang, Tsai, & Chen, 2011).

In rice flour, the representative of glutelins is oryzenin, which is not a gluten protein (Jayaprakash, Bains, Chawla, Fogarasi, & Fogarasi, 2022). The content of albumin, prolamin and insoluble proteins prevails in wheat flour.

The difference in the protein composition of wheat and rice flour affects the structure of the dough, changing the basic structural units of dough and bread with these components in the recipe.

An important indicator of the structural and mechanical properties of the dough is the amount and quality of gluten washed from it. Since there are no gluten proteins in rice flour, a change in the structure of the gluten framework of the dough is predicted when part of the wheat flour is replaced by rice flour (Table 2).

Table 2. **The quantity and quality of gluten washed from the dough**

Sample	Amount of rice flour to replace wheat flour, %	Amount of wet gluten, %	Amount of dry gluten, %	Value of GDI, units	Hydration capacity, %	Extensibility, sm
Control sample	–	25.30±1.23	8.5	70	195.5	15.2
Sample with rice flour	10	19.82±1.18	6.72	89	186.7	15.1
	20	15.46±1.02	5.25	94	182.1	14.8
	30	13.20±0.93	4.48	101	175.2	14.2
	40	11.24±0.43	3.82	107	169.3	13.8

The content of raw gluten decreased when replacing part of the wheat flour with rice flour by 21.6—55.6% with an increase in the percentage of replacement. The elasticity, hydration capacity of gluten and its extensibility also decreased. Rice flour weakens gluten. The decrease in hydration capacity occurs as a result of the physical obstruction of rice starch particles to hydration and the development of the gluten network. The strength of the dough is related to gluten proteins, and replacing wheat flour with rice flour causes their dilution, which can disrupt the integrity of the protein matrix (Ahmad et. al., 2017; Pu et. al., 2017).

The maximum weakening of protein was observed when replacing wheat flour with rice at the level of 40%. This can be explained by a greater disruption of the protein matrix, as replacing wheat flour with rice flour reduces the gluten content. The absence of a gluten protein network in rice flour prevents the formation of a strong viscoelastic structure.

Wheat flour contains more bran, which is a source of the endogenous starch-hydrolyzing enzyme alpha-amylase, while replacing wheat flour with rice flour reduced the enzyme content (Gujral, Sharma, & Singh, 2019; Kaur, Singh, Pal, & Kaur, 2018).

The amino acid composition of raw materials determines the biological value of finished bakery products. The amino acid profile of bread baked with the replacement of part of wheat flour with rice flour was determined. The results are shown in Table 3.

Table 3. **Amino acid composition of bread baked with the replacement of part of wheat flour with rice flour**

EAA	Control sample	Rice flour to replace wheat flour, %			
		10	20	30	40
Leucine	0.71	1.00	1.33	1.68	2.08
Isoleucine	0.39	0.64	0.92	1.23	1.58
Methionine	0.31	0.52	0.76	1.03	1.32
Lysine	0.23	0.41	0.61	0.83	1.08
Phenylalanine	0.68	1.09	1.56	2.07	2.65
Threonine	0.28	0.50	0.73	1.00	1.29
Valine	0.43	0.71	1.02	1.37	1.76
Tryptophan	0.09	0.09	0.10	0.10	0.11

The amino acid score of each amino acid in bread samples was calculated (Table 4).

Table 4. **Amino acid score of amino acids in bread baked with the replacement of part of wheat flour with rice flour**

EAA	Control sample	Rice flour to replace wheat flour, %			
		10	20	30	40
Leucine	1.11	1.56	2.05	2.59	3.19
Isoleucine	1.06	1.74	2.49	3.32	4.23
Methionine	0.97	1.63	2.35	3.16	4.05
Lysine	0.46	0.82	1.20	1.63	2.10
Phenylalanine	1.23	1.98	2.81	3.72	4.74
Threonine	0.77	1.34	1.98	2.68	3.46
Valine	0.93	1.54	2.21	2.95	3.78
Tryptophan	0.98	1.02	1.06	1.10	1.15

Since the percentage of wheat flour in the bread recipe is the highest, its chemical composition will largely determine the biological value of the bread. The limiting amino acid in all bread samples is lysine, but in the control sample its amino acid score is 0.46, while with an increase in the percentage of replacement of wheat flour with rice flour, it increased to 0.82—2.10. In the sample with the replacement of 20% flour and more, the amino acid score for lysine exceeds 1, which means that the protein of these samples is complete.

Trial baking (Figure 1) and expert evaluation of products with the participation of tasters were carried out. The results were processed by the method of mathematical statistics (Table 5).

