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INVESTIGATION OF THE RHEOLOGICAL, NUTRITIONAL, AND SENSORY PROPERTIES OF THE GLUTEN-FREE BREAD PRODUCED FROM RICE, BEAN, AND CHICKPEA FLOUR

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Abstract

In recent years, the demand for gluten-free products has been constantly increasing due to the increase in the number of people suffering from celiac disease. Bread is the main product consumed in our country; therefore, gluten-free bread for celiac patients on the market is mostly of poor quality and low nutritional value, while gluten-free flour has a very high price. The purpose of this work was to investigate the rheological properties of dough, the nutritional value of bread, as well as the sensory properties of gluten-free bread produced from mixtures of raw materials such as rice, chickpea, and bean flour, corn starch, and egg powder.
The results showed that the gluten-free bread had different rheological properties, and only mixes M5 and M6 had similar rheological properties, such as dough development, stability, and degree of softening, to the control bread M1. Gluten-free bread from mixtures M2 and M3 had higher contents of protein, fat, cellulose, and minerals, while bread from mixtures M5 and M6 had medium contents. Bread M2 and M3 had acidity levels above the allowed limits which made them unusable or had a short shelf life. Sensory analyses showed that bread M5 had similar sensory properties to the control bread M1 and fell into the same quality category; also, bread from the M5 mixture has a much better taste and aroma. For consumption, we recommend using gluten-free bread from the M5 mixture, which in its composition has 80% rice flour, 7.5% chickpea flour, 5% bean flour, and 7.5% egg powder.

Keywords: bean flour, sensory properties, nutritional value, gluten-free bread.

1. Introduction

Celiac disease, or gluten-sensitive enteropathy, is a chronic disorder of the small intestine caused by exposure to gluten in genetically predisposed individuals (Hamer, 2005; Laurin et al., 2002). This disease is characterized by a strong immune response to certain amino acid sequences found in the prolamin fractions of wheat, barley, rye, and oats (Hill et al., 2005).
Therefore, if we talk about the production of gluten-free bread, it is difficult to produce it without using wheat flour or gluten, since the quality of bread depends directly on the properties and functionality of gluten (El Khoury et al., 2018). In gluten-free bread, the hydration of the flour results in a liquid but non-viscoelastic dough as its proteins do not possess the network-forming properties usually found in gluten (Renzetti & Rosell, 2016).
Usually, such gluten-containing cereals should be replaced with cereals such as corn, rice, millet, different types of starch (corn, rice, potato), or other mixtures suitable for bread production (Gambus et al., 2001; Sanchez et al., 2002). Rice flour is undoubtedly considered a suitable substitute for the production of gluten-free bread, which has a low level of protein, sodium, fat, and fiber but a high amount of easily digestible carbohydrates (Sanchez et al., 2002; Demirkessen et al., 2010). Corn flour is the second most common base ingredient in gluten-free bread production, especially white corn cultivars, which are the flour and starch sources most commonly used in gluten-free bread production (Hager et al., 2012).

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Other ingredients used in the production of gluten-free bread include gluten-free pseudocereals (amaranth, buckwheat, and quinoa), legumes (beans, peas, chickpeas, lentils, or soy), as well as fruit and vegetable-based ingredients (sweet potato, pumpkin, kiwi puree, orange pomace, and/or unripe banana flour) (Capriles & Areas, 2016). Legumes are often used not only to increase the nutritional value of gluten-free bread but also to improve functionality, sensory profile, and shelf life (Foschia et al., 2017). Also in recent years, gluten-free bread has been produced containing hydrocolloids (xanthan gum, guar gum, etc.), which increase the viscosity of the liquid phase, keeping the starch granules, yeast, and gas bubbles suspended in the fermentation process (Schober, 2009; Dickinson, 2018). HPMC (hydroxypropyl methylcellulose) has given good results in helping to strengthen the blister membrane in the curing process (Haque & Morris, 1994).
The aim of this study was the preparation of gluten-free bread from mixtures of rice, chickpea and bean flour and the influence on the rheological properties with farinograph, nutritional value and sensory properties.

2. Materials and methods

2.1. Materials: For the production of the control bread, to make comparisons with the mixtures created, we used a gluten-free flour mix bought in self-service.
Flour for making gluten-free bread, such as rice flour, is bought ready-made in self-service, while chickpeas and beans are bought in the market, hydrated, dried, and ground into flour in a laboratory mill. To produce gluten-free bread with good sensory qualities and high nutritional value, other additional raw materials are also used: egg powder, starch, sugar, salt, yeast, and baking powder (composition: disodium diphosphate, hydrogen sodium carbonate, corn starch), as well as water according to its absorption capabilities (Table 1).

