Effects of Protein Content, Glutenin-to-Gliadin Ratio, Amylose Content, and Starch Damage on Textural Properties of Chinese Fresh White Noodles

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ABSTRACT

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The independent effects of flour protein and starch on textural properties of Chinese fresh white noodles were investigated through reconstitution of fractionated flour components. Noodle hardness decreased with decreased protein content, whereas it unexpectedly increased as protein content decreased to a very low level (7.0%). Noodle cohesiveness, tensile strength, and breaking length increased with increased protein content. Higher glutenin-to-gliadin ratio resulted in harder and stronger noodles at constant protein content. Increased starch amylose content resulted in increased flour peak viscosity. When water absorption remained the same during noodle making, hardness and cohesiveness of cooked noodles also increased with increased starch amylose content, while springiness did not vary significantly. Increased starch damage of ≈5.5–10.4% effectively improved noodle hardness; however, starch damage >10.4% decreased it. Increased starch damage also enhanced noodle springiness while it decreased cohesiveness.

Flour noodles including fresh white, fresh yellow, dry, and instant are widely consumed wheat (*Triticum aestivum*) products in China and other Asian countries. Appearance, taste, cooking quality, and texture are all critical characteristics for Asian noodle consumers. A number of studies have evaluated the effects of major flour components, protein, and starch on the textural properties of various types of noodles. High-protein noodles were firmer when cooked than low-protein noodles (Miskelly and Moss 1985; Oh et al 1985a; Crosbie et al 1999; Park et al 2003). SDS sedimentation volume is a protein quality parameter significantly correlated with maximum cutting and compression stress of cooked white and yellow Chinese noodles (Huang and Morrison 1988). Recently, Park and Baik (2009) reported that tensile strength of fresh and cooked noodles, as well as hardness of cooked noodles, increased linearly with increased gluten incorporation. In contrast to the many studies on protein and starch, very limited studies investigated the effects of protein fractions on noodle texture. Oh et al (1985a) proposed that high molecular weight glutenin accounted for the different cutting stress of cooked noodles. Hu et al (2007) investigated the effects of protein fractions on the quality of white salted noodle by statistical methods. Soluble glutenin content was positively related to cutting firmness of cooked noodle, while the insoluble glutenin content was positively correlated with thickness, hardness, and cutting firmness. In contrast, monomeric proteins composed of albumin, globulin, and gliadin was not related to these textural parameters. Although many studies showed that the glutenin-to-gliadin ratio had marked influences on dough properties and loaf quality (Pechanek et al 1997; Uthayakumaran et al 1999; Wieser and Kieffer 2001), little is known about its effects on noodle texture.

Starch is the highest portion of wheat flour; thus, its properties are very important for noodle texture. Starch properties such as high swelling power and paste viscosity have been reported as desirable for textural properties of white salted noodles (Crosbie 1991; Panozzo and McCormick 1993). However, low paste viscosity was related to superior qualities of Chinese yellow alkaline noodles (Akashi et al 1999). Components of starch such as the amylose content also was related to noodle texture. Toyokawa et al (1989) indicated that increased levels of amylose were related with improved firming and decreased elasticity of cooked Japanese noodles. Noda et al (2001) showed that low amylose content was associated with good quality of white salted noodle. Guo et al (2003) reported that, with the addition of waxy flour to wild-type flours, the hardness, gumminess, and chewiness of cooked Asian salted noodles significantly decreased whereas cohesiveness, springiness, and resilience increased. Baik and Lee (2003) obtained similar results by reconstitution of starch and protein using waxy and regular starch blends to produce white salted noodles.

Starch damage of flour, one important parameter of the milling process, also influenced noodle texture. Oh et al (1985b) reported that increased starch damage reduced both internal and surface firmness of cooked dry noodles. Recently, Hatcher et al (2008) showed that for kansui (sodium and potassium carbonates at 9:1 ratio) noodles, maximum cutting stress increased as starch damage increased, while it decreased for sodium hydroxide noodles. For both noodles, springiness decreased as starch damage increased. More recently, Hatcher et al (2009) reported that cooked yellow alkaline noodles prepared from starch with low damaged flours within any given particle size range, regardless of the type of alkali employed, yielded the most rheologically elastic-like (firmer) noodles. Nevertheless, to date, little information about the effect of starch damage on the quality of Chinese fresh white noodles was available.

