EFFECTS OF BARLEY FLOUR ADDITION AND BAKING TEMPERATURE ON B-GLUCANS CONTENT AND BISCUITS PROPERTIES

ORIGINAL SCIENTIFIC PAPER

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ABSTRACT

The aim of this study was to investigate opportunities to improve the nutritional value of biscuits. Therefore, the content of β-glucans, physical, chemical and sensory properties of biscuits were determined in relation to a share of added barley flour and a baking temperature. Five different blends of barley and wheat were used for biscuit production: barley/wheat flours in combinations: 0/100; 25/75; 50/50; 75/25 and 100/0 according to the procedure described in AACC method 10-52. The temperatures used for baking were 150 and 205°C for 15 and 11 min, respectively. The obtained results showed the higher β-glucans content in samples when share of barley flour in biscuit formula was higher. The same trend was found on both baking temperatures. Besides, the share of barley flour in samples significantly influenced physical, chemical and sensory parameters. In addition, different baking temperatures affected significant differences between samples according to all parameters investigated, except N (%) and ash (%). After 6 months, β-glucan content was significantly lower in samples with high share of barley flour (75 and 100%), at both baking temperatures.

Key words: β-glucans, barley biscuits, baking temperature, sensory properties.

INTRODUCTION

Barley (*Hordeum sativum* L.) has a long history in food production. In the ancient world barley was one of the most important food grains, grown mostly to provide food resource for human nutrition. As alternative food grains, especially wheat, became available, consumption of barley decreased[1]. However, interest in barley as a food grain is currently reviving and there is an increase in new food products with barley, including biscuits, mainly due to the content of health promoting components[2,3]. Barley is mostly known for its high amount of dietary fibre, but it also has a high content of phenolic acids and other phenolic compound[2,4]. β-glucans, considered as the major fibre constituents of barley, have been implicated in several health benefits[5,6,7,8].

Mixed linkage (1→3)(1→4)-β-D-glucans, commonly named as β-glucans (BG), are linear homopolysaccharides composed solely of D-glucopyranosyl (Glcp) residues linked mostly via two or three consecutive β-(1→4)- linkages which are separated by a single β-(1→3)-linkage[3,9,10]. These polysaccharides are the major component of endosperm and aleurone layer cell walls of commercially important cereals, such as oat, barley, wheat, rye, sorghum and rice[10,11,12,13]. Barley grain is a rich source of BG[3,14,15], which are more concentrated in the endosperm[12]. The content of BG in barley according to the literature references is shown in Table 1.

Barley BG have a positive impact on human health. Barley contribute to lowering the plasma cholesterol, improving lipid metabolism, reducing the glycemic index and reducing the risk of colon cancer[5,6,7,8].

Currently, barley is increasingly incorporated in already established and new food products either as a whole grain or as a food ingredient[2]. The application of barley in these products contributes to an increased content of total and soluble fibre and improved physiological efficacy of fibres[14]. So far, various forms of barley (β-glucan-rich fractions from barley or purified β-glucans) have been added to food products, such as cereals, pasta, noodles, and various baked products (bread, cookies, muffins)[6,16,17,18,19,20,21,22,23] as well as dairy and meat products[24,25]. The nutritional value of food with added barley depends on the amount and type of barley added (hull-less or hulled)[26].

Table 1. Content of BG in barley according to the literature data

BG content (g/100 g of dry mass)	Reference
2,41–8,25	Holtekjolen et al.[13]
1,86–5,37	Havrlentová and Kraic[36]
3,24–4,62	Zhang et al.[15]
6,0–8,0	Lambo et al.[37]
3,75-7,96	Gajdošová et al.[38]
3,20–4,60	Demirbas[11]

Along with providing physiological benefits, the incorporation of different forms of barley changes processing parameters and handling, as well as food texture and some sensory properties, like a delicate nutty flavour. In addition, the incorporation of cereal BG, such as barley BG, improves the stability during storage[27].

