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SCIENTIFIC PAPER

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SOYBEAN BRAN AS THE FAT REPLACER IN GLUTEN-FREE COOKIE FORMULATION: PHYSICOCHEMICAL PROPERTIES AND SENSORY PROFILES

Article Highlights

- Soybean bran was used in a gluten-free cookie formulation as a fat replacer (30%–50%)
- Dough properties, physical, textural, colour and sensory parameters of cookies were examined
- 30% fat replacement resulted in the most acceptable gluten-free cookies
- The nutritional properties of gluten-free cookies were investigated
- A novel value-added product for celiac patients has been developed

Abstract

Soybean bran (SB) partially replaced fat (30%–50%) in a gluten-free cookie formulation. Dough properties, physical (cookie dimension and weight loss), textural (hardness and fracturability), colour and sensory parameters, as well as nutritional profiles were evaluated to characterize full-fat (FFC) and fat-reduced cookies (FRC). Based on the obtained results, it was concluded that the fat reduction in cookie formulation at 30% maintained the sensory properties of the FFC. Furthermore, it was revealed that the fat replacement using SB at 30% resulted in the fat-reduced value-added gluten-free cookies in terms of dietary fibre and minerals. A daily portion of the 30% FRC meets 11.87% and 18.04% of dietary reference intakes (DRIs) for dietary fibres, 26.50% of DRIs for calcium, 35.71% and 46.88% of DRIs for magnesium and 65.43% and 83.61% of DRIs for manganese, for male and female adults, respectively.

Keywords: gluten-free cookies, fat replacers, soybean bran, physicochemical properties, sensory analysis.

Celiac disease is an autoimmune enteropathy triggered by ingesting gluten-containing grains (wheat, barley, rye and possibly oats) in genetically susceptible individuals. Therefore, celiac disease patients are recommended to be on a strict long-life gluten-free diet, which usually lacks in vitamin B, dietary fibres and iron [1,2]. Moreover, an imbalance in the intake of carbohydrates, fat and protein exists in a gluten-free diet [1].

Having in mind that high fat intake has adverse effects on human health and leads to the development of several diseases (obesity, diabetes, cancer, high cholesterol levels and coronary heart diseases), many efforts have been made to reduce fat content in foods regardless of the food category (gluten-containing or gluten-free foods) and replace it with various fat replacers [3,4,5].

Carbohydrate-based fat replacers act as fat mimetics as they form a gel in the presence of water with a flow pattern similar to one of the lipids [6]. Recently, there has been growing interest in valorizing fibre-containing by-products as potential raw materials for producing fat replacers [7]. Cereal milling fractions rich in fibre can serve as fat replacers. The studies with corn bran fibre [8,9], soluble fibre from corn and oats [10], fibre gel produced from rice bran [11] and wheat and oat bran gels [12] were conducted to investigate the possibilities of their utilization as the fat replacers.

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Furthermore, the particular benefit of fibre-containing cereal by-products used as fat replacers is their fibre abundance, which can significantly contribute to the functionality of the obtained low-fat products, especially in gluten-free products, which can often have a weak nutritional and functional profile. Besides increasing the total dietary fibre content in food products, cereal brans can enrich the food with bioactive compounds [12].

Soybean is the most important source of edible plant oil and protein worldwide. To obtain flour and oil, soybean bran (SB) is obtained as a by-product during soybean processing. Thousands of tons of SB and dregs are generated as agricultural by-products and are typically discarded and wasted. Having an insight into its proximate composition and dietary fibre content, 59.9%–72.2% insoluble fibre (IDF) and 3.9%–12.7% soluble fibre (SDF) [13], it seems that SB could be used as a fibre-containing fat replacer in a cookie formulation. Furthermore, since SB is a good source of IDF, it could possess a prebiotic effect on the faecal microbiota [14]. However, no research has been conducted exploring this type of bran as the fat replacer in cookie formulation. In addition, the absence of gluten in SB classifies it as a potential fat replacer for gluten-free food production, such as cookies.

Insufficient amounts of nutrients in gluten-free cookies can be overcome by their fortification to achieve a balanced diet, i.e. to obtain value-added products. For that reason, the authors decided to produce gluten-free fat-reduced cookies (FRC) using SB, aiming to 1) investigate the effects of incorporation of SB as the fat replacer into the cookie formulation on dough characteristics, as well as physical, textural, colour and sensory properties of cookies and 2) characterize cookies in terms of nutritional profiles.

