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# EVALUATION OF PHYSICAL, TEXTURAL AND MICROSTRUCTURAL PROPERTIES OF DOUGH AND HONEY BISCUITS ENRICHED WITH BUCKWHEAT AND RYE

*Wholegrain buckwheat and rye flours were used to partially replace wheat flour in honey biscuit formulation. Characteristics of dough and baked biscuits were studied. Buckwheat was the ingredient that dominantly affected the dough and biscuit quality. Doughs with buckwheat were significantly harder and less sticky. Significant lowering of dough cohesiveness was found only at the maximal tested buckwheat dose. The biscuits enriched with buckwheat had increased spread, hardness and fracturability. Rye showed an improving effect on dough (decreased hardness, increased cohesiveness) and biscuit characteristics (decreased spread, hardness and fracturability) but the effect did not reach significant level. However, no significant differences in sensory tests were obtained among the tested biscuits. Hence, buckwheat has a potential to be used as an ingredient in honey biscuit making to develop more nutritional end-product especially if adequate processing methods to improve its suitability in food applications are additionally considered.*

*Key words: biscuits; buckwheat; dough; texture; biscuit spread.*

Buckwheat is a traditional crop that used to be a staple food in Central and Eastern Europe and in Asia but its use declined over time and became marginal in human nutrition. However, it has been rediscovered as a part of the renewed interest in alternative crops for organic cultivation and healthy foods. Buckwheat was found to have excellent nutritious quality which has been associated to many positive physiological effects. It contains numerous health-promoting compounds: well balanced amino acids and proteins of high biological value, significant contents of microelements, resistant starch, total and soluble dietary fibres, vitamins, polyunsaturated fatty acids, rutin, quercetin and other polyphenols [1-4]. Hence, some nutritionists recommend buckwheat for preventive nutrition.

Today, food uses of buckwheat are mainly regionally limited and include home-prepared ethnic dishes like soups, porridges, noodles, pastas, pancakes and bread [5,6]. However, buckwheat is mainly underutilized in food industry although the number of functional food products containing buckwheat has been recently emerging.

Honey biscuits are popular and delicious biscuits made from honey and spices. Formulations of honey biscuits typically include 35-50% honey, 28--32% sugar, 0-5% fat on a flour weight basis [7]. In the formulations, wheat flour is frequently substituted with rye flour in doses up to 20% (flour basis). In practise, rye flour is frequently used to increase moisture retention and prolong freshness of the product as it contains considerable amounts of pentosans and secalins which exhibit high water absorption capacities. Honey biscuits are highly regarded by consumers because of their low fat content in comparison to other biscuit types and the presence of honey which is generally perceived as a value-adding natural ingredient. As such, honey biscuits can be a good opportunity to introduce buckwheat to human nutrition in the form of convenient ready-to-use food product by replacing a part of wheat flour with buckwheat flour.

In consequence, the aim of this study was to elaborate the adequacy of partial replacement of wheat flour with wholegrain buckwheat flour in honey biscuit production by evaluating physical, textural and microstructural changes in biscuit dough and baked biscuit. The effect of rye addition was also studied.

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## EXPERIMENTAL

### Material

Buckwheat and rye wholegrain flour, wheat flour, honey, vegetable fat, sugar, $NaHCO_3$, lecithin and spice (cinnamon) were purchased from the local market.

