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ORIGINAL ARTICLE

Different sized wheat bran fibers as fat mimetic in biscuits: its effects on dough rheology and biscuit quality

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Abstract The aim of this study is to investigate the effects of various particle sized and different amount of plant fibers as fat mimetic for biscuit formulations instead of biscuit fat. The fibers with different particle sizes were obtained from wheat bran and used instead of fat in biscuit formulations. The texture, rheology and quality analyses of low-fat biscuit (30, 20 and 10% fat) were performed and compared with those of the full-fat control sample (40% fat). Results showed that wheat bran fiber with bigger particle size (Long Fiber, LF) were more favorable in terms of textural properties of the dough and the quality parameters of biscuits while the fibers with smaller particle size (Medium Fiber, MF and Small Fiber, SF) improved viscoelastic properties of dough similar to the control. Although the use of these fibers in the production of low-fat biscuits were suitable in terms of workability of dough increasing fiber content and/or reducing fiber size resulted in harder biscuits with lower spread ratio. This study showed that the texture of biscuits was greatly dependent on the texture of the dough.

Keywords Biscuit · Dough · Fat mimetic · Fiber · Rheology

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Introduction

Biscuits are the most popular bakery items consumed nearly by all levels of society. This is mainly due to its ready to eat nature, good nutritional quality, and availability in different varieties and affordable cost. Most of bakery products are used as a source for incorporation of different nutritionally rich ingredients for their diversification. Several health products have now become available (Sudha et al. 2007).

In a soft dough biscuit formulation, flour, sugar, fat, water and salt are the main components (Maache-Rezzoug et al. 1998). Fat in a biscuit formulation has a multifaceted function. Fat is the principle ingredient responsible for keeping quality, tenderness, grain and texture and it adds a rich quality to cookies. Mechanical properties of biscuits are largely dependent on the fat component of the formulation. Fat interacts with other ingredients to develop mould texture, mouthfeel and overall sensation of lubricity of the product. Fat also influences the rheological properties of cookie dough (Baltsavias et al. 1999).

High fat intake is associated with various health disorders such as obesity (Kim et al. 2016), cancer (Okumura et al. 2017) and coronary heart disease (Lee et al. 2016). This awareness has prompted consumers about the amount of fat in their diet. Because of these reasons, despite of the important role played by fat, there have been continued efforts to reduce the fat content in food products.

Reducing fat in every-day's diet has become a public health issue and a concern for most consumers. Reduced fat alternatives such as spreads and milk are more favorable for the consumers. It was reported that snacks (crisps, confectionery, bakery products, biscuits, fast food) contribute approximately 20% of energy requirements (Smith et al. 2017).

Texture, flavor and appearance are the main quality attributes of cookies. Fat is a very important ingredient of cookies because it contributes texture and pleasing mouthfeel and positively impacts flavor intensity and perception. However, US dietary guidelines focused on reduction of dietary fats (Anonymous 2018).

Texture was the main issue when a percentage of fat was removed: the biscuits got harder and crumblier (Laguna et al. 2012). The importance of cookie texture in consumer acceptance is increasingly recognized. Changes in ingredients and processing cause variations in texture. Fat is one of the principal ingredients that affect cookie texture. Substitution of fat had a greater impact on textural attributes of cookies than substitution of sugar or flour (Campbell et al. 1994). Maache-Rezzoug et al. (1998) investigated the effect of fat content on biscuit texture and found that an increase in fat content resulted in more friable, less crispy products. Reduction of fat in cookies resulted in a chewy texture and a low moisture content (Sanchez et al. 1995). Formulation of bakery products to simulate their high-fat counterparts needs the development of a texture and structure similar to the target but with the use of substitute ingredients (Carroll 1990). Fat could be partially substituted by compounds that present functional properties similar to fat, while creation of a high-quality fat-free product seems impossible (Shukla 1995).

Currently number of ingredients (emulsifiers, sorbitol, polydextrose, and crystalline cellulose) are employed as fat replacers to capitalize on the unique properties and qualities of each bakery product. However, the important point is the consideration of the functionality of these replacers in a variety of products to obtain products with similar quality parameters (Kamel and Rasper 1988).

Fat mimetics are substances of carbohydrate or protein origin which can be used in some foods to imitate the functional and sensorial properties of fat, while providing considerably less calories. Replacement of fat in cookies and similar baked products by fat mimetics has been suggested. Carbohydrate-based fat mimetics, like processed starches, have been reported to imitate fat by binding water and to provide lubricity, desired texture and a pleasing mouth sensation (Nonaka 1997).

Carbohydrate based fat replacers form a gel-like matrix in the presence of substantial levels of water, resulting in lubricant and flow properties similar to those of fats (Yackel and Cox 1992). Replacement of 50% of fat by water soluble β-glucan and amylodextrins derived from oat flour resulted in cookies not significantly different from the full-fat ones, but at higher substitution levels moistness and overall quality were decreased (Inglett et al. 1994). Also, tenderness of biscuits decreased with the increase of fat substitution by pectin-, gum-, or oat-based fat mimetics (Conforti et al. 1996). Polydextrose was another fat mimetic tested in cookies and it was found to affect the textural characteristics estimated by a sensory panel (Campbell et al. 1994).