The objective of this study was to examine the effects of flour protein and starch including protein content, glutenin-to-gliadin ratio, starch amylose content, and starch damage on textural properties of cooked Chinese fresh white noodles using fractionation and reconstitution methods.

MATERIALS AND METHODS

Materials

Wheat grain was a commercial mixture of hard red winter wheat grown in Henan province, China, in 2004. Straight-grade flour was prepared using a Buhler laboratory mill at the Zhengzhou Grain College, Henan University of Technology. Protein (N × 5.7), total starch, and ash contents of flour generated were 11.6, 65.7, and 0.58% (w/w) on a moisture basis (14%), respectively. The amylose content in starch was 30.0% (w/w) and starch damage was 5.5% (w/w). To obtain a high level of starch damage, the wheat flour was further comminuted in a pulverizer (model FDV, Yu Chi, Taiwai), which resulted in starch damage of 12.9% (w/w). Waxy wheat starch with an amylose content of 1.32% (w/w) was kindly provided by the Henan Academy of Agrigultural Sciences (Zhengzhou, China).

Analytical Methods

Moisture, protein, total starch, ash, and starch damage were determined by Approved Methods 44-15.02, 46-13.01, 76-13.01,

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08-01.01, and 76-30.02 (AACC International 2010), respectively. Amylose content was assayed according to the National Standard of China GB/T 15683-1995. Flour pasting properties were determined in duplicate using a Rapid ViscoAnalyser (RVA, model 3D, Newport Scientific, Warriewood, NSW, Australia) as described by Konik et al (1994).

Fractionation of Flour

Flour was fractionated into gluten, starch, and water solubles using the method described by Oh et al (1985a) with some modifications. Flour (150 g, 14% mb) was mixed with 80 mL of distilled water for 4 min using a Hobart N50 mixer (North York, Canada). The dough was placed in a beaker containing 200 mL of chilled distilled water for 20 min and gently kneaded with one hand, then the liquid phase was decanted. Washing and kneading steps were repeated with a series of amounts of chilled water (2 × 150 mL, 4 × 100 mL, 4 × 75 mL, and 6 × 50 mL). After each wash step, the liquid phase was drained through a 32-mesh screen and collected. Small pieces of dough or gluten on the screen were added back to the dough mass. The filtrate was centrifuged at 1,000 × *g* for 20 min to obtain water solubles and starch.

Gluten mass, water solubles, and starch were lyophilized, ground in a mortar, and passed through an 80-mesh sieve (200 μm openings). The quantities isolated were gluten 19–21 g, 14% mb; starch 108–111 g; and water solubles 8–10 g with a recovery of dry solids of 92–95%.

Fractionation of Gluten

Glutenin-rich and gliadin-rich fractions were isolated from gluten using dilute HCl solution (MacRitchie 1985). Freeze-dried gluten powders (30.0 g, 14% mb) were stirred with 600 mL of dilute HCl (2×10^{-3} mol/L) in a mixer for 5 min, followed by centrifugation at 2,000 × *g* for 10 min. Supernatant (gliadin-rich fraction) was decanted into a beaker and sediment (glutenin-rich fraction) was transferred to another beaker. Both fractions were brought to pH ≈ 6 by addition of 0.1*M* NaOH solution. Fractions were lyophilized, ground in a mortar, and passed through an 80-mesh sieve with 180 μm openings. The quantities isolated were gliadin-rich fraction 10.1–11.5 g, 14% mb; glutenin-rich fraction 17.2–18.4 g. The contents of glutenin and gliadin in the original flour, gluten, and glutenin-rich and gliadin-rich fractions obtained were determined in triplicate according to the procedure described by Wang et al (1999) with modifications. Briefly, 6.0 g of flour or 3.0 g of gluten or its fractions (14% mb) was placed in a beaker. Then 50 mL of 0.5*M* NaCl was added. The slurry was stirred for 2 hr followed by centrifugation at 2,000 × *g* for 15 min. Protein (salt-soluble proteins) content of supernatant was determined by Approved Method 46-13.01 (AACC International 2010). Sediment was then extracted three times with 35, 35, and 30 mL of 70% (v/v) ethanol for 2, 2, and 1 hr, respectively. After centrifugation, the supernatants were pooled and the protein (gliadins) content was determined. The glutenin content in the sample was calculated by subtracting the amount of salt and ethanol-soluble protein from total protein.

