Partial replacement of fat with wheat bran in formulation of biscuits enriched with herbal blend

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Abstract

The effects of replacing fat with finely ground wheat bran, at different levels (30, 40 and 50%), in biscuit formulation were investigated with respect to dough texture and final biscuit characteristics and nutritional quality. Fat reduction using wheat bran increased dough hardness, but decreased adhesiveness, cohesiveness and springiness. Biscuit hardness increased and fracturability decreased with increasing fat replacement level. Changes in biscuit colour were detectable; lightness increased whereas yellow tone decreased. Increasing bran level contributed to higher content of protein, fibres and minerals. The achieved calorie reduction spanned over 14.5–16.2%. The dietary fibre content increased 2.1–2.8 times in comparison to the control. The low sensory scores were obtained with over 30% of fat replacement. It could be concluded that fat may be replaced in biscuit formulation, up to 30% with wheat bran. These "reduced fat" biscuits had acceptable sensory properties and additional nutritional improvement due to higher fibres and minerals and fewer calories.

Keywords: biscuit, fat, wheat bran, texture, sensory analysis, nutritional profile.

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Wheat bran is a by-product of wheat milling industry. It has been recognized as an excellent source of proteins, dietary fiber and bioactive compounds. It is cheap and readily available. Wheat bran consists of multiple layers of the outer part of wheat kernel, accounting for 10–15% of kernel weight [1]. The use of wheat and other cereal bran in various food formulations has gained remarkable interest in recent years due to versatile health benefits associated with consumption of high fiber food. Physiological effects of wheat bran can be classified into nutritional effects (due to nutrients present), mechanical effects (due to fiber presence, mainly related to gastrointestinal effects) and antioxidant effects (due to high content of phenolic compounds and other compounds with high antioxidative potency) [2]. Two health claims have been approved for wheat bran by the European Food Safety Authority; both related to gut health and laxation – one for faecal bulking and other for intestinal transit time.

Driven by increased demands for healthier food products, biscuit industry has been facing a challenge to provide novel formulations which are nutritionally more balanced but still tasty. Wheat bran has been extensively studied for use in numerous fibre-enriched baked products (biscuits, layer cakes, muffins). Incorporation of wheat bran into biscuit or cake formulation results in changes in dough properties and product characteristics but, generally, the addition of bran was found to be less detrimental in biscuits and cakes than in other, more aerated products, such as bread [3]. Research showed that biscuit structure depends on bran granulation; coarse bran yielded biscuits with low acceptability [4]. Sozer *et al.* [5] found that biscuits made with fine bran developed more compact structure and less surface and internal defects. Roasted and ground bran was found adequate to be incorporated in formulation of soft biscuit at 30% level [6]. Inclusion of wheat bran to biscuit formulation may decrease the biscuit shelf-life due to high activity of lipolytic enzymes [6].

Another frequent requirement imposed to biscuit industry is fat reduction. It is of common knowledge that health authorities recommend a decrease in fat consumption. Release of low- or reduced-fat biscuits was an answer of the biscuit industry to these requirements. To label a product as "reduced fat", the fat content in the product should contain minimally 25% less fat than an appropriate reference food whereas "low fat" label requires 50% less fat [7,8]. Fat reduction is a difficult task in low moisture products like biscuits because it contributes to tenderness, structural integrity, taste and mouthfeel. To replace high amounts of fat, water is needed, which opens a problem of stabilizing the water surplus in a biscuit system. The problem of fat reduction in biscuit formulation has been addres-

sed in numerous works. Results mainly suggest the use of various fat mimetics for partial replacement of a fat portion [9]. Fat mimetics may be based on proteins and carbohydrates. Fat replacers based on carbohydrates used in biscuits include a wide variety of substances such as gums, modified starches, pectin, fibres, poly-dextrose, maltodextrins, etc. Dietary fibre-based fat replacers have an advantage of being low in energetic value and mainly include several forms of cellulose (powdered cellulose, microcrystalline cellulose and chemically modified cellulose) [10]. Beyond cellulose, application of processed or purified fibres from differ-ent sources such as fruit and legume dietary fibre, res-istant starch, fibre from potato or fruit peels has been reported. Inulin is a dietary fibre frequently elaborated for use as a fat replacer in biscuits.

Reports on simultaneous inclusion of wheat bran and partial exclusion of fat in biscuit formula are scarce. Stanyion and Costello [11] reported on the addition of wheat bran in biscuit formulations in which fat was partially replaced with polydextrose. They found that increasing bran content yielded more crumbly, dryer and chewier biscuit with pronounced aftertaste and bran flavour. Polydextrose was found unable to reduce the aftertaste.