The use of fibers in food industry has constantly been increasing because of their nutritional properties. The nutritional benefits of adding fiber to diets have been investigated in many studies. The production of fiber biscuits has increased during the last years because it has very favorable effects on health. Investigators have reported that a general deterioration occurs in the functional or rheological properties of dough when bran is added (Meers 1981). But there is only limited information and no detailed study on using bran with various properties in dough formulation.

Bread can be attributed as a functional food if its formula is adjusted according to special needs of certain consumers, particularly to beneficial regulation effects on postprandial blood glucose insulin and fasting plasma cholesterol, and total energy of the product (Filipovic and Filipovic 2010). Dietary fibers can be used as carbohydrate based fat replacers in biscuit formulation.

The aim of this study was to present the effect of reduced size wheat bran fiber as fat replacement on rheology and texture of biscuit dough and on the quality of biscuits. In the present study, fat was reduced by 25, 50 and 75%, respectively and replaced with different size wheat bran fiber-gels while total weight was kept constant, which was equivalent to the amount of fat present in the control biscuit dough.

Materials and methods

Raw materials

Commercially available wheat flour (moisture, protein and ash contents of 12.2, 13.3 and 5.01%, respectively), wheat bran and bakery fat were obtained from Ülker A.Ş. (Turkey). Sugar powder, non-fat dry milk, sodium chloride, sodium bicarbonate and ammonium bicarbonate were used in the biscuit formulation.

Fatty acid composition

The methyl esters of the fatty acids and the isomers were prepared according to IUPAC Method 2.301 (IUPAC 1987) and analyzed using a Shimadzu GC-2010 model gas chromatograph (Japan) equipped with a DB23 column (60 m, 0.25 mm i.d., 0.25 mm film thickness; J&W). Injector, column, and detector temperatures were 230, 195, and 240 °C, respectively. The split ratio was 1:80. The carrier gas was helium at a flow rate of 0.75 mL/min.

Iodine value

Iodine value of the fat was calculated from the fatty acid compositions using the AOCS Official Method Cd 1c-85 (AOCS 2005).

Production of wheat bran fiber gels

For softening and easy processing purposes, wheat bran was placed in boiling water and the temperature was kept constant at 50 °C during 24 h (Long Fiber, LF). Later wheat bran was wet-milled with a colloid mill (IKA Magic Lab, Germany), which had a rotation speed of 9000 rpm. The process was repeated thrice to reduce the sizes of fibers to colloidal levels (Medium Fiber, MF). Then milled fibers were passed through a micro-fluidizer (M-110Y Microfluidics, Newton, MA) to have a second size reduction. Fibers were forced through two chambers having micro-pipes with diameters of 200 and 100 µm, respectively, under a pressure of 15,000 psi. Thus, the size of the fibers was further reduced (Small Fiber, SF). Wet milling resulted in wheat bran fiber gels (WbFg) with around 80% moisture by weight. The gel was then pressed using a hydraulic press to standardize its solid content as 10, 20 and 30% by mass.

Scanning electron microscope (SEM)

For the SEM analysis, fiber samples were lyophilized using a freeze dryer (Christ, Alpha 2–4 LD plus, Germany). They were coated with gold–palladium to render them electrically conductive by Sputter Coater Device (Polaron Range, East Sussex, England). Samples were then examined and images were recorded with a scanning electron microscope (QUANTA 400F Field Emission SEM, Eindhoven, Holland) at an accelerating voltage of 20 kV.

Total fiber, cellulose, hemicelluloses and lignin content

Total fiber content (AOAC Official Method 985.29, AOAC 1998), cellulose content (Updegraff 1969), hemicellulose content (TAPPI T03) and lignin content (TAPPI T222) of the produced fibers were determined (TAPPI 1998).

Protein and moisture content

Protein content was determined by AOAC Official Method 920.87 (AOAC 1998). TAPPI T264 test method (TAPPI 1998) was used to determine for moisture content of biscuit.

Water holding capacity test

Water holding capacities of the dried fibers were determined according to McConnell et al. (1974) and given as water holding capacity %.

Preparation of biscuit dough

Soft dough biscuits were prepared according to AACC Standard Method 10-54 (AACC 2001). For the preparation of low fat biscuits, fat content in the biscuit formulation was reduced by 25, 50 and 75%, respectively and the fibers were added in gel-form during fat-sugar creaming whenever included in the composition. Biscuit sample codes and formulations were given in Table 1.

Rheology and mechanical properties of dough

The textural properties of the samples were measured in a texture analyzer (TA.XTplus Texture Analyzer, England). Hardness of dough samples was determined using a probe (P/6 6 mm Cylinder Probe). A test speed of 3 mm/min with a load cell of 30 kg was used.

Rheological measurements were obtained using a Rheometer (TA.AR 2000 EX, USA). The elastic (G′) and viscous moduli (G″) were determined as a function of frequency for each sample. A 20 mm diameter flat plate was selected with a gap of 2 mm. A frequency range of 5–150 rad/s was used. In creep test, shear stress was held at 20 Pa and strain % of samples was determined as a function of time for each sample. The temperature of the samples was held at 25 ± 0.1 °C during rheological measurements.

