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Effects of bran, shorts and feed flour by ultra-fine grinding on rheological characteristics of dough and bread qualities

Jinli Zhang, Hanxue Hou, Haizhou Dong* and Yangyong Dai

Department of Food Science and Engineering, Shandong Agricultural University, Tai'an, 271018, P.R. China.

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Wheat bran, shorts and feed flour are rich in dietary fiber and micronutrients. The effects of ultra-fine ground bran, shorts and feed flour on rheological characteristics of dough and bread qualities were investigated. Water absorption and dough development time gradually increased while mixing tolerance index and dough stability time decreased with the addition of bran, shorts and feed flour. The extension resistance and energy values for all blended flours were significantly higher than those of the control flour. The gluten index decreased while the gluten yield increased with the increase of bran, shorts and feed flour. Peak viscosity of the blended flour significantly decreased compared to the control flour. Pasting temperature rose from 67.05°C to 71.55, 72.6 and 69.25°C for bran, shorts and feed flour blends, respectively. The total scores of sensory evaluation and hardness of crumb texture significantly decreased with the increase of bran, shorts and feed flour.

Key words: Ultra-fine grinding, bran, shorts, feed flour, rheological characteristic, bread quality.

INTRODUCTION

Many epidemiological studies have shown that regular intake of whole grain and whole grain products is related to reduced risks of various chronic diseases such as obesity (Slavin, 2005), cardiovascular disease (Anderson, 2004; Djousse and Gaziano, 2007; Giacco et al., 2009; Madhujith and Shahidi, 2007), type 2 diabetes (Anderson and Pasupuleti, 2008; Kochar et al., 2007; Lutsey et al., 2007), and some cancers (Kasum et al., 2002; Wakai et al., 2006). However, most wheat-based foods in many parts of the world are made with refined white flour from which the germ and bran are removed, although these tissues have considerable nutrition and contain most of the micronutrients, phytochemicals and fiber of the grain (Liu, 2007).

In an industrial mill, the milling by-products include germ, bran, shorts, and feed flour (or red dog). The value of the by-products which serve mainly for animal feeding is usually underestimated because these by-products are

rich in phytochemicals and high antioxidant activity (Beta et al., 2005; Liyana-Pathirana and Shahidi, 2006, 2007). But direct addition of milling by-products to white flour will lead to bad mouthfeel, poor appearance of end products and undesirable processing performance (Noort et al., 2010; Penella et al., 2008; Sudha et al., 2007a). Wheat bran is detrimental to loaf volume (Lai et al., 1989) and crumb colour (Zhang and Moore, 1999). Addition of wheat bran into bread dough can increase dough water absorption, reduce mixing time and dough mixing tolerance (Zhang and Moore, 1997).

Ultra-fine ground bran can be used as a food ingredient to improve the nutritional potential of wheat-based products (Hemery et al., 2011). Particle size is an important factor that affects the characteristics and physiological functions of fiber-rich food materials (Chou et al., 2008; Stewart and Slavin, 2009; Wu et al., 2009). The effects of bran from wheat and other cereals on rheological properties of dough and end products have been studied (Noort, 2010; Sudha et al., 2007a; Zhang and Moore, 1999). However, there have been few reports about the influence of bran, shorts and feed flour by ultra-fine grinding on rheological characteristics of dough

*Corresponding author. E-mail: hzhdong28@yahoo.com.cn. Tel: +86 538 824 2850. Fax: +86 538 8242850.

and bread qualities. Therefore, in this study, the effects of bran, shorts and feed flour by ultra-fine grinding on the qualities of dough and bread were determined.

MATERIALS AND METHODS

Materials

The bread flour as well as the three wheat milling by-products, namely bran, shorts and feed flour, was supplied by Jinan Mintian Flour Co., Ltd (Jinan, China). The extraction rates of white flour, bran, shorts and feed flour were 72, 12, 10 and 5%, respectively. The milling by-products were grounded for 20 min with a WZJ6 vibratory ultra-fine mill (Jinan Beili Powder Machine, Jinan, China).

Physico-chemical analysis

Moisture, ash, protein, crude fat and fiber were determined according to the Standard AACC (2000) method 44-15A, 08-01, 46-11A, 30-10 and 32-10, respectively. The particle size of ultra-fine ground bran, shorts and feed flour was determined in triplicate with a LS 13-320 laser particle size analyzer (Surplus Lab Inc., Michigan, USA) using ethanol as a solvent. The percentages of the volume of granules with different sizes were recorded. Average and median granule diameters were calculated automatically.

