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Studies on functional properties and incorporation of buckwheat flour for biscuit making

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Abstract:The consumer demand is increasing for composite flour based bakery products like biscuits.The incorporation of buckwheat can be justified in composite flour based biscuits as it has beneficial nutraceutical properties and its gluten-free nature can play important role in preventing celiac problem. The physicochemical and functional properties of buckwheat flour were studied and biscuits were prepared with the incorporation of buckwheat flour in 10, 20, 30 and 40 % concentration with refined wheat flour to assess the quality and acceptability of the biscuits. The water absorption capacity of buckwheat flour was lower than that of refined wheat flour ($p \leq 0.05$), whereas oil absorption and foaming capacity of buckwheat flour were significantly higher than that of refined wheat flour ($p \leq 0.05$). The buckwheat flour had higher least gelation concentration (32%) as compared with wheat flour (20%). As the concentration of buckwheat flour was increased, spread ratio of biscuits decreased. The fracture strength of biscuits decreased with the incorporation of buckwheat flour. The acceptability of biscuit color was best for control sample and it decreased with the addition of buckwheat flour. The biscuits formed with addition of 20 and 30% buckwheat flour had overall acceptability score of 6.71 and 6.20 respectively, suggesting acceptability to the consumers.

Keywords: buckwheat flour, functional properties, supplemented biscuits, physicochemical properties, sensory quality

Introduction

Among ready-to-eat snacks, biscuits possess several attractive features including wider consumption base, relatively long shelf-life, more convenience and good eating quality (Akubor, 2003; Hooda and Jood, 2005). Long shelf-life of biscuits makes large scale production and distribution possible. Good eating quality makes biscuits attractive for protein fortification and other nutritional improvements. Development of fortified biscuits or other composite flour bakery products is the latest trend in bakery industry. The growing interest in these types of bakery products is due to their better nutritional properties and possibility of their use in feeding programs and in catastrophic situations such as starvation or earthquakes (Pratima and Yadava, 2000).

Buckwheat (*Fagopyrum esculentum*) is an annual crop, it is a pseudocereal but its grains belong to cereals because of their similar use and chemical composition. Among a variety of buckwheat species, nine have agricultural and nutritional value. Two buckwheat species are commonly cultivated: common buckwheat (*F. esculentum*) and tartary buckwheat (*F. tartaricum*). The structure and characteristics of buckwheat grain are quite different from those of wheat grain. Buckwheat grains contain numerous nutraceutical compounds (Li and Zhang, 2001) and they are rich in vitamins, especially those of B group (Fabjan *et al.,* 2003). The buckwheat flour (BWF) is superior to the wheat flour because of its higher lysine, iron copper and magnesium content (Ikeda and Yamashita, 1994). The significant contents of rutin, catechins and other polyphenols as well as their potential antioxidant activity are also of great significance (Oomah and Mazza, 1996; Wanatabe, 1998). These functional components of buckwheat have health benefits like reducing high blood pressure, lowering cholesterol, controlling blood sugar and preventing cancer risk (Fabjan *et al*., 2003; Kim *et al*., 2004).

Any alteration of the protein during storage or cooking would have a beneficial or deleterious effect on the palatability and quality of resultant products from such flours (Ikeda *et al.,* 1983). Buckwheat flour (BWF) may be used in the manufacture of bread, cookies, pies, pancakes, the macaroni

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products (Almedia, 1978). The incorporation of buckwheat can be justified in composite flour based biscuits as it has beneficial nutraceutical properties and its gluten-free nature can play important role in preventing celiac problem. Buckwheat flour addition into noodle formulation has been observed to show considerable effects on cooking quality, chemical and sensory properties and color values of noodles (Bilgicli, 2008). Cereal grains, including soft wheat are low in protein (7 to 14%) and deficient in some amino acids such as lysine. Buckwheat on the other hand, is higher in protein quality than other cereal grains and could be used to support certain amino acids such as lysine, histidine, valine and leucine. Keeping in view of the nutraceutical and other functional properties of buckwheat, the present study was undertaken with the objectives to compare the functional properties of buckwheat flour with wheat flour and incorporate it in biscuits to assess the quality and acceptability of biscuits.

Materials and Methods

Materials

The buckwheat seeds and refined wheat flour (WF) were purchased from local market and buckwheat flour (BWF) was prepared in laboratory flourmill with particle size of 0.150 µm. Other materials like sugar, fat etc. required for biscuit making were purchased from local market.

