Apparent Restriction of Starch Swelling in Cooked Noodles by Lipids in Some Commercial Wheat Flours[1]

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ABSTRACT

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Chemical and physical properties of a commercial noodle flour from Japan (JCN) and another from Singapore (SCN) were compared to those of a western white (WW) wheat flour and a hard white winter (HWW) wheat flour. The JCN and SCN flours contained 13-23% more nonstarch lipids than either of the American flours, and their pasting curves (amylograms) in water showed restricted swelling. Pasting the four flours in the presence of sodium chloride (2% based on flour) gave amylograms with peaks between 88-64°C during the cooling cycle. The peak for the JCN flour was especially prominent. The starches isolated from the JCN and SCN flours contained amylose 2% lower than that of the HWW flour but 1.5% higher than that of the WW flour. The swelling power of the starches from the JCN and SCN flours were higher at 75 and 83°C than that of the starches from the American flours. The amylograms of the four starches displayed less difference than the flours did. Instant fried noodles made from the JCN flour without carbonate salts in the formula were more firm and more elastic than those made from HWW flour or a 4:1 mixture of HWW and WW flours. Those texture differences appeared to be associated with an unknown lipid in the JCN flour that restricted starch-granule swelling.

Wheat starch is by far the major component of oriental noodles. The pasting properties of wheat starches isolated from 42 flours milled from Australian wheats have been correlated with the eating texture of Japanese salt noodles (Konik et al 1992). A positive correlation was found between the desired softness and elasticity in the cooked noodles and 1) a low pasting temperature, 2) a high pasting peak, and 3) a high breakdown in the amylograph. Crosbie (1991) isolated starch from 13 flours milled from Australian wheats that varied in quality for the production of Japanese salt noodles and found positive correlations (r = 0.80-0.84) between starch swelling power (at 92.5°C), peak viscosity in the amylograph, and the overall texture score of the cooked noodles. In work involving fractionation and reconstitution of four wheat flours, the primary and tailing starch fractions were responsible for the texture of cooked salt noodles measured by a sensory panel (Toyokawa et al 1989a,b). The water-holding capacity (swelling power) of the wheat starches at 75°C correlated positively with the viscoelastic score of the noodles.

Miskelly and Moss (1985) prepared raw Chinese-style noodles from over 150 flours experimentally milled from wheats from all over Australia. The top-quality noodle flours gave cooked Chinese noodles with a firm but not tough bite that were springy and elastic. The eating quality of the Chinese noodles was correlated with starch that showed a low pasting consistency.

Amylose, and probably amylopectin, complex with monoacyl lipids in starches (Eliasson 1986, Takahashi and Seib 1988, Biliaderis 1992, Kim 1992). Even low levels (0.1%, based on starch) of monoacyl lipids affected the pasting and gel properties of starch (Osman and Dix 1960, Miller et al 1973). The amylose level in wheat starch from 13 commercial flours was negatively correlated with the eating quality of salt noodles (Oda et al 1980), which could be interpreted as a positive correlation with starch lipids. In the amylose assay, starch lipids interfered with the level of complexation of amylose and iodine-iodide. The objective of this research was to examine the relationship between wheat flour lipids and the texture of rehydrated, instant fried noodles. The results indicate that restricted swelling of starch is desirable in cooked noodles, which agrees with the findings of Miskelly and Moss (1985) in alkaline noodles containing sodium and potassium carbonate.

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MATERIALS AND METHODS

Flour Samples and Chemicals

Flours were milled from a hard white winter (HWW) wheat (cultivar Rio Blanco) grown in Kansas (Kansas Agricultural Experiment Station, Manhattan), western white (WW) wheat grown in Washington (Western Regional Research Center, Pullman, WA), and Australian standard white (ASW) wheat (origin in Australia unknown). The wheats were milled to ~72% extraction at the Department of Grain Science, Kansas State University, Manhattan, except the Singapore commercial noodle (SCN) flour, which was milled from ASW wheat at Prima Ltd. Flour Mills, Singapore. The SCN flour is sold to producers of wet Chinese-style noodles (*hookien mee*) in Singapore. The fourth flour (Japanese commercial noodle flour [JCN]) was obtained from a Japanese noodle manufacturer of instant fried noodles used for instant soup in a cup.