Flour qualities

Blends of 0, 5, 10, and 15% were prepared by substituting the flour with ultra-fine ground bran, shorts and feed flour. The physico-chemical parameters of the blends changed correspondingly. The effects of different addition levels on dough rheology were determined by a JFZD Farinograph (Dongfu, Beijing, China) according to the standard AACC method 54-21. Parameters measured were water absorption, dough development time, dough stability and mixing tolerance index. The elastic properties of dough with different addition levels of fiber materials were measured with a JMLD150 Extensograph (Dongfu, Beijing, China) according to the standard AACC method 54-10. The parameters studied were resistance to extension (R), extensibility (E), ratio figure (R/E) and energy (Area). Only 90th min values were discussed. Wet gluten and gluten index were determined according to AACC method 38-12A. Pasting properties were determined according to AACC Method 76-21 standard 1.

Bread qualities

The bread was made with a basic dough formula according to AACC (2000) method 10-09 with modification. Basic dough formula on a 100 g flour basis consisted of salt (1 g), instant dry yeast (3 g), sugar (5 g), improver (0.8 g), the amount of water required to reach 500 BU of consistency for flour blends with fiber materials. The doughs were optimally mixed and fermented for 3 h. The doughs were cut into individual portions of 180 g and then shaped to sheets. The sheets were proofed at 30°C to desired height and baked at 220°C for 12 min. The sensory evaluation of samples was performed after cooling for 1 h at room temperature. The other samples were stored in polyethylene bags before other quality evaluations.

Bread evaluation

Physical characteristics

The bread was weighed directly. The volume and moisture content

were determined according to the AACC (2000) method 10-05 and 44-15A. The specific volume (ml/g) of bread was described as bread loaf volume/bread loaf weight. The color of the bread crumb was measured with a Minolta CR-400 Chromameter (Minolta Co., Ltd., Tokyo, Japan), with five replicates. Each loaf of bread was cut into slices of 2.00 cm in thickness. Color values were recorded as "L" (0, black; 100, white), "a" (-a, greenness; +a, redness), and "b" (-b, blueness; + b, yellowness).

Texture analysis

The analyses of texture were carried out 1, 4 and 7 days after baking using a texture analyser (model TA-XT2i, Stable Micro System, England) with a 35 mm probe (P/35) following Carr and Tadini (2003) with modification. The hardness, springiness, cohesiveness, resilience and chewiness of the bread were determined. The crust and the end of the bread were removed, as a result, the bread was a small cube with approximately 3 cm of length. The TPA method was conducted under these conditions: pre-test speed: 2.0 mm/s, test speed: 1.0 mm/s, post-test speed: 2.0 mm/s, distance: 10 mm, trigger type: auto-20 g, time: 5 s.

Sensory evaluation

The loaves were evaluated in appearance (including crust color and shape, 20P), aroma and flavor (20P), crumb cell (20P), elasticity (20P) and mouthfeel (20P) characteristics. The bread samples served as whole slices at room temperature for sensory analysis. The 9 trained panelists were members of the Department of Food Science and Engineering in Shandong Agricultural University ranging in age from 20 to 40, all of whom were nonsmokers with 4 females.

Statistic analysis

The sensory evaluation data were statistically analysed and the treatments were tested using Duncan's multiple range test with significance defined at $P < 0.05$.

RESULTS

Physico-chemical properties of bran, shorts and feed flour

The physico-chemical properties of bran, shorts, feed flour and bread flour used in this study are shown in Table 1. The moisture content of bran, shorts and feed flour was 11.67, 10.77 and 11.51%, respectively. Protein content of feed flour (13.95%) was lower than that of bran (17.28%) and shorts (17.41%). The crude fat content for shorts was the highest (5.12%) followed by bran (4.68%) and feed flour (2.7%). The crude fiber for bran and shorts was 12.14 and 10.10%, respectively. Feed flour had the lowest crude fiber (6.46%) and ash (2.67%). Average granule size of ultra-fine ground bran, shorts and feed flour was 28.81, 25.55 and 21.92 μm , respectively. The particle size distribution of ultra-fine ground bran, shorts and feed flour is shown in Figure 1.