### Preparation of biscuits

Table 1 shows the formulation of biscuit control dough. To this formula buckwheat and rye flour were added at various levels: buckwheat at 30, 40 and 50% (wheat flour replacement level) and 10 and 20% rye (wheat flour replacement level). In this way, total of 12 types of biscuits were produced (control or 100% wheat, 0% buckwheat-10% rye, 0% buckwheat-20% rye, 30% buckwheat-0% rye, 30% buckwheat-10% rye, 30% buckwheat-20% rye, 40% buckwheat-0% rye, 40% buckwheat-10% rye, 40% buckwheat-20% rye, 50% buckwheat-0% rye, 50% buckwheat-10% rye and 50% buckwheat-20% rye). Extra water (1-2%) was added to formulations containing rye whereas less water (3-5%) was added to those containing buckwheat to achieve dough with adequate handling ability. Biscuits were mixed according to single stage method in which all the major ingredients are put in the bowl at the same time. Prior to mixing, honey, sugar and water were first warmed to 65 °C and then cooled to 40 °C. The dough was left to rest over night at room temperature. Following the rest time, the dough was sheeted to a final thickness of 10 mm on a pastry break. Dough pieces with a diameter of 60 mm were cut and baked for 12 min in a deck oven at 170 °C. After cooling, the biscuits were placed in polyethylene bags and stored at ambient temperature until further examination.

*Table 1. Honey biscuit formulation (control formula) [7]*

| Ingredient | Flour basis, % |
|---|---|
| Wheat flour | 100 |
| Honey | 50 |
| Sugar | 10 |
| Vegetable fat | 10 |
| $NaHCO_3$ | 2.1 |
| Cinnamon | 2 |
| Lecithin | 1 |
| Water | 12 |

### Physical and texture measurements

Spread was calculated as the ratio of the biscuit's width and height. Biscuit dimensions were measured by a vernier caliper. Twelve measurements were made per each biscuit type.

Texture profile analysis (TPA) of biscuit dough and biscuit penetration were carried out with a TA.HDplus Texture Analyzer (Stable Micro Systems, England, UK). For TPA, doughs were prepared as for the baking tests. A 36 mm cylindrical aluminium probe and 30 kg load capacity were used in two compression cycles. The test speed was 1.0 mm/s, compression was at 45% and the recovery period between the strokes was 5 s. The recorded parameters were dough hardness, adhesiveness, cohesiveness and springiness. Measurements included seven replications per each biscuit type. The biscuits were analyzed 24 h after baking.

The biscuit penetration test was carried out with a 5 kg load capacity. The biscuit sample was placed on the platform with a holed plate and punctured in an "X" pattern (5 punctures per sample) with a 2 mm cylinder probe through the sample at 0.5 mm/s test--speed. Biscuit hardness and distance (fracturability) were derived from the penetration curve. Four samples were punctured per each biscuit type.

### Microstructure

Dried biscuit dough and baked biscuit samples were mounted on specimen stub using conducting silver paint and sputter-coated with gold at 50 mm working distance, 30 mA during 90 s. The specimen stub was placed on a specimen holder and put into the device. The microstructures of the samples were viewed on a JEOL JSM-6460LV scanning electron microscope (Jeol industries Ltd., Tokyo, Japan) operating at 10kV-20kV using a procedure of secondary electron emission at 10 mm working distance.

### Sensory evaluation

Sensory evaluation was conducted with eight trained panellists (1 male, 7 females) aged 24 to 60, who evaluated the sensory acceptability of biscuits [8]. A 9-point intensity scale was used with 1 indicating attribute not detectable or "dislike extremely" and 9 indicating the highest detection level or "like extremely". In the case of aftertaste, not detecting an attribute (point 1) was equal to "like extremely" category. Samples were analyzed 1 day after baking.

### Statistical analysis

The effects of buckwheat and rye dose on the biscuit quality were determined in a 3×4 factorial design. Analysis of variance was conducted for dough characteristics and sensory attributes to indicate differences among the means and Tukey's HSD at $p < 0.05$ was used to determine which means were different.

The changes on the textural parameters and spread were adjusted to a linear model. In the model equation, $z$ denoted the textural parameter analyzed, $x$ and $y$ the buckwheat and rye dose, respectively. The coefficients were related to the value of studied parameter for the control formulation ($b_0$) and to its change by modifying the formulation ($b_1$, $b_2$ and $b_{12}$). Correlation coefficient $R^2$, standard error and $t$-value were calculated.

