Significance of Amylose Content of Wheat Starch on Processing and Textural Properties of Instant Noodles

Chul Soo Park[1] and Byung-Kee Baik[1,2]

ABSTRACT

The effect of amylose content of starch on processing and textural properties of instant noodles was determined using waxy, partial waxy, and regular wheat flours and reconstituted flours with starches of various amylose content (3.0–26.5). Optimum water absorption of instant noodle dough increased with the decrease of amylose content. Instant noodles prepared from waxy and reconstituted wheat flours with ≤12.4% amylose content exhibited thicker strands and higher free lipids content than wheat flours with ≥17.1% amylose content. Instant noodles of ≤12.4% amylose content of starch exhibited numerous bubbles on the surface and stuck together during frying. Lightness of instant noodles increased from 77.3 to 81.4 with the increase of amylose content of starch in reconstituted flours. Cooking time of instant noodles was 4.0–8.0 min in wheat flours and 6.0–12.0 min in reconstituted flours, and constantly increased with the increase in amylose content of starch. Hardness of cooked instant noodles positively correlated with amylose content of starch. Reconstituted flours with ≤12.4% amylose content of starch were higher in cohesiveness than those of wheat flours of wild-type and partial waxy starches and reconstituted flours with ≥17.1% amylose content. Instant fried noodles prepared from double null partial waxy wheat flour exhibited shorter cooking time, softer texture, and higher fat absorption (1.2%) but similar color and appearance compared with noodles prepared from wheat flour of wild-type starch.

Cereal Chem. 81(4):521–526

Flour characteristics required for making instant noodles are similarly important for making other types of noodles, although steaming and frying are unique to the processing of instant noodles; these processes also influence the characteristics of instant noodles. Blended wheat flours of dark northern spring, hard red winter, and Australian standard white wheat are generally used for making instant noodles in Japan (Kubomura 1998). Protein content of flour has a negative correlation with fat absorption of instant noodles (Moss et al 1987; Baik et al 1994; Park and Baik 2004). Strong protein quality, as well as high protein content, has been related to bright color and low fat absorption of instant noodles, and to firm and elastic texture of cooked instant noodles (Park and Baik 2004).

Potato, waxy corn, barley, rice, and tapioca starches are often used for making instant noodles because the quick gelatinization and high maximum viscosity of these starches are advantageous for the texture of cooked instant noodles (Kubomura 1998). Starch characteristics, including amylose-amylopectin ratio, starch pasting properties, and swelling powers are highly related to eating quality of white salted noodles (Toyokawa et al 1989; Crosbie 1991; Crosbie et al 1992; Konik et al 1992; Baik et al 1994). Wheat flour with reduced starch amylose content is desirable for making white salted noodles because high starch pasting and swelling properties have been highly related to low amylose content of starch (Crosbie 1991; Crosbie et al 1992; Konik et al 1992; Miura and Tanii 1994; Yasui et al 1999; Zhao et al 1998; Abdel-Aal et al 2002). Wheat flours with a double null in granular bound starch synthase (GBSS) have a starch amylose content of 15.4–18.9% and produce softer and more elastic texture of white salted noodles than wheat flours with high amylose content of starch (Baik et al 2003). Double partial waxy wheat and waxy wheat flours have shorter cooking times than wild-type and B null wheat flours (Park and Baik 2004), although cooking time of noodles has been correlated with protein content of flour and water absorption of noodle dough (Oh et al 1985; Moss et al 1987; Kruger et al 1994; Hatcher et al 1999). However, the effect of amylose content of starch in wheat flours on the processing and textural properties of instant noodles has not been investigated.

[1] Research associate and assistant professor, Department of Food Science & Human Nutrition and IMPACT, Washington State University, Pullman, WA 99164-6376.
[2] Corresponding author. Phone: 509-335-8230. Fax: 509-335-4815. E-mail: baik@wsu.edu

Publication no. C-2004-0602-05R.

Therefore, this study was conducted to determine the effect of amylose content on processing characteristics, fat absorption, and textural properties of instant noodles. Instant noodles were prepared from 1) wheat flours with different amylose and protein content, and 2) reconstituted flours with various ranges of amylose content but with constant protein content and quality and analyzed for processing and product properties.

The starches of various amylose content, prepared by blending wild-type and waxy starch, are nonhomogeneous mixtures of starch granules of different amylose content, while wheat flours of wild-type, partial waxy, or waxy starch traits contain starch granules of homogeneous amylose content. However, Baik and Lee (2003) and Baik et al (2003) reported that white salted noodles prepared from reconstituted flours containing blends of wild-type and waxy wheat starch as well as from those containing double null partial waxy wheat starch exhibited a similar decrease in hardness and a similar increase in cohesiveness of cooked noodles.

