Mahsa Majzoobi*, Safora Pashangeh, and Asgar Farahnaky

Effect of Different Particle Sizes and Levels of Wheat Bran on the Physical and Nutritional Quality of Sponge Cake

Abstract

To increase the dietary fiber of sponge cake, it was enriched with wheat bran of different levels (0, 5, 10, 15, and 20%, w/w; flour basis) and particle sizes (90, 170, 280, and 420 μm). The results showed that both crude fiber and phytic acid contents of the bran decreased with the reduction in the particle size. Batter density increased whereas batter consistency decreased with increase in the particle size and the level of the bran. The crust and crumb color became darker, more reddish and less yellowish as the level and particle size of the bran increased. Density of the cakes decreased as higher percentages and coarser brans were included. Determination of the textural properties of the cakes using texture profile analysis technique showed that with increase in the percentage of wheat bran, hardness, gumminess, and chewiness increased whereas, cohesiveness and springiness decreased. According to the taste panel, using no more than 10% bran with particle size smaller than 170 μm resulted in cakes similar to the-control. The total dietary fiber and phytic acid content of the resultant cakes was 5.95% and 2.90 (mg/g), respectively.

Keywords: sponge cake, dietary fiber, particle size, wheat bran, phytic acid

***Corresponding author: Mahsa Majzoobi**, Shiraz University, Shiraz, Iran, E-mail: majzoobi@shirazu.ac.ir
Safora Pashangeh, Shiraz University, Shiraz, Iran, E-mail: pashangeh-s@yahoo.com
Asgar Farahnaky, Shiraz University, Shiraz, Iran, E-mail: farahnak@shirazu.ac.ir

Introduction

The positive effects of dietary fibers including cellulose, hemicelluloses, lignin, pectin and gums on human health have been well documented. Fiber increases the bulk of the food and moves it through the gastrointestinal tract more rapidly and helps in preventing constipation and possible colon and rectal cancer [1]. Diets of low fiber intake are correlated to conditions such as diabetes, atherosclerosis, breast cancer, diverticulitis, hemorrhoids and obesity [2]. Accordingly, it is generally recommended to take about 20–35 g of dietary fiber in the daily diet. Therefore, production of high-fiber foods is increasing in the market and fiber content of foods has now become the third most sought-after health information in supermarkets in countries like India, Australia, Western Europe, and North America [3].

Wheat bran is a low-cost and plentiful source of dietary fiber (36–52%) [4, 5]. It also contains high-quality proteins, vitamins and minerals. Furthermore, wheat bran has a strong antioxidant activity. The main antioxidative components in the bran are ferulic, vanillic, and *p*-coumaric acid [6, 7]. However, the presence of phytic acid in the bran (35–50 mg/g) and its negative effects on bioavailability of minerals such as iron, calcium, magnesium and zinc, proteins and carbohydrate digestibility, and lipid availability have limited its applications [8, 9]. Therefore, there are concerns over foods containing high level of bran. For two most consumed foods; wheat bread and pasta, values of 3.2–7.3 and 0.7–9.1 mg/kg of phytic acid were reported, respectively [10]. To reduce the phytic acid content of wheat bran, different methods have been established including reduction of the particle size, fermentation, and hydrothermal processing of the bran [11, 12].

Bakery products are amongst the most consumed food products, and hence are a suitable means to deliver fibers in human diet. Cakes are one of the most favorite ready to eat foods which are generally produced from white wheat flour, and hence are low in dietary fiber. With the aim of increasing the fiber content of cakes, fiber from vegetables (e.g. potato by-product, fruits (e.g. apple pomace), legumes (chickpea flour), and resistant starch were added in the cake recipe [13–18]. Cereal bran and whole meal grains were also used as sources of fiber in the cakes. For instance, wheat and oat bran of varying particle sizes and percentages were included in the cake recipe [19, 20]. These studies show the interest on production of high-fiber cakes, however, some of these studies have indicated the adverse effects of fibers on cake textural properties and consumer acceptability. Particle size and percentage of the bran have great influence on the textural and organoleptic properties of the products [19–22]. Furthermore, the presence of phytic acid in the cereal bran and legumes is a matter of concern when they are added to the cakes. Thus, when increasing the fiber content of the foods, attempts should be made to reduce the level of phytic acid intake in the diet as well, which has received less attention in the literature.

The main aim of this study was to increase the fiber content of sponge cakes by addition of wheat bran to the cake recipe. Since the amount of phytic acid and the physicochemical properties of the cakes are affected by the percentage and particle size of the bran, different levels and particle sizes were tested to obtain cakes with characteristics similar to those produced from white wheat flour.

Materials and methods

Materials

Wheat bran with particle size of about 1,000 μm was gifted by Sepidam milling factory in Zarghan, Fars, Iran. To obtain different particle sizes of the bran, it was first milled using a laboratory mill (Alexander Werck, Model WEL82, Germany) and then sieved manually to obtain average particle sizes of 420, 280, 170, and 90 μm. Cake ingredients including wheat cake flour, sugar, corn oil, fresh semi-skimmed milk, fresh whole eggs, baking powder (Hermin, Karaj, Iran), and vanilla powder were purchased from local market. Chemicals used for analytical tests were obtained from Merck, Darmstadt, Germany.

The cake flour contained 11.50 ± 0.30% moisture content, 9.35 ± 0.40% protein (N × 5.7), 0.43 ± 0.20% fat, 0.52 ± 0.10% ash, and 78.20 ± 0.30% total carbohydrate content. Wheat bran had 10.90 ± 0.00% moisture content, 11.50 ± 0.10% protein (N × 5.7), 3.50 ± 0.10% fat, 4.39 ± 0.00% ash, and 69.71 ± 0.20% total carbohydrate content as determined by the approved methods of the AACC [23].