## RESULTS AND DISCUSSION

### Texture profile analysis of biscuit dough

The effect of variable amounts of buckwheat and rye in the biscuit formulation on dough texture is shown in Figure 1. Dough containing buckwheat had significantly higher hardness and lower adhesiveness. Springiness and cohesiveness decreased as the level of buckwheat increased but significant differences were observed only among the samples without buckwheat and those supplemented with rye and the ma-

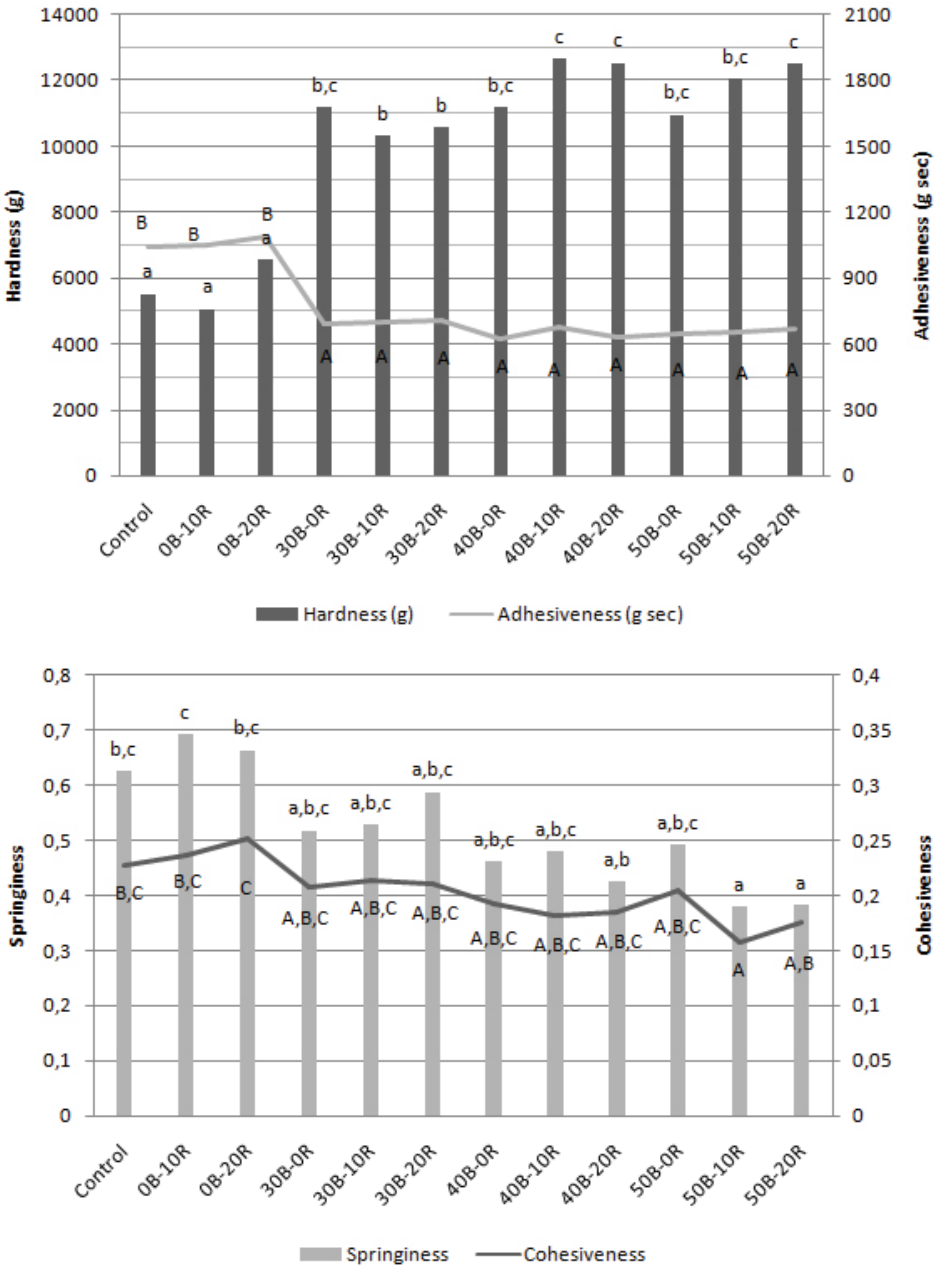


*Figure 1. Honey biscuit dough characteristics; bars denoted with the same letter of the same case are not significantly different ($p > 0.05$); B - buckwheat substitution level in the biscuit formulation (% flour basis); R - rye substitution level in the biscuit formulation (% flour basis).*

ximal buckwheat level. In general, the dough became harder, more plastic and less sticky. Rye demonstrated a decreasing effect on dough hardness and tended to increase springiness but the effects were not significant.