MATERIALS AND METHODS

Raw materials

SB was obtained from AD "Sojaprotein", Bečej, Serbia. SB was double ground to obtain fine granulation (mean particle size < 300 μm). As a result, SB contained 7.90% moisture, 14.8% proteins, 12.7% carbohydrates (the sum of starch and total reducing sugars content), 4.40% fat, 3.96% ash, and 55.3% total dietary fibres on a wet basis.

A gluten-free mixture consisting of corn starch, corn flour, potato starch, potato flour, rice flour, guar gum, baking powder, and salt was purchased from "Nutri Allergy Center", Zemun, Serbia. In addition, vegetable fat, glucose syrup, baking powder, salt, soy lecithin, corn grits and spices were commercially available.

Preparation of gluten-free cookies

Full-fat (FFC) and fat-reduced gluten-free cookies (FRC) were produced using the ingredients listed in Table 1.

Table 1. Ingredients of gluten-free cookie formulations.

Ingredients (%)	Full-fat cookies	30% SB cookies[a]	40% SB cookies[b]	50% SB cookies[c]
Gluten-free mix	100	100	100	100
Vegetable fat	30.18	21.12	18.10	15.09
Soybean bran	0	9.05	12.07	15.09
Glucose syrup	10.71	10.71	10.71	10.71
Spices	4.64	4.64	4.64	4.64
Corn grits	3.57	3.57	3.57	3.57
Salt	1.79	1.79	1.79	1.79
Soy lecithin	0.71	0.71	0.71	0.71
Baking powder	0.54	0.54	0.54	0.54
Water	42.86	48.67	54.00	59.33

[a] cookies in which 30% of fat was replaced with SB; [b] cookies in which 40% of fat was replaced with SB; [c] cookies in which 50% of fat was replaced with SB.

The cookie dough was made in a farinograph mixing bowl (Brabender, Duisburg, Germany) at 30 °C. The dough was prepared using the following method: vegetable fat was mixed with glucose syrup for 3 min to obtain a homogenous mixture, in which the solution of salt, with the rest of distilled water, was added and mixed for 5 min. Finally, all powdery ingredients (gluten-free mixture, SB, corn grits, spices and baking powder) were mixed for 2 min. The dough was kept in a refrigerator for 24 h for better hydration of SB. Afterwards, the dough was tempered to ambient temperature and further processed. A pilot-scale dough sheeter (Mignon, Mestrino, Italy) was used for sheeting the dough to the desired thickness (4.5 mm). Cookies were shaped using a cutter (40 mm × 30 mm) and baked at 220 °C for 2 min and then at 160 °C for 14 min in a laboratory oven (MIWE gusto® CS, Berlin, Germany). The obtained gluten-free cookies were first left to cool down at ambient temperature for 2 h, and then they were packed and stored for 24 h in sealed polypropylene bags before analysis.

Textural properties of cookie dough

Textural properties of cookie dough were measured on a texture analyzer TA-XTplus (TA.XTplus, Stable Micro System, Godalming, United Kingdom). TPA analysis was performed to measure dough properties in compression. The test settings were: test speed 1 mm/s, 50% strain, pause between compressions 5 s. Dough pieces were 46 mm in diameter, and a 75 mm probe was used. Dough hardness, adhesiveness, springiness and resilience were recorded. Dough hardness was also measured in penetration mode using a dough preparation set (A/DP) with a 6 mm cylinder probe. The test settings were: test speed 3 mm/s, distance 20 mm. Each test was carried out on six replicates of each formulation.

Cookie dimensions and weight loss

Cookie dimensions were determined by measuring the length (L), width (W) and height (H) using a digital calliper. The measurements were obtained 30 min after baking in six replicates per batch at ambient temperature (25 °C ± 1 °C).

Baking weight loss (BWL) was determined by measuring the cookie weight before and after baking. It was calculated according to the following Eq. 1:

$$BWL(\%) = \frac{m_0 - m_t}{m_0} \times 100 \tag{1}$$

where m_0 is the cookie weight before baking, and m_t is the weight after baking. Cookie weight (m_0 and m_t) was determined as the average value of six independent measurements.

Textural properties of cookies

The texture of cookie samples was determined on a TA-XT2 Texture Analyzer (Stable Micro System, Godalming, United Kingdom) equipped with a 30 kg load cell and three-point bending rig (HDP/3PB). The measurements were done in a compression mode using the crosshead speed of 3 mm/s during analysis and a travel distance of 8 mm. Cookie samples were placed on supports with a 20 mm gap length.

Maximum force and distance at break were registered and represented indicators of cookie hardness and fracturability. Measurements were performed 24 h after baking in six replicates per batch at ambient temperature (25 °C ± 1 °C).