Determination of total, soluble, and insoluble dietary fiber

The amount of insoluble dietary fiber and total dietary fiber of the bran was determined according to the gravimetric enzymatic method, and the soluble dietary fiber content was calculated by subtraction [24].

Determination of the phytic acid content

Phytic acid was determined based on complexometric titration of residual iron (III) after phytic acid precipitation. Based on the procedure, bran (2 g) was stirred with 40.0 ml of extraction solution (10 g/100 g Na_2SO_4 in 0.4 mol/l HCl) using a magnetic stirrer for 3 h at ambient temperature. The suspension was centrifuged at 4,200 g for 30 min and the supernatant was filtered. Ten milliliters of supernatant (containing between 3.3 and 9.0 mg of phytic acid) was transferred into a 100-ml centrifuge tube together with 10.0 ml of 0.4 mol/l HCl, 10.0 ml of 0.02 mol/l $FeCl_3$ and 10.0 ml of 20 g/100 g sulphosalicylic acid, shaken gently, and the tube used was sealed with a rubber cork through which passes a narrow 30-cm-long glass tube, to prevent evaporation. The tube was placed in a boiling water bath for 15 min, then cooled down at room temperature. The sample was centrifuged at 4,200 g for 10 min, decanted, filtered, and the residue was washed several times with distilled water. The supernatant and washed fractions were diluted to 100.0 ml. An aliquot (20.0 ml) adjusted to pH 2.5 by addition of glycine was diluted to 20 ml. The solution was heated at 70–80 °C and while still warm, titrated with 50 mmol/ 1 EDTA solution. The 4:6 Fe/P atomic ratio was used to calculate phytic acid content [25].

Batter and cake preparation

Cake flour was replaced with bran at different levels 0, 5, 10, 15, and 20% for each particle size, separately. Then, the flour was mixed with other cake ingredients in a sponge cake recipe of 250 g flour blend, 180 g sugar, 200 g fresh milk, 100 g egg, 125 g corn oil, 10 g baking powder and 1 g vanilla. To prepare cake batter, eggs, vanilla, and sugar were whipped together by batter mixer (Moulinex, Model HM 1010, Beginning, China) until a semi-firm foam was resulted. The foam was mixed with fresh milk, after which the flour blend and baking powder were added in small portions, and then the corn oil was included. Cake batter (150 g) was poured into an aluminum pan (18 × 9 × 8 cm) and baked at 190°C in an electrical oven (Karl Welkerkg, Venusbergstr, Germany) until a golden crust was formed (40 min). Cakes were cooled down at room temperature for 1.5 h, packed and sealed in polypropylene bags, and then stored at ambient temperature (20 ± 2°C) before the experiments. The weight of the cakes was 120.00 ± 0.02, with moisture content of 32.5 ± 0.2% as determined according to the approved methods of the AACC [23].

Batter density

Batter density was determined with a measuring cylinder by determination of the relation between the weight of the batter and the same volume of distilled water [26, 27].

Batter Bostwick number

Cake batter (100 g) with temperature of 18 ± 0.5°C was poured in the reservoir of a Bostwick consistometer and left for 2 min, and then the distance moved by the batter (cm) during 15 s was determined. The higher values correspond to the lower batter consistency [27].

Cake density

The volume of a constant weight of a cake was measured by rapeseed displacement method based on the approved methods of the AACC [23]. Knowing the volume of the cakes, the density was determined by dividing cake weight to its volume.

Textural properties

The textural characteristics of the cakes were studied using a Texture Analyser (TA-XT2, Stable Micro Systems Ltd., Surrey, UK). Texture Profile Analysis (TPA) test was carried out by performing a two bite compression test at pretest speed of 5 mm/s, test speed of 0.25 mm/s, time interval of 10 s, and strain deformation of 25%. To determine the texture of the cakes, 1 cm of the top of the cake was removed to make the surface leveled off, and then the rest of the sample was tested using an aluminum cylindrical probe with a diameter of 75 mm. From the force–distance curve (Figure 1), the ratio of the positive area under the first and second compression was defined as cohesiveness (A2/A1). The distance that the food recovered its height during the time that elapsed between the end of first bite and the start of second bite was defined as springiness (elasticity). The slope (gradient) of force–deformation curve and maximum force of first bite of TPA test (F1) were taken as indications of crumb

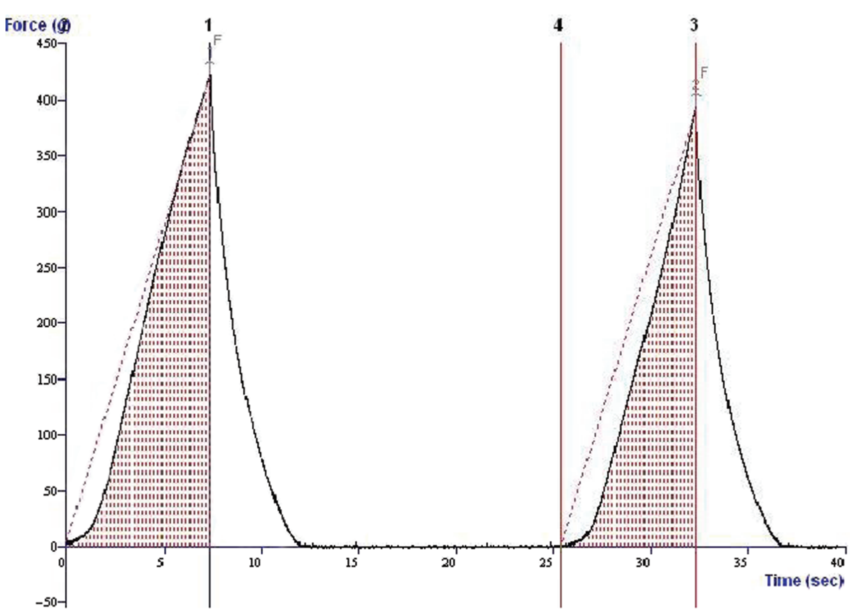

Figure 1 Force vs. time of a typical texture profile analysis of the cakes. Interpretation of texture parameters from a complete record: Hardness: F1; Cohesiveness: A2/A1 and Springiness: t2/t1.

hardness. Springiness was obtained from the ratio of the second peak time to the first peak time (t2/t1) [28].