Similar dough hardening effect was observed by Ikeda and Kishida [9] who surmised that the protein content in buckwheat flour may be related to the textural changes in dough. On the other hand, buckwheat flour is known for its low viscoelasticity due to strong gelling starch. Buckwheat starch was reported to exhibit higher peak and final viscosities than those of cereal starches [10-12].

### Physical and textural properties of honey biscuits

Within the selected factor levels several important quality parameters were analyzed. Figures 2-4 illustrate the results for spread, hardness and fracturability by using three-dimensional interaction surface plots. The surface plots were defined by a regressive Eq. (1):

$$z = b_0 + b_1 x + b_2 y + b_{12} xy \quad (1)$$

where $b_0$, $b_1$, $b_2$, $b_{12}$ denote regression coefficients; $x$, the dose of buckwheat; $y$, the dose of rye; $z$, dependent variable.

According to the estimated regression coefficients, all responses (spread, hardness and fracturability) were significantly influenced by the linear effect of buckwheat dose with a significant intercept which demonstrates that the tested quality attributes are also affected by the quality potential when just basic ingredients are used in the formulation (without buckwheat and rye). The estimated value for the regression coefficients of determination showed that around 80% of variability in the experimental data could be explained by the model.

Spread is a ratio of biscuit width and height. The increasing doses of buckwheat caused shrinkage of biscuit dimensions (data not shown) in comparison to the control, however, their ratio significantly increased due to increased buckwheat level. This is in fine agreement with the results of Baljeet *et al.* [13] regarding buckwheat enriched short-dough biscuit. Rye tended to decrease spread but its effect was negligible. Increased spread is generally advantageous in biscuit making but it might not be so in honey biscuit production since well developed crumb, which is an important quality requirement for honey biscuit according to Gavrilović [7], is easier to achieve at lower spreads. Hardness of honey biscuit increased with buckwheat addition whereas rye showed an opposite but not significant trend. Similar increasing trend caused by inclusion of buckwheat in the biscuit formulation was registered for fracturability. Rye showed an opposite but much lower effect as previously. However, hardness and fracturability significantly differed only be

