Cooking Time of White Salted Noodles and Its Relationship with Protein and Amylose Contents of Wheat

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ABSTRACT

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Optimum cooking time of white salted noodles determined by sensory panel test ranged from 13.6 to 16.2 min in wheat of wild type in granule bound starch synthase (GBSS), from 16 to 17.4 min in B null in GBSS, from 11.4 to 12.4 min in commercial noodle flours, from 8.0 to 8.2 min in waxy wheat, and 14.2 min in BD double null. Both protein and starch amylose content of wheat significantly influenced water absorption for making noodles and cooking time of white salted noodles. Optimum cooking time of noodles increased as protein content of flour increased, except in waxy wheat flours. Waxy wheat flours, despite their high protein content (>17.1%), exhibited the shortest cooking time of noodles, signifying the influence of starch amylose content on cooking time of noodles. Gelatinization enthalpy of starch in noodles from waxy wheat, commercial noodle flour, and wild type wheat flour disappeared after 2, 6, and 10 min of cooking, respectively. Estimated cooking time based on the changes in amylograph onset temperature of noodles during cooking well matched with optimum cooking time as determined by sensory panel test, with a standard error of estimation of 1.23.

Cooking is a primary processing step for many prepared food products. Through the cooking process, food products become more palatable, digestible, and safe from pathogenic as well as nonpathogenic microorganisms. Cooking time is especially important for textural properties of white salted noodles. Undercooked noodles are hard and give a raw flour taste and unpleasant mouthfeel when bitten, while overcooked noodles are soft and soggy to handle and easily broken into small pieces. Accordingly, determination of optimum cooking time is essential, not only to provide valid cooking guidelines for the consumer, but also to accurately evaluate the textural properties of cooked noodles. Short cooking time is a generally desirable quality characteristic of white salted noodles, in addition to bright white appearance, soft elastic texture and smooth surface of cooked noodles (Nagao 1996).

Generally, consumers determine cooking time of noodles by observing noodle strands or tasting a few strands during cooking. Cooking time of noodles, especially dry noodles, is determined more objectively by squeezing noodle strands during cooking between a pair of glass plates and observing the disappearance of the white core in a cooked noodle strand (Oh et al 1983). However, the squeezed noodle strand often fails to provide a reliable estimation of cooking time, especially in fresh noodles because it is difficult to distinguish the disappearance of the white core during cooking. Furthermore, this method of determining the cooking time of noodles mainly relies on the water imbibition of noodle strands during cooking and takes into little consideration changes in noodle constituents. Therefore, a fixed cooking time, selected based on the dimensions of noodle strands, has been applied in laboratories for evaluation of eating quality of white salted noodles.

Major flour constituents (protein and starch) undergo physical and chemical changes such as denaturation of protein and gelatinization of starch during the cooking process. For example, protein extractability of spaghetti in dilute acetic acid decreased during cooking (Dexter and Matsuo 1979). Surface structure is easily disrupted in Cantonese noodles of low protein content, which leads to reduced cooking time for gelatinization of starch granules inside noodle strands (Moss et al 1987). Therefore, it is highly possible that cooking time of noodles may be estimated by monitoring the changes in physicochemical properties of protein and starch during cooking.

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Cooking time of dry white salted noodles determined by squeezing noodle strands during cooking was shorter in noodles prepared from soft wheat flours than in noodles from hard wheat flours (Oh et al 1985a; Rho et al 1988). The positive relationship between protein content and cooking time was reported in white salted noodles (Oh et al 1985b; Hatcher et al 1999) and in Cantonese noodles (Moss et al 1987; Kruger et al 1994; Hatcher et al 1999). The effect of starch characteristics of wheat such as amylose content, starch swelling, and pasting properties on cooking time of white salted noodles has not been investigated, while desirable functional properties of starch for the textural quality of white salted noodles have been reported (Graybosch 1998; Yasui et al 1999; Abdel-Aal et al 2002).

The objectives of this study were to determine the optimum cooking time of noodles prepared from wheat flours of various protein and amylose contents, to explore the relationship between flour components and optimum cooking time of noodles, and to follow the changes in protein extractability, starch gelatinization, and pasting properties of cooked noodles for estimation of optimum cooking time.