Crust and crumb color

The color parameters of the cakes crust and crumb were evaluated using digital imaging method [29]. High-resolution pictures of the samples were taken separately by a digital camera (Finepix, Model JZ300, Beijing, China). Resolution, contrast, and lightness of all images were set to 300 dpi, 62%, and 62%, respectively. To determine the crust color, pictures were taken from the whole crust, whereas to determine the crumb color the sample was sliced horizontally from the middle of the cakes and then the pictures were taken. The pictures were saved in JPEG format and analyzed quantitatively using the Adobe Photoshop 8 software and the color parameters of L (lightness), a (greenness–redness) and b (blueness–yellowness) values were determined in the "Lab" mode of the software.

Sensory analysis

Cakes were served to 12 in-house semi-trained panelists (6 males and 6 females, age between 20 and 35 years) and were evaluated for color, texture, taste, and overall acceptability using a ranking test. The panelists were asked to compare the samples and score them from 0 (for the worst) to 5 (for the best) sample. All the sensory tests were performed in isolated standard booths under standard conditions [30]. To study the effect of bran percentages, a set of experiments was performed by evaluating cakes prepared with different percentage of bran (0–20%) and particle sizes of 420 μm (as the largest size) and 90 μm (as the smallest size). To determine the effect of particle size, cakes containing varying particle sizes at 10% bran were evaluated.

Statistical analysis

The experiments were performed in a completely randomized design and conducted in triplicates, and the mean values and standard deviations were calculated. Analysis of variance (ANOVA) was performed and the results were separated using the Multiple Ranges Duncan's test ($\alpha < 0.05$) using statistical software of SPSS 16 [31].

Results and discussion

The results (Table 1) showed that the bran of original particle size (i.e. ~1,000 μm) had 50.15 ± 2.85 mg/g phytic acid. The phytic acid content of wheat bran varies between 25 and 50 mg/g depending on the wheat variety and method of determination [10]. With reduction in the particle size, the phytic acid content decreased significantly, so that the phytic acid content of the bran with the finest size was 21.60 ± 1.42 mg/g. Therefore, the phytic acid reduction was up to 56.92% for the smallest bran size. It has been reported that the phytic acid content of the coarse bran was significantly higher than the phytic acid content of the fine bran [11]. Phytic acid content of 48.2 mg/g for large, 39.8 mg/g for medium, and 29.5 mg/g for small bran was reported using similar methods for determination of phytic acid [32].

Determination of the dietary fiber content of the samples showed that the bran had more insoluble dietary fibers than soluble dietary fibers. Furthermore, with decrease in the size of the bran, total, soluble, and insoluble dietary fiber content reduced, significantly (Table 1). For example, total dietary fiber content of the bran with largest particle size was 69.7% and it reduced to 32.2% for the finest bran. Similar results were reported [33]. After milling and sieving, the fine bran is obtained from the inner layers of the bran since these layers have softer and more fragile texture, while the larger particle sizes are obtained from the outer layers which have harder structure and cannot be readily milled into smaller particle sizes. The chemical composition of the inner layers of the bran is different from those of out layers. The outer layers contain more fiber and minerals than the inner layers.

Table 1 Phytic acid, total, soluble, and insoluble fibers of different particle sizes of wheat bran*.

Particle size (μm)	Phytic acid content (mg/g)	Total dietary fiber (%)	Soluble dietary fiber (%)	Insoluble dietary fiber (%)
~1,000	50.15 ± 2.85^{a}	69.7 ± 0.2^{a}	12.3 ± 0.1^{a}	57.4 ± 0.3^{a}
420	43.88 ± 2.85^{b}	68.3 ± 0.2^{b}	12.1 ± 0.1^{b}	56.2 ± 0.1^{b}
280	35.63 ± 2.85^{c}	61.2 ± 0.4^{c}	11.2 ± 0.0^{c}	50.0 ± 0.2^{c}
170	29.03 ± 2.85^{d}	59.1 ± 0.3^{d}	10.8 ± 0.2^{d}	48.3 ± 0.4^{d}
90	21.60 ± 1.42^{e}	32.2 ± 0.3^{e}	7.9 ± 0.2^{e}	24.3 ± 0.3^{e}

*Values are the average of triplicates ± standard deviation. Different letters in each column show significant statistical difference ($\alpha < 0.05$).

Table 2 Physical characteristics of cake batter containing different levels and particle sizes of wheat bran*.