Table 1. Physico-chemical properties of bran, shorts and feed flour

Fiber sample	Moisture (%)	Protein ^a (%)	Crude fat ^a (%)	Crude fiber ^a (%)	Ash ^a (%)	Average granule size (μm)	Median granule size (μm)
Flour	11.4 ± 0.25	13.5 ± 0.37	1.3 ± 0.07	0.1 ± 0.03	0.43 ± 0.04	-	-
Bran	11.67 ± 0.07	17.28 ± 0.17	4.68 ± 0.03	12.14 ± 1.7	6.08 ± 0.02	28.81 ± 1.6	24.89 ± 1.4
Shorts	10.77 ± 0.04	17.41 ± 0.13	5.12 ± 0.05	10.10 ± 1.3	4.83 ± 0.06	25.55 ± 2.1	21.43 ± 1.7
Feed flour	11.51 ± 0.10	13.95 ± 0.09	2.7 ± 0.02	6.46 ± 1.4	2.62 ± 0.04	21.92 ± 1.1	20.39 ± 1.3

Values are means ± standard deviations (n = 3). ^a Dry basis

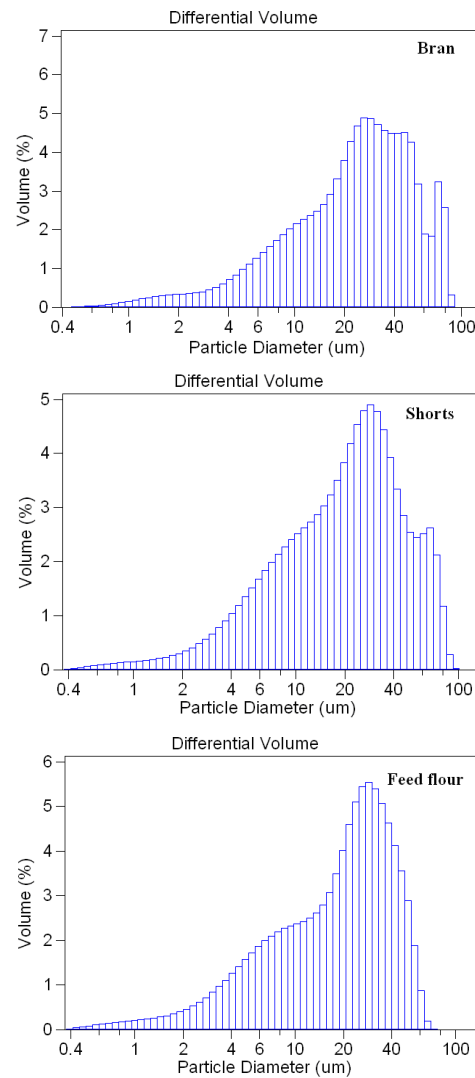


Figure 1. The particle size distribution of ultra-fine ground bran, shorts and feed flour.

Effects of bran, shorts and feed flour on dough mixing properties

Addition of bran, shorts and feed flour at 0, 5, 10 and 15% levels had different effects on farinograph parameters of

the dough. The results are shown in Figure 2. Water absorption and dough development time gradually increased with the increase of bran, shorts and feed flour. The increase extent of water absorption for bran and shorts blends was similar but greater than that of feed

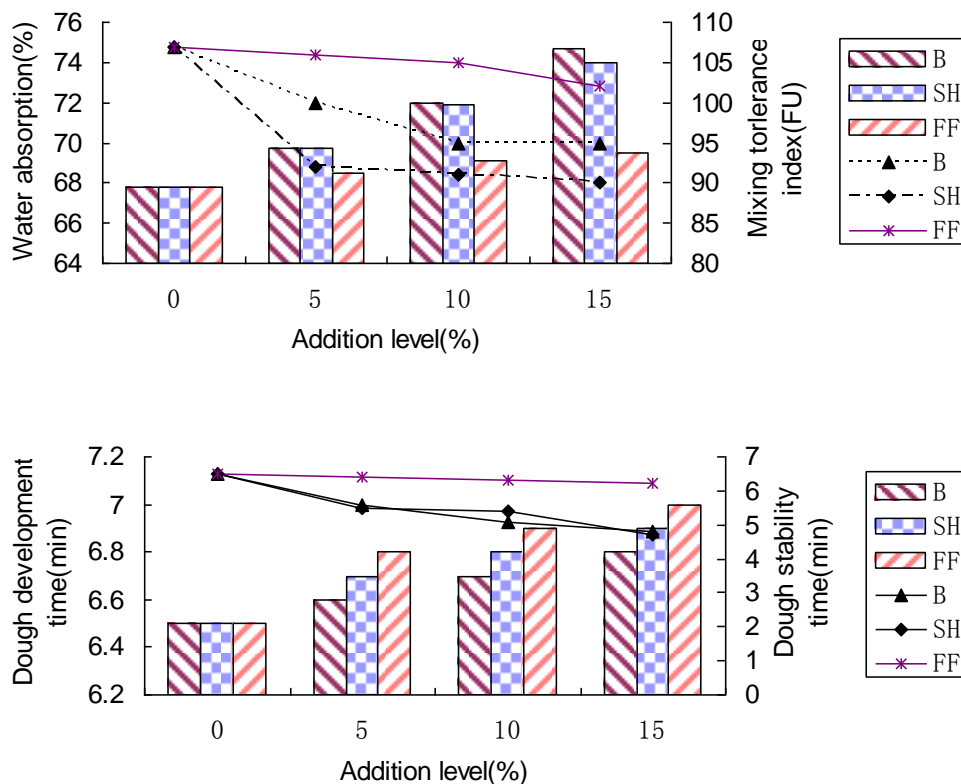


Figure 2. Farinograph characteristics of blending flours with different levels of bran, shorts and feed flour.

