Japanese Noodle Qualities. II. Starch Components

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ABSTRACT

The physical and chemical characteristics of primary and tailing starch fractions from four wheats that differed in noodle quality were studied. The particle size distribution, water holding capacity, and amylose/amylopectin ratio (iodine blue color) were determined. The most apparent difference found was the water-holding capacity at 75°C and the amylose content. The water-holding capacity of these flours was highly correlated with the viscoelastic textural properties of noodles. Increased levels of amylose decreased the water binding of cooked noodles and increased the associated firming and loss of elasticity. Using pure corn starches differing in amylose/amylopectin ratio as a replacement for the inherent primary starches substantiated the relationship found between amylose content and noodle viscoelastic properties. The viscoelasticity properties of noodles appear strongly associated ($r = 0.85$) with the thermophysical properties of the starch as measured by water-holding capacity of the starch at 75°C. There was a highly negative relationship ($r = 0.96$) between amylose content and water-holding capacity at 75°C.

Fractionation and reconstitution studies described by Toyokawa et al (1989) pointed to the starch component in wheat flour as a major determinant in textural qualities of Japanese noodles. Other workers including Oda (1982) concluded that the particle size of flour did not affect noodle quality. Oh et al (1985) reported that with decreased particle size of the same flour, the optimum water absorption of noodle dough increased and that the uncooked noodles (dry noodles) made from such flours had increased breaking resistance. However, nothing from their data was related to cooked noodle quality. Also, Nagao et al (1977a,b) measured specific surface (cm^2/g) by means of the air-permeating speed through compressed flour, and did not find a relationship between specific surface and noodle quality.

Because our earlier work (Toyokawa et al 1989) showed starch plays a role in noodle textural quality, additional work was conducted to study the physical and chemical properties of each starch fraction as well as the other fractions prepared in that study. The results of that investigation, where particle size distribution, water-holding capacity, and amylose content of the starch fractions were determined, are reported here.

MATERIALS AND METHODS

The source of wheat flours, the fractionation and reconstitution procedures used to prepare the fractions, the noodle making and evaluation procedures, and the analytical methods used for protein and moisture are those described by Toyokawa et al (1989).

Starches

Amaizo Amylomaize VII starch, Amaizo 5 TC starch, Amaizo PFP starch, and Amaizo Amioca starch were supplied by the American Maize-Products Company (Hammond, IN). These starches were used to replace the primary and tailing starch fractions in preparing noodles.

Particle Size Analysis

Starch and flour granular size distributions were measured in 5% LiCl/methanol (filtered through 0.2- and 0.45-μm filters) with a Coulter Counter (model TA-II) that has a 16-channel separation using a 280-μm orifice. The instrument was calibrated with standard latex particles with a 10.02-μm diameter (Coulter Electronics, Inc.). Sampling was stopped when a total of at least 10,000 particles was counted (Coulter Electronics 1975, Soulaka and Morrison 1985, Williams 1970, Wilson and Donelson 1970).

Water-Holding Capacity

Flour (5 g) was weighed into a tared 50-ml centrifuge tube, 25 ml of distilled water was added, and the tube was stoppered. The tube was shaken vigorously and allowed to stand for 20 min at 25°C, with shaking every 5 min. It was then centrifuged for 15 min at 1,000 × *g*; the supernatant was decanted, and the tube was drained for 10 min at a 45° angle. The tube was weighed, and the water-holding capacity was expressed as grams of water per gram of dry sample (Sollars 1973a,b). Determinations were made in duplicate or more.

When the water-holding capacity of material at a high temperature (75°C) was determined, an appropriate amount of material (1–2 g) was suspended in 25 ml of distilled water in a tared 50-ml centrifuge tube. The tube was placed in a thermostat-controlled water bath maintained at 75°C and held for 30 min (Leach et al 1959), with shaking every 5 min. The tube was removed and centrifuged for 15 min at 1,000 × *g*; the supernatant was decanted, and the tube was drained for 10 min at a 45° angle. The tube was weighed, and the water-holding capacity was expressed as grams of water per gram of dry sample. Determinations were made in duplicate or more.

