J Food Sci Technol (August 2015) 52(8):5129–5137
DOI 10.1007/s13197-014-1597-y

ORIGINAL ARTICLE

Evaluation of nutritional, textural and particle size characteristics of dough and biscuits made from composite flours containing sprouted and malted ingredients

Dipika Agrahar-Murugkar · Paridhi Gulati · Nachiket Kotwaliwale · Chetan Gupta

Revised: 15 September 2014 / Accepted: 30 September 2014 / Published online: 1 November 2014

Abstract Composite flours (CF) using cereals, legumes, millets, soy-protein isolate, dairy ingredient and fruit without refined flour were used for preparing multi-nutrient biscuits. Dough and biscuits were evaluated for physical, nutritional and textural properties, particle size, colour and sensory evaluation and compared against refined-flour biscuits (C). Effect of malting and sprouting on biscuit quality were also analyzed. The highest volume of particles for CF was 140 μm higher than C flour. CF biscuits had significantly ($p \leq 0.05$) lower spread ratio and % weight loss compared to C. The hardness, stickiness and cohesiveness values of CF doughs were significantly ($p \leq 0.05$) lower than C resulting in lower cutting strength and increased hardness of CF biscuits. Sprouting further decreased hardness of CF dough. Nutrient content of CF biscuits (sprouted and unsprouted) were significantly ($p \leq 0.05$) higher than C biscuits. Sensory evaluation showed CF biscuits especially with sprouted flour had higher acceptability and were superior to C.

Keywords Multi-nutrient biscuits · Particle size · Texture · Organoleptic quality · Nutrient content

Introduction

Bakery products are popular due to their convenience, unique taste and easy availability at reasonable cost. Among bakery products, biscuits/cookies and crackers are the most popular and versatile snack foods (Nagi et al. 2012) due to low cost, varied taste, easy availability and longer shelf life. Refined wheat flour is commonly used for biscuit making owing to its high gluten content but is nutritionally very poor. Thus, there is a need to identify alternative flours which can substitute refined flour partially or completely in bakery products.

Corn (*Zea mays*) and wheat (*Triticum aestivum)* flour are staple cereals while sorghum (*Sorghum bicolor)* and finger millet (*Eleusine coracana*) are minor millets rich in polyphenols and minerals (Viswanath et al. 2009). Green gram (*Vigna radiata)* is an excellent source of protein, dietary fibre and rich in vitamins and minerals while peanuts (*Arachis hypogaea)* are an important high protein oilseed with many health benefits. Roasting is known to increase their antioxidant activity (Marwin et al. 2011). Soy protein isolate (SPI) is important ingredient due to its nutritional value, desirable functional properties and low cost (Hu et al. 2013). Papaya (*Carica papaya L.*) is rich in β-carotene and minerals. Sprouting/ malting is a simple technique that improves the nutritive value of foods. Sprouting increases protein and dietary fiber; reduces tannin and phytic acid and increases mineral bioavailability (Agrahar-Murugkar and Jha 2010; Ghavidel and Prakash 2007) and can be incorporated in mixes to enhance nutrient content of diets.

Many studies have been carried out to incorporate protein rich, mineral rich or fiber rich flours in biscuits individually or through artificial fortification. No work has been reported on using multi-nutrient flours without refined flour along with sprouting/ malting to make biscuits without any artificial fortification.

Thus, with an aim to develop biscuits using ingredients from cereals, millets, pulses, oilseeds, dairy and fruits but without refined flour and to study the effects of sprouting/ malting on biscuit quality, two types of composite flours were developed using corn, wheat, green gram (sprouted and unsprouted), finger-millet (malted and un-malted), sorghum, peanuts, soy protein isolates, milk powder and papaya.

D. Agrahar-Murugkar (✉) · P. Gulati · N. Kotwaliwale · C. Gupta
Central Institute of Agricultural Engineering, Berasia Road, Nabibagh, Bhopal 462038, India
e-mail: dipikaagrahar@yahoo.com

These were further used for development of biscuits and the physical properties, texture and nutrients of dough and biscuits examined and compared with commonly consumed refined wheat flour biscuits.

Materials and methods

Preparation of composite flours Corn flour, whole wheat flour, sorghum flour, whole finger-millets, split green gram, whole green gram, unsalted peanuts, dairy whitener and papaya, were procured from the markets in Bhopal, India. Soy protein isolate containing 95 % protein was procured from Sonic Biochem, Indore, India. Corn, wheat and sorghum flour were sieved through mesh of size 200 microns to obtain a uniform particle size. Finger millet, unsalted peanuts and split green gram were cleaned thoroughly. For sprouting/malting, cleaned whole green gram and finger-millet were surface sterilized with 0.1 % (w/v) potassium permanganate solution, followed by soaking in distilled water for 4 h at room temperature (RT). The seeds were germinated in a Seed Germinator (Indosaw, India) at the 25 °C, 90 % RH for 12–24 h for finger millet and 24–48 h for green gram using the method of Agrahar-Murugkar et al. 2013. After sprouting the seeds were dried in an oven overnight at 60 °C and then cooled at room temperature (RT). Peanuts (100 g) were roasted at 130 °C for 8 min followed by cooling at RT. Papaya was deseeded and de-skinned. The pulp was manually extracted and dried in trays at 60 °C for 24 h in a hot air oven (Meta-Lab Scientific Industries, Mumbai, India). The whole grains and dried papaya were powdered using analytical mill (Cole Parmar, Vernon, IL, USA) at high speed (10,590 G). All powders were then sieved through mesh of size 300 microns. The ingredients used for the preparation of composite flours have been presented in Table 1. Plain refined flour biscuits served as the control.