Colour determination

The colour of the top surface of the cookies was measured 24 h after baking using a chromameter Minolta CR-400 (Konica Minolta Co., Osaka, Japan). The results were expressed as L^*(brightness/darkness), a^* (redness/greenness) and b^* (yellowness/blueness). Browning index (BI) was calculated from Eq. 2 [15]:

$$BI = \frac{[100 \times (X - 0.31)]}{0.172} \tag{2}$$

where X is calculated according to the following Eq. 3:

$$X = a^* + 1.75L^* + a^* - 3.012b^* \tag{3}$$

The total colour difference (ΔE) between the reference (control) and cookie samples with SB was calculated according to the following Eq. 4:

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \tag{4}$$

where ΔL^* is the difference in L^* values between FFC and FRC; Δa^* is the difference in a^* values between FFC and FRC, and Δb^* is the difference in b^* values between FFC and FRC. Colour measurements were taken from each sample in 25 replications (five points, 1 central and 4 corner points, on 5 randomly selected samples per batch.

Hydroxymethylfurfural (HMF) in cookies

The extraction procedure was performed according to the method proposed by Rufián-Henares *et al.* [16] with the modifications done by Petisca *et al.* [17]. First, ten grams of sample were suspended in 5 mL water:methanol (70:30). The mixture was thoroughly stirred for 1 min, and then 2.0 mL of Carrez I and Carrez II solutions were added and centrifuged at 5000 rpm (4 °C) for 15 min, recovering the supernatant to a 15 mL flask. Next, two more consecutive extractions were made with 2 mL of water:methanol (70:30) until collecting 10 mL of supernatant was. Finally, two millilitres of this solution were centrifuged at 8000 rpm for 15 min before being analyzed. The chromatographic separation and quantification of HMF were performed using the HPLC method described by Ariffin *et al.* [18] and Tomasini *et al.* [19] with some modifications. A liquid chromatograph (Agilent 1200 series), equipped with a DAD detector and an Eclipse XDB-C18, 1.8 µm, 4.6 mm × 50 mm column (Agilent), was used for quantification of HMF in the obtained extracts. The injected volume was 2 µL, and the temperature was set at 30 °C. The mobile phase consisted of an isocratic mixture of methanol:water (0.1% formic acid), ratio 10:90 (v:v) at a constant flow of 0.75 mL/min. The DAD wavelength was set at 284 nm. The total run time of the analysis was 5 min.

All tests were performed in triplicate, and the results were averaged.

Sensory evaluation

Sensory descriptive analysis of cookies was performed 24 h after baking at the Accredited Laboratory for Sensory Analysis at the Institute of Food Technology, University of Novi Sad, Novi Sad, Serbia, respecting all protocols to avoid harm and risks to the participants. Sensory evaluation was conducted by the trained sensory panel (7 females and one male, 30–50 years of age). The panellists were recruited from a staff working at the Institute of Food Technology in Novi Sad and selected by their sensory abilities according to ISO 8586:2012 [20]. All panellists received written information about the study, and they signed informed consent to participate. The Institute of Food Technology Ethics Committee approved the study in Novi Sad, University of Novi Sad, Novi Sad, Serbia

(Ref. No. 175/I/10-3).

Panellists evaluated colour nuance, bran visibility, bran odour intensity, saltiness, overall flavour intensity, bran flavour intensity, fracturability, hardness and quality. The intensities of sensory properties were evaluated on a 100 mm line scale, from the lowest intensity (left side) to the highest intensity (right side of the scale). Every panellist was given two cookies per sample in closed odourless plastic containers at ambient temperature (25 °C ± 1 °C) labelled with three randomly chosen digit numbers and drinking water for palate cleansing.

Nutritional cookie profile

Proximate composition of cookies including protein (Method No. 950.36), fat (Method No. 935.38), total dietary fibre (Method No. 958.29), reducing sugar (Method No. 975.14), ash (Method No. 930.22) and moisture content (Method No. 926.5) was determined by AOAC standard methods of analysis [21]. In addition, according to ICC Standard No. 123/1 [22], starch content was determined by hydrochloric acid dissolution.

Minerals were determined by atomic absorption spectrophotometry (Method No. 984.27) on a Varian Spectra AA 10 (Varian Techtron Pty Ltd., Mulgvare Victoria, Australia).

Statistical analysis

Results were expressed as mean ± standard deviation of triplicate analyses for all measurements, except the colour determination performed in 25 repetitions, as well as texture measurements of dough and cookies and R, T and BWL measurements were done in 6 repetitions. Statistical differences between samples were evaluated using a one-way analysis of variance (ANOVA) followed by Tukey's minimum square difference test. The difference between groups was considered significant at $p \leq 0.05$. All data were analyzed using the software package STATISTICA 10.0 (StatSoft Inc., Tulsa, OK, USA). Sensory descriptive data were analyzed using the software package XLSTAT 2018.7 (Addinsoft, Long Island, NY, USA).

