Influence of Alkaline Formulation on Oriental Noodle Color and Texture[1]

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ABSTRACT

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Patent (60% yield) and straight-grade flours of Canada Western Red Spring (CWRS) and Canada Prairie Spring White (CPSW) wheat were used to determine the influence of different ratios of alkaline salts, their concentration, and NaCl on the texture and color characteristics of the yellow alkaline noodles. Addition of 3% (w/w) salt to any formulation resulted in a significant increase in the amount of work required to process the raw noodles, while significantly lower work input was observed for noodles prepared using a 5% (w/w) 9:1 Na-to-K carbonate ratio without salt formula. Wheat class, extraction rate, and alkali formulation had a significant effect on raw noodle brightness with noodles prepared using 5% carbonate being brighter than the 1% carbonate noodles. Maximum cooked noodle thickness was achieved from all flours using a 1% 9:1 Na-to-K carbonate ratio, 3% salt formulation. The inclusion of 3% NaCl into the formula resulted in noodles significantly thicker than the corresponding salt-free formula for all flours. Cooked noodle texture parameters evaluated were maximum cutting stress (MCS), resistance to compression (RTC), recovery (REC), and stress relaxation time. In all cases, the presence of 3% salt in the various formulations resulted in a decrease in each parameter relative to the corresponding salt-free formulation. Desirable bite (MCS), chewiness (RTC, REC), and relaxation times were achieved with a 1% concentration of alkali salts, without NaCl, regardless of the Na-to-K carbonate ratio. Use of a 5% concentration of alkali salts resulted in a significant reduction in texture that was most pronounced for the 1:9 Na-to-K carbonate formulation.

Noodles are a staple of the Southeast Asian diet, with alkaline Chinese or Cantonese noodles having the dominant market share. While commonplace, there is a wide diversity in the formulation and quality available to the consumer. Differences between countries are normal, however neighboring regions within a country also exhibit unique cultural or ethnic preferences. Alkaline noodles are made from flour, water, a variety of alkaline salts, and sodium chloride, depending on local tastes. The alkaline salts are usually sodium and potassium carbonates, exhibiting a diversity of ratios and dosages, although in some countries, particularly Malaysia, sodium hydroxide is also employed. The discriminating consumer initially assesses noodle quality on the basis of its visual appeal (color, brightness, and the absence of undesirable specks) followed by mouthfeel and textural characteristics.

Previous research has primarily focused on biochemical factors (Miskelly 1984; Miskelly and Moss 1985; Moss et al 1986; Kruger et al 1992; Mares 1992; Mares et al 1995) relevant to alkaline noodle color. The alkaline noodles owe their unique color to endogenous colorless flavones known as apigeninglycosides (Mares 1992; Mares et al 1995), which undergo a chromophoric shift in the alkaline environment to impart a yellow color to the noodle. As alkaline noodles are often consumed up to 24 hr after production, numerous studies have been undertaken to investigate factors influencing color stability over time (Hatcher and Kruger 1993; Baik et al 1995; Crosbie et al 1996; Miskelly 1996; Hatcher and Kruger 1996; Hatcher et al 1999; Hatcher and Symons 2000). A proposed standardized method to assess alkaline noodle color (Morris et al 2000) identified noodle sheet thickness, water absorption, sodium chloride levels, and mixing time as factors.

While considerable research has been devoted to studying these important criteria of noodle color, limited investigation (Moss et al 1986; Kruger et al 1994, 1995; Hatcher et al 1999) has been undertaken to explore the impact of different alkaline formulations on the textural attributes of the noodles. Canada Western Red Spring (CWRS) and Canada Prairie Spring White (CPSW) wheat are used extensively by commercial Asian manufacturers for the production of yellow alkaline noodles. The objective of this study was to evaluate the impact of different alkali formulations in the presence or absence of NaCl on the textural attributes of cooked noodles. Noodles were prepared from two flours representing the different degrees of refinement commonly used throughout Southeast Asia, using the two different classes of Canadian wheat to highlight potential differences. Preliminary limited findings from this study were presented at the ICC conference (Hatcher and Anderson 2005).

MATERIALS AND METHODS

Wheat and Flour

Canada Western Red Spring (CWRS) and Canada Prairie Spring White (CPSW) wheat, both No. 1 grades, were milled on a GRL tandem Buhler mill as in Martin and Dexter (1991) to yield patent (60%) and straight-grade flours (74%) characterized in Table I.