Amylose Content

Amylose content of each starch fraction was determined by a rapid iodine method (Williams et al 1970) and expressed as absorbance value per 20 mg of sample (dry basis) at 625 nm. Determinations were made in duplicate or more. Amylopectin interferes with the absorbance value in high (80% or greater) amylopectin starch, therefore, only the absorbance value was used.

Amylograph

A Brabender Amylograph was used to determine the thermal properties of each starch. Starch (45 g dry basis) was suspended in 450 ml of distilled water. The temperature was raised from 30 to 94.5°C at 1.5°C/min and held at 94.5°C for 20 min (Oda et al 1980).

Data were statistically analyzed with the SAS computer packages (SAS 1985a–e).

RESULTS AND DISCUSSION

The particle size distributions of different flours are shown in Figure 1. There was a difference in particle size distributions between HZ (the reference flour) and the other flours. HZ was milled by a Japanese milling company (Showa Sangyo Co., Ltd.) for use as a commercial noodle flour and was generally finer in particle size. The other flours were milled on a laboratory Buhler mill.

The particle size distribution of the primary and tailing starch fractions was determined. The primary starch fraction did not

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clearly have two types of granules (Fig. 2). This may be partly because it was not pure starch, or because granules in the size range intermediate between large and small granules are also present (MacMasters and Waggle 1963), or because of mechanical damage by grinding. The primary starch fractions were very similar in particle size among all the flours. However, the primary starch fraction from different sources affected noodle texture

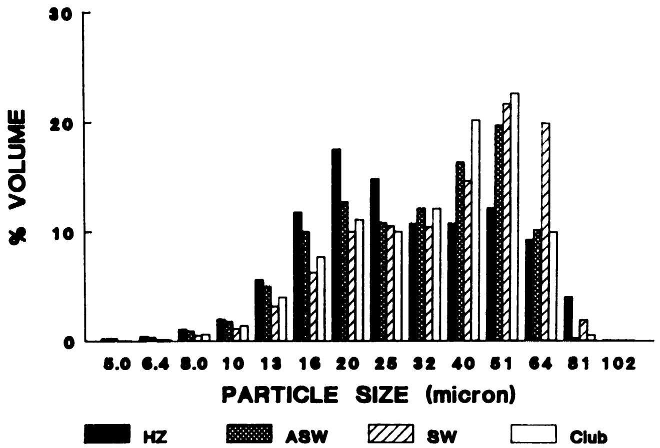

Fig. 1. Particle size distribution of flours expressed as the percent of volume of the sample: Hoshizora (**HZ**), Australian standard white (**ASW**), soft white (**SW**), and white club (**Club**).

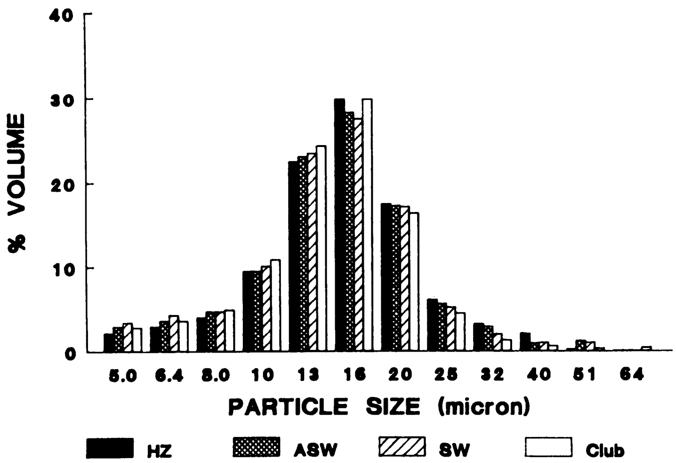

Fig. 2. Particle size distribution of primary starch fractions expressed as percent of volume: Hoshizora (**HZ**), Australian standard white (**ASW**), soft white (**SW**), and white club (**Club**).