flour blends. However, dough development time observed the order of feed flour>shorts>bran with the increase of addition levels. The decreasing extent of mixing tolerance index was high, middle and low for shorts, bran and feed flour blends, respectively with the increased addition level. Dough stability time was significantly decreased for bran and shorts blends while the value for feed flour slightly decreased.

Effects of bran, shorts and feed flour on the elastic properties of the dough

The effects of bran, shorts and feed flour at different addition levels on elastic properties are illustrated in Figure 3. Generally, the resistance to extension (R) values for all blended flour was significantly higher than that for the control flour. R value at 10% addition level was slightly lower than that at 5 and 15% addition level. The extensibility (E) values were slightly decreased with the increase of bran, shorts and feed flour. The energy values of the blended flour were higher than those of the control flour and slightly decreased with the increase of bran, shorts and feed flour. Ratio between resistance and extensibility gradually increased for the blending flour with increasing levels of bran, shorts and feed flour. All extensograph parameters in present study indicated that

addition of bran, shorts and feed flour to bread flour increased dough strength.

Effects of bran, shorts and feed flour on gluten yield and index

The gluten index is a measure for the quality of gluten protein. It was found that the gluten index decreased with the increase of bran, shorts and feed flour (Figure 4). The gluten yield of blended flours increased from 39.4% to 48.2%-49.5% at 5% addition level of the fiber materials.

Effects of bran, shorts and feed flour on pasting properties

Table 2 shows the pasting properties of bread flour and the blends with bran, shorts and feed flour. Peak viscosity (PV) of the blended flours markedly decreased compared to the control flour except for 5% feed flour blend. The trough viscosity (CV) and final viscosity (FV) gradually decreased with the increase of bran, shorts and feed flour. The values of breakdown and setback did not vary with the increase of ultra-fine ground bran, shorts and feed flour. Pasting temperature (PT) increased from 67.05°C to 71.55, 72.6 and 69.25°C for bran, shorts and feed flour blend, respectively.