Analytical Methods

Protein content (% N × 5.7) was determined by combustion nitrogen analysis (CNA) (model FP-248 Dumas CNA analyzer, Leco Corp., St. Joseph, MI) calibrated with EDTA. Ash content, starch damage, farinograph, extensigraph, and amylograph were determined by Approved Methods 08-01, 22-10, 54-10, 54-20,

TABLE I
Canada Western Red Spring (CWRS) and Canada Prairie Spring White (CPSW) Flour Properties

	CWRS		CPSW	
Properties[a]	Patent	Straight-Grade	Patent	Straight-Grade
Protein (%)	11.8	12.2	10.4	11.0
Wet gluten (%)	31.5	31.7	31.7	32.7
Ash (%)	0.40	0.49	0.43	0.52
Color (SIU)	–3.7	–1.8	–4.4	–2.5
Agtron (%)	80	66	86	74
Starch damage	6.0	6.3	5.3	5.2
Amylograph (BU)	530	480	785	750
Farinograph				
Absorption (%)	61.5	62.4	60.0	60.1
DDT (min)	3.50	3.75	2.50	2.50
MTI (BU)	25	30	90	85
Stability (min)	10.5	7.50	2.50	2.00
Extensigraph				
Length (cm)	20	21	23	26
Max. height (BU)	525	410	200	185
Area (cm^2)	145	125	75	75

[a] DDT, dough development time; MTI, mixing tolerance index; SIU, Satake international units; BU, Brabender units; AU, arbitrary units.

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and 76-31, respectively (AACC International 2000). Wet gluten was determined by Standard Method no. 137 (ICC 1980) using the Glutomatic system. Flour grade color was determined (Simon Series IV, Satake UK, Stockport, UK) following the Flour Testing Panel Method No. 007/4 (Flour Milling and Baking Research Association 1991) and expressed in Satake International units (SIU) in which the lower the number, the brighter the flour.

Noodle Preparation

Noodles were prepared using the method previously described by Kruger et al (1994). The ratio of alkaline reagents, sodium to potassium carbonate (1:9 vs. 9:1) in combination with their relative weight percentage to the flour (1 or 5%, w/w), were investigated. The varying ratios of sodium to potassium reflect the wide variations in formulation throughout Southeast Asia; range in concentration was chosen to highlight their influence. The presence of 3% (w/w) salt (NaCl) within the formulation was also studied. This elevated level, while not beyond the range of some commercial practices, was chosen to maximize any potential salt effect. The various reagents were dissolved in water and added to 200 g of flour during the initial 30 sec of mixing (N50 mixer, Hobart Canada, North York, ON). A four-stage mixing regime over 5 min ensured a homogeneous crumb mixture. Preliminary investigation was required to determine the optimum water absorption requirements, which although remaining consistent across flours, varied for different reagent combinations (32–38% at 14% mb) to yield dough with a proper hand feel that would process properly on the noodle sheeter.

The crumb mixture was sheeted on a laboratory noodle machine (Ohtake, Tokyo) with an initial gap setting of 3.0 mm. Two passes were made at this setting with the noodle sheet folded between passes to ensure homogeneity. The dough sheet was subjected to seven further reduction passes (3.0–1.1 mm) with energy requirements captured on an analog-digital board (Labmaster DMA, Scientific Solutions, Solon, OH) interfaced to a computer using Labtech Notebook software (Laboratory Technologies, Wilmington, MA). A subsequent (nonrecorded) pass through a No. 22 cutter (Kruger et al 1994) yielded individual noodle strands.

The fresh noodles were prepared and rested for 1 hr before cooking and texture evaluation. The noodles were optimally cooked until no visible core was present, rinsed under running distilled water maintained at 20°C, drained, and stored in a small sealed plastic tubs until textural analyses as in Kruger et al (1994). The preliminary evaluation of the dough crumb mixture by hand feel resulted in significant variation in the water absorption levels (32–38%). It is believed that the addition of increasing amounts of water with salt and the high carbonate concentration accounted for the relatively consistent optimum cook time (±0.25 min) achieved within the respective classes. The CPSW samples were all cooked at a standardized time of 9.0 min, while the CWRS noodle samples were cooked for 12.0 min. Cooked noodle water uptake was calculated as cooked noodle weight minus the initial 25 g of raw noodle weight.

Raw Noodle Color and Cooked Texture Analyses

A spectrocolorimeter (Labscan II, HunterLab, Reston, VA) equipped with a D65 illuminant using the CIE 1976 L^*, a^*, and b^* color scale was used to measure raw noodle color. A portion of the raw noodle sheet was folded to provide three layers of thickness and placed on the spectrocolorimeter's port. The sheet was enclosed within a blackened container to remove ambient light. Measurements were made in triplicate at two locations on the noodle sheet surface for each sample. The raw noodle sheet was stored in a sealed plastic bag at 24°C over the 24-hr period and expressed on an initial per gram basis.