Particle size (μm)	0% bran	5% bran	10% bran	15% bran	20% bran
Density (g/cm^3)					
420	$1.03 \pm 0.00^{A\ d}$	$1.08 \pm 0.00^{A\ c}$	$1.09 \pm 0.00^{A\ c}$	$1.10 \pm 0.00^{A\ b}$	$1.10 \pm 0.00^{A\ a}$
280	$1.03 \pm 0.00^{A\ d}$	$1.06 \pm 0.00^{B\ c}$	$1.08 \pm 0.00^{B\ b}$	$1.09 \pm 0.00^{A\ a}$	$1.09 \pm 0.00^{B\ a}$
170	$1.03 \pm 0.00^{A\ e}$	$1.04 \pm 0.00^{C\ d}$	$1.07 \pm 0.00^{C\ c}$	$1.07 \pm 0.00^{B\ b}$	$1.08 \pm 0.00^{C\ a}$
90	$1.03 \pm 0.00^{A\ d}$	$1.02 \pm 0.00^{D\ e}$	$1.04 \pm 0.00^{D\ c}$	$1.06 \pm 0.00^{C\ b}$	$1.08 \pm 0.00^{C\ a}$
Batter Bostwick number (cm)					
420	$7.42 \pm 0.01^{A\ a}$	$7.19 \pm 0.00^{D\ b}$	$7.02 \pm 0.02^{D\ c}$	$6.85 \pm 0.00^{D\ d}$	$6.69 \pm 0.00^{D\ e}$
280	$7.41 \pm 0.01^{A\ a}$	$7.29 \pm 0.01^{C\ b}$	$7.14 \pm 0.01^{C\ c}$	$6.98 \pm 0.00^{C\ d}$	$6.81 \pm 0.01^{C\ e}$
170	$7.40 \pm 0.01^{A\ a}$	$7.35 \pm 0.00^{B\ b}$	$7.28 \pm 0.01^{B\ c}$	$7.13 \pm 0.01^{B\ d}$	$7.03 \pm 0.01^{B\ e}$
90	$7.42 \pm 0.01^{A\ a}$	$7.40 \pm 0.01^{A\ a}$	$7.37 \pm 0.01^{A\ b}$	$7.29 \pm 0.02^{A\ c}$	$7.16 \pm 0.01^{A\ d}$

*Values are the average of triplicates ± standard deviation. Different capital letters in each column and small letters in each row (for each characteristic) indicate significant statistical difference ($\alpha < 0.05$).

The results (Table 2) showed that the batter density increased with increasing bran level. Inclusion of the smaller size bran reduced the density of the batter. Moreover, the results showed that increasing bran percentage had a negative effect while decreasing particle size had a positive effect on the batter Bostwick number. Therefore, inclusion of higher level of bran increased batter consistency while reducing the particle size decreased batter consistency. Bran contains high level of fiber and proteins (hydrocolloids) which can absorb the water of the batter and hence increase batter consistency. The hydrocolloids present in the bran may also interact with the biopolymers present naturally in the flour (starch, proteins, and pentosans) and form a network which can trap some water, reducing the fluidity of the batter. It has been indicated that coarse bran can significantly retain more water than medium or fine bran [22]. It has been reported that batter made with the coarser fiber can entrap less amount of air resulting in higher density [34]. Higher-batter viscosity has been obtained when higher levels of apple pomace with smaller particle size were used [16].

Consistency and density of cake batter have some influence on the volume of the cakes. Batter of high density and consistency is not suitable for cake making, since it does not let enough air bubbles to form during batter mixing and can impede expansion [20, 35]. On the other hand, batter of too low consistency results in low-cake volume as the air bubbles (trapped in the batter during mixing) and CO_2 (produced from baking powder) will escape quickly during baking [35]. Moreover, large starch granules sink easily in a batter of low density and accumulate at the bottom of the batter. As a result, a rubbery layer is formed underneath the cake resulting in the inferior cake quality.

From the results (Table 3), it was found that the cake density decreased with increase in the bran percentage whereas it increased with decreasing bran particle size. In general, cake density is negatively correlated with its volume. Previous results of this study (Table 2) showed that batter density increased with increasing bran level and particle size. The denser batter can hold more air bubbles and CO_2, and release them more slowly during cooking resulting in a higher-cake volume (less density). Different results were found in the literature; some authors reported a negative correlation between the cake volume and fiber content [13, 36], whereas others found a positive correlation between these parameters [34]. Such contradiction can be related to the different recipes used and the kind of fiber used as well as the influence of the fiber on the consistency of the batter. A small increase of batter consistency could assist the retention of gases and

Table 3 Density of the cakes containing different levels and particle sizes of wheat bran*.

Particle size (μm)	0%	5%	10%	15%	20%
420	$0.315^{A\ a}$	$0.311^{A\ b}$	$0.307^{B\ c}$	$0.302^{C\ d}$	$0.301^{C\ d}$
280	$0.315^{A\ a}$	$0.312^{A\ b}$	$0.308^{B\ c}$	$0.305^{C\ d}$	$0.304^{B\ d}$
170	$0.315^{A\ a}$	$0.313^{A\ b}$	$0.310^{A\ c}$	$0.307^{B\ d}$	$0.305^{B\ e}$
90	$0.315^{A\ a}$	$0.314^{A\ a}$	$0.312^{A\ b}$	$0.310^{A\ b}$	$0.309^{A\ c}$

*Values are the average of triplicates. Different capital letters in each column and small letters in each row indicate significant statistical difference ($\alpha < 0.05$).

Table 4 Crust color parameters of cakes containing different levels and particle sizes of wheat bran*.