RESULTS AND DISCUSSION

Texture analysis of cookie dough

The replacement of fat (30%–50%) in the gluten-free cookie formulation using SB affected the textural properties of the cookie dough. SB can mimic fat functionality in food systems due to the presence of a high amount of fibre (55.3%), taking into account that fibres are known to have the ability to absorb considerable amounts of water and thus express gelling properties [23]. It was the reason for initially adding higher water in the bran-containing cookie doughs than the control one (adding bran in cookie formulation increased the amount of water required to obtain workable consistency). Villemejane *et al.* [24] also found that incorporating fibres in biscuit formulation required increasing dough hydration.

Increasing SB in the cookie formulation led to increased dough hardness and resilience (Table 2). The results agree with Sudha *et al.* [25] and Pareyt *et al.* [26], who also concluded that fat reduction resulted in increased cookie dough hardness. Since fat is the essential ingredient associated with dough processability and the baking quality of the product, increased hardness of SB-containing dough was related to a decrease in fat content. Furthermore, Sanchez *et al.* [27] also found that decreasing fat content in cookie dough formulations increased resilience.

The elastic properties of the dough are characterized by springiness, which was decreased by reducing the fat content in the formulation, and the adhesiveness decreased in the same manner. Decreasing adhesiveness could be interpreted as an improvement because stickiness is considered a common problem in the baking industry and is not desired behaviour for cookie production [28]. However, no significant ($p \leq 0.05$) differences in cookie dough springiness and adhesiveness were observed between cookies with different fat replacement levels (30%–50%).

Table 2. Dough properties of the control (full-fat) gluten-free cookie formulation and fat-reduced gluten-free cookie formulations.

	Full-fat dough	30% SB dough	40% SB dough	50% SB dough
Hardness (kg)	$(13.3 \pm 1.76)^{a}$	$(27.7 \pm 3.13)^{b}$	$(29.7 \pm 1.56)^{b,c}$	$(35.9 \pm 2.83)^{c}$
Adhesiveness (kg/s)	$(2.85 \pm 0.35)^{b}$	$(0.57 \pm 0.16)^{a}$	$(0.49 \pm 0.20)^{a}$	$(0.20 \pm 0.06)^{a}$
Springiness	$(0.75 \pm 0.14)^{b}$	$(0.34 \pm 0.05)^{a}$	$(0.35 \pm 0.04)^{a}$	$(0.40 \pm 0.04)^{a}$
Resilience	$(0.15 \pm 0.01)^{a}$	$(0.26 \pm 0.01)^{b}$	$(0.28 \pm 0.02)^{b}$	$(0.34 \pm 0.02)^{c}$
Hardness (kg)	$(0.22 \pm 0.02)^{a}$	$(0.52 \pm 0.03)^{b}$	$(0.59 \pm 0.04)^{c}$	$(0.61 \pm 0.01)^{c}$

Values are means (n = 6) ± standard deviations; Means in the same row with different superscripts are statistically different ($p \leq 0.05$).

Cookie dimensions and weight loss

Partial replacement of vegetable fat in the cookie formulation by finely ground SB at 30%–50% level influenced cookie dimension and weight loss during baking (Table 3). Weight loss during baking is a consequence of water evaporation, which was lower in

FRC, but there were no significant ($p \leq 0.05$) differences between the control cookies and FRC (Table 3). Although a higher level of SB might have caused better water retention in the dough, making water less available for easy evaporation [29], no significant differences between the samples were observed.

Cookie width decreased with an increasing level of fat substitution by SB, but a significant ($p \leq 0.05$) difference was observed only in the case of the highest replacement level (50%). Similarly, length gain was lower in FRC, but there were no significant ($p \leq 0.05$) differences between samples. FRC's height was higher than the control's but did not reach statistical significance ($p \leq 0.05$). Similar observations were published by Pareyt *et al.* [26], who concluded that less cookie spread was associated with a lower fat content due to impaired lubrication and decreased mobility in the dough system. The same authors noticed that increasing fat contents correlated linearly ($R^2 = 0.98$) with increasing cookie diameter and, consequently, with decreasing cookie height. Lee and Inglett [30] found that cookie diameter significantly decreased and its thickness significantly increased when shortening was replaced by oat bran in a cookie formulation.