Texture measurements of cooked noodle "bite", defined as maximum cutting stress (MCS); chewiness through recovery (REC); and resistance to compression (RTC) were conducted using a texture analyzer (TA-XT2i, Texture Technologies, Scarsdale, NY) with fixtures and procedures similar to those described by Oh et al (1983) and Kruger et al (1994). Cooked noodle thickness was determined by subtracting the distance traveled by the fixture at the point where a 2-g load was registered from the initial preset height (5 mm) for the fixture.

Stress relaxation was determined using the method of Sopiwnyk (1999), a modified version of the methods presented by Heaps et al (1968), Frazier et al (1973), and Rasper and deMann (1980). Cooked noodles (three strands) were compressed to a 250-g load and the stress was allowed to relax under constant sample deformation using the texture analyzer. Normal stress relaxation requires waiting until 36.7% of the initial stress is achieved (Rasper and deMann 1980). However as this was not practical, requiring >10 min/test, the time when reduction achieved 85% of the initial stress as used by Sopiwnyk (1999) was chosen.

MCS was determined exactly 10 min after cooking with REC, RTC, and stress relaxation initiated at subsequent timed 5-min intervals.

Experimental Design

All noodle formulations were prepared in triplicate following a randomized block design. Texture measurements of cooked noodles were made five times on sets of three noodles strands for each noodle replicate. All statistical analyses were conducted using the Statistical Analysis System (v.8.2, SAS Institute, Cary, NC). The analysis of variance (ANOVA) was determined using Proc GLM recognizing flour types nested within wheat class and formulation nested within flour types (Table II). Use of significance throughout the manuscript is $P < 0.05$ unless stated otherwise.

RESULTS AND DISCUSSION

Flour Analyses

While the protein content of the CWRS flours was significantly greater than that observed for CPSW, wet gluten was comparable or slightly higher in the CPSW flours (Table I). The degree of flour refinement was reflected for both wheats with an equivalent 0.09% increase in ash content in the straight-grade versus patent flours. The ash content in the CWRS flours was slightly lower than those observed for the CPSW, yet this was not reflected in either flour color grade or Agtron flour color values. The CPSW wheat due to its white seed coat exhibited preferred brightness values. The differentiating character of the wheat protein quality was evident in both the farinograph and extensigraph results. The stronger gluten dough properties of CWRS, particularly due to the

TABLE II
ANOVA Probability Results (P values) of Various Processing Parameters of Alkaline Noodles

		Raw Noodle Color				Cooked Noodle	
	Work Input	L^* 2 hr	L^* 24 hr	b^* 2 hr	b^* 24 hr	Thickness	Water Uptake
Wheat class	0.0091	0.0001	ns	0.0001	0.0001	0.0001	0.0001
Flour (wheat)	0.0020	ns[a]	0.0006	0.0027	0.0004	0.0079	ns
Treatment (flour)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
r^2	0.88	0.98	0.99	0.91	0.89	0.87	0.92

[a] Not significant.

presence of high molecular weigh subunits (HMW), 5 and 10 on HMW-D, versus the corresponding 2 and 12 for CPSW, resulted in longer farinograph dough development and stability times. The currently dominant agronomic CWRS cultivars also differ with subunit 2* located on HMW-A, while CPSW lines have subunit 1. This was confirmed by extensigraph where maximum peak height and total area were much greater for CWRS flours compared with CPSW.

Work Input and Raw Noodle Color

The gluten matrix within the noodle dough is not formed during mixing but is developed during the sheeting process. The amount of energy required to properly develop the gluten is a significant component affecting the price of the final product. Wheat class, flour type, and alkali formulation all significantly affected the amount of work required to sheet noodles.

The presence of salt significantly increased the amount of work/g of dough within most formulations (Table III) even though the salt samples required greater water content to ensure proper hand feel. Although minor variations were noted, noodles prepared from either wheat class or flour type exhibited the maximum work input when prepared using a 1% alkali concentration in the presence of salt, regardless of the Na-to-K carbonate ratio. Significantly less work was generally required when noodles were prepared using a 9:1 Na-to-K carbonate ratio at a 5% concentration without salt. No influence due to protein content was discernible as differences between patent and straight-grade flours were minimal and overridden by the various alkaline formulations.

Consumers prefer alkaline noodles that are bright, free from discoloration, and have a strong yellow color. Evaluation of raw noodle sheet color prepared from both patent and straight-grade flours over time indicated that wheat class, extraction rate, and alkali formulation had a significant effect on raw noodle sheet brightness and yellowness (Table II). In all cases, the noodles prepared using the 5% alkali concentration, regardless of formulation, yielded significantly brighter noodles than their 1% counterparts over the 24-hr period. CPSW noodles, prepared from both patent and straight-grade flours using the 1:9 ratio of Na-to-K carbonates at the 5% level, yielded the brightest noodles at both 2 and 24 hr (Tables IV and V).