This study was intended to explore the possibility of fat replacement by finely ground wheat bran at 30, 40 and 50% level in a formulation of special biscuit enriched with herbal blend Vitalplant®. This special biscuit was previously shown to possess high antioxid-ative and antimicrobial potential as well as longer shelf-life due to presence of phenolic compounds in the Vit-alplant® herbal blend, specifically tailored to meta-bolism stimulation and body weight regulation [12]. In order to make it more suitable in the diet of people striving to lose weight, it was decided to improve the Vitalplant®-enriched biscuit formulation by reducing the fat content. Dough properties, textural, sensory and nutritive properties of biscuit were investigated.

EXPERIMENTAL

Materials

Wheat bran was procured from a wheat milling plant implementing HACCP Regulations. Wheat bran were double grinded to obtain fine granulation (mean particle size < 200 µm). Wheat bran contained 8.1% moisture, 17.0% proteins, 15.1% carbohydrates (starch with reducing sugars), 8.7% cellulose, 4.11% fat and 6.8% ash.

Herbal blend Vitalpant® was obtained from the Ins-titute of Medicinal Plants "Josif Pančić" from Belgrade (Serbia). Characterization of the Vitalplant® blend was reported elsewhere [12].

Other ingredients for preparation of biscuits were commercially available: refined wheat flour, corn starch, vegetable fat, sugar, fructose, glucose syrup, salt, baking powder, diacetyl tartaric acid ester of mono- and diglycerides (DATEM) and lecithin.

Preparation of biscuits

In the formula, the ratio of wheat flour to corn starch was 80:20 and represented the flour basis. The formula, based on flour basis, was: 40% fat, 15% sugar, 15% fructose, 2% Vitalplant® blend, 2% lecithin, 1% salt, 1% baking powder and 0.5% DATEM. In fat-red-uced biscuits, 30, 40 and 50% of fat content was rep-laced with bran (the respective biscuit formulations therefore contained 28 % fat and 12 % bran, *i.e.*, 24 % fat and 16 % bran, *i.e.*, 20% fat and 20% bran). Water levels were 33% for control and 52.0, 57.5 and 63% for the fat-reduced and bran supplemented variants.

Doughs were mixed in a faringraph mixer with Z-arms. The mixing process consisted of three phases: Phase 1 was mixing and homogenizing of powdery ing-redients (wheat flour, corn starch, bran, sugar, herbal blend, raising agent and DATEM) for 1 min; Phase 2 was mixing in fat for 3 min; Phase 3 was the addition of liquid ingredients (tempered water in which glucose syrup was dissolved previously). Dough mixing was con-tinued for 7 min at 25 °C. After mixing, the dough was rested for 30 min in sealed plastic tubs. Dough was further gradually sheeted to 4.5 mm thickness on a laminator. Dough pieces were cut manually with a cutter (30 mm×40 mm inner dimensions). The biscuits were baked for 14 min at 170 °C.

Dough measurements

Textural properties of biscuit dough were measured on a texture analyser TA-XTplus (Stable Micro System, England). TPA analysis was performed to measure dough properties in compression. The test settings were the following: test speed 1 mm/s, 50% strain, pause between compressions 5 s. Dough pieces were 46 mm in diameter and 75 mm probe was used. Dough hardness, springiness, adhesiveness and cohesiveness were recorded. Dough hardness was also measured in penetration mode using a dough preparation set (A/DP) with a 6 mm cylinder probe. Each test was carried out on six replicates of each formulation.

Biscuit characteristics

Biscuit texture was determined on a texture ana-lyser TA-XTplus (Stable Micro System, England) equip-ped with a 30-kg load cell. Three-point bending test was used. Biscuit samples were placed on supports with a 20 mm gap length. The cross head speed was 3 mm/s and travel distance 8 mm. Maximum force and distance at break were registered and represented

indicators of biscuit hardness and fracturability. Each measurement was performed in six replications.

Colour determination

Top surface colour of biscuits was determined using a Chroma Meter Conica MINOLTA, CR-400 (Minolta Co., Ltd., Osaka, Japan) with D-65 luminescence, 2° standard observing angle and an 8-mm blend on optical probe. Result were given in CIE L*a*b* mode (CIE, 1976) where L* is colour lightness, positive a* is red and positive b* is yellow tone. Variation in colour was determined according to the following equation [13]:

$$\Delta E = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2} \qquad (1)$$

Colour measurements were taken from each sample at five points (1 central and 4 corner points). Measurements were made in 25 replications.

