PAPER

IMPACT OF BUCKWHEAT FLOUR GRANULATION AND SUPPLEMENTATION LEVEL ON THE QUALITY OF COMPOSITE WHEAT/BUCKWHEAT GINGER-NUT-TYPE BISCUITS

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ABSTRACT

Effects of gradual wheat flour substitution with buckwheat flour in ginger-nut biscuit formulation were investigated regarding dough characteristics, physical and textural characteristics of final product assessed after baking and 30 days of storage. Buckwheat flour was added at 30, 40, 50% levels and two granulations (fine and coarse). Addition of buckwheat flour significantly increased dough hardness and decreased adhesiveness. Spread significantly increased in biscuits with 40% and 50% of coarse buckwheat flour. Biscuits containing coarse flour were harder and more fracturable than the control, whereas those with fine flour tended to be softer and less fracturable. Textural properties were significantly correlated to protein stability to heat and retrogradation tendency of starch in biscuit dough as well as moisture content.

- Keywords: buckwheat; biscuit; dough; storage; texture -

INTRODUCTION

Ginger-nut biscuit (GNB) is a sweet biscuit containing honey and aromatic spices (cinnamon, ginger, cloves), which is very popular globally. By this term, variety of sweet biscuit types are described. They may range from thin (less than 3 mm thick), crisp varieties with smooth surfaces to thicker (over 3 mm thick), smaller in diameter and softer varieties with prominent cracks on top surface. The large variation in ingredients and their proportions contributed to a wide range of biscuit types. For example, the finest quality Nürnberg *Lebkuchen* does not even contain flour but nuts and candid fruits deposited on thin wafer base whereas the Polish *Pierniki Toruńskie* is made from the highest quality flour. The similar feature in all of them is that they all contain honey and spices. In Serbia, ginger-nut biscuits are traditionally produced by artisans, although their production has been industrialized (GAVRILOVIĆ, 2003). In appearance, they mostly resemble the gingersnaps from the United States: usually circularly shaped, over 6 mm thick with cracks on the top surface and soft crumb.

Formulations of GNB typically include 35-50% honey, 28-32% sugar, 0-5% fat on a flour weight basis (GAVRILOVIĆ, 2003), whereas the levels of major ingredients in common sweet biscuits are 30-75% sugar, 15-50% fat and 7-20% water (MANLEY, 2000). According to PYLER (1998), basic ratios of flour, fat and sugar in cookies vary from 100:30:30; 100:50:50 to 100:50:variable depending on processing type but may considerably deviate. GNB flour can be specified as a wheat flour with good bread-making performance (quality group B, peak amylogram value 300 B.U.), preferably of higher extractions (ash contents 0.8-1.15% d.b.) due to higher protein, hydrocolloid and enzyme content as opposed to the quality requirements in common biscuit production. The flour in common biscuits is usually soft wheat flour with lower protein content and moisture absorption and ash contents 0.34-0.38% d.b. (PYLER, 1998) and weak gluten (PAREYT and DELCOUR, 2008). In contrast to common biscuits whose final moisture content is low and ranges between 1-5% (CHEVALLIER *et al.*, 2000, 2002), the lowest recommended moisture content in GNB is 7% (GAVRILOVIĆ, 2003). Below this value, the quality deteriorates due to increased hardness, fracturability and crumbling. The crumb of GNB is porous with denser or looser pore structure, soft and elastic. Its upper surface is cracked which is a common pattern with formulations high in sugar and low in fat and is attributed to sugar recrystallization on the surface area (PAREYT *et al.*, 2009).

GNB is traditionally perceived as healthier in relation to other types of sweet biscuits probably because they contain honey and low amount of fat. As such, they can be seen as a convenient medium for providing further improvement in nutritional value and functionality by replacing a part of wheat flour with other nutritionally more valuable cereal or non-cereal flour. One such ingredient having an excellent reputation for its nutritious quality and abundance in bioactive compounds is common buckwheat. Buckwheat is most commonly used for producing flour and groats. While groats are mainly used for porridge and in various ethnic dishes, buckwheat flour is used as an ingredient in a variety of baked, cooked and extruded products: breads made from wheat-buckwheat flour blends at different ingredient proportions, flat bread, pasta (pizzoccheri in Italy), noodles (soba in Japan, extruded noodles in China and Korea), pancakes, breakfast cereals (based on extrudates made from buckwheat, rice, and/or corn blends), and biscuits (buckwheat added at 20-30% wheat flour basis).