Particle size (μm)	0% bran	5% bran	10% bran	15% bran	20% bran
			***L*-value**		
420	$80.00 \pm 0.00^{A\ a}$	$79.04 \pm 0.10^{B\ a}$	$78.00 \pm 0.00^{B\ b}$	$76.34 \pm 0.20^{C\ c}$	$75.07 \pm 0.06^{C\ d}$
280	$80.00 \pm 0.00^{A\ a}$	$79.96 \pm 0.05^{A\ a}$	$79.01 \pm 0.01^{A\ b}$	$78.34 \pm 0.20^{B\ c}$	$76.00 \pm 0.00^{B\ d}$
170	$80.00 \pm 0.00^{A\ a}$	$79.97 \pm 0.05^{A\ a}$	$79.63 \pm 0.10^{A\ a}$	$79.00 \pm 0.00^{A\ b}$	$78.34 \pm 0.20^{A\ c}$
90	$80.00 \pm 0.00^{A\ a}$	$79.99 \pm 0.05^{A\ a}$	$79.96 \pm 0.00^{A\ a}$	$79.00 \pm 0.00^{A\ b}$	$78.96 \pm 0.05^{A\ b}$
			***a*-value**		
420	$0.77 \pm 0.00^{A\ d}$	$0.98 \pm 0.05^{A\ d}$	$2.03 \pm 0.06^{A\ c}$	$2.99 \pm 0.07^{A\ b}$	$3.48 \pm 0.06^{A\ a}$
280	$0.77 \pm 0.00^{A\ d}$	$0.86 \pm 0.00^{B\ d}$	$1.73 \pm 0.10^{B\ c}$	$2.78 \pm 0.05^{A\ b}$	$3.09 \pm 0.00^{A\ a}$
170	$0.77 \pm 0.00^{A\ c}$	$0.84 \pm 0.10^{B\ c}$	$1.25 \pm 0.01^{B\ b}$	$1.99 \pm 0.00^{B\ b}$	$2.64 \pm 0.20^{B\ a}$
90	$0.77 \pm 0.00^{A\ c}$	$0.79 \pm 0.00^{C\ c}$	$0.99 \pm 0.50^{C\ c}$	$1.79 \pm 0.50^{B\ b}$	$2.08 \pm 0.00^{B\ a}$
			***b*-value**		
420	$6.98 \pm 0.00^{A\ a}$	$5.87 \pm 0.05^{C\ b}$	$5.36 \pm 0.06^{C\ b}$	$5.09 \pm 0.00^{C\ b}$	$4.84 \pm 0.06^{C\ c}$
280	$6.98 \pm 0.00^{A\ a}$	$6.33 \pm 0.00^{B\ a}$	$6.05 \pm 0.10^{B\ a}$	$5.84 \pm 0.05^{C\ b}$	$5.38 \pm 0.00^{B\ b}$
170	$6.98 \pm 0.00^{A\ a}$	$6.84 \pm 0.10^{B\ a}$	$6.65 \pm 0.01^{B\ a}$	$6.35 \pm 0.00^{B\ a}$	$5.74 \pm 0.20^{B\ b}$
90	$6.98 \pm 0.00^{A\ a}$	$7.00 \pm 0.00^{A\ a}$	$7.00 \pm 0.00^{A\ a}$	$7.00 \pm 0.00^{A\ a}$	$6.96 \pm 0.05^{A\ a}$

increase the cake volume. In opposition, a high increase of batter consistency could obstruct the expansion and reduce the cake volume.

Determination of the crust color of the samples (Table 4) showed that with increasing bran particle size and percentage, the *L*- and *b*-values decreased slightly, while the *a*-value increased. This means that the crust became darker, more reddish and less yellowish. Similar pattern was also observed for the crumb color (Table 5). Crust color is mainly affected by the Maillard and caramelization reactions occurring during baking of the cakes. The chemical components of the bran such as proteins and sugars may enhance such reactions. The hydrocolloids of the bran can also change the water availability to these reactions by changing the water activity. It has been reported that different fibers including wheat and oat bran and cellulose microcrystalline affected the crust color of the cakes. Crumb color is rather affected by the components used in the cake recipe. Bran contains natural dark pigments which can affect the crumb color. With increase in the particle size of the bran, its dark color becomes more obvious resulting in the darker crumb color. Similar findings were reported in the literature [13, 19].

The effects of bran percentage and particle size on the textural properties of the cakes can be observed in

Table 5 Crumb color parameters of cakes containing bran of different levels and particle sizes*.

Particle size (μm)	0% bran	5% bran	10% bran	15% bran	20% bran
			***L*-value**		
420	$85.18 \pm 0.20^{A\ a}$	$83.34 \pm 0.10^{B\ b}$	$82.58 \pm 0.00^{C\ c}$	$81.64 \pm 0.20^{D\ d}$	$80.69 \pm 0.06^{D\ e}$
280	$85.18 \pm 0.20^{A\ a}$	$83.68 \pm 0.00^{B\ b}$	$83.18 \pm 0.01^{B\ b}$	$82.78 \pm 0.20^{C\ c}$	$81.84 \pm 0.00^{C\ d}$
170	$85.18 \pm 0.20^{A\ a}$	$84.27 \pm 0.05^{A\ b}$	$83.63 \pm 0.10^{B\ c}$	$83.42 \pm 0.00^{B\ c}$	$82.34 \pm 0.20^{B\ d}$
90	$85.18 \pm 0.20^{A\ a}$	$84.67 \pm 0.50^{A\ b}$	$84.06 \pm 0.10^{A\ b}$	$84.02 \pm 0.00^{A\ b}$	$83.41 \pm 0.40^{A\ c}$
			***a*-value**		
420	$-5.94 \pm 0.00^{A\ d}$	$-5.26 \pm 0.50^{A\ d}$	$-4.46 \pm 0.50^{A\ c}$	$-3.66 \pm 0.50^{A\ b}$	$-2.76 \pm 0.50^{A\ a}$
280	$-5.94 \pm 0.00^{A\ c}$	$-5.63 \pm 0.10^{A\ c}$	$-5.03 \pm 0.00^{B\ c}$	$-4.06 \pm 0.50^{B\ b}$	$-3.66 \pm 0.50^{B\ a}$
170	$-5.94 \pm 0.30^{A\ c}$	$-5.86 \pm 0.30^{A\ c}$	$-5.43 \pm 0.00^{B\ c}$	$-4.36 \pm 0.00^{B\ b}$	$-3.86 \pm 0.50^{B\ a}$
90	$-5.94 \pm 0.40^{A\ b}$	$-6.00 \pm 0.0^{B\ b}$	$-5.65 \pm 0.00^{B\ b}$	$-5.23 \pm 0.00^{C\ b}$	$-4.82 \pm 0.00^{C\ a}$
			***b*-value**		
420	$7.96 \pm 0.00^{A\ a}$	$6.00 \pm 0.00^{B\ b}$	$5.93 \pm 0.10^{C\ c}$	$4.78 \pm 0.00^{D\ d}$	$3.68 \pm 0.00^{D\ e}$
280	$7.90 \pm 0.00^{A\ a}$	$6.73 \pm 0.00^{B\ b}$	$6.00 \pm 0.01^{B\ b}$	$5.00 \pm 0.00^{C\ c}$	$4.67 \pm 0.50^{C\ d}$
170	$7.93 \pm 0.00^{A\ a}$	$7.63 \pm 0.50^{A\ a}$	$7.37 \pm 0.50^{A\ a}$	$6.00 \pm 0.00^{B\ b}$	$5.33 \pm 0.00^{B\ c}$
90	$7.95 \pm 0.00^{A\ a}$	$7.86 \pm 0.50^{A\ a}$	$7.56 \pm 0.50^{A\ a}$	$7.09 \pm 0.00^{A\ a}$	$6.23 \pm 0.00^{A\ b}$

