Effects of Flour Particle Size and Starch Damage on Processing and Quality of White Salted Noodles

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ABSTRACT

Several reduction grinding conditions were used on a Canadian Western Red Spring (CWRS) farina to yield flours of comparable protein content within three specific particle size ranges (132–193, 110–132, 85–110 µm) at three starch damage levels (3.0, 3.9, 7.0 Megazyme units). White salted noodles (1% w/w NaCl) were initially processed at a fixed absorption (32%). Dynamic oscillatory and large deformation creep measurements indicated that doughs with lower starch damage, thick or thin, exhibited lower G' (storage modulus), higher tan δ (G''[loss modulus]/G') values, and greater maximum strain during creep than doughs with higher starch damage. There were no clear trends between work input during sheeting and either starch damage or particle size. Instrumental texture analysis of raw noodles showed no significant differences due to either starch damage or flour particle size. Flours with fine particle size gave cooked noodles with the best textural attributes, whereas starch damage exhibited no consistent relationship with cooked noodle texture. Cooking loss was greatest in samples with highest starch damage and coarsest particle size; water uptake was inversely related to starch damage and particle size. Experiments were repeated at adjusted water absorptions (32–36.5%) for fine and coarse flours with highest and lowest starch damage. Differences in raw noodle dough rheological properties were largely eliminated, confirming that differences noted at constant absorption were primarily due to flour water absorption. Work input during sheeting was inversely related to starch damage and was higher for fine particle size. Cooking losses were highest for higher starch damage and fine particle size. Water uptake was highest for fine particle size, but in contrast to cooking loss, was higher at lower starch damage. Textural parameters indicated superior cooking quality when particle size was finer and starch damage was lower. Flour particle size and starch damage (as indicated by water absorption) are both primary quality determinants of white salted noodle properties and, to some extent, exert their influence independently.

Major discriminating criteria for consumers of Asian noodles are a combination of color and brightness of the product, with an acceptable mouthfeel to the cooked noodle. Extensive study has been undertaken to determine biochemical factors relevant to noodle quality (Oh et al 1983, 1985a,b; Miskelly 1984; Miskelly and Moss 1985; Moss et al 1986; Toyokawa et al 1989a,b; Kruger et al 1992, 1994, 1995) with minimal attention being paid to milling techniques and the effect on the flour characteristics and subsequent product performance.

Water absorption in noodle production has a significant effect on noodle L^*,a^*, and b^* color characteristics (Hatcher et al 1999). Methods for determining optimum water absorption (Oh et al 1986; Rogers and Hoseney 1987) have met with mixed success. At present, the elusive optimum still depends primarily on operator experience and handfeel to gauge proper dough consistency. Flour particle size and starch damage are presumed to play a major function in optimum water absorption for noodle doughs. Insufficient water causes difficulty in achieving a cohesive dough, while too much results in handling problems during mixing, and undesirable noodle stretching and thinning during processing. Edwards et al (1996), using a dynamic rheometer, showed that water absorption levels significantly influenced the elastic modulus (G') of raw noodle dough, while Baik et al (1995) suggested that detrimental color changes are a function of water activity in the incompletely developed noodle dough. Investigation of particle size and starch damage on noodle quality has been confined to work conducted by Oh et al (1986), but the influence was only inferred, as they used a series of flours from different wheat classes of varying protein levels to evaluate the influence of these factors.

The objective of this study was to examine the effects of particle size and starch damage on noodle dough properties and noodle quality through the use of high quality patent flours with equivalent protein content derived from the same wheat. A second objective was to determine whether adjusting the consistency of noodle dough by altering water absorption levels could overcome the effect of starch damage and particle size on noodle processing and end product quality.

MATERIALS AND METHODS

Flour

Commercially grown Canadian Western Red Spring (CWRS) wheat graded No. 1 was milled on the Grain Research Laboratory (GRL) pilot mill to produce farina following the mill flow described by Fajardo et al (1995). Coarse middlings were collected as overs of 132-µm sieves after first, second, and third breaks, and from first and second purifiers, to give a farina of ≈45% extraction on a clean wheat basis. Farina was rebolted over a 193-µm sieve to remove residual flour and fine middlings, and then repurified on a laboratory-scale purifier (Black 1966) to remove bran-rich particles.

To produce flours with varying degrees of starch damage, farina was reduced on a GRL 25-cm research mill (Black et al 1980) using either fluted or frosted reduction rolls at various roll differentials and roll gaps. Flour with low starch damage was produced using fluted rolls with 12.6 corrugations/cm (32/in.) set dull to dull at a roll gap of 0.076 mm (0.003 in.) and a differential of 1.77:1. Flours with medium and high starch damage were produced using smooth frosted rolls with a differential of 2:1. By adjusting the roll gap to 0.051 mm (0.002 in.) and 0.025 mm (0.001 in.), medium and high degrees of starch damage were induced, respectively.

Following each of the three grinding treatments, ground farina was separated into particle size ranges by sifting on a box sifter equipped with sieves of 193, 132, 110, and 85 µm aperture. Overs of the 193-µm sieve and throughs of the 85-µm sieves were discarded, yielding a total of nine flours (three starch damage levels by three particle size ranges). Flour particle size distribution for each of the flours was further defined using a series of five sieves on a Ro-tap shaker (W.S. Tyler Co, St. Catherines, ON).