Results from previous studies (FILIPČEV *et al.*, 2012) revealed that buckwheat flour has a potential as an ingredient in GNB formulation but a main disadvantage was related to the coarse granulation of commercially available buckwheat flour which reflected gritty texture of the final product. Therefore, this study was conducted to investigate the effect of substitution level and granulation of wholegrain buckwheat flour on dough characteristics and GNB physical and textural characteristics. The effects of three substitution levels (30%, 40%, 50%) and two flour granulation sizes (fine (FBF) and coarse (CBF)) were studied.

MATERIALS AND METHODS

Materials

Commercially available wheat flour (WF) type 850 (ash content 0.81% dry basis, moisture content 12.53%), and wholegrain buckwheat flour (ash 2.20% d. b., moisture content 12.31%) were used in the experiment. Other ingredients honey, vegetable fat (from sunflower), sugar, $NaHCO_3$, lecithin and spice (cinnamon) were obtained from a local food store (Novi Sad, Serbia). The purchased buckwheat flour was coarsely granulated. To obtain finer granulation, it was remilled on a Falling Number 3100 mill (Perten Instruments). The granulation of used flours is given in Table 1.

Water absorption capacity of flours

Flour sample (5 g) was mixed with an excess of distilled water (25 ml), kept at ambient temperature for 30 min and then centrifuged at

2000 x g for 15 min. Water absorption capacity was expressed as g of water bound by 100 g of dry matter.

Syneresis degree of wheat and buckwheat flours

The method described by SINGH *et al.* (2003) was used. Flour suspensions (6 % w/v) were heated in a water bath to 90°C and held 20 min at this temperature. Cooled flour paste (30 mg) was poured into a centrifuge tube. The tubes were stored for 1 and 10 days at 4°C. Syneresis was measured as % of water expelled after centrifugation of sample.

Biscuit making

GNB was prepared by substituting wheat flour with buckwheat (0, 30, 40, 50 %). Formulae are found in Table 2. Firstly, a basic dough was formed by warming a mixture of honey, sugar and water to 80°C and adding part of the flour (75% of total) to a hot mixture. The mixture was mixed to obtain a thick, homogenous mass. After cooling to 40°C, basic dough was sprinkled over with flour, covered with a plastic foil, and left to rest at ambient temperature for two days. Other ingredients (remaining flour amount, spices, raising agents dissolved in water, fat and lecithin) were added and mixed using a kitchen mixer with a spiral hook for 10 min. The amount of added water was adjusted to obtain a maximally soft dough with acceptable handling characteristics. The consistency of dough was evaluated subjectively by an experienced baker. Dough moisture content ranged between 17.8-21.7%. After mixing, the dough was sheeted on a pastry break to 10-mm thickness (Sfogliatrice Mignon, Maestrino, Pd, Italy). The dough was cut to a diameter of 60 mm and baked for 15 min in a deck oven at 170°C. After 1 hour of cooling at room temperature, the biscuits were packed in polyethylene bags and stored at room temperature.

Texture profile analysis of biscuit dough

Dough characteristics were evaluated using a texture analyzer (TA.XTPlus Stable Micro Systems Ltd., Surrey, UK) equipped with a 30-kg load cell. Texture Profile Analysis (TPA) was employed to measure dough properties as described by (GALLAGHER *et al.*, 2005). Doughs were prepared as for the baking test and cut into round pieces (60 mm). A 36-mm cylindrical aluminium probe was used in two compression cycles at test speed 1.0 mm/s. Pre and post-test speeds were 2.0 mm/s. The force was measured at 45% compression. The recovery period between the strokes was 5 s. The following 4 parameters were recorded: hardness, adhesiveness, cohesiveness and springiness. Seven measurements per each biscuit type were made. Measurements were performed on dough after the resting period.

Table 1 - Particle size distribution of used flours.

Particle size (weight %)	Wheat flour (WF)	Coarse buckwheat flour (CBF)	Fine buckwheat flour (FBF)
>350 mm	0.00	55.30	5.74
>250 mm	0.02	9.40	11.32
>180 mm	0.40	4.76	11.11
>150 mm	1.32	3.80	8.90
>105 mm	22.54	10.14	18.86
>85 mm	26.85	9.80	30.76
bottom	48.87	6.80	13.31

Table 2 - Ginger nut biscuits formulations.