Table 1 Composition of various composite flours for biscuits

CF I		CF II	
CF I A	CF I B	CF II A	CF II B
Corn	Corn	Corn	Corn
Wheat	Wheat	Wheat	Wheat
FM	MFM	Sorghum	Sorghum
GG	GGG	GG	GGG
SPI	SPI	SPI	SPI
DI	DI	DI	DI
RP	RP	RP	RP
Papaya	Papaya	Papaya	Papaya

FM Finger-millet, *MFM* Malted finger millet, *GG* Green gram, *GGG* Germinated green gram, *SPI* Soy protein isolate, *DI* Dairy ingredient

Particle size analysis of flours Particle size analysis for average particle sizes (d3,2 – Surface-weighted mean diameter – Sauter Mean Diameter and d4,3 – Volume-weighted mean diameter – De Brouckere Mean Diameter) of various composite flours and refined wheat flour were determined using a particle size analyzer (Mastersizer, Malvern Inc., Worcestershire, United Kingdom) with the dry feed attachment. The, Mean diameters d3,2 and d4,3 are defined by:

$$d3,2 = \sum ni\ di\wedge 3 / \sum nidi\wedge 2 \text{ and}$$
$$d4,3 = \sum ni\ di\wedge 4 / \sum ni\ di\wedge 3,$$

Where ni is the number of particles of diameter di. The obscuration of all samples was maintained between 1 and 6 %. Feed rate and pressure of the instrument was set at 2–3 and 6–8 bar respectively. All analyses were performed in triplicate.

Preparation of biscuit dough and biscuits Biscuit dough for all biscuits including control was prepared by creaming technique. The basic formulation used was 100±2 g composite flour/ refined flour, 50±5 g castor sugar, 38±2 g fat, 0.5 g baking powder and 20±1.0 ml water. Flour and baking powder were sieved together. Fat and sugar were manually creamed together uni-directionally and the sieved mixture of flour and baking powder were added and mixed. Water was heated to a temperature of 55±5 °C and added to the above mixture and manually kneaded to get a dough consistency. The prepared dough was subjected to sheeting of 4 mm thickness manually. Finally sheets were cut to 4.5±1.0 cm diameter by using a die and were subjected to baking at 180±10 °C for 20±5 min. The baked biscuits were cooled to room temperature; sealed in LDPE packs and kept in desiccators before further analysis.

Analysis of biscuit characteristics

Physical characteristics The weight loss during baking (WL) was calculated by using the following equation:

$$WL = \left[\left(W_{dough} – W_{biscuit} \right) / W_{dough} \right] * 100$$

Where, W denotes weight (g). From each formulation, 10 samples were weighed individually before (W_{dough}) and after ($W_{biscuit}$) baking and WL was calculated (Rodriguez-Garcia et al. 2012).

Biscuit diameter and thickness was measured using digital Vernier calliper at two and four different places, respectively in each biscuit and the average value was reported for each. The average of 10 biscuits was recorded for each batch and reported. Spread ratio was calculated by dividing the average value of diameter by average value of thickness of biscuits.

Proximate analysis The moisture, fat, protein, fiber and ash contents of the control as well as composite flour biscuits were estimated by standard AOAC methods (2005).

Textural properties of dough and biscuits The textural characteristics of dough and biscuit samples were measured using TA-XT plus Texture Analyser of Stable Micro Systems Surrey, UK withTexture Expert™ software. Following texture tests were performed on dough and biscuits.

Dough texture

Penetration test Dough made using CF-I (A & sB), CF-II (A & B) and refined wheat flour were tested for their firmness by penetration test. Samples were taken in a concentric cylinder of 30 mm diameter and placed under a cylindrical probe having 5 mm diameter (P/5, Stable Micro Systems, UK). Texture analyzer settings were kept as: pre-test speed of 2 mm/s, test speed of 3 mm/s, post-test speed of 10 mm/s, with a 50 kg load cell and the strain was set at 60 %. On running the test, the probe penetrated to 60 % of the dough height and then returned to its original position. From the resulting force–time curve, the absolute peak force obtained was taken as dough firmness (Tyagi et al. 2007). Each dough type was tested for its hardness 5 times and the average value was recorded.

Stickiness, adhesion and dough strength test Dough stickiness, adhesion and dough strength test for dough samples was performed using SMS/ Chen-Hosney Dough Stickiness Cell and 25 mm Perspex cylinder probe (Stable Micro Systems, UK). The texture analyzer settings were kept at: pre-test speed of 2 mm/s, test speed of 2 mm/s, post-test speed of 10 mm/s, trigger force of 40 g, return distance of 3 mm and contact time of 10 s (Bourne 2002; Raina et al. 2005; Singh et al. 1993). The positive peak force from the resulting curve was considered as the stickiness force. The area falling under this force-distance curve indicated the work of adhesion and the distance of sample extension during probe return was considered as dough strength or cohesiveness (Tyagi et al. 2007).

Biscuit texture

Snap test The snap test or three point bending test was conducted using a 3-point bending rig (A/3 PB, Stable Micro Systems, UK) attached to texture analyzer. Following settings were used for the test, Pre-test speed: 1.0 mm/s, Test speed: 1 mm/s, Post-test speed: 10.0 mm/s, Distance: 10 mm to contact the biscuit with a 50 kg load cell. The downward movement was continued till the biscuit broke. The maximum force was recorded as the 'hardness' of the biscuit. An average value of 10 replicates is reported (Mamat et al. 2010).

Cutting strength of biscuit Cutting strength of biscuit was measured using HDP/BS blade of texture analyzer (Stable Micro Systems, UK). The individual samples of biscuits were placed on the platform and the blade was attached to the crosshead of the instrument. The TA settings selected were Pre-test speed: 2 mm/s, test speed: 3 mm/s, post-test speed: 10 mm/s and distance: 5 mm. The absolute peak force of the resulting curve was considered as cutting strength of the biscuit (Singh et al. 1993; Tyagi et al. 2007).