Textural properties of biscuits

Spread ratios of biscuits were determined according to AACC Standard Method 10-54 (AACC 2001). Fracturability and hardness of the biscuits were measured in a Texture Analyzer (TA.XTplus Texture Analyzer, England) with a probe (HDP/3PB 3-Point Bending Rig). A test speed of 0.5 mm/min with a load cell of 30 kg was used. The force required to break of biscuits individually was recorded. Average values with standard deviations were reported.

Statistical analyses

Statistical analysis was performed using SPSS 15.0 statistical software (SPSS Inc., Chicago, USA). Data for each of the samples (n = 8) were evaluated by a one-way ANOVA procedure using the Duncan's multiple range test to find

Table 1 Biscuit samples codes and formulations

Samples			Ingredients*			
			Fat (g)	Fat (%)	WbFg (g)	Fiber (%)
Control samples						
Control40			32.0	40	–	–
Control30			24.0	30	–	–
Control20			16.0	20	–	–
Control10			8.0	10	–	–
10% dry matter of WbFg						
10**-30***LF	10-30MF	10-30SF	24.0	30	8.0	1
10-20LF	10-20MF	10-20SF	16.0	20	16.0	2
10-10LF	10-10MF	10-10SF	8.0	10	24.0	3
20% dry matter of WbFg						
20-30LF	20-30MF	20-30SF	24.0	30	8.0	2
20-20LF	20-20MF	20-20SF	16.0	20	16.0	4
20-10LF	20-10MF	20-10SF	8.0	10	24.0	6
30% dry matter of WbFg						
30-30LF	30-30MF	30-30SF	24.0	30	8.0	3
30-20LF	30-20MF	30-20SF	16.0	20	16.0	6
30-10LF	30-10MF	30-10SF	8.0	10	24.0	9

WbFg Wheat bran Fiber-gel, *LF* Long Fiber, *MF* Medium Fiber, *SF* Small Fiber

*Other ingredients: sugar powder (33.6 g), nonfat dry milk (0.8 g), sodium chloride (1 g), ammonium bicarbonate (0.4 g), sodium bicarbonate (0.8 g), wheat flour (80 g), water (18.4 g)

** Dry matter of WbFg

*** Fat ratio of biscuit dough

out if there are any significant differences between samples (Duncan 1955).

Result and discussion

Raw materials analyses

Palmitic (46.8 ± 2.1%), oleic (36.6 ± 1.1%) and linoleic acids (9.5 ± 0.9%) were the main components of the biscuit fat (having 49.1 ± 1.1 iodine value) used in the formulation. Protein, total fiber, cellulose, hemicellulose, lignin content and water holding capacity of different sized fibers are shown in Table 2. The results showed that all fibers used were similar in terms of composition, but water-holding capacity of the fibers increased by reducing fiber size. Therefore, the fibers of different sizes have different characteristics in terms of structure (Fig. 1). Water holding capacity of SF was higher than those of the others (LF and MF). Therefore, wheat fiber having different proportions of water holding ability were compared in this study for their functionality as fat mimetic.

Rheological properties of biscuit dough

Elastic (G′) and viscous (G″) modulus values and creep properties of dough samples obtained using a rheometer were given in Figs. 2 and 3. In case of short dough

Table 2 Protein, total fiber, cellulose, hemicellulose, lignin content and water holding capacity of different sized wheat bran fibers

	Protein %	Total fiber %	Cellulose %	Hemicellulose %	Lignin %	Water holding capacity %
LF	9.8 ± 0.08^a	40.2 ± 0.89^a	35.2 ± 0.82^a	0.31 ± 0.015^a	0.30 ± 0.025^a	320 ± 20.5^a
MF	9.8 ± 0.03^a	40.5 ± 0.48^a	35.4 ± 0.90^a	0.31 ± 0.011^a	0.30 ± 0.018^a	488 ± 22.2^b
SF	9.7 ± 0.06^a	40.5 ± 0.59^a	35.6 ± 0.85^a	0.30 ± 0.021^a	0.29 ± 0.026^a	595 ± 25.1^c

Different superscript letters in the same column indicate significant differences between mean values at $P < 0.05$

LF Long Fiber, *MF* Medium Fiber, *SF* Small Fiber

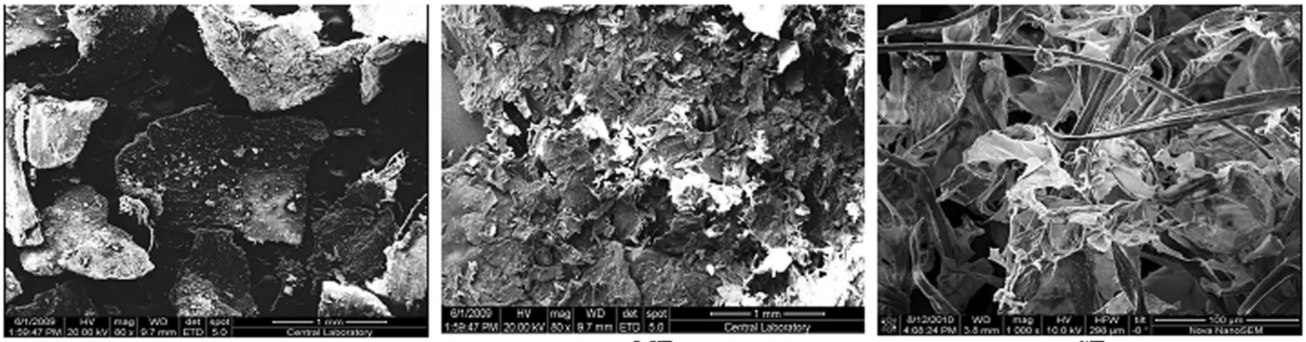


Fig. 1 Electron microscope images of fibers produced. *LF* Long Fiber, *MF* Medium Fiber, *SF* Small Fiber