Analytical Methods

Protein content (%N × 5.7) was determined by combustion nitrogen analysis (CNA) using a CNA analyzer (model FP-248 Dumas, Leco Corp., St. Joseph, MI) calibrated with EDTA. Ash content, starch damage, and farinograph absorption were determined by Approved Methods 08-01, 76-31, and 54-20, respectively (AACC 2000). Mixograph tests were conducted using a 2-g direct drive mixo-

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graph (National Manufacturing Division, TMCO, Lincoln, NE) at farinograph absorption, with data analyses performed using Mixsmart software provided with the instrument for mid-line analysis. Flour grade color was determined by a flour color grader (Series IV, Satake UK, Stockport, UK) using Flour Testing Panel Method No. 007/4 (FMBRA 1991) and expressed in Satake International units (SIU), in which the lower the value the brighter the flour.

Noodle Preparation

Noodles were prepared using the method previously described by Kruger et al (1994). Salt (NaCl) dissolved in water was added to 200 g of flour to yield a 1% salt (w/w) dough. The water absorption value initially used was 32% (14% mb). Subsequent testing was conducted at adjusted water absorption levels to yield constant dough consistency. The mixture was sheeted on a laboratory noodle machine (Ohtake, Tokyo, Japan) with an initial gap setting of 3.0 mm. Two passes were made at this setting with the noodle sheet folded between passes to ensure homogeneity. A 2.5-cm diameter circular piece was cut from the 3.0-mm thick sheet for immediate rheological analysis (subsequently referred to as the thick sample). A 25-cm long section was cut from the noodle sheet and subjected to seven reduction passes (3.0 to 1.1 mm) with work input requirements measured and expressed on a per gram of dough basis (Kruger et al 1994). Upon completion of the final pass, the noodle sheet length and thickness were recorded and a second 2.5-cm circular piece was cut out for rheological analysis (subsequently referred to as the thin sample). The noodle sheet was divided for further testing; one portion was cut into noodles and underwent immediate cooking and subsequent textural analysis and the remaining portion was retained as a sheet for time-dependent color measurements.

Determination of Adjusted Absorption Level

Estimation of adjusted water absorption level is a method developed by GRL to objectively determine equivalent handfeel of the crumbly dough used in noodle preparation. A 35-g mixograph (National Mfg.) was used to prepare the dough crumb. Flour was initially mixed dry for 30 sec, the salt solution was added over a 30-sec period, and the dough was mixed for another 12 min at 140 rpm. The crumb mixture was covered and allowed to stand in the bowl for 10 min before being remixed for an additional 12 min. After the final mixing, the crumbly mixture was placed on a 3-mm aperture sieve and gently shaken for 3 min. The weight of material passing through the sieve and of that retained on the sieve was recorded. Adjusted absorption was considered to be when the weight of material retained was equal to the weight of crumbs passing through the sieve.

TABLE I
Particle Size Distribution Range (%) of Flours with Low, Medium, and High Starch Damage

Collected Flours	>132 µm	>110 µm	>85 µm
Held on:			
149 µm	16.2–25.5	0.07–0.10	0.02–0.08
125 µm	46.9–59.8	9.1–42.0	0.07–0.3
104 µm	11.6–18.4	40.7–50.5	2.6–20.3
90 µm	1.9–5.4	14.3–31.3	31.3–49.8
74 µm	0.4–1.7	2.6–9.6	4.9–14.3
Pan	0.3–1.5	1.6–4.3	5.4–17.0

Rheological Testing of Raw Noodles

A rheometer (model SR 500, Rheometrics Scientific, Piscataway, NJ) was used for both oscillatory and large deformation creep tests. The rheometer was equipped with 25-mm serrated upper and lower parallel plates that were maintained at 25°C.

Disks were cut from noodle sheets with a 25-mm punch, loaded into the rheometer, and the sample edges were coated with mineral oil (Sigma, St. Louis MO) to prevent drying. Stress sweeps of thick-sheeted material conducted at 1 Hz indicated that applied stress of 630 Pa was within the linear viscoelastic region. Stress sweeps of thin sheeted material exhibited a linear viscoelastic region in the area of 1,350 Pa. Subsequent frequency sweeps were conducted at 0.5–8 Hz using 630 Pa and 1,350 Pa applied stress for

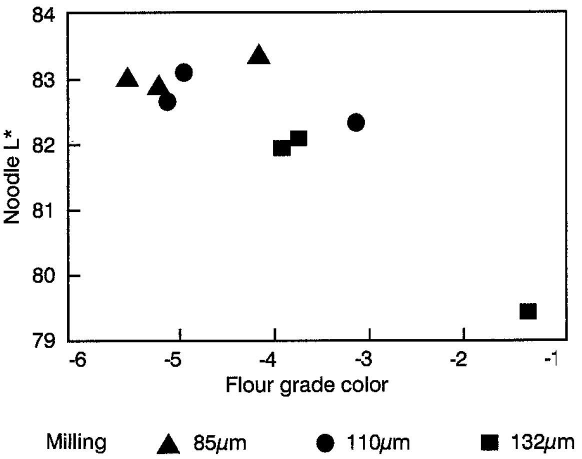


Fig. 1. Influence of flour color on brightness of raw noodle (32% water absorption) after 2 hr.

