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Bran characteristics impact the whole wheat noodle quality

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Abstract

In this study, whole wheat flour (WWF) was prepared by blending one commercial noodle flour with ten different bran samples from white and red winter wheat varieties. The whole wheat dough properties and noodle qualities were investigated. In general, brans from red wheat varieties exhibited higher total phenolic contents than those from white wheat varieties. Mixolab analysis revealed significant relationships between bran ash, starch, and insoluble dietary fiber (IDF) contents and the mixing and pasting properties of WWF dough. Concerning the noodle quality, bran protein content showed a positive correlation with tensile strength ($P < 0.01$), elongation distance, springiness, and resilience of cooked noodles. Also, bran IDF content was positively related to the hardness of cooked whole-wheat noodles. These results suggest that bran with higher protein content and lower IDF content is more desirable for the production of whole wheat noodles.

Keywords: whole wheat flour; bran characteristics; mixing and pasting properties; noodle quality.

Practical Application: This study aims to use different varieties of bran added to commercial flours to make whole wheat flour. To study its effect on dough and noodle quality. Hopefully, it can provides useful information to noodle manufacturers to select suitable wheat varieties for the production of WWN.

1 Introduction

Compared to refined wheat flour, whole wheat flour (WWF) is rich in dietary fibers, minerals, vitamins, and antioxidants. Whole wheat intake is believed to reduce the risk of many diseases, such as hypertension, obesity, and colon cancers (Wang et al., 2016). However, regardless of these benefits, the addition of WWF in foods can result in weak structure and inferior sensory quality, which reduce consumer acceptance. Therefore, it is challenging to produce whole wheat products, especially those with equivalent quality to the traditional products without bran addition.

The composition of wheat bran depends on many factors, such as wheat variety, growing environment, grain shape, bran layer thickness, and milling system (Zhang & Moore, 1997; Cai et al., 2014). The variation in bran composition can substantially affect the quality of whole wheat products (Cai et al., 2014; Ma et al., 2019; Ma et al., 2018; Navrotskyi et al., 2019; Seyer & Gélinas, 2009). Therefore, finding bran with desirable characteristics is the prime requirement for the manufacture of quality whole wheat products (Ma et al., 2018).

Noodle is a staple food that is routinely consumed and very popular in China and other Asian countries (Niu et al., 2014c). Therefore, the development of whole wheat noodles (WWN) can be an effective way to promote whole wheat food consumption. However, so far, little is known about the impact of bran characteristics on the quality of WWN. This study aimed to identify the influences of bran chemical composition on the dough properties and quality of WWN. Bran from 10 different white and red winter wheat varieties was tested for its effects on dough properties and quality of WWN. This study provides useful guidance for the improvement of WWN quality and other whole-wheat products.

2 Materials and methods

2.1 Materials

Ten hard wheat varieties, including five each red (Huai mai 35, Ningmai 13, Yang mai 20, Su mai 188 and Ji mai 22), and white winter (Yang mai 23, Hao mai 1, Annong 0711, E mai 596 and Zheng mai 7698) varieties harvested in May 2019 were kindly provided by School of Agronomy of Anhui Agricultural University, China. Commercial noodle wheat flour (protein content 12.2%, moisture 14%) was provided by Fengzheng Food Company (Weifang, China)

2.2 Bran powder preparation

Wheat grains were tempered 24 h to 16% moisture and milled using a Brabender GmbH &Co. KG mill (Germany). Bran fractions from all wheat varieties were ground using a hammer mill fitted with a 0.5 mm screen (FS200L, Jungong Co., Ltd, Changdong, China). Brans were stored in plastic bags at -18 °C for further composition analysis and noodle-making experiments.

2.3 Bran composition analysis

Bran ash, protein, and starch contents were measured according to AACC-approved methods 08-01.01, 46-30.01, and

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76-13.01, respectively. Crude fat was determined following the AOAC method 920.39C. The contents of total (TDF), soluble (SDF), and insoluble dietary fibers (IDF) were measured according to AACC-approved method 32-07.01. Phenolic and phytate contents in wheat bran were measured as described by Cai et al. (2014).