Table 6 Textural characteristics of the cakes containing different levels of bran of varying particle sizes*.

Particle size (μm)	0% bran	5% bran	10% bran	15% bran	20% bran
			Hardness (N)		
420	2.69 ± 0.09[A e]	3.07 ± 0.05[A d]	3.66 ± 0.09[A c]	4.21 ± 0.31[A b]	5.24 ± 0.42[A a]
280	2.69 ± 0.09[A e]	2.84 ± 0.45[B d]	3.45 ± 0.37[B c]	4.01 ± 0.35[A b]	4.87 ± 0.01[B a]
170	2.69 ± 0.09[A d]	2.77 ± 0.32[C d]	3.36 ± 0.15[B c]	3.88 ± 0.14[B b]	4.45 ± 0.14[C a]
90	2.69 ± 0.09[A d]	2.69 ± 0.32[C d]	3.23 ± 0.35[C c]	3.64 ± 0.42[C b]	4.23 ± 0.23[D a]
			Cohesiveness		
420	0.83 ± 0.01[A a]	0.81 ± 0.04[A b]	0.75 ± 0.01[C c]	0.65 ± 0.00[D d]	0.54 ± 0.00[D e]
280	0.83 ± 0.01[A a]	0.82 ± 0.04[A a]	0.78 ± 0.00[B b]	0.68 ± 0.00[C c]	0.66 ± 0.02[C c]
170	0.83 ± 0.01[A a]	0.82 ± 0.01[A a]	0.81 ± 0.01[A b]	0.76 ± 0.00[B c]	0.73 ± 0.01[B d]
90	0.83 ± 0.01[A a]	0.83 ± 0.05[A a]	0.82 ± 0.04[A a]	0.80 ± 0.00[A b]	0.79 ± 0.02[A b]
			Springiness		
420	0.91 ± 0.01[A a]	0.91 ± 0.02[A a]	0.87 ± 0.02[C b]	0.84 ± 0.02[C c]	0.80 ± 0.01[D d]
280	0.91 ± 0.01[A a]	0.92 ± 0.02[A a]	0.88 ± 0.05[B b]	0.86 ± 0.01[B c]	0.83 ± 0.05[C d]
170	0.91 ± 0.01[A a]	0.91 ± 0.00[A a]	0.89 ± 0.02[A b]	0.87 ± 0.03[A c]	0.84 ± 0.01[B d]
90	0.91 ± 0.01[A a]	0.92 ± 0.03[A a]	0.90 ± 0.01[A b]	0.87 ± 0.01[A c]	0.85 ± 0.04[A d]

*Values are the average of triplicates ± standard deviation. Different capital letters in each column and small letters in each row (for each color parameter) indicate significant statistical difference ($\alpha < 0.05$).

Table 6. The results showed that with increasing bran level and particle size, the hardness of the cakes increased, while cohesiveness and springiness of the cakes decreased. Negative correlation between batter Bostwick number and cake hardness ($R^2 = 0.70$) and positive correlation between cake density and its hardness ($R^2 = 0.85$) were found. The correlations between batter density and either of cake springiness ($R^2 = 0.70$) or cohesiveness ($R^2 = 0.78$) were negative. Strong correlations between cake volume, elasticity and chewiness have been established, but not between cake volume and cohesiveness or resilience [19]. Such correlations may indicate that the texture of the cake is affected notably by the density of the batter and cake which can be related to the quantity of air retained by the batter.

To determine the effects of bran particle size on the sensory attributes of the cakes are given in Table 7. At both particle sizes tested in this experiment, increasing the percentage of the bran had negative effect on the sensory attributes of the cakes, particularly when bran content of the cakes increased to more than 10%. The effects of particle size on the cake quality are presented in Table 8. The results indicate that with the increase in the particle size, the scores given to the samples reduced,

Table 7 Sensory evaluation of the cakes made with different levels of bran with the largest (420 μm) and smallest (90 μm) particle sizes used in this study*.