Textural properties of cookies

The effect of fat replacement with SB on the textural properties of gluten-free cookies is summarised in Table 3. The hardness values ($p \leq 0.05$) increased with increasing levels of fat replacer in the cookie formulation. The obtained results agree with Pareyt *et al.* [26] and Laguna *et al.* [31]. It happens because the major role of fat is lubrication by coating the matrix; less fat allows higher accessibility of flour and fibre particles to water. Higher hydration leads to the formation of harder doughs (Table 2) and, hence, harder cookies [26]. Chevallier *et al.* [32] considered that dough with reduced fat content is characterized by a smaller amount of incorporated air, leading to a more pronounced strength of the cookies. The force required to break cookies containing 50% less fat than the control sample was more than three times higher than that required to break the control ones. This finding agreed with our earlier results, where fat was replaced with oat and wheat bran gels in a cookie formulation [12].

Fat replacement using SB in the gluten-free cookie formulation resulted in a less fracturable product (as shown by an increase in the distance at break). Still, the differences were not significant ($p \leq 0.05$) (Table 3).

In general, the textural measurements indicate that using SB as the fat replacer resulted in cookies with a less tender texture, suggesting that lower amounts of SB in FRC were acceptable.

Table 3. Physical and textural characteristics, colour parameters, browning index and HMF content of the control (full-fat) gluten-free cookies and fat-reduced gluten-free cookies.

	Full-fat cookies	30% SB cookies	40% SB cookies	50% SB cookies
		Physical properties		
BWL (%)	$(23.5 \pm 0.19)^a$	$(23.5 \pm 0.56)^a$	$(22.6 \pm 0.31)^a$	$(21.9 \pm 0.48)^a$
Width change (%)	$+4.41^b$	$+1.41^{a,b}$	$+0.20^{a,b}$	-1.71^a
Length change (%)	-0.55^a	-0.39^a	-3.40^a	-1.63^a
Height gain (%)	$+30.55^a$	$+35.26^a$	$+32.43^a$	$+30.60^a$
		Textural properties		
Hardness (g)	$(2880 \pm 456)^a$	$(5349 \pm 829)^b$	$(8974 \pm 955)^c$	$(9520 \pm 1118)^c$
Fracturability (mm)	$(0.69 \pm 0.15)^a$	$(0.78 \pm 0.06)^a$	$(0.83 \pm 0.11)^a$	$(0.91 \pm 0.06)^a$
		Colour parameters		
L^*	83.12^c	74.67^b	71.41^a	71.10^a
a^*	-0.47^a	1.30^b	1.89^c	2.05^d
b^*	23.98^c	22.70^b	22.30^{ab}	22.13^a
BI	32.36^c	36.24^b	38.08^a	38.12^a
ΔE		8.72^a	12.00^b	12.42^b
HMF (mg/kg)	0.11^a	0.11^a	0.11^a	0.11^a

BWL - baking weight loss; L^*- lightness; a^*- a colour coordinate (red tone); b^*- b colour coordinate (yellow tone); BI - browning index; ΔE - colour differences; HMF - hydroxymethylfurfural. Values are means (n = 6 for physical and textural properties; n = 25 for colour parameters; n = 3 for HMF content) ± standard deviations. Means in the same row with different superscripts are statistically different ($p \leq 0.05$).

Colour parameters and HMF content of cookies

Colour is essential in the consumer's acceptance of a food product. Fat replacement with SB caused significant ($p \leq 0.05$) changes in L^*, a^* and b^* values (Table 3). In addition, cookies with SB were significantly darker, redder and less yellow than the control sample. Sudha *et al.* [25] also reported that the colour of wheat cookies became darker when bran from different sources (wheat, rice, oat, and barley) was incorporated into the formulation.

There was a significant ($p \leq 0.05$) increase in the browning index in cookies containing SB. The browning index (BI) represents the purity of brown colour and is reported as an important parameter in processes where enzymatic or non-enzymatic browning occurs [15]. The production of brown pigments in baked goods is mainly caused by the Maillard reaction and caramelization[33]. These reactions are influenced by many factors, such as pH, high temperature, low moisture content, sugar, protein, fat, amino acid and dietary fibre content [34]. However, the obtained BI results in Table 3 indicated that cookies were darker due to the increasing amount of SB in the cookie formulation, i.e. they could not be addressed to the development of Maillard reaction products. Namely, HMF, the Maillard reaction product formed during baking, was under the limit of quantification in all examined cookie samples (Table 3). Therefore, it suggests that the non-enzymatic browning reaction was not intensely expressed in the production of gluten-free cookies.