Ingredients, g	Control	Biscuit supplemented with CBF[a]			Biscuit supplemented with FBF[a]		
Wheat flour	100	70	60	50	70	60	50
Buckwheat flour	0	30	40	50	30	40	50
Honey	50		50			50	
Sugar	10		10			10	
Vegetable fat	5		5			5	
$NaHCO_3$	2.1		2.1			2.1	
Spice blend	2		2			2	
Lecithin	1		1			1	
Water	20	18	17	16	20	21	22

[a] CBF-coarse buckwheat flour; FBF-fine buckwheat flour

Analysis of thermo-mechanical properties of biscuit dough by Mixolab

Mixing and pasting properties of the ginger nut biscuit doughs were studied on Mixolab (Chopin, Tripette and Renaud, Paris, France). This device measures in real time the torque produced by dough during mixing at conditions of controlled temperature regime which include dough heating to 90°C, maintenance at constant temperature and dough cooling to 50°C. In this way, the behaviour of both proteins and starch under dual mechanical shear stress and temperature constraint can be measured (ROSELL *et al.*, 2006). Usually, individual flours or flour blend slurries are analysed in this way. In our study, previously prepared GNB dough was subjected to analysis using a modified Mixolab protocol. For the assays, 80 g of dough was inserted to Mixolab bowl, followed by the next regime: mixing speed 80 rpm, tank temperature: 30°C, 1st plateau temperature 30°C, duration of first plateau 5 min, heating rate 4.0°C/min, 2nd plateau temperature 90°C, duration of 2nd plateau 7 min, cooling rate 4.0°C/min, 3 rd plateau temperature 50 °C, duration of 3rd plateau 5 min.

Main derived parameters from the Mixolab curves are: development (C1) or maximum torque reached during mixing at 30°C, protein weakening (C2) or the minimum torque produced as a consequence of heating and mechanical stress, maximal torque (C3) produced during the heating stage as a consequence of starch gelatinization, minimal torque at the stage of cooling (C4) and the torque after cooling at 50°C (C5).

Measurements were replicated twice for each biscuit dough type after the resting period.

Textural analysis of ginger nut biscuits

Hardness and fracture of GNB were measured 24 h post-bake by penetration test on TA.XTPlus Texture Analyzer (Stable Micro Systems, England, UK). The test mode was force in compression. A 5 kg load cell was used. The sample was placed on the platform with a holed plate and centrally punctured with a 2 mm cylinder probe through the sample at test-speed 0.5 mm/s. Hardness of the sample was calculated from the area under the curve whereas fracturability was calculated from the linear distance. Four biscuits from each treatment were punctured five times in an 'X' pattern avoiding the outer 1 cm to prevent from edge effects.

Biscuit dimensions and density

Diameter (width) and height (thickness) of biscuits were measured using a vernier calliper. Diameter was calculated as an average of long and short diameter. Spread was calculated from the ratio of width and height. For the measurements, twelve randomly chosen biscuits were taken. Density was calculated as a ratio of biscuit mass and volume. Since biscuits had a regular shape, their volume was approximated to the volume of cylinder according to formula $V=\pi*(R/2)^2*h$ where h is biscuit height and R is average biscuit diameter.

Moisture content

Moisture was calculated according to AOAC Method 926.5 (2000). Two composite samples of each biscuit type were analyzed in duplicates. The composite samples were prepared by homogenization of six individual biscuit samples.

Statistical analysis

An analysis of variance (ANOVA) of data was performed by using a Statistica 7.1 statistical software package (StatSoft Inc., Tulsa, Oklahoma). Tukey's post-hoc test was used to compare the means at 95% confidence interval. Correlation analysis was conducted using Spearman's rank correlation coefficient applied to mean values for each biscuit.

RESULTS AND DISCUSSION

Water absorption capacity (WAC) and syneresis degree of used flours

Buckwheat flour showed higher WAC in comparison to WF (Table 3). This might be due to various reasons: higher hydration capacity of buckwheat starch in comparison to wheat starch (QIAN *et al.*, 1998); presence of other hydrophilic constituents in the wholegrain buckwheat flour (fibers). In contrast, BALJEET *et al.* (2010) reported that buckwheat flour had lower WAC, higher oil absorption capacity, higher foaming capacity and higher least gelation concentration than wheat. WAC of FBF increased but not significantly in comparison to CBF which might be explained by the fact that milling does not tend to increase the amount of damaged starch in buckwheat. It has been shown by QIAN and co-workers (1998) that

Table 3 - Water absorption capacity (WAC) and syneresis (%) of wheat and buckwheat flour.

Flour	WAC (g/100 g dry matter)	Syneresis (%)	
		1 day	10 days
Wheat flour	63.96[a]	9.27[a]	14.57[a]
Buckwheat flour, coarse	101.10[b]	39.27[b]	46.86[c]
Buckwheat flour, fine	104.14[b]	40.20[b]	42.67[b]

[a,b,c] Figures followed by the same letters in a column are not significantly different (p>0.05).