Chemical analyses

Proximate composition of biscuits was performed in accordance to standard AOACI methods [14] – protein (method No. 950.36), fat (method No. 935.38), crude fibre content (method No. 950.37), starch content (method No. 996.11), reducing sugar (method No. 80-68), ash (method No. 930.22) and water contents (method No. 926.5) were determined by standard methods of analysis.

Mineral content of biscuits was determined following the standard methods described by AOACI [14]. Minerals were determined by atomic absorption spectrophotometry (method No. 984.27) on a Varian Spectra AA 10 (Varian Techtron Pty Ltd., Mulgvare Victoria, Australia).

Sensory analysis

Sensory evaluation of biscuits was performed 24 h after baking by a panel consisting of 6 trained members, 30–50 years of age, recruited from a staff working at the Institute of Food Technology in Novi Sad. To evaluate the sensory properties, relevant descriptors were first identified by consensus. The list of twelve descriptors was established (appearance, bran odour, herbal odour, flavour, taste, aroma, aftertaste, texture, fracturability, particle coarseness in the mouth (particle size and shape), fat content, overall quality). The intensity of each descriptor was presented on a 100 mm linear scale, where 0 indicated the absence of descriptor's presence and 100 indicated highly expressed descriptor.

Statistical analysis

Statistical analysis followed the procedure of one-way ANOVA using the Tukey's (HSD) post hoc test ($p <$ 0.05). Statistica 12 software package was used to analyse data (StatSoft Inc., Tulsa, OK).

RESULTS AND DISCUSSION

Texture analysis of biscuit dough

Dough properties are important as they affect dough processing. Inadequate dough consistency may cause unsatisfactory dough machining and dough piece formation, thereby impairing biscuit quality. Higher dough consistencies may also increase the load on sheeters and moulders. Table 1 shows the effect of fat replacement by wheat bran on the biscuit dough properties as measured on texture analyser in compression mode (TPA analysis) and penetration mode using a specially designed cylinder and a 6-mm cylinder probe for dough hardness measurement. The results showed that dough hardness increased with fat replacement by bran. Dough springiness, adhesiveness and cohesiveness decreased at higher levels of fat replacement (40 and 50%). Low fat doughs are generally tougher and stickier [8]. Elastic properties of dough are characterized with springiness. Biscuit dough with higher bran levels showed lower ability to recover deformation (decreased springiness). Elastic properties of dough highly affect biscuit geometry and uniformity of shapes [15]. Decreased cohesiveness and springiness may be the consequence of dough matrix disruption by wheat bran particles.

Similar effects were reported by Nandeesh *et al.* [6] for inclusion of variously treated wheat bran at higher level than used in our study (30% flour basis) in soft biscuits, and by Collar *et al.* [16] for addition of pea hull and sugar beet fibre in bread dough. In this study, significant changes in dough consistency were recorded mostly at 40–50% fat replacement levels, which, when recalculated to flour basis, is 16–20% of bran. Reaching significant effects at lower doses might be due to use of finely ground bran in our work.

Table 1. Effect of fat replacement with wheat bran on biscuit dough properties; WB 0: control sample; WB 30–WB 50: 30–50% of fat in the biscuit formula replaced by wheat bran; a,b,c,d: means in the column indicated with the same letters are not significantly different (HSD, p > 0.05)

Biscuit	TPA Hardness, kg	TPA Adhesiveness, kg/s	TPA Springiness	TPA Cohesiveness	Hardness by penetration, kg
WB 0	17.85[a]	2.57[b]	0.72[b]	0.53[c]	0.98[a]
WB 30	21.47[b]	2.20[b]	0.68[b]	0.50[b]	1.05[a,b]
WB 40	26.03[c]	1.08[a]	0.43[c]	0.42[a]	1.28[b,c]
WB 50	32.86[d]	0.49[a]	0.33[c]	0.41[a]	1.50[c]

Biscuit dimension and weight loss

Weight loss during baking is due to water evaporation. It was significantly higher in the fat-replaced biscuits (Table 2). Higher water evaporation may be due to initially higher water content in the bran-containing biscuit dough as compared to the control because addition of bran to biscuit formulation increases the level of water required. Weight loss somewhat decreased in formulations with higher fat replacement by wheat bran. Higher bran level in formulation might have caused better water retention in dough, making water less available for easy evaporation.