All chemicals were reagent-grade unless otherwise noted.

General Methods

Protein (N × 5.7), moisture, ash, falling number, damaged starch, color of flours, and free lipids in flours were determined by AACC (1983) methods 46-13, 44-15A, 08-01, 56-81B, 76-30A, modified 14-30 (dry method), and 30-25, respectively. Free lipids in flours were extracted with hot petroleum ether; total nonstarch lipids in flours were extracted with water-saturated n-butanol at 25°C. The total lipids were then fractionated by silica-gel-column chromatography into nonpolar (eluted with chloroform) and polar lipids (methanol) (Pomeranz et al 1966). The lipid analyses were replicated four times. Optimum mixing time and dough absorption were determined using the 10-g mixograph method described by Finney and Shogren (1972). All mixograph data were collected automatically and analyzed by an IBM computer interfaced with the mixograph.

Particle-size distribution of a flour (50 g) was determined with the Alpine Air Jet (model A200LS, Alpine Ag., Augsburg, Germany) on sieves with openings of 38, 53, 75, 106, and 125 μm. The percentages of the fractions were determined from the weights of the overs on the sieves.

All assays were done at least in duplicate.

Peroxidase Activity

Peroxidase activity was assayed by a modification of the method of Fretzdorff (1980). Sodium dihydrogen phosphate monohydrate (6.9 g) was dissolved in water (900 ml), and the mixture was adjusted to pH 5 with 10M sodium hydroxide. Ethylenediaminetetraacetic acid (EDTA) disodium salt dihydrate (0.6 g) was added, and the solution was made to volume (1 L) with water to give the EDTA-0.05M phosphate buffer. The chromophore reagent was prepared by adding 1.0 ml of 1% o-dianisidine (Sigma

Chemical Co., St. Louis, MO) in water to a solution of the EDTA-0.05*M* phosphate buffer (25 ml) mixed with glycerol (75 ml). Standard solutions of peroxidase were prepared from a stock solution of peroxidase (10 mg, Sigma P-8125) in the EDTA-phosphate buffer (2.0 ml). Aliquots (0.1–0.5 ml) of the stock solution were made to volume (100 ml) with the buffer.

A standard solution of peroxidase (2.5 ml) was added to the chromophore reagent (2.5 ml), followed by 0.003% aqueous hydrogen peroxide (1 ml). After gentle mixing, the solution was incubated at 37°C for 30 min, at which time the reaction was terminated by adding 9*M* sulfuric acid (2.0 ml). Absorbance was read at 540 nm against the appropriate blank, and a standard curve was plotted with peroxidase activity versus absorbance.

Flour (1 g) was stirred in EDTA-0.05*M* phosphate buffer (20 ml) for 3 min at 25°C, and the mixture was filtered through Whatman No. 1 filter paper. The flour extract (2.5 ml), and that of an autoclaved flour (blank), were used in place of the standard solution of peroxidase in the procedure described above. Peroxidase activity was estimated from the standard curve.

Starch Isolation

Starch was recovered using a slight modification of the procedure described by Wolf (1964). A stiff dough was prepared by mixing wheat flour (~100 g) with distilled water (60–65 ml). The dough ball was covered with a moistened towel and stored at room temperature for 1–2 hr. The dough was kneaded and rinsed inside a 2-L beaker five times in succession with distilled water (5 × 200 ml). The starch granules were separated from the cell walls and gluten proteins by sieving through a nylon bolting cloth (70 μm, HC3-60 Nitex). The filtrate was collected and centrifuged at 1,500–2,500 × *g* for 15 min. The supernatant was discarded, as was the upper pigmented sediment (tailings fraction) that was carefully removed by scrapping with a spatula. The white prime starch was recovered, air-dried at room temperature, and stored in a glass bottle.