MATERIALS AND METHODS

Materials

Two sets of wheat flours were used in this study. The first set included flours of four hard wheats with various protein and amylose contents. The second set consisted of reconstituted flours with different amylose contents. Two hard wheat cultivars (IDO377S and Winsome) and a soft wheat cultivar (Alpowa) were obtained from the Western Wheat Quality Lab (Pullman, WA). Winsome and Alpowa were wild-type in GBSS, while IDO377S was B single null in GBSS. Two advanced breeding lines of hard wheat that were BD double null and a waxy wheat were obtained from Northwest Plant Breeding Co. (Pullman, WA). Wheats were milled using a Bühler experimental mill, and flour of 60% extraction was prepared by compounding the millstreams in the order of increasing ash content.

Alpowa, IDO377S, BD double null, and waxy wheat were used to make reconstituted flours. Flours were fractionated into gluten, solubles, tailings starch, and prime starch according to the method of Czuchajowska and Pomeranz (1993), and the yield of each fraction was determined. Gluten, solubles, and tailings starch were lyophilized, and prime starches were dried at 24°C for three days. Each fraction was ground on a cyclone mill (Udy, Fort Collins, CO) fitted with a perforated screen with 0.25-mm openings. The moisture content of the lyophilized gluten and tailings starch was adjusted to the moisture content of the prime starch (≈10%).

Reconstituted Flours

Gluten, tailings starch, and solubles isolated from IDO377S were used to prepare reconstituted flours. The proportion of fractions for making reconstituted flour was 4.7% solubles, 16.0% tailings starch, 17.1% gluten, and 62.2% prime starch. Prime starches for making reconstituted flours were those of Alpowa, IDO377S, BD double null, and waxy wheat. The blends of prime starch were also prepared by mixing prime starches of Alpowa containing wild-type starch in amylose content with 20–80% of prime starch from waxy wheat and used to prepare reconstituted flours.

Analytical Methods

Moisture and protein content of wheat flour were determined according to Approved Methods 44-15A and 46-30 (AACC 2000). Amylose content of prime starches was determined according to the procedures of Williams et al (1970).

Making of Instant Noodles

Both native wheat flours and reconstituted flours (100 g, 14% mb) were mixed with brine solution in a pin mixer (National Mfg., Lincoln, NE) for 4 min. The optimum water absorption for making noodle dough was determined by experienced personnel through trial and error, based on appearance of the dough and dough sheet, and on handling properties of the dough sheet during the noodle-making process. The concentration of brine solution for making noodles with different absorption was adjusted to contain 1.71% sodium chloride, 0.09% sodium carbonate, and 0.09% potassium carbonate in the noodle dough. Dough was passed through the rollers of a noodle machine (Ohtake, Tokyo, Japan) with a 3-mm gap at 8 rpm. The noodle dough sheet was folded and put through the sheeting roll. The folding and sheeting were repeated twice more for flours and 10 more times for reconstituted flours. The dough sheet was rested for 1 hr and then put through the sheeting rollers six times at progressively decreasing gaps of 2.60, 2.33, 2.00, 1.75, 1.40, and 1.20 mm. After the last sheeting, thickness of the dough sheet was measured by a micrometer dial thickness gauge (Peacock Dial Thickness Gauge G, Ozaki Mfg., Ozaki, Japan) in three replicates. The dough sheet was cut through no. 20 cutting rolls with 1.50-mm grooves.

Steaming and frying procedures were conducted according to the procedures of Baik et al (1994). Fresh noodles were steamed at atmospheric pressure for 3 min using a steam blancher (model M-6, Dixie Canner, Athens, GA) and fried in soybean oil at 148°C for 1 min. New oil was used for frying noodles of each wheat flour. Thickness of instant noodle strands was measured using a micrometer dial thickness gauge G (from the uncut side in 10 replicates). The instant noodles were then ground with a mortar and pestle to pass through a sieve of 1.0-mm openings. Ground instant noodles were packed in a transparent plastic dish (35 mm diameter), covered with a lid, and inverted. The color of the ground instant noodles was measured through the transparent plastic dish using a CM-2002 spectrophotometer (Minolta, Osaka, Japan) with an 11-mm measurement aperture. The color of noodle sheets were recorded as CIE-LAB L* (lightness), a* (redness-greenness), and b* (yellowness-blueness) values. Free lipids were determined according to Approved Method 30-25 (AACC 2000).