TABLE II
Characterization of Single Source Canadian Western Red Spring (CWRS) Flour (14% mb) Samples

					Micromixograph Results at Farinograph Absorption				
Particle Size (µm)	Starch Damage[a]	Flour Grade Color (SIU)[b]	Flour Protein (%)	Flour Ash (%)	Absorption (%)	Mixing Time (min)	PDR Units[c]	BWPR Units[d]	WI Units[e]
Low									
>132	3.0	–3.4	11.4	0.38	59.0	3.4	54.7	30.4	124.6
>110	2.9	–4.6	11.3	0.32	58.3	3.4	57.5	30.8	139.4
>85	3.1	–4.9	11.5	0.32	58.6	3.3	58.5	33.8	128.1
Medium									
>132	3.8	–3.2	11.4	0.40	60.0	3.4	55.1	28.2	132.5
>110	3.9	–4.8	11.3	0.33	58.4	3.4	57.7	31.4	136.4
>85	4.0	–5.3	11.5	0.31	59.5	3.2	59.3	33.6	126.3
High									
>132	6.3	–0.4	11.6	0.54	65.4	3.8	51.4	24.0	131.0
>110	7.4	–2.5	11.5	0.42	66.2	4.0	51.8	26.9	143.3
>85	7.4	–3.7	11.5	0.35	66.0	4.5	52.9	27.7	164.4

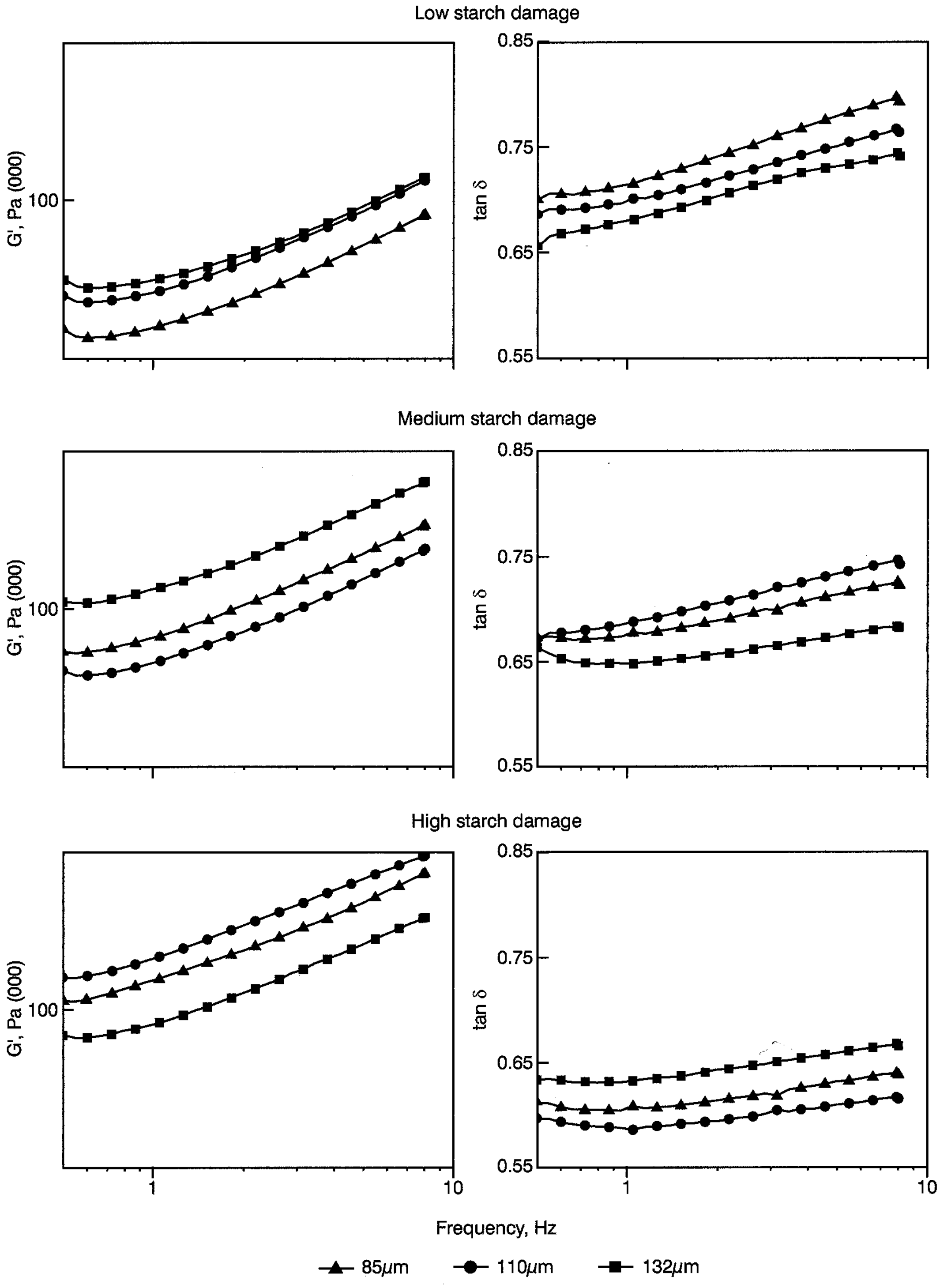
[a] Megazyme starch damage units.
[b] Satake International units.
[c] Peak dough resistance.
[d] Bandwidth at peak dough resistance.
[e] Work input to time of peak dough resistance.

thick and thin sheets, respectively. Data obtained were storage modulus (G'), shear loss modulus (G''), complex modulus (G^*) and tan δ (G''/G'), although only storage modulus and tan δ are discussed.