Phospholipid in Starch

The level of phospholipid in wheat starch was quantified by the phosphorus in the starch (Morrison 1964). Starch (22–23 mg) was digested for 1.5 hr in concentrated sulfuric acid (2.2 ml) using a 30-ml micro-Kjeldahl flask. Hydrogen peroxide (1–2 drops, 30%) was added slowly to the flask and thoroughly shaken. The flask was heated for 1–2 min and then cooled. The digest was transferred quantitatively to a volumetric flask (50 ml) with several rinses of deionized water (total 25 ml). Sodium sulfite solution (1 ml, 33%) was added and thoroughly mixed, followed by mixing with 2% ammonium molybdate (10 ml) and 10% ascorbic acid (1 ml). The solution was heated for 5 min in a boiling water bath, cooled, and made to volume (50 ml) with deionized water. Absorbance was read at 822 nm against a blank, and the percent phosphorus in a starch sample was determined based on absorbance of a standard solution of orthophosphate (20 μg of phosphorus per ml). The level of phospholipid in wheat starch was calculated by multiplying the percent phosphorus by 16 (Morrison 1978). The standard deviation of the assay was 0.05%.

Swelling Power and Solubility

A mixture of starch (0.5 g) and water (25 ml) was heated in a centrifuge tube at either 75 or 83°C for 40 min and gently stirred using a magnetic stir bar. Immediately after centrifuging, the weight of sediment was recorded, and the carbohydrate in the supernatant was determined using phenol-sulfuric acid (Dubois et al 1956). Swelling power was calculated as the ratio of the wet mass of the sedimented gel to the dry matter in the gel. Solubility was calculated as the percent of starch dissolved in the continuous liquid phase. The coefficients of variance were 4.8% for solubility and 1.4% for swelling power.

Iodine Binding Capacity and Differential Scanning Calorimetry (DSC)

The amylose level in a starch was determined by iodine binding capacity as described by Schoch (1964), except that lipids were removed before assay by four successive extractions with hot 70% ethanol (Morrison and Coventy 1985). DSC measurements were made on a Perkin-Elmer instrument (DSC-2, Norwalk, CT) equipped with an FTS Systems Flexi-Cooler and temperature controller (FTS Systems, Inc., Stone Ridge, NY). The instrument was calibrated with indium. Samples of starch and water (1:3, w/w) were added to aluminum pans. The mixture was held overnight and then heated at 10°K/min from 280–400°K. A second aluminum pan, which contained an appropriate amount of aluminum to balance the heat capacity of the sample, was used as reference. Data were collected and analyzed using the Data acquisition, retention and examination system for DSC (DARES, V 1.4, Industrial Technology Research Institute, Cambridge). The temperatures recorded were the initiation of gelatinization (T_o), which was determined by the intercept of the extrapolated baseline and the leading edge of the peak; the peak temperature (T_p); and the final temperature (T_f), which was determined in a manner similar to T_o. Enthalpy (ΔH) was calculated using the area under an endotherm.

Pasting Curves of Starches and Flours

The pasting properties of starches and flours were measured in water using the Brabender Visco-Amylograph according to AACC (1983) method 22-10. Amylograms of flours were measured also in sodium chloride solution (2%, based on flour).

Instant Fried Noodles

The JCN flour, HWW wheat flour, and a 4:1 (w/w) mixture of HWW and WW flours were used to make instant fried noodles.

A noodle dough was prepared (Rho et al 1986) using flour (100 g, 14% mb), water (34–36 g), and sodium chloride (2 g). The ingredients were blended for 1 min at slow speed (speed 1) and 4 min at medium speed (speed 2) in a Hobart mixer fitted with a cake paddle. The crumbly mixture was pressed into a thick sheet (5.5 mm), and the sheet was rested for 15 min and sheeted (seven steps) from 5.5 to 0.8 mm thick. The dough sheet was cut into noodles 0.8 mm wide that were configured in a wavy pattern by moving the collecting plate. The noodles were steamed at atmospheric pressure for 3 min and gained 0.2–0.3% water. Squeezing the steamed noodles between glass plates indicated ~25% gelatinization. The surfaces of the steamed noodles were dried by forced-air at 25°C for 4 min. The noodles were folded and placed in a wire basket fitted with a lid, and the basket was submerged under hot palm oil (177°C) for 50 sec. The fried noodles were drained (2 min) of surface oil and cooled (2–3 hr) to room temperature. They were stored in plastic bags for less than a week before testing.