2.4 Mixolab measurements

Reconstituted WWFs were prepared by blending the respective bran sample with the same noodle flour (1 : 4 dry basis). The dough rheological properties were measured using the Mixolab (Chopin, Paris, France) 'Chopin^{+}' protocol. The parameters including water absorption (%), C1 time (the dough development time, min), stability (the elapsed time that the torque was kept at 1.1 Nm, min) and values such as C3 (peak viscosity, Nm), C3-C4 (stability of the hot-formed gel, Nm), and C5-C4 (the degree of starch retrogradation, Nm) were recorded.

2.5 Fresh WWN making process

The noodles consist of 100 g of reconstituted WWF (14% moisture basis), distilled water (Mixolab water absorption values multiplied by 62%), and 1 g of salt. The dough was mixed for 5 min using a high-speed mixer (SJJ-B10Q1, Xiaoxiong Co., Ltd., Foshan, China) and then rested for 20 min at room temperature (RT). Next, the dough was sheeted using a noodle machine (PTN-168, Perkone scientific Ltd., Zhejiang, China). The final dough sheets were cut into noodle strands (width 2 mm, thickness 1 mm, and length 20 cm).

2.6 Cooking properties of fresh WWN

The optimum cooking time of noodles was measured as described by Li et al. (2019). For the cooking loss measurements, about 20 g noodles were put into 500 mL of boiling water and cooked for optimal cooking time; the water was evaporated to a constant weight at 105 °C. Cooking loss was calculated as the mass ratio of the filtrate weight after drying and the weight of uncooked noodles (dry basis).

2.7 Texture analysis

The textural properties of cooked noodles were measured exactly 5 min after cooking using a TA-XTPlus texture analyzer (Stable Micro Systems, UK). For textural profile analysis (TPA), five noodle strands were placed in parallel on the test board and compressed with a TA-47 W pasta blade. Pre-test, test, and post-test speeds were 2 mm/s and the compression ratio was 70%. For the tensile test, noodles were stretched with an A/SPR probe. Pre-test, test, and post-test speeds were 3 mm/s, and the probe distance was 100 mm. Tensile strength and elongation distance parameters were recorded from the tensile test.

2.8 Statistical analysis

All results are presented as means of at least three independent trials and statistical analysis was performed using the SPSS 20.0 program. A one-way analysis of variance and Duncan's test were conducted to compare the influence of wheat variety on the bran characteristics (Tables 1-2), dough properties (Table 3), and quality parameters of WWN (Table 4). The correlations of bran characteristics with dough properties (Table 5) and quality parameters of WWN (Table 6) were determined using Pearson's correlation analysis.

3 Results and discussion

3.1 Composition of wheat bran

Chemical analysis of the bran samples from different varieties revealed significant differences in protein, fat, ash, and starch contents (Table 1). Bartnik & Jakubczyk (1989) suggested that many factors could affect the composition of wheat bran, such as wheat variety, growing environment, grain shape, bran layer thickness, and milling system. It is believed that bran dietary fiber with high water-absorbing capacity reduces the product quality of whole wheat products (Navrotskyi et al., 2019). The bran contents of TDF, SDF, and IDF in the ten wheat varieties are presented in Table 1. For all wheat varieties, the main component of wheat bran fiber was IDF. Compared to the brans from white wheat classes, wheat bran from red wheat classes had higher SDF

Table 1. Composition of bran samples from different wheat varieties[a].