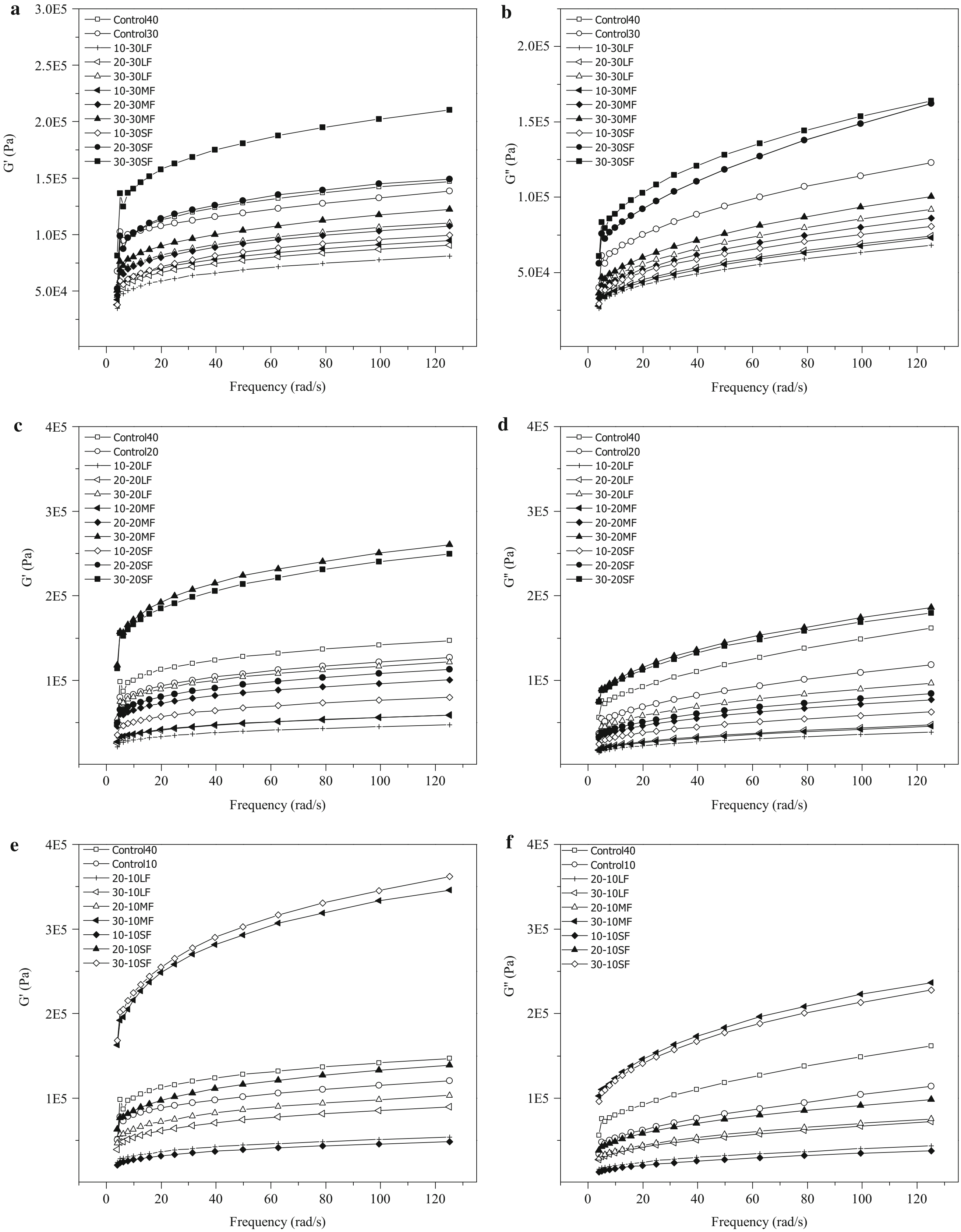
products such as biscuit and cookies, strong gluten network formation is usually avoided. Dough from strong wheats having high amount and high quality gluten showed higher G′ and G″ values compared to dough from weak wheats (Singh and Singh 2013). Therefore, short dough products contain significant amount of fat which hinders interactions between gluten subunits and improves tenderness (Sudha et al. 2007). Especially solid fraction of fat can form a uniform phase when the system is rich in fat or can be dispersed when present at lower levels (Baltsavias et al. 1999). According to Ghotra et al. (2002), when a sufficient amount of fat is present, it can surround and isolate the starch and the proteins, which causes breaking the continuity of the protein and starch structure and giving desired texture in biscuits. In this study, the results of textural and rheological analyses showed that the replacing fat with WbFgs affected the texture of biscuit dough by decreasing their tenderness. Reduction in fat content also increased the creep resistance of the biscuit dough. Creep test is often correlated with the spread of baked products (Faridi and Faubion 2012). Replacing the fat with bran fiber in biscuit formulation reduced the plasticizing effect of lipid molecules. Furthermore, fibers especially microfluidized fibers (SF) hold water more effectively, which reduces free water and limits plasticizing effect of water molecules (Mert et al. 2014). Combined effect of restricted fat and water resulted higher resistance creep stress in fiber added dough samples.