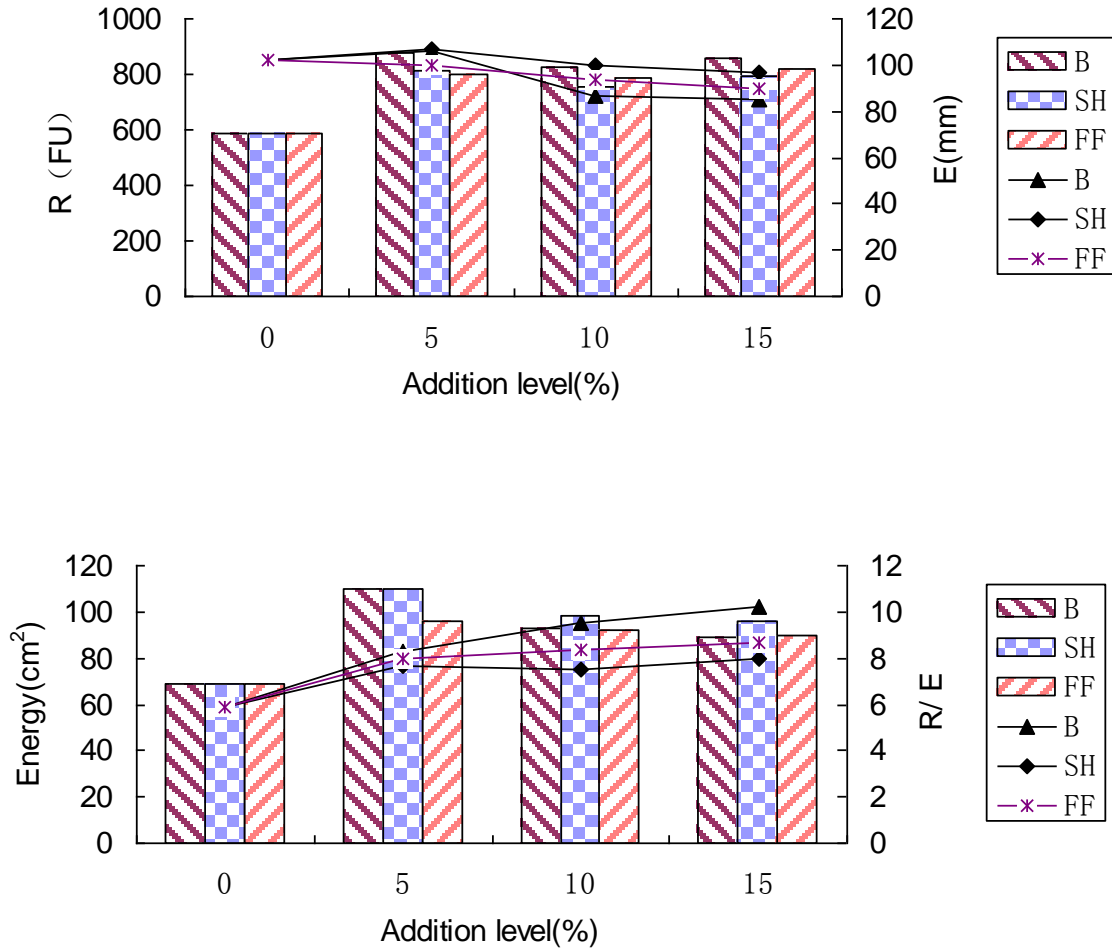


Figure 3. Extensograph characteristics of blending flours with different levels of bran, shorts and feed flour. R, resistance to extension; E, extensibility; R/E, ratio between resistance to extension and extensibility.

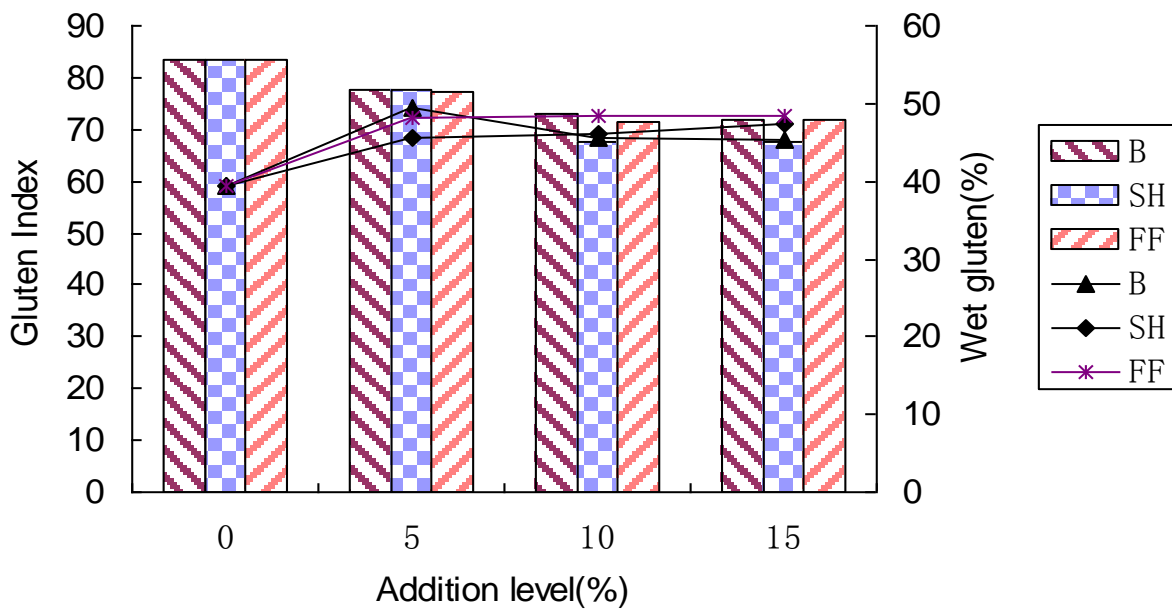


Figure 4. Effects of bran, shorts and feed flour on gluten yield and gluten index.

Table 2. Effects of bran, shorts and feed flour on pasting properties.

Sample	PV(cP)	TV(cP)	BD(cP)	FV(cP)	SB(cP)	PT(°C)
Control	2064 ± 12	1379 ± 14	685 ± 16	2817 ± 16	1438 ± 11	67.05 ± 0.25
Bran 5%	1794 ± 17	1173 ± 7	621 ± 11	2520 ± 19	1347 ± 10	68.5 ± 0.11
Bran 10%	1786 ± 6	1110 ± 10	676 ± 14	2504 ± 24	1394 ± 14	69.8 ± 0.07
Bran 15%	1582 ± 3	990 ± 16	592 ± 18	2357 ± 21	1367 ± 12	71.55 ± 0.26
Shorts 5%	1929 ± 21	1202 ± 12	727 ± 13	2629 ± 19	1427 ± 10	67.55 ± 0.14
Shorts 10%	1686 ± 11	1035 ± 9	651 ± 13	2447 ± 14	1412 ± 15	69.45 ± 0.21
Shorts 15%	1543 ± 14	927 ± 19	616 ± 17	2313 ± 17	1386 ± 17	72.6 ± 0.23
Feed flour 5%	2084 ± 14	1321 ± 13	763 ± 10	2783 ± 15	1462 ± 16	68.1 ± 0.19
Feed flour 10%	1874 ± 18	1152 ± 14	722 ± 14	2556 ± 14	1404 ± 14	68.7 ± 0.13
Feed flour 15%	1814 ± 12	1070 ± 18	744 ± 15	2443 ± 18	1373 ± 12	69.25 ± 0.09