Wheat varieties	Protein (%)	Fat (%)	Ash (%)	Starch (%)	IDF (%)[b]	SDF (%)[b]	TDF (%)[b]
Red wheat							
Huai mai 35	16.18 ± 0.50^{c-e}	3.93 ± 0.15^{e-h}	4.58 ± 0.15^{ab}	17.15 ± 0.06^{de}	49.38 ± 0.43^{ab}	4.58 ± 0.05^{h}	53.96 ± 2.33^{a}
Yang mai 23	16.48 ± 0.39^{c}	4.40 ± 0.20^{ab}	4.53 ± 0.10^{a-c}	15.85 ± 0.19^{i}	48.10 ± 0.14^{d}	4.13 ± 0.05^{g}	52.23 ± 2.00^{a-d}
Ning mai 13	15.13 ± 0.35^{fg}	4.18 ± 0.13^{a-e}	4.33 ± 0.05^{a-e}	16.73 ± 0.22^{g}	49.55 ± 0.06^{a}	3.50 ± 0.08^{e}	53.05 ± 1.82^{a-c}
Hao mai 1	17.70 ± 0.26^{a}	3.83 ± 0.22^{f-i}	4.28 ± 0.22^{c-f}	17.78 ± 0.10^{a}	48.70 ± 0.16^{c}	4.85 ± 0.13^{i}	53.55 ± 2.43^{ab}
Yang mai 20	14.28 ± 0.22^{h}	3.95 ± 0.10^{d-g}	4.28 ± 0.15^{c-g}	17.55 ± 0.06^{abc}	46.55 ± 0.31^{f}	3.95 ± 0.06^{f}	50.50 ± 1.86^{d-g}
White wheat							
An nong 0711	15.28 ± 0.40^{f}	4.43 ± 0.15^{a}	4.60 ± 0.12^{a}	16.85 ± 0.10^{fg}	47.33 ± 0.13^{e}	2.35 ± 0.13^{c}	49.68 ± 1.13^{d-h}
Su mai 188	15.05 ± 0.34^{fg}	4.33 ± 0.05^{a-c}	3.93 ± 0.28^{hi}	16.18 ± 0.21^{h}	49.03 ± 0.10^{bc}	2.65 ± 0.06^{d}	51.68 ± 1.23^{ae}
E mai 596	17.10 ± 0.22^{b}	3.65 ± 0.17^{g-i}	4.38 ± 0.22^{a-d}	17.33 ± 0.22^{cd}	46.05 ± 0.53^{g}	1.88 ± 0.10^{a}	47.93 ± 0.87^{f-i}
Ji mai 22	16.23 ± 0.22^{cd}	4.00 ± 0.28^{d-f}	4.13 ± 0.32^{d-i}	17.65 ± 0.37^{ab}	47.58 ± 0.05^{e}	2.10 ± 0.00^{b}	49.68 ± 0.87^{d-i}
Zheng mai 7698	16.03 ± 0.25^{c-e}	4.25 ± 0.40^{a-d}	4.15 ± 0.13^{d-h}	17.10 ± 0.23^{def}	48.00 ± 0.16^{d}	1.78 ± 0.17^{a}	49.78 ± 1.07^{d-f}

[a]The results (means ± SD) are based on a dry weight basis. Values followed by the same letters in the same column are not significantly different ($P > 0.05$). [b]TDF, SDF, and IDF denote total, soluble, and insoluble dietary fibers, respectively.

contents. Similarly, Park et al. (2018) also reported that hard red wheat has higher SDF content than hard white wheat. Cai et al. (2014) reported that bread produced from WWF with lower IDF but higher SDF contents produced a larger loaf volume. Therefore, the lower fiber content in red wheat bran might have a less detrimental effect on the quality of noodles.

Table 2. Phenolic and phytate contents in bran samples from different wheat varieties[a].