Reconstitution of Flours

Gluten and starch were brought to ≈14% moisture by hydration in a closed container as described by Chung et al (1981). Varied gluten or starch amounts were added to the original flour to generate protein contents of 7.0, 9.3, 14.3, 16.9, and 19.6% (w/w), respectively.

Gluten and glutenin-rich and gliadin-rich fractions were added to the original flour to generate varied glutenin-to-gliadin ratios of 0.87, 0.97, 1.20, and 1.49, respectively. During this process, protein content was kept constant at 120%. Waxy wheat starch and regular starch isolated from the original flour were incorporated into the original flour for generating varied amylose contents of 21.7, 23.8, 25.8, 27.9, and 30.0% (w/w), respectively. During this process, protein content was kept constant at ≈9%.

The original and finely comminuted flours were blended at different ratios to generate varied amounts of starch damage at 5.5, 7.1, 8.9, 10.4, and 12.9% (w/w), respectively.

Production of Raw Noodle

Noodle samples were made from original and reconstituted flours as described in our previous study (Lu et al 2009). The flour (100 g, 14% mb) and tap water (35 mL) were mixed into noodle dough in a Hobart N50 mixer for 30 sec at slow speed and then for 4 min at medium speed. The stiff dough obtained was allowed to sit in sealed containers at room temperature for 30 min. Next, the dough was sheeted eight times in a noodle making machine (6YM-220-250, Chongqing, China). For the initial pass, the roll gap was 2 mm. The sheeted dough was then doubled over and passed through the same gap again. Then the roll gap was adjusted to 3.5 mm and dough passed it once. After that, dough passed five more times through roll gaps that reduced progressively to 1 mm. Finally, the dough sheet was cut into 2 mm-wide noodles. The raw noodles were placed in a zip-lock bag and stored at 4°C for no longer than 24 hr before cooking.

Analysis of Noodle Texture

Noodles (20 strips, 10 cm in length for compressive test; 12 strips, 18 cm in length for tensile test) were cooked for 4 min in 200 mL of tap water maintained at a rolling boil. The cooked noodles were placed in 200 mL of water (20°C) for 3 min, drained for 30 sec, and analyzed by compressive (texture profile analysis, TPA) and tensile tests using the TA-XT2i texture analyzer (Scarsdale, NY; Stable Micro Systems, UK). Three replicates of cooked noodles were prepared for these experiments.

TPA of cooked noodles was performed with the same holder and attachments described by Epstein et al (2002). A set of three strands of cooked noodles was placed in parallel on a flat metal plate. Instrument settings were compression mode, trigger type, auto-20 g; pretest speed, 2.0 mm/sec; posttest speed, 0.8 mm/sec; test speed, 0.8 mm/sec; strain, 70%; interval between two compressions, 1 sec. From the force-distance curves generated, three texture parameters can be obtained: hardness (g), springiness (ratio), and cohesiveness (ratio).

A tensile test was performed with another probe described by Seib et al (2000). One strand was positioned on the upper and lower L-shaped hook (the lower L-shaped hook was fixed to the texture analyzer), and an increased tensile load was applied until breakage occurred. Instrument settings were extension mode, trigger type, auto-0.5 g; pretest speed, 2.0 mm/sec; posttest speed, 10 mm/sec; test speed, 2.0 mm/sec; original distance between the two L-shaped hooks, 100 mm. From the force-distance curves obtained, two texture parameters were obtained: tensile strength (the tensile force at break) and breaking length (the walking distance of the upper L-shaped hook at break).

For each replicate of cooked noodles, five determinations (TPA and tensile test, respectively) were made. But the highest and lowest values were discarded, thus only three strands were used for data analysis.

Statistical Analyses

Analysis of variance (ANOVA) was performed using SPSS v.13.0 for Windows. Significance of differences was defined at $P < 0.05$ with Duncan's multiple range test.