Texture Profile Analysis on Cooked Noodles

Commercial cup noodles (two samples) were rehydrated by adding boiling water and holding for 3 min. Three samples of instant fried noodles (20 g each) prepared in the laboratory were cooked in boiling water (1 L) for 3 min. After boiling, the noodles were drained (2 min), and several strands were laid individually on a glass dish. The dish was placed in a desiccator over 19.9 wt% sulfuric acid (90% rh at 25°C), and the noodles were allowed to equilibrate for 20 min. One noodle strand was removed and placed on Whatman No. 541 filter paper (12.5 cm) affixed to a plexiglass plate with double-sided adhesive tape. The width of the noodle strand was estimated using a caliper. Texture profile analysis (Bourne 1978) was done using a texture analyser (model TA.XT2, Texture Technologies Corp., Scarsdale, NY) equipped with the XTRA.DIMENSION software program. The instrument was equipped with a cylindrical probe (3.8 cm, Probe Model TA-4) and was operated in the compression mode at a probe speed of 1.0 mm/sec. The compression distance was 75% of the noodle thicknesses of cup noodles and laboratory-prepared noodles (1.0 mm and 1.3 mm, respectively). The maximum force settings were 1.5–2.5 and 3.0–4.0 kg-force for laboratory-prepared and cup noodles, respectively. The pause between the first and second compressions was 0.5 sec. Individual measurements included peak forces, peak areas, and distances (time) along the x-axis. Ten individual noodle strands were tested over a period of approximately 15 min. Generally, the data from 2–3 noodle strands were rejected due to high variance, and the remaining data was used to obtain means and standard deviations. Cohesiveness and percent recovery were calculated in the normal fashion (Bourne 1978). The coefficients of variance for the various measurements were: <0.3% firmness, <4% cohesiveness, <20% adhesiveness, and <0.1% recovery.

RESULTS AND DISCUSSION

Flour Assay

The protein levels in the four flours ranged from 10.0 to 10.6%, except 8.1% in WW flour (Table I). HWW dough strength was greater than JCN and WW dough strength was greater than SCN. All flours were from sound wheat, as indicated by falling numbers above 400 sec. Among the flours, the one from WW wheat differed in starch damage. The JCN and SCN flours contained elevated lipid levels, especially their nonpolar fractions (Table I). Japanese millers have reported plugging of equipment during the milling of ASW wheat (R. Maas, *private communication*). Cohesion of flour is affected by its lipid (solubles in petroleum ether) and moisture levels as well as particle size and shape (Neel and Hoseney 1984). Of those factors, lipid had the greatest effect.

TABLE I
Analyses on Flours from Four Wheats[a]

Source	HWW	WW	JCN	SCN
Extraction rate, %	72	72	60–65	72
Assay data[b]				
Ash, %	0.4	0.4	0.4	0.5
Agtron color[c]	61	72	68	66
Protein, %	10.4	8.1	10.6	10.0
Falling number, sec	412	439	428	429
Starch damage, %	2.6	2.0	2.7	2.7
Lipid assay[d]				
Free, %	0.80	0.94	0.85	1.13
Total, %	0.99 C[e]	1.10 B	1.33 A	1.36 A
Nonpolar, %	0.60 B	0.62 B	0.84 A	0.89 A
Polar, %	0.32 B	0.30 B	0.46 A	0.34 B
Recovery, %	93.0	94.0	98.0	90.0
Mixograph data				
Absorption, %	60	56	62	58
Mixing time, min	5.0	3.0	3.4	4.3
Mixing strength[f]	Strong	Weak	Medium	Medium

[a] HWW = hard white winter, WW = western white, JCN = Japanese commercial noodle, SCN = Singapore commercial noodle.
[b] Calculated on 14% moisture basis.
[c] The higher the number, the whiter (lighter) the color of flour.
[d] Calculated on dry basis. Free lipids were extracted with warm hexane and total nonstarch lipids with water-saturated *n*-butanol at 25°C. The values are the means of four replicates.
[e] Analysis of variance showed those levels with different letters were significantly different at $P = 0.0001$.
[f] Strong flour showed a wide mixing curve and high stability to overmixing.

TABLE II
Particle Size Distributions (wt %) of Four Flours[a]

Size (μm)	HWW	WW	JCN	SCN
<38	31	39	34	31
38–53	20	25	22	22
53–75	22	18	20	21
75–106	26	18	24	25
106–125	1	0	0	1
>125	0	0	0	0

[a] The moisture contents of hard white winter wheat (HWW), western white wheat (WW), Japanese commercial noodle (JCN), and Singapore commercial noodle (SCN) flours were 10.4, 10.2, 10.6, and 10.6%, respectively.