Product development

The biscuits were prepared with the incorporation of BWF in 10, 20, 30 and 40% concentration with refined WF keeping sugar and fat amount constant to 60 and 35 g respectively on 100 g flour basis. White flour biscuits were considered as control. Fat and ground sugar were creamed in a mixer with a flat beater for 2 min at slow speed. The flour, required amount of milk and 1.5 g ammonium bicarbonate were added to the creamed mixture and mixed for 8 min at medium speed in dough mixer to obtain a homogenous mixture. The batter was sheeted to a thickness of 4.5 mm with help of rolling pin and an aluminum frame of standard height. The biscuits were cut with biscuits die to desired diameter of 50 mm and transferred to a lightly greased aluminum baking tray. The biscuits were baked at 190^{0}C for 12 min in a baking oven. The baked biscuits were cooled and stored in an air tight container for further analysis.

Analytical methods

The functionality of flours of cereals grains, which depends to a great extent upon starch and protein content of flours, contribute a lot to the formulation and properties of the final product Therefore, flours were analyzed for their physicochemical and functional properties. Particularly, the functional properties are required for the formulation of value added composite bakery products. Protein (micro-Kjeldahl, Nx6.25), fat (solvent extraction), moisture, ash and crude fiber were determined by the AOAC (1990) methods. The carbohydrate content was calculated by subtraction method.

Water and oil absorption capacity

The water and oil absorption capacities were determined by the method of Sosulski *et al*. (1976). The sample (1.0 g) was mixed with 10 ml distilled water or refined soybean oil, kept at ambient temperature for 30 min and centrifuged for 10 min at 2000×g. Water or oil absorption capacity was expressed as percent water or oil bound per gram of the sample.

Bulk density

The bulk density was determined according to the method described by Okaka and Potter (1977). The sample (50 g) was put into a 100 ml graduated cylinder and tapped 20-30 times. The bulk density was calculated as weight per unit volume of sample.

Least gelation concentration

The least gelation concentration was determined using method of Coffman and Garcia (1977) with some modifications. The flour dispersions of 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22 and 30, 32, 34% (w/v) prepared in 5 ml distilled water were heated at 90^{0}C for 1 h in a water bath. The contents were cooled under tap water and kept for 2 h at 10±2^{0}C. The least gelation concentration was determined as that concentration when the sample from inverted tube did not slip.

Swelling capacity

The method of Okaka and Potter (1977) with some modifications was used for determining the swelling capacity. The sample filled up to 10 ml mark in a 100 ml graduated cylinder was added with water to adjust total volume to 50 ml. The top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. The suspension was inverted again after 2 min and allowed to stand for further 30 min. The volume occupied by the sample was taken after 30 min.

Foaming capacity and foaming stability

Foaming capacity and foaming stability were determined as described by Narayana and Narasinga Rao (1982) with slight modifications. Sample (1.0 g) was added to 50 ml distilled water at 30±2^{0}C in a graduated cylinder. The suspension was mixed and shaken for 5 min to foam. The volume of foam after whipping for 30 sec was expressed as foaming capacity.

Where, AW: After whipping, BW: Before whipping

The volume of foam was recorded 1h after whipping to determine foaming stability as percent of the initial foam volume.

Fracture strength of biscuits

Fracture strength of biscuits was measured with the help of Texture Analyzer (model TA-XT2i, Stable Micro systems, Haslemere, U.K) using a 3-point Bending Rig and 5 kg load cell. The distance between the two beams was 40 mm. Another identical beam was brought down from above at a pre-test speed of 1.0 mm/s, test speed of 3.0 mm/s, post-test speed of 10.0 mm/s. The downward movement was continued till the biscuit broke. The peak force was reported as fracture strength.

Sensory analysis of biscuits

Biscuit samples were analyzed for sensory characteristics. Sensory quality characteristics were evaluated by a panel of 10 semi-trained members using a 9-point Hedonic scale. The biscuits were evaluated for their color, appearance, flavor, texture, taste and overall acceptability.

$$FC = \frac{\text{Volume of foam (AW)} - \text{Volume of foam (BW)}}{\text{Volume of foam (BW)}} \times 100$$

Emulsion activity

The emulsion activity and stability were determined by the method of Yasumatsu *et al*. (1972). The emulsion (1 g sample, 10 ml distilled water, 10 ml soybean oil) was prepared in a calibrated centrifuge tube. The emulsion was centrifuged (REMI 412 LAG) at 2000 × g for 5 min. The ratio of the height of the emulsion layer to the total height of the mixture was calculated as the emulsion activity expressed in percentage.