Large deformation creep tests were conducted using 1,500 Pa applied stress for 300 sec immediately after frequency sweeps. Stress was applied at a level that exceeded the linear viscoelastic range in an attempt to simulate large deformation conditions exerted during noodle sheeting. Maximum strain attained under large deformation creep conditions provides information on both dough strength and extensibility (Edwards et al 1999).

Noodle Color and Textural Analyses

A spectrocolorimeter (Labscan II, HunterLab, Reston, VA) equipped with a D65 illuminant using the L^*, a^*, and b^* color scale (CIE 1986) was used to measure raw noodle color. The noodle sheet was folded into three layers, placed on the spectrocolorimeter opening, and enclosed within a blackened container to remove ambient light. Measurements were made in triplicate at each of two locations on the noodle sheet surface for each sample. Between measurements, the raw noodle sheet was stored in a sealed plastic bag at 25°C over the 24-hr examination period.


Low starch damage

Medium starch damage

High starch damage

Fig. 2. Dynamic rheometry frequency plots of elastic modulus (G') and tan δ for raw noodles 1 hr after preparation from flours of different starch damage and particle size.

Optimum cooking times for the samples were 10 ± 0.5 min using the squeeze test to visually determine the loss of the uncooked core material. All samples were cooked for 10 min. Noodles were cooked, cooled for 1 min under running distilled water thermostated at 20°C, drained, stored for 10 min at 25°C, and immediately analyzed as described by Kruger et al (1994).

Textural measurements were made on raw and cooked noodles using an Instron universal testing machine (IUTM model 4201, Instron, Canton, MA) with fixtures and procedures similar to those described by Oh et al (1983, 1985a) and Kruger et al (1994).

EXPERIMENTAL DESIGN

Analytical testing was conducted in duplicate, with the exception of single farinograph analyses. Noodles were processed in duplicate following a randomized design. Rheological tests were conducted on two disks cut from each set of noodle doughs. Cooking tests were made on five sets of three noodle strands for each noodle dough replicate. All statistical analyses were made using the Statistical Analysis System (v 6.11, SAS Institute, Cary, NC). Significance was defined at 5% ($P < 0.05$).

RESULTS

Flour Characteristics

Measurement of flour particle size distribution range (Table I) confirmed the expected shift in relative distribution patterns for each of the coarse (132–193 µm), intermediate (110–132 µm), and fine (85–110 µm) flours, with the majority of particles falling within the range expected regardless of degree of starch damage. Differences in milling procedure used to produce varying degrees of starch damage and particle size of the flours did not affect protein content (Table II). The coarsest fractions and the highest starch damage levels exhibited poorest color and highest ash. This is related to flattening of bran particles, which is most pronounced at high roll pressure (small gap), resulting in enrichment of coarse flour with bran particles.

Farinograph data were difficult to interpret. There was a general trend of increasing absorption with increasing starch damage, however, particle size did not demonstrate any clear relationship to absorption. Stabilities (not shown), in many cases, were very long (>30 min), which was not surprising as high quality patent flours from CWRS wheat tend to exhibit long stabilities (Preston and Dexter 1994). Some flours appeared to have a secondary development peak (data not shown) which was possibly the result of moisture redistribution. To gain further information on dough mixing characteristics under more rigorous mixing conditions, the 2-g mixograph was used at farinograph absorption (Table II). Mixing time to peak, peak dough resistance, bandwidth at peak, and work input to peak were only moderately affected and generally unrelated to the degree of starch damage or particle size at low and medium levels of starch damage. Regardless of the particle size, the high starch damage flours exhibited longer mixing times, lower peak resistance, and narrower band width. Lower peak dough resistance suggests that the farinograph slightly overestimated water absorption requirements of the high starch damage flours.

TABLE III
Dynamic and Creep Measurements of Thick Dough (taken at 20 min)

Starch Damage	Particle Size (µm)	*G′* (kPa)	Tanδ	Creep (%)
Low	132	166c–e	0.53a	15.3ab
	110	156de	0.53a	14.7a–c
	85	133e	0.54a	19.4a
Medium	132	224ab	0.49bc	10.3c–e
	110	189b–d	0.51ab	13.1b–d
	85	160de	0.53a	15.0ab
High	132	234ab	0.48cd	9.3de
	110	267a	0.47d	7.4e
	85	263a	0.48cd	7.7e

[a] Values followed by the same letter are not significantly different ($P < 0.05$).