MATERIALS AND METHODS

Materials

Two soft wheats, cvs. Stephens and Treasure, and three hard wheats, cvs. IDO377S, Klasic, and Winsome, were obtained from the Western Wheat Quality Lab (Pullman, WA). Stephens, Treasure, and Winsome were wild type wheats in granule bound starch synthase (GBSS), while IDO377S and Klasic were B single null in GBSS. Five advanced breeding lines of hard wheat, three *Wx-B1* and *Wx-D1* double null in GBSS, and two unnamed advanced breeding lines of waxy wheat lines were provided by Northwest Plant Breeding Company (Pullman, WA). BD double null hard wheats are referred to as BD1, BD2, and BD3. Waxy wheat lines are referred to as waxy1 and waxy2 in this study. Waxy and double null wheat lines were derived from Kanto107 / Bai-Huo // IDO377S and Kanto107 / Bai-Huo // Klasic, respectively. Wheat was milled to ≈60% extraction on a Bühler experimental mill. Two commercial wheat flours suitable for making udon noodles were obtained from Nissin Flour Milling Corp. (Tokyo, Japan) and are referred to as Com1 and Com2. One commercial noodle flour for making Korean dry noodles (Com3) was provided by W. J. Park, U.S. Wheat Associates, Seoul, South Korea, through the Wheat Marketing Center (Portland, OR).

Analytical Methods

Moisture, protein, and ash contents of wheat flour were determined according to Approved Methods 44-15A, 46-30, and 08-01

(AACC 2000). The determination of damaged starch content followed the procedure described by Gibson et al (1992), using an enzymatic assay kit (MegaZyme International Ireland Ltd., Bray, County Wicklow, Ireland). The determination of amylose content was performed according to the procedure described by Gibson et al (1997) using an enzymatic assay kit (Megazyme Pty., North Rocks, Australia). Pasting properties of flours were measured using a micro visco-amylograph (C. W. Brabender Instruments, Inc., South Hackensack, NJ). Flour (7.0 g, db) was suspended in 100 mL of distilled water and heated from 30 to 95°C at a ratio of 7.5°C/min, held at 95°C for 5 min, cooled to 50°C at a ratio of 5.0°C/min and then held at 50°C for 2 min under constant stirring (110 rpm). The viscosity was expressed in Brabender units (BU). Peak viscosity and breakdown viscosity were obtained from the pasting curve.

White Salted Noodle Preparation

White salted noodles were prepared with optimum water absorption to have a uniform, smooth, and nonsticky noodle dough. The optimum water absorption for making white salted noodles was determined based on appearance and sheeting and handling properties of the dough during the noodle-making process by experienced personnel, through trial and error. Commercial noodle flour, which required 35% absorption to make uniform, smooth, and nonsticky dough was used as a reference to be compared with other flours during the determination of optimum water absorption.

Flour (100 g, 14% mb) was mixed with sodium chloride solution and the concentration was adjusted to 2.0% with different water absorption of noodle dough in a pin mixer (National Mfg. Co., Lincoln, NE) for 4 min. Dough was passed through the rolls of a noodle machine (Ohtake Noodle Machine Mfg. Co., Tokyo, Japan) at 8 rpm and a 3-mm gap; dough was folded and put through the sheeting rolls. The folding and sheeting were repeated twice more. The dough sheet was rested for 1 hr and then put through the sheeting rolls three times at progressively decreasing roll gaps of 2.40, 1.85, and 1.30 mm. Immediately after the last sheeting, thickness of the dough sheet was measured by a micrometer dial thickness gauge (Peacock dial thickness gauge G, Ozaki Mfg. Co., Ozaki, Japan). The dough sheet was cut through no. 12 cutting rolls into strips ≈30 cm in length, with 0.3 × 0.2 cm cross-section.

Determination of Optimum Cooking Time of Noodles by Sensory Panel Test

The panel consisted of 10 graduate students and faculty members recruited from the Department of Food Science and Human Nutrition, Washington State University, Pullman, WA. Panelists were trained to determine the optimum cooking time of cooked noodles. Training was conducted in two sessions. In the first training session, panelists tasted noodles prepared from Com1 and cooked for 2–18 min at 2-min intervals. The cooking time count started immediately after putting noodles into boiling water. The panelists discussed the optimally cooked noodles and their characteristics, including surface smoothness, firmness, and absence of raw texture. In the second session, noodles prepared from Com1, Winsome, and waxy2 were cooked for 2–18 min at 2-min intervals and tasted by panelists for identification of the optimum cooking time. Consensus was obtained among panelists on the optimally cooked noodles or optimum cooking time . The panelists were again served the noodles cooked for the identified optimum cooking time and asked to remember the characteristics of the noodles.