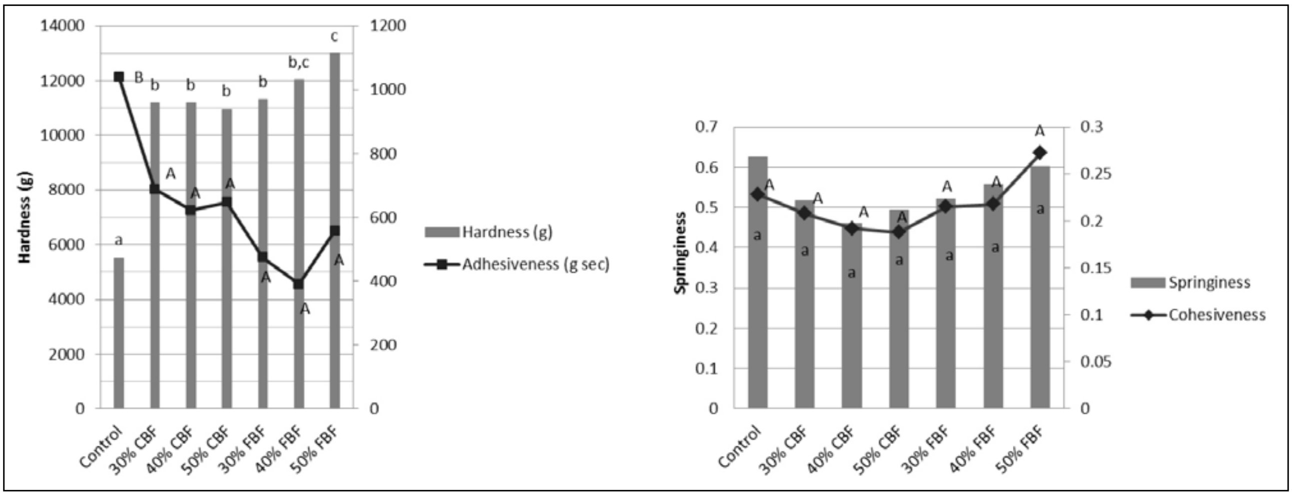

Fig. 1 - Dough hardness, adhesiveness, cohesiveness and springiness for different formulations of GNB.
[a,b,c ,... A, B,...] Values followed by same letters of the same case are not significantly different (p>0.05).

buckwheat flour has lower amounts of damaged starch than wheat.

The syneresis value (%) of cooked pastes from wheat and buckwheat flour significantly differed. WF showed much less syneresis than buckwheat. During storage, syneresis of the pastes increased. The highest syneresis was observed in the paste made from CBF (46.9%), followed by FBF (42.7%). The retrogradation properties of the flours are generally attributed to composition, ratio and interactions of flour constituents: proteins, starch, lipids, fibers.

GNB dough characteristics

The addition of buckwheat significantly increased dough hardness in comparison to the control (p<0.05) (Fig.1). The dough hardness increased remarkably in the case of finely ground buckwheat flour. TPA adhesiveness showed a declining trend which was significant in comparison to the control. Dough springiness and cohesiveness also tended to decline with increased proportion of buckwheat, but there were no significant differences between the samples. FBF increased dough cohesiveness in comparison to CBF.

These effects can be related to the particularities of buckwheat flour and flour particle size. Buckwheat is characterized by resistant starch, which may contribute to low viscoelastic properties of dough and increased hardening (QIAN *et al*., 1998; DE FRANCISCHI *et al*., 1994; LI *et al*., 1997; QIAN and KUHN, 1999; YOSHIMOTO *et al*., 2004; HATCHER *et al*., 2008). The observed variations in dough hardness and adhesiveness were mainly due to the effect of buckwheat flour granularity. Even though WAC between FBF and CBF did not significantly differ, it seems that finer flour particles were able to absorb more water during mixing, thereby forming more cohesive and harder dough. Lowering of dough adhesiveness and cohesiveness as a consequence of increasing amounts of coarse wheat flour was reported earlier (SINGH GURJAL *et al*. 2003). This coincides with our findings. Furthermore, dough made with wholegrain buckwheat flour was reported to have lower adhesiveness in comparison to the majority of other buckwheat flour fractions (IKEDA and KISHIDA, 1992).

Parameters related to thermo-mechanical behaviour of GNB dough made with coarse and fine buckwheat flour is given in Table 4. Buck-

Table 4 - Dough mixolab parameters for different formulations of gnb (CBF-coarse buckwheat flour; FBF-fine buckwheat flour).

