Starch and Protein Quality Requirements of Japanese Alkaline Noodles (Ramen)

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ABSTRACT

Studies on samples of 20 hard-grained wheat cultivars and a commercial flour that varied in starch and protein quality showed that both characteristics influenced the texture of Japanese alkaline noodles (ramen). Flour swelling volume (FSV) and flour pasting characteristics (peak viscosity and breakdown) determined with a Rapid-Visco Analyser (RVA) assessed independently of α-amylase effects, were negatively correlated with total texture score. Protein quality, as indicated by farinograph stability, was positively correlated with total texture score. RVA pasting characteristics were substantially affected by small levels of α-amylase, and inactivation by means of 1 m*M* $AgNO_3$ was a critical requirement in characterizing the quality of the starch component of flour.

Alkaline noodles, referred to as "ramen" in Japan, represent more than 40% of all noodles manufactured in that country and exceed the levels of other noodle types including udon, soba, and durum wheat products (Crosbie et al 1990). One reason for the popularity of ramen over other noodle types is a preference for the flavor and texture of ramen by younger Japanese consumers. Both flavor and texture of ramen are influenced by the addition of ≈1% alkali, usually a mixture of sodium and potassium carbonates (Miskelly and Moss 1985). Alkaline noodles include the popular steamed and fried instant ramen, although this type has less exacting flour quality requirements than the main type of ramen (Nagao 1996).

The texture of ramen is an important factor influencing consumer acceptance. Ideally, the boiled ramen should be firm, springy, not sticky, and smooth. Similar textural characteristics are preferred in other alkaline noodle types including Cantonese (Miskelly and Moss 1985) and Hokkien noodles (Moss 1984, Shelke et al 1990).

In studies on factors influencing alkaline noodle texture, wheat or flour protein content has been positively associated with noodle firmness (Shirao and Moss 1978, Miskelly 1981, Moss 1984, Shelke et al 1990, Konik et al 1994, Ross et al 1997) and elasticity (Shirao and Moss 1978, Miskelly 1981, Ross et al 1997), and negatively linked with smoothness (Konik et al 1994, Ross et al 1997). Noodle texture was also affected by protein quality. Flours with stronger dough properties were reported to give noodles that were firmer (Miskelly 1981, Moss 1984, Miskelly and Moss 1985, Ross et al 1997) and more elastic (Miskelly and Moss 1985, Ross et al 1997) but less smooth (Ross et al 1997).

The importance of starch quality to the texture of white salted noodles, particularly udon, has been well established. Improved noodle texture has been associated with lower flour gelatinization temperature (Nagao 1977), low starch paste stability or high starch paste peak viscosity (Shirao and Moss 1978, Moss 1980, Oda et al 1980, Crosbie 1991, Konik and Moss 1992, Yun et al 1996), and high starch and flour swelling power or swelling volume (Endo et al 1988; Crosbie, 1989, 1991; Toyokawa et al 1989; Crosbie and Lambe 1990, 1993; McCormick et al 1991; Crosbie et al 1992; Konik et al 1993; Wang and Seib 1996; Yun et al 1996).

In contrast, fewer studies have been undertaken on the effects of starch quality on alkaline noodles, and these have varied in their results and conclusions. Shirao and Moss (1978) found that starch pasting characteristics were important, but to assess them it was important to isolate the starch from the flour to assess the potential of the flour for alkaline (and white salted) noodles. This view was also supported by Miskelly and Moss (1985). On the other hand, Baik et al (1994) reported that, in contrast to udon, starch characteristics may be less important in other noodle types, including alkaline Cantonese noodles. However, more recent studies (Konik et al 1994, Batey et al 1997, Ross et al 1997) have confirmed the importance of the starch component and have reported significant correlations between textural characteristics of alkaline noodles and selected flour pasting characteristics (peak viscosity and breakdown) determined with a Rapid-Visco Analyser (RVA) or swelling parameters derived on flour or whole meal.

In the studies in which starch or flour paste characteristics have been considered important for alkaline noodles, results have varied in relation to the importance of specific paste viscosity parameters. Starch paste stability (breakdown), assessed at constant peak viscosity, was found to be significant by Shirao and Moss (1978) and Miskelly and Moss (1985). This was supported by the study of Konik et al (1994), who conducted tests on starch and flour using a constant sample weight and reported that RVA breakdown was positively correlated with smoothness and negatively with firmness. In the case of starch, RVA breakdown was negatively correlated with elasticity and eating quality. Later, Batey et al (1997) and Ross et al (1997) also confirmed the importance of RVA breakdown assessed on flour and a constant sample weight to indicate textural characteristics of alkaline noodles. There has been less agreement in the case of another parameter, peak viscosity. Batey et al (1997) reported that the correlations between

