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NADA NIKOLIĆ[1]
JELENA DODIĆ[2]
MIRJANA MITROVIĆ[1]
MIODRAG LAZIĆ[1]

[1]University of Niš, Faculty of Technology, Leskovac, Serbia
[2]University of Novi Sad, Faculty of Technology, Novi Sad, Serbia

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RHEOLOGICAL PROPERTIES AND THE ENERGETIC VALUE OF WHEAT FLOUR SUBSTITUTED BY DIFFERENT SHARES OF WHITE AND BROWN RICE FLOUR

In order to produce dough with a lower gluten content, more enriched with rice components and satisfactory rheological properties, the rheological properties, energetic value and cake baking properties of wheat and white or brown rice flour in shares from 3 to 30% (w/w) were investigated in this paper. The water absorption in wheat-rice flour mixtures was lower and decreased to 53.5% and 54.0% along with the increase of the white and the brown rice flour share, respectively, than in wheat flour, where it was 58.8%. In the dough made from rice flour, a gluten network had thinner filaments, about 2 and 1 μm in width for white and brown rice flour, respectively, compared to those in the dough from wheat flour only, where it was about 7 μm. The dough from rice flour had almost twice higher gelatinization maximum than the gelatinization maximum of the wheat flour only. The energetic values of the dough from rice flour were smaller than the energetic value of the wheat flour, for only 1.32%. Based on Cluster analysis, the white or brown rice flour share of 20% was pointed out.

Key words: rice; wheat; dough; rheology; energetic value.

Rice (*Oryza sativa* L.) is a very nutritive, biologically active tropic plant: it is gluten-free and has low content of sodium, a high content of easily digested carbohydrates, desirable in some diets, and components with antioxidant properties [1,2]. The content of fat, starch, mineral matters and vitamins, especially vitamin E and B in rice is variable and mostly depends on genetic diversity [3]. The rice bran is a good source of protein, lysine, low saturated fat [4,5] and can be used for fiber and mineral enriched bread and cookies [6]. The consumption of rice bran reduces the risks of cardiovascular diseases and colon cancer [7], and oryzanol obtained from rice bran has the ability to reduce plasma lipid content and lipoprotein cholesterol concentration [8].

The dough rheology is very important for the prediction of the final bakery product quality [9,10] such as mixing behavior, sheeting and baking performance, and based on starch gelatinization data the overall cooking behavior and product properties can be determined [11]. Dough rheology depends on many factors: milling parameters of wheat varieties [12], dough mixing time and temperature [13], lipid content [14,15], cyclodextrinase content [16] and additives application [17]. Lipids are important due to the interaction with gluten proteins, which occurs during dough mixing [18,19]. During baking, the solid lipids allow bubbles to expand without rupting [20] as their crystals melt and make possible crystal-liquid incorporation into the surface of the bubbles [13]. According to Li *et al.* [21] results showed that polar lipids were present in protein matrix, in gas cell walls and at the surface of some particles, probably starch granules, while non-polar lipids mainly occurred on the surface of particles, which may be starch, and in small lipid droplets.

The manufacture of bread from rice flour only, which means without gluten, has considerable technological difficulties [22,23] because gluten is the most important structure for making bread [16,24] and gluten matrix must be replaced with other components such as hydrocolloids [25]. Various studies have been conducted to examine the effects of additives on rice bread quality. The results of Sivaramakrishnan *et al.* [17] showed that the gum type additives, such as hydroxyl propyl methyl cellulose (HPMC), re-

Correspondening author: N. Nikolić, University of Niš, Faculty of Technology, Food Technology and Biotechnology Department, Bulevar oslobodjenja 124, 16000 Leskovac, Serbia.
E-mail: nadanikolic64@yahoo.com
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sulted in successful formation of rice bread showing the optimum volume expansion, while Gujral and Rosell [26] found that the enzyme glucose oxidase can be incorporated into the rice bread formula to improve the bread quality. In order to examine the dough rheological properties and produce bread or other food products with rice, different formulations are made: rice starch was added to wheat flour [27,28], wheat flour was replaced by pre-germinated brown rice [29], by non-defatted [30] or defatted rice bran [31], by rice flour different cooking properties [32], etc.