Reversal of the Na-to-K ratio (9:1) at the 5% level resulted in CPSW patent and straight-grade noodles displaying significantly lower L^* values for both time periods. No significant influence was detected in L^* within the 5% formulations on the basis of salt.

TABLE III
Influence of Alkaline Formulation and Flour Refinement on Water Absorption and Work Requirements for Noodle Production[a]

Na-to-K Ratio	Alkaline Conc (%)	Salt (%)	Water Absorption (%)	CPSW[b] Work (J/g)		CWRS[b] Work (J/g)	
				Patent	Straight-Grade	Patent	Straight-Grade
1:9	1	0	32	13.19bc	14.57c	14.69b	14.47bc
1:9	1	3	34	14.86a	16.95a	17.54a	16.02ab
1:9	5	0	36	13.74b	13.52de	14.11bc	12.53de
1:9	5	3	38	15.55a	14.42cd	15.07b	13.49cd
9:1	1	0	32	12.19d	14.09cd	14.99b	14.47bc
9:1	1	3	34	15.27a	15.96b	17.88a	17.17a
9:1	5	0	36	11.20e	10.36f	10.93d	12.92cd
9:1	5	3	38	12.63cd	13.00e	12.94c	10.89e

[a] Means with followed by the same letter within a column are not significantly different at $P = 0.05$.
[b] Canada Western Red Spring (CWRS) and Canada Prairie Spring White (CPSW) flour.

TABLE IV
Influence of Alkaline Formulation and Flour Refinement on Raw CPSW Noodle Color Over Time[a]

Na-to-K Ratio	Conc (%)	Salt (%)	Patent				Straight-Grade			
			L^* 2 hr	b^* 2 hr	L^* 24 hr	b^* 24 hr	L^* 2 hr	b^* 2 hr	L^* 24 hr	b^* 24 hr
1:9	1	0	83.7c	26.1a	79.2d	26.5c	80.8bc	26.0cd	73.1d	26.2c
1:9	1	3	83.2d	24.5cd	77.4f	25.0e	80.3cd	25.4d	70.3f	24.5d
1:9	5	0	84.7a	25.1bc	81.8a	26.3d	81.4a	26.6bc	77.0a	27.6ab
1:9	5	3	84.6a	24.8cd	81.4a	26.2d	81.1ab	27.4ab	76.6a	27.2b
9:1	1	0	83.6c	26.4a	78.2e	26.7b	80.4cd	26.5bc	71.8e	25.8c
9:1	1	3	83.5cd	24.2d	76.8f	24.5f	80.2d	25.3d	69.6f	23.8e
9:1	5	0	84.2b	26.2a	80.7b	27.4a	80.5cd	28.0a	75.6b	28.2a
9:1	5	3	84.0b	25.9ab	80.7b	26.5c	80.4cd	27.8a	75.6b	27.2b

[a] Mean values followed by the same letter for each color attribute are not significantly different at $P = 0.05$.

TABLE V
Influence of Alkaline Formulation and Flour Refinement on Raw CWRS Noodle Color Over Time[a]

Na-to-K Ratio	Conc (%)	Salt (%)	Patent				Straight-Grade			
			L^* 2 hr	b^* 2 hr	L^* 24 hr	b^* 24 hr	L^* 2 hr	b^* 2 hr	L^* 24 hr	b^* 24 hr
1:9	1	0	82.6 c	27.3a	78.5e	28.3a	79.3d–f	28.6 a–c	73.2d	29.3a–c
1:9	1	3	82.8c	25.5de	77.7f	26.7d	78.7f	27.9c–e	71.8e	28.1e
1:9	5	0	84.1a	24.9e	81.4a	26.4d	80.8a	27.5de	76.7a	28.2de
1:9	5	3	83.6ab	26.2cd	80.8b	27.2c	80.2ab	28.2b–d	76.0b	28.5c–e
9:1	1	0	82.9c	26.8a–c	77.8f	27.9b	79.4c–f	28.1b–d	72.2e	28.7
9:1	1	3	82.8c	25.3e	77.1g	26.4d	78.9ef	27.0e	70.9f	27.0f
9:1	5	0	83.1bc	27.4a	80.0c	28.5a	80.0b–d	29.5a	76.0b	29.6ab
9:1	5	3	83.2bc	26.4bc	80.1c	27.3c	80.0bc	28.9ab	75.8b	29.1b–d

[a] Mean values followed by the same letter for each color attribute are not significantly different at $P = 0.05$.