RESULTS AND DISCUSSION

Effects of Protein Content and Glutenin-to-Gliadin Ratio on Noodle Texture

Incorporation or reconstitution methods of specific wheat flour components have been widely conducted to specifically demonstrate functions on the quality of wheat products. In the present study, gluten or starch was added to the original flour to investigate the effects of flour protein content on the quality of Chinese fresh white noodles. As shown in Fig. 1A, noodle hardness did not change significantly when protein content in the flour varied at 9.3–14.3%. However, when protein content was >14.3%, noodle hardness increased sharply, which was in accordance with many previously reported results for other types of noodles (Miskelly and Moss 1985; Crosbie et al 1999; Park et al 2003, 2009). Interestingly, when protein content was reduced to 7.0%, noodle hardness unexpectedly increased (Fig. 1A). The reason for this may be related to water absorption. Park et al (2003) reported that optimum water absorption of noodle dough decreased as protein content increased because flours with low protein content require more water for forming a uniform protein matrix and making a continuous noodle sheet with good handling properties. When the same amount of water is used for preparation of noodles from flours of varying protein contents, the dough made of flour with low protein content would feel much drier, resulting in noodle dough sheets of different dimensions. Because water absorption was not optimized in the preparation of noodles in the present work, the dry noodle dough obtained at the low protein content probably led to the increased hardness of noodles. Noodle springiness (Fig. 1B) varied insignificantly at low protein levels, but it increased remarkably at high protein contents. Similarly, cohesiveness of noodles (Fig. 1C), significantly increased with the increment of protein contents, which suggested that the more gluten in the flour, the greater the ability of noodles to stick to themselves. Moreover, tensile strength and breaking length of cooked noodles also increased as protein content was enhanced (Fig. 1D and E.) This relationship between noodle tensile strength and protein content was consistent with that reported by Park et al (2009). Therefore, it can be concluded that gluten incorporation into flour effectively improves noodle texture. However, starch incorporation generally impairs noodle textural characteristics, except hardness.

As shown in Fig. 2A, higher glutenin-to-gliadin ratios with constant protein content resulted in harder noodles, which agreed with the conclusion that gluten fractions of high molecular weight contributed to hardness of noodles (Oh et al 1985a; Hu et al 2007).