Wheat varieties	Phytate (mg/g of bran)	Phenolics (mg of gallic acid equivalent/g of bran)		
		Free	Bound	Total
Red wheat				
Huai mai 35	18.20 ± 0.59^{f}	1.05 ± 0.10^{e-g}	7.63 ± 0.15^{a}	8.68 ± 0.27^{a}
Yang mai 23	26.23 ± 0.33^{e}	1.38 ± 0.05^{b-d}	6.53 ± 0.05^{bc}	7.91 ± 0.06^{b}
Ning mai 13	35.25 ± 0.85^{b}	2.20 ± 0.22^{a}	4.78 ± 0.10f^{g}	6.98 ± 0.06^{d}
Hao mai 1	14.85 ± 0.52^{h}	1.25 ± 0.06^{c-f}	6.80 ± 0.08^{b}	8.05 ± 0.12^{b}
Yang mai 20	15.48 ± 0.55^{gh}	1.03 ± 0.17^{f-h}	6.35 ± 0.06^{c}	7.38 ± 0.04^{c}
White wheat				
An nong 0711	31.65 ± 0.62^{d}	1.28 ± 0.15^{c-e}	5.30 ± 0.18^{d}	6.58 ± 0.22^{e}
Su mai 188	39.20 ± 0.57^{a}	1.55 ± 0.06^{b}	5.13 ± 0.15^{de}	6.68 ± 0.17^{e}
E mai 596	18.00 ± 0.73^{f}	0.93 ± 0.29^{g-i}	3.95 ± 0.13^{h}	4.88 ± 0.20^{g}
Ji mai 22	16.18 ± 0.75^{g}	1.48 ± 0.15^{bc}	5.03 ± 0.50^{d-f}	6.51 ± 0.31^{e}
Zheng mai 7698	33.78 ± 0.59^{c}	0.95 ± 0.19^{g-i}	4.55 ± 0.24^{g}	5.50 ± 0.09^{f}

[a]The results (means ± SD) are based on a dry weight basis. Values followed by the same letters in the same column are not significantly different (P > 0.05).

Table 3. Mixolab parameters of whole wheat dough[a].

Wheat varieties	WA[b] (%)	C1 time[b] (min)	Stability[b] (min)	C3[b] (Nm)	C3-C4[b] (Nm)	C5-C4[b] (Nm)
Red wheat						
Huai mai 35	62.78 ± 0.69^{a}	2.69 ± 0.04^{d-f}	5.12 ± 0.08^{a}	1.86 ± 0.05^{a}	1.60 ± 0.16^{c-i}	0.84 ± 0.05^{e-g}
Yang mai 23	61.20 ± 0.14^{gh}	2.74 ± 0.06^{c-e}	4.74 ± 0.03^{cd}	1.62 ± 0.06^{i}	1.66 ± 0.07^{b-h}	0.93 ± 0.05^{b-d}
Ning mai 13	62.25 ± 0.49^{b-d}	3.01 ± 0.15^{a}	4.77 ± 0.10^{c}	1.83 ± 0.03^{a-d}	1.68 ± 0.02^{b-g}	0.83 ± 0.02^{e-h}
Hao mai 1	62.23 ± 0.15^{b-e}	3.06 ± 0.04^{a}	4.55 ± 0.07^{e}	1.85 ± 0.06^{ab}	1.72 ± 0.07^{b-e}	0.79 ± 0.07^{f-i}
Yang mai 20	61.68 ± 0.21^{fg}	2.38 ± 0.06^{h}	4.35 ± 0.06^{h}	1.78 ± 0.06^{a-f}	1.78 ± 0.08^{ab}	0.96 ± 0.05^{ab}
White wheat						
An nong 0711	61.95 ± 0.30^{d-f}	2.78 ± 0.06^{b-d}	4.66 ± 0.01^{d}	1.83 ± 0.09^{a-e}	1.73 ± 0.13^{b-d}	0.95 ± 0.07^{bc}
Su mai 188	62.60 ± 0.08^{ab}	2.85 ± 0.07^{bc}	4.50 ± 0.06^{e-g}	1.77 ± 0.03^{a-g}	1.61 ± 0.09^{c-i}	0.74 ± 0.07^{i}
E mai 596	60.68 ± 0.39^{i}	2.68 ± 0.08^{d-g}	4.96 ± 0.03^{i}	1.75 ± 0.10^{c-h}	1.89 ± 0.09^{a}	0.92 ± 0.09^{b-e}
Ji mai 22	61.55 ± 0.17^{f-h}	2.59 ± 0.08^{fg}	4.42 ± 0.08^{gh}	1.85 ± 0.08^{a-c}	1.74 ± 0.10^{bc}	1.04 ± 0.04^{a}
Zheng mai 7698	62.48 ± 0.43^{a-c}	2.88 ± 0.09^{b}	4.54 ± 0.06^{ef}	1.69 ± 0.09^{f-i}	1.71 ± 0.07^{b-f}	0.88 ± 0.08^{b-f}