Physical analysis of biscuits

Diameter of biscuits was measured by laying six biscuits edge to edge with the help of a scale rotating them 90^0 and again measuring the diameter of six biscuits (cm) and then taking average value. Thickness was measured by stacking six biscuits on top of each other and taking average thickness (cm). Weight of biscuits was measured as average of values of four individual biscuits with the help of digital weighing balance. Spread ratio was calculated by dividing the average value of diameter by average value of thickness of biscuits. Percent spread was calculated by dividing the spread ratio of supplemented biscuits with spread ratio of control biscuits and multiplying by 100.

Statistical analysis

Data were analyzed using one-way and two-way analysis of variance (ANOVA) procedures in a randomized complete block design with three replications. Statistical analysis was performed using the OPSTAT software version opstat1.exe (Hisar, India).

Results and Discussion

Proximate composition of flours

The proximate composition as given in Table 1 shows that fat content of buckwheat and refined wheat flour did not differ significantly ($p \leq 0.05$). However, a significant difference was observed in ash, crude fiber, carbohydrate and protein content of buckwheat and refined wheat flour ($p \leq 0.05$) and buckwheat flour showed lower protein content (8.73%) and higher carbohydrates (75.84%) and crude fiber content (0.70%) in comparison to refined wheat flour. Buckwheat flour contains from 8.5% to near 19% of proteins depending on the variety, pesticides used, and fertilization that are likely to affect the total concentration of buckwheat proteins (Fornal, 1999). The ash content of buckwheat flour (1.32%) observed in this study is comparable with that reported by Taira (1974). Since the carbohydrate content for flours was calculated by difference, the variation in carbohydrate content may be attributed to the differences in other constituents. The similar value of carbohydrates in BWF was reported by Franchischi *et al*. (1994).

Functional properties of flours

The functional properties of flours play important role in the manufacturing of products. The buckwheat flour (BWF) and refined wheat flour (WF) were analyzed for their functional properties. Table 2 shows the various functional properties of flours. The water absorption capacity (WAC) of buckwheat flour was found to be significantly lower than that of wheat flour ($p \leq 0.05$). The lower WAC of buckwheat flour could be attributed to the presence of lower amount of hydrophilic constituents in BWF (Akubor and Badifu, 2001). The oil absorption capacity (OAC) of BWF was significantly higher than that of refined WF ($p \leq 0.05$). The oil absorption capacity (OAC) of flour is equally important as it improves the mouth feel and retains the flavor. The higher OAC suggested the presence of apolar amino acids in the BWF (Taira, 1974). The swelling capacities of BWF and refined WF were 15.77 and 16.37 ml respectively. The foaming capacity of BWF was higher than that of refined WF. Foaming capacity is assumed to be dependent on the configuration of protein molecules. Flexible proteins have good foaming capacity but highly ordered globular molecule gives low foam ability (Graham and Philips, 1976). The foam expansion and foam stability have been correlated with water-dispersible nitrogen (Yasumatsu *et al.*, 1972). Food ingredients with good foaming capacity and stability can be used in bakery products (Akubor *et al*., 2000). The emulsion activity did not differ significantly between the BWF and refined WF and the corresponding values were 0.44 and 0.43% ($p \leq 0.05$).

The bulk density of BWF was 0.81 g/ml, significantly higher ($p \leq 0.05$) than that of the refined WF (0.73 g/ml). The BWF had higher least gelation concentration (32%) as compared with refined WF (20%). The variation in the gelling properties of flours was attributed to the relative ratio of protein, carbohydrates and lipids that make up the flours and interaction between such components (Sathe et al 1982).