The aim of this paper was to investigate the possibility of making dough with the lower gluten content having satisfactory dough rheological properties, by using rice flour and without additive. At the same time, dough can be enriched with the nutritive rice components. The production of the wheat-rice dough could be especially suitable for different food products in the countries where the rice production is at a higher level than the wheat one. For these purposes, the effect of the white or brown rice flour addition to the wheat flour in share 3-30% on farinograph, extensograph and amylograph properties of the dough and cake baking parameters were examined. Due to find an optimal rice flour share for the dough with most similar dough rheological properties to those of the wheat flour only, the Cluster analysis was used. As informing of consumers about the energetic value is important and often required, the energetic value of investigated flour mixtures was calculated based on protein, lipid and carbohydrates content and compared to those of the wheat flour. In order to investigate a disposal of the wheat and rice starch granules and rice bran in the wheat-gluten network, scanning microscopy was also performed.

EXPERIMENTAL

Flour analysis

Wheat flour type 500 (Kikinda Mill, Serbia) and rice grains were bought at a local market. The rice flour was obtained by milling grains of white var. San Andreas and brown rice var. Basmati. A flour mixture was obtained by adding rice flour to the wheat flour in shares of 3, 5, 10, 15, 20 and 30% (w/w). The moisture content was determined by a Scaltec SMO 01 instrument (Scaltec instruments, Germany) when the flour (5 g) was put into the disk plate analyzer dried at 110 °C to a constant weight and the moisture content was read out on the display. The ash content was determined by staking oven dry samples at 800 °C during 5 h. The starch content was determined by the method of polarimetry (ISO 10520:1997) and the protein content by Kjeldahl method ISO 5983 (1997). In order to determine the lipid content, n-hexane extraction in duplicate by using reflux were performed. The flour-solvent ratio was 1:20 w/v, temperature was solvent boiling temperature and the extraction time was 60 min. The extracts were combined and the lipid residue content was determined by the Scaltec SMO 01 instrument (Scaltec instruments, Germany): 3 ml of combined extracts was dried at 110 °C to a constant weight and content was read out on the display. The gluten content was determined by ISO 21415-4:2006 method and the total carbohydrates content by Luff-Schoorl's method [33]. Triplicate determinations were performed for all analyses and flours.

Energetic value

Based on total carbohydrates (*CHC*), the protein (*PC*) and lipid content (*LC*), the energetic value (*EV*, kJ/100g) of wheat flour and white and rice flour mixtures was calculated as:

$$EV = 17(CHC + PC) + 37LC$$

Rheological measurement

The Brabender farinograph (Brabender, model 810 101, Duisburg, Germany) according to ISO 5530-1 test procedure, was used for water absorption values (*WA*, %), the development time (*DT*, min), dough stability (*DSt*, min) and a degree of softening (*DSf*, farinograph units: BU) determination.

For extensograph measurements, a Brabender extensograph (Brabender, model 8600-01, Duisburg, Germany) and test procedure ISO 5530-2 were used. The samples were prepared from flour, distilled water and salt, and the data for energy (E, cm^2), resistance (R, extensograph unit: EU) and extensibility (Ex, mm) were recorded on the extensograph curve. To obtain amylograph data, gelatinization temperature (T_{max}, °C) and gelatinization maximum, (η_{max}, amylograph unit: AU), the amylograph (Brabender, model PT 100, Duisburg, Germany) and ISO 7973 test procedures were used.

Baking procedure

The dough base formulation used comprised: wheat flour and rice the flour to obtain flour mixture with 3 to 30% of rice flour shares, 10% of vegetable fat, 30% of sugar, 1.8% of sodium chloride, 6% sodium hydrogen carbonate, 0.15% of ascorbic acid and the water amount based on farinograph data. The ingredients were mixed in a farinograph and the dough was allowed to rest 30 min at room temperature. Then the dough was shortened and round shape cakes with 3.5 cm in diameter and 1 cm of height were cut out. The cake "holding" value before baking (HV^1) as the ratio of the cake height to diameter, was determined.

The cakes were baked at 180 °C for 15 min. After baking and cooling, the cake "holding" value after baking (HV^2) was also determined. The cake weight was also measured before and after baking. In order to determine the cake volume before and after baking, the cake was enveloped by foil, sunk into the water and the volume of the ousted water was measured. Based on these data, baking loss (BL, %) and volume rise (VR, %) were obtained as:

$$BL = \\ = 100\frac{\text{Weight before baking} - \text{Weight after baking}}{\text{Weight before baking}}$$

$$VR = \\ = 100\frac{\text{Volume after baking} - \text{Volume before baking}}{\text{Volume before baking}}$$

Scanning electron microscopy

For scanning electron microscopy, a small portion of dough (dough ofrom pure wheat, dough from white or brown rice flour share of 30% prepared in the farinograph was cut with a razor blade, fixed with glutaraldehyde (1:30, w/v) for 2 h and embedded in graded acetone series (25, 50, 75 and 80 g/100 g) for 20 min at each concentration, in accordance with the Ribotta *et al.* [34] procedure. Then, the samples were embedded in 100% acetone for three consecutive 20 min intervals to ensure full dehydratation and then drying at "critical point". Drying at "critical point" allows acetone removal in CO_2 without surface tension force that may distort the sample. The dehydrated samples were coated with gold particles for 4 min. The images were taken by using a JEOL 35 CF, Japan, scanning electron microscopy with the 20 and 30 kV acceleration voltages. The micrographs were taken by using 3500 and 7500× magnification.