For determining optimum cooking time by sensory panel test, noodles (80 g) were cooked for 2–18 min in boiling distilled water (2,000 mL) and then immediately rinsed with cold water for 30 sec. Because double null partial waxy flours exhibited relatively similar starch characteristics and amylograph characteristics of cooked noodles when flour protein content was comparable, and also because there was a shortage of wheat flour samples of BD1 and BD3, only BD2 noodles were subjected to sensory cooking time determination. Cooked noodles were served in a disposable plastic container coded with a random number within 5 min after rinsing. Panelists were instructed to define the cooked noodles using a scale of 1–3, where 1 = undercooked, 2 = optimally cooked, and 3 = overcooked. Each panelist was provided with a partitioned booth illuminated with white light at 22°C in the sensory lab. The sensory panel test was conducted in two-stage experiments. In the first stage, panelists tasted five sets of noodles cooked at 4-min intervals of 2–18 min. In the second stage, three sets of noodles cooked for +2, 0, or –2 min of the cooking time chosen from the first stage were served to panelists for estimation of more accurate cooking time. Cooking time determined in the second stage was averaged and used as optimum cooking time as determined by sensory panel test.

TABLE I
Composition and Pasting Properties of Wheat Flours and Properties of Noodle Dough[a]

				Pasting Properties		Noodle Dough	
Wheat Flour	**Ash (%)**	**Protein (%)**	**Amylose (%)**	**Peak Viscosity (BU)**	**Breakdown (BU)**	**Abs[b] (%)**	**Thickness (mm)**
Wild type[c]							
Stephens	0.47	12.2	27.3	347.5	46.5	34	1.7
Treasure	0.52	10.3	25.6	310.0	63.0	35	1.7
Winsome	0.36	14.3	27.3	532.0	132.0	34	1.8
B Null							
IDO377S	0.51	13.6	21.8	681.0	188.5	33	1.9
Klasic	0.46	14.9	20.9	681.0	211.5	31	2.0
BD Double Null							
BD1	0.43	10.2	17.3	717.0	303.0	36	1.8
BD2	0.43	15.1	15.9	796.0	329.0	33	2.0
BD3	0.37	15.2	15.7	789.5	342.5	33	2.0
Waxy							
Waxy1	0.45	19.3	2.2	717.5	336.5	38	1.9
Waxy2	0.42	17.1	3.4	743.5	361.0	38	1.8
Commercial							
Com1	0.36	10.1	22.0	730.5	221.5	35	1.7
Com2	0.37	10.2	23.8	557.0	140.5	35	1.7
Com3	0.42	10.8	23.7	579.0	172.5	35	1.7
LSD[d]	0.07	0.11	2.63	25.24	20.11		0.23

[a] Composition of flour expressed on a dry weight basis.
[b] Optimum water absorption of noodle dough.
[c] Wild type in granule bound starch synthase (GBSS); B null is *Wx-B1* null allele in GBSS; BD double null is *Wx-B1* and *Wx-D1* double null in GBSS; waxy wheat lacks all three GBSS; and three commercial noodle flours.
[d] Least significant difference ($P = 0.05$). Differences between two means exceeding this value are significant.

Changes in Protein Extractability, Pasting Properties, and Starch Gelatinization of Noodles During Cooking

Changes in protein and starch characteristics of noodles during cooking could provide useful information for the determination of the cooking time of noodles. Therefore, the proportion of acetic acid insoluble protein, starch gelatinization, and pasting properties ascertained using amylograph and differential scanning calorimetry (DSC) were determined in noodles cooked for different periods of time for estimation of optimum cooking time.

Noodles (20 g) were cooked for 2–18 min at 2-min intervals in boiling distilled water (500 mL) and then rinsed with cold water for 30 sec. Uncooked noodles and noodles cooked for 2–18 min at 2-min intervals were lyophilized and ground using a Udy Cyclone sample mill (Udy Co., Fort Collins, Co) fitted with a perforated screen with 0.25-mm round openings.

Protein extractability of noodles was determined according to the procedure of Dexter and Matsuo (1979) with modifications. Ground noodles (500 mg, db) were homogenized with 8 mL of 0.05*M* acetic acid for 30 sec. After being homogenized, acetic acid soluble protein was extracted in an ice bed for 1 hr with a brief vortex every 15 min and then centrifuged at 2,500 × *g* for 5 min. The pellet was again homogenized, repeated for extraction of protein, and centrifuged. The pellet was freeze-dried and weighed, and its protein content was determined. The quantity of protein in the pellet was divided by the protein quantity of raw noodles to determine the proportion of acetic acid insoluble protein.