Minimal differences were observed in CPSW noodle brightness at 2 hr based a 1% Na-to-K carbonate ratio (1:9 vs. 9:1) in the presence or absence of salt. However, aging raw CPSW noodles for 24 hr highlighted differences due to both the Na-to-K carbonate ratio and the presence of salt. Noodles, patent or straight-grade, prepared with 1% 1:9 Na-to-K carbonate, without salt, yielded significantly brighter noodles than the corresponding salt-free 1% 9:1 Na-to-K carbonate noodles. In all 1% Na-to-K noodle preparations, the incorporation of salt into the formulation resulted in a significant decline in noodle brightness at 24 hr which was not observed at the 5% level.

Noodles prepared using CWRS flour exhibited the same general patterns as those of CPSW although the differences were not as noticeable (Tables IV and V). The brightest noodles at 2 hr were achieved with 5% alkali 1:9 Na-to-K carbonate formulas, which were significantly brighter than those prepared with any 1% alkali formula. The 5% 1:9 Na-to-K no-salt formula CWRS patent or straight-grade flour noodles were also significantly brighter at both 2 and 24 hr than the corresponding 9:1 Na-to-K formula. The addition of 3% salt to any formulation (1 or 3%) did not influence CWRS noodle brightness at 2 hr. However, significant differences in brightness were observed with aging. The 5% 1:9 Na-to-K formula patent or straight-grade noodles demonstrated a significant decline in L^* values at 24 hr in the presence of salt, which was not apparent in the noodles prepared using the 5% 9:1 Na-to-K formulations. All CWRS noodles prepared using any of the 5% formulations were significantly brighter than the corresponding 1% formulations after 24 hr.

Noodle yellowness is an important criterion for discriminating consumers. As the colorless flavanoids undergo a chromophoric shift in an alkaline environment, measurement of the pH of the kansui solutions due to the alkali formulation or concentration indicated no differences (pH 11.3 ± 0.1). Analysis of b^* values indicated that the 5% 9:1 Na-to-K carbonate no-salt formulation consistently yielded the highest b^* values for both CPSW patent and straight-grade flours at both 2 and 24 hr. While the addition of 3% salt in this formula did not influence yellowness values at 2 hr, a significant decline in b^* was detected at 24 hr. The lowest b^* values were consistently observed in CPSW patent and straight-grade noodles using a 1% 9:1 Na-to-K carbonate, 3% salt formula across both time periods. Consistent with CPSW, CWRS patent and straight-grade noodles exhibited the highest b^* values at both time intervals when prepared using a 5% 9:1 Na-to-K no-salt formula. However, unlike CPSW, use of the 1% 1:9 Na-to-K carbonate no-salt formula yielded statistically equivalent b^* values for both CWRS patent and straight-grade flours.

Cooked Noodle Water Uptake and Thickness

Wheat class and alkali formulation both significantly influence water uptake at $P < 0.0001$ (Table II) while flour type was not significant. Water uptake during cooking of CPSW patent noodles (Table VI) was consistent for the majority of formulations. However a significant reduction in cooking water uptake was observed for noodles prepared using either of the 1% alkali no-salt formulas, regardless of the Na-to-K carbonate ratio. While no significant difference due to the Na-to-K carbonate ratio was observed within the CPSW patent noodles, straight-grade noodles prepared using the 1% 1:9 Na-to-K carbonate no-salt formula exhibited significantly lower water uptake than the corresponding 9:1 Na-to-K formula. Introduction of 3% w/w salt into either of these 1% alkali formulas significantly increased water uptake in both CPSW patent and straight-grade noodles.

Cooking water uptake in CWRS patent and straight-grade noodles was significantly greater than that observed for the corresponding CPSW noodles using the same formula (Table VI). Consistent with the CPSW samples, significantly lower water uptake during cooking was observed in CWRS patent or straight-grade noodles prepared using either 1% alkali no-salt formulas. Similarly, the addition of 3% salt to either 1% alkali formula resulted in a significant increase in water uptake during cooking.

In both wheat classes, the 1% alkali 9:1 Na-to-K, 3% salt formula generally yielded significantly thicker noodles than the other formulas, regardless of flour refinement (Table VI). Reversing the Na-to-K carbonate ratio (1:9) significantly reduced noodle thickness (with one exception) yet it still yielded noodles that were significantly thicker than the remaining formulas. Cooked CWRS noodles were always thicker than their corresponding CPSW counterparts, which was consistent with the greater water uptake. However, the relationship between water uptake and resulting noodle thickness was not consistent within a wheat class or flour type. The thickest cooked noodles did not correspond to those displaying maximum water uptake during cooking, particularly for CWRS. The presence of salt in the formulation, regardless of flour type or wheat class, resulted in a thicker cooked noodle; however no consistent concurrent increase in water uptake was observed. The reason for this lack of correlation in not known at this time.