Statistical analysis

The statistical analysis was performed by Statistica program, version 5.0. The means and standard deviations were obtained by Descriptive Statistics, marking the Median & Quartiles and Confirm Limits for Means. For statistical dependences, the data for dependent samples were analyzed by *t*-test. The correlation coefficients were obtained by basic Statistics and Tables, marking the Correlations matrices with p&N display. In order to classify the mixtures of wheat flour with different rice flour share into groups, the Cluster analysis and the Euclidean method with the complete linkage was used.

RESULTS AND DISCUSSION

Chemical properties of wheat and rice flour

The results analyses of flour moisture, ash, starch, protein, lipid, gluten and carbohydrates content are showed in Table 1. Data are presented as means of three determinations with standard deviation. Based on the protein, lipid and carbohydrates content the wheat flour is significant different comparing to both rice flour and it contains the gluten, while both rice flours are gluten free. Based on ash and starch content the wheat flour is significant different comparing to brown rice flour. Between white and brown rice flour there is significant difference in ash, protein lipid and carbohydrates content and there is no significant difference in starch content. This is in accordance to An and King [11] results as their sample of brown rice flour had higher ash, lipid and protein content and lower carbohydrates content than both investigated white rice flours.

Energetic value

The obtained energetic values are presented in Table 2. By substituting wheat flour with white and brown rice flour, the results show that the energetic values were slightly smaller than energetic value of wheat flour (1594 kJ/100 g), except in mixture with 3% share of brown rice flour. These decreased from 0.13 to 1.32% when white rice flour shares were from

Table 1. The contents (%) of components in wheat and rice flour. Data are presented as means of three determinations ± SD; the values followed by the same letter in the same column are not significantly different at $p < 0.05$

Flour	Moisture	Ash	Starch	Protein (N×5.95)	Lipid	Gluten	Carbohydrates
Wheat flour	12.8±0.6^a	0.48±0.04^b	76.6±1.2^a	9.86±0.34^a	1.9±0.05^b	23.9±0.4	79.8±2.2^b
White rice flour	12.2±0.5^a	0.31±0.04^b	69.8±0.9^{a,b}	4.49±0.29^c	1.3±0.04^c	0	81.2±3.1^a
Brown rice flour	12.5±0.6^a	1.61±0.06^a	64.9±0.8^b	5.33±0.32^b	2.8±0.06^a	0	77.4±1.9^c

Table 2. The energetic value (kJ/100 g) of the wheat flour and mixtures with different shares of white and brown rice flours

Flour	Flour mixture with wheat and white rice flour share, %					
	3	5	10	15	20	30
White rice flour	1592	1591	1587	1584	1580	1573
Brown rice flour	1595	1592	1590	1586	1584	1578

3 to 30% and from 0.13 to 1.00% when brown rice flour shares were from 5 to 30%. The energetic value of the dough made from white rice flour was only 0.32% less than the dough from brown rice flour.

Rheological properties

Farinograph data of wheat flour and six dough mixtures with different shares of white and brown rice flour are given in Table 3.

The water absorption decreased from 58.0 to 53.5% with increasing the white rice flour share and from 57.5 to 54.0% with increasing the brown rice flour share. This might to be due to the decrease of the gluten content in the dough when wheat flour was substituted by white or brown rice flour, as rice is gluten free. According to Belton [35] and Letang *et al.* [36] model, during mixing gluten absorbs water tending to align cross-links polymeric chains with disulphide bonds and the flour with higher protein i.e. gluten content for wheat flour, has higher level of water intake [37]. The decrease of water absorption value was also noticed when brown rice was used to substitute wheat flour in share of 10, 20 and 30% [29] and when the rice bran was added to wheat flour in share from 2 to 20% [30]. On the other hand, the marginal increase of water absorption is noticed when the rice bran was used in share of 10 to 40% [38] and when 0.25 to 0.50% of rice water-soluble non-starch polysaccharides were added to wheat flour [39].

As rice bran contains high fiber content of 20--27% [40], it could be expected that the presence of fibres will increase the water absorption value. But, based on these results, they probably do not absorb water during dough mixing but in some later stage, maybe during baking.