Calculated CIELAB colour difference (ΔE) between the FFC and FRC exceeds the limit for sensory perceptibility (ΔE > 0.5) [35] (Table 3), thus indicating that cookies exhibited different colours from a sensory point of view, as well.

Sensory evaluation

The sensory properties of cookies evaluated by the panel were correlated with the instrumentally measured textural and colour properties. The PCA graph (Fig. 1) shows the sensory space characterized by four cookie samples considering nine evaluated attributes. The parameters measured instrumentally were over-imposed into the map as supplementary variables. Samples were well discriminated against based on the evaluated attributes. The control FFC sample was associated with positive attributes for this type of product (saltiness, fracturability and overall flavour intensity) and with significantly ($p \leq 0.05$) higher overall quality in comparison to other analyzed cookie samples. Using SB as the fat replacer led to statistically significant ($p \leq 0.05$) changes in the sensory profile of gluten-free cookies. Samples 40% SB and 50% SB became darker with highly visible bran particles, the bran odour and flavour, were more pronounced, and the hardness increased. At the same time, fracturability decreased, and these samples were scored with a lower overall quality. It was observed that overall quality significantly ($p \leq 0.05$) declined when fat was replaced with SB at levels higher than 30%. On the other hand, replacing 30% of fat with SB did not appreciably impair colour nuance, savoury taste, overall flavour intensity, fracturability, hardness and overall quality compared to the control FFC. Textural parameters measured instrumentally (hardness and firmness) were highly correlated to sensory-evaluated hardness (R = 0.979, $p \leq 0.05$) and firmness (R = - 0.939, $p \leq 0.05$). Colour parameters (L^*, a^* and b^*) were well correlated with bran visibility (RL^* = - 0.980, Ra^* = 0.986, Lb^* = - 0.989, $p \leq 0.05$) and flavour intensity (RL^* = - 0.976, Ra^* = 0.975, Lb^* = - 0.975, $p \leq 0.05$).

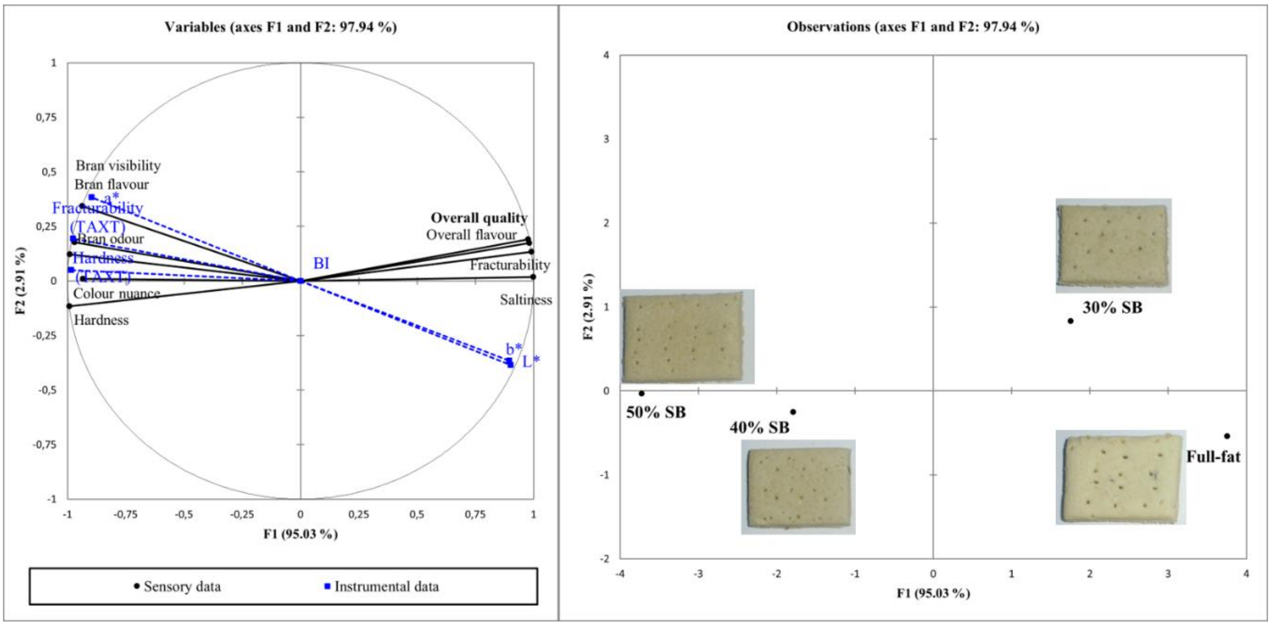

Figure 1. PCA plot performed with the scores of sensory attributes (left side) evaluated for gluten-free cookies (right side) together with instrumentally measured parameters of texture and colour as supplementary quantitative variables.

