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Quality of Noodles Made from Colour-Grained Wheat

Dongyun MA[1]*, *Jian ZHANG*[2], *Yaoguang LI*[1] *and Chenyang WANG*[1]

[1]*College of Agronomy and* [2]*Department of Food Science and Technology; Henan Agricultural University; Zhengzhou, China*

**Corresponding author: xmzxmdy@126.com*

Abstract

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The protein content (PC), total phenolic content (TPC) and quality of fresh Chinese noodles made from flour processed from four colour-grained wheat cultivars using three milling methods were investigated in this study. The highest PC and sedimentation volumes were shown in partially debranned grain flour (PGF) and refined flour (RF), respectively. Whole wheat flour (WWF) and PGF had significantly higher TPC and total flavonoid contents (TFC) than RF. Wheat cv. Jizi439 (JZ) showed the highest PC, while cv. Heibaoshi (HBS) showed the highest TPC in all three milling methods. In textural profile analysis of noodles HBS showed the lowest hardness, gumminess and chewiness irrespective of milling method, while cv. Shandongzimai (SDZM) expressed higher values depending on milling method. The total sensory score of noodles decreased with increased bran retention, and noodles made from HBS RF and PGF had the highest total scores. The results suggest that PGF made from black wheat HBS can be used to make fresh Chinese noodles with improved nutrient status and without any loss of food sensory quality.

Keywords: different-coloured wheat grain; fresh Chinese noodles; sensory quality

Abbreviations: DW – dry weight; GAE – gallic acid equivalent; HBS – Heibaoshi; JZ – Jizi439; PC – protein content; PGF – partially debranned grain; RF – refined flour; SDZM – Shandongzimai; TFC – total flavonoid content; TPA – texture profile analysis; TPC – total phenolic content; WWF – whole wheat flour; YU – Yumai 49-198

Flour noodles are the most widely consumed common wheat products in China, representing about 40% of national wheat consumption. Miskelly (1984) reported that increases in flour protein and brown pigments decreased flour brightness, producing dull and dry noodles. However, the effects were not significant once the noodles had been cooked. Sedimentation volume and mixograph mixing time were positively correlated with the texture of cooked noodles (Huang & Morrison 1988; Baik *et al*. 1994). Wheat cultivar type influences noodle quality; the softest noodles were produced from lines carrying null alleles at both wx-A1 and wx-B1, while lines with a null only at wx-B1 were intermediate in softness (Graybosch *et al*. 2004). Colour-grained wheat represents a new germplasm resource in cereal crops and has invoked great interest due to its high nutrient value. Several studies showed that black-grained wheat had higher protein content (PC) and levels of antioxidants such as flavonoids and vitamin C (Li *et al*. 2006; Zong *et al*. 2006). A study on the anthocyanin content of wheat grain showed that total anthocyanin content in blue aleurone wheat was higher than that of purple pericarp and red pericarp grains (Siebenhandl *et al*. 2007). An additional study suggested that purple wheat grains are a promising source of anthocyanins and proposed them as raw material for baking (Bustos *et al*. 2012).

Previous studies showed that the most physiologically beneficial functional ingredients of nutrient are to be found in the aleurone layer. Tosi *et al*. (2011) reported that the total PC was higher in the outer parts of starchy endosperm. With respect to antioxidants, the total phenolic content was as high as 18.24 mg (gallic acid equivalent) GAE/g in the aleurone layer and the highest antioxidant activity

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was also shown in the aleurone layer (Shi *et al.* 2011). Conventional modern milling methods result in the removal of most of the bran and germ and reduce the levels of important constituents such as total phenols and flavonoids (Adom *et al.* 2005). However, regular intake of whole-grain products could reduce the risk of cardiovascular disease and certain cancers (Arts & Hollman 2005). To investigate the effect of grain colour and milling method on the quality of fresh Chinese noodles, three coloured wheat cultivars (deep purple, light purple and black) and one white wheat cultivar were milled to different degrees (yielding whole wheat flour, partially debranned grain flour and refined flour). The PC, TPC, and TFC of different flours, noodle texture and sensory characteristics were analysed. The results of this study may be useful for the utilisation of colour-grained wheat and for the breeding of nutrient-dense wheat.