Values are means ± standard deviations (n = 3). PV, Peak viscosity; TV, trough viscosity; BD, breakdown viscosity; FV, final viscosity; SB, setback viscosity; PT, pasting temperature.

Table 3. Effects of bran, shorts and feed flour on physical characteristics of bread.

Sample	Specific volume (cm ³ /g)	Crumb color			Moisture content (%)		
		L	a	b	1 day	4 day	7 day
Control	4.43 ± 0.04	75.26 ± 1.3	-0.45 ± 0.02	15.32 ± 0.28	36.98 ± 0.31	36.56 ± 0.13	34.46 ± 0.32
5% bran	3.67 ± 0.07	73.49 ± 1.9	1.49 ± 0.04	17.93 ± 0.34	33.24 ± 0.21	31.84 ± 0.17	28.96 ± 0.26
10% bran	3.09 ± 0.03	70.24 ± 2.1	1.82 ± 0.16	19 ± 0.26	34.36 ± 0.26	32.14 ± 0.15	31.5 ± 0.24
15% bran	2.86 ± 0.16	66.96 ± 1.1	2.8 ± 0.09	19.85 ± 0.14	36.73 ± 0.24	36.49 ± 0.31	34.71 ± 0.27
5% shorts	4.15 ± 0.11	73.68 ± 1.5	-0.6 ± 0.03	15.31 ± 0.27	33.25 ± 0.14	31.65 ± 0.24	30.36 ± 0.23
10% shorts	3.63 ± 0.05	72.55 ± 1.4	0.17 ± 0.01	16.35 ± 0.22	34.62 ± 0.34	32.19 ± 0.29	31.47 ± 0.12
15% shorts	3.26 ± 0.08	70.7 ± 1.6	0.73 ± 0.05	16.87 ± 0.11	35.69 ± 0.10	33.22 ± 0.25	31.71 ± 0.17
5% feed flour	3.67 ± 0.17	74.69 ± 1.8	1.26 ± 0.06	16.83 ± 0.19	36.10 ± 0.09	35.02 ± 0.13	32.23 ± 0.19
10% feed flour	3.05 ± 0.09	72.87 ± 1.5	2.56 ± 0.04	19.28 ± 0.20	36.77 ± 0.21	36.19 ± 0.16	32.9 ± 0.15
15% feed flour	2.92 ± 0.11	70.15 ± 1.6	3.62 ± 0.07	20.19 ± 0.29	36.83 ± 0.22	36.46 ± 0.21	33.7 ± 0.13

Values are means ± standard deviations (n = 3).

Effects of bran, shorts and feed flour on bread qualities

Physical characteristics

Physical characteristics of bread made from the control flour and the blends with bran, shorts and feed flour are presented in Table 3. Specific volume of bread made from the control flour was the largest among the bread samples. Specific volume decreased gradually with the increase of bran, shorts and feed flour. Addition level of 15% bran, shorts and feed flour reduced the specific volume from 4.43 to 2.86, 3.26 and 2.92 cm³/g, respectively.

The moisture content of bread made from the blended flour was generally lower than that of the control bread during short time storage (Table 3). The moisture content for all samples decreased with the increase of storage time. The decrease extent of moisture content for bread made from the blended flours was greater than that of the control flour. The changes of moisture content for bread at

15% bran addition level were similar to those of the control bread.

The effects of bran, shorts and feed flour on bread crumb color are shown in Table 3. L values gradually decreased with the increase of fiber materials. The highest L value for the control flour was 75.26 and the lowest L value for 15% bran-blended flour was 66.96. The change of L value indicated that the color of crumb became darker with the addition of fiber materials. Crumb-a values changed from green to red and b values changed from blue to yellow. Crumb-a values for bread made from the blending flour with shorts were much lower than those for bread made from the blended flour with bran and feed flour.