Physical Properties of Flours

Table II shows that the soft wheat (WW) flour had a finer granulation than the SCN and HWW flours. The JCN flour displayed an intermediate granulation between soft and hard wheat flours. The coarse granulation of the SCN flour, and its appearance under scanning electron microscopy (SEM), indicate that the flour was probably not from supplies of ASW noodle segregation (Konik et al 1992).

SEM photomicrographs supported the supposition that the JCN flour was a mixture of hard and soft wheat flours (photomicrographs not shown). The particles in the SCN and HWW wheat flours were typical of hard wheats because they showed starch granules tightly packed in a gluten matrix with no air spaces (Hoseney and Seib 1973). In contrast, the particles of soft wheat flour (WW) showed a more open structure with visible granules and some individual starch granules free of the protein matrix. The JCN and WW flours showed a high angle of repose, typical of soft wheat flours. Finally, peroxidase activity in the JCN flour was 80% of that in WW and SCN flours and equal to that in HWW flour, which indicated that the noodle flours had not been treated with moist heat.

Pasting Curves of Flours

The pasting curves of the flours determined in the amylograph (12% solids in water) are shown in Figure 1. Two major differences were observed between the amylograms of the WW and HWW flours and those of the commercial noodle flours. The pasting curves of the HWW and WW flours showed high pasting peaks, which, in the case of WW flour, may be attributed to a 2% higher level of starch. In addition, a breakdown in consistency occurred when the cold (30°C) pastes of the HWW and WW flours were stirred 20 min. The curves of the JCN and SCN flours showed pastes of reduced consistency but increased stability when stirred at 30°C. These differences may be due to flour lipids.

The 13–23% higher levels of lipids in the JCN and SCN wheat flours (Table I) probably caused restricted swelling of the starch granules, as shown by the low consistencies of their pasting curves. Furthermore, at 30°C, after pasting, it appears the starch-lipid complex in the JCN flour somehow either decreased paste consistency or delayed its development. The cold paste of the SCN flour did not gain consistency upon stirring, but it did not lose consistency as did the pastes of HWW and WW wheat flours. The extra nonpolar lipids in the JCN and SCN wheat flours could be free fatty acids or monoglycerides (Pomeranz et al 1966). Sodium stearate and monoglycerides restricted the swelling of corn starch granules (Gray and Schoch 1962).

We also examined the amylograms of the wheat flours in water containing sodium chloride (2%, based on flour). The cooling

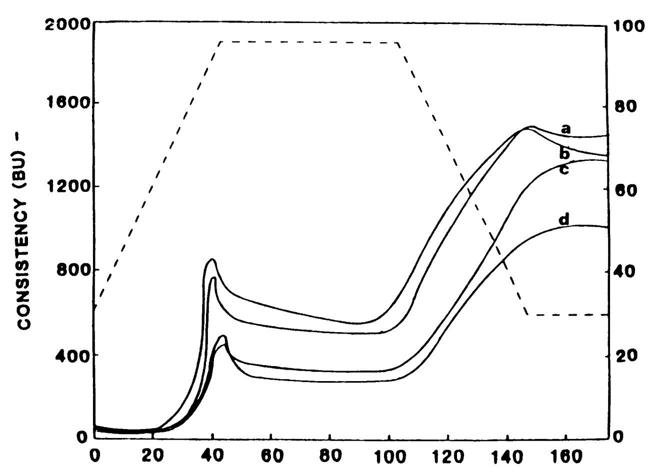

Fig. 1. Amylograms of different wheat flours in water at 12% dry solids. Dashed line = temperature profile between 30°C to 95°C. Solid lines = pasting curves of western white (**a**), hard white winter (**b**), Japanese commercial noodle (**c**), and Singapore commercial noodle wheat flours (**d**).

portion of the amylograms of all four flours showed a broad to moderately broad peak (Fig. 2) that was not present in amylograms of the flours without sodium chloride (Fig. 1). Peaks during the cooling cycle in amylograms were observed previously for noodle flours in brine (Endo et al 1989) and for bread crumb in water (Xu et al 1993). The amylogram of the JCN flour, which was likely milled from ASW noodle segregation (Nagao, 1981, Konik et al 1992), showed an especially prominent peak in its cooling cycle (Fig. 2).