Bran level (%)	Crust Color	Crumb Color	Crust Texture	Crumb Texture	Taste	Total Acceptance
			Bran particle size; 420 μm			
0	4.6 ± 0.0[a]	4.8 ± 0.0[a]	3.5 ± 0.1[a]	4.5 ± 0.2[a]	4.7 ± 0.2[a]	4.7 ± 0.5[a]
5	4.6 ± 0.1[a]	4.7 ± 0.1[a]	3.5 ± 0.0[a]	4.2 ± 0.2[a]	4.5 ± 0.2[a b]	4.2 ± 0.1[a b]
10	4.5 ± 0.0[a]	4.7 ± 0.1[a]	3.3 ± 0.2[a]	3.5 ± 0.1[b]	4.3 ± 0.1[b]	4.2 ± 0.1[a b]
15	4.4 ± 0.2[a b]	3.2 ± 0.2[b]	3.3 ± 0.1[a]	2.8 ± 0.1[c]	3.8 ± 0.1[c]	3.9 ± 0.2[b c]
20	4.3 ± 0.0[b]	3.2 ± 0.0[b]	3.3 ± 0.2[a]	2.5 ± 0.1[c]	3.7 ± 0.1[c]	3.7 ± 0.1[c]
			Bran particle size; 90 μm			
0	4.6 ± 0.0[a]	4.7 ± 0.0[a]	3.5 ± 0.1[a]	4.8 ± 0.2[a]	4.7 ± 0.0[a]	4.7 ± 0.2[a]
5	4.7 ± 0.0[a]	4.6 ± 0.0[a]	3.5 ± 0.1[a]	4.6 ± 0.2[a]	4.6 ± 0.1[a b]	4.5 ± 0.2[a b]
10	4.6 ± 0.2[a]	4.4 ± 0.2[a]	3.2 ± 0.2[a]	4.1 ± 0.1[b]	4.5 ± 0.1[b]	4.0 ± 0.2[b]
15	4.6 ± 0.0[a]	4.7 ± 0.0[a]	3.3 ± 0.0[a]	3.4 ± 0.1[c]	3.3 ± 0.1[c]	3.2 ± 0.1[c]
20	4.6 ± 0.1[a]	4.3 ± 0.1[b]	3.4 ± 0.1[a]	3.2 ± 0.1[c]	3.4 ± 0.1[c]	3.5 ± 0.8[c]

*Values are the average of triplicates ± standard deviation. Different letters in each column indicate significant statistical difference for each particle size ($\alpha < 0.05$).

Table 8 Sensory attributes of the cakes containing 10% bran at varying percentage*.

Particle size (μm)	Crust Color	Crumb Color	Crust Texture	Crumb Texture	Taste	General acceptance
420	4.2 ± 0.0^{b}	3.6 ± 0.0^{b}	3.7 ± 0.1^{b}	3.4 ± 0.2^{b}	3.7 ± 0.0^{c}	3.5 ± 0.3^{c}
280	4.4 ± 0.0^{a}	4.0 ± 0.0^{b}	3.7 ± 0.1^{b}	3.6 ± 0.2^{b}	4.0 ± 0.1^{b}	3.7 ± 0.1^{b}
170	4.4 ± 0.2$^{a\ b}$	4.7 ± 0.2^{a}	4.1 ± 0.1^{a}	4.8 ± 0.1^{a}	4.3 ± 0.1^{a}	4.2 ± 0.4^{a}
90	4.4 ± 0.0^{a}	4.8 ± 0.0^{a}	4.3 ± 0.0^{a}	4.8 ± 0.1^{a}	4.4 ± 0.1^{a}	4.8 ± 0.1^{a}

*Values are the average of triplicates ± standard deviation. Different capital letters in each column and small letters in each row indicate significant statistical difference ($\alpha < 0.05$).

particularly when the particle size increased to more than 170 μm. From the results it may be concluded that the addition of bran with particle size of less than 170 μm at levels less than 15% results in cakes with similar sensory quality to that of cakes with no bran. Determination of the total dietary and phytic acid content of these samples was about 5.95% and 2.9 mg/g, respectively. It has been indicated that heating can reduce the amount of phytic acid [37]. Therefore, the phytic acid content of the cakes may even be less than the values calculated in this study.

Conclusion

The results of this study indicated that it is possible to increase the fiber content of sponge cake by addition of wheat bran. However, inclusion of wheat bran had some undesirable effects on batter and cake quality as well as increasing the phytic acid content. Selection of the appropriate particle size and level of the bran can minimize these adverse effects. Inclusion of bran in the cake recipe increased consistency and density of the batter, darkened the cake crust and crumb, decreased cake volume and increased its hardness. These effects were more pronounced when higher levels and larger particle sizes were used. Apparently, the effects of bran percentage on the physical properties of the batter and cakes were greater than those of bran particle size. Such effects were recognized by the panelist only when more than 10% bran with particle size greater than 170 μm was included. The resulting cake had about 6% fiber and 2.9 mg/g phytic acid contents.