Sensory evaluation

In general, the bread qualities fell significantly with the increase of bran, shorts and feed flour (Table 4). The

Table 4. Effects of bran, shorts and feed flour on sensory quality of breads.

sample	Appearance	Flavor	Structure	Elasticity	Mouth-feel	Total score
Control	18.37 ± 0.70 ^a	17.61 ± 0.87 ^b	18.29 ± 0.59 ^a	18.78 ± 1.08 ^{ab}	17.57 ± 0.75 ^a	90.62
5% bran	16.86 ± 0.42 ^b	16.14 ± 0.73 ^{bc}	15.43 ± 0.72 ^{bc}	18.26 ± 0.63 ^{abc}	13.29 ± 0.56 ^e	79.98
10% bran	12.42 ± 0.83 ^{de}	11.16 ± 0.74 ^d	12.61 ± 1.01 ^d	12.56 ± 0.86 ^d	11.87 ± 0.42 ^f	60.62
15% bran	11.82 ± 0.47 ^e	9.71 ± 0.79 ^d	10.48 ± 1.12 ^e	11.83 ± 0.75 ^d	10.48 ± 0.31 ^g	54.32
5% shorts	15.30 ± 0.42 ^c	16.80 ± 1.04 ^b	14.74 ± 0.84 ^c	17.61 ± 0.38 ^{bc}	16.12 ± 0.60 ^{bc}	78.57
10% shorts	13.40 ± 0.52 ^d	14.74 ± 0.68 ^c	14.26 ± 0.99 ^c	16.88 ± 0.75 ^c	11.65 ± 0.22 ^f	72.93
15% shorts	11.15 ± 0.80 ^e	14.70 ± 0.45 ^c	9.76 ± 0.98 ^e	12.58 ± 1.09 ^d	10.46 ± 0.67 ^g	58.65
5% feed flour	18.31 ± 1.48 ^a	19.69 ± 1.03 ^a	16.83 ± 0.70 ^b	19.68 ± 1.44 ^a	16.87 ± 0.34 ^{ab}	91.38
10% feed flour	16.84 ± 0.93 ^b	16.12 ± 1.08 ^{bc}	15.45 ± 0.67 ^{bc}	16.89 ± 0.97 ^c	15.43 ± 0.51 ^{cd}	80.73
15% feed flour	11.84 ± 0.64 ^e	14.72 ± 1.32 ^c	14.26 ± 0.19 ^c	14.59 ± 0.33 ^d	14.75 ± 0.45 ^d	70.16

Values are means ± standard deviations (n = 9). Mean values with different letters are significantly different (P < 0.05).

quality of bread made from 5% bran, 5% shorts, 5% and 10% feed flour blends was acceptable. The appearance scores of bread decreased significantly with fiber material addition, particularly at 15% addition level for all materials. The desirable crust color of bread was golden brown, which became darker brown with bran, shorts and feed flour additions. Breads containing feed flour had better appearance than breads containing bran and shorts. Bread from ultra-fine ground bran blend had lower flavor score than that from shorts and feed flour blends. The scores of structure, elasticity and mouth-feel of breads made from feed flour blend were higher than those of breads made from bran and shorts blends.

Texture profile analysis

Crumb texture properties of breads at 1, 4 and 7 days after baking are shown in Table 5. It can be seen that the control bread had the softest crumb, and the increase of bran, shorts and feed flour in blends led to obvious increase in crumb hardness. The hardness of bread samples was 9725, 6143 and 3197 g at 15% addition level of bran, shorts and feed flour, respectively. Hardness also increased with the increase of storage time.

Differences of crumb springiness were not distinct with the increase of fiber materials and storage time. Cohesiveness remained unchanged at varying levels of fiber materials and slightly decreased with the increase of storage time. The resilience decreased with the increase of fiber materials and storage time. It indicated that the elasticity of crumb is reduced. The chewiness significantly increased with the increase of fiber materials.

DISCUSSION

Generally speaking, the addition of wheat bran fractions to white flour leads to poor dough performance and bread qualities. Effects of bran, shorts and feed flour on dough mixing properties in this study were very similar to those

previously reported by Sudha et al. (2007a) who studied the influence of fiber from different cereals on the rheological characteristics of wheat flour dough. Water absorption increased for the blended flours because fibers typically bind more water compared to main flour components (Rosell et al., 2001). Feed flour had less fiber than bran and shorts, so water absorption for the flour blended with feed flour was lower than that of the flour with bran and shorts. By hampering the formation of network structure of gluten protein, fibers increased dough development time and decreased dough stability time and mixing tolerance index (Noort et al., 2010).

The increase extent of dough strength indicated by R, E, Energy and R/E was smaller than that previously reported by Sudha et al. (2007a), which may be explained by different fiber materials used. In this present study, bran, shorts and feed flour were ultra-fine ground and had different fiber content. The morphology, structure and physico-chemical properties of fiber materials greatly changed after ultra-fine grinding (Hemery et al., 2011; Noort et al., 2010).