Table 1. Mixtures created for the production of gluten-free bread

Mixtures	**Flour Mix Bread (g)**	**Rice flour (g)**	**Chickpea flour (g)**	**Bean flour (g)**	**Water (mL)**	**Starch (g)**	**Egg powder (g)**	**Sugar (g)**	**Salt (g)**	**Yeast (g)**	**Baking powder (g)**
M1	440	-	-	-	590	-	-	2.2	7.9	15	-
M2	-	176	66	44	270	88	66	2.2	7.9	12	6.6
M3	-	220	66	44	280	44	66	2.2	7.9	12	6.6
M4		308	22	44	340	22	44	2.2	7.9	12	6.6
M5	-	352	33	22	350	-	33	2.2	7.9	12	6.6
M6	-	352	44	-	360	22	22	2.2	7.9	12	6.6

2.1.1. Gluten-free bread production: Gluten-free bread was produced according to the mixtures presented in Table 1. Dough preparation was carried out in a double-spiral kneader, but in a much shorter time than wheat bread doughs. The prepared dough was placed in molds and sent to the fermenter, where fermentation was carried out at 30-32 °C for a duration of 60 minutes. Baking was done in the Memmert oven, in Germany, at a temperature of 230 °C and a duration of about 35 minutes.

2.2. Methods: Moisture, protein, lipid, ash, and cellulose content of gluten-free breads were determined according to the AOAC (2005) method. Carbohydrates were calculated from the difference between protein and fat (Eyeson and Ankrah, 1975). Total calories were calculated using the formula of James (1995) as follows: Total calories = fat x 9 + protein x 4 + total carbohydrates x 4.

The determination of the rheological properties of the dough, such as the development, stability, and degree of softening of the dough, was performed with a farinograph Brabender in accordance with ISO 5530-1:2003 (Hoxha et al., 2020). Free Acidity was determined by using the titrimetric method (Xhabiri & Sinani, 2011).
Sensory properties of bread, such as volume, appearance, aroma and taste of crust and crumb, were analyzed by a panel of eleven professional evaluators. All analyzed bread properties were evaluated with 1–5 points, and the obtained points were multiplied by the coefficient of importance for each feature, and the total points were obtained (Kaluerski & Filipović, 1998).

2.2.1. Statistical analysis: Statistical analysis results were presented as mean values ± standard deviation (SD) of three replications. Statistical analysis was conducted using the one-way analysis of variance (ANOVA) and means of results for each experiment compared, using the Duncan multiple comparison test $p < 0.05$ confidence levels. Data analysis was performed using SPSS 16.

3. Results and Discussion

3.1. Physico-chemical qualities of raw materials: Table 2 shows the chemical composition of the raw materials, respectively rice, bean, and chickpea flour, that were used for the production of gluten-free bread. Rice flour had the highest carbohydrate content with 74.81±1.68 g/100g, while bean flour had the lowest. Bean flour had the highest protein content with a total of 24.21±0.47 g/100 g, while in terms of fats, chickpea flour had a much higher content than rice and bean flour. The content of cellulose and minerals was the highest in bean flour and wheat flour.

Table 2. Physico-chemical qualities of flour

	Rice flour	**Chickpea flour**	**Bean flour**
Moistures (%)	12.56±0.45^{b}	10.93±0.26^{a}	11.82±0.36^{ab}
Carbohydrate (g/100g)	74.81±1.68^{b}	50.84±0.96^{a}	48.96±0.84^{a}
Protein (g/100)	9.32±0.36^{a}	18.98±0.52^{b}	24.21±0.47^{c}
Fats (g/100g)	1.06±0.18^{a}	6.27±0.12^{b}	1.33±0.06^{a}
Cellulose (g/100g)	1.17±0.09^{a}	9.43±0.54^{b}	10.06±0.34^{b}
Minerals (g/100g)	0.84±0.02^{a}	2.87±0.08^{b}	3.04±0.06^{b}

3.2. Rheological properties with Brabender farinograph: Table 3 shows the rheological properties with farinograph of the mixtures created for the production of gluten-free bread. Water absorption was variable; respectively, control samples M1 had higher absorption with 66.7±1.61%, while other mixtures had much lower absorption, especially mixtures M2 and M3, which were significant for $p<0.05$. The dough from the M2 mixture had the highest dough development time, while the dough from the M4 mixture had the lowest. Dough stability is mainly influenced by the quality of gluten and its resistance to kneading forces (Catteral, 1995), and in our case, it is observed that apart from the dough from the control mixture M1, which had average stability, dough M5 and M6 had stability over one minute, while other dough had low dough stability. The control mixture M1 also had the best degree of softening, which was lower, while the dough from the other mixture had a much higher degree of softening. Similar results were also obtained by Ahmed et al. (2013) and Xhabiri et al. (2023).