Cooked Noodle Texture

Oh et al (1983) demonstrated significant correlations between sensory assessment of noodle texture and objective instrumental measurements. Noodle bite as determined by MCS (1-mm blade simulating the front tooth) is the consumers' first assessment of the product's texture. Alkaline noodles should ideally exhibit a firm bite characteristic. CPSW noodles prepared from either patent or straight-grade flours demonstrated equivalent maximum MCS values when prepared with a 1% alkali concentration using either 1:9 or 9:1 Na-to-K carbonate ratio no-salt formula. Straight-grade noodles made from these formulations exhibited higher MCS values than their corresponding patent noodles (Fig 1A). A sig-

TABLE VI
Influence of Alkaline Formulation and Canada Western Red Spring (CWRS) and Canada Prairie Spring White (CPSW) Flour Refinement on Water Uptake and Cooked Noodle Thickness[a]

			CPSW				CWRS			
			Patent		Straight-Grade		Patent		Straight-Grade	
Na-to-K Ratio	Alkaline Conc (%)	Salt (%)	Uptake (g/g)	Thickness (mm)	Uptake (g/g)	Thickness (mm)	Uptake (g/g)	Thickness (mm)	Uptake (g/g)	Thickness (mm)
1:9	1	0	1.12b	2.13fg	1.06d	2.17e	1.24e	2.28b	1.21e	2.30cd
1:9	1	3	1.25a	2.30b	1.18bc	2.36b	1.37cd	2.48a	1.30d	2.51b
1:9	5	0	1.26a	2.14fg	1.24a	2.19de	1.45ab	2.21c	1.46a	2.19e
1:9	5	3	1.25a	2.23cd	1.25a	2.34b	1.46a	2.30b	1.40b	2.27d
9:1	1	0	1.12b	2.16fg	1.13c	2.25c	1.22e	2.30b	1.14f	2.32c
9:1	1	3	1.25a	2.37a	1.26a	2.42a	1.36d	2.50a	1.34cd	2.58a
9:1	5	0	1.26a	2.13g	1.23ab	2.18e	1.45ab	2.21c	1.44a	2.20e
9:1	5	3	1.23a	2.26bc	1.17bc	2.26c	1.39bc	2.31b	1.39b	2.33c

[a] Mean values followed by the same letter within a column are not significantly different at $P = 0.05$.

nificant reduction in CPSW patent or straight-grade noodle MCS was observed when salt (3%) was added to either formula.

Increasing the alkaline concentration to 5% for either Na-to-K ratio formula, with or without salt, resulted in further, significant decreases in cooked CPSW noodle bite. Noodles prepared with the 5% 1:9 Na-to-K carbonate formulas yielded the poorest CPSW bite characteristics, representing ≈50% of the maximum values. CWRS noodles, straight-grade and patent, displayed the identical pattern as those observed for CPSW noodles (Fig. 1E).

Asian consumers generally prefer yellow alkaline noodles that offer noticeable "chewiness" on their back molars. Resistance to compression (RTC) and recovery (REC) provide a means to instrumentally assess two components of this parameter (Oh et al 1983). RTC represents the first phase of the chewing process, highlighting the resistance offered by the cooked noodle as the back molars come together. CPSW noodles, patent or straight-grade, assessed by RTC demonstrated similar traits to those for noodle bite (MCS). Maximum equivalent RTC values were observed for either 1% alkali 1:9 or 9:1 Na-to-K carbonate no-salt formulas (Fig. 1B). As previously observed, the introduction of 3% salt reduced the RTC values for both formulas and flours by ≈10%. Increasing the concentration of alkali to 5% again demonstrated a significant detrimental impact; both Na-to-K ratio formulas yielded significantly poorer RTC values. Although 5% alkali 9:1 Na-to-K