Pasting properties of the cooked, lyophilized, and ground noodles were measured according to the procedure of pasting properties of flours using a micro visco-amylograph. Amylograph onset temperature obtained from amylograph pasting curves was used to estimate the cooking time of noodles. Gelatinization of starch in noodles prepared from Com1, Treasure, and waxy2 during cooking was determined using differential scanning calorimetry (DSC, Pyris1, Perkin-Elmer Co., Norwalk, CT). Three wheat flours were selected for thermal analyses of cooked noodles based on their starch characteristics. Cultivar Treasure represents wild type starch endosperm, waxy2 represents waxy type starch, and Com1 represents partial waxy type starch endosperm. Lyophilized noodles (10 mg) cooked for different periods of time and 20 μL of distilled water were placed in a stainless steel capsule, sealed, and allowed to equilibrate for 24 hr at 24°C. The samples were then heated in the calorimeter from 20 to 180°C at 10°C/min. A capsule with an inert material (aluminum oxide) and water (1:2 ratio) served as the reference. Onset temperature and peak temperature were determined for each endotherm. The transition enthalpy of gelatinization was calculated from the peak area and expressed as J/g of dry matter.

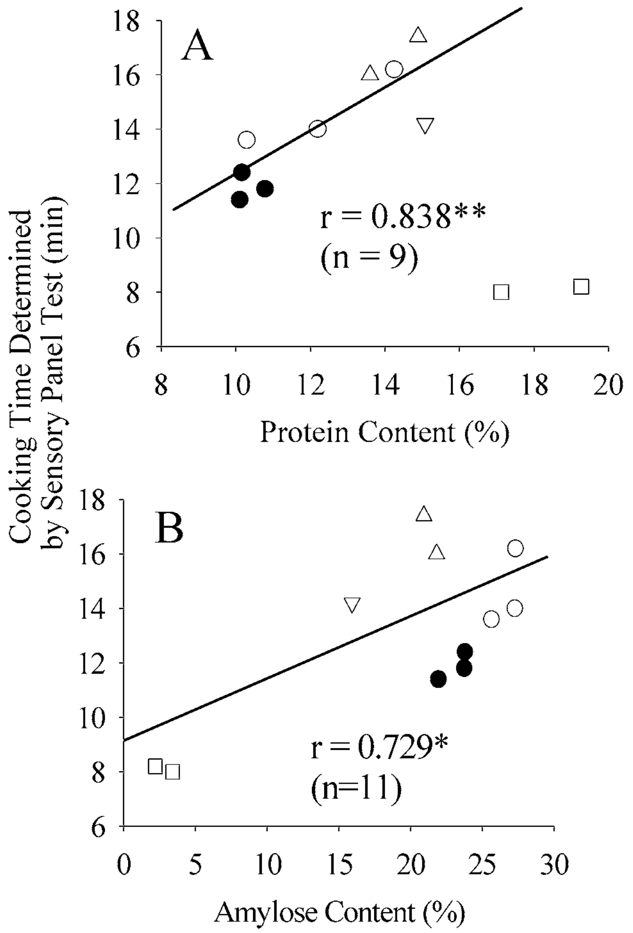

Fig. 1. Relationship between optimum cooking time determined by sensory panel test, protein content (**A**) and amylose content (**B**). Correlation coefficient between optimum cooking time and protein content for nine wheat flours excluding two waxy wheat flours. Wild type wheat cultivars (○); IDO377S and Klasic (△); BD2 (▽); waxy1 and 2 (□); commercial noodle flours (●).

Statistical Analysis

All tests, except sensory analysis, were run at least in duplicate in a completely randomized design. A randomized block design was applied to the sensory analysis of the optimum cooking time with the panelist as a blocking factor. Statistical analysis of data was performed by SAS software (SAS Institute, Cary, NC) using Fisher's least significant difference procedure, Pearson correlation coefficient and linear regressions. Differences were considered significant at $P < 0.05$, unless otherwise specified.

RESULTS AND DISCUSSION

Characteristics of Flour and Noodle Dough

Composition and pasting properties of wheat flours are summarized in Table I. Ash content of wheat flours was 0.36–0.51%.