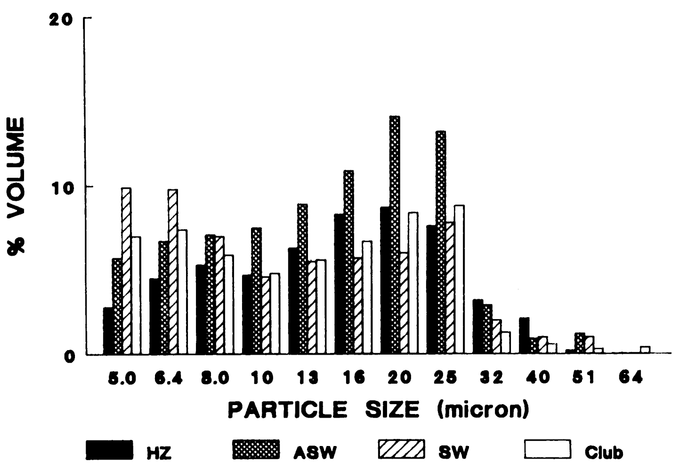

Fig. 3. Particle size distribution of tailing starch fractions expressed as percent of volume: Hoshizora (**HZ**), Australian standard white (**ASW**), soft white (**SW**), and white club (**Club**).

differently (Toyokawa et al 1989), indicating the difference was due to other factors. The tailing starch fraction may contain damaged starch, proteins, and other polysaccharides in addition to starch. Although there were differences in the particle size distribution of the tailing starch fraction (Fig. 3), no apparent relationship between the particle size distribution and noodle quality existed. Similiarly, no other paper was found that reported a relationship between the particle size of starch and noodle quality.

Water-holding capacities (WHC) of each flour, each fraction, and of different sources of other starches studied were determined. The WHC of samples at 25 and 75°C are shown in Tables I and II. At high temperature (75°C), the WHC among the flours increased dramatically over 25°C. However, the WHC of Australian standard wheat and HZ at 75°C were higher than those of soft white and club wheats. The WHC of these flours at 75°C related well with the viscoelasticity of cooked noodle texture (Fig. 4).

There was a small difference in WHC among the gluten fractions at 25°C, whereas the WHC of the gluten fraction at 75°C showed a large difference (Table I). However, the WHC of gluten fractions was relatively small compared with the WHC of the primary and tailing starch fractions. Also, the WHC of the tailing starch fractions at 75°C were about equal among the flours.

TABLE I
Water Holding Capacity (WHC) of Flours and Their Fractions
(g H_2O/g solid db)

Flour/ Fraction	WHC 25°C	SD	WHC 75°C	SD
Hoshizora				
Flour	0.91	0.02	5.56	0.09
Gluten	1.47	0.05	2.56	0.04
Primary starch	0.88	0.01	6.18	0.09
Tailing starch	2.67	0.03	7.60	···
Water-soluble	ND[a]	···	ND	···
Australian standard white				
Flour	0.92	0.02	5.90	0.05
Gluten	1.42	0.02	2.99	0.00
Primary starch	0.90	0.00	6.45	0.09
Tailing starch	2.51	0.09	7.69	···
Water soluble	ND	···	ND	···
Soft white wheat				
Flour	0.80	0.02	5.21	0.01
Gluten	1.47	0.44	2.81	0.02
Primary starch	0.90	0.02	5.80	0.08
Tailing starch	2.67	0.19	7.66	···
Water-soluble	ND	···	ND	···
White club wheat				
Flour	0.78	0.04	5.18	0.02
Gluten	1.40	0.01	3.29	0.04
Primary starch	0.85	0.01	5.92	0.08
Tailing starch	2.63	0.00	7.67	···
Water-soluble	ND	···	ND	···

[a]Not determined.