The development time of the dough mixture with both rice flour and share up to 15%, was similar to the development time of dough from wheat flour only (up to 2.5 min instead 2 min which was for the wheat flour), while development time of the dough with rice

Table 3. Rheological data of dough from wheat flour and mixtures with different shares of white and brown rice flours. Data are presented as means of three determinations ± SD, significance level of 0.05 (WA - water absorption; DT - development time; DSt - dough stability; DSf - degree of softening; E - energy; R- resistance; Ex- extensibility; T_{max} - gelatinization temperature; η_{max} - gelatinization maximum)

Parameter	Flour mixture with wheat and white rice flour share, %						
	Wheat	3	5	10	15	20	30
	Farinograph data						
WA / %	58.2±0.6	58.0±0.6	57.7±0.6	57.0±0.6	55.4±0.6	54.5±0.6	53.5±0.6
DT / min	2.0±0.2	2.0±0.2	2.0±0.2	2.2±0.3	2.5±0.3	4.5±0.5	7.0±0.2
DSt / min	1.5±0.1	1.5±0.1	1.5±0.1	1.5±0.2	2.0±0.3	4.5±0.4	4.5±0.2
DSf / BU	40±2	40±3	40±2	40±2	40±3	30±2	20±2
	Extensograph data						
E / cm^2	101.2±5.8	88.1±4.6	88.4±4.2	85.6±4.5	71.3±3.6	65.6±3.8	52.2±3.2
R / EU	370±10	320±10	310±12	310±12	270±10	280±10	280±10
Ex / EU	144±10	148±12	148±10	145±10	142±11	136±9	120±6
	Amylograph data						
T_{max} / °C	88.4±1.1	88.0±1.2	88.2±1.2	88.2±1.3	88.7±1.3	98.1±1.5	98.1±1.5
η_{max} / AU	480±20	490±20	500±25	560±25	595±30	635±30	790±30
	Flour mixture with wheat and brown rice flour share, %						
	Farinograph data						
WA / %	58.2±0.6	57.5±0.5	57.4±0.5	56.5±0.6	55.5±0.5	54.6±0.6	54.0±0.6
DT / min	2.0±0.2	2.0±0.2	2.5±0.3	2.5±0.2	2.5±0.2	6.0±0.3	8.0±0.3
DSt / min	1.5±0.1	1.5±0.1	1.5±0.1	2.0±0.3	2.5±0.3	3.0±0.3	3.0±0.3
DSf / BU	40±2	40±2	40±3	30±2	30±2	30±2	30±2
	Extensograph data						
E / cm^2	101.2±0.6	98.3±0.6	98.0±0.6	82.8±0.6	83.1±0.6	75.2±0.6	52.0±0.6
R / EU	370±10	370±10	370±10	350±10	350±10	350±10	340±10
Ex / mm	144±10	140±10	140±10	136±12	131±10	118±10	99±6
	Amylograph data						
T_{max} / °C	88.4±1.1	88.5±1.2	88.8±1.2	88.9±1.5	88.9±1.5	90.2±1.5	90.2±1.5
η_{max} / AU	480±20	520±15	560±25	610±25	680±30	715±30	870±30

share of 20 and 30% was considerably prolonged (4.5 to 7 min for the white rice flour dough and 6 to 8 min for the brown rice flour dough, respectively). The longer development time was also noticed by Sivaramakrishnan *et al.* [17] for pure rice flour. The dough stability was longer than the stability of wheat flour dough, when the rice share was over 10% and for the share of 30%, it was 4.5 and 3 min for white and brown rice flour dough, respectively, compared to wheat flour dough, where this value was 1.5 min. This is in accordance with Oszvald *et al.* [32] investigations where the addition of wheat protein to rice flour had less stable dough as the result. In the investigations of Watanabe *et al.* [29], the dough stability time was shorter when wheat flour was substituted by brown rice flour in share of 10, 20 and 30% compared to wheat flour only. These differences might be caused by different rice grains used for obtaining rice flour and the chemical composition of used wheat flour. When compared to the dough made from the wheat flour only, the degree of softening decreased for 10 and 20 BU in the dough made from white rice flour shares of 20 and 30%, respectively. In the dough made from brown rice flour shares of 10% and over 10%, the degree of softening decreased for 10 BU.

The data obtained on the extensograph are presented in Table 3. The dough with rice flour had lower energy value and lower dough resistance (except the dough with brown rice flour share of 3 and 5%), compared to the wheat flour dough. These values decrease with the increase of the share of white or brown rice flours. The lower value of dough energy showed that by adding rice flour the dough was weaker than dough from the wheat flour. The extensibility of white rice flour dough was in the range from 148 to 120 EU and brown rice flour dough in the range from 140 to 99 EU, while the extensibility of the wheat flour dough was 144 EU. So, the share of the white rice flour of 15% and over, and all shares of brown rice flour, made less extensible dough.