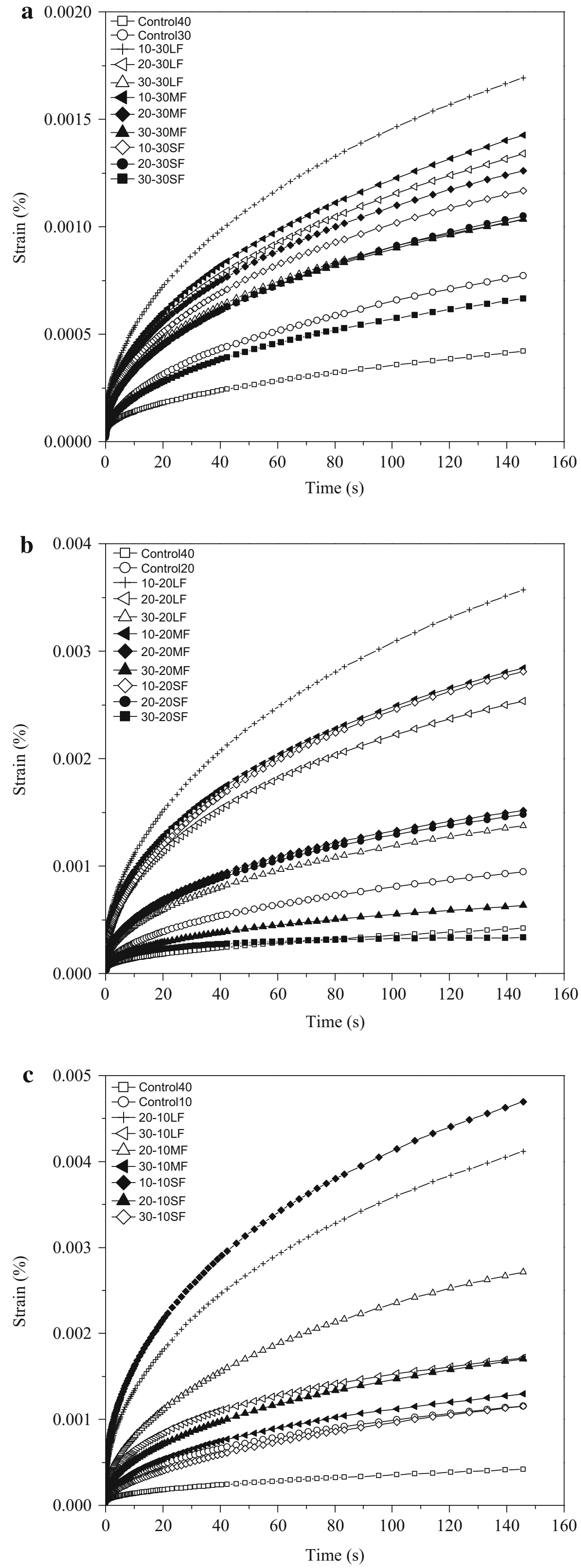
The results indicated that using more and lower size WbFg having 20 and 30% dry matter instead of fat, more viscous and elastic biscuit dough samples were obtained. On the contrary, increasing WbFg having 10% dry matter decreased G′ and G″ values of dough samples, which was possibly because of more water in the latter application. These results suggest that replacing fat with WbFg having low dry matter is more suitable for biscuit dough. Similarly, Ketenoglu et al. (2014) found that increasing dietary fiber content from 1 to 3% caused increases in G′ and G″ values of both colloidal and microfluidized emulsions. On the other hand, the results of creep test showed that using more amount and lower size of WbFg as fat mimetic, dough samples with lower creep resistance were produced. The decrease of creep resistance of the dough is due to amount of viscoelastic fiber fibrils. Elastic and viscous modules values of 20-30SF, 10-20MF and 20-10SF samples were similar to the Control40 sample. Biscuit dough samples with 30–20% fat were more like Control40 sample than the biscuit dough samples with 10% fat. Using SF with 30% dry matter (30-30SF, 30-20SF and 30-10SF samples) was suitable in terms of creep properties of dough. The use of these fibers in the production of low-fat biscuits was suitable in terms of workability of dough samples (Figs. 2, 3).

Textural properties of biscuit dough and physical qualities of biscuits

Firmness measurements showed that the dough samples became harder when fat content was reduced in the formulation. In biscuit dough formulation, the use of WbFg instead of fat prevented dough hardening caused by fat reduction. On the other hand, as the amount of WbFg increased and the fiber size decreased in the dough formulation, harder doughs were obtained.