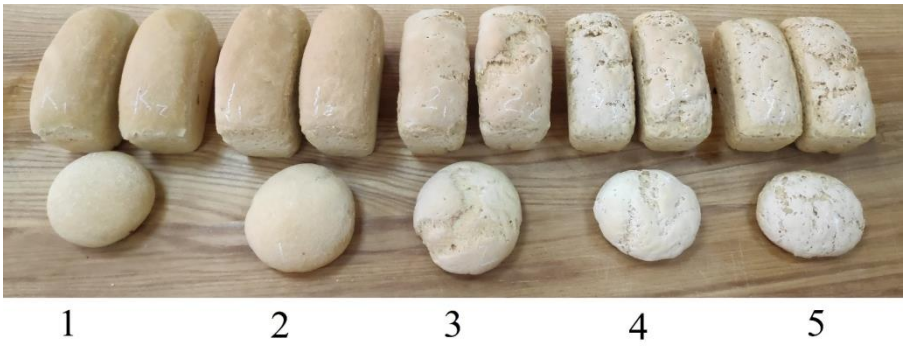

Figure 1. Samples of bread with the replacement of part of the wheat flour with rice flour:
1 — control sample; 2 — replacement of 10%; 3 — replacement of 20%; 4 — replacement of 30%; 5 — replacement of 40%

Table 5. **Sensory assessment of the bread on a 100-point scale taking into account the weighting factor of quality indicators**

Indicators	Weighting factor	Control sample	Rice flour to replace wheat flour, %			
			10	20	30	40
Specific volume of bread, $cm^3/100$ g	0.15	4.6±0.3	4.7±0.3	3.5±0.3	2.5±0.3	2.0±0.3

Continuation of table 5

Shape stability of bread, baked without form	0.15	convex upper crust	convex upper crust	convex upper crust	convex upper crust	convex upper crust
		5.0±0.3	4.3±0.3	3.5±0.3	2.5±0.3	2.0±0.3
Color of the crust	0.05	light yellow	light yellow	light yellow	pale	pale
		5.0±0.3	5.0±0.3	5.0±0.3	4.0±0.3	3.0±0.3
Surface condition	0.05	smooth, without cracks	with cracks	with significant cracks	with large cracks	with large cracks
		5.0±0.1	4.6±0.1	3.9±0.1	3.0±0.1	2.0±0.1
Color of the crumb	0.05	light	light	light	light	light
		5.0±0.1	5.0±0.1	4.7±0.1	4.5±0.1	4.0±0.1
Porosity structure	0.09	even, small thin-walled	even, small thin-walled	even, small thin-walled	not developed	not developed
		4.8±0.3	4.8±0.3	4.8±0.3	3.5±0.3	3.0±0.3
Elasticity of the crumb	0.12	elastic	elastic	elastic	not elastic	not elastic
		4.8±0.1	5.0±0.1	5.0±0.1	4.0±0.1	4.0±0.1
Aroma	0.11	inherent in the product	inherent in the product	inherent in the product	inherent in the product	inherent in the product
		4.6±0.3	4.8±0.3	4.8±0.3	4.8±0.3	4.8±0.3
Taste	0.13	inherent in the product	inherent in the product	inherent in the product	inherent in the product	inherent in the product
		4.8±0.3	4.8±0.3	4.8±0.3	4.8±0.3	4.8±0.3
Chewiness of the crumb	0.10	good chewiness	good chewiness	good chewiness	good chewiness	good chewiness
		5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1	5.0±0.1
Score (out of 100 points)		97.2±0.2	96.0±0.2	90.0±0.2	77.2±0.2	69.2±0.2

The analysis of baked products indicates the appearance of cracks on the surface of samples with 20—40% replacement of wheat flour with rice flour. There is also a decrease in specific volume, porosity and dimensional stability, which was established in previous studies (Дробот, Шевченко, & Літвинчук, 2021).

Expert assessment and sensory indicators of the products indicated that in order to obtain bakery products of high quality and complete in terms of amino acid composition, it is worth replacing about 20% of wheat flour with rice flour.

Conclusions

Rice flour contains less amount of total protein than wheat flour, but it is more complete. It was established that the limiting amino acid of wheat flour is lysine, the amino acid score of which is 0.44, in rice flour it is 6.92. The limiting amino acid of rice flour is tryptophan, the amino acid score of which is 1.61. This indicates that rice flour is complete in terms of amino acid composition, since the amino acid score of the limiting amino acid is more than 1.

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Considering the obtained results, it is worth replacing about 20% of wheat flour with rice flour.

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