Oriental Noodle Dough Rheology: Relationship to Water Absorption, Formulation, and Work Input During Dough Sheeting

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ABSTRACT

Flours from three Canadian wheat classes were processed into oriental noodles at four water absorptions, without additive or with 1% NaCl, 1% kansui, or 1% NaOH. Noodles were prepared using an Ohtake noodle maker equipped with pressure transducers and a data capture system to measure pressure exerted against the rolls during sheeting. Dynamic rheological properties of the doughs were measured with a Bohlin VOR rheometer 2.5 and 24 hr after processing. Rheological properties were contributed to mainly by the elastic character of the doughs. Water absorption and formulation significantly affected the elastic modulus (G'). These trends were consistent between wheat classes. Dough stiffness showed an inverse relationship to water absorption. When compared to doughs prepared without additive, NaCl had little effect on dough stiffness. NaOH greatly increased dough stiffness; kansui showed an intermediate effect. Doughs containing NaOH continued to increase in stiffness over 24 hr, indicating that the effect of pH may be time-dependent.

Oriental noodles are a major dietary component in many Asian countries. Noodles differ widely in composition, method of preparation, and presentation depending on regional preference. Common ingredients in oriental noodles include sodium chloride, kansui (mixtures of sodium and potassium carbonates), and occasionally NaOH, in combination with flour and water. Ingredients and wheat type affect processing characteristics and quality attributes of resulting doughs and noodles.

Moss et al (1986) found that alkaline conditions from addition of kansui or NaOH increased water absorption and reduced farinograph mixing requirements. Similar farinograph results were reported by Lorenz et al (1994) using various mill fractions. Extensigraph testing indicated that doughs containing alkaline salts were tougher and less extensible (Lorenz et al 1994, Moss et al 1986). Doughs containing NaOH could not be tested in the extensigraph because at higher absorptions doughs were too sticky to handle (Moss et al 1986). Testing in all of these studies was carried out at moisture levels corresponding to bread dough absorptions.

Dynamic mechanical testing has been used to study fundamental rheological properties of wheat flour doughs at bread dough absorptions by several researchers (Navickis et al 1982, Dreese al 1988, Lindahl and Eliasson 1992, Berland and Launay 1995). Some studies have been carried out to determine the effects of oxidizing and reducing agents (Dong and Hoseney 1995) and emulsifiers (Berland and Launay 1995) on wheat flour doughs, also at bread dough absorptions, using dynamic testing methods. We are unaware, however, of any published rheological data where testing was performed at moisture contents used in noodle doughs or on the effects of additives used in noodle formulations.

This study examines the rheology of noodle doughs as affected by various formulations for flour milled from three different wheat classes. The rheological technique used was small strain dynamic rheometry and was carried out in absorption ranges typically used for the production of oriental noodles.

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MATERIALS AND METHODS

Wheats

Wheats of milling grade representing three classes, Canada Western Red Spring (CWRS), Canada Prairie Spring White (CPSW), and Canada Western Soft White Spring (CWSWS), were obtained from commercial sources.

Milling

Sixty-kilogram samples were milled using the Grain Research Laboratory pilot mill (Black 1980). Wheats were tempered overnight to the appropriate moisture content: 16.5% for CWRS, 15% for CPSW, and 14.5% for CWSWS. Mill streams of the highest refinement in terms of ash content were used to produce patent flours of approximately 60% extraction (Table I).

Flour Characteristics

Protein content was determined by the Kjeldahl method as modified by Williams (1973). Ash content and starch damage were determined according to AACC (1983) methods 08-01 and 76-30A, respectively (Table I). All analytical data are expressed on a 14% moisture basis. Flour grade color was determined using a Colour Grader Series IV (Satake UK, Stockport, UK) using Flour Testing Panel Method No. 007/4 (Flour Milling and Baking Research Association 1991) and expressed in Satake International colour grade units. Farinograph mixing characteristics were obtained using AACC (1983) method 54-21.