TABLE II
Water-Holding Capacity (WHC) of Purified Primary Starches and Selected Starches
(g H_2O/g solid db)

Starch	WHC 25°C	SD	WHC 75°C	SD
Purified primary starch				
HZ	0.91	0.00	6.47	0.14
ASW	0.90	0.00	6.68	0.13
SW	0.90	0.00	6.05	0.10
Club	0.86	0.00	6.11	0.12
Amylomaize VII	1.39	0.00	1.78	0.01
Amylomaize V TC	1.37	0.00	2.00	0.03
PFP Starch	0.97	0.01	6.50	0.01
Amioca	1.24	0.00	>25.00	···

[a]HZ, Hoshizora, reference flour; ASW, Australian standard wheat; SW, soft wheat; Club, white club wheat.

To investigate the differences of WHC between Australian standard wheat and soft white wheats, amylose content was determined and expressed as absorbance value at 625 nm per 20 mg sample (dry basis) (Table III). The absorbance value for the primary starch fraction of Australian standard wheat was lower than those of the other flours except that of club. Therefore, the primary starch fraction was purified by the following procedure. The starch fraction was suspended in distilled water and centrifuged. The process was repeated three times. Each time, 20% of the primary starch from the top was discarded, and the amylose content was determined. The amylose contents of purified primary starches are also shown in Table III. A highly negative relationship was found between amylose content (absorbance value) and WHC (at 75°C) of purified primary starch fractions of the flours (Fig. 5). Also, there was a statistically significant relationship between the WHC of the purified primary starch fraction at 75°C and the viscoelasticity score for noodle texture (Fig. 6). In all cases, the absorbance value for Australian standard wheat purified primary starch was lower than for the other purified primary starches. These data agree with those of Oda et al (1980).

Because of the apparent importance of amylose, the influence of the amylose/amylopectin ratio on noodle quality was studied. Starches of varied amylose/amylopectin ratios were selected and incorporated into Japanese noodles. Different amylose/amylopectin ratio wheat starches were not commercially available, so as a second choice, corn starches differing in amylose/amylopectin ratios were used. The amylose contents of the corn starches used are presented in Table IV. The amylose content of Amylomaize VII was higher than the others, whereas the WHC at 75°C of the high-amylopectin Amioca was higher than the others (Table II). The Amylomaize VII and Amylomaize V TC did not show a maximum viscosity during a 30–94.5°C heating period in the amylogram. The maximum viscosity of Amioca was higher than the other corn starches, and the initial gelatinization temperature of Amioca was lower than the others. This observation corresponds to the negative relationship between

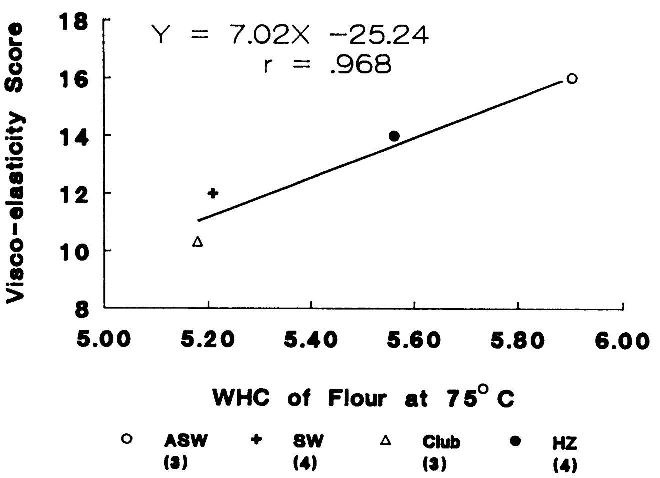

Fig. 4. Plot of the viscoelasticity score of cooked noodles vs. water-holding capacity (**WHC**) at 75°C. Statistically significant at $P < 0.001$. Hoshizora (**HZ**), Australian standard white (**ASW**), soft white (**SW**), and white club (**Club**).