[a]The results are expressed as means ± SD values; different superscript letters in the same column indicate significant differences (P < 0.05). [b]WA, water absorption (at 14% moisture), C1 time (the dough development time, min), stability (the elapsed time that the torque was kept at 1.1 Nm, min), C3 (peak viscosity, Nm), C3-C4 (stability of the hot-formed gel, Nm), and C5-C4 (the degree of starch retrogradation, Nm).

Table 4. Cooking and textural properties of whole wheat noodles[a].

Wheat varieties	Cooking loss rate (%)	Tensile strength (g)	Elongation distance (mm)	Hardness (g)	Springiness	Resilience
red wheat						
Huai mai 35	0.73 ± 0.02^{f}	26.86 ± 0.07^{e}	-26.07 ± 0.18^{d}	8248.82 ± 39.76^{c}	0.94 ± 0.15^{a}	0.53 ± 0.02^{ab}
Yang mai 23	0.65 ± 0.01^{g-e}	27.01 ± 0.05^{c}	-26.12 ± 0.23^{de}	8107.51 ± 3.82^{e}	0.93 ± 0.02^{a}	0.56 ± 0.01^{ab}
Ning mai 13	0.69 ± 0.01^{f-h}	22.20 ± 0.07^{i}	-34.91 ± 0.04^{h}	8220.77 ± 14.28^{cd}	0.92 ± 0.06^{a}	0.54 ± 0.02^{ab}
Hao mai 1	1.28 ± 0.03^{d}	28.84 ± 0.23^{b}	-23.90 ± 0.11^{a}	7531.93 ± 25.13^{f}	0.97 ± 0.06^{a}	0.58 ± 0.01^{a}
Yang mai 20	0.82 ± 0.09^{e}	22.03 ± 0.15^{j}	-49.62 ± 0.12^{j}	6575.47 ± 61.81^{h}	0.89 ± 0.07^{a}	0.52 ± 0.01^{ab}
white wheat						
An nong 0711	2.38 ± 0.04^{a}	23.47 ± 0.09^{g}	-26.60 ± 0.07^{f}	6895.66 ± 14.31^{h}	0.91 ± 0.07^{a}	0.50 ± 0.06^{ab}
Su mai 188	1.39 ± 0.03^{c}	23.20 ± 0.15^{h}	-23.96 ± 1.74^{ab}	9347.25 ± 47.16^{a}	0.90 ± 0.09^{a}	0.46 ± 0.02^{b}
E mai 596	0.70 ± 0.02^{fg}	30.46 ± 0.21^{a}	-24.78 ± 0.14^{c}	7531.54 ± 66.12^{g}	0.95 ± 0.12^{a}	0.57 ± 0.02^{a}
Ji mai 22	0.70 ± 0.01^{fg}	26.97 ± 0.30^{cd}	-30.43 ± 0.11^{g}	8007.26 ± 12.82^{f}	0.94 ± 0.08^{a}	0.53 ± 0.08^{ab}
Zheng mai 7698	2.08 ± 0.03^{b}	25.50 ± 0.17^{f}	-36.47 ± 0.13^{i}	8695.81 ± 77.90^{b}	0.96 ± 0.04^{a}	0.51 ± 0.09^{ab}

[a]Values followed by the same letters in the same column are not significantly different (P < 0.05).