The amylograph data in Table 3 showed that the dough with white rice flour shares of 15, 20 and 30% and dough with all brown rice flour shares had a higher gelatinization temperature than dough from wheat flour only. Watanabe *et al.* [29] found that the brown rice flour had higher gelatinization temperatures and gelatinization maximum than the wheat flour. The reason for this might be a different shape and size of wheat and rice starch grains as according to Wang et al. [41] and Gregorová *et al.* [42] investigations: the rice starch is the smallest type with the medium size of 4.4-4.8 μm, while the wheat starch is intermediate type with the medium size of 12-21 μm. The reason for this might also be a different amylose content in wheat and rice starch, which could cause differences in thermal characteristics [11]. Saif *et al.* [43] found that besides the amylose content, the rice varieties also significantly affected the gelatinization temperatures. Our dough from white rice flour had a higher gelatinization temperature, for even 7.9 °C, than the dough from brown rice flour, and the reason for this is probably the different amylose content in starch as well as different rice varieties.

The gelatinization maximum for all flour mixtures increases, from 490 to 790 AU with the increase of the white rice flour share and from 520 to 870 AU with the increase of the brown rice flour share and it was almost twice higher than gelatinization maximum of wheat flour. This tendency is in accordance with the results obtained by Schober *et al.* [23] where in dough made from rice flour only this value was over ten times higher than dough made from wheat flour only.

By comparing the rheological properties of the dough made from the white and the dough made from the brown rice flour with share of 20%, the dough with brown rice flour had longer development time and shorter stability time, higher energy and maximum gelatinization value, less extensibility, lower gelatinization temperature and a better "holding" value.

Baking properties

The baking properties of the dough with different white and brown rice flour shares such as baking volume rise (*VS*), baking loss of weight (*BL*) and the cake "holding" value as the ratio of HV^1 and HV^2, were calculated and given in Table 4.

The cakes obtained by the mixtures of white rice flour had higher BL than those obtained by mixtures of brown rice flour and with wheat flour only, and the cakes made from brown rice flour had less BL than the cakes made from wheat flour only. This might be due to the rice bran i.e. its fibers which during baking probably hydrated and bound water. The VR values of the cakes were lower for both rice flour mixtures compared to the VR obtained for cakes from wheat flour only. The cake "holding" value was best in the cake from wheat flour only, while using the white rice flour decreases this value along with the increase of the rice flour share. When brown rice flour was used, the cake with brown rice flour share of 3 and 5% had higher "holding" value than cake from wheat flour only. The higher protein content is one of parameters responsible for better *VR* value, as shown by a correlation coefficient between these parameters in Table 5.

Scanning electron microscopy

Scanning electron micrographs (SEM) of the dough from wheat flour only (a), from white rice flour

Table 4. Baking properties data of cake made from wheat flour and mixtures with different shares of white and brown rice flours. Data are presented as means of three determinations ± SD, significance level of 0.05 (SV - specific volume, VR - volume rise, BL - baking loss, HV^1 - "holding" value before baking, HV^2 - "holding" value after baking)

Properties	Flour mixture with wheat and white rice flour share, %						
	Wheat	3	5	10	15	20	30
BL / %	30.0±0.2	30.3±0.2	30.8±0.2	31.2±0.2	31.7±0.2	31.9±0.2	32.0±0.2
VR / %	54.7±0.6	46.8±0.2	47.1±0.2	47.7±0.2	48.9±0.2	49.5±0.2	50.6±0.2
HV^1/HV^2	1.63±0.2	1.57±0.2	1.47±0.1	1.46±0.1	1.37±0.1	1.23±0.2	1.29±0.1
	Flour mixture with wheat and brown rice flour share, %						
BL / %	30.0±0.2	29.9±0.2	29.9±0.2	29.6±0.2	29.3±0.3	29.1±0.2	28.9±0.3
VR / %	54.7±0.6	46.2±0.7	46.8±0.6	47.3±0.5	48.6±0.5	49.4±0.6	50.1±0.7
HV^1/HV^2	1.63±0.2	1.76±0.2	1.67±0.2	1.63±0.2	1.62±0.2	1.60±0.2	1.36±0.1

(b) and brown rice flour (c), with the share of 30%, are presented in Figure 1. The isometric, non-spherical, small, polyhedral rice starch granules and larger spherical wheat starch granules [41,42] can be seen.