Texture of Instant Noodles

Cooking time of instant noodles was determined by the method used for dry noodles, in which cooking time is usually determined by the point at which the white core disappears when cooked noodle strands are squeezed between a pair of glass plates (Oh et al 1983). Raw noodles (30 g) were cooked at the determined cooking time in 1,000 mL of boiling distilled water and then rinsed with

TABLE I
Characteristics of Wheat Flour and Reconstituted Flour

Wheat Flour[a]	Amylose (%)	Protein (%)	Ash (%)
Flour			
Winsome	25.3a[b]	14.2b	0.50a
IDO377S	22.7a	13.8b	0.46a
BD Double Null	16.5b	11.6d	0.38c
Waxy	3.0c	15.4a	0.42b
Reconstituted flour[c]			
I (Waxy)	3.0f	14.4a	0.33a
II (80% Waxy + 20% Alpowa)	7.7e	14.5a	0.32a
III (60% Waxy + 40% Alpowa)	12.4d	14.4a	0.32a
IV (40% Waxy + 60% Alpowa)	17.1c	14.5a	0.32a
V (20% Waxy + 80% Alpowa)	21.8b	14.4a	0.31a
VI (Alpowa)	26.5a	14.4a	0.32a
VII (IDO377S)	22.7b	14.4a	0.31a
VIII (BD Double Null)	16.6c	14.4a	0.33a

[a] Flour characteristics were expressed on dry weight basis.
[b] Values followed by same letters are not significantly different at $P < 0.05$ within flours and reconstituted flours.
[c] Prepared by blending gluten, tailings starch, and soluble fractions of IDO377S, and prime starch isolated from Alpowa, IDO377S, BD double null, and waxy wheat or prime starch blends of Alpowa and waxy wheat. Source of prime starch of reconstituted flour in parentheses.

TABLE II
Optimum Water Absorption (OWA) of Noodle Dough, Dough Sheet Thickness (DST), and Characteristics of Instant Noodles Prepared from Wheat Flour and Reconstituted Flour[a,b]

			Instant Noodles				
					Color		
Wheat Flour	OWA (%)	DST (mm)	Thickness (mm)	Free Lipids (%)	L*	a*	b*
Flour							
Winsome	34c	1.8a	1.9b	20.5c	76.8a	–0.4c	19.2b
IDO377S	33d	1.7a	1.8c	20.2c	77.5a	0.1b	18.4c
BD Double Null	35b	1.7a	1.8c	21.7b	77.4a	–0.6d	20.6a
Waxy	38a	1.7a	2.6a	35.8a	70.1b	0.3a	20.0a
Reconstituted flour[c]							
I (Waxy)	49a	1.8a	3.0a	35.8a	77.3e	–0.3b	15.6a
II (80% Waxy + 20% Alpowa)	46b	1.8a	2.8b	32.5b	78.9d	–0.2a	15.7a
III (60% Waxy + 40% Alpowa)	43c	1.8a	2.6c	29.0c	79.5c	–0.3ab	15.4ab
IV (40% Waxy + 60% Alpowa)	41d	1.9a	2.1d	25.4d	80.3b	–0.3ab	14.8c
V (20% Waxy + 80% Alpowa)	39e	1.8a	2.1d	23.3e	81.1a	–0.2a	15.3a–c
VI (Alpowa)	39e	1.8a	2.1d	23.3e	81.2a	–0.2a	15.6a
VII (IDO377S)	39e	1.9a	2.0d	23.6e	81.2a	–0.2a	15.2a–c
VIII (BD Double Null)	41d	1.9a	2.1d	25.4d	81.4a	–0.2a	15.0bc

[a] L* = lightness; a* = redness-greenness; b* = yellowness-blueness.
[b] Values followed by same letters are not significantly different at $P < 0.05$ within flours and reconstituted flours.
[c] Prepared by blending gluten, tailings starch, and soluble fractions of IDO377S, and prime starch isolated from Alpowa, IDO377S, BD double null and waxy wheat or prime starch blends of Alpowa and waxy wheat. Source of prime starch of reconstituted flour in parentheses.

cold water. Two replicates of cooked noodles were evaluated by texture profile analysis (TPA) using a TA-XT2 texture analyser (Stable Micro Systems, Haslemeres, England) within 5 min after cooking. A set of five strands of cooked noodles was placed parallel on a flat metal plate and compressed crosswise twice to 70% of their original height using a 3.175-mm metal blade at a speed of 1.0 mm/sec. From force-time curves of the TPA, hardness, springiness, and cohesiveness were determined according to the description of Park et al (2003).

Statistical Analysis

All tests were run at least in duplicate in a completely randomized design. Statistical analysis of data was performed using SAS software (SAS Institute, Cary, NC) for Duncan's multiple range test, Pearson correlation coefficient, and linear regressions. Differences were considered significant at $P < 0.05$, unless otherwise specified.

RESULTS AND DISCUSSION

Characteristics of Wheat Flour and Noodle Dough

Amylose, protein, and ash contents of four wheat flours were 3.0–25.3%, 11.6–15.4%, and 0.38–0.50%, respectively (Table I). Starch damage in the flours, which is not listed in Table I, was slightly elevated for the waxy and partial waxy wheats as found previously (Park and Baik 2004). Amylose content of starch was highest in Winsome (25.3%), less in IDO377S (22.7%), and BD double null (16.6%), and lowest in waxy wheat (3.0%). Protein content was 14.4–14.5% in reconstituted flours. Gluten fraction of IDO377S was selected for making reconstituted flour because hard wheat flours exhibit brighter and less yellow color of instant noodles and lower fat absorption of instant noodles than soft wheat flours (Park and Baik 2004). Protein content of prime starch of Alpowa, IDO377S, BD double null, and waxy wheat was ≈0.7%. Amylose content of Alpowa starch was 26.5% and amylose content of blended starches from Alpowa and waxy wheat starch was 7.7–21.8%. Alpowa starch (26.5% amylose) rather than Winsome starch (25.3% amylose) was used in the reconstituted flours because of availability.