Increasing LF content in dough formulation instead of shortening led to softer doughs; however, harder doughs were obtained when increasing MF content. Using SF having the smallest size resulted in the hardest doughs. On the other hand, the increase in firmness due to reduction in shortening content in the doughs can be reduced by the use of WbFg (Excluding MF and SF with 30% dry matter). The lower the amount of shortening, the greater the amount of added WbFg in the dough formulas. The dough must be softer with increasing amount of water in the dough formulation and the amount of water in the formula could be increased with the use of WbFg. The use of LF and 10% dry matter MF and SF resulted in softer doughs with increased moisture content in the dough depending on the


a
G' (Pa)
3.0E5
2.5E5
2.0E5
1.5E5
1.0E5
5.0E4
Control40
Control30
10-30LF
20-30LF
30-30LF
10-30MF
20-30MF
30-30MF
10-30SF
20-30SF
30-30SF
Frequency (rad/s)
b
G'' (Pa)
2.0E5
1.5E5
1.0E5
5.0E4
c
G' (Pa)
4E5
3E5
2E5
1E5
Control40
Control20
10-20LF
20-20LF
30-20LF
10-20MF
20-20MF
30-20MF
10-20SF
20-20SF
30-20SF
d
G'' (Pa)
e
G' (Pa)
Control40
Control10
20-10LF
30-10LF
20-10MF
30-10MF
10-10SF
20-10SF
30-10SF
f
G'' (Pa)
0 20 40 60 80 100 120



◀**Fig. 2** Typical changes observed for the elastic (G′) and viscous (G″) modulus of dough samples at 25 °C. *LF* Long Fiber, *MF* Medium Fiber, *SF* Small Fiber. **a** The elastic modulus (G′) of dough samples containing 30% fat, **b** the viscous modulus (G″) of dough samples containing 30% fat, **c** the elastic modulus (G′) of dough samples containing 20% fat, **d** the viscous modulus (G″) of dough samples containing 20% fat, **e** the viscous modulus (G′) of dough samples containing 10% fat, **f** the viscous modulus (G″) of dough samples containing 10% fat

amount of WbFg used. Therefore, 10-10LF and 10-10MF samples were not produced because of their high stickiness. However, it was observed that the use of MF and SF with 20% dry matter caused forming of harder dough, even though the amount of water increased. This can be explained by the increase in water holding capacity due to the reduction of the size of the fibers. Therefore, it was found that the use of 20 and 30% dry fiber did not allow softening of the dough because the water was retained by the fibers. 20-30LF, 10-30MF and 20-30MF with 30% fat, 30-20LF, 20-20MF and 20-20SF with 20% fat and 30-10LF and 20-10MF samples with 10% fat are similar to Control40. The results show that use of WbFg did not have any undesirable effect on dough processing (Table 3).

Texture characterization of biscuits were performed using three pint bending rig and the force required to break samples was recorded as the hardness. Because the samples contained fiber with different water holding ability, the biscuits prepared with the microfluidized fibers (SF) had significantly higher moisture content than the biscuits prepared with MF and LF. The structural differences shown in Fig. 1 was the main reason for this different moisture contents. One important impact of microfluidization process is the conversion of wheat bran into extremely thin fibrous and flaky structures, resulting in higher number of binding sites for the water molecules. In order to minimize effect of moisture content on texture and to obtain more meaningful comparisons under similar conditions, the biscuits were conditioned by keeping in a closed container. The relative humidity in the container was approximately 20% due to the saturated lithium chloride solution placed at the bottom of the container. The moisture content of the equilibrated biscuit samples (Table 4) showed that SF containing samples still had slightly higher moisture content than MF and especially LF containing samples. The highest moisture content was observed for 30-10SF sample containing 10% shortening and 30% dry matter SF-WbFg (8.0%) (Table 4). The hardness results shown in Table 4 indicated that fat plays a critical role in biscuit texture and as the amount of fat decreased the biscuits became harder. Solid crystals of the fat covers gluten protein during kneading and prevents formation of extended gluten network which in turn results

◀**Fig. 3** Typical changes observed for the creep properties of dough samples at 25 °C. *LF* Long Fiber, *MF* Medium Fiber, *SF* Small Fiber. **a** The creep properties of dough samples containing 30% fat, **b** the creep properties of dough samples containing 20% fat, **c** the creep properties of dough samples containing 10% fat

in the soft and short (crumbling) structure of the biscuits. The hardness in biscuits as a result of fat reduction was correlated to hardness of biscuit dough samples (r = 0.86). Force required to break biscuits containing 75% less fat was almost twice more than that required to break the control biscuits. These results were in accordance with the previous works, which have also reported that a reduction in fat levels leads to harder biscuits (Laguna et al. 2012; Yildiz et al. 2016).