Thus, the barley enriched products have potential to exhibit acceptable sensory properties, especially with incorporation of barley ingredients at low to moderate levels. Berglund et al.[16] reported that sensory scores of various wheat-based products including bread, bars, muffins and cookies prepared with barley added in different share were similar to those for the standard products. Similar results were reported by Newman et al.[22] for baked products, such as bread, biscuits, sugar cookies and muffins enriched with the barley fibre and by Knuckles et al.[21] for bread with 20% β-glucans barley fractions. Sudha et al.[23] found that biscuits containing 20% barley bran were highly acceptable. Gupta et al.[18] showed that barley flour incorporation improved the colour of the cookies, where the level of 30% was the best. The same level of incorporation was reported by Hassan et al.[19] as the best in terms of overall acceptability of biscuits enriched with barley meal, and as the barley meal ratio increased, all sensory attributes scores also increased.

Biscuits are popular baked products popular as food product due to their favourable taste and texture. These products are available in a variety of tastes, good nutritional quality, affordable cost and long shelf life[28]. These products have been suggested as a good way to use composite flours with the aim of improving nutritional value, since they are ready-to-eat, provide a good source of energy, and are consumed widely throughout the world[29].

This study was undertaken to investigate the opportunities to improve the nutritional value of biscuits by preparing biscuits with different combinations of wheat and barley flour. In addition, the study aimed to evaluate the effects of barley flour and baking temperature primarily on BG content and physico-chemical and sensory characteristics of biscuits.

MATERIALS AND METHODS

Materials

Barley and wheat flour samples of milling extraction rate of 87%, provided by local farmers from Breza and Nišići, Bosnia and Herzegovina, were used in this study. Blends of wheat and barley flour were obtained by replacing wheat flour with barley flour at 0%, 25%, 50%, 75% and 100%.

Blends were analyzed for water (WAC) and oil absorption capacity (OAC) as described by Sosulski et al.[30]; bulk density (BD) and swelling capacity (SC) according to Okaka et al.[31].

Biscuit-making procedure

Biscuits were prepared according to the procedure described in AACC method 10-52[32] with some modifications. Sucrose level was reduced from 60% for the standard recipe to 40%, and 5 cm diameter circular mould was using for cutting, instead the 6 cm one, required by method. The amount of used flour was calculated based on 14% moisture content. The dough was sheeted to a thickness of 8 mm, cut using a circular mould and baked at different temperatures (150 and 205°C) for different times (15 and 11 min). After baking, biscuits were cooled for 30 min. A part of produced biscuit samples was packed in sealed bags, stored for 6 months (20°C±2, 40±5% humidity) and used for BG determination. Total of 10 biscuit samples were prepared in two replicates.

Physical analysis of biscuit samples

Diameter and thickness before and after baking were measured with an electronic digital vernier caliper (MIB Messzeuge GmbH, Spangenberg, Germany) with a sensitivity of 0,01 mm. Diameter of biscuits was determined by taking an average value of diameter of five biscuits from each replication; simultaneously, thickness was determined by taking an average of thickness of five biscuits from each replication. Consequently, the average of ten biscuits was recorded for each sample. Diameter (DI) and thickness increase (TI) were calculated as the ratio of biscuits diameter and thickness before and after baking, and expressed in %. Spread ratio (SR) was calculated by dividing the average values of diameter by thickness for 10 biscuits at a time. Specific volume (SV) was calculated as volume (seed replacement) divided by biscuits weight.

Chemical analysis

The BG content in flour blends, biscuit samples and samples after 6 months was determined according to the enzymatic-gravimetric method (AOAC method 995.16)[33] using the Mixed-linkage beta-glucan assay kit (Megazyme, Bray, Ireland). Total nitrogen (Kjeldahl) and ash contents were determined using the standard methods of analysis[33].

Sensory evaluation

The sensory evaluation was carried out by a panel of 10 trained members at the Faculty of Agriculture and Food Sciences, University of Sarajevo, B&H. The panelists were selected and trained according to recommendations in ISO 8586[34]. They participated in five 1h trainings and three 30 min evaluation sessions on different days over 4 weeks. Prior to the assessment, the panel members were trained on various samples of biscuits, made in different combinations of barley and wheat flours. The biscuits were evaluated by Quantitative Descriptive Analysis (QDA) using a scale of 1-5 scores on 4 properties: taste, aroma, melting and overall acceptability. The obtained sensory data were counted from 10 replicates (panelists were considered as replicate).