Sample	C1 (Nm)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	C1-C2 (Nm)	C5-C4 (Nm)
Control	3.45[a]	2.73[e]	3.04[f]	1.65[e]	1.66[b]	0.72[a]	0.005[a]
CBF							
30%	3.99[b,c]	1.20[d]	1.40[c]	1.39[c]	2.71[e]	2.79[c]	1.32[d]
40%	4.31[c]	0.86[c]	1.53[c]	1.54[d]	2.24[d]	3.45[e]	0.70[b]
50%	3.68[a,b]	0.68[a]	1.81[d]	1.62[e]	2.69[e]	3.00[d]	1.06[c]
FBF							
30%	4.22[c]	1.30[d]	1.30[b]	0.97[b]	1.85[c]	2.92[d]	0.88[c]
40%	4.19[c]	0.75[b]	2.00[e]	0.91[b]	1.52[b]	3.44[e]	0.61[b]
50%	5.32[d]	0.85[c]	1.10[a]	0.63[a]	0.95[a]	4.47[e]	0.32[b]

[a,b,c ,...] Figures followed by the same letters in a column are not significantly different (p>0.05).

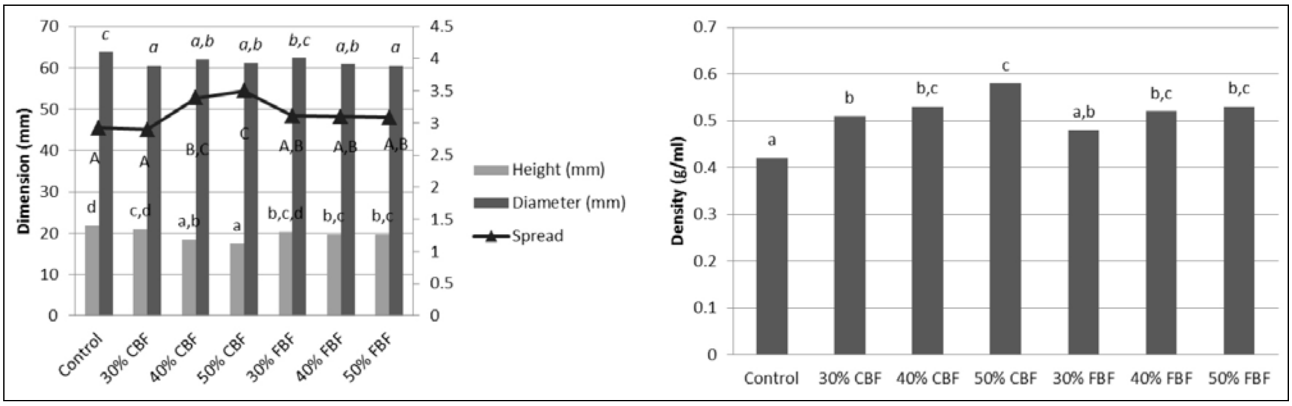

Fig. 2 - Effect of GNB formulation on biscuit dimensions (height, diameter, spread) and density.
[a,b,c ...., A, B,...] Values followed by same letters of the same case are not significantly different (p>0.05).

wheat supplemented dough was characterized with higher maximal torque during mixing (C1) and lower resistance to thermal and mechanical stresses (low C2 and high C1-C2) than the control dough. These effects seem to be more pronounced in the case of dough supplemented with coarse buckwheat flour. Both buckwheat flours affected these parameters in a similar way. This behaviour is probably due to dilution of gluten by addition of non-glutenous buckwheat flour which contributed to the formation of weaker protein network. The control dough showed higher maximal peak during heating (C3) than the buckwheat supplemented doughs. The decrease in peak viscosity of the buckwheat supplemented doughs may be attributed to lower swelling of starch granules and poorer gelatinization which is probably due to native characteristics of buckwheat starch and limited water amount in GNB doughs. Similar results were reported by HADNAĐEV and co-workers (2008), even in systems with higher moisture content, resembling bread dough. The buckwheat doughs exhibited lower breakdown torque (C4) which indicates lower stability of warm gel. Final torque (C5) and total setback values (C5-C4) are parameters used to characterize starch retrogradation that occurs during cooling to 50°C. Final torque (C5) was lower in the control dough and dough made with fine buckwheat flour. The total setback was the lowest in the control dough followed by FBF dough. Hence, regarding the ability to resist retrogradation, the tested GNB doughs follow the order: wheat dough > fine buckwheat flour dough > coarse buckwheat flour dough.