Noodle Dough Preparation

Ingredients and flours were mixed at four water absorption levels (28, 30, 32, and 34%) using 200 g of flour in a Hobart N50 mixer and sheeted using an Ohtake noodle maker (Kruger et al 1994a). At each water absorption level, ingredients included either 1% NaCl, 1% NaOH, 1% kansui (9:1 Na_2CO_3 and K_2CO_3), or no additive (control). Each sample was processed in triplicate. The Ohtake noodle maker was equipped with pressure transducers that measured pressure exerted against the rolls during sheeting. Work input was calculated from the measurements taken during sheeting passes. Samples were stored in self-sealing plastic bags immediately after processing.

Dynamic Rheometry

A Bohlin VOR rheometer (Bohlin Reologi Inc., Edison, NJ) was used in oscillatory mode to measure noodle dough viscoelastic properties. The rheometer was equipped with 30-mm parallel plate geometry and a 93.2 g·cm torque element. Strain sweeps were performed at fixed frequency of 0.2 Hz with increasing strain. A linear viscoelastic region was established at strain between 0.02 and 0.06% (Fig. 1). Viscoelastic measurements were subsequently taken at constant temperature of 25°C and frequency range of 0.02–5.0 Hz, and noodle texture determined in terms of elastic modulus (G'), viscous modulus (G''), and dynamic viscosity (η'). Data points at the two lowest frequencies (0.02 and 0.05 Hz) were dropped because they appeared erratic, probably because the torque was too low to be accurately measured.

Three 30-mm discs were cut from each sample for testing. The outer exposed edge of the disc was coated with light mineral oil (Sigma Chemical Co., St. Louis, MO) once the disc was placed in position for testing and the upper plate brought down to the sample surface. This prevented drying of the sample at the edges, which can lead to altered moduli. There was no evidence of migration of oil between the sample and plate surfaces, indicating little possibility of slippage due to oily sample surface.

Experimental Design

Noodle doughs were prepared containing either 1% NaCl, 1% NaOH, 1% kansui, or no additive as a control, at each of four water absorptions (28, 30, 32 or 34%) in triplicate (n = 144). A sample of CWRS with 1% salt at 28% water absorption was processed and tested daily to monitor consistency. Sheeted doughs from a single wheat class were prepared and tested in all possible combinations over the period of one week in random order. Samples were stored in self-sealing plastic bags and allowed to rest 2.5 hr before rheological testing. All samples were tested again after 24 hr. The model was a randomized block design, with the main factors being wheat class, additive, absorption level, and time. Statistical analyses were carried out using the general linear model analysis of variance procedure provided by SAS statistical software (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Flour Characteristics

Starch damage increased with increasing wheat hardness. Farinograph results for the three flours showed them to be typical of their wheat class (Table I). The strongest flour was CWRS with relatively long stability and low mixing tolerance index, followed by CPSW, which was intermediate in strength, and CWSWS, which showed short development time and stability and high mixing tolerance index. Water absorption was highest for CWRS (63.5%) and lowest for CWSWS (53.6%). These variations in water absorption result from intrinsic differences in protein content and quality and in starch damage.

TABLE I
Flour Properties[a]

Property	CWRS	CPSW	CWSWS
Protein, %	12.3	10.0	9.0
Ash, %	0.40	0.47	0.39
Flour Grade Color, Satake International units	–1.6	–2.9	-0.4
Starch Damage, AACC units	8.7	7.1	4.2
Farinograph			
Absorption, %	63.5	58.8	53.6
DDT[b], min	2.25	2.25	0.75
MTI[c], BU	25	95	165
Stability, min	8.50	2.50	1.00

[a] CWRS = Canada Western Red Spring, CPSW = Canada Prairie Spring White, CWSWS = Canada Western Soft White Spring.
[b] Dough development time.
[c] Mixing tolerance index.

Sheeting Characteristics

Work measurements taken during dough sheeting decreased as absorption level increased and consistently ranked CWRS as stronger than CPSW, with CWSWS requiring the least work input during sheeting (Fig. 2). Preliminary work by Kruger et al (1994b) demonstrated similar results. Absorption levels used were significantly lower than optimum absorptions determined by farinograph (Table I). Rankings of work input during sheeting at lower noodle absorptions was consistent with farinograph mixing characteristics regardless of additive.

Addition of common salt or NaOH "toughened" the various doughs resulting in increased work measurements during sheeting relative to control samples (Fig. 2). Salt addition to CWRS at lower absorptions, and addition of salt as well as NaOH to CPSW and CWSWS resulted in significant increases in work input relative to control samples. In general, work input requirements upon addition of kansui were not significantly different from control samples. Similar results have been previously reported by other authors (Lorenz et al 1994, Moss et al 1986), using farinograph data at higher absorptions.