The optimum water absorption for making instant noodles was 33–35% in Winsome, IDO377S, and BD double null wheat flours (Table II). Waxy wheat flour showed much higher water absorption of noodle dough (38%) than other wheat flours because waxy wheat flours absorb and retain more water during dough mixing than wheat flours of wild-type or partial waxy starch (Baik and Lee 2003). Optimum water absorption of noodle dough prepared from reconstituted flours was higher (39–49%) than wheat flours with similar protein content. Reconstituted flour required more water to combine each fraction of flour during the mixing process to form a homogenous mass. Rogers and Hoseney (1989) reported that for

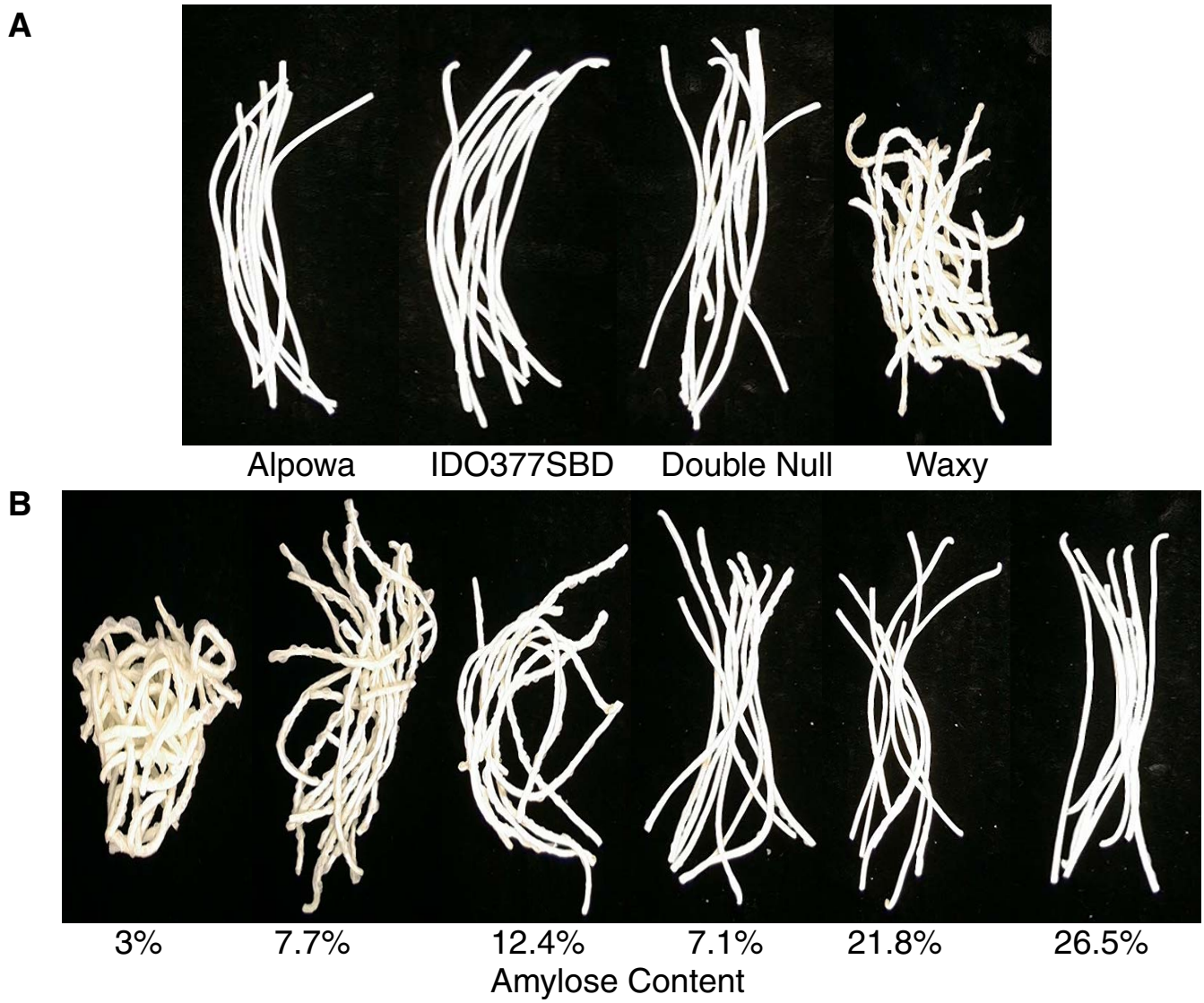

Fig. 1. A, Instant noodles prepared from wheat flours. **B,** Instant noodles prepared from reconstituted flours.