As the largest part of the dough obtained from wheat-rice flour mixtures is still wheat flour, the micrographs show a characteristic dough structure where the wheat and rice starch granules were embedded in the gluten network. The addition of rice flour made flour mixtures weaker and the gluten network had thinner filaments, about 2 and 1 μm in width for white and brown rice flour, respectively, compared to those in the dough made from wheat flour only, where filaments were about 7 μm in width. The bran particles in the brown rice flour dough are seen as particles with the pike.

Statistical analysis

The correlation coefficients between the component content (ash, starch, protein and lipid content), rheological properties (*WA*, *DT*, *DSt*, *Ex* and T_{max}) and baking properties (*VR* and HV^1/HV^2) for wheat flour and the mixtures of rice flour are presented in Table 5. The sample size was thirteen (N = 13): wheat flour, six mixtures of wheat-white rice flour and six mixtures

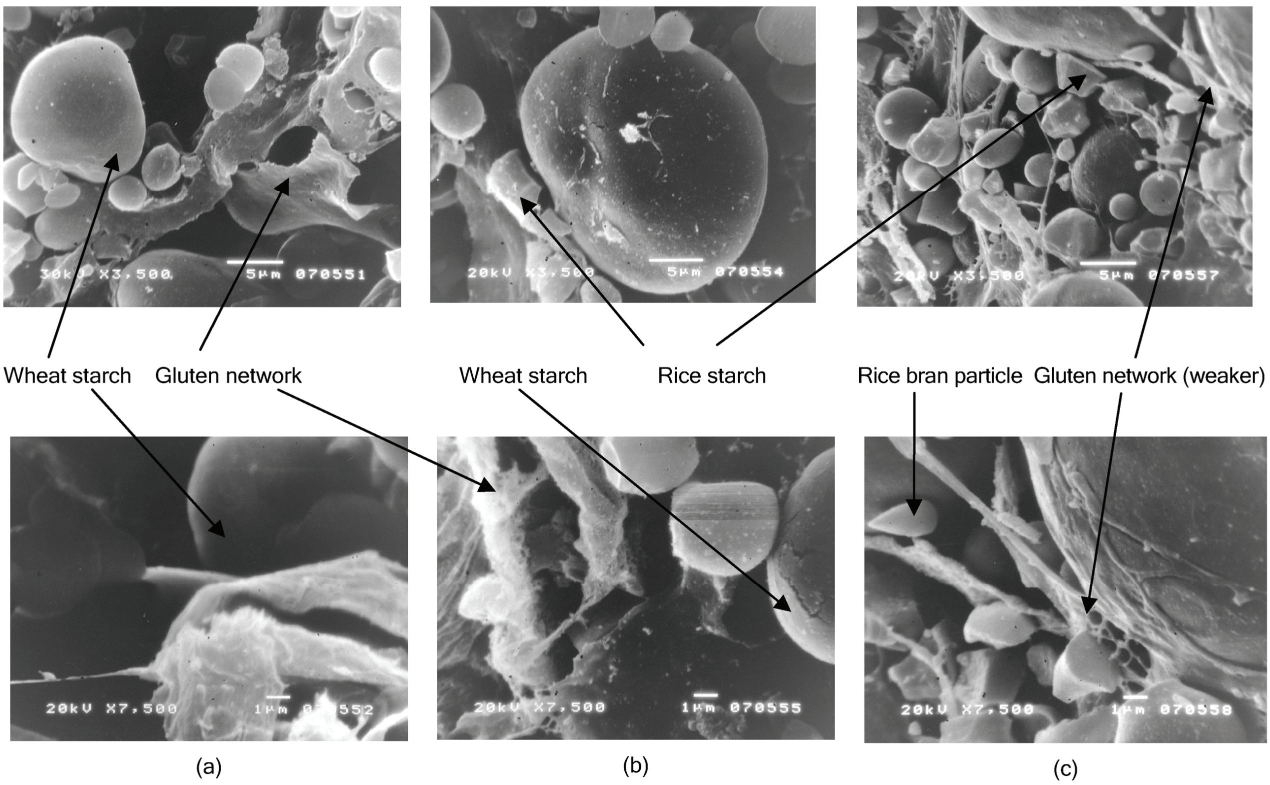


Figure 1. Scanning electron micrographs of dough from wheat flour only (a), with 30% of white (b) and 30% of brown rice flour share (c), at magnification of 3500× - first row and 7500× - second row.

of wheat-brown rice flour. There are eleven correlations absolute values of which are above of 0.8.