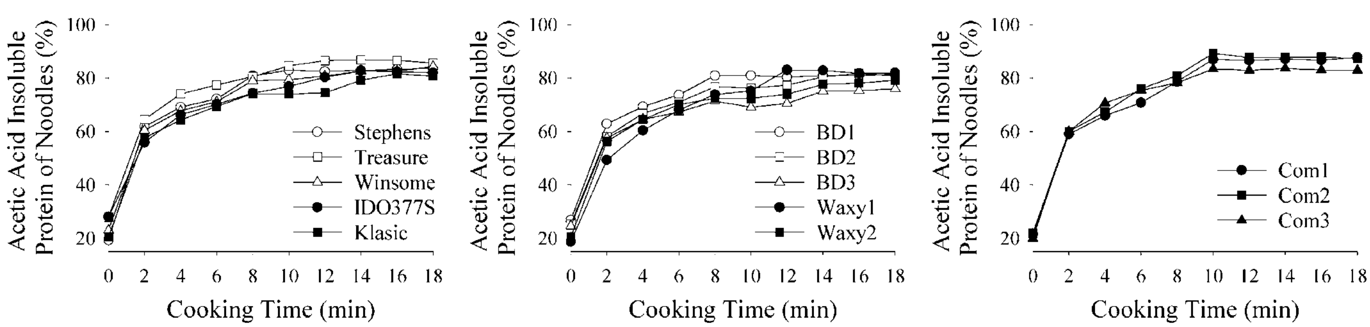

Fig. 2. Changes in proportion of acetic acid insoluble protein of noodles during cooking.

Flour protein content of hard wheat flours, including Winsome, single and double null, was >13.6%, except in BD1 (10.2%), while protein content of soft wheat flours, Stephens, and Treasure, was <12.2%. Waxy1 and waxy2 had extremely high protein content (19.3 and 17.1%, respectively). Protein content of the three commercial noodle flours was 10.1–10.8%. Commercial noodle flours showed similar amylose content to wheat flours of B null. Amylose content of BD1, BD2, and BD3 was <17.3%. Generally, reduction in the amylose content of starch contributed to higher peak and breakdown viscosity. Wheat flours of waxy and BD double null showed higher peak and breakdown viscosity than wheat flours of wild type. B null wheat flours also exhibited higher peak and breakdown viscosity than wheat flours of wild type. Com2 and Com3 exhibited lower peak and breakdown viscosity than Com1, despite similar amylose and protein content. The difference in pasting properties of commercial noodle flours could be due to other components than amylose content, such as particle size, damaged starch, or water retention capacity. Waxy wheat flours exhibited peak viscosity at 73°C, while peak viscosity of double null wheat flours was observed at >88°C. Waxy wheat flours showed lower peak viscosity than two out of three BD double null wheat flours, despite lower amylose content. The lower peak viscosity of waxy wheat flour might be due to quick disintegration of waxy starch granules under shear and hydrolysis of starch by α-amylase. Yasui et al (1999) also reported that waxy wheat flours showed lower peak viscosity than nonwaxy wheat flours, and verified that paste viscosity was markedly suppressed by α-amylase in waxy wheat flour.

Table I shows the optimum water absorption of noodle dough and thickness of the noodle dough sheet. Optimum water absorption of noodle dough was 31–38% in wheat flours. Thickness of the noodle dough sheet was 1.7–2.0 mm. Optimum water absorption of noodle dough generally decreased and thickness of the noodle dough sheet increased as protein content increased in wild type, B null, BD double null, and commercial noodle flours. Noodle dough from BD2 and BD3 exhibited higher water absorption (33%) compared with Klasic (31%), although these flours have similar protein content. Waxy wheat flours exhibited the highest optimum water absorption (38%), despite high protein content (>17%). Water absorption of noodle dough largely depended on protein content during mixing in wild type and B null wheat flours. The damaged starch content of waxy wheat flours had a range of 2.3–4.1%, much lower than that (10.4%) reported by Guo et al (2003), and was comparable to that of wild type wheat flours used in this study (3.1–6.0%) (Park and Baik 2002). Discrepancy in the damaged starch content of waxy wheat flours could be due to differences in wheat milling conditions as well as the assay used. Baik and Lee (2003) reported that water retention capacity in starch granules increased with the decrease of amylose content of starch. Guo et al (2003) reported much increased farinograph water absorption for a waxy wheat flour that had only moderately increased starch damage content. Accordingly, high water absorption of waxy wheat flours, which absorb and retain more water during dough mixing than nonwaxy wheat starches, could be mainly due to their starch properties.

Optimum Cooking Time of Noodles

Table II summarizes optimum cooking time of noodles as determined by sensory panel test. Optimum cooking time of noodles from commercial noodle flours was shorter (<12.4 min) than that of noodles prepared from wild type and B null wheat flours. Noodles prepared from wheat flours of low protein content (<10.8%), such as Treasure and commercial noodle flours, generally required shorter cooking time than noodles from flours of high protein content (>12.2%). Optimum cooking time of noodles from BD2 was 14.2 min. BD2 was higher in protein content (15.1%) than IDO377S, Klasic, and Winsome, but required shorter cooking time by 2 min than IDO377S, Klasic, and Winsome. Optimum cooking time of noodles from waxy1 and waxy2 was <8.2 min, despite their high protein content (>17.1%). These results indicate that in addition to protein content, starch amylose content significantly influences the cooking time of noodles. Sasaki et al (2000) reported that waxy wheat starch exhibited a sharp increase in paste viscosity at much lower temperature than wild type starches. Baik and Lee (2003) reported a positive correlation between amylose content of starch and amylograph peak temperature of starch. Accordingly, noodles prepared from waxy or partial waxy wheat flours can be cooked at lower temperatures