The origin of the peak in the cooling cycle of the amylogram and the role of sodium chloride in accentuating that peak are unknown. We speculate that the peak was due to formation of an amylose-monoacyl lipid complex, and that the complex increased paste consistency until it lost solubility (Biliaderis et al 1985, 1986; Kim 1992). When the cold (30°C) paste of SCN wheat flour in brine was reheated in the amylograph, a small peak was observed during the reheating step, between 87 and 95°C, as compared to 88 and 80°C during the cooling cycle. Formation and melting of amylose-monoacyl lipid complexes are reversible, and their melting characteristics show marked temperature hysteresis (Biliaderis et al 1985). The prominent peak displayed by the JCN flour, as compared to the SCN flour, indicates that the JCN flour may have been prepared from an ASW wheat with a high level of the functional lipid fraction, provided no additive was in the flour.

Properties of the Starches from the Flours

Starches were isolated in 62–75% yield from the flours using a dough-washing procedure. The extra lipids in the JCN and SCN flours (Table I) were not detected in the starches. The starches from those two flours contained 0.1–0.2% less lysophospholipid than did the starches isolated from the HWW and WW wheat flours (Table III). Approximately 90% of the lipids in wheat starch are lysophospholipids (Morrison 1978), which were conveniently estimated by the phosphorus in the starches. The soft wheat (WW) starch contained 3.5% less apparent amylose than the hard wheat (HWW) starch did, whereas the starches from JCN and SCN flours contained approximately 2% less (Table III).

The swelling powers of the starches from the JCN and SCN flours at 75 and 83°C were higher than those of the starches from HWW and WW wheats (Table III). This is in agreement with many previous investigations on Japanese salt noodles (Moss 1980, Lee et al 1987, Endo et al 1989, Toyokawa et al 1989b, Crosbie 1991, Konik et al 1992). It appears that the soft wheat component in the JCN flour may have been from ASW noodle segregation. The positive correlation of high swelling power of starch with good eating quality (elastic bite) of cooked salt noodles presents an interesting paradox. It would seem that limited, rather than high, swelling of starch in cooked noodles, especially those low in protein, should give high elasticity and low stickiness. How is it, then, that flours for salt noodles that contain high-swelling starches give elastic noodles?

In our laboratory, starches from soft wheats have been shown, generally, to swell more than starches from hard wheats (Liu et al, *unpublished data*) because those starches contain 1–2% less amylose than do common hard wheats. At the same time, genes on the short arm chromosome 5D in wheat are associated with both the free polar and glycolipid contents in endosperm and the softness of endosperm (Morrison 1989, Morrison et al 1989). The data in the present investigation, albeit on a limited number of flours, suggest that lipids endogenous to the flour, not to its starch, largely control elasticity in noodles made from ASW noodle segregation. Thus, it appears that the high swelling of isolated wheat starch may be correlated with the nonpolar lipids in those flours, and that the lipids somehow migrate to the starch during noodle preparation or cooking. Rho et al (1988) examined the role of flour lipids in salt noodles, but the two flours (WW and HRW wheat) in that study were both from the United States and did not contain elevated lipid levels.

The differences observed in the paste consistencies of the flours (Fig. 1) were largely absent in the amylograms of their starches (Fig. 3), except that the starches from the JCN and SCN flours showed high cold-paste consistencies. The amylograms of all the starches showed a very broad peak between 95 and 70°C in their cooling cycles that we attributed to an amylose-monoacyl lipid complex. The formation of such a complex in the starch pastes was verified by DSC experiments. Heating any of the four starches in three parts water showed the same temperature and enthalpy

TABLE III
Characteristics of Starches from Wheat Flours[a]

Starch Source	Apparent Amylose (%)[b]	Phospholipid (%)	Swelling Power (g/g) 75°C	Swelling Power (g/g) 83°C	Solubility (%) 75°C	Solubility (%) 83°C
HWW	30.2	1.2	8.4	9.5	4.1	5.0
WW	26.7	1.3	8.4	10.1	3.9	5.4
JCN	28.4	1.1	9.1	10.5	4.8	6.5
SCN	28.2	1.1	9.1	10.7	6.1	6.7

[a] HWW = hard white winter wheat, WW = western white wheat, JCN = Japanese commercial noodle, SCN = Singapore commercial noodle.
[b] Apparent amylose was determined by iodine binding capacity using a value of 20.0% bound iodine for pure amylose. Phospholipids were estimated by percent of P × 16.