Between the components content the only correlation is between lipid and ash content and it is positive. This is probably due to these components being present together in the rice bran. The higher protein content was with higher *WA* value, the shorter time of dough development and stability, lower gelatinization temperature and a better cake "holding" value. Thereby, the dough with higher water absorption had shorter time of development and stability but higher extensibility. Among the correlations between dough rheological properties there is one which indicates that the dough which needed a longer time for development had less extensibility and the dough which had longer stability time had a higher gelatinization temperature. There were no any correlations between the baking properties and other correlated parameters.

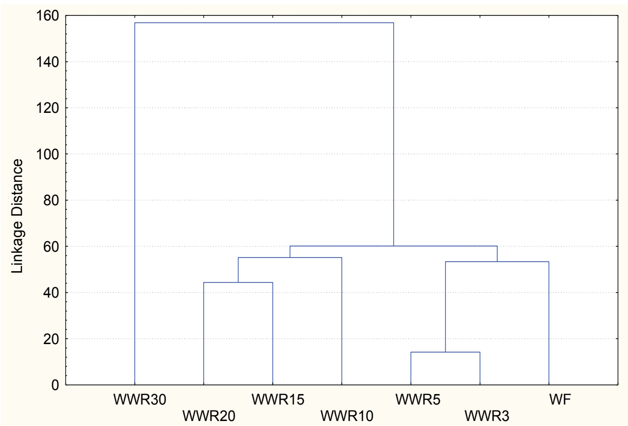
By cluster analysis, the wheat flour and the mixtures of wheat flour with different white and brown rice flour shares were classified into groups on the basis of multiple variables (number of variables was seven: wheat flour and four mixture of wheat flour with 3, 5, 10, 15, 20 and 30% of rice flour share; number of case were twelve: *WA*, *DT*, *DSt*, *DSf*, *E*, *R*, *Ex*, T_{max}, η_{max}, *VR*, *BL* and ratio HV^1/HV^2). The resulting dendrogram for wheat flour and the mixtures of wheat flour with white rice flour is shown in Figure 2a, and for wheat flour and mixtures of wheat flour with brown rice flour in Figure 2b.

Generally, the linkage distance increases with increasing the share of rice flour, independent of whether it is white or brown. The mixtures with shares of 3 and 5% showed the largest similarity with the wheat flour and the mixture with 30% share of rice flour showed the lowest similarity. The linkage distance is in the range of 14.5 to 157, for the mixtures with white rice flour, and in the range of 38 to 158, for the mixtures with brown rice flour.

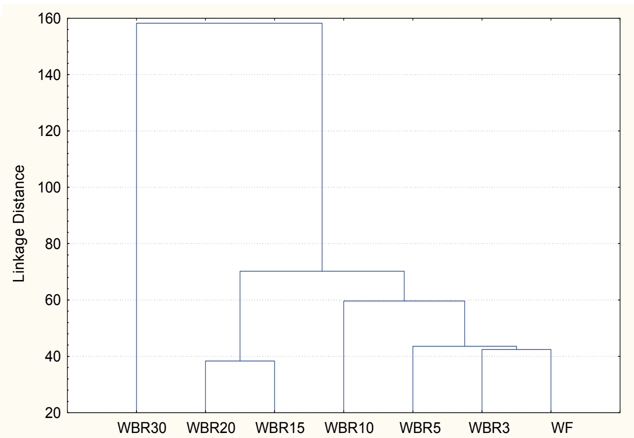
The mixtures with wheat flour and 3 and 5% of white rice flour share, being the first group, are joined with wheat flour at the same distance level of 53,

Table 5. Correlation coefficients between the component content, rheological and baking properties of wheat flour and mixtures with different share of white and brown rice flour (N = 13); correlations are significant at p ≤ 0.05

	AC	*SC*	*PC*	*LC*	*WA*	*DT*	*DSt*	*Ex*	T_{max}	*VR*
SC	0.2	1								
PC	0.16	0.09	1							
LC	0.96	0.23	0.09	1						
WA	0.37	0.16	0.94	0.12	1					
DT	0.51	0.08	-0.86	0.30	-0.86	1				
DSt	0.12	0.11	-0.95	0.11	-0.90	0.77	1			
Ex	0.76	0.18	0.72	0.58	0.81	-0.93	-0.64	1		
T_{max}	0.11	0.29	-0.87	0.09	-0.71	0.61	0.91	0.27	1	
VR	0.04	0.4	0.26	0.04	0.21	0.33	0.34	0.30	0.18	1
HV^1/HV^2	0.19	0.09	0.81	0.34	0.64	0.55	-0.68	0.34	-0.70	0.23



(a)



(b)

Figure 2. Dendrograms of dough from wheat flour only (WF) and with different share (3-30%) of white (WWR) (a) or brown rice flour (WBR) (b).

while the mixtures with wheat flour and 10, 15 and 20% of white rice flour share, being the second group, are joined with wheat flour at the linkage distance level of 60. The mixture of wheat flour and 30% of white rice flour, being the third group, was at the greatest distance from wheat flour of 157.