TABLE II
Optimum Cooking Time Determined by Sensory Panel Test and Cooking Times Estimated from Changes in the Proportion of Acetic Acid Insoluble Protein and Amylograph Onset Temperature of Cooked Noodles

Wheat Flour	Optimum Cooking Time[a] (min)	Acetic Acid Insoluble Protein		Micro Visco-Amylograph	
		CTP[b] (min)	Proportion[c] (%)	CTS[d] (min)	Onset Temperature[e] (°C)
Wild type					
Stephens	14.0	10	83.0	12	72.1
Treasure	13.6	10	84.6	12	72.3
Winsome	16.2	14	83.6	14	69.2
B Null					
IDO377S	16.0	12	80.4	14	64.1
Klasic	17.4	14	79.2	14	54.5
BD Double Null					
BD1	. . .	8	79.9	6	45.8
BD2	14.2	14	80.5	10	48.0
BD3	. . .	14	75.2	10	46.0
Waxy					
Waxy1	8.2	12	80.1	6	32.5
Waxy2	8.0	14	77.7	4	32.9
Commercial					
Com1	11.4	10	87.0	10	53.1
Com2	12.4	10	89.3	10	55.9
Com3	11.8	10	83.5	12	53.5
LSD[f]	0.94		2.24		2.37

[a] Optimum cooking time determined by sensory panel test.
[b] Cooking time exhibiting statistically insignificant increase in the proportion of acetic acid insoluble protein of noodles during cooking.
[c] Proportion of acetic acid insoluble protein of noodles during cooking at CTP.
[d] Cooking time exhibiting statistically insignificant decrease in micro visco-amylograph onset temperature of noodles during cooking.
[e] Micro visco-amylograph onset temperature of noodles during cooking at CTS.
[f] Least significant difference ($P = 0.05$). Differences between two means exceeding this value are significant.

than noodles prepared from wild type wheat flours. Moss et al (1987) reported that Cantonese noodles with low protein content exhibited considerable surface disruption during cooking because of the weaker protein network in cooked noodles. Surface disruption could result in more rapid water absorption of starch in Cantonese noodles. White salted noodles prepared from flour with low protein content may also cook faster than noodles made from wheat flours of high protein content.

Protein content positively correlated with optimum cooking time in wild type, B null, BD double null, and commercial noodle flours ($P < 0.01$). Waxy wheat flours were aberrant from other wheat flours in the plots of relationships between protein content of flour and optimum cooking time (Fig. 1A) because, despite their high protein content (>17.1%), waxy wheat flours showed the shortest optimum cooking time of noodles. Optimum cooking time of noodles positively correlated with amylose content of flour ($P < 0.05$, Fig. 1B). However, with the exclusion of waxy wheat flours, there was no significant relationship between optimum cooking time and starch amylose content, probably due to the compound effects of flour protein content in addition to starch amylose content on cooking time of noodles.

Changes in Acetic Acid Insoluble Protein of Noodles During Cooking

Figure 2 shows the changes in the proportion of acetic acid insoluble protein of noodles during cooking. The cooking time (CTP), at which there were no significant changes in the proportion of acetic acid insoluble protein, is summarized in Table II. The proportion of acetic acid insoluble protein of cooked noodles rapidly increased during the first 2 min of cooking and then leveled off. A statistically insignificant increase in the proportion of acetic acid insoluble protein of cooked noodles was observed at 10 min of cooking in Stephens, Treasure, and commercial noodle flours, all of which had lower protein content (<12.2%). CTP of noodles from B null and BD double null wheat flours was >12 min, except in BD1. CTP of noodles prepared from BD1 was 8 min, probably due to its low protein content. In waxy1 and waxy2, CTP was 12 and 14 min, respectively. CTP of noodles positively correlated with protein content of flour ($r = 0.765$, $P < 0.01$).

Wild type and commercial wheat flours exhibited a higher proportion of acetic acid insoluble protein of cooked noodles (>83.0%) than waxy, B null and BD double null wheat flours. There were no differences in the proportion of acetic acid insoluble protein of cooked noodles between waxy, B null, and BD double null wheat flours.