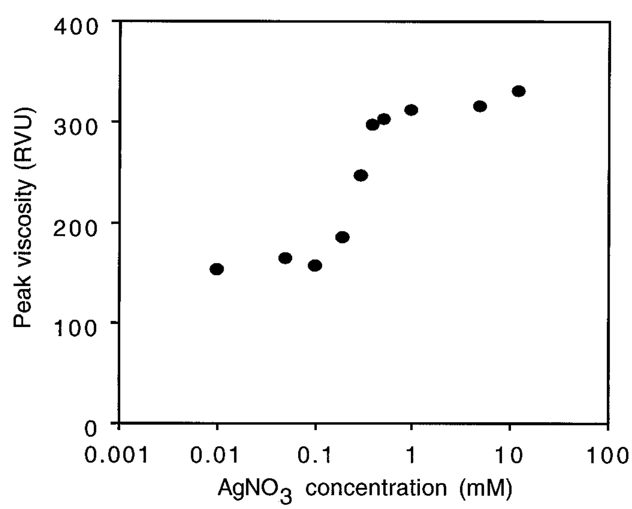

Fig. 1. Effect of $AgNO_3$ concentration on peak viscosity measured in Rapid-Visco Analyser units (RVU) of a whole meal flour with a falling number of 209 sec.

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flour paste breakdown and flour peak viscosity and various noodle textural characteristics were highly significant and of similar magnitude. However, Konik et al (1994) reported much lower, nonsignificant correlations between peak viscosity assessed on flour and starch and textural characteristics of the noodles.

Some of the variation in results may be due to the fact that in several of the studies, no inactivation treatment was applied to eliminate the effects of α-amylase in flour paste viscosity tests. The importance of this in determining inherent pasting properties of flour was stressed by Dengate (1984), who also reported that an inactivation treatment may be needed in tests on starch because of possible carryover of α-amylase activity in the starch isolation process.

Among various treatments applied to inactivate α-amylase, the use of $AgNO_3$ at a range of concentrations has proved popular. Hutchinson (1966) favored use at a level of 1 mg/2 g of flour (0.3–0.4 m*M* in amylograph tests). Crosbie and Lambe (1993) reported the use of 0.5 m*M* $AgNO_3$ to eliminate the effect of α-amylase in flour swelling volume (FSV) tests on whole meal flour to assess potential noodle quality of breeding lines severely affected by field sprouting. Bhattacharya and Corke (1996) used 0.5 m*M* $AgNO_3$ and Bhattacharya et al (1997) used 1 m*M* $AgNO_3$ in RVA tests to assess starch pasting properties of whole meal flour. Batey et al (1997) favored the use of a much higher concentration (12 m*M* $AgNO_3$) in measuring the pasting characteristics of flour to assess suitability for white salted noodles. This was based on an improvement in the correlation between flour paste peak viscosity and total texture score when 12 m*M* $AgNO_3$ was used instead of water. However, when the study was repeated on a different set of samples that had been assessed for alkaline noodle quality, high correlations were achieved with both water and $AgNO_3$ treatments, and it was concluded that an inactivation treatment was not necessary when assessing flour for alkaline noodles. On the other hand, Ross et al (1997) found 3.125% Na_2CO_3 to be useful in reducing effects of low levels of α-amylase associated with improved correlations between peak viscosity and textural properties of Cantonese noodles when compared with those obtained using water alone.

There were three goals in the present study: 1) to determine an appropriate concentration of $AgNO_3$ to use to inactivate α-amylase in RVA tests on flour; 2) to test the effectiveness of the selected inactivation treatment in RVA tests on samples of grain varying widely in α-amylase level; and 3) to apply these results and extend the work done in assessing the importance of starch and protein quality in relation to alkaline noodles by focusing on Japanese ramen as assessed by the established Japanese method (NFRI, MAFF 1985).