The gluten index decreased with the increase of bran, shorts and feed flour which indicated that fiber-rich materials decreased the forming ability of gluten network. The gluten yield of blended flours increased with the addition of fiber materials which may be caused by higher water binding capacity of fiber-rich materials than that of the white flour. This result is not in agreement with previous reports (Noort et al., 2010). The difference may be caused by variation in composition and physical properties of bran fractions, variation in bread baking procedure and formulation.

Peak viscosity (PV) of the blended flours decreased with the addition of the fiber rich materials which indicated that the swelling of starch in the blends was inhibited by the fiber materials. The result was consistent with the report of Sudha et al. (2007b). The trough viscosity (TV) and final viscosity (FV) gradually decreased with the increase of bran, shorts and feed flour. The increase of pasting temperature may be due to higher water binding

Table 5. Effects of bran, shorts and feed flour on texture properties of breads.

Sample	Hardness (g)			Springiness			Cohesiveness			Resilience			Chewiness (g)		
	1 day	4 day	7 day	1 day	4 day	7day	1 day	4 day	7 day	1 day	4 day	7day	1 day	4 day	7 day
Bread flour	875	1791	2232	0.9261	0.8983	0.8964	0.5501	0.4234	0.4182	0.2269	0.1493	0.1424	445	681	837
5% Bran	2097	4428	4863	0.9237	0.8777	0.8843	0.5172	0.4272	0.3818	0.1735	0.144	0.1181	1002	1660	1641
10% Bran	4389	9198	9244	0.9212	0.8927	0.899	0.5561	0.3987	0.348	0.1587	0.1211	0.0978	2248	3274	2892
15% Bran	9726	12784	14367	0.9536	0.9507	0.8737	0.4128	0.3415	0.3225	0.1282	0.1055	0.0904	3828	4664	3602
5%Shorts	2373	2629	4117	0.9289	0.9114	0.8911	0.5743	0.4472	0.3767	0.1814	0.1575	0.11	1265	1071	1382
10% Shorts	3841	4637	6230	0.9353	0.8926	0.8908	0.5099	0.4459	0.4028	0.1405	0.1238	0.0949	1831	1680	2457
15% Shorts	6143	6832	8409	0.9172	0.9024	0.8779	0.5027	0.3942	0.3865	0.1283	0.1175	0.0943	2832	2430	2690
5% feed flour	1399	2452	4050	0.9321	0.9003	0.8702	0.5383	0.4449	0.3929	0.2222	0.1605	0.1253	702	982	1385
10%feed flour	2259	3865	5265	0.9286	0.8909	0.8829	0.5188	0.4044	0.3743	0.1817	0.1213	0.1146	1088	1392	1740
15%feed flour	3197	4328	5321	0.9259	0.899	0.8807	0.5056	0.4133	0.3557	0.1555	0.1236	0.106	1496	1608	1667

capacity of fiber materials which reduced the free water molecule around starch granules.

The decrease of loaf volume was due to the dilution of gluten protein and interaction between gluten protein and fiber materials (Anil, 2007; Noort et al., 2010; Sullivan et al., 2011). Addition of fiber materials to white flour destroyed the optimal gluten network formation and more gas was lost during the fermentation and baking of bread.

The color and sensory qualities of bread decreased with increased levels of fiber materials. The addition of fiber materials increased the difficulty in biting and swallowing of the products. Hardness increase of the bread with bran, shorts and feed flour indicated the deterioration of bread texture (Al-Saqer et al., 2000). Sullivan et al. (2011) reported similar effects of barley middlings on crumb hardness at different addition levels and with different storage time. So in order to obtain bread with richer fiber and phytochemicals, more improving ingredients should be added in bread

formula.

Conclusion

Addition of ultra-fine ground bran, shorts and feed flour at 0, 5, 10 and 15% levels had different effects on rheological characteristics of the dough and bread qualities. Water absorption and dough development time gradually increased while mixing tolerance index and dough stability time decreased with the increase of bran, shorts and feed flour. The values of resistance to extension and energy for all blended flours were significantly higher than those of the control flour. The gluten index decreased while the gluten yield increased with the increase of bran, shorts and feed flour. Peak viscosity of the blended flours significantly decreased compared to the control flour. Pasting temperature increased from 67.05°C to 71.55, 72.6 and 69.25°C for bran, shorts and feed flour

blends, respectively. The total scores of sensory evaluation and hardness of crumb texture significantly decreased with the increase of bran, shorts and feed flour. To obtain bread of high quality with richer fiber and phytochemicals, more baking ingredients should be added in bread formula.

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