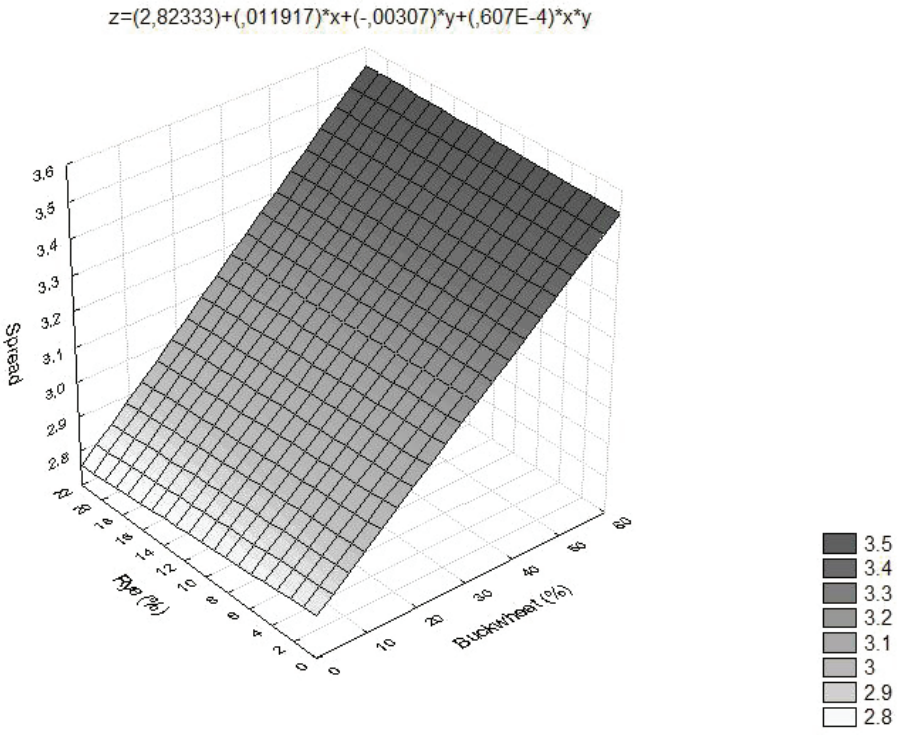


*Figure 2. Effect of buckwheat and rye inclusion to honey biscuit formulation on biscuit spread.*

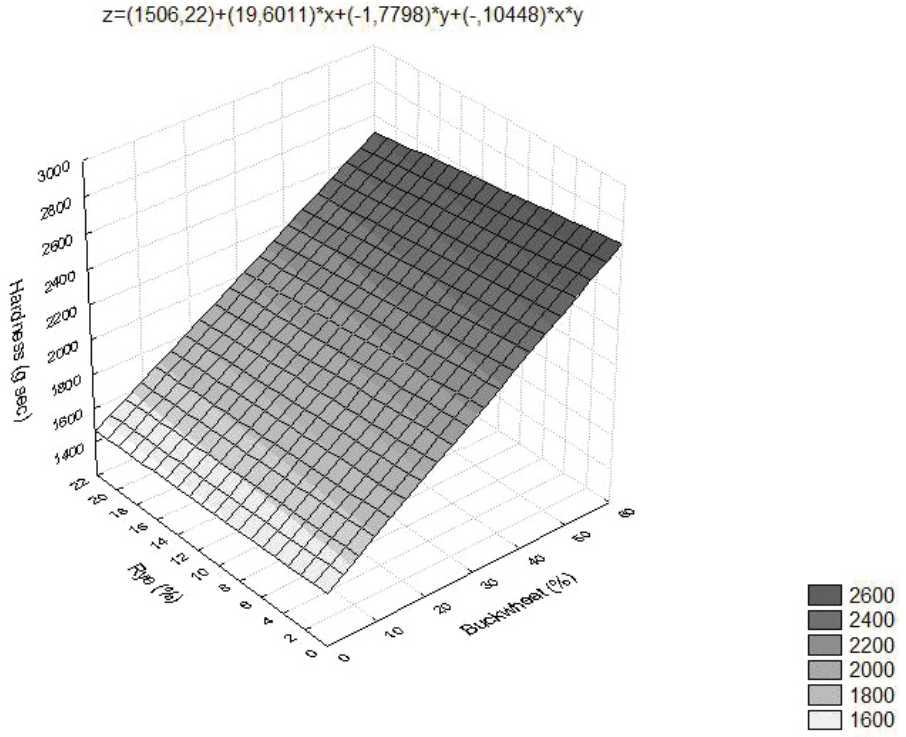


*Figure 3. Effect of buckwheat and rye inclusion to honey biscuit formulation on biscuit hardness.*