Color analysis Color of biscuits was determined in terms of using Lab scan XE spectro-colorimeter (Hunter Associate Laboratory Virginia, USA, Model LX16244) following the method of McGuire (1992). Biscuits from each batch were placed in a glass sample cup of 5.8 cm internal diameter and color coordinates were measured. An average of 10 readings was reported for each sample.

Sensory analysis Sensory evaluation was carried out on all prepared biscuits including control. Ten semi-trained panelists evaluated the sensory attributes of biscuits (Agrahar-Murugkar and Jha 2011). Panelists were familiar with product sensory evaluation, most having participated in previous related projects. All types of biscuit samples were served in duplicates in a plate with random arrangement. The attributes evaluated were appearance, taste, texture, flavor and overall acceptability. For each sample, panelists scored their liking of these characteristics using the nine point Hedonic scale. Average of ten scores for each parameter is reported.

Statistical analysis Nutritional, functional and textural analysis was done in replicates and their statistical significance was analyzed using Two-way ANOVA with replicates in Microsoft Excel-2010.

Results and discussion

Particle size analysis of biscuit flours Particle size of flour greatly influences the water absorption capacity, density and spread of biscuits. Figure 1 shows the particle size distribution for various composite flours (CF) and refined wheat flour (C-control). Two distinct peaks were observed in all the CF whereas the first peak in C was not as distinct showing that the particle size distribution of all flours was bimodal which is in agreement to the findings of Wilson et al. 2006. The second peak had a higher volume showing that a maximum of samples had particle sizes around 100 μm. Both mean volume diameter (d4,3 : 67.07 μm) and mean surface area diameter of C flour (d3,2 : 24.3 μm) were found to be statistically ($p\leq$ 0.05) less than the CF (d4,3 : 81–82 μm ; d3,2 : 31 μm, respectively). No significant difference ($p\leq$0.05) was found

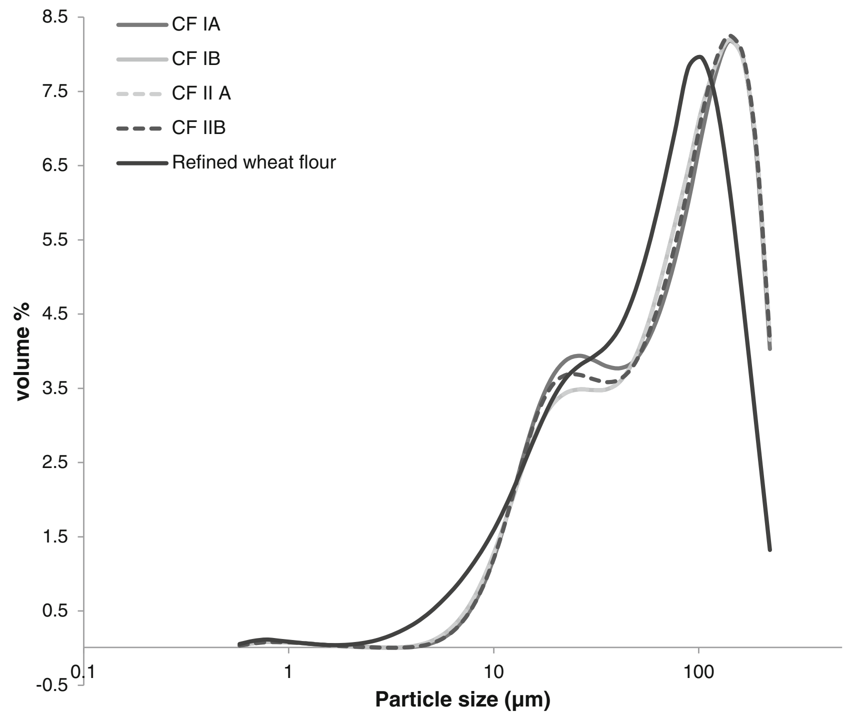

Fig. 1 Particle size analysis of composite flours and refined wheat flour (control)

among the two types of CFs or among sprouted and un-sprouted combination of same flour. Particle size distribution of all flours ranged from 0.1 to 100 µm with the highest volume of particles for all CF's at around 140 µm and for C flour at around 89 µm. A smaller flour particle size is generally related to lower protein and fiber content (Gaines et al. 1988). Flours with finer particle size when used to make hard doughs give biscuits with a higher density and result in less development during baking (Manley 2000). Thus, a coarser particle size as obtained for composite flours is desirable for making hard dough biscuits.

Physical properties of biscuits Biscuits made with CF's had significantly ($p \leq 0.05$) lesser diameter and higher thickness compared to C biscuits (Table 2). These changes in diameter and thickness are reflected in their spread ratio which reduced for CF biscuits. Spread ratio is considered as one of the most important quality parameter of biscuits as it correlates with texture, grain finesse, bite and overall mouth feel of the biscuits (Bose and Shams-ud-din 2010). Two main factors affect the spread ratio: expansion of dough by leavening and gravitational flow. Since the thickness of the CF biscuits were higher than C biscuits, expansion of dough by leavening was adequate. Therefore the reduced spread-ratios of CF biscuits can be attributed to CF containing more water absorbing constituents like protein and fiber. Several reports (Patel and Rao 1996; Hooda and Jood 2005) showed that reduced spread ratio was observed when wheat flour was substituted by high protein and /high fiber ingredients in CF. Among CF biscuits it was observed that CF I and II B had lower diameter and spread ratio as compared to CF I and II A. This could be due to the higher protein and fiber content of CF with sprouted or malted ingredients as in evident from Table 3. Sprouting and malting bring about increase in the protein content of ingredients (Agrahar-Murugkar and Jha 2009) and presence of seed coat in flours with sprouted and malted ingredients increased the fiber content of flours. These constituents form aggregates with available hydrophilic sites thus reducing free water in