References

1. Yotsuzuka F. Curdlan. In: Cho SS, Dreher ML, editors. Handbook of dietary fiber. New York: Marcel Dekker, 2001:727–57.
2. Gutkoski LC, de Bonamigo JMA, de Teixeira DMF, Edo I. Development of oat based cereal bars with high dietary fiber content. Ciênc Tecnol de Alimentos 2007;27:355–63.
3. Mehta RS. Dietary fiber benefits. Cereal Foods World 2005;50:66–71.
4. Bonnand-Ducasse M, Della Vella G, Lefebvre J, Saulnier L. Effect of wheat dietray fiebrs on bread dough development and rheological properties. J Cereal Sci 2010;52:200–6.
5. Adom KK, Sorrells ME, Liu RH. Phytochemical profiles and antioxidant activity of whear varieties. J Agric Food Chem 2003;51:7825–34.
6. Zhu K, Huang S, Peng W, Qian H, Zhou H. Effect of ultrafine grinding on hydration and antioxidant properties of wheat bran dietray fiebr. Food Res Int 2010;43:943–8.
7. Wu P, Tian J, Walker CE, Wang F. Determination of phytic acid in cereals-a brief review. Int J Food Sci Technol 44:1671–6.
8. Kumar V, Sinha AK, Makkar PS, Becker K. Dietary roles of phytate and phytase in human nutrition: a review. Food Chem 2010;120:945–59.
9. Greiner R, Konietzny U. Phytase for food application. Food Technol Biotechnol 2006;44:125–40.
10. Servi S, Ozkaya H, Colakoglu AS. Dephytinization of wheat bran by fermenation with bakers yeast, incubation with barley malt flour and autocalving at different pH levels. Journal of Cereal Science 2008;48:471–6.
11. Liu Z, Wang H, Wang X, Xu H, Gao D, Zhang G, et al. Effect of wheat pearling on flour phytase activity, phytic acid, iron, and zinc content. LWT-Food Sci Technol 2008;41:521–7.
12. Grigelmo-Miguel N, Carreras-Boladeras E, Martin-Belloso O. Development of high-fruit-dietray fiber muffins. Eur Food Res Technol 1999;210:123–8.
13. Kaack K, Pedersen L. Low energy chocolate cake potato pulp and yellow pea hull. Eur Food Res Technol 2005;221:367–75.
14. Lin PY, Czuchajowska Z, Pomeranz Y. Enzyme-resistant starch in yellow layer cake. Cereal Chem 1994;71:69–75.
15. Masoodi FA, Bhavana S, Chauhan GS. Use of apple pomace as a source of dietary fiber in cakes. Plant Foods Hum Nutr 2002;57:121–8.
16. Baixauli R, Sanz T, Salvador A, Fiszman SM. Muffins with resistant starch: baking performance in relation to the rheological properties of the batter. J Cereal Sci 2008;47:502–9.
17. Sudha ML, Baskaran V, Leelavathi K. Apple pomace as a source of dietray fiber and polyphenols and its effect on the

rheological characteristics and cake making. Food Chem 2007;104:686–92.
18. Gomez M, Moraleja A, Oliete B, Ruiz E, Caballero PA. Effect of fiber size on the quality of fiber-enriched layer cakes. LWT-Food Sci Technol 2010;43:33–8.
19. Gomez M, Manchon L, Oliente B, Ruiz E, Caballero PA. Adequacy of wholegrain non-wheat flours for layer cake elaboration. LWT-Food Sci Technol 2010;43:507–13.
20. Chen JS, Fei MJ, Shi CL, Tian JC, Sun CL, Zhang H, et al. Effect of particle size and addition level of wheat bran on quality of dry white Chinese noodles. J Cereal Sci 2011;53 (2):217–224.
21. Zhang D, Moore WR. Wheat bran particle size effects on bread baking performance and quality. J Sci Food Agric 1999;79:805–9.
22. AACC. Approved methods of the American Association of Cereal Chemists, 10th ed. St. Paul, MN: American Association of Cereal Chemists. (Method number 46–12 for protein; 44–15 for moisture; 08–01 for ash; 50–20 for fat; 32–07 for crude fiber and 10–05 for cake volume).
23. Prosky L, Asp NG, Schweizer TF, DeVries JW, Furda I. Determination of insoluble, soluble and total dietary fiber in foods and food products: Inter laboratory study. J Assoc Off Anal Chem 1988;71:1017–23.
24. Garcia-Estepa RM, Guerra-Hernandez E, Garcia-Villanova B. Phytic acid content on milled cereal products and breads. Food Res Int 1999;3:217–21.
25. Ayadi MA, Abdelmaksoud W, Ennouri M, Attia H. Cladodes from Opuntia ficus indica as a source of dietray fiber: effect on dough characteristics and cake making. Ind Crops Prod 2009;30:40–7.
26. Baeva MR, Panchev IN, Terzieva VV. Comparative study of texture of normal and energy reduced sponge cakes. Nahrung/Food 2000;44:242–6.
27. Steffe JF. Rheological methods in food process engineering. New York: Freeman Press, 1996.
28. Yam KLS, Papadakis E. A simple digital imaging method for measuring and analyzing color of food surfaces. J Food Eng 2004;61:137–42.
29. Stone H, Sidel JL. Sensory evaluation practices. California: Elsevier Academic Press, 2004.
30. Steel RGD, Torrie JH. Principles and procedures of statistics: a biometrical approach, 2nd ed. New York: McGraw-Hill, 1980.
31. Wu P, Zhao T, Tian JC. Phytic acid contents of wheat flours from different mill streams. Agric Sci China, 2010;9:1684–8.
32. Shenoy A, Prakash J. Wheat bran (Triticum aestivum): composition, functionality and incorporation in unleavened bread. J Food Qual 2002;25:197–211.
33. Gomez M, Oliete B, Rosell CM, Pando V, Fernandez E. Studies on cake quality made of wheat-chickpea flour blends. LWT-Food Sci Technol 2008;41:1701–9.
34. Hoseney RC. Principals of cereal science and technology, 2nd ed. Minnesota: American Association of Cereal Chemists.
35. Chen H, Rubenthaler GL, Leung HK, Baranowski JD. Chemical, physical and baking prpeties of apple fiber compared with wheat and oat bran. Cereal Chem 1988;65:244–7.
36. Gargari BP, Mahboob S, Razavieh SV. Content of phytic acid and its mole ratio to zinc in flour and breads consumed in Tabriz, Iran. Food Chem 2007;100:1115–19.