Raw Noodle Color

Flour particle size appeared to affect raw white salted noodle color, until flour grade color and ash content were considered. The fine particle size flours tended to yield the brightest noodle dough regardless of starch damage level, while the coarse flours yielded the dullest (Fig. 1). However, flour grade color demonstrated the same trend and was strongly correlated with L^* (r >–0.88) and a^* (r >0.83), which would indicate that noodle dough brightness and redness were influenced by flour refinement rather than particle size. As discussed previously, flour ash content tended to increase and grade color tended to decrease with increasing particle size and with increasing level of starch damage (Table II). The trends remained consistent after 24 hr. Noodle dough yellowness (b^*) was not affected by degree of refinement, starch damage or particle size, but increased over time due to continuing oxidation of flavanoids.

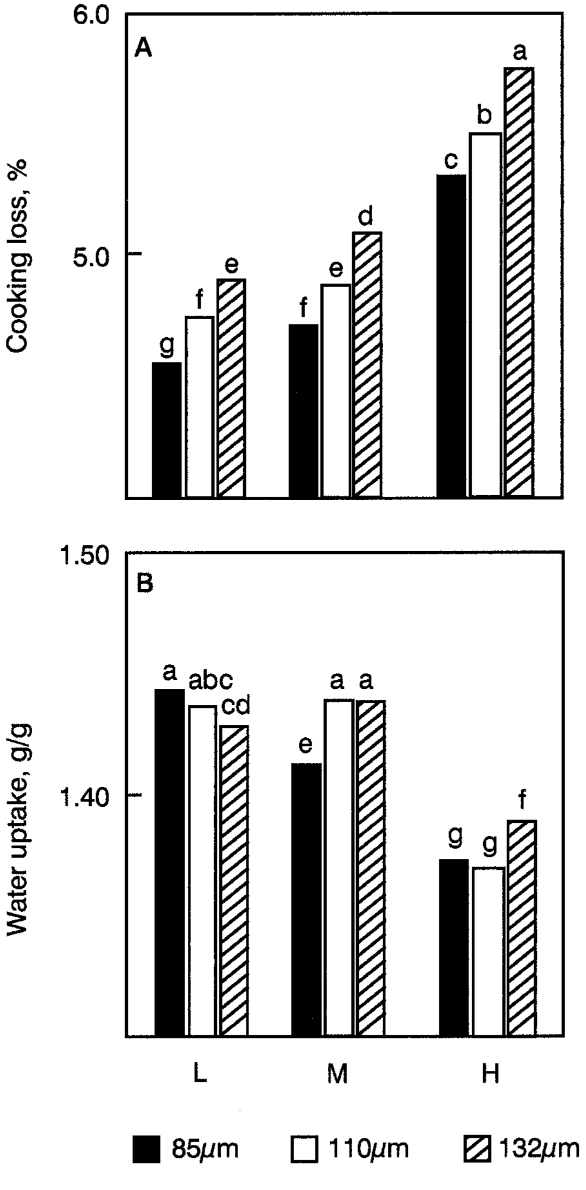


Fig. 3. Influence of starch damage and particle size on processing characteristics of noodles prepared at 32% water absorption. **A,** cooking loss; **B,** water uptake. L = low starch damage; M = moderate starch damage; and H = high starch damage.

Raw Noodle Rheometry

Dynamic rheometry of both thick and thin raw noodle sheets indicated that starch damage had a significant influence on *G′* whereas particle size had very little influence (Table III). A consistent trend seen throughout testing was that *G′* increased with increasing degree of starch damage, irrespective of particle size. In other words, noodle dough prepared from flour with higher starch damage at a constant absorption resulted in stiffer doughs than did flour with low starch damage. Resting of these doughs for up to 20 min resulted in only a minor decrease in response while maintaining the same overall trends. Examples of frequency sweeps (Fig. 2) show data on thin noodle dough captured 60 min after processing. Only one time is presented as consistent trends were observed across time.

Tan δ values (ratio of the viscous to elastic moduli, *G″*/*G′*) for both thick and thin raw noodle sheets at different time intervals also were influenced primarily by the level of starch damage (Fig. 2). Tan δ values for doughs from flours with high starch damage were significantly lower than for low and medium starch damage, indicating that high starch damage resulted in stiffer dough. Creep measurements of the thick noodle sheet also indicated no significant effect due to particle size, but a consistent, significant influence of starch damage. The fine low starch damage thick dough exhibited a maximum strain of 15.8% compared with 7.7% for the corresponding high starch damage dough at 0 hr (data not shown), and increased further for the fine low starch damage dough after 20 min of rest (Table III). The increase in maximum strain over time for thick dough