Nutritional cookie profile

The content of macronutrients (proteins, carbohydrates, fats, and dietary fibres) and minerals (Na, K, Ca, Mg, Fe, Zn, Cu and Mn) were determined in the control and FR gluten-free cookies to demonstrate the effect of the fat replacement with SB on the nutritional profile of gluten-free cookies (Table 4). The results indicated significant ($p \leq 0.05$) increases in protein, ash and dietary fibre content in FRC. Carbohydrates decreased in comparison to the control cookies. However, no significant ($p \leq 0.05$) differences in FRC concerning the fat replacement level were observed. Compared to the control, fat content decreased significantly ($p \leq 0.05$) by 14.01%, 28.68%

and 37.58% in samples with 30%, 40%, and 50% fat replacement using SB. Furthermore, gluten-free cookies with 30% of SB could be considered a high-fibre product [36] (Table 5). Moreover, an average daily portion of gluten-free cookies with 30% of SB (50 g) would meet 11.87% and 18.04% of DRIs for dietary fibres for male and female adults, respectively [37] (Table 5). It is important due to its possible contribution to enhancing the dietary fibre status of celiac patients. As is known, the consumption of an adequate amount of dietary fibres is related to important health benefits such as the prevention of colon cancer, diabetes and cardiovascular disease [38]. Gluten-containing cookies used as representatives of commercially available products had dietary fibre content to meet 12% to 20% of DRIs [33] with a portion of 50 g (data obtained by analyzing their nutrition labels). Therefore, it can be concluded that gluten-free cookies with 30% of SB were comparable with gluten-containing counterparts.

Gluten-free products are often low in micronutrients, contributing to the risk of deficiencies [39]. Increasing substitution levels increased the mineral content of gluten-free cookies. Marked increases were recorded for all observed macro and microelements (K, Ca, Mg, Fe, Zn and Mn) except for sodium and copper, which was less pronounced (Table 4). By substituting fat with SB at 30%, a significant increase in the contribution of minerals intake to the recommended DRIs was achieved (Table 5). FR gluten-free cookies meet 26.50% of DRIs (for adults) for calcium, 35.71% and 46.88% of DRIs (for males and females) for magnesium and 65.43% and 83.61% of DRIs (for males and females) for manganese (Table 5).

Table 4. Proximate composition and mineral contents of the control (full-fat) gluten-free cookies and fat-reduced gluten-free cookies.

Proximate composition	Full-fat dough	30% SB dough	40% SB dough	50% SB dough
Proteins (g/100 g d.m.)	$(2.73 \pm 0.01)^a$	$(3.42 \pm 0.04)^b$	$(3.61 \pm 0.03)^c$	$(4.35 \pm 0.04)^d$
Carbohydrates (g/100 g d.m.)	$(77.6 \pm 0.18)^b$	$(75.1 \pm 0.09)^a$	$(75.4 \pm 0.19)^a$	$(75.4 \pm 0.16)^a$
Fat(g/100 g d.m.)	$(18.4 \pm 0.30)^d$	$(15.8 \pm 0.36)^c$	$(13.1 \pm 0.08)^b$	$(11.5 \pm 0.11)^a$
Dietary fibre(g/100 g d.m.)	$(4.10 \pm 0.21)^a$	$(9.02 \pm 0.34)^b$	$(10.3 \pm 0.20)^c$	$(11.4 \pm 0.18)^d$
Ash (g/100 g d.m.)	$(1.00 \pm 0.01)^a$	$(1.04 \pm 0.01)^b$	$(1.10 \pm 0.02)^c$	$(1.24 \pm 0.01)^d$
		Minerals		
Na (g/100 g d.m.)	$(6.54 \pm 0.01)^b$	$(6.59 \pm 0.01)^c$	$(6.58 \pm 0.01)^{b,c}$	$(6.44 \pm 0.00)^a$
K (g/100 g d.m.)	$(0.72 \pm 0.00)^a$	$(1.62 \pm 0.03)^b$	$(1.93 \pm 0.02)^c$	$(2.55 \pm 0.01)^d$
Ca (g/100 g d.m.)	$(0.17 \pm 0.00)^a$	$(0.53 \pm 0.001)^b$	$(0.64 \pm 0.02)^c$	$(0.81 \pm 0.00)^d$
Mg (g/100 g d.m.)	$(0.17 \pm 0.01)^a$	$(0.30 \pm 0.00)^b$	$(0.34 \pm 0.00)^c$	$(0.37 \pm 0.01)^d$
Fe (mg/100 g d.m.)	$(8.21 \pm 0.07)^a$	$(36.5 \pm 0.46)^b$	$(47.6 \pm 0.47)^c$	$(49.6 \pm 0.76)^d$
Zn (mg/100 g d.m.)	$(3.86 \pm 0.01)^a$	$(14.1 \pm 0.44)^b$	$(14.5 \pm 0.29)^{b,c}$	$(14.9 \pm 0.04)^c$
Cu (mg/100 g d.m.)	$(1.71 \pm 0.28)^a$	$(1.80 \pm 0.15)^a$	$(1.66 \pm 0.24)^a$	$(2.02 \pm 0.09)^a$
Mn (mg/100 g d.m.)	$(1.48 \pm 0.04)^a$	$(3.01 \pm 0.04)^b$	$(3.32 \pm 0.03)^c$	$(3.98 \pm 0.09)^d$