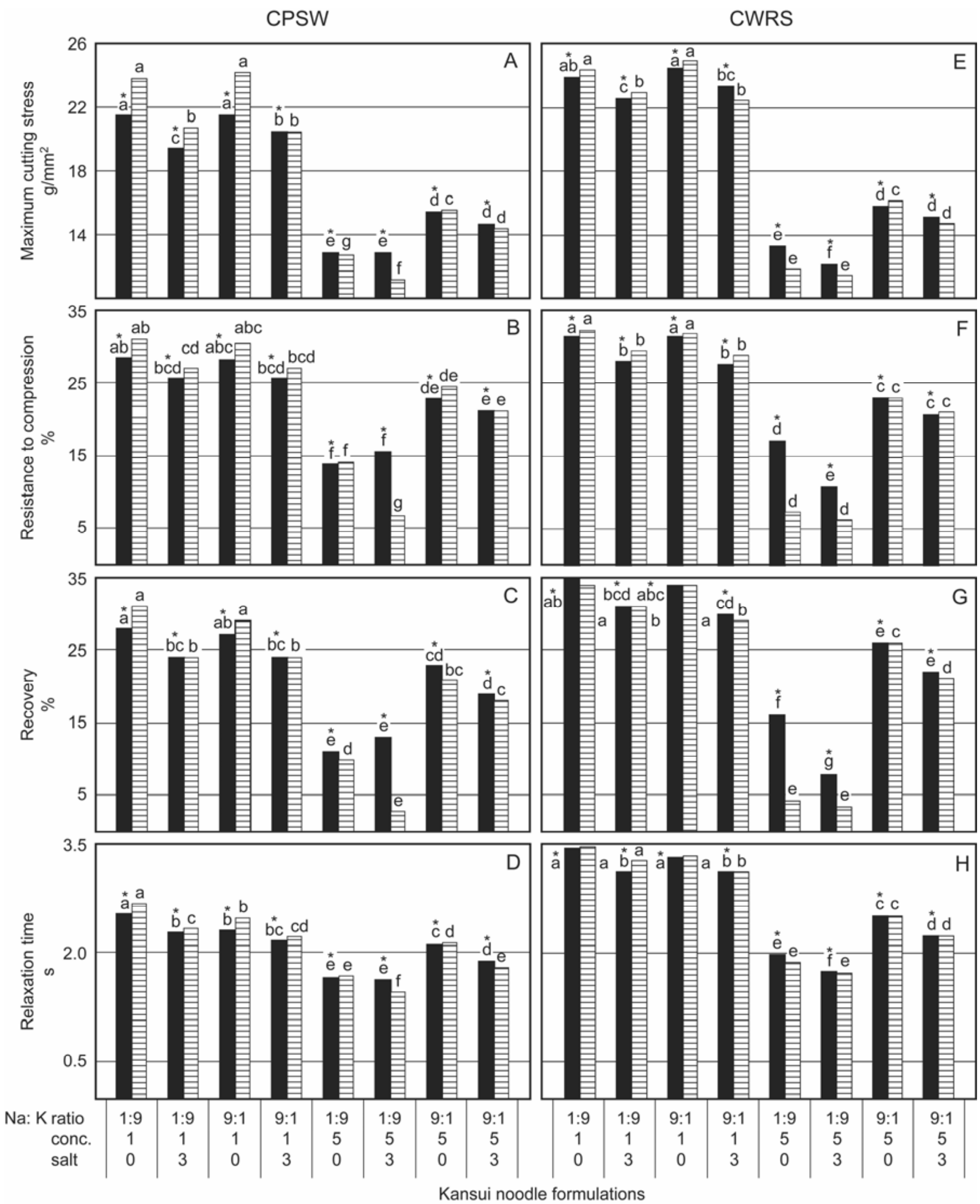

Fig. 1. Texture parameters (A–H) of cooked noodles prepared from Canada Western Red Spring (CWRS) and Canada Prairie Spring White (CPSW) patent flours (solid bars) and straight-grade flours (striped bars) using different formulations. Bars with the same letter within a flour type are not significantly different at $P = 0.05$.

carbonate preparations exhibited significantly higher RTC values than 1:9 counterparts, neither formula yielded RTC values that would be acceptable to consumers. Identical trends in formulation were observed for all of the CWRS noodles (Fig. 1F).

Recovery, the second phase of the chewing cycle, represents the elasticity of the noodle as it tries to return to its original state when the molars come apart. Maximum equivalent recovery (REC) values for the cooked noodles after compression were shown with either 1% alkali for 1:9 or 9:1 Na-to-K carbonate formulas with 0% salt for all CPSW and CWRS noodles (Fig. 1C,G). CWRS noodles prepared from both flours, using either 1% carbonate formulas, exhibited maximum REC values, significantly greater than the corresponding CPSW noodles. The addition of 3% salt to either of the 1% carbonate formulas reduced REC values within both wheat classes. Increasing the carbonate concentration to 5% caused an additional significant reduction in REC values for all samples. As previously observed, the 5% 1:9 Na-to-K carbonate formulas, with or without salt, resulted in significantly lower values than the corresponding 9:1 formulas and would be unacceptable to the consumer as great care was required not to damage the noodles when placing them on the testing platform.