Dynamic Rheology

Doughs were characterized by elastic modulus (G') as this was by far the largest contributor to dough viscoelastic properties. The trends for G^*, the complex modulus from which G' and G'' are derived, followed those of G' and indicated the strong contribution of the elastic component. Abdelrahman and Spies (1986) established phase angle of wheat flour doughs to be approximately

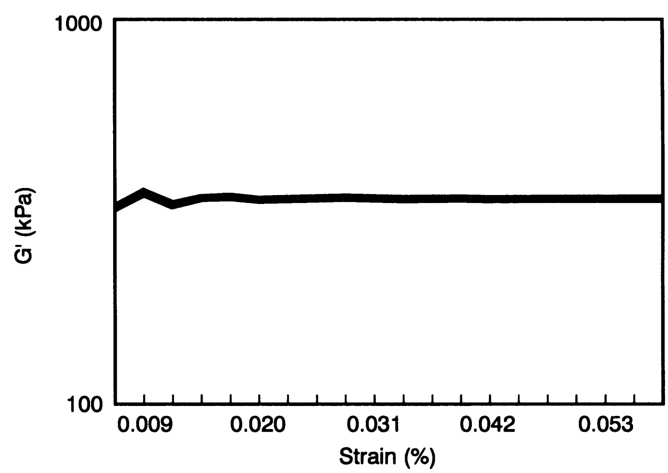

Fig. 1. Strain sweep, 0.2 Hz.

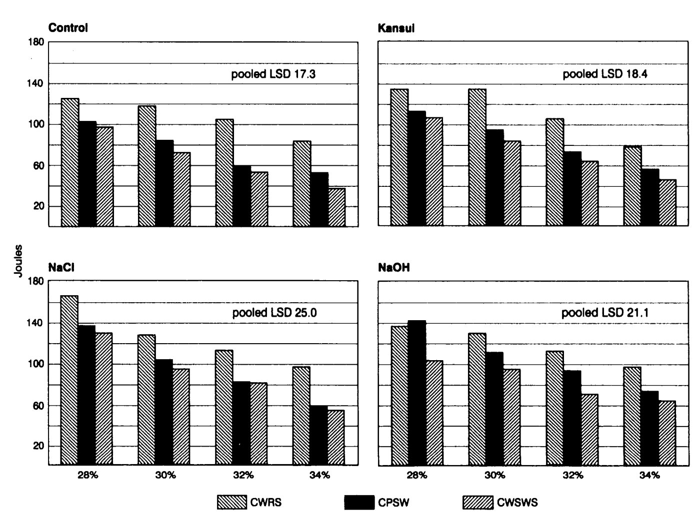

Fig. 2. Work input during noodle dough sheeting.

30°, where 0° is completely elastic and 90° is completely viscous. This was later confirmed by Lindahl and Eliasson (1992) working with lower moisture durum and common wheat flour doughs.

Water absorption strongly affected dynamic rheological results. Elastic modulus decreased with increased moisture for all classes and all noodle dough types (Fig. 3). This phenomenon has been documented in flour doughs (Lindahl and Eliasson 1992, Navickis et al 1982). It is worth noting that doughs used in this study were lower moisture systems than those previously reported and that the same trends held true.

Little difference was observed among the elastic moduli of the three wheat classes for a given additive at a given absorption (Fig. 3). Kansui noodle doughs tested 2.5 hr after processing displayed no statistically significant ($P > 0.05$) differences among wheat classes at any absorption. CPSW dough containing NaOH at 28% absorption was stiffer (higher G') than both CWRS and CWSWS, but there were not differences among wheat classes at any other absorption. Control doughs displayed no statistically significant differences except at 32% absorption where CWSWS was stiffer than CWRS and CPSW. Salt doughs made from CWSWS were stiffer than both CWRS and CPSW at all absorptions. The general lack of large differences in rheological properties among wheat classes persisted after resting doughs for 24 hr after processing (Fig. 4). To ensure that this conclusion on lack of differences among wheat classes based on G' was correct, the results for G^* were examined. There were three cases where G^* was significantly different ($P < 0.05$) among wheat classes at a given absorption where G' was not significantly different. The extremes in absorption, 28 and 34%, in the control sample accounted for two of the cases. The third was salt at 28% absorption. The largest phase angle observed in any of these three cases was 19°, leaving G' remaining as the largest contributor to the viscoelastic properties of the doughs, and confirming the conclusion on the effect of wheat class on noodle dough rheology.