sheeted cracker dough, it was necessary to wet the reconstituted flour to ≈40% moisture content and air-dry the dough particles to achieve good crackers. Without the wetting and air-drying treatment of reconstituted flour to increase the particle density, the extra water was probably needed to help development of dough from the blends of freeze-dried fractions. Optimum water absorption of noodle dough negatively correlated with amylose content of reconstituted flours ($P < 0.001$). The negative relationship between optimum water absorption and amylose content of starch has also been found in white salted noodles made from reconstituted flours of different amylose contents (Baik and Lee 2003). The thickness of noodle dough sheet ranged from 1.7 to 1.8 mm in native wheat flours and from 1.8 to 1.9 mm in the reconstituted flours, exhibiting no effect of starch amylose content on the thickness of noodle dough sheet.

Characteristics of Instant Noodles

The appearance of instant noodles prepared from wheat flours and reconstituted flours is illustrated in Fig. 1. During frying, many bubbles formed on the surface of instant noodles prepared from waxy wheat flour, and the noodle strands stuck together. Reduced steaming time (from 3 min to 2 or 1 min), lowered frying temperature (from 148 to 140, 130, or 120°C) and reduced frying time (from 1 min to 30 sec) did not alleviate the occurrence of bubbles on instant noodles prepared from waxy wheat flour. Instant noodles prepared from wheat flours of wild-type and partial waxy starches showed few bubbles on the surface and separated well. Distinctive appearance of instant noodles was also found in instant noodles prepared from reconstituted flours. The appearance of instant noodles with ≤12.4% amylose content was similar to that of instant noodles prepared from waxy wheat flour, although surface bubbles and separation of instant noodles improved as amylose content of reconstituted flours increased. With ≥17.1% amylose content, the appearance of instant noodle strands was similar to instant noodles prepared from wheat flour of wild-type starch with few bubbles. Moss et al (1987) reported that instant noodles with low protein content (9.0%) formed large bubbles on the surface, whereas fewer such bubbles appeared on the surface of noodles with intermediate protein content (12.0%), and there were no bubbles on the surface of noodles with high protein content (18.7%). This result indicates that, in addition to protein content, starch amylose content significantly affects the development of bubbles on the surface of instant noodle strands.

The characteristics of instant noodles prepared from wheat flours and reconstituted flours are summarized in Table II. Moisture content of instant noodles was 5.0–6.2% in wheat flours and 6.2–9.1% in reconstituted flours. The moisture content of instant noodles is within the range report by Kim (1996) and Kubomura (1998). Instant noodle strands prepared from waxy wheat flour were thicker (2.6 mm) than instant noodles prepared from wild-type and partial waxy wheat flours (1.8–1.9 mm). Thickness of instant noodle strands was higher in reconstituted flours of ≤12.4% amylose content of starch (2.6–3.0 mm) than in flours of ≥17.1% amylose content (2.0–2.1 mm). The increase in thickness of instant noodle strands as starch amylose content decreased at <12.4% corresponded well with the increase in optimum water absorption for making noodles.

Free lipids content of instant noodles prepared from waxy wheat flour was much higher (35.8%) than in wheat flours of wild-type and partial waxy starches. BD double null showed higher free lipids content of instant noodles (21.7%) than Winsome (20.5%) and IDO377S (20.2%). A distinctive pattern was found in free lipids content of instant noodles prepared from reconstituted flours. Free lipids content of instant noodles of ≤12.4% amylose content of

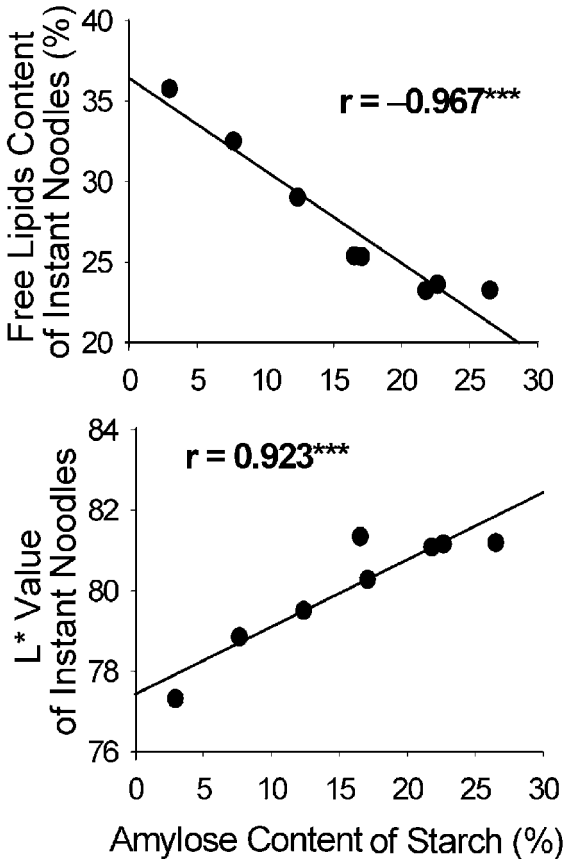

Fig. 2. Relationship between amylose content of starch and free lipids content and L* value of instant noodles prepared from reconstituted flours ($n = 8$).