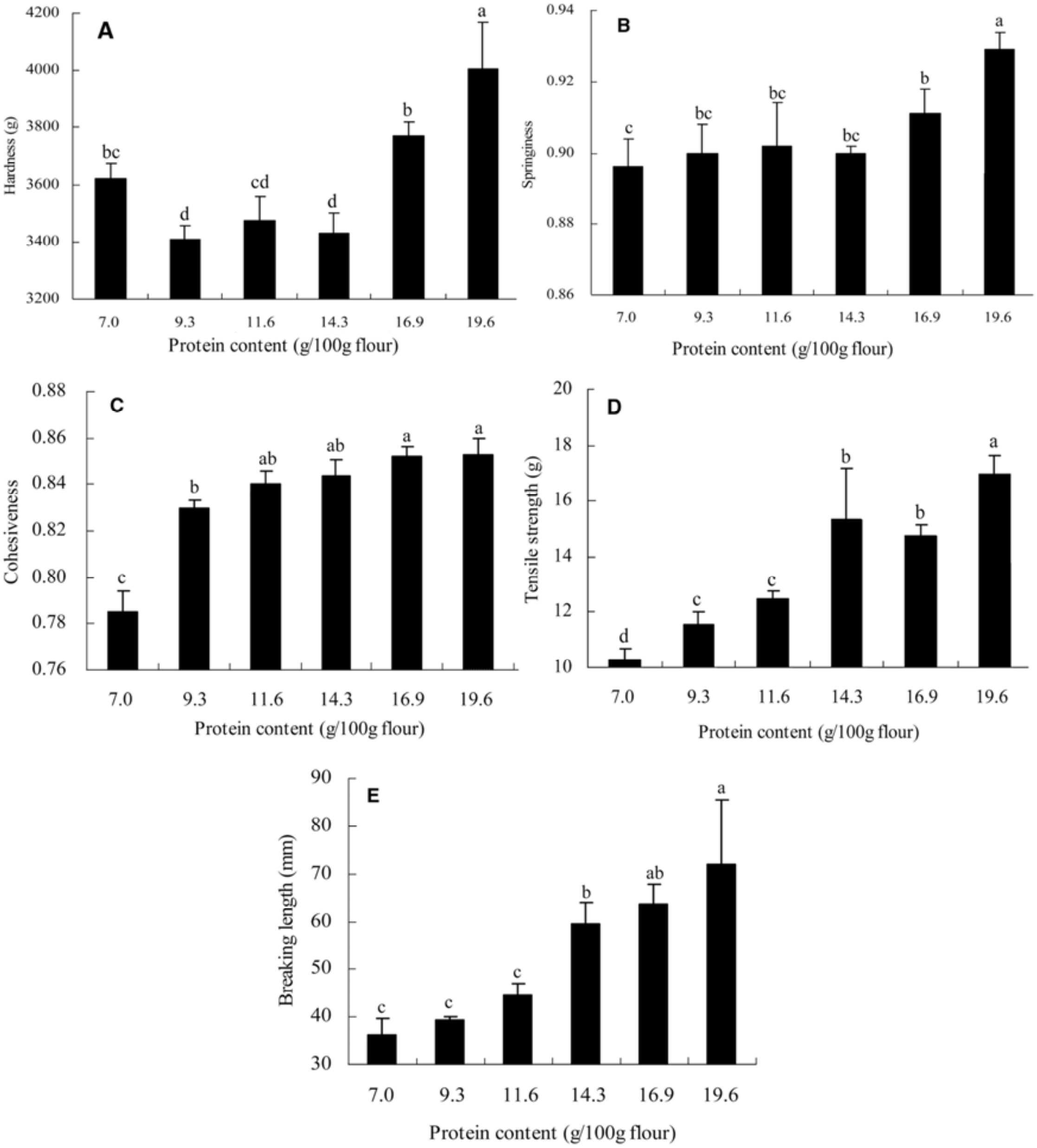

Fig. 1. Effects of protein content on hardness (**A**), springiness (**B**), cohesiveness (**C**), tensile strength (**D**) and breaking length (**E**) of cooked noodles. Means followed by the same letter are not statistically different ($P < 0.05$).

While noodle springiness did not change as much as glutenin-to-gliadin ratio, it significantly decreased at the ratio of 0.97 as compared to 1.49 (Fig. 2B). Increased glutenin-to-gliadin ratio (Fig. 2C and D) led to increased noodle tensile strength while not affecting breaking length. It has been suggested that gliadins generally contribute to dough viscosity, while glutenins contribute to dough elasticity (Khatkar and Schofield 1997). Uthayakumaran et al (1999) reported that increased glutenin-to-gliadin ratio was associated with increased maximum resistance to extension (equivalent to tensile strength) and decreased dough extensibility. According to the present study, breaking length of cooked noodles was significantly increased at low or high glutenin-to-gliadin ratios, which differed from the relationship between glutenin-to-gliadin ratios and extensibility of raw dough. Because low molecular weight (LMW) glutenin proteins strongly aggregated upon heat treatment (Feillet et al 1989), it is not hard to understand why breaking length of cooked noodles was increased at high glutenin-to-gliadin ratios in this study.

Effects of Amylose Content on Flour Pasting Properties and Noodle Texture

Konik et al (1994) suggested that the RVA viscosity parameters (except peak viscosity) of starch and flour were correlated with each other; however, the RVA parameters of flour were better correlated with the eating quality of yellow alkaline noodle than those of starch. As can be seen in Table I, flour peak viscosity, breakdown, final viscosity, and setback consistently increased, as amylose content increased from 21.7 to 30%, whereas peak time and pasting temperature did not vary significantly. These results were consistent with that of Hayakawa et al (1997), which demonstrated that peak viscosity and setback of waxy wheat starch was much lower than the nonwaxy wheat. However, these results did not agree with reports that amylose content was negatively correlated with peak viscosity of purified starch (Collado et al 1999; Black et al 2000; Baik et al 2003). The contradiction may be due to the different starch concentrations used for pasting property tests (Baik et al 2003).