It was unexpected that there was no difference in G' among wheat classes given the intrinsic differences in the wheats. Kruger et al (1994a) demonstrated dramatic time-dependent changes in raw Cantonese noodles when later cooking the product to determine noodle texture, particularly in the first 4 hr after processing. They suggested the changes may be the result of protein relaxation, as well as alteration of protein and starch by enzymes and effects of alkali. The relaxation processes noted by Kruger et al (1994a) may have been acting on our noodle dough samples over the 2.5 hr between processing and dynamic mechanical measurements, thus reducing wheat class differences.

As seen by the farinograph results, the wheat classes vary in their optimum water absorptions and mixing strength characteristics due to a combination of differences in protein quality and quantity, and in starch damage produced during milling (Table I). Noodle doughs are inherently limited in moisture content, thus accentuating competition for available water. Daniels (1975) established that there are fundamental changes in dough structures at 45% absorption resulting in formation of a truly extensible dough system. At absorption levels lower than 45% there was insufficient available water present to allow gluten development. It is possible that at noodle dough absorptions there is sufficient water deficit to preclude detection of differences among flours of different wheat classes that are apparent at bread dough absorptions.

Differences can be expected in the relationship between the work required to sheet the dough and storage modulus. In this study, in general, there was not good correlation between work input and storage modulus. Sheeting measurements were essentially taken from time zero when all particles may not be fully hydrated and moisture distribution not uniform, compared to storage modulus determinations taken at 2.5 and 24 hr. Moss et al (1987) found that during the mixing stage there was very little gluten development in noodle doughs. After compression and reduction sheeting of dough containing salt or kansui, there was a uniform protein matrix with endosperm particles fused together. Dexter et al (1979) found that the addition of 2% common salt to Japanese noodle dough resulted in uniform matrix development. Moss et al (1986) reported that the protein matrix of dough containing NaOH was not as continuous or as uniform as in doughs prepared with common salt or kansui after the compression stage of sheeting. After reduction passes, dough containing NaOH was somewhat more developed, but still not to the same extent as doughs containing salt or kansui. The added salt, kansui, or NaOH may have increased competition for available water to varying degrees, resulting in delayed protein hydration and matrix development, contributing to the "toughness" of these noodle doughs relative to the control during sheeting. Doughs containing salt in these experiments appeared to "mellow" over the 2.5 hr prior to dynamic mechanical testing and were not different from the control samples. As mentioned previously, it is possible that over the initial 2.5 hr, relaxation of the proteins occurred, as well as moisture redistribution resulting in similar G' values.

Regardless of wheat class or water absorption level, doughs ranked consistently according to additive (Fig. 3). Doughs containing NaOH were stiffest, with the highest G'. Salt had no effect on G' relative to control samples irrespective of wheat class or absorption level. Kansui appeared to exert an effect intermediate to NaOH and control samples. Differences due to additive became more pronounced as water absorption increased. Comparison of Figure 4 with Figure 3 indicates that NaOH continued to exert an

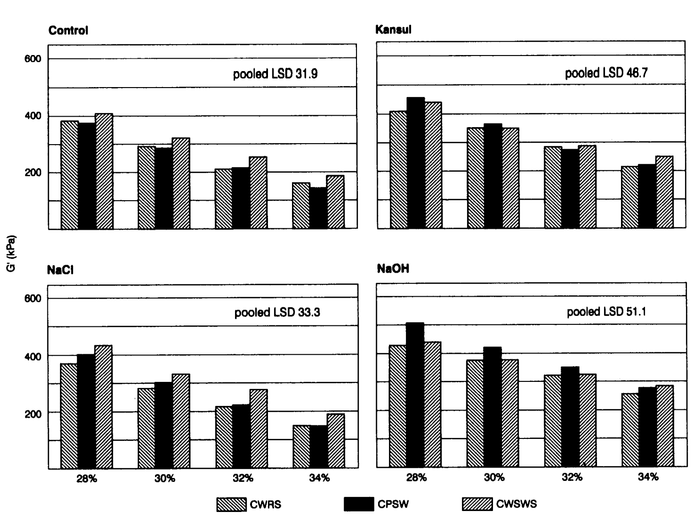

Fig. 3. Elastic modulus at 2.5 hr. Values are means across the frequency range of 0.1–5.0 Hz.