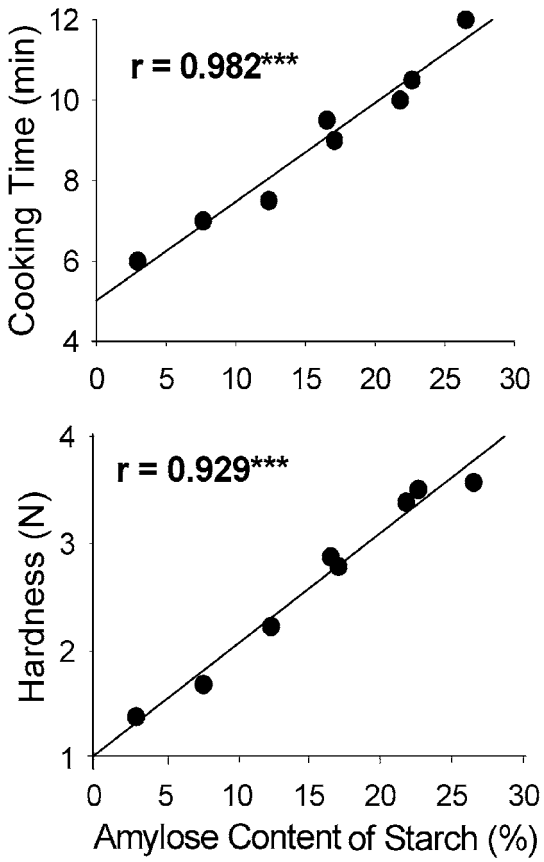

Fig. 3. Relationship between amylose content of starch, cooking time, and hardness of cooked instant noodles prepared from reconstituted flours ($n = 8$).

starch was much higher (29.0–35.8%) than that of ≥17.1% amylose content (23.3–25.4%). These results indicate that wheat flours with lower amylose content (≤12.4%) are unsuitable for making instant noodles because of higher fat absorption, as well as undesirable appearance of noodle strands (Fig 1). Instant noodles prepared from reconstituted flour with starches of IDO377S and BD double null partial waxy showed higher free lipids content of instant noodles (23.6 and 25.4%) than instant noodles prepared from corresponding wheat flours (20.2 and 21.7%). Compared with noodles prepared from wheat flours, instant noodles prepared from reconstituted flours produced noodles of less compact and homogenous structure, probably due to the lower degree of gluten development during noodle making, which contributed to the high fat absorption of instant noodles.

Lightness (L*) of instant noodles was 70.1 in waxy wheat flour and much lower than in wheat flours of wild-type and partial waxy wheat flours (≥76.8). High optimum water absorption and fat absorption probably contributed the low L* of instant noodles prepared from waxy wheat flour. Reconstituted flours of ID0377S and double null partial waxy wheat produced instant noodles of higher L* and lower b* compared with corresponding wheat flours. Redness-greenness (a*) and yellowness-blueness (b*) of instant noodles exhibited relatively small variation among wheat flours, ranging from –0.6 to 0.3 and from 18.4 to 20.6. L* of instant noodles prepared from reconstituted flours decreased consistently as starch amylose content decreased from 21.8 to 3.0%. There was no difference in a* and b* between instant noodles prepared from reconstituted flours of various starch amylose content.

Figure 2 shows the relationship between amylose content, free lipids content and L* values of instant noodles prepared from reconstituted flours. Amylose content negatively correlated with free lipids content of instant noodles ($r = –0.976$, $P < 0.001$) and positively correlated with L* of instant noodles ($r = 0.919$, $P < 0.001$). However, L* values did not vary for instant noodles prepared from reconstituted flours with starches from Alpowa, ID0377S and double null partial waxy wheat. Free lipids content of instant noodles negatively correlated with L* of instant noodles ($r = –0.968$, $P < 0.001$). Negative relationships between protein content of flour and fat absorption, and between fat absorption and L* of instant noodles, were previously reported by Park and Baik (2004).

Properties of Cooked Noodles

Cooking time and textural properties of cooked instant noodles are summarized in Table III. Instant noodle strands are easily separated from each other in hot water because the surfaces of fried noodle strands absorb oil during frying (Hou 2001). Strands of instant noodles prepared from waxy wheat flour also easily separated during boiling, even though they stuck together during the frying process. Cooking time of instant noodles was 4 min for waxy wheat flour, 6 min for BD double null, and 8.0 min for IDO377S and Winsome. Park and Baik (2004) reported that cooking time of instant noodles prepared from hard wheat flours of wild-type or single null partial waxy starches was 7.5–8.0 min. Cooking time of instant noodles ranged from 6.0 to 12.0 min in reconstituted flours and consistently increased with the increase of amylose content of starch ($P < 0.001$) (Fig. 3). This result indicates that cooking time of instant noodles can be reduced by using wheat flours with low amylose content of starch.