Table 3. Rheological properties with Brabender farinograph

Mixtures	Farinograph			
	Water absorption (%)	Dough development time (min)	Stability (min)	Degree of softening (FU)
M1	66.7±1.61^{e}	2.38±0.03^{b}	3.66±0.09^{f}	74±1.89^{a}
M2	35.9±1.15^{a}	3.76±0.08^{e}	0.29±0.02^{a}	248±1.04^{f}
M3	38.06±1.48^{a}	3. 47±0.09^{d}	0.44±0.03^{b}	235±1.32^{e}
M4	43.4±0.97^{b}	2.18±0.07^{a}	0.82±0.04^{c}	193±1.25^{d}
M5	50.1±1.11^{d}	2.62±0.09^{c}	1.06±0.03^{d}	148±1.04^{c}
M6	47.7±0.75^{c}	2.41±0.08^{b}	1.21±0.02^{e}	149±1.49^{b}

3.3. Nutritional values of gluten-free bread: Gluten-free bread available on the market is often ignored by people on a gluten-free diet, and that is because of its relatively inferior characteristics: taste, aroma, texture, artificial ingredients, or very poor nutritional value (Kowalczewski et al., 2021). Table 4 shows the nutritional values of gluten-free bread. Starch, as the main representative of carbohydrates, facilitates dough preparation and baking (Witczak et al., 2012). The results show that the control bread M1 had a higher content of carbohydrates 49.57±1.01 g/100g, while bread from the mixtures M2 and M3 had a low content of carbohydrates. The bread with the highest protein content was the bread from the M2 and M3 mixtures, while the bread from the M6 mixture had the lowest protein content with 8.73±0.36 g/100g. The fat content was highest in bread from mixtures M2 and M3, even though bread from other mixtures had much higher fat content than the control bread M1, which had only 1.60±0.08 g/100g. The cellulose content was also higher in the bread from the mixtures M2 and M3, while it was much lower in the control bread, M1. All the bread from the created mixtures has a much higher content of minerals, but the bread from the mixtures M2 and M3 had a higher content, which was also significant among themselves for $p < 0.05$. As for energy, it depends directly on the content of moisture and macronutrients. The results show that bread from mixtures M2 and M3 had a lower energy value with 203.0 and 206.5 kcal/100g, while the control bread M1 had more energy with a total of 258.8 kcal/100g. Krupa-Kozak et al. (2022) also had similar results.

Table 4. Nutritional values of gluten-free bread

Mixtures	Moistures (%)	Carbohydrate (g/100g)	Protein (g/100g)	Fats (g/100g)	Cellulose (g/100g)	Minerals (g/100g)	Energy (kca/100g)
M 1	35.25±0.77^{a}	49.57±1.01^{e}	11.57±0.38^{c}	1.60±0.08^{a}	0.42±0.03^{a}	0.58±0.03^{a}	258.8±5.98^{c}
M 2	45.73±1.01^{d}	27.25±1.09^{a}	16.84±0.24^{e}	2.96±0.08^{d}	3.47±0.08^{e}	3.18±0.04^{e}	203.0±5.91^{a}
M 3	43.45±0.80^{c}	28.46±0.88^{a}	16.74±0.30^{e}	2.86±0.09^{d}	3.52±0.04^{e}	3.28±0.08^{e}	206.5±4.99^{a}
M 4	41.53±1.02^{b}	36.31±0.69^{b}	12.95±0.21^{d}	2.62±0.07^{c}	3.12±0.05^{d}	2.91±0.06^{d}	220.6±2.33^{b}
M 5	40.28±0.84^{b}	39.46±0.79^{c}	10.48±0.28^{b}	2.44±0.06^{b}	2.86±0.06^{c}	2.74±0.05^{c}	221.7±4.63^{b}
M 6	40.62±0.73^{b}	42.21±0.94^{d}	8.73±0.36^{a}	2.27±0.06^{b}	2.66±0.07^{b}	2.49±0.04^{b}	224.2±5.00^{b}

3.4. Acidity of gluten-free bread: In the baking process, a high temperature can break down compounds in oil and increase the content of free fatty acids in bread (Mohamed et al., 2014). But high acidity directly affects the shelf life of gluten-free bread, i.e., the bread starts to crumble very quickly and thus becomes old. From Figure 1, it can be seen that we had an increase in acidity above the optimal limits in bread from the M2 and M3 mixtures, while all other bread had an acidity above the optimal limits.