Amylose content remarkably influenced noodle quality; Fig. 3A indicates that significant increases in amylose content were associated with increases in noodle hardness when protein contents was kept constant, which was consistent with many previous studies (Toyokawa et al 1989; Seib 2000; Baik et al 2003; Guo et al 2003). Toyokawa et al (1989) suggested that high amylose led to a rigid and tight structure through decreasing water absorption, which may explain the increases in noodle hardness. Interestingly, springiness of noodles did not change significantly when amylose content increased (data not shown), which was consistent with the results of Baik et al (2003). However, cohesiveness of noodles was significantly elevated when starch amylose content increased (Fig. 3B), which was inconsistent with the results of Baik et al (2003) and Guo et al (2003). This discrepancy was possibly attributed to two factors: the different sources of waxy wheat starches used to adjust the amylose content and water absorption used for making noodles. Not only the amylose-to-amylopectin ratio but also other important chemical properties of starch would affect the noodle texture (Batey et al 1997). Waxy starch has higher water absorption than regular starch. Accordingly, to have similar dough mixing and sheeting properties, increased amounts of water should be used in preparation of noodles from flour of low amylose content. Otherwise, there could be increased gluten development and large differences in the dimension of dough sheets and noodles. However, fixed water absorption for making noodles was adopted in the present study. Therefore, the relative shortage of water amount in mixing dough from flour of low amylose content could result in a corresponding decrease in noodle cohesiveness that may be mainly dependent on gluten development of noodle dough.

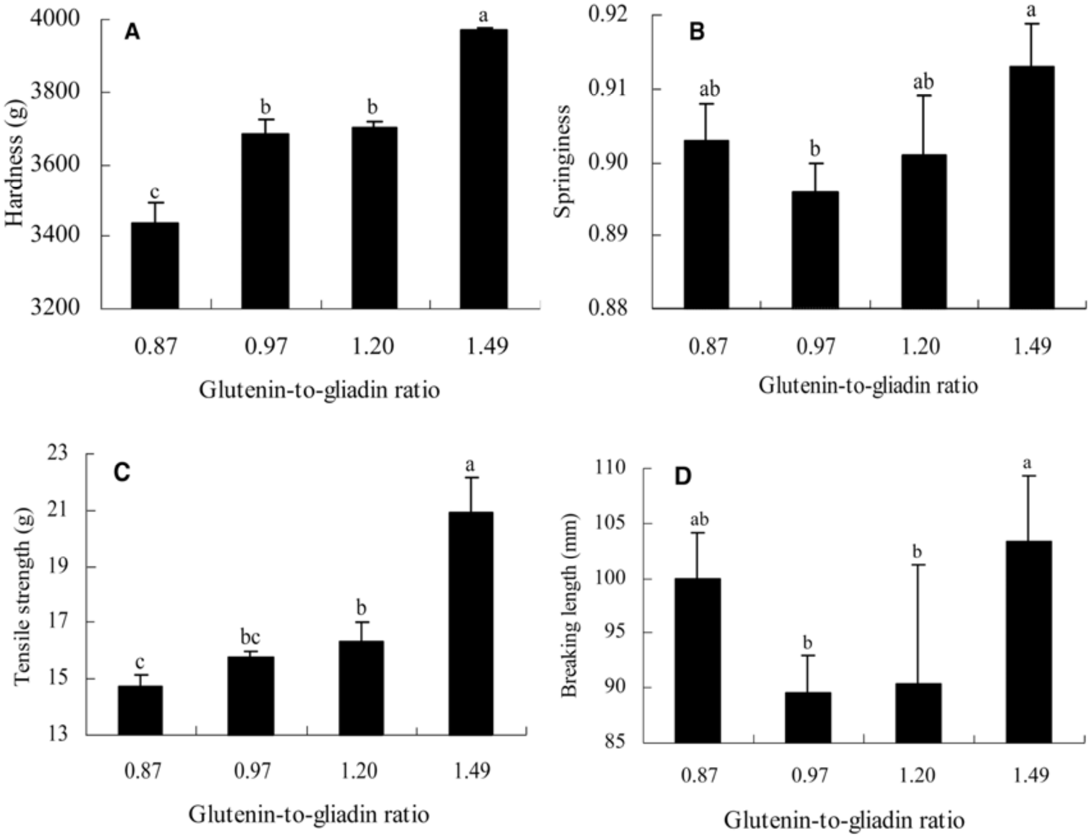

Fig. 2. Effects of glutenin-to-gliadin ratio on hardness (**A**), springiness (**B**), tensile strength (**C**) and breaking length (**D**) of cooked noodles. Means followed by the same letter are not statistically different ($P < 0.05$).