Proximate composition of biscuits

The proximate composition of biscuits is shown in Table 3. The ash content of biscuits increased with the addition of BWF up to 30% concentration. The increase in ash content may be due to the high mineral content in the BWF i.e. iron, copper and magnesium (Francischi *et al.,* 1994). The moisture content ranged from 2.43 (40% BWF) to 3.37 % (control). The decrease in moisture content may be due to the decrease in protein content. Mustafa *et al*. (1986) reported an increase in moisture content of bakery products with increase in protein content. The fat content of control biscuits was 21.27% and it increased to 23.17% in 40% BWF biscuits. This was probably due to the oil retention ability of buckwheat flour during baking process (Rufeng *et al*., 1995). Higher oil retention improves the mouth feel and retains the flavor of the biscuits. No definite trend in increase or decrease in crude fiber contents was observed. The protein content of biscuits ranged from 5.60 to 7.20%. The biscuits showed decrease in protein content when BWF concentration was increased. The carbohydrate content as determined by difference method was found to be higher in 20% BWF biscuits.

Physical characteristics of biscuits

The physical properties of biscuits prepared from BWF and refined WF are shown in Table 4. The diameter of biscuits made from 20, 30 and 40% BWF was found significantly lower than that of control biscuit ($p \leq 0.05$). The thickness of biscuits ranged from 0.79 to 0.86 cm. It increased with the incorporation of BWF. Increase in thickness may be due to the decrease in diameter. The changes in diameter and thickness were reflected in spread ratio and percent spread of biscuit. The spread ratio and percent spread of control biscuits were 8.02 and 100, respectively. Spread ratio and percent spread decreased with the addition of buckwheat flour. Other research workers also reported reduction in spread ratio when soy flour and fenugreek flour were substituted for wheat flour (Singh *et al*., 1996; Hooda and Jood, 2005). Reduced spread ratios of BWF fortified biscuits were attributed to the fact that composite flours apparently form aggregates with increased numbers of hydrophilic sites available that compete for the limited free water in biscuit dough (McWatters, 1978).The weight of biscuits increased as the concentration of BWF increased in the blends. The range of biscuit weight was 10.73 to 12.00 g with maximum value in 40% BWF biscuits. The increase in biscuit weight was probably due to the ability of buckwheat flour to retain oil during baking process (Rufeng *et al*., 1995).

The fracture strength determined from the texture profile analysis (TPA) curve is shown in Figure 1. The fracture strength of biscuits decreased with the incorporation of BWF. The fracture strength of control biscuit was found to be highest (3144.1 g).

Table 1. Proximate composition of flours

Parameter	Buckwheat flour	Refined wheat flour
Moisture (%)	11.60 ±0.12[a]	13.29 ±0.03[b]
Ash (%)	1.42 ±0.05[b]	1.32 ±0.06[a]
Fat (%)	1.81 ±0.03[a]	1.78 ±0.08[a]
Crude fibre (%)	0.70 ±0.01[b]	0.62 ±0.01[a]
Protein (%)	8.73 ±0.14[a]	13.00 ±0.03[b]
Carbohydrate (%)*	75.74	69.99

The values are mean ± S.D of three independent determinations. The values with different superscripts in a row differ significantly ($p \leq 0.05$).
* Calculated by difference method.

Table 2. Functional properties of flours

Property	Buckwheat flour	Refined wheat flour
WAC (%)	133.67 ±0.67[a]	151.00±1.16[b]
OAC (%)	181.37 ±0.58[b]	169.97±3.38[a]
SC (ml)	15.77 ±0.15[a]	16.37 ±0.32[a]
FC (%)	15.47 ±0.08[b]	12.42 ±0.09[a]
FS (%)	93.91 ±0.32[a]	96.48 ±0.55[b]
EA (%)	0.44 ±0.02[a]	0.43 ±0.01[a]
BD (g/ml)	0.81 ±0.03[b]	0.73 ±0.01[a]
LGC (%)	32.0	20.0

The values are mean ± S.D of three independent determinations. The values with different superscripts in a row differ significantly ($p \leq 0.05$).
WAC= Water absorption capacity; OAC= Oil absorption capacity; SC=Swelling capacity; FC= Foaming capacity; FS= Foaming stability; EA= Emulsion activity; BD= Bulk density; LGC= Least gelation concentration