Biscuit dimension, density and spread

Data related to the biscuit dimension and density is displayed in Fig. 2. Majority of the variables showed significant differences as compared to the control especially at higher replacement levels (40% and 50%). The height and diameter decreased with increasing levels of both FBF and CBF. Despite general shrinkage, the interrelation between both dimensions was such that spread increased significantly at 40% and 50% of CBF addition whereas in other cases, spread did not significantly vary from the control. There was a strong inverse correlation between spread and height ($r=-0.84$, $p<0.01$) showing that reduction in height dominantly affected spread whereas spread and diameter were not significantly correlated ($r=-0.17$, $p>0.01$). The spread of the biscuit during baking is caused by expansion of dough by leavening and gravitational flow (HOSENEY and ROGERS, 1994). It depends on factors that control dough viscosity: the amount of water free to act as solvent and the strength of dough (RAM and SINGH, 2004). It also depends on partitioning of available water between the ingredients. The lesser the amount of water held by ingredients, the more the amount of water is available to dissolve sugar, decrease dough viscosity and increase spread (PAREYT and DELCOUR, 2008). Coarse flour has been reported to contribute to greater spread (SINGH GURJAL *et al*., 2003; MANLEY, 1991). Substitution of wheat flour with a finely ground light and dark buckwheat flour (granulation size 100-150 μm) in sugar-snap cookie formulations lowered the cookie spread (MAEDA *et al*., 2004). It was also found that buckwheat flour of similar granulation dosed at 10-40% level (flour basis) decreased the spread in sugar snap cookies (BALJEET *et al*., 2010). Results obtained in this study confirmed the relation between spread and flour granularity: in relation to the control, the addition of CBF increased the spread. Higher biscuit spread is considered advantageous in biscuit making (PAREYT and DELCOUR, 2008). But, in contrast to majority of biscuits, the main quality requirement for GNB is well developed and soft crumb (GAVRILOVIĆ, 2003). Therefore, high spread may not be necessarily considered as preferable in GNB making since the increased thickness (height) is needed to develop a porous and soft crumb.

Regarding biscuit density, a general trend was that density increased in the combined formulations. There was a strong inverse correlation between the biscuit dimensions and density r=-0.97 (p<0.01) and -0.76 (p>0.05) for height and diameter, respectively, confirming that higher density reduces biscuit development.

Biscuit moisture content

Minimal moisture content required for the retention of freshness in GNB is 7%. Moisture contents below this value render biscuits unacceptable owing to their increased tendency to dry out during storage. The moisture content of biscuits was significantly affected by the level of flour substitution with buckwheat flour as well as its granulation: increased buckwheat doses and coarse flour tended to decrease it whereas FBF increased the moisture content (Fig. 3). As a result, the composite biscuits with 40% and 50% of CBF were significantly lower in moisture (8.00-8.50%, p<0.05, respectively). Other formulations had higher moisture contents with the highest registered in GNB made with FBF and the control (≥ 10.0% moisture content). The water content in GNB formula was significantly correlated to biscuit hardness (r=-0.84, p<0.01), dough cohesiveness (r=0.84, p<0.01) and C5 (r=-0.92, p<0.01). These results indicate that higher moisture content is advantageous in this category of biscuits as it contributes to softer texture, more cohesive and stable dough. Over time, a decrease in moisture contents was observed in all samples. The most marked moisture content decrease (by 8%-10.7%, p<0.05) were in the biscuits substituted with FBF and much less in other samples (by 2.6%-3.8%), in spite of the lower syneresis degree of FBF. Although subjected to the high moisture loss, these biscuits remained higher in moisture content than the control due to higher initial moisture. During storage, moisture migration and evaporation occurs because gluten and starch undergoes such transformations which result in water release (WILLHOFT, 1971; SENTI and DIMLER, 1960).

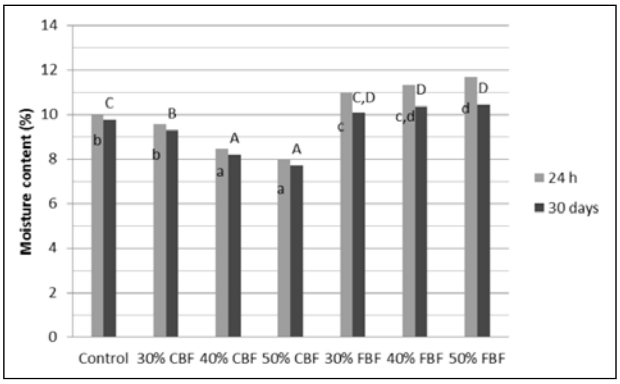

Fig. 3 - Effect of GNB formulation and storage time on biscuit moisture content.
a,b,c ,... A, B,... Values followed by same letters of the same case are not significantly different (p>0.05).