TABLE IV
Texture Analysis of Raw Noodles Prepared at 32% Absorption

Size (μm)	Starch Damage	MCS[a] (g/mm^2) 0 hr	MCS[a] 1 hr	MCS[a] 2 hr	RTC[b] (%) 0 hr	RTC[b] 1 hr	RTC[b] 2 hr	REC[c] (%) 0 hr	REC[c] 1 hr	REC[c] 2 hr
>132	Low	34.26c[d]	32.52a	32.47ab	77.93bc	80.01a–c	81.48ab	26.64b–e	28.06ab	29.77a–d
>110	Low	35.50a–c	32.19a	35.57ab	76.94cd	77.74c–e	78.29cd	24.42de	24.92bc	26.22d
>85	Low	36.34a–c	32.62a	34.22ab	74.88e	77.91cd	79.36b–d	22.78e	24.84bc	26.50cd
>132	Medium	38.38a–c	35.75a	37.73a	80.01a	82.18a	82.54a	32.27a	31.14a	31.33ab
>110	Medium	41.13a	37.48a	34.27ab	78.63a–c	80.96ab	80.82a–c	30.44a–c	31.62a	32.99a
>85	Medium	40.81ab	36.15a	35.29ab	79.84a	80.22a–c	80.65a–c	31.96a	28.56ab	32.20ab
>132	High	32.85c	31.34	31.31b	78.55a–c	81.07ab	81.03a–c	27.72a–e	31.40a	32.66a
>110	High	35.58a–c	32.14a	34.31ab	79.85a	79.63bc	82.26a	31.08ab	29.33ab	31.21ab
>85	High	34.69a–c	32.66a	31.91ab	77.53b–d	79.52bc	80.94a–c	28.31a–d	29.07ab	30.59a–c

[a] Maximum cutting stress.
[b] Resistance to compression.
[c] Recovery.
[d] Values followed by the same letter are not significantly different ($P < 0.05$).

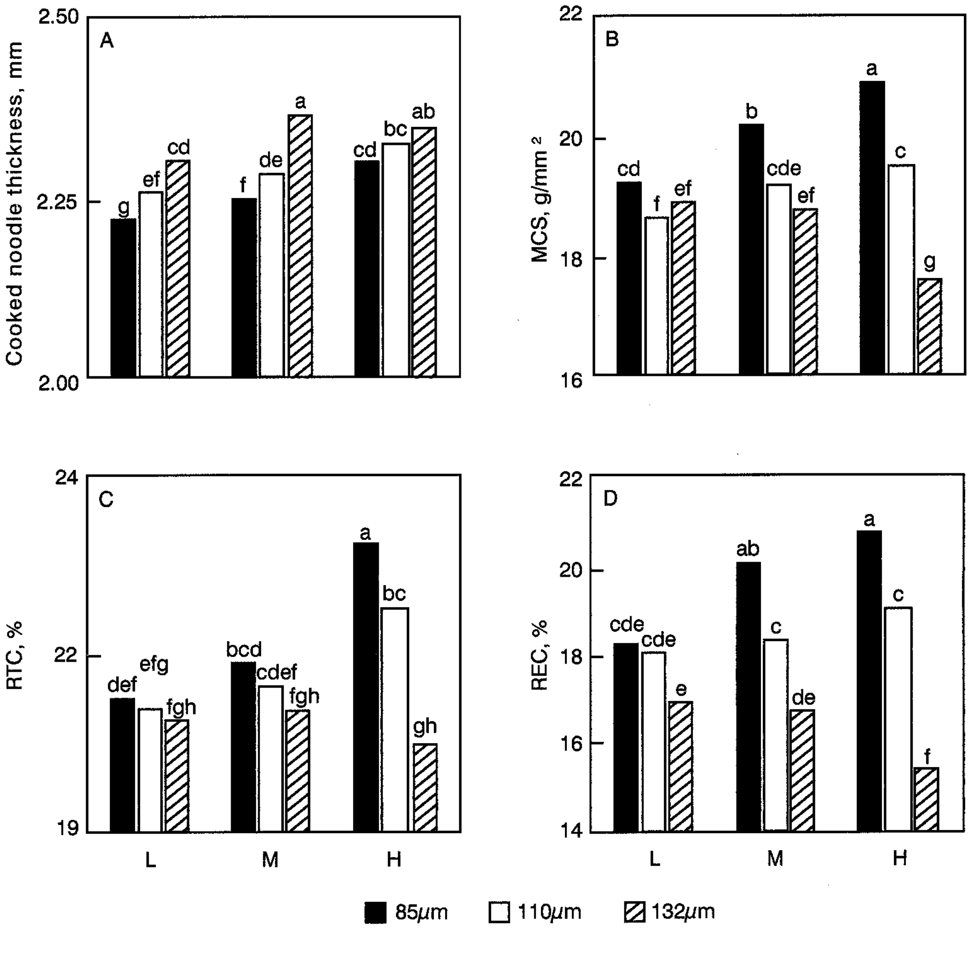


Fig. 4. Influence of particle size and starch damage on cooked noodles prepared at 32% absorption. **A,** thickness; **B,** maximum cutting stress; **C,** resistance to compression; **D,** recovery. L = low starch damage; M = moderate starch damage; and H = high starch damage.

from fine low starch damage flour was probably due to redistribution of water that was not tightly held by lightly damaged granules. Similar trends were seen for thin doughs measured at 10 min, with the high starch damage dough remaining much stiffer and less extensible than the other flour doughs. Additional creep measurements at 60 and 120 min maintained the same trend where doughs with low and medium starch damage continued to be more extensible than doughs prepared from flours with high levels of starch damage (Table III). Dough prepared from flour with the finest particle size exhibited the greatest extensibility under all conditions.