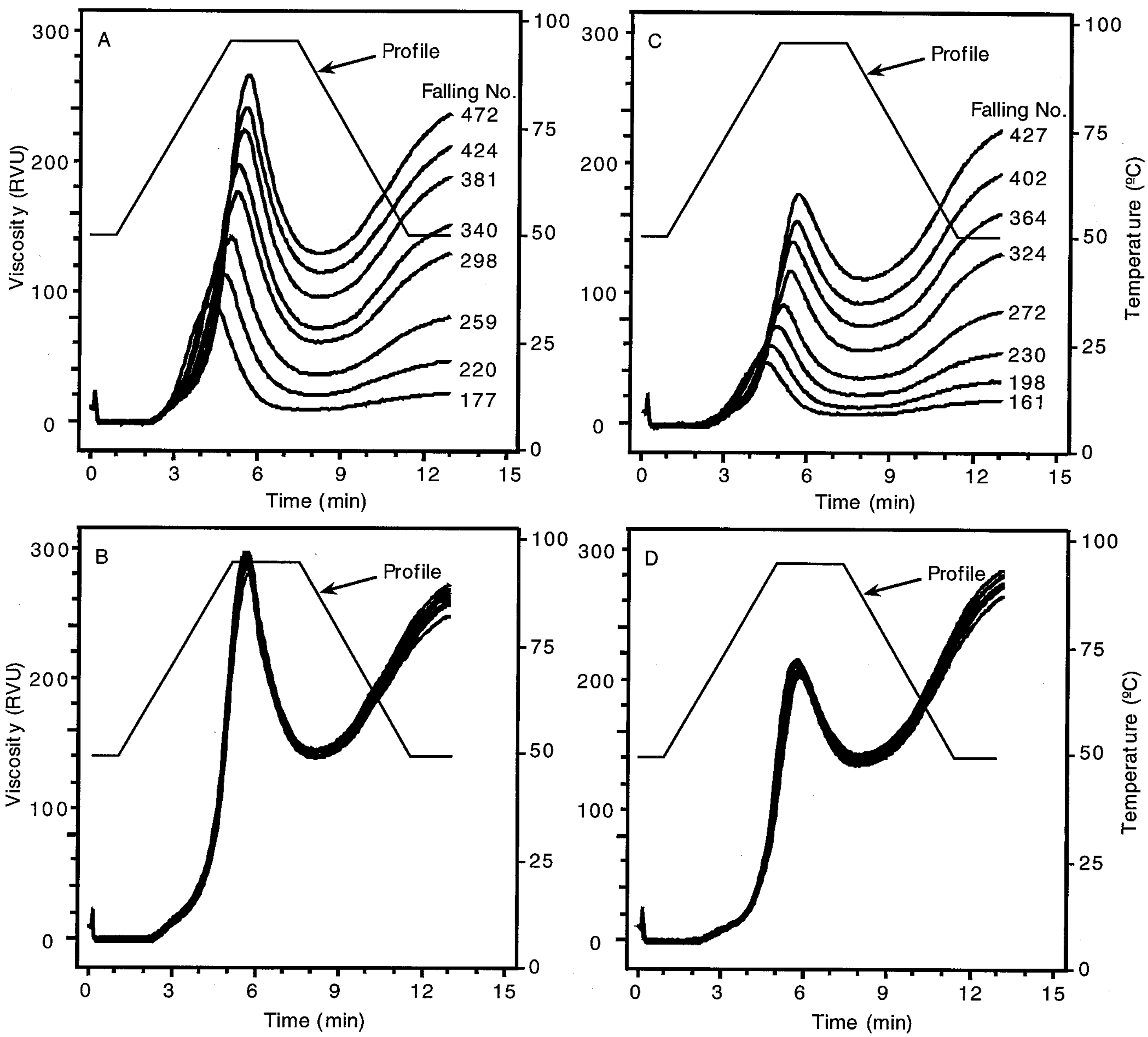

Fig. 2. Viscosity measured in Rapid-Visco Analyser units (RVU) for blends of sound and sprouted whole meal flour. Eradu tested in water (**A**) and 1 m*M* $AgNO_3$ (**B**). Kulin tested in water (**C**) and 1 m*M* $AgNO_3$ (**D**). Falling number values were 177–472 sec for Eradu and 161–427 sec for Kulin.

MATERIALS AND METHODS

Grain and Flour Samples and Subsequent Treatments

Experiment 1. Determination of an appropriate $AgNO_3$ concentration to inactivate α-amylase in RVA tests. In this experiment, a wheat sample affected by preharvest rain in 1996 was ground in a Tecator laboratory grinder fitted with a 0.5-mm sieve. The whole meal flour was analyzed for falling number (FN) and then subjected to a series of RVA tests using $AgNO_3$ solutions of various concentrations instead of distilled water. The $AgNO_3$ concentrations ranged from 0.01 to 12 m*M*.

Experiment 2. Effectiveness of the selected inactivation treatment. Samples of sound grain of wheat cultivars Eradu (high-swelling) and Kulin (low-swelling) were germinated in the laboratory and various blends of whole meal flour from the sound and germinated grain were prepared to produce two sets of samples that varied in α-amylase level; these samples were analyzed for FN. RVA and FSV tests were conducted in water to assess the relative effects of α-amylase on these tests. The samples were also analyzed by RVA to test the effectiveness of the selected inactivation treatment from experiment 1. FSV tests were also conducted with 0.5 m*M* $AgNO_3$, which had previously been established as an effective treatment to inactivate α-amylase in this test (Crosbie and Lambe 1993).