Biscuit texture characteristics

Granulation of buckwheat flour affected hardness and fracturability of GNB. In general, two trends were observed: as the level of CBF increased, hardness also increased, whereas the addition of FBF decreased hardness (Fig. 4). However, the produced results were similar to the control except in the case of GNB made with 50% CBF, which produced significantly higher hardness. Fracturability showed a similar trend (Fig. 4). BALJEET and others (2010) said that the addition of finely ground buckwheat flour decreased the hardness of composite biscuits.

Increased hardness has been usually related to increased association of wheat proteins as correlated by GAINES (1990) in sugar snap cookies and HATCHER *et al.* (2008) in the buckwheat supplemented soba noodles. In contrast to common biscuits, good quality wheat flour is required in the production of ginger nut biscuits. Consequently, its texture is related to the quality of flour proteins with the ability to provide unique viscoelastic and network-forming properties. The results of this study showed a significant correlation (r=0.74, p<0.05) between the biscuit hardness and a Mixolab parameter

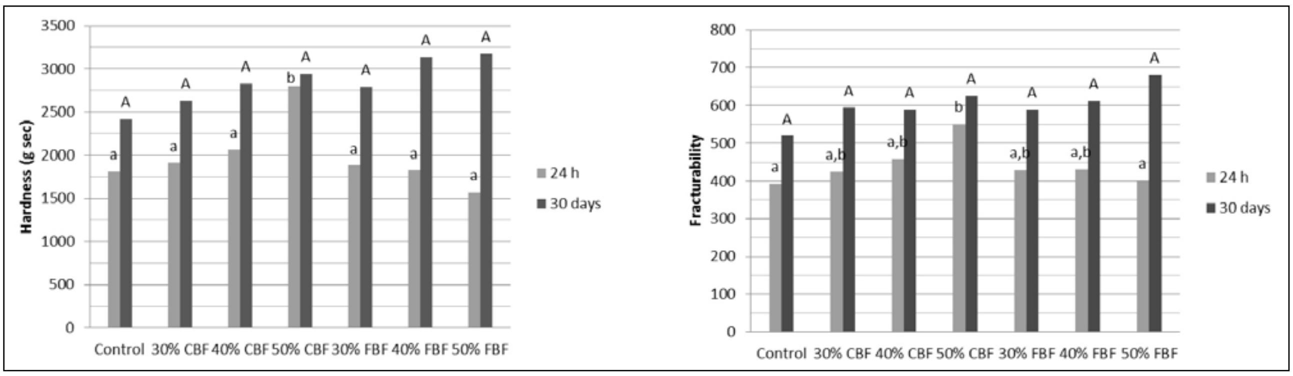

Fig. 4 - Effect of GNB formulation on biscuit hardness and fracturability measured after 24 h and 30 days.
a,b,c ... A, B,... Values followed by same letters of the same case are not significantly different (p>0.05).

related to the quality of proteins, C1-C2. As already noted, C1-C2 indicates protein weakening during heating: higher difference means increased protein weakening i.e. lower stability to heat.

GAVRILOVIĆ (2003) suggested that GNB hardness is also affected by starch pasting properties. In this study, significant correlation (r=0.84 and 0.81, p<0.01) was found only between hardness and Mixolab parameters which indicates starch gel retrogradation (C5 and C5-C4 (total setback), respectively) i.e. higher biscuit hardness can be related to higher setback and C5 values which are indicators of higher susceptibility to staling. The ability of the buckwheat starch to increase hardness of GNB can be counteracted by using ingredients able to retain more water (such as an observed decreasing trend for hardness in the biscuits made with FBF (Fig. 4)). Actually, it was found that the moisture content significantly affected biscuit hardness; there was a significant inverse correlation between hardness and formula water content i.e. biscuit moisture content (r=-0.84 (p<0.01) and -0.74 (p<0.05), respectively).

According to GAVRILOVIĆ (2003), fracturability of GNB can be related to the presence of partially dehydrated gluten in the dough matrix. CHARLES and co-workers (2004) proposed that the presence of discontinuous phase in gluten network was related to an increase in fracturability in flaky snack. Here in the study, significant correlation was found between the biscuit fracturability and two Mixolab parameters related to the behaviour of protein during heating (C2 and C1-C2): C2 denotes the minimum torque produced during heating as a consequence of the beginning of protein weakening (r=-0.84, p<0.01) and C1-C2 can be associated with protein stability (r=0.95, p<0.01). Lower value of C2 and higher value for C1-C2 indicate lower protein stability. In other words, increasing fracturability of GNB can be related to all such factors that may lower the protein stability or discontinue the gluten network such as the addition non-gluten ingredient like buckwheat, especially in the form of coarse flour. There was also a significant correlation between biscuit fracturability and setback value (C5-C4) (r=0.78, p<0.05).