MATERIAL AND METHODS

Whole wheat flour preparation. Four common winter wheat (*Triticum aestivum* L.) cultivars, including white wheat cv. Yumai 49-198 (YM), light purple wheat cv. Shandongzimai (SDZM), deep purple cv. Jizi439 (JZ), and black wheat cv. Heibaoshi(HBS), were used in this study. Three milling methods were used to produce whole wheat flour (WWF), partially debranned grain flour (PGF) and refined wheat flour (RF). For WWF, whole wheat kernels were milled in a Cyclotec 1093 mill (Foss Tecator, Sweden) without removal of bran or germ. For PGF, the bran layer of whole wheat kernels was first stripped using a grain polisher (TYT200; Tianyang Machinery Co. Ltd., China), and then the kernels were milled. Hulling degree was approximately 5% DW. For RF, wheat kernels were milled in a Brabender Junior laboratory mill (AACC Method 26-21A, 1995). All sample flours were passed through 80-mesh sieves (sieve size 0.180 mm).

Sedimentation volume, protein, total phenolic and total flavonoid content. Flour PC was determined with a Kjeltec 2300 analyser unit (Kjeltec2300; Foss, Sweden). The sodium alkyl sulphate twelve (SDS) sedimentation value was determined according to the AACC International Approved Method 56-70. Total phenolic content (TPC) was determined using the Folin-Ciocalteu reagent method according to Singleton *et al.* (1999) and expressed as milligrams of gallic acid equivalent per gram of dry weight (μg/g DW). Total flavonoid content (TFC) was determined using a colorimetric method according to (Shen *et al.* 2009) and expressed as rutin equivalents (μg/g DW).

Preparation of fresh Chinese noodles. Fresh Chinese noodles were prepared as described by Ma *et al.* (2009) and Liu *et al.* (2003). Flour (200 g) was mixed with enough water to achieve 35% water absorption in a pin mixer for 4 minutes. Dough was rested for 30 min in a plastic bag before sheeting, then folded and sheeted three times with a 5 mm gap. Five sheeting reductions were applied until a 1.2 mm sheet was obtained. The final dough sheet was cut to produce 15-cm-long noodle strands. Noodles were cooked in boiling water until the white core disappeared. The cooked noodle strands were then rinsed with cold water and evaluated by six trained panellists as reported by Liu *et al.* (2003) with minor modifications. Noodle score included colour score (bright not including whiteness, weighting 10), palate (medium firmness is desirable, 20), appearance (smooth noodle surface, 10), stickiness (no adherence to teeth when chewed, 25), elasticity (elastic and cohesive when chewed, 25), smoothness (smooth when eaten, 5) and taste/flavour (aromatic taste, 5). The experiment was performed at a room temperature of 20–25°C and a relative humidity of 50–60%. Noodle cooking properties included water uptake and cooking loss. Water uptake was calculated by subtracting the initial sample weight (20 g) from the cooked sample weight and dividing by the initial sample weight. Cooking loss is defined as the mass of solids lost into the cooking water during boiling.

Noodle texture. Cooked noodle texture was evaluated with texture profile analysis (TPA) using a TA-XT2 texture analyser (Stable Micro Systems, UK) within 5 min after cooking. A set of five strands of cooked noodles was placed parallel on a flat metal plate and measured using a pasta firmness/stickiness rig code (HDP/PFS) metal blade. The settings used were the following: pre-test speed: 1 mm/s, test speed: 2 mm/s; post-test speed: 1 mm/s. From the TPA force-time curve, hardness, gumminess and chewiness were determined.

Statistical analysis. All treatments were carried out twice, and each sample was measured in duplicate. Data were analysed using SPSS 19.0 (Statistical Program for Social Science) software with one-way analysis of variance. Means were compared using Duncan's multiple range test at $P < 0.05$.