Carbohydrate content represents the sum of starch and total reducing sugars content. Values are means (n = 3) ± standard deviations. Means in the same row with different superscripts are statistically different ($p \leq 0.05$).

Table 5. Contribution of macronutrients and micronutrients intake to the recommended DRIs based on the average portion (50 g) of cookies consumption.

	Gender	DRIs	Contribution to DRIs (%)	
			Full-fat cookies	30% SB cookies
		Macronutrient (g/day)		
Protein (g/day)*	Male	56	2.44	3.05
	Female	46	2.97	3.72
Carbohydrate	Adults	130	29.84	28.87
Fat	Adults	nd	/	/
Dietary fibre	Male	38	5.39	11.87
	Female	25	8.02	18.04
		Micronutrients (mg/day)		
Ca	Adults	1000	8.50	26.50
Mg	Male	420	20.24	35.71
	Female	320	26.56	46.88
Mn	Male	2.3	32.17	65.43
	Female	1.8	41.11	83.61

nd - not determined. DRIs - Dietary Reference Intake set by the Food and Nutrition Board of the National Research Council for male and female adults (30–50 years of age); *Based on g protein per kg of body weight for the reference body weight, e.g., for adults, 0.8 g/kg body weight for the reference body weight [37].

CONCLUSION

FR gluten-free cookies were produced using SB at 30%–50%. FRC was compared with the FFC evaluating their textural dough properties, physical (cookie dimension and weight loss), textural (hardness and fracturability), colour and sensory parameters, and nutritional profile. Based on the investigated characteristics, it was evident that fat substitution at the level of 30% did not distinctly affect the cookie profile. Furthermore, the value-added cookies containing 30% of SB instead of fat were superior in dietary fibre and minerals to the control cookies. So, it is possible to obtain highly acceptable gluten-free cookies with fat content reduced by 30%, whereas fibre content was more than 2 times higher than in the control sample. These cookies represent a novel value-added product for celiac patients as a valuable source of essential nutrients.

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NAUČNI RAD

SOJINE MEKINJE KAO ZAMENJIVAČI MASTI U FORMULACIJI BEZGLUTENSKOG KEKSA: FIZIČKO-HEMIJSKA SVOJSTVA I SENZORSKI PROFIL

Sojine mekinje su korišćene za delimičnu zamenu masti (30%–50%) u formulaciji bezglutenskog keksa. Karakteristike testa, kao i fizička (dimenzija keksa i gubitak težine) i teksturna (tvrdoća i lomljivost) svojstva keksa, te parametri boje i senzorske svojstva, kao i nutritivni profil su određivani u svrhu karakterizacije punomasnog keksa i keksa sa smanjenim sadržajem masti. Na osnovu dobijenih rezultata, zaključeno je da smanjenje masti u formulaciji keksa na nivou od 30% rezultira neznatno promenjenim senzorskim svojstvima punomasnog keksa. Zamena masti korišćenjem sojinih mekinja na nivou od 30% rezultirala je dobijanjem bezglutenskog keksa sa smanjenim sadržajem masti, ali sa dodatom vrednošću u pogledu dijetnih vlakana i minerala. Dnevni unos keksa sa 30% zamene masti zadovoljava 11,87% i 18,04% preporučenog dnevnog unosa u ishrani (DRI) za dijetna vlakna, 26,50% DRI za kalcijum, 35,71% i 46,88% DRI za magnezijum i 65,43% i 83,61% DRI za mangan, za odrasle muškarce i žene, respektivno.

Ključne reči: bezglutenski keks, zamenjivači masti, sojine mekinje, fizičko-hemijska svojstva, senzorska analiza.