On the other hand, the use of WbFg instead of fat reduced fracturability and increased hardness of biscuits. In fact, as the amount of moisture increases in the product, the hardness reduces. Due to the water-holding capacities of the dietary fibers, harder biscuits have been produced. In particular, the decrease in fiber size and the increase in the fiber amount in the formulation have significantly increased the hardness of the biscuits. As in dough samples, the hardest biscuits were those containing %10 shortening and %9 SF (301.9 ± 17.2 N). Increasing WbFg instead of shortening and use of lower size fibers increased

Table 3 Hardness of dough contains wheat fiber of different size

Size	Sample	Dry matter in WbFg (%)	Fiber (%)	Shortening (%)	Water (%)	Dough firmness (N)
	Control40	0	0	40	23	1.8 ± 0.1^{f,g}
	Control30	0	0	30	23	2.4 ± 0.1^{h,j}
	Control20	0	0	20	23	3.4 ± 0.1^{l,m}
	Control10	0	0	10	23	4.5 ± 0.2^{n,o}
Long Fiber, LF	10*-30**LF	10	1	30	32	1.5 ± 0.1^{e}
	10-20LF		2	20	41	0.8 ± 0.0^{b}
	10-10LF		3	10	50	Very sticky dough
	20-30LF	20	2	30	31	1.8 ± 0.1^{f,g}
	20-20LF		4	20	39	1.2 ± 0.1^{d}
	20-10LF		6	10	47	1.0 ± 0.0^{c}
	30-30LF	30	3	30	30	2.0 ± 0.1^{h,j}
	30-20LF		6	20	37	1.9 ± 0.1^{g,h}
	30-10LF		9	10	44	1.8 ± 0.1^{f}
Medium Fiber, MF	10-30MF	10	1	30	32	2.1 ± 0.1^{h,j}
	10-20MF		2	20	41	1.0 ± 0.0^{d}
	10-10MF		3	10	50	Very sticky dough
	20-30MF	20	2	30	31	1.8 ± 0.1^{f}
	20-20MF		4	20	39	1.9 ± 0.1^{f,g}
	20-10MF		6	10	47	1.9 ± 0.0^{f,g,h}
	30-30MF	30	3	30	30	2.0 ± 0.1^{g,h}
	30-20MF		6	20	37	4.2 ± 0.2^{n}
	30-10MF		9	10	44	5.5 ± 0.2^{a}
Small Fiber, SF	10-30SF	10	1	30	32	2.1 ± 0.0^{h,j}
	10-20SF		2	20	41	1.5 ± 0.0^{e}
	10-10SF		3	10	50	1.1 ± 0.1^{c}
	20-30SF	20	2	30	31	2.5 ± 0.0^{k}
	20-20SF		4	20	39	2.2 ± 0.1^{j}
	20-10SF		6	10	47	2.7 ± 0.0^{l}
	30-30SF	30	3	30	30	3. 8 ± 0.1^{m}
	30-20SF		6	20	37	4.2 ± 0.2^{n}
	30-10SF		9	10	44	5.9 ± 0.2^{a}

Different superscript letters in the same column indicate significant differences between mean values at $P < 0.05$

* Dry matter of WbFg

** Fat ratio of biscuit dough

Table 4 Moisture content, hardness, fracturability and spread ratio of biscuits made using variable amount of wheat fibers of different size