Table 2 Physical properties of biscuits

Sample	Diameter (mm)	Thickness (mm)	Spread ratio	Weight loss (%)
CF I A biscuits	49.64±1.06[a]	5.36±0.32 [a]	9.27±0.4 [b]	11.78±0.35 [a]
CF I B biscuits	48.86±0.43 [a]	5.54±0.02 [b]	8.82±0.05 [a]	11.91±0.13 [a]
CF II A biscuits	49.63±0.07 [b]	5.20±0.04 [a]	9.54±0.09 [b]	10.98±0.04 [a]
CF II B biscuits	48.33±0.90 [a]	5.41±0.4 [b]	8.93±0.68 [a]	11.58±0.65 [a]
Control biscuits	50.38±0.40 [c]	5.18±0.19 [a]	9.73±0.36 [b]	14.82±0.22 [b]

Mean ± SD, results are the average of six replicates; for each analysis, data followed by different letters in the same column are significantly different ($p \leq 0.05$)

Table 3 Nutritional analysis of biscuits

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fiber (%)
CF I A biscuits	2.21±0.14 ^{b}	13.0±0.20 ^{b}	23.5±0.54 ^{c}	1.71±0.05 ^{c}	0.32±0.03 ^{a}
CF I B biscuits	2.8±0.40 ^{c}	13.6±0.29^{b}	22.56±0.8 ^{b}	1.83±0.05 ^{d}	0.72±0.04^{c}
CF II A biscuits	2.25±0.17 ^{b}	14.2±0.32^{c}	23.0±0.42^{c}	1.6±0.06 ^{b}	0.26^{a}±0.05 ^{a}
CF II B biscuits	2.65±0.23 ^{c}	14.3±0.06 ^{c}	21.02±0.3 ^{b}	1.73±0.02 ^{c}	0.46±0.01^{b}
Control biscuits	1.0±0.03 ^{a}	7.5±0.25^{a}	18.9±0.18^{a}	0.9±0.01^{a}	–

Mean ± SD, results are the average of six replicates; for each analysis, data followed by different letters in the same column are significantly different ($p \le 0.05$)

biscuit dough (McWatters 1978). Rapid partitioning of free water of these hydrophilic sites occurs during dough mixing and increases dough viscosity, thereby limiting biscuit spread. A reduced spread ratio seen in CF biscuits increases their suitability for rotary mold preparation in which a lower spread is desirable to keep the embossing intact (Hooda and Jood 2005).

A significant ($p \le 0.05$) reduction in % weight loss on baking of CF biscuits was observed when compared with C biscuits. Among the CF flours of the same combination, no significant ($p \le 0.05$) difference was found in the weight loss. The main proportion of the weight loss during baking is due to the evaporated water. The lower weight loss in CF formulations can be ascribed to the higher accessibility of the water to flour components resulting in less free water remaining in the biscuits, to be evaporated during baking. A lower weight loss is desirable for retaining its shape and its components to baking (Rodriguez-Garcia et al. 2012).

Nutritional analysis of biscuits The moisture, protein, fat and ash content of biscuits made from both types of CFs were significantly ($p \le 0.05$) higher than C biscuits (Table 3). The higher protein content of CF biscuits was probably due to the protein rich ingredients in flours like green gram, soy protein isolate, roasted peanuts and dairy ingredient. Among CF I and CF II biscuits, the latter had significantly ($p \le 0.05$) higher protein, probably due to the presence of sorghum which has a higher protein content (Haikerwal and Mathieson 1971) compared to finger millet (Singh and Raghuvanshi 2012). The moisture content of CF biscuit as compared to C was higher which could be due to the higher amount of water required during dough making due to its high protein content. Flours rich in protein need more water to obtain a machinable cookie dough as the proteins are not hydrated enough to form a network (Zucco et al. 2011). Among CF flours CF I and II B required significantly ($p \le 0.05$) higher water for preparation of dough, probably due to sprouted green gram. Sprouting is known to break the bio-molecules into smaller subunits resulting in more available water binding sites (Dev and Quensil 1988) increasing the requirement of water to make a dough. Fat content of CF biscuits was significantly ($p \le 0.05$) higher than C biscuits which could be due to high fat ingredients like corn flour and roasted peanuts. Sprouting significantly ($p \le 0.05$) reduced the fat content in CF biscuits which is attributed to fat utilization in the sprouting process as energy sources (Kumar et al. 2006; Bau et al. 1997). Ash content of CF was significantly higher than C biscuits due to finger-millet and sorghum present and with CF biscuits the finger millet biscuits showed higher ash content as finger millet is known to have higher mineral content as compared to sorghum, (Singh and Raghuvanshi 2012). Sprouting of green gram and malting of finger millet was found to significantly ($p \le 0.05$) increase the ash content in both CFI and II biscuits, which is in agreement with results obtained by Shah et al. 2011. Thus, the nutritional value of CF biscuits was better than C biscuit which was further enhanced by the sprouting process.

Texture of dough and biscuits The values of firmness and stickiness of dough and hardness and cutting strength of biscuits are shown in Table 4. Curves for dough firmness as obtained from penetration test and dough stickiness from stickiness test has been presented in Fig. 2a and b, respectively. Dough firmness, dough stickiness and cohesiveness (dough strength), was found to be significantly lesser ($p \le 0.05$) in all types of CFs dough compared to the C dough. Reduced dough firmness is related to the high fat content in formulations which disrupts the gluten network development lubricating the entire matrix and making it hydrated (O'Brien et al. 2003; Rodriguez-Garcia et al. 2012). Sprouting results in swelling and fading of cell wall (Autio et al. 1998) which resulted in lower firmness value in CF I and II B dough making sprouted dough softer than dough made from C flour (Hussain et al. 2011).