Statistical analysis

All results are expressed as mean ± standard deviation (SD). One-way analysis of variance was applied on flour blends properties; and differences between BG content in samples immediately after baking and 6 months of storage. Two-way analysis of variance with interactions (ANOVA) was used to evaluate whether significant differences existed between the biscuit samples depending on barley flour addition and the baking temperature. Determined differences were tested by the Tukey test for $p < 0,05$. Multivariate analysis of data by Principal Component Analysis (PCA) using the statistical computer package StatBox 6.7 (Grimmer Soft, France) was performed to obtain comprehensive visualization of the samples relationships.

RESULTS AND DISCUSSION

Flour blends characteristics

The results of blends characteristics (Table 2) showed an increase of WAC from 1,35 to 2,10 fold ($p < 0,05$) and SC from 20,25 to 22,25 mL while the BF share in blend was higher. Significant differences between flour blends in terms of OAC and BD were found, also.

Table 2. Effects of barley flour addition on physical blends characteristics

Barley flour (%)	**WAC (%)**	**OAC (%)**	**BD (g/mL)**	**SC (mL)**
0	1,35 ± 0,21c	1,50 ± 0,00c	0,72 ± 0,01b	20,25 ± 0,35a
25	1,40 ± 0,14c	1,90 ± 0,00ab	0,74 ± 0,01a	21,00 ± 0,71a
50	1,50 ± 0,00bc	1,85 ± 0,07b	0,72 ± 0,00ab	21,50 ± 0,71a
75	1,95 ± 0,07ab	1,80 ± 0,00b	0,71 ± 0,00b	22,00 ± 0,00a
100	2,10 ± 0,00a	2,05 ± 0,07a	0,63 ± 0,00c	22,25 ± 0,35a

All data are the mean value ± DS of three replicates. Different letters in columns from a to c for each parameter indicate significantly different values among flour blends at $P < 0,05$.
Abbreviations: WAC, water absorption capacity; OAC, oil absorption capacity; BD, bulk density; SC, swelling capacity.

Physical and chemical characteristics of biscuits

The results of physical and chemical characteristics of biscuit samples are presented in Table 3. The physical characteristics of biscuit samples were affected significantly with addition of BF and with the baking temperature. DI and TI ranged from 38,26 to 67,38%, and -13,28 to 39,33%, respectively. The sample B0T205 had the highest, while the sample B100T205 had the lowest DI and was significantly different from other samples baked at 205°C. TI of some samples was decreased during baking at both baking temperatures (B100T150 and B0T205) which indicated a negative value of TI. As the level of added BF samples baked at 205°C was increased, TI was significantly increased, while DI was significantly decreased. The changes in DI and TI were consequently reflected in SR values. SR values were decreased while BF addition in blends was higher, but this trend was found only when the baking temperature was 205°C. The similar decreasing trend of SR values were reported by Gupta et al.[18]. SV ranged from 1,52 to 2,39 cm3/g. The sample with no BF added (B0T205) had the highest SV as similar to the results reported by Osella et al.[35].

Table 3. Physical and chemical characteristics of biscuit samples in relation to BF addition and baking temperature