Experiment 3. Effect of starch and protein quality on texture of ramen. This experiment involved the testing of flour milled from 20 wheat cultivars and one commercial ramen flour. These were analyzed for FSV and RVA parameters, with and without inactivation of α-amylase, and farinograph stability. Relationships between the results from these analyses and the texture of ramen prepared from the same flours were examined. Other analyses included FN tests on the 20 wheat samples, and protein and ash determinations on the flours.

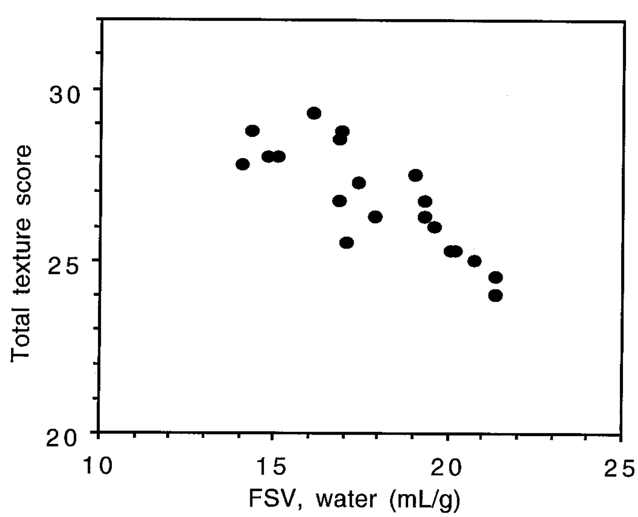

Fig. 3. Relationship between flour swelling volume (FSV) assessed in water and total texture score.

Germination of Grain Samples

Grain samples were germinated as previously reported (Crosbie and Lambe 1993).

Preparation of Flours

Samples of 20 wheat cultivars were prepared by blending grain from trials grown in 1996. The samples were blended so as to produce grain with an average protein content of ≈12.8% to give appropriate protein levels in the resultant flours. Cultivars were selected to include a range of types varying in starch quality and dough strength.

Low-extraction flours (40%) were prepared from the grain samples using a Buhler laboratory mill. This low-extraction level was used to produce flour samples comparable with the low-ash flours used commercially for the manufacture of ramen. This meant, for most samples, the selection of first reduction flour, but in several cases a small component of first break flour was also incorporated. A commercial ramen flour from Nippon Flour Mills Co., Ltd., was also included in the study.

RVA Tests

In experiments 1 and 2, RVA tests were conducted on whole meal flour. Whole meal (4 g on a 14% moisture basis) was added to distilled water or $AgNO_3$ solution (25 mL), stirred, and inserted into the RVA. The temperature of the RVA was set at 50°C for 1 min, then increased at 12°C/min to 95°C, held at 95°C for 2.5 min, reduced at 12°C/min to 50°C, and held for 2 min; total time was 13 min. Cannisters coated on the inside with polytetraflouroethylene were used in tests involving $AgNO_3$ solution.

In the final experiment, RVA tests were conducted on flour (3.5 g on a 14% moisture basis), distilled water or 1 m*M* $AgNO_3$ solution (25 mL) using the temperature profile described by Ross et al (1997). Here, the RVA was set at 65°C for 2 min, then increased at 15°C/min to 95°C, held at 95°C for 6 min, decreased at 15°C/min to 50°C, and held for 5 min; total time was 18 min.

RVA parameters measured included: peak viscosity (PV), highest viscosity during 95°C heating stage; holding strength (HS), lowest viscosity during 95°C heating stage; breakdown (BD), difference between peak viscosity and holding strength; final viscosity (FV), highest viscosity during 50°C cooling stage; and setback (SB), difference between final viscosity and holding strength.

FSV Tests

FSV was determined using the method described by Crosbie et al (1992) and modified by Crosbie and Lambe (1993).