Table 5. Correlation coefficients between bran characteristics and whole dough properties[a].

Bran characteristics	WA[b] (%)	C1 time (min)	Stability (min)	C3 (Nm)	C3-C4 (Nm)	C5- C4 (Nm)
Fat	0.09	-0.01	-0.11	-0.48	-0.49	0.23
Ash	-0.32	-0.04	0.70*	-0.08	0.06	0.19
Protein	-0.32	0.39	0.54	-0.04	0.29	-0.02
Starch	0.19	-0.06	-0.13	0.89**	0.34	-0.06
Phytate	0.43	0.41	-0.07	-0.48	-0.61	-0.22
Phenolics						
Bound	0.33	-0.13	0.15	0.06	-0.05	-0.27
Free	0.19	0.52	-0.02	0.12	-0.56	-0.33
Total	0.41	0.07	0.15	0.11	-0.28	-0.41
DF						
IDF	0.69*	0.66*	0.26	-0.02	-0.74*	-0.72*
SDF	0.29	0.11	0.23	0.16	0.01	-0.44
TDF	0.57	0.45	0.28	0.08	-0.42	-0.68*

[a]significance at the level of 0.05 and 0.01, respectively. *Indicate significance at P < 0.05. **Indicate significance at 0.01. [b]WA, water absorption.

Table 6. Correlation coefficients between quality parameters of whole wheat noodle and bran characteristics[a].

Bran characteristics	Cooking loss rate (%)	Tensile strength (g)	Elongation distance (mm)	Hardness (g)	Springiness	Resilience
Fat	0.15	-0.43	0.24	0.09	-0.52	-0.45
Ash	-0.06	0.48	0.55	-0.31	0.27	0.35
Protein	-0.16	0.95**	0.66*	0.16	0.89**	0.75*
Starch	0.01	0.14	-0.32	0.54	0.28	0.28
Phytate	0.53	-0.55	0.13	0.57	-0.36	-0.58
Phenolics						
Bound	-0.23	0.03	0.00	-0.16	0.05	0.15
Free	-0.21	-0.51	-0.14	0.33	-0.23	-0.11
Total	-0.32	-0.17	-0.04	-0.03	-0.04	0.11
DF						
IDF	-0.04	-0.20	0.33	0.65*	0.15	-0.14
SDF	-0.36	0.01	-0.01	-0.19	0.12	0.34
TDF	-0.24	-0.11	0.16	0.26	0.14	0.12

[a]significance at the level of 0.05 and 0.01, respectively. *Indicate significance at P < 0.05. **Indicate significance at 0.01.

3.2 Phenolic and phytate contents of wheat bran

Many studies reported that phenolic acid and phytate contents in WWF negatively affect gluten development lowering baking performance, such as lower loaf volume, dark color, and bitter taste (Challacombe et al., 2012; Park et al., 2016). Phenolic contents in different wheat bran samples are shown in Table 2. The free phenolic content (FPC) was 1.03-2.20 and 0.93-1.55 mg of gallic acid equivalents (GAE)/g in brans from red and white wheat varieties, respectively. In the same bran sample, bound phenolic content (BPC) was about 3-5 times higher than FPC; 4.78-7.63 and 3.95-5.30 mg of GAE/g in red and white wheat varieties, respectively. Overall, total phenolic content (TPC) in red wheat varieties was significantly higher than in white wheat varieties. Likewise, Challacombe et al. (2012) and Kim et al. (2006) also found a significant correlation between wheat color and TPC, and TPC content was higher in red wheat varieties than in white wheat varieties. However, Beta et al. (2005) did not find such a correlation between wheat color and TPC.

Significant differences were also observed in phytate contents between red (14.85-35.25 mg/g in bran) and white (16.18-39.20 mg/g in bran) wheat varieties. The values in our study are a little higher than that reported by Cai et al. (2014). Between the two wheat classes, bran phytate contents were not always higher in the red wheat class, indicating the absence of a clear correlation between wheat color and phytate content.