Size	Sample	Dry matter in WbFg (%)	Fiber (%)	Shortening (%)	Water (%)	Moisture (%)	Hardness (N)	Fracturability (mm)	Spread ratio
	Control40	0	0	40	23	4.8 ± 0.0	48.1 ± 2.6[a]	9.9 ± 0.1[a]	6.1 ± 0.0
	Control30	0	0	30	23	4.8 ± 0.0	64.5 ± 1.6[a,b]	10.0 ± 0.0[a]	5.9 ± 0.0
	Control20	0	0	20	23	4.9 ± 0.0	92.3 ± 2.4[a,b,c]	11.0 ± 0.4[a,b]	5.6 ± 0.0
	Control10	0	0	10	23	4.9 ± 0.0	127.6 ± 2.0[c,d,e]	13.0 ± 0.1[ef]	4.3 ± 0.0
Long Fiber, LF	10*-30**LF	10	1	30	32	5.1 ± 0.0	58.4 ± 1.7[a]	12.8 ± 0.9[d,e]	5.3 ± 0.0
	10-20LF		2	20	41	5.5 ± 0.0	78.4 ± 7.8[a,b,c]	15.7 ± 0.1[k,l,m]	4.1 ± 0.0
	10-10LF		3	10	50	No product			
	20-30LF	20	2	30	31	5.0 ± 0.0	68.9 ± 6.0[a,b]	11.7 ± 0.4[b,c]	5.0 ± 0.0
	20-20LF		4	20	39	5.2 ± 0.0	83.0 ± 11.9[a,b,c]	16.2 ± 0.1[m,n]	3.7 ± 0.0
	20-10LF		6	10	47	6.0 ± 0.0	173.7 ± 3.9[f,g]	18.0 ± 0.0[o]	3.1 ± 0.0
	30-30LF	30	3	30	30	6.3 ± 0.0	55.6 ± 4.4[a]	12.4 ± 0.0[d,e]	4.8 ± 0.0
	30-20LF		6	20	37	6.5 ± 0.0	90.4 ± 25.6[a,b,c]	14.9 ± 0.3[h,j]	3.9 ± 0.0
	30-10LF		9	10	44	6.8 ± 0.0	206.7 ± 12.14[g,h]	16.6 ± 0.3[h]	3.4 ± 0.0
Medium Fiber, MF	10-30MF	10	1	30	32	6.3 ± 0.0	77.6 ± 9.3[a,b,c]	14.3 ± 0.4[f,g]	4.2 ± 0.0
	10-20MF		2	20	41	6.5 ± 0.0	117.6 ± 5.3[c,d,e]	16.0 ± 0.2[m,n,o]	3.6 ± 0.0
	10-10MF		3	10	50	No product			
	20-30MF	20	2	30	31	6.0 ± 0.0	72.3 ± 12.1[a,b,c]	12.4 ± 0.1[c,d,l,m]	4.5 ± 0.0
	20-20MF		4	20	39	6.0 ± 0.0	144.5 ± 20.6[d,e,f]	15.5 ± 0.4[j,k,n]	3.8 ± 0.0
	20-10MF		6	10	47	6.5 ± 0.0	254.2 ± 16.0 [h,j]	15.8 ± 0.7[l,m]	3.3 ± 0.0
	30-30MF	30	3	30	30	6.1 ± 0.0	88.5 ± 1.8[a,b,c]	12.0 ± 0.2[c,d]	4.5 ± 0.0
	30-20MF		6	20	37	6.3 ± 0.0	169.1 ± 19.0[f,g]	13.9 ± 0.6[f]	3.6 ± 0.0
	30-10MF		9	10	44	6.6 ± 0.0	247.5 ± 10.2 [h,j]	14.1 ± 0.6[f,g]	3.3 ± 0.0
Small Fiber, SF	10-30SF	10	1	30	32	5.5 ± 0.0	76.2 ± 5.5[a,b,c]	13.1 ± 0.2[e]	4.3 ± 0.0
	10-20SF		2	20	41	6.0 ± 0.0	113.7 ± 7.0[b,c,d]	16.3 ± 0.3[m,n]	3.5 ± 0.0
	10-10SF		3	10	50	6.3 ± 0.0	250.1 ± 22.1 [h,j]	18.1 ± 0.3[o]	2.9 ± 0.0
	20-30SF	20	2	30	31	6.0 ± 0.0	63.7 ± 19.7[a]	12.7 ± 0.2[d,e,l]	4.4 ± 0.0
	20-20SF		4	20	39	6.5 ± 0.0	170.4 ± 14.1[f,g]	15.1 ± 0.2[j,k,j]	3.6 ± 0.0
	20-10SF		6	10	47	6.7 ± 0.0	288.9 ± 19.6[j,k]	14.8 ± 0.1[g,h,]	3.2 ± 0.0
	30-30SF	30	3	30	30	6.0 ± 0.0	77.3 ± 6.6[a,b,c]	12.7 ± 0.3[d,e]	4.2 ± 0.0
	30-20SF		6	20	37	7.2 ± 0.0	160.6 ± 14.6[e,f]	12.7 ± 0.4[d,e]	3.9 ± 0.0
	30-10SF		9	10	44	8.0 ± 0.0	301.9 ± 17.2[k]	11.2 ± 0.2[b]	4.0 ± 0.0

Different superscript letters in the same column indicate significant differences between mean values at $P < 0.05$

* Dry matter of WbFg

** Fat ratio of biscuit dough

hardness values of biscuits. Similarly, Zoulias et al. (2002) also found that the hardness of low-fat biscuits increased with the use of some fat mimetics (polydextrose, maltodextrin with low dextrose, oat product rich in β-glucans, oligofructose and a blend of micro-particulated whey proteins and emulsifiers). In addition to that, Seker et al. (2010) studied fat replacement by apricot kernel flour in a wire-cut cookie and reported that the force necessary to break the biscuit increased with using of apricot kernel flour as fat replacement.

On the other hand, as seen in the control samples (Table 4), a reduction in the amount of shortening caused the fracturability of the biscuits to decrease. In addition, the fracturability of the biscuits was reduced by increasing the moisture content, depending on the amount of WbFg used in the biscuit formulation. Contrary to this, as the amounts of SF and MF–WbFg with 30% dry matter were increased, the fracturability of the final product increased. This result can be explained by the decrease in the amount of water available in the final product depending on the water holding capacities of the dietary fibers.

The spread ratio of the biscuits reduced significantly when fat was reduced in the formulation. Biscuits containing 40% shortening had a spread ratio of 6.1, which reduced to 4.3 when fat content was reduced 75% in the formulation. The more WbFg, the thicker and the lower spread ratio values were observed (Table 4). Similarly, Laguna et al. (2012) and Seker et al. (2010) have also reported that replacing fat by fat mimetics affected shape of biscuits by increasing their thickness and decreasing their spread ratio.

Conclusion

The biscuit dough properties changed with replacing fat by WbFg. When fat in biscuit formulation is reduced, the resulted dough become harder. The elastic and viscous properties increased using 20–30% of WbFg instead of fat. Large size wheat bran fibers showed favorable effects in terms of textural properties of the dough and the quality parameters of biscuits while the fibers with smaller size improved viscoelastic properties of dough similar to the control. This study showed that the texture of biscuits was greatly dependent on the texture of the dough.

Although the use of these fibers in the production of low-fat biscuits were suitable in terms of workability of dough samples, increasing fiber content and/or reducing fiber size resulted in harder biscuits with lower spreading ratio.

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