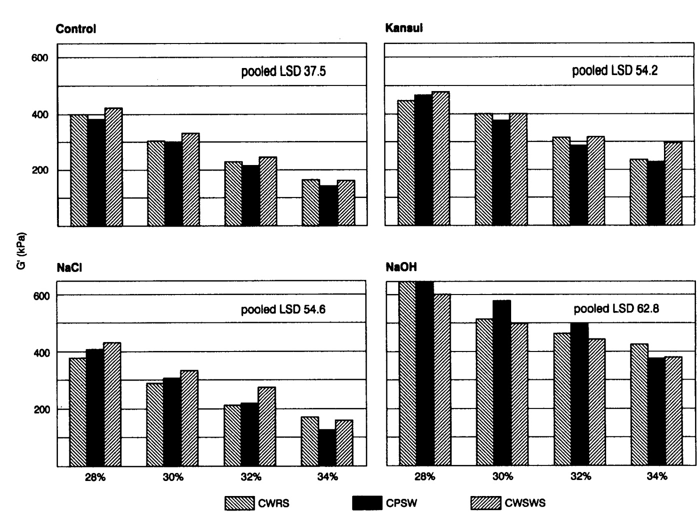

Fig. 4. Elastic modulus at 24 hr. Values are means across the frequency range of 0.1–5.0 Hz.

effect on noodle doughs over a 24-hr period, with G' increasing. Neither salt nor kansui displayed any change after initial measurements taken 2.5 hr after processing. Ranking of noodle dough formulations was in agreement with the work of Moss et al (1986) in which they ranked similar formulations using farinograph data at high (bread dough) water absorptions. Shelke et al (1990) found that addition of salt to noodle dough had no effect on firmness of partially cooked noodles, in agreement with the current dynamic mechanical testing results.

Kansui and NaOH addition increase pH of the doughs substantially. Measurements by Moss et al (1986) indicated pH values of doughs with these additives, at the same level of addition, were 9.8 or greater. Noodle doughs containing kansui appeared to increase in firmness over the first 2.5 hr after processing relative to the work during sheeting rankings, giving higher G' than salt-containing or control samples, indicating that the effect of pH was time-dependent. Doughs containing NaOH, which were more alkaline than kansui, were the stiffest doughs and G' increased over a 24-hr time period. Addition of NaOH may have resulted in swelling and gelatinization of starch granules (Lancaster and Conway 1968, Ragheb et al 1995), which over time retrograded, thus increasing G' over 24 hr. Increased cross-linking and chain aggregation and entanglements have been shown to increase G' in aging starch gels (Biliaderis and Zawistowski 1990).

CONCLUSIONS

Ranking of wheats by work exerted during sheeting was consistent with their mixing strength characteristics, with CWRS > CPSW > CWSWS. In contrast, there was little difference in elastic modulus (G') among wheat classes within treatments even though at bread dough absorptions they were very different in mixing strength characteristics.

Work measurements during sheeting indicated that addition of salt or NaOH strengthened the doughs relative to control doughs. Doughs containing kansui required similar work input to control samples during sheeting.

When ranked by G' salt doughs and control doughs were the same. Doughs containing NaOH were consistently the stiffest and those containing salt and the control doughs were always most compliant. Doughs containing kansui were intermediate to NaOH and salt or control. These rankings were unaffected by wheat type or water absorption. Ranking of dough stiffness according to formulation was in agreement with farinograph data obtained by Moss et al (1986) using higher (bread dough) absorptions.

Dynamic rheological testing indicated that the effect of pH may be time dependent. Noodle doughs containing kansui were somewhat stiffer (higher G') than salt and control doughs 2.5 hr after processing. Doughs made with NaOH had significantly higher G', and continued to increase in G' over 24 hr. Increased G' may have been due to alkaline gelatinization and subsequent retrogradation of starch.

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