Stickiness is an important factor that affects handling convenience in dough processing. Sticky dough is considered troublesome since it may cause damage to machinery (Tseng and Lai 2002). Sprouted flour dough had lowest stickiness value when compared with their un-sprouted counterparts or C flour, owing to their high water absorption capacity. Lower dough stickiness and corresponding work of adhesion are related to the higher water absorption capacity and the higher fat content of the CFs.

Figure 3a shows the hardness curve obtained for various biscuits. Hardness of biscuits measured by three point bending test was found to be significantly higher

Table 4 Texture of biscuit dough and color and texture of biscuits

Sample	Dough				Biscuits				
	Firmness (N)	Stickiness (N)	Work of adhesion (N-s) ($\times 10^{-3}$)	Dough strength (mm)	L*	a*	b*	Cutting strength (N)	Hardness (N)
CF I A	3.66±0.09[b]	0.14±0.01[a]	3.42±0.2[b]	0.34±0.02[b]	63.77±1.7[a]	10.89±0.43[b]	35.08±1.31[b]	42.05±3.2[b]	16.12±0.97[a]
CF I B	3.50±0.06[a]	0.10±0.03[a]	3.10±0.4[a]	0.28±0.03[a]	63.80±0.81[a]	11.77±0.50[b]	36.98±0.60[b]	38.24±1.68[a]	17.22±1.88[b]
CF II A	3.70±0.05[b]	0.16±0.13[a]	3.30±0.36[b]	0.40±0.07[bc]	71.92±0.85[b]	12.58±0.92[c]	42.52±0.58[c]	41.80±1.11[b]	15.96±1.44[a]
CF II B	3.61±0.03[ab]	0.11±0.05[a]	2.90±0.16[a]	0.33±0.02[b]	72.29±0.96[b]	12.75±0.40[c]	42.86±1.92[c]	37.7±2.45[a]	16.98±1.9[b]
Control	4.52±0.06[c]	0.23±0.01[b]	4.90±0.4[c]	0.53±0.13[c]	83.45±0.80[c]	7.29±0.17[a]	32.54±0.24[a]	61.97±1.62[c]	15.05±0.77[a]

Mean ± SD, results are the average of six replicates; for each analysis, data followed by different letters in the same column are significantly different ($p \leq 0.05$)

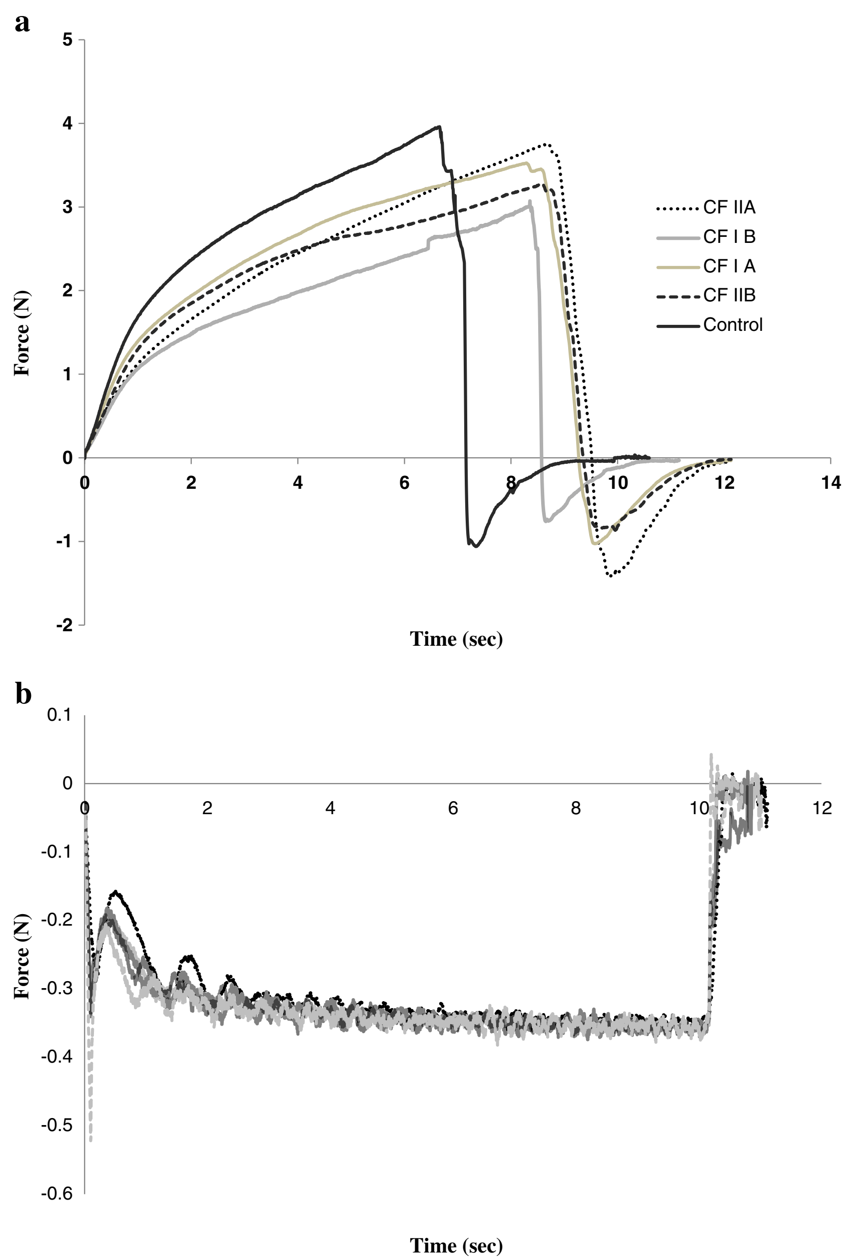

Fig. 2 **a** Curve for dough firmness of CF and refined wheat flour **b** Curve for stickiness of composite flours CF IA (▬▬), CF IB (▬▬), CF II A(‒ ‒ ‒), CF IB (‒ ‒ ‒) and refined wheat flour (⋯⋯)