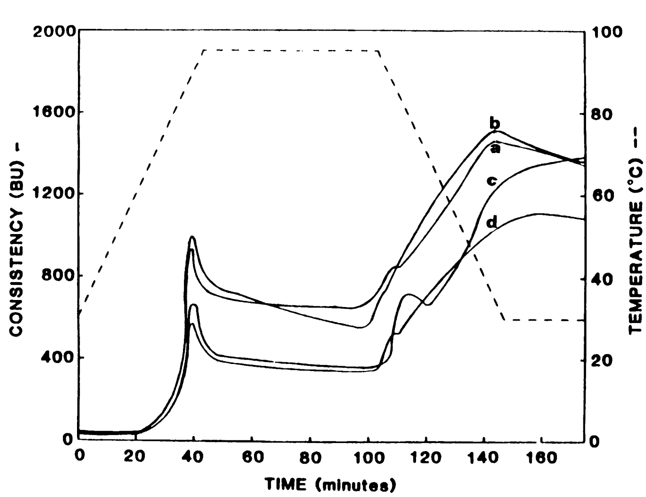

Fig. 2. Amylograms of different classes of wheat flour (12% flour solids) in 2% (based on flour) sodium chloride in water. Dashed line = temperature profile. Solid lines = pasting curves of western white (**a**), hard white winter (**b**), Japanese commercial noodle (**c**), and Singapore commercial noodle wheat flours (**d**).

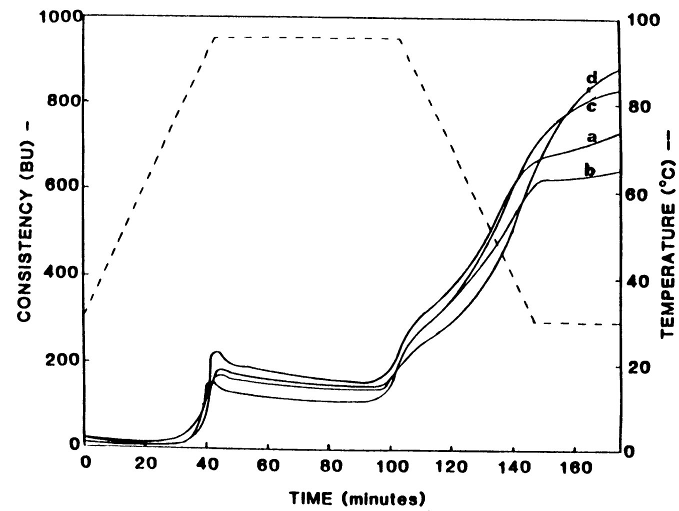

Fig. 3. Amylograms of starches isolated from the different classes of wheat flour at 7.5% solids in water. Dashed line = temperature profile. Solid lines = pasting curves of western white (**a**), hard white winter (**b**), Japanese commercial noodle (**c**), and Singapore commercial noodle wheat flours (**d**).

for the amylose-lipid transition (Table IV), except that the leading edge of the endotherm for the starch from the JCN flour appeared to change slope twice.

Instant Fried Noodles and Texture Profile Analysis

Texture profile analysis was done using two successive compression strokes of a probe on a cooked noodle strand that was constrained horizontally. The noodle strand had to remain stationary as the probe was withdrawn after the first stroke. That problem was solved by placing the noodle on a stationary paper surface so that a higher adhesion occurred between the paper and noodle than between the plexiglass probe and the noodle.