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RESULTS AND DISCUSSION

Flour quality parameters. As presented in Table 1, the highest PC was observed in partially debranned grain flour (PGF) and the lowest value was noted in RF (refined flour). The low values in RF are likely due to the fact that most of the germ and aleurone had been removed by this milling method. It is well known that the protein percentage in grain is low in the cells near the endosperm cavity and increases in an outward radial direction (Farrand & Hinton 1974). No significant difference was observed for the average PC between WWF and PGF: average values were 14.99 and 15.28%, respectively. Similar results were found by Tosi *et al.* (2011). This is mainly because the PGF retains most of the outer endosperm (aleurone layer). PC (mass per unit fresh volume) in the sub-aleurone cells in the dorsal region was nearly twice that in the cells adjacent to the endosperm cavity (Ugalde & Jenner 1990). The results also indicated that partly removing bran (PGF) would not only result in removal of pericarp (fruit coat) and testa (seed coat), but also improve PC in flour. Colour-grained wheat is a new germplasm resource, and it has been reported that black-grained wheat had higher PC (Li *et al.* 2006). In this study, we found that purple wheat cvs DZM and JZ showed a significantly higher PC than cultivar YM when the same milling method was used. However, black wheat cv. HBS exhibited a lower PC (average 13%) than white wheat cv. YU (average content 14.23%) when the same milling method was used. These differences are due to the fact that coloured or pigmented wheat did not consistently exhibit higher protein accumulation.

The sedimentation value of flour positively influences the texture of cooked noodles (Huang *et al.* 1988). Interestingly, compared with PC, SDS sedimentation value showed a different tendency with respect to milling method. The highest value was observed in RF and the lowest value was exhibited by WWF. The main reason for these differences is the gradients in protein content and composition in the starchy endosperm. The flour fractions derived from the central endosperm, although lower in total PC, generally have better functional properties than flour derived from the outer layers (Yahata *et al.* 2006;

Table 1. Quality parameters of differently milled flour of colour-grained wheat

Milling method	Cultivar	Flour				Noodle flour	
		protein (% DW)	sedimentation (ml)	TPC (μg/g DW)	TFC (μg/g DW)	TPC (μg/g DW)	TFC (μg/g DW)
WWF	YU	14.85^{c}	9.50^{b}	1436.78^{b}	823.77^{a}	310.75^{b}	148.98^{c}
	HBS	13.15^{d}	10.25^{b}	1811.55^{a}	876.50^{a}	552.04^{a}	274.95^{a}
	SDZM	15.60^{b}	10.25^{b}	1270.69^{c}	694.74^{a}	496.67^{a}	159.39^{c}
	JZ	16.35^{a}	11.75^{a}	1443.17^{b}	841.81^{a}	507.67^{a}	182.14^{b}
	mean	14.99^{A*}	10.43^{C*}	1490.55^{A*}	809.20^{A*}	466.78^{A*}	191.36^{A*}
PGF	YU	14.90^{c}	12.50^{ab}	1152.50^{c}	689.19^{b}	234.05^{c}	162.30^{b}
	HBS	13.75^{d}	11.25^{bc}	1570.94^{a}	790.47^{a}	461.18^{a}	202.25^{a}
	SDZM	15.95^{b}	10.75^{c}	1171.67^{c}	683.63^{b}	322.77^{b}	145.09^{c}
	JZ	16.50^{a}	12.75^{a}	1190.84^{b}	747.46^{ab}	343.72^{b}	159.25^{b}
	mean	15.28^{A*}	11.81^{B*}	1271.49^{B*}	727.68^{B*}	340.43^{B*}	167.15^{B*}
RF	YU	12.95^{b}	12.35^{b}	572.25^{a}	146.76^{c}	176.91^{a}	106.60^{b}
	HBS	12.10^{c}	12.25^{b}	619.09^{a}	267.38^{a}	212.75^{a}	152.86^{a}
	SDZM	13.25^{b}	13.00^{b}	598.86^{a}	180.06^{b}	180.43^{a}	67.67^{c}
	JZ	15.25^{a}	14.75^{a}	562.66^{a}	106.42^{c}	212.40^{a}	88.49^{c}
	mean	13.39^{B*}	13.06^{A*}	588.22^{C*}	175.16^{C*}	195.62^{C*}	103.90^{C*}

Mean (n = 2) in the same column by the same milling method followed by different letters are significantly different (P < 0.05); mean (n = 8) in the same column followed by different capital case letters are significantly different (P < 0.05); WWF – whole wheat flour, PGF – partially debranned grain flour; RF – refined flour; YM – cv. Yumai49-198 (white grain); HSB – cv. Heibaoshi1 (black grain); SDZM – cv. Shandongzimai (light purple grain); JZ – cv. Jizi439 (deep purple grain); DW – dry weight; noodle flour mean that the cooked noodles were dried and milled into noodle powder with a small grinder