T	150°C						205°C								
M	**B0**	**B25**	**B50**	**B75**	**B100**	***T***	**B0**	**B25**	**B50**	**B75**	**B100**	***T***	***T***	**M**	***T*xM**
DI (%)	64,12 ± 8,20a	61,42 ± 3,80a	47,03 ± 5,36b	49,55 ± 6,52b	58,98 ± 15,17a	x	67,38 ± 6,04a	63,84 ± 4,98ab	58,63 ± 6,81bc	51,98 ± 3,83c	38,26 ± 4,08d	y	***	***	***
TI (%)	3,64 ± 4,91c	5,94 ± 8,08b	7,43 ± 6,12b	15,79 ± 11,93a	−13,28 ± 7,21d	x	−4,41 ± 5,82c	0,06 ± 4,20c	1,04 ± 5,32c	17,59 ± 8,90b	39,33 ± 7,94a	y	***	***	***
SR	9,93 ± 0,82b	9,58 ± 0,91b	8,59 ± 0,68c	8,14 ± 0,81c	11,52 ± 1,36a	x	10,99 ± 0,89a	10,26 ± 0,69ab	9,85 ± 0,83b	0,77 ± 8,13c	6,21 ± 0,25d	y	***	***	***
SV (cm^3/g)	1,58 ± 0,11a	1,54 ± 0,20a	1,61 ± 0,35 a	1,71 ± 0,17a	1,79 ± 0,26a	x	2,39 ± 0,60a	1,89 ± 0,10bc	1,98 ± 0,17ab	2,11 ± 0,26ab	1,52 ± 0,16c	y	***	***	***
Ash (%)	1,49 ± 0,01b	1,59 ± 0,04ab	1,54 ± 0,02ab	1,82 ± 0,05ab	1,89 ± 0,08a	x	1,58 ± 0,12b	1,56 ± 0,01 b	1,64 ± 0,03b	1,83 ± 0,04ab	2,03 ± 0,03a	x	ns	**	ns
Total N (%)	0,94 ± 0,01a	0,97 ± 0,04a	1,01 ± 0,05a	1,06 ± 0,00a	1,00 ± 0,26a	x	0,88 ± 0,02a	0,90 ± 0,17 a	0,89 ± 0,09a	1,06 ± 0,04a	1,06 ± 0,02a	x	ns	ns	ns

Different letters in rows from a to d for each parameter indicate significantly different values among mixture at $P < 0,05$. Different letters in rows from x to y for each parameter indicate significantly different values among temperatures at $P < 0,05$.

Abbreviations: B0, B25, B50, B75, B100 – samples with 0, 25, 50, 75 and 100% barley flour added. *T* – temperature; M – mixture; TxM – interaction between temperature and mixture. DI – diameter increase; TI – thickness increase; SR – spread ratio; SV – specific volume. ns – not significant; * – significant differences at *P*-value below 0,05; ** – significant differences at *P*-value below 0,01; *** – significant differences at *P*-value below 0,001.

Ash content and N (%) were not affected significantly with the baking temperature, while WF addition affected only the ash content. The results of the ash content in samples with 25% of BF were in accordance with the results reported by Hassan et al.[19] but lower than those reported by Gupta et al.[18].

BG content in flour blends (Fig. 1A) significantly increased with the BF level added, as expected. The rising trend of the BG content in the blends is obviously related to the BG content in the biscuit after baking at both baking temperatures (Fig. 1B, C). BF content at all levels as well as all chosen baking temperatures resulted in significant influence on the BG content. Higher values of BG were found in the biscuits baked at 205°C. BG values in biscuit samples with 25% BF were similar as reported by Hassan et al.[19], but lower than those reported by Gupta et al.[18].