Thermal Properties of Noodles During Cooking

Table III shows DSC thermal properties of noodles cooked for different periods of time. Uncooked noodles prepared from waxy2 showed higher onset and peak temperature of gelatinization and higher gelatinization enthalpy of starch than those of Com1 and Treasure. Yasui et al (1996) and Fujita et al (1998) also reported that waxy wheat starch showed higher peak temperature and enthalpy than nonwaxy wheat starches. Gelatinization enthalpy of starch in raw noodles was higher in Com1 than in Treasure because Com1 had a higher proportion of amylopectin in starch. In waxy2 flour, gelatinization enthalpy of starch in noodles disappeared after 2 min of cooking. Gelatinization enthalpy of starch disappeared after 6 and 10 min in Com1 and Treasure, respectively. Onset and peak temperature of starch gelatinization in noodles increased, and gelatinization enthalpy decreased with increased cooking time. Based on the gelatinization properties of starch in noodles, starches in cooked noodles of Com1 and Treasure were fully gelatinized after 6 and 10 min of cooking, respectively, while starch in noodles of waxy2 was fully gelatinized in 2 min of cooking. The shorter cooking time of noodles for starch gelatinization in waxy2 as well as Com1, compared with wild type wheat cultivar Treasure, was probably due to their reduced starch amylose content.

Pasting Properties of Noodles Cooked for Different Periods of Time

Figure 3 shows amylograph onset temperature of noodles cooked for different periods of time. Amylograph onset temperature of uncooked noodles was ≈67°C, similar to that of wheat flours. With 2 min of cooking, amylograph onset temperature of noodles rapidly increased, and then decreased with further cooking in wild type, B null, and BD double null wheat flours. Amylograph onset

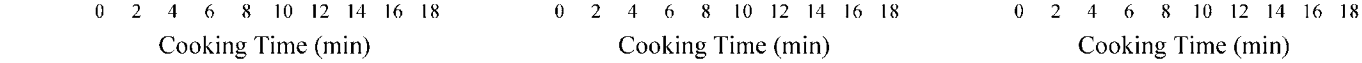

Fig. 3. Changes in amylograph onset temperature of noodles during cooking.

TABLE III
Differential Scanning Calorimetry Thermal Properties of Noodles Cooked for Different Times[a]

Cooking Time (min)	Waxy2			Treasure			Com1		
	T_o (°C)	T_p (°C)	ΔH (J/g)	T_o (°C)	T_p (°C)	ΔH (J/g)	T_o (°C)	T_p (°C)	ΔH (J/g)
0	67.4	74.2	9.0	60.3b[b]	66.8b	6.3a	60.3b	67.1b	7.2a
2	nd[c]	nd	nd	77.5a	82.3a	0.5b	77.8a	82.1a	0.1b
4	nd	nd	nd	80.9a	84.6a	0.2b	76.1a	82.1a	0.4b
6	nd	nd	nd	80.5a	86.4a	0.1b	nd	nd	nd
8	nd	nd	nd	81.0a	86.3a	0.1b	nd	nd	nd
10	nd	nd	nd	nd	nd	nd	nd	nd	nd

[a] T_o, onset temperature of gelatinization; T_p, peak temperature of gelatinization; ΔH = gelatinization enthalpy.
[b] Values followed by same letters in the column are not significantly different at $P < 0.05$.
[c] Not detected.

temperature of noodles prepared from wild type and B null wheat flours was 80°C at 2 min of cooking, then slowly decreased. Amylograph onset temperature of noodles prepared from BD double null wheat flours and cooked for 2 min was 72–77°C, and rapidly decreased with further cooking up to 8 min. Noodles prepared from waxy wheat flours showed different patterns of amylograph onset temperature of noodles from other flours. Amylograph onset temperature of waxy wheat flours rapidly decreased for the first 6 min of cooking without showing initial increases. Overall, noodles prepared from waxy and BD double null wheat flours exhibited lower amylograph onset temperature.

Table II shows the cooking times (CTS) at which no significant changes in the amylograph onset temperature of noodles occurred as cooking time increased. CTS of noodles was 12 min in noodles prepared from Stephens and Treasure and 14 min in noodles prepared from Winsome, IDO377S, and Klasic. CTS of noodles was 10 min in Com1 and Com2, and 12 min in Com3. CTS was 10 min in noodles prepared from BD2 and BD3, and 6 min in noodles of BD1. The much lower CTS of BD1 compared with BD2 and BD3 was probably due to its lower protein content by ≈5% than that of BD2 and BD3 (Table I). In noodles prepared from waxy1 and waxy2, CTS was 6 and 4 min, respectively. CTS of noodles positively correlated with amylose content of flours ($r = 0.816$, $P < 0.001$), but showed no significant relationship with protein content of flours.