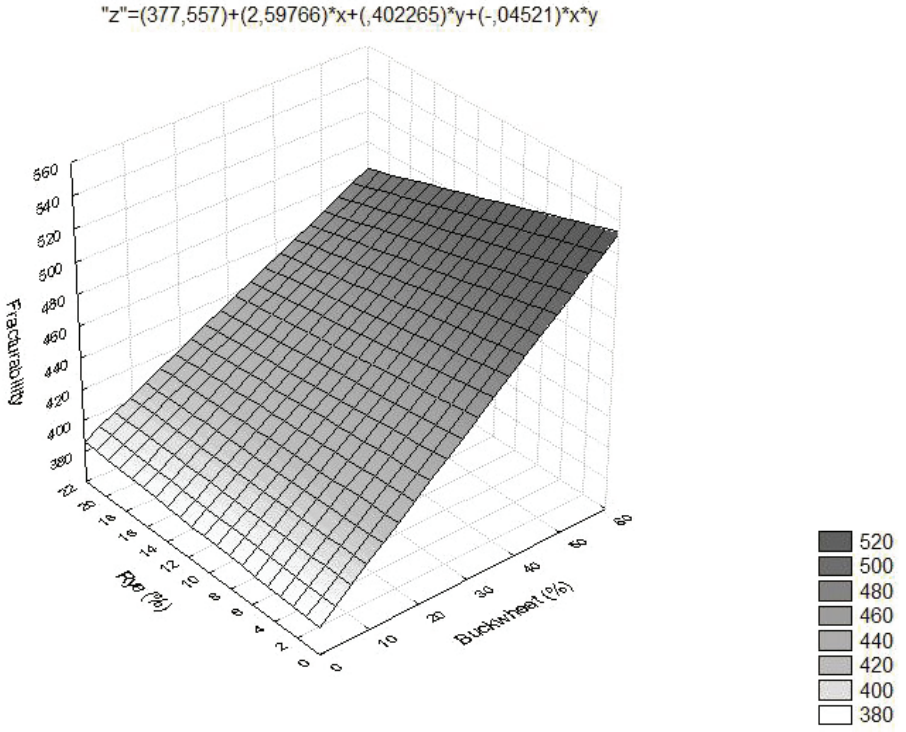


*Figure 4. Effect of buckwheat and rye inclusion to honey biscuit formulation on biscuit fracturability.*

tween the sample 50B-OR and those made without buckwheat (control, 0B-10R, 0B-20R). Baljeet *et al.* [13] reported fracture strength lowering along increasing buckwheat levels in short-dough biscuits. This conflicting finding is presumably due to different composition and ratio of ingredients between honey and short-dough biscuits. Gavrilović [7] claims that hardness of honey biscuits depends on starch pasting properties. Increasing hardness in the buckwheat enriched honey biscuits is probably due to strong gelling

properties of buckwheat starch [10,14-16]. Kreft and Škrabanja [17] reported that isolated buckwheat starch directly affected the texture of products by increasing their hardness. On the other hand, Ikeda *et al*. [18] associated protein to be the major factor that impairs the textural attributes of cooked buckwheat dough (noodles). Inglett *et al*. [19] reported that buckwheat flours containing different ratios of various anatomic parts of grain showed different pasting and water-holding characteristics and proposed that high protein and low viscosity flour can be used for the production of breads and cookies.

In general, rye tended to improve the physical and textural characteristics of honey biscuit but its effect was much less marked due to lower dose and lack of sufficient amounts of water to hydrate rye components as honey biscuit represents a low-moisture system and interfering ingredients like sugar and fat which additionally impair hydration. This can be supported by analyzing the microstructure of the honey biscuits before and after baking (Figure 5). As seen from the micrographs, smooth, round spherical starch granules of varying size (especially in the composite samples that contained both rye and buckwheat) can be observed both in the dough and in the baked biscuit. This observation implies to lack of sufficient water for starch gelatinization in all samples which is generally true for the majority of biscuit types. Chevallier [20] describes the biscuit structure as a composite matrix of sugars, protein aggregates and lipids in which intact or partially damaged starch granules are embedded, which is very similar to the structure observed in our microphotographs (Figure 5 - A2, B2 and C2). Manley [21] suggests that softer biscuits are obtained if starch granules remain intact. Starch gelatinization also depends on the amount and type of sugars in the recipe.