Hardness of cooked instant noodles were lowest in waxy wheat flour (2.10 N), intermediate in BD double null (3.18 N), and highest in Winsome and IDO377S (3.71–3.72 N). Springiness of cooked instant noodles prepared from waxy and BD double null (0.87 and 0.84, respectively) was lower than in IDO377S and Winsome (0.90 and 0.89, respectively). Waxy wheat showed higher cohesiveness of cooked noodles (0.67) than wheat flours of wild-type and partial waxy wheat starches (0.62–0.63). Hardness of cooked instant noodles prepared from reconstituted flours was 1.39–3.57 N, and positively correlated with amylose content of starch ($P < 0.001$) (Fig. 3). No discontinuity is seen in Fig. 3 for the linear correlations of cooking time and hardness with amylose content despite the noodles being made from reconstituted flours containing either blends of waxy and wild-type starches or regular and partial waxy starches. Those data suggest that, at least for cooking time and hardness, the reconstituted flours made with mixtures of waxy and wild-type starches performed the same as indigenous starches in flours at the same amylose contents. There was no significant difference in springiness of cooked noodles prepared from reconstituted flours, except for reconstituted flours with Alpowa starch (0.87). Cohesiveness of instant noodles was 0.70 in reconstituted flours with ≤12.4% starch amylose content, 0.68 in reconstituted flours with 17.1–21.8% starch amylose content, and 0.65 in Alpowa reconstituted flour (26.5% starch amylose content). Cohesiveness of instant noodles prepared from reconstituted flours was >0.69 with starches of IDO377S and BD double null. Cohesiveness of cooked noodles with ≥17.1% starch amylose content was <0.69, except for BD double null (0.72). Compared with noodles prepared from respective native wheat flours, noodles prepared from ID0377S reconstituted flour and double null partial waxy starches exhibited longer cooking time and lower hardness but higher cohesiveness of cooked noodles. Instant noodles prepared from wheat flours with low amylose content have shorter

TABLE III
Cooking Time and Textural Properties of Cooked Instant Noodles Prepared from Wheat Flour and Reconstituted Flour

Sample	Cooking Time (min)	TPA Parameters		
		Hardness (N)	Springiness (Ratio)	Cohesiveness (Ratio)
Flour				
Winsome	8.0a[a]	3.72a	0.89a	0.63b
IDO377S	8.0a	3.71a	0.90a	0.62b
BD Double Null	6.0b	3.18b	0.84c	0.62b
Waxy	4.0c	2.10c	0.87b	0.67a
Reconstituted flour[b]				
I (Waxy)	6.0h	1.39f	0.90a	0.70b
II (80% Waxy + 20% Alpowa)	7.0g	1.69e	0.91a	0.70b
III (60% Waxy + 40% Alpowa)	7.5f	2.23d	0.90a	0.70b
IV (40% Waxy + 60% Alpowa)	9.0e	2.79c	0.90a	0.68c
V (20% Waxy + 80% Alpowa)	10.0c	3.39b	0.90a	0.68c
VI (Alpowa)	12.0a	3.57a	0.87b	0.65d
VII (IDO377S)	10.5b	3.51a	0.91a	0.69c
VIII (BD Double Null)	9.5d	2.88c	0.91a	0.72a

[a] Values followed by same letters are not significantly different at $P < 0.05$ within flours and reconstituted flours.
[b] Prepared by blending gluten, tailings starch, and soluble fractions of IDO377S, and prime starch isolated from Alpowa, IDO377S, BD double null, and waxy wheat or prime starch blends of Alpowa and waxy wheat. Source of prime starch of reconstituted flour in parentheses.

cooking time, softer texture and higher cohesiveness than instant noodles prepared from flours of wild-type starch. Double null partial waxy wheat flour also produces instant noodles with short cooking time and cohesive texture of instant noodles.

CONCLUSIONS

Amylose content of starch has effects on water absorption of instant noodle dough, L* value, fat absorption, and cooking time of instant noodles, and texture properties of cooked instant noodles. Waxy wheat flours and reconstituted flours with <12.4% starch amylose content exhibit unsuitable characteristics for making instant noodles because of higher fat absorption, darker color, undesirable appearance on the surface of instant noodles, and extremely soft texture of cooked noodles, despite shorter cooking time and more cohesive texture than instant noodles of high starch amylose content. Double null partial waxy wheat flour of 16.5% starch amylose content produces instant fried noodles with shorter cooking time and softer texture compared with wheat flours of wild-type starch, with a relatively small increase in fat absorption, but without development of undesirable appearance.