3.3 Whole wheat dough properties

The rheological properties of whole wheat dough were determined by Mixolab (Table 3). The first phase of a typical Mixolab curve refers to the protein properties of dough under mixing at 30 °C. The addition of wheat bran to flour negatively affected the dough-mixing properties. Besides the dilution effect, the bran compounds such as enzymes, fiber, or phytates interact with the gluten and impede its network formation (Noort et al., 2010). As shown in Table 3, significant differences were observed in dough water absorption, development time (C1 time), and stability among different bran-source varieties that ranged 61.20-62.78%, 2.59-3.06 and 4.42-5.12 min, respectively. The second phase of the Mixolab curve exhibits the starch pasting properties of dough under mixing and heating constraints. Niu et al. (2014a) reported that starch pasting properties of whole-wheat flour significantly correlate with the quality of noodles, and should be used as guiding information for the production of noodles. Similar to the dough mixing properties, significant differences were observed in peak viscosity (C3), stability of the hot-formed gel (C3-C4), and the degree of starch retrogradation (C5-C4) values among different bran source varieties, 1.62-1.86 Nm, 1.60-1.89 Nm and 0.74-1.04 Nm, respectively. These results clearly showed that bran from different wheat varieties significantly affected the rheological properties of whole dough.

3.4 Cooking and textural properties of WWN

Cooking loss is a key quality parameter of noodles. It represents the amount of noodle solid components that leach into the water during cooking, indicating the bonding between different ingredients in the noodles. Among the 10 wheat varieties, noodles produced from WWF with An nong 0711 bran exhibited the highest cooking loss rate (2.35%), which was almost 3 times higher than the noodles produced with Yang mai 23 bran (0.65%) (Table 4). The gluten network might be weaker in noodles produced from An nong 0711 bran than those produced from Yang mai 23 bran, which resulted in increased amylose leaching during cooking.

Noodle texture is another important feature that affects consumers' acceptance (Li et al., 2018). Liu et al. (2003) reported that resistance and extensibility of dough positively correlate with dry white Chinese noodle quality. However, compared to white wheat flour alone, incorporation of bran into wheat flour reduced the maximum resistance and dough extensibility (Wang et al., 2016). Niu et al. (2014b) also reported that bran addition to wheat flour increases the hardness, but decreases the springiness, cohesiveness, and resilience values of noodles. Therefore, it seems that the higher resistance, longer extensibility, lower hardness, and higher springiness, cohesiveness, and resilience values are desirable qualities for whole wheat noodle production. As shown in Table 2, significant differences were found in the textural properties of whole wheat noodles produced from different bran-source varieties, which can be attributed to substantial variation in bran characteristics.

Likewise, Cai et al. (2014), Ma et al. (2018), and Navrotskyi et al. (2019) also reported that bran characteristics significantly influenced the final quality of whole wheat foods, such as cracker, bread, pancake, and steamed bread. In this study, WWFs were produced by blending different bran samples with one wheat flour and showed that bran sources significantly affected the quality parameters of WWN. Although many sensory studies showed that whole wheat products produced from red or white wheat significantly vary in terms of appearance, flavor, texture, and overall taste (Grafenauer et al., 2020), cooking and textural properties showed no evident differences in this study.