Table 2 displays that biscuit dimensions changed with fat replacement by bran. Biscuit width decreased but significant difference was observed only with the highest replacement level (50%). Similarly, length gain was lower in the fat-replaced samples but did not reach statistical significance. Height gain was significantly higher for formulations with 30 and 40% fat replacement by bran whereas it was not statistically different from the control at 50% replacement level. Less biscuit spread has been associated with lower fat content as the consequence of impaired lubrication and consequent decreased mobility in dough system [17]. Lower fat and higher bran content caused the formation of harder but less elastic dough due to simultaneous effect of higher hydration of flour and fibrous particles, thereby influencing dough behaviour during baking and hence leading to less spread. Interactions of bran fibres with the flour constituents may enhance the gluten network and decrease spread. Lower spread was reported for incorporation of 10% of wheat bran in cookie formulation [18].

Biscuit texture analysis

Three-point bending test results are shown in Table 3. The results showed that the addition of wheat bran to replace fat in biscuit formulations caused a significant increase in the breaking force whereas fracturability decreased (as shown by an increase in distance at break). This is consistent with the findings of Nandeesh *et al.* [6] and Singh Gurjal *et al.* [18]. Sozer *et al.* [5] found that smaller bran particle size imparts higher fracture stress and elastic modulus to biscuits than bigger bran particles. Smaller bran particles seem to better incorporate into biscuit matrix, hence improving

its overall strength. Fat reduction in biscuit formulation generally results in increased hardness. This is because fat has a textural function in dough [8]. The major role of fat is lubrication by coating the matrix, thereby less fat allowed higher accessibility of flour and fibre particles to water. Higher hydration of matrix led to the formation of harder doughs and, hence, harder biscuits. However, no significant impact of the increased bran content was seen in the fat-replaced samples; within these samples, hardness tended to decrease, which may be due to the disruption of partially hydrated gluten network by increasing amounts of bran particles.

Table 3. Biscuit texture characteristics determined with a 3-point bending rig; a,b,c: means in the column indicated with the same letters are not significantly different (HSD, p > 0.05)

Biscuit	Force at break-hardness, g	Distance at break-fracturability, mm
WB 0	3078.04[a]	0.61[a]
WB 30	8593.93[b]	2.16[c]
WB 40	8029.41[b]	1.21[a,b]
WB 50	7810.41[b]	1.25[b,c]

Chemical composition of biscuits

Table 4 presents the effects of fat replacement with wheat bran on the chemical composition of biscuits. The results indicated that there was a significant increase in protein, ash and fiber content in the fat-replaced samples. Carbohydrates increased in comparison to control but did not change significantly with increasing replacement levels. Moisture content was significantly higher in the fat-replaced samples (5.5–6.9%) than in the control (3.2%). Compared to control, fat content decreased significantly by 31.4, 38.2 and 40.6% in samples with 30, 40 and 50% fat replacement using bran whereas dietary fibres and cellulose content increased 2.1, 2.5, 2.8 and 3.9, 4.6, 5.5 times, respectively. Drop in the fat content was low enough to allow "fat reduced" or "less fat" claim on biscuit label. As compared to the control, energy value of the biscuits decreased by 14.5–16.2%.

Increasing fat-replacement levels with bran progressively increased the mineral content of biscuits, Table 5; marked increases were recorded for all obs-

Table 2. Mean values of weight loss during baking and physical properties for the biscuit formulations; WB 0: control sample; WB 30–WB 50: 30–50% of fat in the biscuit formula replaced by wheat bran; a,b,c: means in the column indicated with the same letters are not significantly different (HSD, p > 0.05)

Biscuit	Weight loss, %	Width gain, %	Length gain, %	Height gain, %
WB 0	12.5[a]	+8.9[b]	+5.7[a]	+55.5[a]
WB 30	16.8[c]	+7.2[a,b]	+3.6[a]	+69.7[c]
WB 40	16.6[b,c]	+8.0[a,b]	+3.7[a]	+60.8[b]
WB 50	15.7[b]	+4.4[a]	+4.3[a]	+51.3[a]

Table 4. Proximate analysis of biscuits for the formulations with reduced fat and control; WB 0: control sample; WB 30–WB 50: 30–50% of fat in the biscuit formula replaced by wheat bran. Carbohydrate content represents the sum of starch and total reducing sugars content; a,b,c,d: means in the column indicated with the same letters are not significantly different (HSD, p > 0.05)