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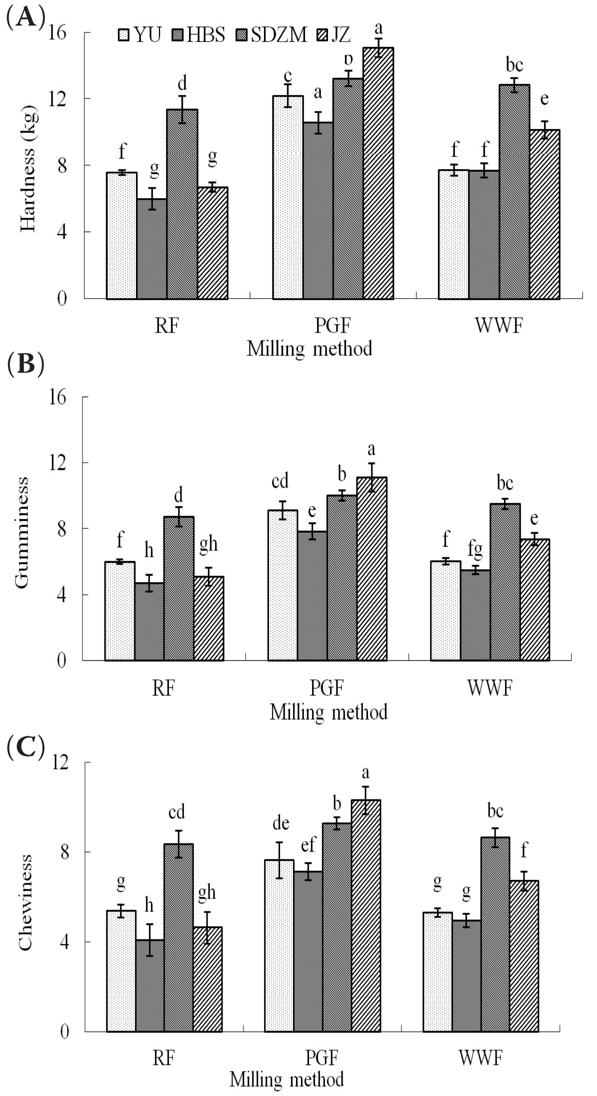

Figure 1. Comparison of TPA parameters, hardness (**A**), gumminess (**B**) and chewiness (**C**) of Chinese fresh noodles made from flour milled from color-grained wheat using different methods

WWF – whole wheat flour, PGF – partially debranned flour; RF – refined flour; TPA – texture profile analysis; YM – cv. Yumai 49-198 (white grain), HSB – cv. Heibaoshi (black grain), SDZM – cv. Shandongzimai (light purple grain) and JZ – cv. Jizai439 (deep purple grain); different lower case letters above columns using the same milling method indicate significant differences ($P < 0.05$).

Okrajková *et al.* 2007). Tosi *et al.* (2011) also found that high-molecular-weight subunits of glutenin are more abundant in the inner endosperm layers, and the low-molecular-weight subunits of glutenin are more abundant in the subaleurone. Regardless of the milling method, cv. JZ had the highest sedimentation value among the four wheat cultivars.

TPC and TFC all showed an obviously increasing trend from RF to WWF. If the comparison was made with corresponding WWF, PGF, and RF decreased TPC by 14.6 and 60.5% on average and decreased TFC by 10.07 and 78.35%, respectively. Among different wheat cultivars, the highest TPC was shown in black wheat cv. HBS (with a value of 1811.55 μg/g DW, 1570.94 μg/g DW, and 572.25 μg/g DW in WWF, PGF and RF, respectively), and lower values, which ranged from 619.09 μg/g DW to 1436.7 μg/g DW 1, was exhibited by white cv. YU. A similar trend was also observed with TFC, but no significant difference was noted in WWF. These results indicate that the higher TPC in black wheat can be mainly ascribed to the substance present in bran which also accounts for grain colour. However, the nutrient value of black wheat would be greatly decreased if the wheat grains were milled into commercial refined flour. Compared with the corresponding value of flour, the TPC and TFC of noodle flour (the cooked noodles were dried and milled into noodle powder with a small grinder) were decreased by 70.1 and 72.98%, respectively. The reductions in TPC and TFC were likely due to the loss of antioxidants during food processing, because antioxidant compounds present in flour are damaged or degraded by thermal treatment (Leenhardt *et al.* 2006). Additionally, in noodle flour, the highest TPC value was obtained in the black wheat cv. HBS (212.75–552.04 μg/g DW, mean 408.66 μg/g DW), and the lowest TPC value was obtained in the white wheat cv. YU (176.91–310.75 μg/g DW, mean 240.57 μg/g DW).