In a similar way, the mixtures of brown rice flour are also divided into groups. The first group consists of mixtures of brown rice flour shares of 3 and 5% (joined with wheat flour at the linkage distance of 44), the second group was mixture of the brown rice flour share of 10% (joined with wheat flour at the linkage distance of 60), the third group with mixtures of 15 and 20% (joined with wheat flour at the linkage distance of 70), and the fourth group with the mixture of brown rice flour of 30% (joined with wheat flour at the linkage distance of 158). Since the linkage distance was in the range 38 to 158, the difference in the linkage distance of 10 existing between the second and third group (60 and 70, respectively) is of little significance and the second and third groups can be connected into one. In this way, the mixtures with the white and brown rice flour can be divided into three groups. In order to produce the dough with a lower gluten content, more enriched with the rice components and more similar to these of the wheat flour only, the white or brown rice flour share of 20% is pointed out.

CONCLUSIONS

In white and brown rice flour there are significant differences between the ash, protein, lipid and carbohydrates contents. Dough rheology depends on the rice flour share in flour mixtures. The dough with rice flour had less water absorption than the dough made from wheat flour. This value decreased along with the increase of the white rice flour share. The addition of the rice flour made flour mixtures weaker and the gluten network had thinner filaments, about 2 and 1 μm in width for white and brown rice flour, respectively, compared to those in the dough made from the wheat flour only where filaments were about 7 μm in width. The gelatinization maximum value was twice higher than the gelatinization maximum value for the wheat flour. The energetic values were less for maximal value of 1.32% than the energetic value of wheat flour only, and energetic value of the dough with 30% of white rice flour share was for only 0.32% than the dough from brown rice flour and same share. The higher protein content appeared to be responsible for shorter dough development and stability time, lower gelatinization temperature and better cake "holding" value. In order to produce the dough with a lower gluten content, more enriched with the rice components and more similar to these of the wheat flour only, the white or brown rice flour share of 20% is pointed out.

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NADA NIKOLIĆ[1]
JELENA DODIĆ[2]
MIRJANA MITROVĆ[1]
MIODRAG LAZIĆ[1]

[1]Univerzitet u Nišu, Tehnološki fakultet, Bulevar oslobodjenja, 124, 16000 Leskovac, Srbija

[2]Univerzitet u Novom Sadu, Tehnološki fakultet, Bulevar cara Lazara 1, 21000 Novi Sad, Srbija

NAUČNI RAD

REOLOŠKA SVOJSTVA I ENERGETSKA VREDNOST PŠENIČNOG BRAŠNA SA RAZLIČITIM UDELIMA BELOG I INTEGRALNOG PIRINČANOG BRAŠNA

U radu su ispitana reološka svojstva, energetske vrednosti i svojstva pečenja testa dobijenog od pšeničnog i brašna od belog i integralnog pirinča, sa udelom od 3 do 30 mas.%. Cilj rada je bio ispitivanje mogućnosti primene pirinčanog brašna za proizvodnju testa i prehrambenih proizvoda sa smanjenim sadržajem glutena, koji su obogaćeni nutritivnim i biološki vrednim sastojcima pirinča i imaju zadovoljavajuća reološka svojstva. Rezultati ispitivanja pokazuju da mešavine pšeničnog i pirinčanog brašna imaju manju moć upijanja vode u odnosu na pšenično brašno kao kontrolni uzorak, gde je ta vrednost iznosila 58,8%. Moć upijanja vode samnjuje se sa porastom udela pirinčanog brašna od 53,5 do 54,0%. Testa sa belim i integralnim pirinčanim brašnom imaju manju debljinu filamenata glutenske mreže, oko 2 i 1 μm, redom, u odnosu na testo sa pšeničnim brašnom, gde je debljina filamenata iznosila oko 7 μm. Takodje, testa sa pirinčanim brašnom imaju skoro dvostruko veću vrednost temperature želatinizacije skroba u odnosu na temperaturu želatinizacije skroba pšeničnog brašna. Energetska vrednost testa sa pirinčanim brašnom manja je od energetske vrednosti testa od pšeničnog brašna za samo 1,32%. Na osnovu Cluster analize kao optimalni udeo pirinčanog brašna dobijen je udeo od 20%.

Ključne reči: pirinač; pšenica; testo; reologija; energetska vrednost.