TABLE I
Means, Standard Deviation (SD), and Coefficients of Variation (CV) for Flour Swelling Volume and Individual Rapid-Visco Analyser (RVA) Parameters[a] Tested With and Without Treatment to Inactivate α-Amylase[b]

			Water			$AgNO_3$ Solution		
Sample Set	Falling No. (sec)	Parameter	Mean	SD	CV	Mean	SD	CV
Kulin	161–427	FSV	13.6	0.2	1.2	13.7	0.1	1.0
		PV	107	47	44.1	204	6	2.7
		BD	57	9	16.0	70	3	4.5
		SB	62	38	61.7	134	5	3.6
		FV	113	77	68.5	268	7	2.7
Eradu	177–472	FSV	17.7	0.2	0.9	17.9	0.3	1.5
		PV	175	60	34.3	295	9	3.0
		BD	112	18	16.2	151	6	3.9
		SB	65	33	51.7	123	6	4.9
		FV	129	76	59.2	267	9	3.3

[a] FSV = flour swelling volume; PV = peak viscosity; BD = breakdown; SB = setback; FV = final viscosity.
[b] 1 m*M* $AgNO_3$ used for RVA tests; 0.5 m*M* $AgNO_3$ used for FSV tests.

Farinograph Tests

Farinograph tests were conducted using a 50-g bowl in accordance with Approved Method 54-21 (AACC 1995).

Falling Number, Protein, Ash, and Moisture Tests

Standard methods were used for the analysis of samples for FN, protein (N × 5.7), and ash by Approved Methods 56-81B, 46-30, and 08-01, respectively (AACC 1995). Results were calculated on a 14% moisture basis. Moisture was determined in accordance with Approved Method 44-15A (AACC 1995). All analyses were made in duplicate.

Noodle Preparation

The methods used for preparing and assessing the noodles were based on those described in a publication of the National Foods Research Institute, Ministry of Agriculture, Forestry and Fisheries (1985). These were translated from Japanese to English by Tanaka and Crosbie (*unpublished*), copies of which are available from the senior author. The methods, in a less detailed form, were also described by Nagao (1996).

Flour (400 g on a 13.5% moisture basis) was mixed on a Hobart N-50 dough mixer fitted with a flat beater. A solution containing analytical-grade potassium carbonate (2.4 g), analytical-grade sodium carbonate (1.6 g), analytical-grade sodium chloride (4g), and sufficient distilled water (adjusted according to flour moisture content, equal to 128 g at 13.5% moisture content) was added in a steady trickle down the side of the mixing bowl within 0.5 min of the commencement of mixing. Mixing profile was 1 min on slow speed, 1 min on medium, and 3 min on slow. The crumb temperature at the conclusion of mixing was within 24–28°C, achieved, if necessary, by adjustment of the temperature of the added water

The noodle crumb was sheeted through an Ohtake laboratory noodle machine with the roll temperature maintained at 25°C through water circulation. The rolls were adjusted to 9 rpm and the roll gap set at 3.0 mm. The sheet was folded in half and the two layers combined by passing again through a 3.0-mm gap. This process was repeated once. The sheets were rested on plastic rolls for 30 min (the standard method allows resting from 0–1 hr), wrapped in plastic film. Subsequent treatment to reduce the sheet to a final thickness of 1.4 ± 0.05 mm involved reduction ratios more evenly graduated than those recommended in the established method. This overcame a frequent problem of noodle sheet overrun at the cutting stage. The reduction in sheet thickness was achieved by successive passes through roll gaps of 2.2, 1.6, 1.2, and ≈0.9 mm. The gap between the rolls for the final pass was determined precisely using a test piece cut from the main sheet after the previous pass. The sheet was then passed through a no. 20 cutting roll to produce noodle strands with cross-sectional dimensions of 1.5 × 1.4 mm. The strands were cut into 25-cm lengths, dusted with starch, placed in air-tight plastic bags, and stored for 24 hr in a refrigerator at 5°C.

Noodle Assessment

In previous studies (Miskelly and Moss 1985, Konik et al 1994, Ross et al 1997), texture has generally been considered in relation to each of its components (i.e., firmness, elasticity, and smoothness) immediately after or at a fixed time after cooking, and on the same day the noodles were prepared. In the established Japanese method for ramen used in the present study, the raw noodles were held for 24 hr at 5°C before cooking, boiled for 3 min, drained, and assessed twice,

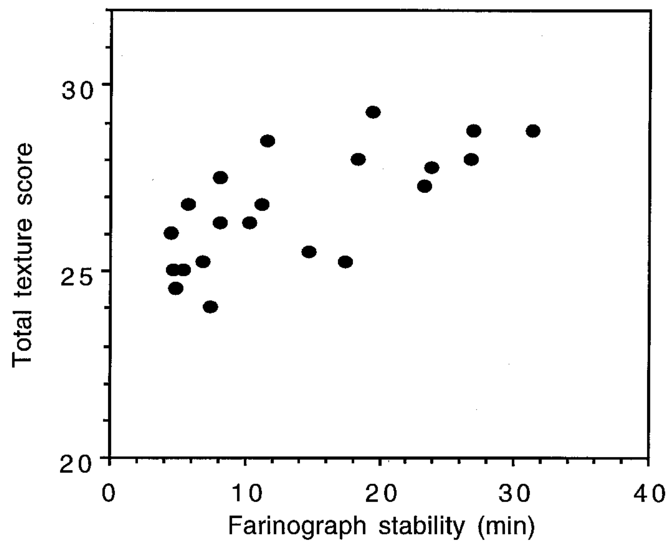

Fig. 4. Relationship between farinograph stability and total texture score.