Biscuit	Proteins g/100 g d.m.	Carbohydrates g/100 g d.m.	Fat g/100 g d.m.	Cellulose g/100 g d.m.	Dietary fibres g/100 g d.m.	Ash g/100 g d.m.	Energy value cal/100 g	Energy reduction compared to the control
WB 0	5.30[a]	44.54[a]	24.47[a]	0.23[a]	3.41[a]	0.89[a]	412.8	–
WB 30	6.65[b]	46.78[b]	16.79[b]	0.90[b]	7.28[b]	1.33[b]	353.0	14.5%
WB 40	8.03[c]	47.03[b]	15.08[c]	1.05[c]	8.41[c]	1.53[c]	348.3	15.6%
WB 50	8.13[c]	47.16[b]	14.54[d]	1.27[d]	9.58[d]	1.54[c]	345.7	16.2%

erved macro and microelements (K, Ca, Mg, Fe, Zn and Cu) except for sodium, which was less pronounced. Similar tendencies were reported in the work of El--Sharnouby *et al.* [19]. Regarding bioavailability of minerals, the positive effect of wheat bran on the mineral profile of fat-replaced biscuit may be counteracted by the higher content of phytic acid. On the other hand, higher phytic acid content may provide other beneficial health effects such as, decrease in plasma cholesterol and triglycerides, delayed post-prandial absorption, inhibition of renal stone formation, and other effects associated with its antioxidant action [2].

Colour characteristics of biscuits

Product colour is an important factor that affects the initial acceptability of product by consumers. Fat replacement by wheat bran at various levels in biscuit formulations caused changes in biscuit colour detectable by the human eye (ΔE > 3, Table 6). According to Francis and Clydesdale [20], if ΔE < 1, the variation in colour cannot be perceived by the human eye; 1 < ΔE < 3 – the colour variation is not significant for the human eye; ΔE > 3 – the colour variation is perceived by the human eye. Change in biscuit formulation caused a significant increase in biscuit lightness and decrease in yellow tone in comparison to the control. Red tone was unaffected by fat replacement with wheat bran. Similar reduction in yellow tone was reported by Majzoobi *et al.* [21] in bread, and Gomez *et al.* [4] in layer cakes, however, our findings contrasted theirs regarding trends in lightness and red tone which may be due to product type and different granulation of used bran. Here, biscuits already enriched with the herbal blend

Vitalplant were used. Herbal powder provided initial dark colour to biscuits whereas bran addition seems to counteract the colour effect of aromatic herbs.

Table 6. CIELab color parameters of the top surface and HMF content of fat-reduced biscuits; WB 0: control sample; WB 30–WB 50: 30–50% of fat in the biscuit formula replaced by wheat bran; HMF – hydroxymethylfurfural content; a,b,c: means in the column indicated with the same letters are not significantly different (HSD, p > 0.05)

Biscuit	L*(D65)	a*(D65)	b*(D65)	ΔE	HMF, mg/kg
WB 0	58.13[a]	7.83[a]	31.99[c]	–	4.31
WB 30	62.63[b]	7.68[a]	29.11[b]	5.34	6.29
WB 40	62.20[b]	7.74[a]	29.03[b]	5.03	6.61
WB 50	63.45[c]	7.55[a]	27.20[a]	7.15	5.48

Sensory evaluation

Figure 1 displays the mean results of sensory evaluation of biscuits with different levels of fat replacement by bran. Changes in biscuit formulation were perceived by panellists mostly as an increase in bran odour intensity accompanied with a decrease in the intensity of herbal blend. Fat replacement with bran did not affect the shape and appearance score of biscuits probably due to harder, less elastic and less adhesive dough. It was observed that sensory profile significantly declined when fat was replaced with brans at levels higher than 30%. These samples received lower scores for aroma, taste, textural properties and overall quality and had higher percentage of coarse particles at swallowing. On the other hand, replacing 30% of fat with bran, although yielding harder and coarser product than the control, did not appreciably

Table 5. Mineral composition (g/100 g d.m.) of biscuits with reduced fat and control biscuit; WB 0: control sample; WB 30–WB 50: 30–50% of fat in the biscuit formula replaced by wheat bran; a,b,c,d: means in the column indicated with the same letters are not significantly different (HSD, p > 0.05)