Greater extensibility and higher tan δ of dough from flour with lower starch damage may be reflective of better hydration of the protein matrix. Increased competition for water with increasing degrees of starch damage would result in declining protein hydration and plasiticization leading to stiffer, less extensible dough.

Raw Noodle Texture

Texture analyses of fully processed raw noodle sheets were conducted at 0 (immediately after production), 1 and 2 hr (Table IV). No significant starch damage or particle size effects were detected on the textural attributes of the noodles.

Aging of the raw noodles displayed a significant effect ($P < 0.0001$) on maximum cutting stress (MCS) and resistance to compression (RTC) values. The most noticable decreases in MCS values were detected between readings at 0 and 1 hr, whereas significant increases in RTC were observed over the same time period. Changes from 1 to 2 hr were minimal, suggesting that the dough was fully relaxed and water was redistributed within that time period. Both raw noodle RTC and recovery (REC) at 2 hr were positively correlated with G' ($r = 0.83$ and 0.73, respectively) and negatively correlated with tan δ ($r = -0.81$ and –0.75, respectively), substantiating the ability of RTC and REC to discriminate elasticity and extensibility properties in raw noodle doughs. MCS was not correlated with any rheological characteristics of raw noodle dough.

Cooking Characteristics

Loss of solids to cooking water was significantly influenced ($P < 0.001$) by both starch damage and particle size. Cooking loss consistently decreased with decreasing particle size within each starch damage level and consistently increased with increasing degree of starch damage at each particle size (Fig. 3A).

Analysis of water uptake during cooking (Fig. 3B) clearly indicated a general trend of a decline in water uptake with increasing starch damage. Water uptake was not affected by particle size. Water uptake and cooking loss were inversely related ($r = -0.71$), indicating that lower water uptake was partially the result of greater loss of material to the cooking water.

Cooked Noodle Textural Attributes

Cooked noodle thickness was significantly influenced by both flour starch damage and particle size (Fig. 4A), although particle size was the dominant factor ($F = 24.34$ and 85.01, respectively). Overall, coarse flours yielded the thickest cooked noodles at all levels of starch damage, while fine flours produced the thinnest. Flours with fine and intermediate particle sizes produced noodles that significantly increased in thickness with increasing starch damage.

A general trend observed for MCS of noodles prepared at 32% water absorption was a decrease in MCS within each starch damage level as particle size increased (Fig. 4B). In all cases, the fine flour noodles had significantly higher MCS values than either the intermediate or coarse flour noodles within each starch damage level. The greatest effect of particle size on MCS within a starch damage series was observed for high starch damage.

Cooked noodle RTC (Fig. 4C) followed a similar trend to that observed for MCS, a decrease in RTC with increasing particle size within each starch damage level. Maximum RTC was found for fine high starch damage in flour noodles. Significant differences were seen between the finest and coarsest flours within the medium and high starch damage series, and between all three particle sizes at high starch damage. The degree of starch damage did exert a significant effect on RTC of fine and intermediate particle size flour noodles, where RTC increased with increasing starch damage, but did not significantly affect RTC of the coarse flours.

Noodle recovery (REC %) trends were consistent with RTC and MCS, declining with increasing particle size within a starch damage series (Fig. 4D). Particle size at low starch damage did not have a significant effect on REC. Interestingly, the REC of fine particle size noodles increased with increasing starch damage, while the coarse flours decreased. REC of intermediate particle size flour noodles was not significantly influenced by starch damage.

Adjusted Water Absorption

The objective of this part of the study was to determine to what extent differences amongst noodles prepared at 32% water absorption (using flours varying widely in particle size and starch damage) were due to differences in water absorption capacity. Flours representing the two variable extremes, fine and coarse flours with low and high starch damage, were made into white salted noodles using adjusted water absorption to minimize differences in dough consis-

TABLE V
Influence of Particle Size and Starch Damage on Work Input, Cooking Loss, and Water Uptake During Cooking for Noodles Prepared at Adjusted Water Absorption

Particle Size (μm)	Water Absorption (%)	Starch Damage	Total Work (J/g)	Cooking Loss (%)	Water Uptake (g/g)
>85	34.5	Low	20.48a[a]	4.6c	1.47a
>132	36.0	Low	15.86b	4.6c	1.44b
>85	36.5	High	14.79c	5.1b	1.41c
>132	38.3	High	13.34d	5.4a	1.41c

[a] Values followed by the same letter are not significantly different ($P < 0.05$).

TABLE VI
Influence of Particle Size and Starch Damage on Cooked Noodle Texture for Noodles Pepared at Adjusted Water Absorption

Particle Size (μm)	Water Absorption (%)	Starch Damage	MCS[a] (g/mm^2)	RTC[b] (%)	REC[c] (%)
>85	34.5	Low	19.34a[d]	22.03a	19.61a
>132	36.0	Low	17.10b	19.28b	16.42b
>85	36.5	High	19.05a	21.30a	19.03ab
>132	38.3	High	16.98b	15.83c	10.81c

[a] Maximum cutting stress.
[b] Resistance to compression.
[c] Recovery.
[d] Values followed by the same letter are not significantly different ($P < 0.05$).

tency, as would be done commercially. As anticipated, the high starch damage flours required more water than low starch damage for both particle sizes. The high starch damage fine flour required 36.5% water absorption to display an equivalent consistency to low starch damage fine flour at 34.5%. A similar absorption difference was observed for coarse particle size material at 38.3 and 36.0%, respectively.