TABLE II
Analytical Results for 21 Samples of Wheat Flour and Ramen[a]

Sample	Flour (%)		FSV (mL/g)[b]		Stability	Water				1.0 m*M* $AgNO_3$				Noodle Texture Score		
	Protein	Ash	Water	$AgNO_3$	(min)	PV	BD	SB	FV	PV	BD	SB	FV	0 min	7 min	Total[c]
JR-1	11.2	0.40	17.1	18.2	14.8	191	103	114	202	276	157	137	256	13.5	12.0	25.5
JR-2	11.5	0.38	20.2	21.7	17.5	209	124	96	180	284	173	116	226	12.5	12.8	25.3
JR-3	11.3	0.36	19.3	21.0	5.8	207	120	100	187	284	178	122	227	13.8	13.0	26.8
JR-4	11.1	0.37	17.5	18.7	23.3	175	95	104	184	255	140	137	252	14.0	13.3	27.3
JR-5	10.5	0.37	21.4	22.4	5.0	185	107	92	171	278	171	116	223	12.5	12.0	24.5
JR-6	11.8	0.38	19.0	19.8	8.2	138	92	64	110	264	159	119	225	14.3	13.3	27.5
JR-7	11.5	0.36	16.1	16.7	19.5	183	90	122	215	239	115	141	264	14.5	14.8	29.3
JR-8	11.6	0.38	19.6	20.8	4.5	196	118	89	167	277	171	112	217	12.8	13.3	26.0
JR-9	10.6	0.40	19.3	20.1	10.5	175	98	90	168	258	143	127	241	13.0	13.3	26.3
JR-10	12.2	0.38	17.0	17.5	31.5	225	124	117	218	267	151	135	250	14.5	14.3	28.8
JR-11	11.3	0.32	21.4	22.7	7.4	222	133	97	186	280	178	113	215	12.0	12.0	24.0
JR-12	11.6	0.40	16.9	18.9	11.6	192	100	117	209	247	128	139	257	14.3	14.3	28.5
JR-13	11.5	0.37	20.8	22.9	5.4	220	133	96	182	295	186	118	227	13.0	12.0	25.0
JR-14	11.2	0.38	20.8	22.9	4.7	201	119	90	172	289	176	117	230	12.5	12.5	25.0
JR-15	11.1	0.34	16.9	18.8	11.4	172	92	106	185	261	141	141	261	13.8	13.0	26.8
JR-16	11.0	0.38	17.9	19.3	8.2	193	95	123	221	274	142	151	283	13.8	12.5	26.3
JR-17	11.6	0.40	14.1	15.2	23.9	231	111	143	263	278	140	154	291	14.0	13.8	27.8
JR-18	10.0	0.34	20.1	22.3	7.0	217	135	98	181	312	198	125	240	13.3	12.0	25.3
JR-19	10.9	0.34	14.4	15.2	27.0	215	104	130	241	268	144	141	265	14.3	14.5	28.8
JR-20	11.6	0.37	14.8	16.1	26.8	202	98	133	237	237	116	145	266	14.0	14.0	28.0
Commercial	11.0	0.33	15.1	17.0	18.5	182	95	118	205	238	125	126	239	14.0	14.0	28.0

[a] FSV = flour swelling volume; PV = peak viscosity; BD = breakdown; SB = setback; FV = final viscosity.
[b] 0.5 m*M* $AgNO_3$ used for FSV tests.
[c] Total score may not equal sum of components due to rounding.

immediately after boiling (within 2–3 min) and after immersion in hot water or soup for 7 min. In this method, texture was assessed as a single score representing a balance of textural properties: springiness, firmness or hardness, smoothness, and "cutting feel". The noodles should ideally be firm, springy, and smooth, and have a clean, nonsticky cutting feel. Assessments were made by a trained panel of four people in accordance with the method described by Nagao (1996). The samples were coded and randomized with the control being the only sample known to the panel. No communication between panelists was permitted while the sensory tests were conducted. Noodles made from the commercial ramen flour served as the control sample in this study. Samples were scored in relation to the control, which was given a score of 14 points, or 70% of the maximum 20 points allocated for texture, at each of the two times of assessment. Total texture score was the sum of the two scores. The median score of the four panelists was used in the various statistical analyses.