TABLE III
Amylose Content of Primary and Tailing Starch Fractions

Flour[a]/ Fraction	Amylose Content (absorbance value)	SD[b]
HZ		
Primary starch	0.406	0.016
Tailing starch	0.291	0.002
ASW		
Primary starch	0.407	0.028
Tailing starch	0.291	0.003
SW		
Primary starch	0.416	0.012
Tailing starch	0.291	0.004
Club		
Primary starch	0.401	0.010
Tailing starch	0.292	0.021
Purified primary starch		
HZ	0.417	0.005
ASW	0.413	0.005
SW	0.431	0.002
Club	0.424	0.006

[a] HZ, Hoshizora, reference wheat; ASW, Australian standard wheat; SW, soft wheat; Club, white club wheat.
[b] SD = Standard deviation.

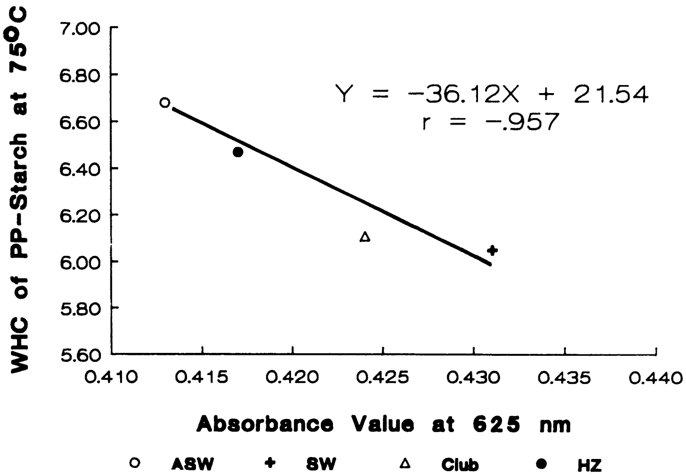

Fig. 5. Plot of the water-holding capacity (**WHC**) of the purified primary starch vs. the amylose content expressed as absorbance at 625 nm. Statistically significant at $P < 0.05$. Hoshizora (**HZ**), Australian standard white (**ASW**), soft white (**SW**), and white club (**Club**).

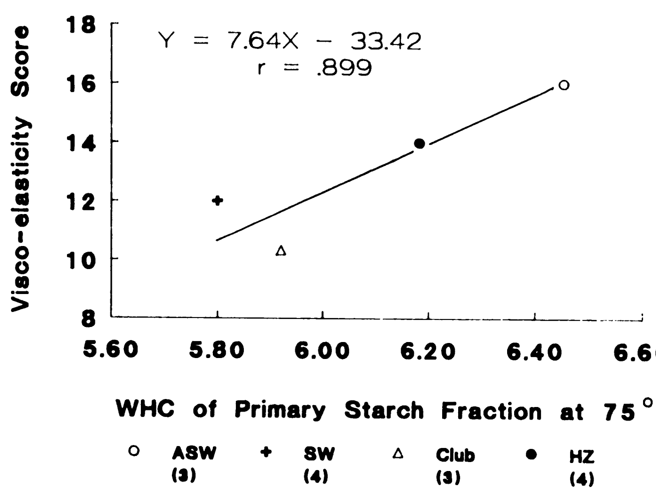

Fig. 6. Plot of the viscoelasticity score of cooked noodles vs. the water-holding capacity (**WHC**) at 75°C of the primary starch fractions. Statistically significant at $P < 0.001$. Hoshizora (**HZ**), Australian standard white (**ASW**), soft white (**SW**), and white club (**Club**).

TABLE IV
Moisture, Ash, and Amylose Content of Selected Starches

Starch	Moisture (%)	Ash[a] (%)	Amylose Content[b] (absorbance value)	SD
Amylo 7[c]	14.99	0.09	0.915	0.091
Amylo 5[d]	13.98	0.09	0.708	0.042
PFP[e]	12.10	0.08	0.405	0.004
Amioca	13.25	0.05	0.108	0.010

[a] 14% mb.
[b] 20 mg dry basis at 625 nm.
[c] Amaizo Amylomaize VII Starch.
[d] Amaizo 5 TC Starch.
[e] Amaizo PFP Starch.