3.5 Correlations between whole wheat dough properties and bran characteristics

Correlations between whole wheat dough properties and bran characteristics are presented in Table 5. The dough mixing parameters such as water absorption ($P < 0.05$) and development time ($P < 0.05$) showed significant relationships with bran IDF content. Positive correlations were also found between bran SDF, TDF, and dough mixing parameters, but these were not significant ($P > 0.05$). This indicates that the changes in dough mixing properties were primarily induced by bran IDF. These results are consistent with Cai et al. (2014) that also reported a significant correlation between the bran IDF and TDF contents and dough water absorption and mixing time. Structurally, fibers contain several hydroxyl groups, which can bind more water through hydrogen bonds increasing water absorption of dough (Rosell et al., 2010). Compared to protein and starch, fibers (cellulose) need a longer time to absorb water which increases dough development time and stability (Torbica et al., 2010). However, in contrast to our study, Cai et al. (2014) and Ma et al. (2018) reported that bran characteristics did not affect the mixing properties of whole wheat dough. In addition, a significant correlation was found between bran ash and dough stability ($P < 0.05$), which is consistent with Navrotskyi et al. (2019). They suggested that ash elements can interact with protein charges which reduces repulsive forces between similarly charged side chains and stabilizes the protein network.

Concerning the starch pasting properties, bran starch was positively associated with peak viscosity (C3, $P < 0.01$). A negative correlation was observed between bran IDF content and the C3-C4 value ($P < 0.05$). Adding fibers into a starch-water system inhibits the water absorption of starch granules and thus hinders the starch granule rupturing during gelatinization (Collar et al., 2006). Bran IDF also exhibited a negative correlation with the starch retrogradation (C5-C4, $P < 0.05$). This can be attributed to bran IDF, which can disrupt the formation of the macromolecular network during cooling via disrupting secondary forces or creating steric and physical hindrances (Ktenioudaki et al., 2013). The above results suggest that compared to SDF, IDF is the major fiber fraction that affects the starch pasting properties of WWF.

3.6 Correlations between whole wheat noodle qualities and bran characteristics

Correlations between the quality parameters of WWN and bran characteristics are shown in Table 6. Bran protein content positively correlated with tensile strength ($P < 0.01$), elongation distance ($P < 0.05$), springiness ($P < 0.01$), and resilience ($P < 0.05$) of cooked noodles. This suggests that WWF with protein-rich bran can produce WWN of desirable quality. Similarly, Ma et al. (2018, 2019) also found a positive correlation between the bran protein content and qualities of whole wheat biscuit and steamed bread. Protein-rich bran has a protein-enriched sub-aleurone cell structure, which can hold more gluten proteins increasing the quality of whole wheat products (Jacobs et al., 2015). In contrast, Cai et al. (2014) reported that bran protein content did not affect the quality of bread. A positive relationship was also found between the bran IDF content and the hardness of WWN ($P < 0.05$). Apart from these, no other bran characteristics correlated with the quality parameters of cooked noodles. Besides bitter taste, phenolics significantly influence the dough properties and qualities of whole wheat products Koh & Ng (2008) reported that phenolic acid significantly affected the quality of wheat products that are produced from the fermentation process, while the fermentation was not affected. It seems that phenolics content influenced the interaction with other flour components. Since noodle production does not require a fermentation procedure, this parameter might be insignificant.

4 Conclusions

Large variations were found in bran composition among 10 white and red wheat varieties. Compared with white wheat brans, only TPC content was higher in red wheat brans, indicating no correlation between wheat color and protein, fat, ash, dietary fiber, and phytate contents. Bran ash, starch, and IDF contents consistently correlated with the mixing and pasting properties of whole wheat doughs. Concerning the noodle quality, bran protein content positively correlated with tensile strength ($P < 0.01$), elongation distance ($P < 0.05$), springiness ($P < 0.01$), and resilience ($P < 0.05$) of cooked noodles, which are the desired parameters of noodle production. Also, bran IDF content positively correlated to hardness ($P < 0.05$) of cooked noodles.

Based on the results of this article, we found bran composition significantly affected dough properties and noodle quality. Bran with high protein and low IDF contents is desirable for making whole wheat noodles. Overall, this study provides useful information to noodle manufacturers to select suitable wheat varieties for the production of WWN.

Abbreviations

WWF: whole wheat flour. IDF: insoluble dietary fiber. WWN: whole wheat noodles. TDF: total dietary fiber. SDF: soluble dietary fiber. TPA: textural profile analysis. FPC: free phenolic content. BPC: bound phenolic content. TPC: total phenolic content.

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