Statistical Analyses

Statistical analyses were made using Microsoft Excel Version 5.0. Pearson and partial correlation coefficients were calculated to determine associations between flour parameters and noodle texture scores.

RESULTS AND DISCUSSION

Effect of $AgNO_3$ Concentration on α-Amylase in RVA Tests

The rain-damaged wheat sample had a FN of 209 sec. Inactivation of the α-amylase in this sample was essentially achieved at $AgNO_3$ concentrations of ≥0.5 m*M* (Fig. 1). This concentration was higher than that required for the inactivation of high levels of α-amylase in the FSV test in which much of the enzyme was heat-inactivated (Crosbie and Lambe 1993). In subsequent RVA tests, a higher concentration of 1 m*M* was used to allow for the possibility of higher α-amylase levels in some samples. This concentration was the same as that used by Bhattacharya et al (1997) to inactivate α-amylase in RVA studies on Iranian landraces of wheat, but much lower than the 12 m*M* solution used in studies by Batey et al (1997).

Effectiveness on Blends of Sound and Germinated Grain

Falling number values of the blends of sound and germinated grain ranged from 177 to 472 sec for the Eradu sample set and 161 to 427 sec for the Kulin set. The general effectiveness of 1 m*M* $AgNO_3$ as an inactivation treatment for use in RVA tests is indicated in Fig. 2. Without inactivation, the varying levels of α-amylase caused substantial variation in the RVA traces for each set of samples. However, the use of 1 m*M* $AgNO_3$ resulted in a much narrower spread of RVA traces for each set.

The tests confirmed that 1 m*M* $AgNO_3$ was effective in nullifying the effect of α-amylase on RVA peak viscosity tests on whole meal, at FN levels down to at least 161 sec (Fig. 3). Without inactivation, peak viscosity is particularly sensitive to changes in α-amylase at FN levels up to at least 500 sec; this has important implications in any research where the inherent starch quality is to be measured. The extreme sensitivity of PV to α-amylase was previously reported by Ross et al (1997). Close inspection of Fig. 2 shows that, without inactivation, a sample of the high-swelling cultivar Eradu with FN ≈ 300 sec could be misclassified as a low-swelling type because its RVA peak viscosity was similar to that of a sound sample of the low-swelling cultivar Kulin.

The relative effect of α-amylase on FSV and individual RVA parameters is indicated by the respective coefficients of variation, for tests made in water on each of the two sample sets (Table I).

Among RVA parameters, BD gave the lowest coefficient of variation in water, suggesting that it was the RVA parameter least affected by α-amylase. FSV had the lowest coefficient of variation of all parameters measured, confirming the relative insensitivity of this test to α-amylase (Crosbie and Lambe 1993).

Coefficients of variation were substantially reduced for all RVA parameters when tests were made in 1 m*M* $AgNO_3$ (Table I), again confirming the importance of α-amylase inactivation in RVA tests if the prime focus is to measure the inherent pasting properties.

Relationships Between Flour and Noodle Qualities

The wheat samples that were milled to produce 20 of the 21 flours used in this study had FN 408–706 sec. These levels are normally considered indicative of sound grain containing low levels of α-amylase. Analytical data on the flours and corresponding noodle texture scores are presented in Table II.

Protein content of the 21 flour samples was 10.0–12.2%, while ash levels were 0.32–0.40%. These levels are similar to those quoted by Nagao (1996) for alkaline noodle flours in Japan (10.5–12.0% and 0.33–0.38%, respectively). The commercial ramen flour included in this study contained 11.0% protein and 0.33% ash. The FSV of the commercial flour, assessed in water, was the fourth lowest (15.1 mL/g) of the values for the sample set. The PV and BD of the commercial sample assessed in 1 m*M* $AgNO_3$ were the second lowest and third lowest of the sample set (238 and 125 RVU, respectively). Dough stability of the trial samples varied widely, while that of the commercial flour was within this range (18.5 min). The texture of the boiled noodles prepared from the trial samples also varied widely, with only four samples exceeding the total quality score of the commercial flour (28.0 total texture score).