### Sensorial evaluation

The sensorial evaluation data is displayed in Table 2. The results showed that the buckwheat enriched honey biscuits did not statistically differ from the control regarding the tested attributes that included appearance, taste, aftertaste, structure and overall acceptability except for the sample enriched with 50% buckwheat which had worse structure in comparison to the one with the best structure - the sample with 20% rye without buckwheat. This could indicate that differences obtained in the instrumental analysis of spread, hardness and fracturability were not high enough to impair their acceptability. There was significant correlation ($r = 0.40$, $p < 0.05$) between fracturability measured instrumentally and overall acceptability, whereas hardness was not found to affect the overall acceptability of the biscuits. It is important to note that buckwheat has a specific taste often rejected by consumers not used to it. However, in the case of honey biscuits, the rich sweet taste in combination with spice (cinnamon) successfully masked the buckwheat aroma, which contributed to excellent scores for taste and aftertaste.

The use of buckwheat in biscuit production is very attractive for the food industry which has to cope with increasing consumer demands after variety and healthier food choices. The introduction of buckwheat enriched honey biscuits would increase the diversity

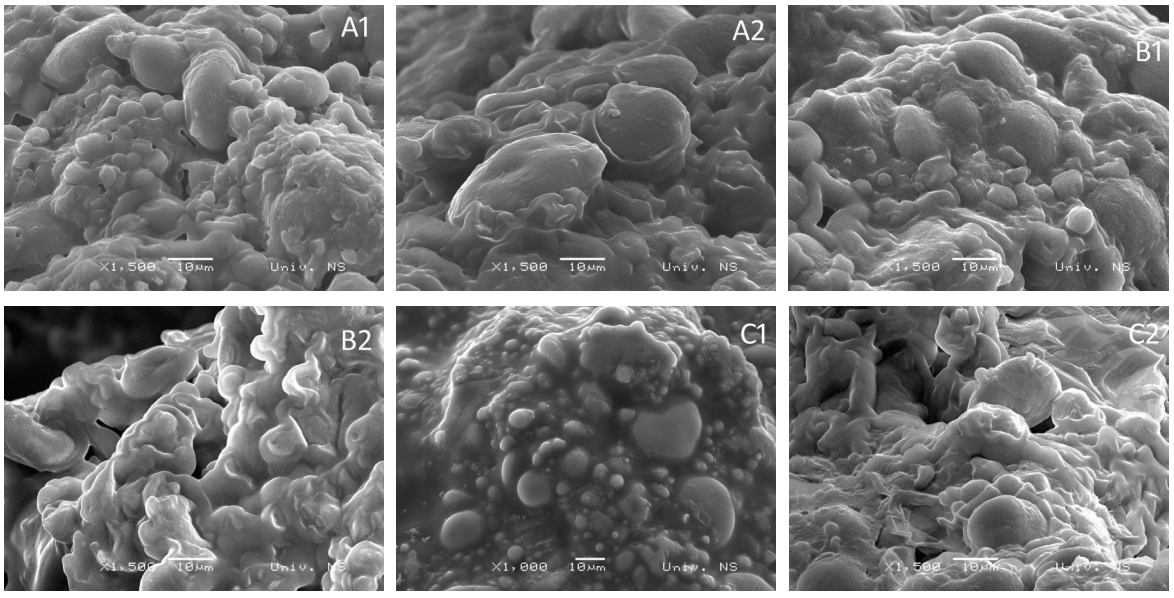


*Figure 5. Microstructure of honey biscuit dough and baked biscuit. A) Control sample: 1 - dough, 2 - biscuit; B) sample 50% buckwheat-0% rye: 1 - dough, 2 - biscuit; C) sample 50% buckwheat-20% rye: 1 - dough, 2 - biscuit.*