Significantly higher work input was required for noodles with low starch damage than for high damage, and a clear particle size influence was detected (Table V). The fine low starch damage noodle required significantly higher work input than the corresponding coarse flour noodle. While the work input range for high starch damage noodles was smaller, the fine flour continued to require significantly higher work input during sheeting than the coarse flour noodle.

Previous research (Hatcher et al 1999) indicated that incremental changes (6% total range) in the water absorption percentage had minimal effects on the L^*, a^*, and b^* values of raw CWRS white salted noodles at 2 or 24 hr. A similar pattern was observed in this series of experiments. No discernable effect was observed on L^* while a nonsignificant decrease in a^* and b^* values was observed (not shown).

Adjusting the moisture content of the noodle doughs largely eliminated previously seen differences in dynamic oscillatory and creep measurements of the low and high starch damage fine and coarse flours (not shown). The one exception was thick noodle dough prepared from coarse low starch damage flour, which had significantly higher G' values. However, once sheeted to its final thickness, the difference was eliminated, suggesting that the larger particle size required longer hydration time to reach its final consistency because of its lower particle surface area in combination with low levels of starch damage. These data confirm that differences in elasticity and extensibility among noodle doughs were primarily due to differences in flour water absorption.

Cooking loss of noodles at adjusted absorption continued to be significantly affected by particle size and starch damage (Table V). Particle size played a role in differences between high starch damage flour noodles that were distinct from each other and displayed significantly higher cooking losses than the corresponding low starch damage noodles. No significant difference in cooking loss due to particle size was detected for low starch damage flour noodles.

At low starch damage, particle size had a significant effect on water uptake during cooking. The fine low starch damage flour noodle was significantly higher in water uptake than the corresponding coarse flour noodle. However, particle size did not affect water uptake of high starch damage samples. Low starch damage resulted in significantly higher water uptake compared with high starch damage, probably due to the inability of extremely damaged starch granules to retain structural integrity during cooking, as indicated by higher loss of solids to the cooking water.

Even under adjusted water absorption conditions, starch damage levels affected the thickness of cooked noodles. The coarse low starch damage flour noodles were significantly thicker (2.32 mm) than corresponding high starch damage flour noodles (2.24 mm). Both coarse flour noodles were thicker than either the fine low or high starch damage flour noodles.

MCS analysis of the cooked noodles processed at comparable raw dough consistency showed a significant particle size effect (Table VI). The noodles from fine particle size flours, irrespective of level of starch damage, were significantly firmer than noodles from coarse flour. Response of noodles prepared at adjusted water absorption to RTC testing differed from the responses observed at fixed absorption. At adjusted absorption, the fine particle size noodles were not affected by the level of starch damage and had significantly higher RTC values than the coarse flour noodles. The coarse flour noodle RTC value, however, was larger at low starch damage than at high starch damage, which is the inverse of the fixed absorption results. In addition, at adjusted absorption, there was a significant effect of particle size within both starch damage series where no difference was seen previously (32% absorption) at low starch damage.

Adjusted absorption eliminated the differences in REC due to starch damage at fixed absorption between the fine flour noodles (Tables IV and VI). Previously, at fixed absorption, REC of the coarse low starch damage flour noodle was significantly higher than the coarse high starch damage. REC results showed that at adjusted water absorption, flour particle size continued to display a significant effect within a starch damage series.

CONCLUSIONS

Procedures were developed to produce flours with varying degrees of starch damage and particle size while maintaining similar protein content, allowing a direct comparison of the effects of flour starch damage and particle size for the first time, independent of protein content and wheat class, on white salted noodle rheological and textural properties. Rheological analysis of the raw dough noodle sheets at a fixed water absorption showed that low starch damage noodle dough sheets exhibited lower G' (less elastic), higher tan δ values (greater viscous component), and greater maximum strain during creep studies (extensibility). Cooking loss was greatest in noodles prepared from the highest starch damage, coarsest particle size flour. Water uptake was inversely related to starch damage and particle size. Cooked noodle textural characteristics at fixed absorption (32%) indicated no consistent relationship with starch damage. However, flour particle size had a critical effect on the quality of the final product. Cooked noodles prepared from flours of finer particle size displayed significantly better MCS, REC, and RTC noodle characteristics. The added benefits of faster water uptake by the finer particles, in conjunction with the reduced work input requirement, would suggest that, at a constant starch damage level, the finer particle sized flour would be the preferred flour for commercial noodle manufacturers.

Adjusting the water absorption to achieve comparable dough consistency largely eliminated differences in the raw noodle dough rheological properties, emphasizing that the effects observed at fixed absorption were due to differences in flour water absorption capacity. Analysis of cooked texture using noodles prepared from doughs of comparable consistency indicated superior cooking quality when particle size was finer and starch damage minimized. It is our intention to extend this research to investigate both starch damage and particle size influence on yellow alkaline noodles.

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