Correlations between RVA parameters and texture scores of alkaline noodles were improved by the use of $AgNO_3$ (Table III). This was consistent with the findings of Ross et al (1997), who reported improvement when Na_2CO_3 solution, which inactivated α-amylase, was used. Greatest improvement occurred with PV. When assessed

TABLE III
Pearson Linear and Partial Correlation Coefficients Between Flour Pasting and Swelling Parameters and Ramen Texture Scores

	Texture Score					
	Water			$AgNO_3$ Solution[a]		
Test Measurement	**0 min**	**7 min**	**Total**	**0 min**	**7 min**	**Total**
Pearson correlation coefficient						
Peak viscosity (PV)	–0.21	–0.08	–0.14	–0.58**	–0.74**	–0.71**
Breakdown (BD)	–0.57**[b]	–0.49*	–0.56**	–0.69**	–0.77**	–0.78**
Setback (SB)	0.51*	0.52*	0.55**	0.71**	0.49*	0.63**
Final viscosity (FV)	0.41	0.46*	0.47*	0.65**	0.46*	0.59**
Flour swelling volume (FSV)	–0.80**	–0.77**	–0.83**	–0.80**	–0.79**	–0.85**
Partial correlation coefficient, holding farinograph stability constant						
Peak viscosity (PV)	–0.46*	–0.34	–0.43	–0.64**	–0.62**	–0.57**
Breakdown (BD)	–0.54*	–0.45*	–0.55*	–0.49*	–0.60**	–0.62**
Setback (SB)	0.13	–0.05	0.12	0.53*	0.11	0.35
Final viscosity (FV)	0.01	0.00	0.00	0.45*	0.10	0.31
Flour swelling volume (FSV)	–0.64**	–0.50*	–0.63**	–0.64**	–0.53*	–0.66**

[a] 1 m*M* $AgNO_3$ used for Rapid-Visco Analyser (RVA) tests; 0.5 m*M* $AgNO_3$ used for flour swelling volume (FSV) tests.
[b] * and ** = $P \leq 0.05$ and 0.01, respectively.

with water, this character was not correlated with texture; however, when assessed in 1 m*M* $AgNO_3$, PV was significantly correlated with total texture score and its components. BD, SB, and FV were more stable RVA parameters with low but significant correlations with total texture when assessed in water but higher correlations in 1 m*M* $AgNO_3$. While PV, BD, SB, and FV were all significantly correlated with noodle texture when measured in 1 m*M* $AgNO_3$, the correlations involving PV and BD were of highest magnitude.

FSV was also highly correlated with the various texture scores, when assessed in water (Fig. 3) and 0.5 m*M* $AgNO_3$. This further indicated the relative insensitivity of the FSV test to low levels of α-amylase.

Partial correlation analysis also indicated that FSV, PV, and BD were significantly correlated (negatively) with total texture score and its two components independently of any effect of protein quality (farinograph stability).

Effect of Protein Content and Quality

Protein content was not correlated with total texture score, reflecting the deliberate selection of material with a small protein range.

Farinograph stability was significantly correlated with texture score assessed immediately after boiling ($r = 0.67$, $P \leq 0.01$), after 7 min ($r = 0.70$, $P \leq 0.01$), and with total texture score ($r = 0.71$, $P \leq 0.01$). Partial correlation analysis, holding RVA breakdown constant, confirmed that farinograph stability had a fundamental relationship with texture score at 7 min ($r = 0.44$, $P \leq 0.05$) and total texture score ($r = 0.46$, $P \leq 0.05$). An inspection of the data points in Fig. 4 indicates that the best ramen produced from this sample set came from lines of medium to high dough stability.

CONCLUSIONS

This study has pointed to a requirement of low to moderately low starch-swelling properties (FSV ≈14–17.5 mL/g) and moderately high to high farinograph dough stability (≈10–30 min) in flour for the manufacture of Japanese ramen. This is in addition to an established protein requirement of ≈10.5–12.0% in the flour (Nagao 1996). Starch quality in this study was characterized by RVA and FSV testing. RVA parameters were influenced appreciably by low levels of α-amylase in the flour, with PV being more affected than BD. Also, 1 m*M* $AgNO_3$ was found to be an effective inactivation treatment. The need for inactivation of α-amylase in RVA tests was also apparent from studies of relationships between flour RVA parameters and noodle texture. Correlation coefficients were significantly increased if RVA tests were made in 1 m*M* $AgNO_3$ instead of water. The increase with PV was greater than with BD, which is consistent with the relative effects of α-amylase on these two characteristics. The lack of use of an inactivation treatment in some previous studies explains why BD has consistently been reported as a useful indicator of noodle texture and also explains why PV was sometimes not correlated with texture. FSV was highly correlated with the various noodle texture scores when assessed in water and 0.5 m*M* $AgNO_3$, confirming that the FSV test was relatively unaffected by low levels of α-amylase. Farinograph stability was also significantly correlated with texture score. These results are further indication that starch characteristics, in addition to protein quantity and quality, need to be considered when selecting flour and wheat breeding lines with superior quality for the manufacture of Japanese ramen.

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