Over the 30-day trial period, a significant increase in hardness and fracturability occurred for GNB made with FBF whereas all others showed insignificant increases as related to the initial values (Fig. 4). But, there were no significant differences in hardness and fracturability within all biscuits measured after 30 days of storage.

On the basis of the above mentioned high correlation between the texture and Mixolab parameters that indicate starch susceptibility toward retrogradation, it could be thought that the lower the susceptibility of starch in biscuit dough to retrograde, the lower the biscuit hardness, fracturability and presumably its tendency towards staling. But, the results obtained after storage showed that GNB made with FBF, which initially gave the softest biscuit and which paste had lower syneresis degree, significantly increased in hardness (in relation to the initial values). This could be due to higher moisture evaporation and more compact structure in comparison to the granular structure of GNB made with CBF. It is also worth noting that GNB dough represents a low-moisture system containing up to 25% moisture and, in addition, interfering ingredients like sugar and fat which might have caused different behaviour and tendencies regarding starch pasting. Interestingly, dough hardness was strongly positively correlated with biscuit hardness and fracturability after storage (r=0.84 and r=0.81, p<0.01).

In the literature, there is little data on the functional properties of buckwheat flour; more data exist on buckwheat starch. Furthermore, data on the ability of buckwheat starch to retrograde are rather contrasting. In the study of QIAN and colleagues (1998), besides increased hardness and stability, buckwheat starch gels exhibited lowered retrogradation as compared to cereal starches, even after storage. Lower susceptibility to retrogradation was also suggested in reports on thermomechanical properties of buckwheat flour slurries or wheat/buckwheat blends slurries (Chopin's Mixolab User's Manual 2005, BANU *et al.*, 2010). In another study, however, a stronger retrogradation peak was observed in buckwheat thermogram than that in wheat (LIU *et al.*, 2006). ZHENG and associates (1998) reported that buckwheat starch had a higher peak viscosity and setback value than maize and wheat starches which may suggest higher retrogradation tendencies in buckwheat starch since setback viscosity indicates the degree of starch retrogradation, mainly its amylase fraction. Starch pasting properties depend on the hydration level (ZHOU *et al.*, 2009). It was concluded that buckwheat starch gelatinization temperatures and enthalpies increased along with the decrease of water content, which can be associated with an increased retrogradation tendency.

Moreover, there is little data to relate starch pasting behaviour with the final properties in a biscuit-like products. It was reported that the addition of corn flour produced harder cookies than did the addition of potato flour, although corn flour had been shown to give lower syneresis (retrogradation) than potato flour (SINGH *et al.*, 2003). Some authors did not find any correlation between pasting properties of batters and characteristics of layer cakes (GÓMEZ *et al.*, 2010). Others suggested that dehulled buckwheat flour, although showing a tendency to retrograde, can be used in buckwheat enriched products (MARIOTTI *et al.*, 2008). IN-

GLETT and his team (2009) proposed that only specialty buckwheat flour with low paste viscosity is suitable for mixing with wheat flour to produce bread and cookies. Much earlier, LORENZ and DILSAVER (1982) mentioned that inclusion of native buckwheat starches in cake formulations did not produce cakes of acceptable quality.

CONCLUSIONS

The results indicated that the addition of buckwheat significantly increased dough hardness and decreased dough adhesiveness. Springiness and cohesiveness of buckwheat doughs were reduced but no significant difference within the samples was observed.

The dimensions of GNB decreased, but since the biscuit height was more affected by the rising doses of buckwheat, the spread increased in the composite biscuits (significant difference was noted with CBF at 40% and 50% replacement level). Hardness and fracturability of GNB increased with increasing doses of CBF whereas FBF decreased hardness and fracturability. However, a significant change was noted only with the addition of 50% CBF.

Hardness and fracturability of GNB significantly correlated to the quality of proteins; lower stability of proteins to heat was associated to increased hardness and fracturability in GNB. Tendency of starch gel in biscuit dough to retrograde was found to be in significant positive correlation with biscuit hardness and fracturability, however, after 30 days of storage, hardness and fracturability increased most markedly in the biscuits made with FBF which were initially softer than the others. Biscuit hardness was in significant inverse relation with the formula water content which might additionally support the importance of protein quality and starch pasting behaviour to the quality of GNB.

Comparing GNB and common biscuits made from short and semi-sweet dough from literature, it seems that GNB exhibits different behaviour. Better quality characteristics are obtained when more water is added to the dough and increased spread cannot be regarded as positive since well-developed crumb is more advantageous for better textural properties.

The addition of FBF to GNB formulation is appropriate at the investigated doses. However, since they have been inclined to excessive drying out, the use of humectants or suitable edible coatings would be appropriate.

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