Table II also shows amylograph onset temperature of noodles cooked for CTS. Amylograph onset temperature of cooked noodles was >69.2°C in wild type wheat flours, 64.1°C in IDO377S and 54.5°C in Klasic. Commercial noodle flours exhibited similar amylograph onset temperature of noodles to Klasic. Amylograph onset temperature of noodles was <48.0°C in BD double null wheat flours. Amylograph onset temperature of cooked noodles in waxy1 and waxy2 was 32.5–32.9°C. Amylograph onset temperature of cooked noodles at CTS showed positive correlation with amylose content ($r = 0.919$, $P < 0.001$), but negatively correlated with protein content ($r = -0.569$, $P < 0.05$).

Relationships Between Cooking Time Determined by Sensory Test and Changes in Characteristics of Noodles During Cooking

There was no significant relationship between optimum cooking time and CTP estimated from the changes in the proportion of acetic acid insoluble protein of noodles during cooking. Noodles prepared from waxy wheat flours were aberrant from other noodles in the plots of relationships between optimum cooking time and CTP. Correlation coefficients increased from $r = 0.194$ ($P > 0.05$) to $r = 0.793$ ($P < 0.05$) between optimum cooking time and CTP, and from $r = -0.116$ ($P > 0.05$) to $r = -0.770$ ($P < 0.05$) between optimum cooking time and the proportion of acetic acid insoluble protein at CTP by omitting noodles prepared from waxy wheat flours.

Optimum cooking time positively correlated with amylograph onset temperature of cooked noodles at CTS ($r = 0.734$, $P < 0.05$), as well as CTS ($r = 0.924$, $P < 0.001$). The changes of amylograph onset temperature of cooked noodles may be more useful and accurate for the prediction of cooking time of noodles than protein extractability of cooked noodles. The regression equation for the prediction of cooking time of noodles using amylograph onset temperature of cooked noodles is: Estimated cooking time = 0.869 CTS + 3.698 ($r^2 = 0.855$, $P < 0.001$).

Estimated cooking time from the above equation correlated with optimum cooking time of the sensory panel test ($r = 0.924$, $P < 0.001$) (Fig. 4). The prediction model estimated the optimum cooking time as determined by sensory panel test with a standard error of estimation of 1.23.

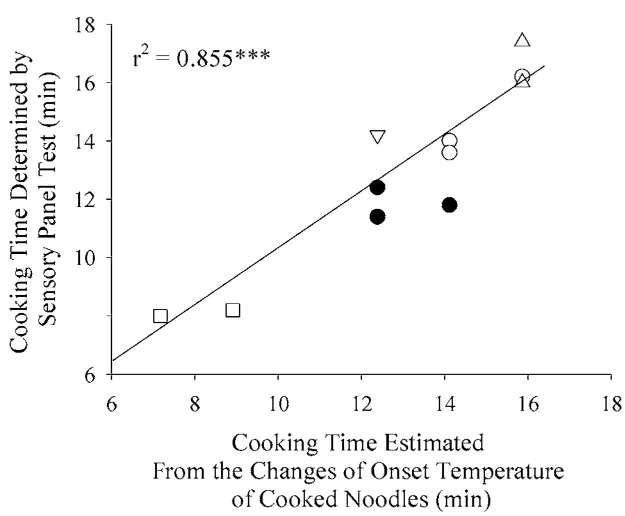

Fig. 4. Relationship between cooking time determined by sensory panel test and cooking time estimated from amylograph onset temperature of cooked noodles. Wild type wheat cultivars (○); IDO377S and Klasic (△); BD2 (▽); waxy1 and 2 (□); commercial noodle flours (●).

CONCLUSIONS

Optimum cooking time of white salted noodles varied widely, from 8.0 min to 17.4 min, in wheat flours of diverse protein and starch amylose content. Cooking time of white salted noodles was significantly influenced by and correlated with protein content of flours, with the exception of waxy wheat flours. Cooking time of noodles prepared from wheat flours with high protein content was longer than for noodles from low protein content with similar amylose content. White salted noodles prepared from waxy, double null partial waxy and commercial wheat flours of reduced starch amylose content generally required shorter cooking time than those prepared from wheat flours of wild type in starch amylose content. In addition to a sensory test or the method of squeezing noodle strands and observing the disappearance of the white core during cooking, the optimum cooking time of noodles can be estimated objectively by monitoring the changes in amylograph onset temperature of noodles during cooking.

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