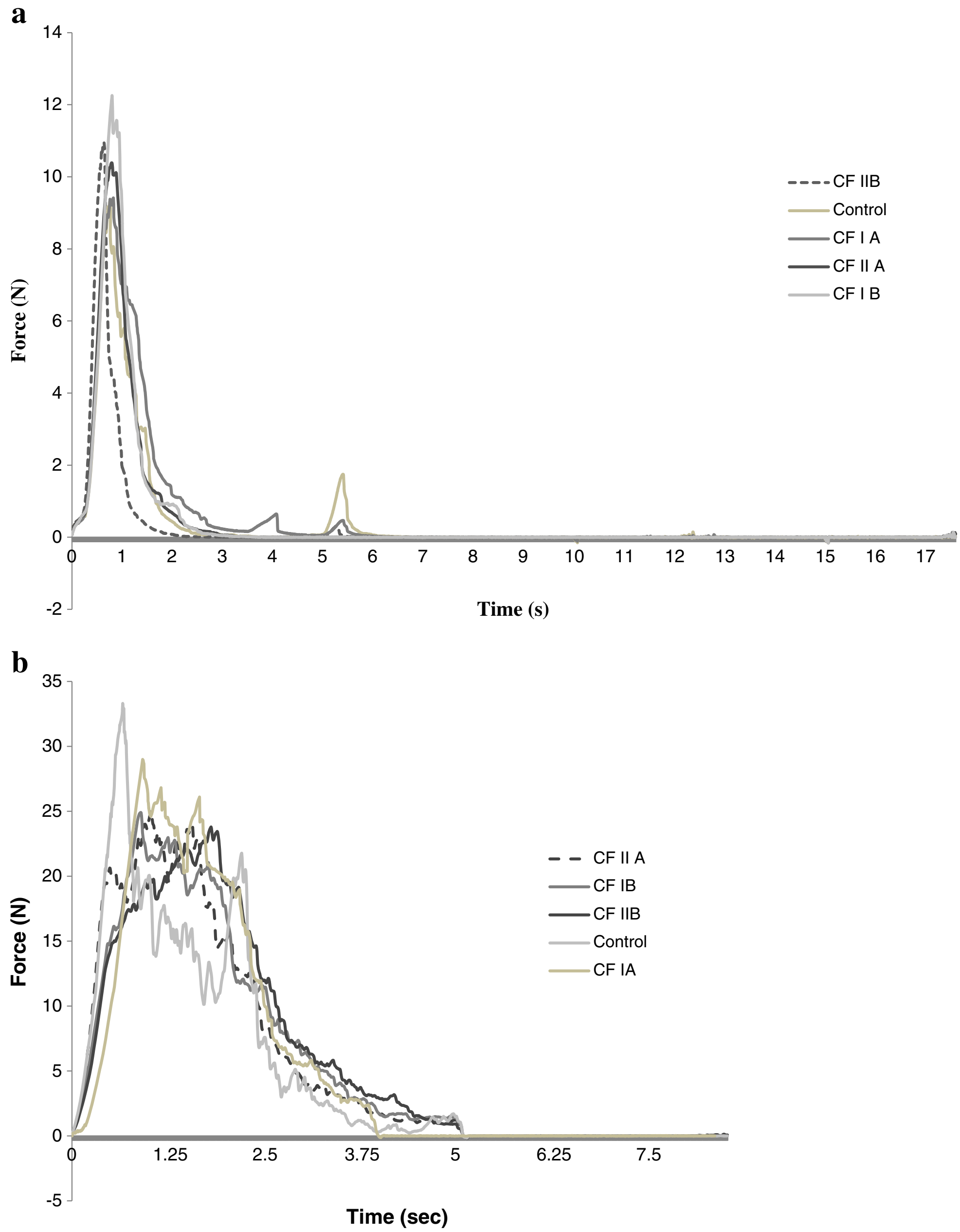

Fig. 3 **a** Curves for 3-pt bending test (Hardness) of biscuits from composite flours and refined wheat flour **b** Curves for cutting strength of biscuits from composite flours and refined wheat flour

($p \leq 0.05$) for CF biscuits as compared to C biscuits which could be due to the high protein content of C and their ability to absorb more water. The sprouted flour biscuits were found to be further harder as compared to un-sprouted flour biscuits due to the free sugars available on sprouting. Olewnik and Kulp 1984 described that sugar present in flour crystallizes on cooling, causing hardening effects on the biscuit. Similar results have been reported by Gallagher et al. 2005; Zucco et al. 2011. The cutting strength of various biscuits has been shown in Fig. 3b. The cutting strength was found to be lower for CF biscuits when compared with C biscuits with the lowest cutting strength being for sprouted flours which is due to weaker gluten network which reduced the dough cohesiveness and strength and ultimately a lower cutting strength.