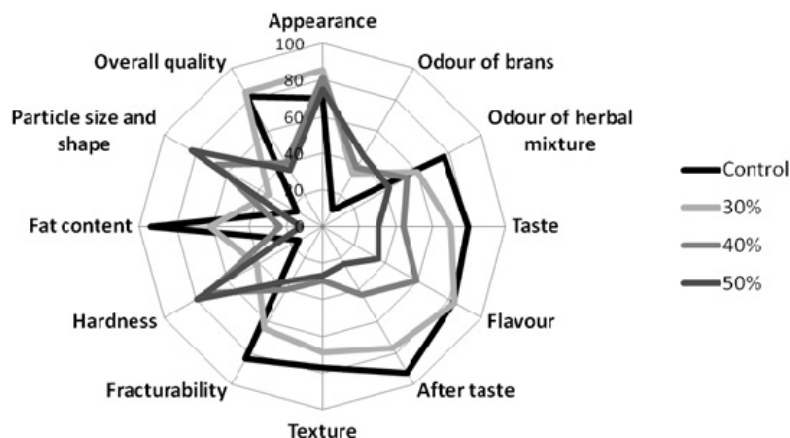| Biscuit	Na	K	Ca	Mg	Fe	Zn	Cu
WB 0	2.96[a]	8.48[a]	3.47[a]	1.53[a]	10.71[a]	5.75[a]	0.91[a]
WB 30	2.80[a]	17.62[b]	3.77[b]	4.88[b]	18.10[b]	7.10[b]	2.50[b]
WB 40	3.19[b]	22.40[c]	4.28[c]	6.96[c]	21.66[c]	9.01[c]	2.67[b,c]
WB 50	3.18[b]	26.85[d]	4.39[c]	7.96[d]	23.61[d]	9.92[d]	3.01[c]

Figure 1. Radial diagram of sensory scores for the control and fat-reduced biscuits.

impair taste, texture, aroma, and overall quality. Earlier studies have shown that panellists, when performing textural hedonic analysis, take into account several aspects, not just hardness itself but also, for example, cohesiveness and maybe some other aspects not quantified instrumentally [4].

Despite some differences in sensory profiles between the control and biscuit with 30% fat replacement, high scores obtained for the majority of parameters indicated that they were not disagreeable by panellists.

CONCLUSION

This study showed that it is possible to obtain highly acceptable biscuit in which fat content was reduced by 30% and energy value decreased by 14.5% whereas fibre content was twice as high as in the control sample. This was achieved by replacing 30% of fat in the formulation by finely ground wheat bran. It was found that 30% fat replacement level affected the textural properties of biscuits, yielding harder but less fracturable product, however, sensory panel did not perceive this as unacceptable. At 30% replacement level, dough properties similar to the control dough were obtained implying that no considerable problems should be expected on production lines.

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IZVOD

DELIMIČNA ZAMENA MASNOĆE PŠENIČNIM MEKINJAMA U FORMULACIJI KEKSA OBOGAĆENOG BILJNOM MEŠAVINOM

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(Naučni rad)

U radu je ispitivan efekat delimične zamene masnoće (30–50%) fino samlevenim pšeničnim mekinjama u formulaciji specijalnog keksa obogaćenog biljnom mešavinom. Delimična zamena masnoće je uticala na povećanje tvrdoće testa i smanjenje lepljivosti, kohezivnosti i elastičnosti. Povećanje udela mekinja na račun masnoće dovelo je do povećanja tvrdoće i smanjenja lomljivosti keksa kao i do promene boje (povećanje udela žutog tona i svetloće). Dodatak mekinja umesto dela masnoće u ispitivanim dozama uticao je na poboljšanje nutritivnog sastava jer je doveo do povećanja sadržaja proteina (1,25–1,53 puta), dijetalnih vlakana (2,1–2,8 puta) i minerala (kalijuma 2–3 puta, magnezijuma 3–5 puta, gvožđa 1,7–2,2 puta, cinka 1,2–1,7 puta) kao i do smanjenja energetske vrednosti keksa (za 14,5–16,2%), u odnosu na kontrolni keks. Međutim, zamena 40 i 50% masnoće mekinjama je pogoršala senzorska svojstva keksa što se pokazalo kao limitirajući faktor. Keks u kojem je 30% masnoće zamenjeno mekinjama je pokazao dovoljan pad u sadržaju masti da bi mogao da se deklariše kao "keks sa smanjenim sadržajem masti" a istovremeno se karakteriše značajno boljim nutritivnim sastavom u odnosu na kontrolni keks.

Ključne reči: Keks • Mast • Pšenične mekinje • Tekstura • Senzorska svojstva • Nutritivni profil