Effects of Starch Damage on Noodle Texture

As starch damage increased (Fig. 4A), hardness of noodles increased linearly, reaching a maximum level of 10.4%, while falling to a low value thereafter. It has been suggested that higher starch damage generally results in lower firmness for cooked dry noodles, while a slight increase in starch damage (<6%) increases internal firmness of cooked noodles prepared from the pin-milled soft wheat flours (Oh et al 1985b). In addition, when starch damage increased, maximum cutting stress of kansui noodles increased whereas that of sodium hydroxide noodles decreased (Hatcher et al 2008). We found moderate increases in starch damage (5.5–10.4%) effectively improved the hardness of white noodles while too much starch damage reduced it. Springiness of noodles (Fig. 4B) was significantly enhanced with increased starch damage, which was, however, different from the results of Hatcher et al (2008) for yellow alkaline noodles. It was well known that dam-

TABLE I
Relationships Between Amylose Content in Starch (%) and RVA Pasting Properties of Flour[a]

Amylose Content	Peak Viscosity (cP)	Breakdown (cP)	Final Viscosity (cP)	Setback (cP)	Peak Time (min)	Pasting Temp (°C)
21.7	1,999e	812d	2,097e	910e	5.89a	62a
23.8	2,138d	863d	2,293d	1,018d	5.87a	63a
25.8	2,254c	927c	2,439c	1,112c	5.92a	63a
27.9	2,478b	1,038b	2,696b	1,257b	5.89a	63a
30.0	2,641a	1,155a	2,874a	1,388a	5.87a	63a

[a] Means within the same column followed by the same letter are not statistically different ($P < 0.05$).

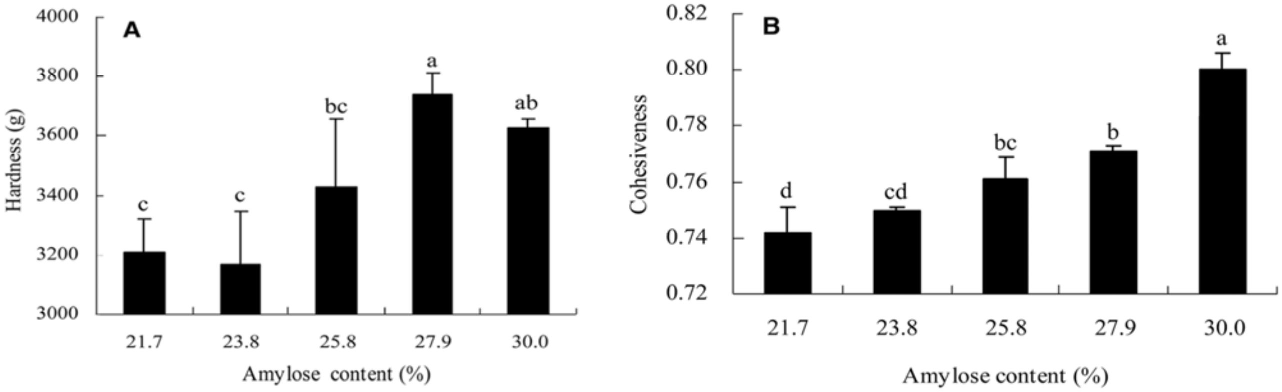

Fig. 3. Effects of starch amylose content on hardness (**A**) and cohesiveness (**B**) of cooked noodles. Means followed by the same letter are not statistically different ($P < 0.05$).