Color analysis Color of the biscuit samples, expressed in terms of tri-stimulus attributes, L*, a* and b* values, has been presented in Table 4. Significant difference was found in the color parameters for all three biscuits. The L* value of all CF's biscuits were lower than C biscuits indicating darker color due to the nature of ingredients. CF II had higher L values compared to CF I biscuits as sorghum in CF II is lighter than finger

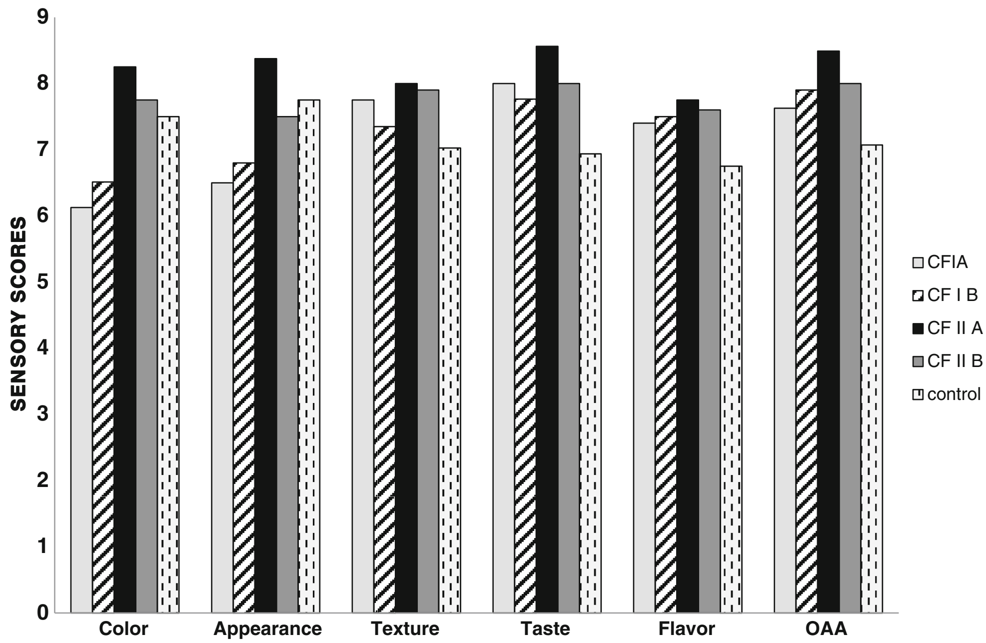

Fig. 4 Sensory evaluation of biscuits from composite flours and refined wheat flour

millet in CF I whose seed coat turns darker on heat treatment (Krishnan et al. 2011). CF biscuits also had higher protein content than C which is known to have a negative correlation with L* value (Mamat et al. 2010). The positive a* value represents redness and high a* values were found for both CF biscuits. A positive b* value is a measure of the yellowness. The surface color of biscuits was found to be significantly ($p \leq 0.05$) yellower in CF biscuits than C biscuits due to the presence of corn flour in all the CFs (Ergin and NurHerken 2012). Among CF I and CF II biscuits significant difference in b* values can be due to sorghum flour which is lighter in color compared to finger millet flour.

Sensory analysis The organoleptic acceptability of biscuits on a 9 point Hedonic scale is given in Fig. 4. The scores obtained for OAA for all types of CF biscuits were significantly ($p \leq 0.05$) higher than C biscuits. Texture scores for all types of CF biscuits were on an average 9 % more than the C biscuits. Thus, the higher hardness in CF biscuits as found on texture analysis was more acceptable due the probability of being perceived as more crunchy. Similarly, taste of CF biscuits which is an extremely important parameter for consumer acceptance was 14 % more than the C. Flavor which is a combined effect of taste and after-taste of biscuits was found to be similar for all types of CF biscuits. Among the various CF biscuits, CF II A biscuit obtained highest score with respect to all sensory attributes. CF IA and IB biscuits which were darker in color recorded the lowest score for color and appearance. However on an average they were 9%more acceptable than control biscuits indicating that CFs biscuits had more subjective acceptability than C biscuits.

Conclusion

Multi-nutrient biscuits made from both types of composite flours (CFI and CFII) were found to be superior to the refined wheat flour biscuits with respect to physical, nutritional, texture and sensory attributes. CF biscuits had lower spread ratio, higher protein and fiber, were harder and had a lower cutting strength. Even though the CF biscuits were darker in colour due to basic nature of the ingredients, they had higher organoleptic acceptability on the 9 point hedonic scale. Sprouting of green gram and malting of finger-millet had major effect on nutritional quality of biscuits and texture of biscuit dough. Decrease in hardness of dough due to sprouting resulted in reduced cutting strength and increased hardness of corresponding biscuits. The taste, texture and OAA scores of CF biscuits were higher than the control biscuits making them more acceptable on sensory scale. Thus, it can be concluded that biscuits made from sprouted composite flours can be accepted as a healthy snack.

References

Agrahar-Murugkar D, Jha K (2009) Effect of sprouting on nutritional and functional characteristics of soybean (*Glycine max* L). J Food Sci Technol 46(3):240–243

Agrahar-Murugkar D, Jha K (2010) Effect of drying on the nutritional and functional quality and electrophoretic pattern of soy flour from sprouted soybean (*Glycine max*). J Food Sci Technol 47(5):482–483