Figure 4 shows typical texture profile analysis curves for rehydrated (3 min in boiling water) instant fried noodles made from either JCN flour or a 4:1 mixture of HWW-WW flours. Instant fried noodles were made from the flours because the JCN flour is sold for use in instant cup noodles. Sodium or potassium carbonate salts were eliminated from the formula to accentuate differences caused by lipids in the flours because carbonate ions restrict starch swelling (Moss et al 1986). From the texture profile analysis curves, we calculated firmness (hardness), the peak force during compression; cohesiveness, the ratio of the second peak area divided by the first peak area; adhesiveness, the negative area after the first compression; and percent recovery, 100× the time during the second compression from probe contact to maximum peak 2 divided by the time during the first compression from probe contact to maximum peak 1. The data for four noodles are given in Table V. The hardness values indicate that the laboratory noodles made from the JCN flour were more firm after cooking than those made from HWW alone or a HWW-WW mixture. Furthermore, the recovery values show that those noodles were more elastic.

The rehydrated cup noodles made in Japan, probably from ASW wheats, were more firm and more elastic than those made in the United States (Table V). Those differences between cup noodles were confirmed by an untrained taste panel composed of five Asian students. All five agreed that the cup noodles made in the United States were less elastic than the cup noodles made in Japan, and that the surfaces of the U.S. noodles were not as smooth. The differences in the textures of commercial noodles were assumed to be due to starch properties. However, the commercial noodles contained gums, modified starch, and sodium potassium carbonates that may have been responsible, in part, for the commercial noodles having higher firmness than those prepared in our laboratory.

TABLE IV
Differential Scanning Calorimetry of Wheat Starches Isolated from Flours[a]

Starch Source[b]	Gelatinization T_o	T_p	T_f	ΔH cal/g	Amylose-Lipid Complex T_o	T_p	T_f	ΔH cal/g
HWW	56	60	68	2.3	88	99	105	0.5
WW	57	62	69	2.4	87	97	104	0.6
JCN	56	60	69	2.4	92[c]	102	106	0.5
SCN	58	63	71	2.5	86	100	104	0.5

[a] Starch to water ratio = 1:3, w/w.
[b] HWW = hard white winter wheat, WW = western white wheat, JCN = Japanese commercial noodle, SCN = Singapore commercial noodle. T_o = initiation of gelatinization, T_p = peak temperature, T_f = final temperature, ΔH = enthalpy.
[c] The leading edge of the peak had two slopes, and the extrapolated value of T_o had two values (88 and 92°C).

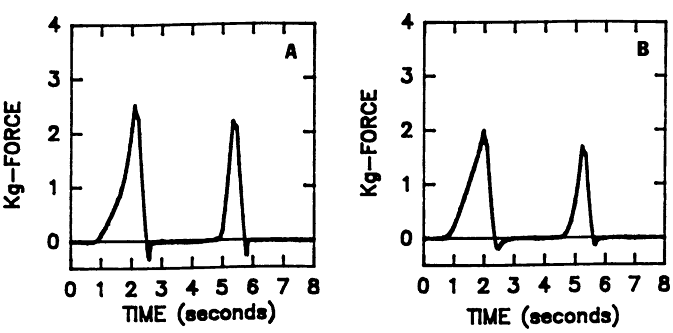

Fig. 4. Texture profile analysis curves on noodles made from Japanese commercial noodle (**A**) flour and a 4:1 mixture of hard white winter-western white flour (**B**). (Firmness in kg-force is converted to Newtons by multiplying by 9.8.)

CONCLUSION

It is hypothesized that nonstarch lipids are elevated in soft wheat flours renowned for noodle quality. Those lipids restrict starch swelling during cooking of noodles, thereby increasing their elasticity. In alkaline noodles made from hard wheat flours that contain an average level of lipid, starch swelling appears to be inhibited by the carbonate ions in the alkaline salts.

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TABLE V
Texture Profile Analysis of Cooked Noodles

Source[a]	Firmness, N First Stroke	Second Stroke	Cohesiveness	Surface Adhesiveness (N-sec)	Recovery (%)
Commercial cup noodles					
Made in Japan	35	33	0.7	−0.3	78
Made in USA	32	29	0.7	−0.2	70
Laboratory-prepared noodles					
JCN flour	24	21	0.6	−0.4	78
HWW flour	15	13	0.5	−0.2	70
HWW-WW (4:1) flour	19	16	0.5	−0.4	73

[a] Wheats: JCN = Japanese commercial noodle, HWW = hard white winter, WW = western white.

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