Table 3. Chemical composition of biscuits

	Ash (%)	Moisture (%)	Fat (%)	Crude fiber (%)	Protein (%)	Carbohydrates
A	0.54 ±0.02[a]	3.37±0.20[b]	21.27±0.24[a]	2.11±0.02[b]	7.20 ±0.05[e]	65.51
B	0.56 ±0.02[a]	3.23±0.15[b]	21.67±0.12[ab]	2.06±0.04[ab]	6.54 ±0.03[d]	65.94
C	0.62 ±0.02[b]	3.00±0.20[ab]	22.00±0.12[b]	1.98±0.02[a]	6.08 ±0.03[c]	66.32
D	0.67 ±0.01[b]	2.47±0.20[a]	22.77±0.15[c]	2.06±0.03[ab]	5.86 ±0.04[b]	66.17
E	0.67 ±0.01[b]	2.43±0.22[a]	23.17±0.20[c]	2.06±0.04[ab]	5.60 ±0.06[a]	66.07

A = Control; B= 10% BWF; C= 20%BWF; D=30%BWF; E=40%BWF
The values are mean ± S.D of three independent determinations. The value with different superscripts in a column differ significantly ($p \leq 0.05$).
*Values calculated by difference method.

Table 4. Physical properties of biscuits

Biscuit Samples	Diameter (cm)	Thickness (cm)	Spread ratio	Weight (g)	% spread	Fracture strength (g)
A	6.34±1.20[c]	0.79±0.33[a]	8.02±0.67[c]	10.70±0.23[a]	100.0	3144.1
B	6.31±1.45[c]	0.79±0.33[a]	7.99±0.25[bc]	10.73±0.34[a]	99.62	3108.6
C	6.21±1.45[b]	0.81±0.67[a]	7.67±0.67[b]	10.82±0.08[a]	95.63	2318.0
D	6.13±0.33[b]	0.86±1.00[b]	7.13±0.31[a]	11.27±0.20[b]	88.90	2074.5
E	6.02±1.00[a]	0.86±0.58[b]	7.00±0.05[a]	12.00±0.22[c]	87.28	2066.6

A = Control; B= 10% BWF; C= 20%BWF; D=30%BWF; E=40%BWF
The values are mean ± S.D of three independent determinations except fracture strength values. The values with different superscripts in a column differ significantly ($p \leq 0.05$).