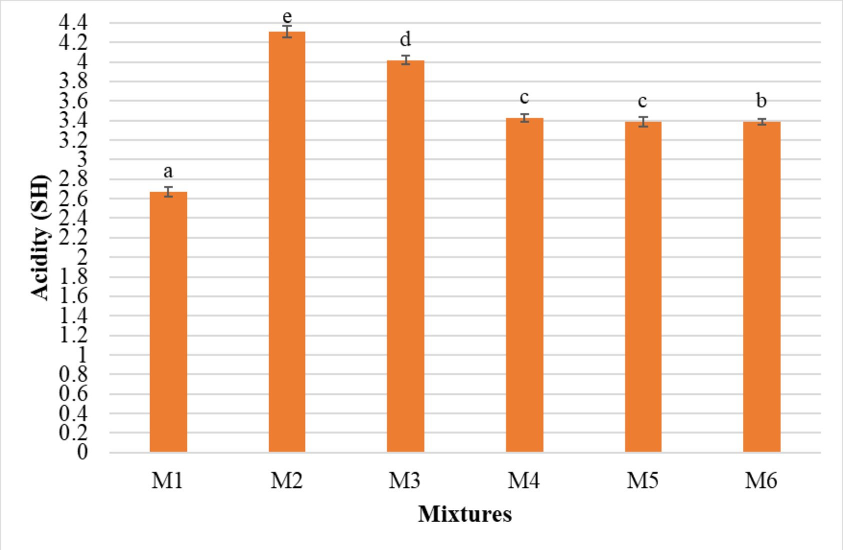

Figure 1. Acidity of gluten-free bread

3.5. Sensory properties of gluten-free bread: Images of gluten-free bread are presented in Figure 2, while evaluations of sensory properties are in Table 5. The control bread M1 had the best volume, while the bread from the mixtures M2, M3, and M4 had the weakest volume and had no significant differences between them for $p<0.05$. Our results are similar to those of Ostermann-Porcel et al. (2017), who identified that the greater presence of okara in gluten-free cookies caused a smaller volume. The control bread M1 had the best exterior appearance, but the bread from the M5 mixture had a good external appearance, while the bread from the M2 and M3 mixtures had the worst external appearance. The appearance of the best crumb also had control bread M1 and bread from mixtures M5 and M6 had a good crumb appearance, while bread from mixtures M2 and M3 had the worst. The control bread M1 and the bread from the mixtures M5 and M6 had the best flavor which was significant for $p<0.05$, while the M2 bread was weaker. The bread from the M5 mixture had the best taste, while the bread from the M2 and M3 mixtures had the weakest taste. Even Różyło et al. (2017), in their study using carbon fiber, achieved good results for the taste of gluten-free bread. From the accumulated total points, we notice that the control bread M1 and the bread from mixture M4 had more accumulated points, while the bread from the mixtures M2 and M3 had fewer points.

Figure 2. View of gluten-free bread

Table 5. Sensory properties of gluten-free bread

Mixtures	Volume	Exterior appearance	Appearance of the crumb	Aroma of the crust and crumb	Taste of the crust and crumb	Total point
	k=4	k=3	k=5	k=3	k=5	
M 1	18.5±2.02[c]	13.4±1.56[c]	21.4±3.23[c]	12.8±1.40[c]	20.0±3.87[bc]	**86.1±6.65[c]**
M 2	11.6±2.81[a]	8.7±2.10[a]	14.5±3.51[a]	8.5±1.81[a]	14.1±3.02[a]	**57.5±6.91[a]**
M 3	12.0±2.52[a]	9.3±2.49[a]	15.0±3.16[a]	9.5±1.81[ab]	14.5±3.51[a]	**60.4±6.81[a]**
M 4	12.7±2.41[a]	11.5±2.25[b]	16.8±4.62[ab]	10.4±2.06[b]	17.7±3.44[b]	**69.1±6.36[b]**
M 5	16.4±3.33[bc]	13.1±1.52[bc]	20.0±3.16[bc]	13.4±1.56[c]	21.8±3.37[c]	**84.9±5.20[c]**
M 6	15.5±3.33[b]	12.8±1.94[bc]	19.1±3.75[bc]	13.1±2.02[c]	20.5±3.51[bc]	**81.1±7.71[c]**

Note: *k* – coefficient of importance.

4. Conclusions

Bread produced from mixtures created from raw materials had different results. The rheological properties with the Babender Farinograph showed that the control dough M1 had much better properties, but both the M5 and M6 dough had better dough stability and degree of softening than the dough from the other mixtures. Gluten-free bread from mixtures M2 and M3 had higher protein, fat, cellulose, and mineral content, while bread from mixtures M5 and M6 had average content. The control bread M1 had the highest energy content, while the bread from the M2 mixture had the lowest. The acidity of gluten-free bread was above normal in mixtures M2 and M3, which made them have a short shelf life; other bread had an acidity level within normal limits. Sensory analyses showed that the bread from mixture M5 had the aroma and taste of the crust and crumb, and a total score better than the bread from other mixtures but similar to the control bread M1. Based on this, we recommend for consumption to use gluten-free bread from the M5 mixture with a composition of 80% rice flour, 7.5% chickpea flour, 5% bean flour, and 7.5% egg powder.

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