LITERATURE CITED

AACC. 2000. Approved Methods of the AACC. 10th Ed. Methods 30-25, 44-15A, and 46-30. The Association: St. Paul, MN.

Abdel-Aal, E.-S. M., Hucl, P., Chibbar, R. N., Han, H. L., and Demeke, T. 2002. Physicochemical and structural characteristics of flours and starches from waxy and nonwaxy wheats. Cereal Chem. 79:458-464.

Baik, B.-K., and Lee, M.-R. 2003. Effects of starch amylose content of wheat on textural properties of white salted noodles. Cereal Chem. 80:304-309.

Baik, B.-K., Czuchajowska, Z., and Pomeranz, Y. 1994. Role and contribution of starch and protein contents and quality to texture profile analysis of oriental noodles. Cereal Chem. 71:315-320.

Baik, B.-K., Park, C. S., Paszczynska, B., and Konzak, C. F. 2003. Characteristics of noodles and bread prepared from double null partial waxy wheat. Cereal Chem. 80:627-633.

Crosbie, G. B. 1991. The relationship between starch swelling properties, paste viscosity and boiled noodle quality in wheat flours. J. Cereal Sci. 13:145-150.

Crosbie, G. B., Lambe, W. J., Tsutsui, H., and Gilmour, R. F. 1992. Further evaluation of the flour swelling volume test for identifying wheats potentially suitable for Japanese noodles. J. Cereal Sci. 15:271-280.

Czuchajowska, Z., and Pomeranz, Y. 1993. Protein concentrates and pure starch from wheat flours. Cereal Chem. 70:701-706.

Hatcher, D. W., Kruger, J. E., and Anderson, M. J. 1999. Influence of water absorption on the processing and quality of oriental noodles. Cereal Chem. 76:566-572.

Hou, G. 2001. Oriental noodles. Adv. Food Nutr. Res. 43:141-193.

Kim, S. G. 1996. Instant noodles. Pages 195-225. in: Pasta and Noodle Technology. J. E. Kruger, R. B. Matsuo, and J. W. Dick, eds. Am. Assoc. Cereal Chem.: St. Paul, MN.

Konik, C. M., Miskelly, D. M., and Gras, P. W. 1992. Contribution of starch and non-starch parameters to the eating quality of Japanese white salted noodles. J. Sci. Food Agric. 58:403-406.

Kruger, J. E., Anderson, M. H., and Dexter, J. E. 1994. Effect of flour refinement on raw Cantonese noodle color and texture. Cereal Chem. 71:177-182.

Kubomura, K. 1998. Instant noodles in Japan. Cereal Foods World 43:194-197.

Miura, H., and Tanii, S. 1994. Endosperm starch properties in several wheat cultivars preferred for Japanese noodles. Euphytica 72:171-175.

Moss, R., Gore, P. J., and Murray, I. C. 1987. The influence of ingredients and processing variables on the quality and microstructure of Hokkien, Cantonese and instant noodles. Food Microstructure 6:63-74.

Oh, N. H., Seib, P. A., Deyoe, C. W., and Ward, A. B. 1983. Noodles. I. Measuring the textural characteristics of cooked noodles. Cereal Chem. 60:433-438.

Oh, N. H., Seib, P. A., Ward, A. B., and Deyoe, C. W. 1985. Noodles. IV. Influence of flour protein, extraction rate, particle size, and starch damage on the quality characteristics of dry noodles. Cereal Chem. 62:441-446.

Park, C. S., and Baik, B.-K. 2004. Relationship between protein characteristics and instant noodle making quality of wheat flour. Cereal Chem. 81:159–164.

Park, C. S., Hong, B. H., and Baik, B.-K. 2003. Protein quality of wheat desirable for making fresh white salted noodles and its influence of processing and texture of noodles. Cereal Chem. 80:297-303.

Rogers, D. E., and Hoseney, R. C. 1989. A fractionation and reconstitution method for saltine cracker flours. Cereal Chem. 66:3-6.

Toyokawa, H., Rubenthaler, G. L., Powers, J. R., and Schanus, E. G. 1989. Japanese noodle qualities. I. Flour components. Cereal Chem. 66:382-386.

Williams, P. C., Kuzina, F. D., and Hlynka, I. 1970. A rapid calorimetric procedure for estimating the amylose content of starches and flours. 47:411-420.

Yasui, T., Matsuki, J., Sasaki, T., and Matsuki, J. 1999. Milling and flour pasting properties of waxy endosperm mutant lines of bread wheat (*Triticum aestivum* L.). J. Sci. Food Agric. 79:687-692.

Zhao, X. C., Batey, I. L., Sharp, P. J., Crosbie, G., Barclay, I., Wilson, R., Morell, M. K., and Appels, R. 1998. A single genetic locus associated with starch granule properties and noodle quality in wheat. J. Cereal Sci. 27:7-13.

[Received June 25, 2003. Accepted December 17, 2003.]