Cooking properties and sensory evaluation of fresh Chinese noodles. Water uptake and cooking loss are important parameters determining noodle cooking properties. As presented in Table 2, noodles made from PGF showed a lower average water uptake than those made from RF and WWF. Lower water uptake in PGF may be due to the fact that most of the pericarp (fruit coat) and testa (seed coat) are removed using this milling method. Cooking loss showed a decreasing trend with increasing bran removal, and noodles made from RF exhibited the lowest cooking loss. The type of ingredients in the noodle mix influences the loss of soluble components and solids during cooking, and a compact texture of the pasta often results in less cooking loss than what is observed for loose textured pasta (Del Nobile *et al.* 2005). In PGF and WWF, a higher bran concentration alters the rheological properties of dough and affect the cooking loss. A similar report showed that fortification with non-traditional

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ingredients tends to weaken the gluten, which otherwise forms a strong protein-starch network (Petitot *et al*. 2010). Cooking loss differed significantly among the wheat cultivars; YM and HBS had significant higher values than cvs SDZM and JZ when the same milling method was used.

The average scores for appearance using different milling methods showed an increasing trend with increasing bran removal (Table 2). The highest score was observed in RF, and the lowest value was shown in WWF. Similar trends were also observed for palate, toughness, stickiness and total score. Chen *et al*. (2013) found that bran-enriched flour altered the rheological properties of dough and finally affected the quality and sensorial properties of the end-product. However, fibre-enriched (bran) food and whole wheat food products remain of constant and even growing interest owing to their likely beneficial effects in reducing the risk of health problems such as hypertension, diabetes and colon cancer. Zhao *et al*. (2008) found that Chinese noodles containing 5% wheat bran were of similar quality to noodles without wheat bran. In this study, we found that even though there was a decreasing trend in the tested parameters with increasing bran retention, there was no significant difference in the average total score of noodles made from RF and PGF. This result indicates that noodles made from PGF were of similar quality to noodles made from RF. Additionally, noodles made from cv. HBS RF and PGF achieved comparable total scores of 86.3 and 86.1, respectively. This suggests that noodles made from black wheat cv. HBS PGF would provide benefits for human health without any loss of noodle quality. Of course, it should be noted that the colour sensory evaluation of noodles made from colour-grained wheat differs slightly from that of white flour. The absence of white or cream is required for a higher colour score, but a uniform bright colour is accepted.

Textural properties of fresh Chinese noodles. As presented in Figure 1, noodle textural parameters varied among the wheat cultivars and milling methods. The highest values for hardness, gumminess and chewiness were exhibited by PGF, while the lowest values were exhibited in RF. These results are in agreement with the findings of Young *et al*. (1998). The higher