Relaxation time provides an insight into the noodle's structural matrix as it gives an indication of the time to achieve a fixed deformation under a constant, applied strain. A longer relaxation time indicates better structural integrity and the ability of the structure to resist collapse. CPSW patent or straight-grade noodles prepared with 1% alkali 1:9 Na-to-K carbonate no-salt formula demonstrated the greatest relaxation time (Fig. 1D). This was the only texture parameter that exhibited a significant difference to the corresponding 9:1 Na-to-K carbonate no-salt formulation. The introduction of salt into the formulas generally resulted in a decrease in CPSW noodle relaxation times. The use of any of the 5% carbonate concentration formulas also resulted in a significant decrease in relaxation time compared with the 1% formula.

Relaxation times of the CWRS noodles were all longer than those of the corresponding CPSW noodles, reflecting the differences in HMW subunits and stronger gluten strength (Fig. 1H). CWRS cultivars all contain the desirable HMW 5 and 10 on the D chromosome for breadmaking while current CPSW lines contain subunits 2 and 12. Additionally, CWRS cultivars predominantly have the 2* HMW subunit on the A chromosome while CPSW cultivars have the 1 subunit. While the 1% 1:9 Na-to-K carbonate no-salt formula yielded the longest relaxation time for both patent and straight-grade flour noodles, they were equivalent to the corresponding 1% 9:1 Na-to-K carbonate no-salt noodles. Addition of salt to either 1% carbonate formula generally resulted in a reduction, although not always significant, in relaxation time. The consistent detrimental pattern observed on texture with the introduction of the 5% carbonate formulas was reflected in the data. CWRS noodles prepared with any 5% carbonate formula displayed significantly shorter relaxation times than their corresponding 1% formulations. The 5% alkali 1:9 Na-to-K formulations, with or without salt, displayed the shortest relaxation period for both flour types, significantly different from other formulas.

Correlation analyses of the four different texture parameters, assessed by the three different techniques, indicate that within a wheat class there were extremely strong correlations ($r > 0.92$) between all of the texture parameters examined. These strong correlations are due to the 5% alkali formulas causing a severe loss of texture as well as the consistent detrimental impact of salt on each texture parameter.

The reason for these textural differences may be due to the noodles prepared using 5% alkali solutions having minimal or no ability to resist compression and quickly lose any existing structural integrity. Protein content and starch strongly influence noodle texture (Miskelly 1984; Miskelly and Moss 1985). Moss et al (1986) demonstrated that alkaline salts decreased farinograph mixing requirements, while Huang and Morrison (1988) demonstrated that alkali increased starch gelatinization temperatures up to 4.9°C in British wheat. Using kansui solutions (1:1 Na-to-K carbonate) of 0.25, 0.50, and 1.0%, Shiau and Yeh (2004) demonstrated a significant impact on flour protein extractability due to increasing alkaline concentrations. They showed that a modest increase in alkali concentration, below those used in the current study, resulted in a significant decrease in wheat flour extractable protein. They provided further support for the modification of protein by the alkali reagent as they demonstrated a significant loss in free sulfhydryl groups and an increase in disulfide linkages with increasing carbonate levels. The noodles evaluated in this study sat for 1 hr before cooking and texture testing, reflecting commercial production practice. This rest period, combined with the significantly elevated alkali concentration, would therefore be expected to result in some modification or hydrolysis of protein components. The additional influence of alkali on starch gelatinization characteristics (Huang and Morrison 1988) are consistent with the results observed in noodle texture.

Preston (1989) and the subsequent research of Larsson (2002) and Wellner et al (2003) have demonstrated the impact of both Na^+ and Cl^- ions on gluten proteins. At NaCl concentrations similar to those used in this study, Preston (1989) demonstrated a significant increase in CWRS extensigraph peak height. He stated that, at this concentration, interactions between charged groups were minimized due to ionic shielding and that the effects on protein structure and properties were dependent on salt type and concentration. Elevated levels of neutral salts (NaCl) increased inter- and intraprotein hydrophobic interactions and stabilized the native protein structure. While the dough strengthening observed in CWRS extensigraph peak height (Preston 1989) was reflected in the greater work input required for noodle manufacture in the presence of salt during this study, the effect was inversely reflected in this study's noodle texture. This may be due in part to the fact that noodle sheeting and extensigraph measures raw dough characteristics while the noodle texture measurements reflect cooked product characteristics.

CONCLUSIONS

Significant differences in noodle color and, to a much larger extent, texture were reflected in modifications to the kansui formula employed. Addition of salt had a detrimental impact on the amount of work required to process noodles, their raw color over time, and the various resulting texture parameters. The variations in Na-to-K carbonate ratios at the 1% level generally yielded equivalent texture characteristics but did affect raw noodle color. Use of any 5% carbonate formula, while yielding brighter noodles, resulted in significantly poorer cooked noodle texture. The wide diversity in alkaline noodle formulations within countries and between nations clearly reflects consumers' subtle preferences in color and texture.

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