*Table 2. Sensory attributes of honey biscuits by different proportions of buckwheat and rye in the formulation*

| Sample | Appearance | Taste | Aftertaste | Structure of fracture surface | Overall acceptability |
|---|---|---|---|---|---|
| Control | 8.50[a] | 7.79[a] | 1.78[a] | 7.58[a,b] | 7.79[a] |
| 0B-10R[b] | 8.58[a] | 7.83[a] | 1.79[a] | 7.96[a,b] | 8.00[a] |
| 0B-20R | 8.63[a] | 7.92[a] | 1.71[a] | 8.04[b] | 8.13[a] |
| 30B-0R | 8.38[a] | 7.75[a] | 1.96[a] | 7.38[a,b] | 7.54[a] |
| 30B-10R | 8.42[a] | 7.79[a] | 1.92[a] | 7.46[a,b] | 7.63[a] |
| 30B-20R | 8.46[a] | 7.83[a] | 1.88[a] | 7.54[a,b] | 7.67[a] |
| 40B-0R | 8.29[a] | 7.79[a] | 1.83[a] | 7.25[a,b] | 7.58[a] |
| 40B-10R | 8.33[a] | 7.75[a] | 1.79[a] | 7.33[a,b] | 7.63[a] |
| 40B-20R | 8.38[a] | 7.83[a] | 1.75[a] | 7.42[a,b] | 7.67[a] |
| 50B-0R | 8.17[a] | 7.71[a] | 1.79[a] | 6.62[a] | 7.50[a] |
| 50B-10R | 8.25[a] | 7.75[a] | 1.81[a] | 7.00[a,b] | 7.54[a] |
| 50B-20R | 8.21[a] | 7.67[a] | 1.80[a] | 7.08[a,b] | 7.63[a] |

[a] Values in the same column with the same letter are not significantly different ($p>0.05$); [b] B - buckwheat substitution level in the biscuit formulation (% flour basis); R- rye substitution level in the biscuit formulation (% flour basis)

of biscuit products with improved nutritional quality on the market. Although health aspects remain important in consumers' choice of food, the key criterion is still related to good sensory properties. Therefore, further research should be expanded to estimation of the consumers' acceptance of the new product.

## CONCLUSION

Results showed that buckwheat was the ingredient that mostly affected the biscuit quality. Dough with buckwheat were significantly harder and less sticky. Significantly lower springiness and cohesiveness was found only at maximal buckwheat level. Buckwheat caused biscuits to increase spread, hardness and fracturability whereas rye showed an opposite effect but its significance was not shown. Despite these instrumental differences, no differences in sensorial appearance were observed, showing that buckwheat has good potential in biscuit making. However, it would be useful to consider technological procedures which could change the viscoelastic properties of buckwheat and make them more suitable in food processing. Also, investigation on the selection of buckwheat varieties with good biscuit making potential is required.

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NAUČNI RAD

# FIZIČKA, TEKSTURNA I MIKROSTRUKTURNA SVOJSTVA TESTA I MEDENJAKA OBOGAĆENIH DODATKOM HELJDE I RAŽI

*U radu su ispitivana svojstva testa i medenjaka u čijim formulacijama je deo pšeničnog brašna zamenjen brašnima celog zrna heljde i raži u različitim proporcijama. Dodatak heljde je imao dominantan uticaj na svojstva testa i gotovih medenjaka. Dodatak heljde je izazvao smanjenje lepljivosti i povećanje tvrdoće testa. Pri dodatku maksimalne ispitivane doze heljde došlo je do značajnog smanjenja kohezivnosti testa. Gotovi medenjaci su pokazali veće širenje, tvrdoću i lomljivost. Raž je delovala u pravcu poboljšanja svojstava testa (smanjenje tvrdoće, povećanje kohezivnosti) i gotovih medenjaka (smanjenje širenja, tvrdoće i lomljivosti) ali pri ispitivanim dozama ovaj efekat se nije pokazao značajnim. Međutim, uprkos razlikama utvrđenih instrumentalnim metodama, ispitivanje senzorskih svojstava su pokazala da nije bilo značajnih razlika između ispitivanih medenjaka. Primena heljde kao sirovine u proizvodnji medenjaka u cilju dobijanja nutritivno vrednijeg proizvoda ima potencijala ali je, u cilju dobijanja što kvalitetnijeg proizvoda, neophodno primeniti adekvatne tehnološke postupke kojim bi se izvršilo poboljšanje i prilagođavanje svojstava heljde za primenu u prehrambenoj industriji.*

*Ključne reči: medenjak; heljda; testo; tekstura; širenje.*