Agrahar-Murugkar D, Jha K (2011) Influence of storage and packaging conditions on the quality of soy flour from sprouted soybean. J Food Sci Technol 48(3):325–328
Agrahar-Murugkar D, Kotwaliwale N, Kumar M, Gupta C (2013) Effect of roasting parameters on soy-butter product quality. Int J Food Sci Technol 48:1359–1365
AOAC (2005) Method 920.87. Official methods of analysis. association of official analytical chemists, 14th edn. AOAC, Arlington
Autio K, Fabritius M, Kinnunen A (1998) Effect of germination and water content on the Micro-structure and rheological properties of two rye doughs. Cereal Chem 75:10–14
Bau H, Villaume C, Nicolas J, Mejean L (1997) Effect of germination on chemical composition, biochemical constituents and anti-nutritional factors of soya bean (*Glycine max*) seeds. J Sci Food Agric 73(1):1–9
Bose D, Shams-Ud-Din S (2010) The effect of chickpea (*Cicer arietinim)* husk on the properties of cracker biscuits. J Bangladesh Agric Univ 8(1):147–152
Bourne M (2002) Food texture and viscosity: concept and measurement. Academic, New York, pp 353–368
Dev DK, Quensil E (1988) Preparation and functional properties of Linseed protein products containing differing levels of vegetable protein products. J Food Sci 40:805
Ergin A, Nurherken E (2012) Use of various flours in gluten-free biscuits. J Food Agric Environ 10(1):128–131
Gaines CS, Donelson JR, Finney PL (1988) Effects of damaged starch, chlorine gas, flour particle size and dough holding time and temperature on cookie dough handling properties and cookie size. Cereal Chem 65(5):384–389
Gallagher E, Kenny S, Arendt EK (2005) Impact of dairy protein powders on biscuit quality. Eur Food Res Technol 221:237–243
Ghavidel RA, Prakash J (2007) The impact of germination and de-hulling on nutrients, anti-nutrients in vitro iron and calcium bioavailability and in vitro starch and protein digestibility of some legume seeds. Lebensm Wiss Technol 40(7):1292–1299
Haikerwal M, Mathieson AR (1971) The protein content and amino acid composition of sorghum grain. AACC 48:690–699
Hooda J, Jood S (2005) Organoleptic and nutritional evaluation of wheat biscuits supplemented with untreated and treated fenugreek flour. Food Chem 90:427–435
Hu H, Wu J, Li-Chan ECY, Zhang F, Xu X, Fan G, Wang L, Huang X, Pan S (2013) Effects of ultrasound on structural and physical properties of soy protein isolate (SPI) dispersion. Food Hydrocoll 30: 647–655
Hussain S, Anjum FM, Alamri MS (2011) Fortification of pan bread with healthy flaxseed. Aus J Basic Appl Sci 5:978–983
Krishnan R, Dharmaraj U, Manohar RS, Malleshi NG (2011) Quality characteristics of biscuits prepared from finger millet seed coat based composite flour. Food Chem 129:499–506
Kumar V, Rani A, Chauhan GS (2006) Influence of germination temperature on oil content and fatty acid composition of soy sprouts. J Food Sci Technol 43:325–326
Mamat H, Hardan MOA, Hill SE (2010) Physico-chemical properties of commercial semi-sweet biscuit. Food Chem 121:1029–1038
Manley DJR (2000) Technology of biscuits, crackers and cookies, 3rd edn. Woodhead Publishing, Cambridge
Marwin M, Abdul-hamid A, Baharin BS, Anwar F, Basu MC, Pak-dek MS (2011) Phenolic compounds and anti-oxidant activity of peanut's skin, hull, raw kernel and roasted kernel flour. Pak J Bot 43(3): 1635–1642
McGuire RG (1992) Reporting of objective color measurements. Hortic Sci 27:1254–1255
Mcwatters KH (1978) Cookie baking properties of defatted peanut, soybean, and field pea flours. Cereal Chem 55:853–863
Nagi HPS, Kaur J, Dar BN, Sharma S (2012) Effect of storage period and packaging on the shelf life of cereal bran incorporated biscuits. Am J Food Technol 7(5):301–310
O'Brien CM, Chapman D, Neville DP, Keogh MK, Arendt EK (2003) Effect of varying the microencapsulation process on the functionality of hydrogenated vegetable fat in short dough biscuits. Food Res Int 36:215–221
Olewnik MC, Kulp K (1984) The effect of mixing time and ingredient variation on farinograms of cookie dough. Cereal Chem 61:532–537
Patel MM, Rao GV (1996) Effect of untreated, roasted, and sprouted black gram (*Phaseolus mungo*) flours on the physico-chemical and biscuit (cookie) making characteristics of soft wheat flour. J Cereal Sci 22:285–291
Raina CS, Singh S, Bawa AS, Saxena DC (2005) Textural characteristics of Pasta made from rice flour supplemented with proteins and hydrocolloids. J Texture Stud 36(4):402–420
Rodriguez-Garcia J, Laguna L, Puig A, Salvador A, Hernando I (2012) Effect of fat replacement by inulin on textural and structural properties of short dough biscuits. Food Bioprocess Technol. doi:10.1007/s11947-012-0919-1
Shah SA, Zeb A, Masood T, Noreen N, Abbas SJ, Samiullah M, Muhammad A (2011) Effects of sprouting time on biochemical and nutritional qualities of mung-bean varieties. Afr J Agric Res 6(22):5091–5098
Singh P, Raghuvanshi RS (2012) Finger millet for food and nutritional security. Afr J Food Sci 6(4):77–84
Singh B, Bajaj M, Kaur A, Sharma S, Sidhu JS (1993) Studies on the development of high protein biscuits from composite flours. Plant Foods Hum Nutr 43(2):181–189
Tseng CS, Lai HM (2002) Physico-chemical properties of wheat flour dough modified by microbial transglutaminase. J Food Sci 67(2): 750–755
Tyagi SK, Manikantan MR, Oberoi HS, Kaur G (2007) Effect of mustard flour incorporation on nutritional, textural and organoleptic characteristics of biscuits. J Food Eng 80:1043–1050
Viswanath V, Urooj A, Malleshi NG (2009) Evaluation of antioxidant and antimicrobial properties of finger millet polyphenols (*Eleusine coracana*). Food Chem 114:340–346
Wilson JD, Bechtel DB, Todd TC, Seib PA (2006) Measurement of wheat starch granule size distribution using image analysis and laser diffraction technology. Cereal Chem 83(3):259–268
Zucco F, Borsuk Y, Arntfield SD (2011) Physical and nutritional evaluation of wheat cookies supplemented with pulse flours of different particle sizes. Lebensm Wiss Technol 44:2070–2076