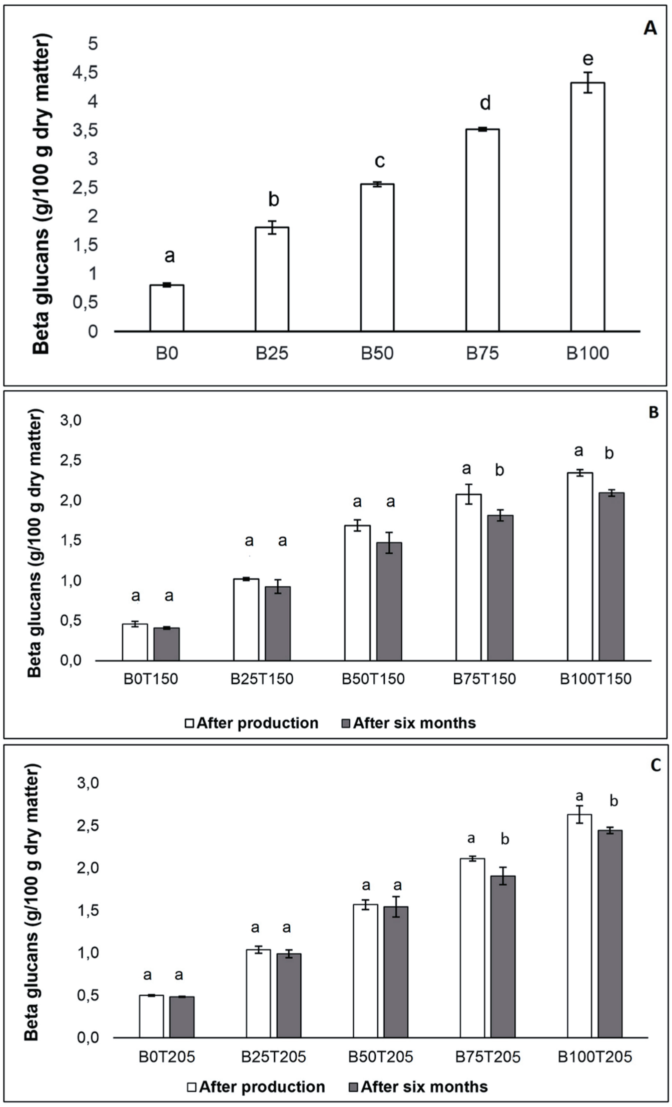

Figure 1. BG content in flour blends (A), BG content in biscuits baked on 150°C after baking and 6 months of storage (B), BG content in biscuits baked on 205°C after baking and 6 months of storage (C). Samples codes reflect share of barley in the dough B0; B25; B50, B75; B100 and used temperature of baking T 150°C and T 205°C. Different letters above the columns from a to e in each graph indicate significantly different values among flour blends (A) and the same biscuit samples (B, C) at P < 0,05.

After 6 months of storage, the BG content in all samples decreased, while the differences between samples containing high share of BF (75 and 100%) at both temperatures were significant.

Sensory evaluation of biscuits

According to the two-way ANOVA all sensory properties were significantly influenced by the addition of BF at all levels and the baking temperature. The samples baked at 205°C were characterized by significantly higher scores for taste, melting and overall acceptability, than the samples baked at 150°C.

Table 4. Sensory evaluation of biscuit samples in relation to BF addition and baking temperature

T	150°C						205°C								
M	B0	B25	B50	B75	B100	*T*	B0	B25	B50	B75	B100	*T*	*T*	M	*T*xM
Taste	3,70 ± 0,95ab	3,65 ± 0,47a	3,75 ± 0,54a	3,85 ± 0,67a	3,35 ± 0,67a	x	3,90 ± 0,57a	3,75 ± 0,63a	3,85 ± 0,47a	4,35 ± 0,67a	3,75 ± 0,54a	y	***	***	***
Aroma	3,55 ± 1,07ab	3,80 ± 0,42ab	3,45 ± 0,69ab	4,05 ± 0,6a	3,25 ± 0,63b	x	3,70 ± 0,48ab	3,25 ± 0,42b	3,80 ± 0,42ab	4,00 ± 0,47a	3,90 ± 0,32a	y	***	***	***
Melting	3,15 ± 1,00b	3,70 ± 0,48ab	3,90 ± 0,57a	3,60 ± 0,70ab	3,85 ± 0,67a	x	3,50 ± 0,71b	3,90 ± 0,32ab	4,05 ± 0,50ab	4,50 ± 0,58a	4,15 ± 0,34ab	y	***	***	***
General acceptability	3,70 ± 0,95ab	3,80 ± 0,42ab	3,95 ± 0,60ab	4,00 ± 0,47a	3,30 ± 0,86b	x	3,70 ± 0,48b	3,80 ± 0,42ab	3,85 ± 0,47ab	4,35 ± 0,47a	4,10 ± 0,52ab	y	***	***	***

Different letters in rows from a to b for each parameter indicate significantly different values among mixture at $P < 0,05$.
Different letters in rows from x to y for each parameter indicate significantly different values among temperatures at $P < 0,05$.
Abbreviations: B0, B25, B50, B75, B100 – samples with 0, 25, 50, 75 and 100% barley flour added; *T* – temperature; M – mixture; TxM – interaction between temperature and mixture. ns – not significant; * – significant differences at P-value below 0,05; ** – significant differences at P-value below 0,01; *** – significant differences at P-value below 0,001.