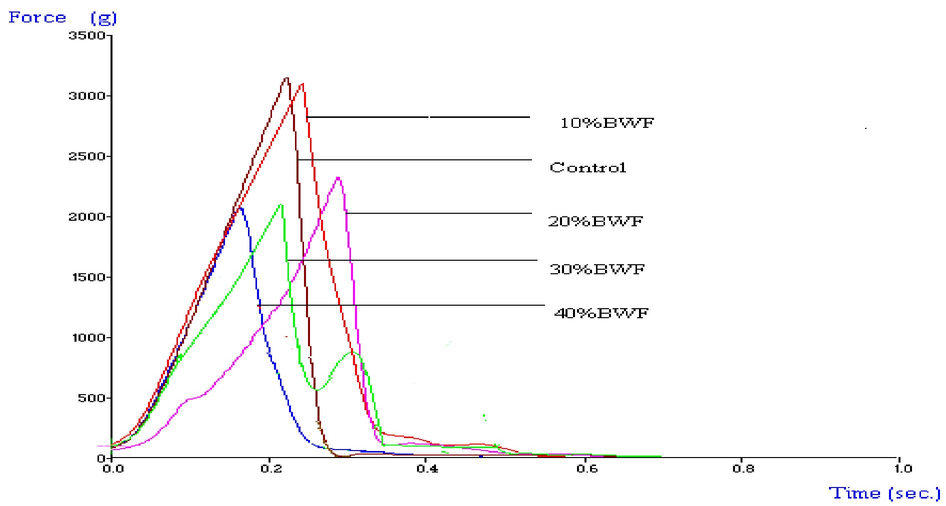

Figure 1. Fracture strength profile of biscuits as measured by texture analyzer

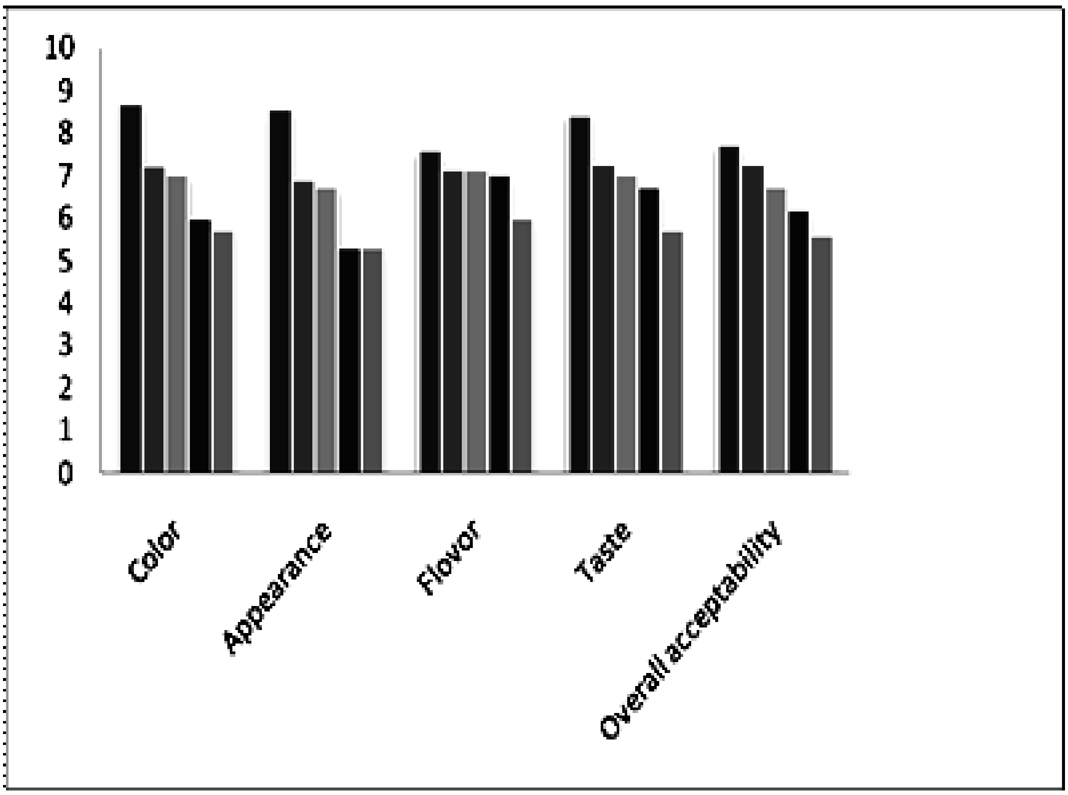

Figure 2. Sensory characteristics of biscuits as affected by incorporation of buckwheat flour (The bars in a group for a particular sensory attribute represent control, 10%BWF, 20% BWF, 30% BWF and 40% BWF biscuits from left to right)

The fracture strength of 40% BWF biscuits (2066.6 g) was observed to be lowest. This may be due to the decreasing gluten content in the buckwheat flours, as the biscuits became soft with increasing BWF content.

Sensory characteristics of biscuits

Figure 2 depicts the effects of BWF incorporation on the sensory characteristics of biscuits. With the increase in the level of BWF in the formulation, the sensory scores for color, texture, appearance and flavor of biscuits decreased. The acceptability of biscuits color was best for control sample. The acceptability of color decreased with the addition of BWF because the BWF had lower lightness and higher yellowness and redness value than control sample (Duarte *et al.,* 1996). The score of appearance reduced to 5.28 at 40% concentration of BWF. This was because of cracks formed with the addition of gluten free BWF. The use of no-glutenous composite flours in cookie preparation reduces the textural strength of cookies where such strength is dependent upon approximate levels of gluten development. This is because in contrast to bread, the gluten network in cookies is to be only slightly cohesive without being too elastic (Schober *et al*., 2003). The score of taste reduced significantly to 5.71 at higher concentrations, possibly due to presence of flavonoid compound (rutin) having bitter taste in BWF. The biscuits formed with addition of 20 and 30% BWF got overall acceptability score of 6.71 and 6.20, respectively.

Conclusion

BWF addition into biscuit formulation had considerable effects on physicochemical and sensory properties of biscuits. It may be concluded from the present study that buckwheat flour can be successfully incorporated in refined WF biscuits up to a level of 20% to yield biscuits of enhanced nutritional quality with acceptable sensory attributes. Hence, development and utilization of such functional foods will not only improve the nutritional status of the population but also helps those suffering from degenerative diseases. More studies should be conducted to investigate the possibility of using BWF as an ingredient in other food products in order to increase applications of such value-added food ingredient.

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