Table 2. Cooking properties and sensory evaluation of Chinese fresh noodle

Milling method	Cultivars	Cooking properties		Sensory evaluation				
		water uptake (g/g)	cooking loss (%)	appearance	palate	toughness	stickiness	total score
RF	YU	1.44^{ab}	11.25^{a}	8.2^{a}	16.7^{b}	20.7^{a}	22.6^{a}	84.6^{b}
	HBS	1.51^{a}	12.17^{a}	8.3^{a}	18.8^{a}	21.6^{a}	20.5^{b}	86.3^{a}
	SDZM	0.98^{c}	8.03^{b}	8.2^{a}	17.2^{a}b	21.8^{a}	20.7^{b}	84.5^{b}
	JZ	1.11^{c}	8.51^{b}	8.1^{a}	18.0^{a}b	20.7^{a}	21.5^{ab}	84.7^{b}
	mean	1.26^{A}	9.99^{C}	8.2^{A}	17.7^{A}	21.2^{A}	21.4^{A}	85.0^{A}
PGF	YU	1.10^{a}	10.77^{b}	7.6^{a}	16.8^{ab}	20.5^{ab}	21.0^{a}	81.7^{b}
	HBS	1.11^{a}	13.00^{a}	8.1^{a}	18.7^{a}	21.8^{a}	20.6^{a}	86.1^{a}
	SDZM	0.89^{a}	8.87^{c}	8.2^{a}	17.0^{ab}	21.5^{a}	21.1^{a}	82.9^{b}
	JZ	0.85^{a}	8.44^{c}	8.2^{a}	16.3^{b}	18.6^{b}	21.2^{a}	80.1^{b}
	mean	0.99^{B}	10.27^{B}	8.0^{A}	17.2^{A}	20.6^{AB}	20.9^{AB}	82.7^{AB}
WWF	YU	1.70^{a}	14.01^{a}	6.5^{b}	15.7^{b}	17.5^{b}	19.7^{a}	74.1^{c}
	HBS	1.04^{bc}	12.03^{b}	8.3^{a}	18.0^{a}	21.2^{a}	21.1^{a}	85.2^{a}
	SDZM	0.89^{c}	8.04^{d}	7.8^{ab}	17.0^{ab}	20.0^{ab}	20.2^{a}	80.1^{b}
	JZ	1.38^{b}	10.00^{c}	8.1^{ab}	15.7^{b}	19.5^{ab}	21.3^{a}	79.5^{b}
	mean	1.25^{A}	11.02^{A}	7.6^{B}	16.6^{A}	19.5^{B}	20.5^{B}	79.7^{C}

Total score include colour, smooth, and taste/flavour score; ^{a}mean (n = 2) in the same column by the same milling method followed by different lower case letters are significantly different (P < 0.05); ^{b}mean (n = 8) in the same column followed by different capital case letters are significantly different (P < 0.05); WWF – whole wheat flour, PGF – partially debranned grain flour, RF – refined flour; YM – cv. Yumai49-198 (white grain); HSB – cv. Heibaoshi (black grain); SDZM – cv. Shandongzimai (light purple grain); JZ –cv. Jizi439 (deep purple grain)

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values in PGF might be ascribed to the higher PC in this flour, because PC exhibited a positive relationship with the hardness of cooked noodles (Ma *et al*. 2009). However, a bran-enrichment experiment showed that the hardness and gumminess of cooked dry white noodles decreased with increasing addition of wheat bran (Chen *et al*. 2013). This difference can be explained by concentration range and bran particle size. Another reason might lie in difference in the noodle-making process (dry noodles vs. fresh noodles).

Among the different wheat cultivars, noodles made from cv. SDZM RF and WWF had the highest noodle hardness, gumminess and chewiness, and noodles made from cv. JZ PGF exhibited the highest values when the same milling method was used. Noodles made from black wheat cv. HBS exhibited lower values irrespective of milling method. Compared with the white cv. YU, light purple wheat cv. SDZM increased hardness, gumminess and chewiness by 36.17, 32.63, and 43.39% on average, respectively. Noodle texture is influenced by flour characteristics, and wheat flour with approx. 10% protein content is acceptable for making white salted noodles (Hou 2001). He *et al*. (2004) reported that medium to strong (not overly strong) dough is desirable for white Chinese noodle quality. In this study, we found that cvs JZ and SDZM had higher PC (above 15%) in PGF and WWF. Thus, bread making or flour blending from colour-grained wheat (SDZM and JZ) with high PC should be considered further. However, we found that noodles made from cv. JZ RF (with PC 15.25%) exhibited lower textural parameters than those made from cv. YU RF. This difference may be due to noodle texture, which is not only influenced by protein content but also by protein composition and starch properties (He *et al*. 2005). Generally, the use of different colour wheat cultivars resulted in production of noodles of different quality. Further investigation should be carried out to improve the properties of black wheat for food production without decreasing its nutrient value. This also suggests that the breeders of nutrient-dense wheat cultivars should consider the quality of produced food.

CONCLUSIONS

In the present study, we described significant differences in flour protein, antioxidant contents, and quality of fresh Chinese noodles among the different colour-grained wheat cultivars depending on the milling method. PGF can improve protein content and flour antioxidant levels without decreasing food quality, suggesting its use for the production of nutrient-rich food. Among different wheat cultivars, black wheat cv. HBS showed the highest sensory score. Generally, fresh Chinese noodles made from black wheat cv. HBS PGF provide benefits to improve human health without any loss of sensory quality.

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