In general the best sensory profile was observed in the sample with 75% BF contained, baked at 205°C, as it won the highest score for taste, melting and overall acceptability. On the other hand, the sample containing only BF, baked at 150°C had the weakest sensory properties.

Sensory evaluation (taste, aroma, melting, overall acceptability) of biscuit samples revealed that in a 5-scores scale, all sensory results were in the range of 3,15-4,5 indicating that these biscuits were moderately acceptable. A kind of nutty flavour was noticed in samples with 75 and 100% BF share at the baking temperature of 205°C.

Principal Component Analysis (PCA)

The results of physical, chemical and sensory characteristics were subjected to the multivariate analysis by Principal Component Analysis (PCA) with the aim of interpreting relationships between samples concerning the BF content and the baking temperature (Fig. 2). In this analysis, those parameters which did not allow to discriminate the samples were excluded. The following variables: SR, SV, BG, ash, total N, taste, aroma, melting and overall acceptability were considered. For the here performed PCA, the two major principal components explained 79% of the data variability (Fig. 2). PC1 (56% of the total statistical significance) was correlated to the content of ash, BG and N, then SV and finally to all sensory attributes. PC2 (22% of the total statistical significance) was related to the SV and taste.

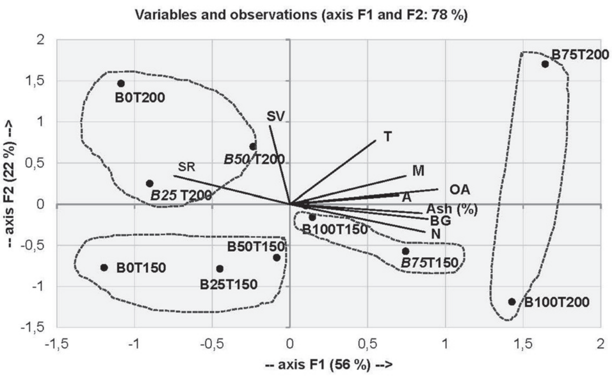

Figure 2. PCA biplot of the measured physicochemical and sensory data and overall positioning of 10 biscuit samples. Samples codes reflect share of barley in the dough B0; B25; B50, B75; B100 and used temperature of baking T 150°C and T 205°C. Physicochemical data are: SR, spread ratio; SV, specific volume; BG, β-glucans content; Ash; N. Sensory data are: T, taste; M, melting; A, aroma; OI, overall acceptability.

All samples distributed were spread on both sides of the PCA plot (related to PC1). The position of the samples was obviously dependent on the BF amount in the biscuits. The samples with a high BF content (75 and 100%) were positioned on the positive side of the plot (PC1). This side of the plot was mainly influenced by N, ash and BG. It is obvious that samples with high BF content were described by desirable sensory properties. On the other hand, the samples with no BF added and low BF content (25 and 50%) were found on the negative side of PC1. This side was mainly influenced by SR (PC1) and SV (PC2). In addition, sample clustering related to the baking temperature was observed. So, the samples with high BF amount baked at 205°C were more favourable than similar samples baked at 150°C with respect to sensory properties. Thus, higher contribution of BF means the higher content of ash, N and BG, specifically found at baking temperatures at 205°C.

On the opposite side (positive section of PC1), the samples with low BF content were located. They were mainly dependent on the baking temperature. The samples with low BF content (high WF content and baked at 205°C) were mainly described by SV and SR. Unlike this, samples baked at 150°C and containing the low level of BF were not described by any of examined parameters.

CONCLUSIONS

The here presented results confirm that barley flour is suitable addition for the biscuit formula and improves the nutrition value of the final product due to the increased BG content. In addition, barley provides acceptable sensory quality. Better physical properties and sensory quality was achieved when the baking temperature was chosen at 205°C over 150°C.

Barley flour is, thus, a good choice for improving the final baked products quality by increasing the BG content of usually used wheat flour only. However, more in-depth follow-up information of consumers is required for arguing to select these products and allow reasonable food quality assessment, especially with respect to confectionery products.

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