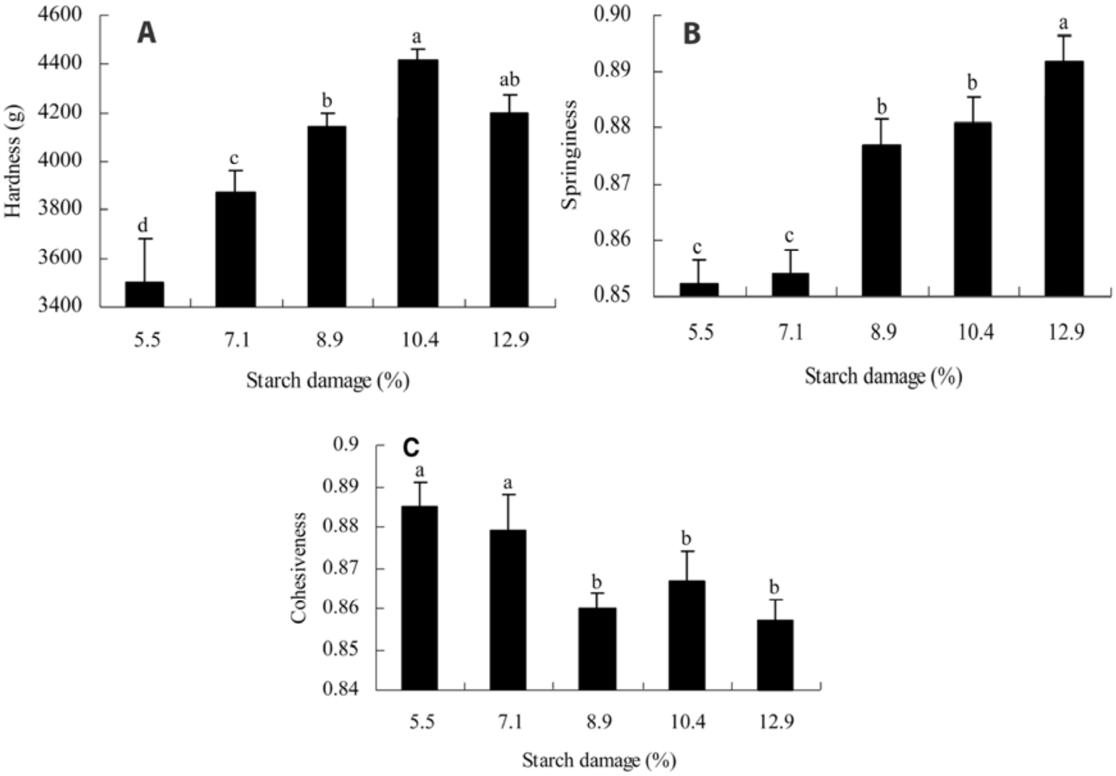

Fig. 4. Effects of starch damage on hardness (**A**), springiness (**B**), and cohesiveness (**C**) of cooked noodles. Means followed by the same letter are not statistically different ($P < 0.05$).

aged starch has higher water absorption than intact starch. As a result, when the same amount of water is used for making noodles from flours of varying starch damage, the dough made with flour of high damaged starch content should be drier than that with flour of low damaged starch content, This may explain the unusual increases of hardness and springiness of noodles when starch damage increased in this study. Figure 4C shows noodle cohesiveness was significantly reduced when starch damage was >7.1%. High levels of damaged starch likely goes against the development of raw noodle dough by competing with proteins for water. It also disrupts the integrity of the gluten protein network to a great extent by an excessive swelling of starch granules upon cooking, thereby reducing cohesiveness of cooked noodles.

CONCLUSIONS

Protein content, glutenin-to-gliadin ratio, starch amylose content, and starch damage had significant effects on textural properties of cooked Chinese fresh white noodles. When water absorption was fixed during noodle making, hardness of noodles decreased with decreased protein content, whereas it unexpectedly increased at a very low protein level of 7.0%. Noodle cohesiveness, tensile strength, and breaking length increased with increased protein content. The ratio of glutenin-to-gliadin had a positive effect on noodle hardness and tensile strength when protein content was constant. Increased starch amylose content led to increased hardness and cohesiveness of cooked noodles. Increased starch damage (at 5.5–10.4%) effectively improved noodle hardness. However, too much of it impaired noodle hardness. As it increased, noodle springiness was enhanced but cohesiveness was decreased.

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