TABLE V
Effect of Corn Starches Differing in Amylose/Amylopectin Ratio on Cooked Noodle Quality

Parameter	Control	Interchanged Starch[a]			
		A	B	C	D
Fractions					
Gluten	HZ	HZ	HZ	HZ	HZ
Starch	HZ	VII	V	PFP	Amioca
Water-soluble	HZ	HZ	HZ	HZ	HZ
Amylose content in starch (A)[b]	0.383	0.915	0.708	0.405	0.108
Quality					
Color	21	15	15	18	20
Surface appeal	14	2	2	10	8
Hardness	7	1	1	4.5	4.5
Viscoelasticity	14	2	2	8	12
Smoothness	7	1	1	6	4
Taste	7	4	4	7	6
Total	70	25	25	53.5	54.5

[a]VII, Amylomaize VII; V, Amylomaize V TC; PFP, Powdered starch.
[b]Absorbance value.

TABLE VI
Effect of Amylose/Amylopectin Ratio of Corn Starches on Cooked Noodle Quality

Parameter	HZ[a] Control	Interchanged Starch			
		A	B	C	D
Fraction					
Gluten	HZ	HZ	HZ	HZ	HZ
Starch (PFP/Amioca)[b]	HZ	12.5	5.5	4.5	1.8
Water-soluble	HZ	HZ	HZ	HZ	HZ
Amylose content in starch (A)[c]	0.383	0.383	0.360	0.350	0.300
Quality					
Color	21	20	20	20	20
Surface appeal	14	10	11.5	12	10
Hardness	7	3	4	3	3
Viscoelasticity	14	8	9	0	10
Smoothness	7	6	7	6	6
Taste	7	7	7	7	7
Total	70	54	58.5	57	56

[a]Hoshizora, reference flour.
[b]Ratio of PFP (powdered corn starch) to Amioca.
[c]Absorbance value.

WHC at 75°C and amylose content absorbance values of the prime starches (Fig. 5).

The noodle data of the starch interchange with the starches varying in amylose/amylopectin are shown in Table V. The cooked noodles made from Amylomaize VII and V TC (high-amylose starches) were extremely poor. These noodles could not hold water and form a noodle structure. The WHC of Amylomaize VII and V TC (Table II) explains the poor quality of the noodles, i.e., the water is not absorbed into the starch molecules because high amylose makes a rigid and tight structure. The texure of these noodles was also extremely poor. The noodles made from Amioca (approximately 100% amylopectin) were very viscous and sticky. The data indicate there is an optimum amylose/amylopectin ratio for good noodle quality, i.e., as the amylose content is reduced there is an increase in the noodle texture score. A series of amylose-amylopectin ratios were evaluated and the results are shown in Table VI. It was observed that as the amylose/amylopectin ratio decreased, the viscoelastic score increased. A similar but opposite relationship between amylose and amylopectin was observed in spaghetti (Matsuo and Dexter 1986).

CONCLUSIONS

The most apparent difference among the four flours was WHC and amylose content of the primary starch fraction. The WHC of these flours related well with the viscoelasticity of cooked noodle texture. This relationship holds promise to provide a simple and quick predictive test for noodle texture and warrants further investigation. There was a statistically significant relationship between the WHC of the primary starch fraction at 75°C and the viscoelasticity score for noodle texture. Further support for the relationships between WHC of the primary starch fractions and viscoelasticity of the noodle texture is the general trend found in the study, which demonstrated that as amylose content increased, the WHC and viscoelastic properties decreased. However, the possible effect of flour particle size and starch granule size on noodle texture cannot be excluded. Other factors that may influence performance and contribution of starch to noodle-making properties and quality include starch damage, gelatinization and retrogradation characteristics, and three-dimensional structure.

The highly significant relationships between the WHC of the primary starch fractions at 75°C, amylose content, and the viscoelastic properties of noodles suggest that further purification and fractionation of the primary starch fraction may yield more information relating to the texture of noodles.

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