Effect of Flour Refinement on Raw Cantonese Noodle Color and Texture[1]

J. E. KRUGER, M. H. ANDERSON, and J. E. DEXTER

ABSTRACT

Cereal Chem. 71(2):177–182

Wheats representing the five major common wheat classes grown in western Canada were milled on an Allis-Chalmers laboratory mill, and individual streams were composited on the basis of ascending ash content to represent extraction rates of approximately 30, 50, 60, 70, and 75%. Raw Cantonese noodles prepared from these flours were: 1) assessed for raw noodle color with a HunterLab reflectance spectrocolorimeter, and 2) assessed for cooked noodle texture with an Instron Universal Testing Machine. Raw noodle brightness (L^*) decreased, and yellowness (b^*) increased with time and decreased with flour refinement for all wheat classes. Red-green chromaticity ($\pm a^*$), on the other hand, was class dependent; the color in raw noodles either increased (became redder) or decreased (became greener) at 4 hr after preparation. All the raw noodles became redder after 24 hr. In general, raw noodles prepared from different wheat flours were comparably ranked in terms of brightness and yellowness for each level of flour refinement. Interaction effects between wheat class and flour refinement were minimal. Instron Universal Testing Machine textural measurements included maximum cutting stress, resistance to compression, and surface firmness. Increases in flour protein levels and strengths from the different classes were accompanied by increases in the values of textural properties of the cooked noodles. Within classes, the effects on textural properties caused by differences in flour refinement were not pronounced, with the exception of the Canada Western Red Spring class. Thus, the overall rankings of noodle quality according to color and texture are largely independent of flour refinement. A straight-grade flour can be satisfactorily used, therefore, for the comparative evaluation of the noodle-making quality of different flours.

In many Asian countries, noodles are prepared from patent flours to enhance the quality attributes, notably color, of the final product. Laboratory studies on dried, white, salted noodles showed a decline in dried-noodle brightness with increasing flour extraction rate, although no detrimental effect could be observed in the overall firmness of cooked noodles (Oh et al 1985b). Similarly, dried, white, Korean noodles increased in yellowness with increasing extraction rate, but there was little effect on the cutting force of cooked noodles, as measured with a rheometer (Lee et al 1987). The appearance of the cooked noodles noticeably declined when the extraction rate increased from 45 to 75%.

Raw Cantonese noodles have the added complication that an alkaline reagent (*Kansui*) is used in preparation, and the noodles may be stored for up to one day before use. This presents potential problems because time-dependent changes can occur before cooking. Previous studies in this laboratory have indicated that certain cultivars of wheat have increased levels of the enzyme polyphenol oxidase (PPO), which can produce a deleterious dull brown color rather than the pale yellow color desired in raw Cantonese noodles (Kruger et al 1992). The enzyme is located largely in the bran and, hence, increases exponentially with increasing mill extraction rate (Hatcher and Kruger 1993). High-extraction milling would consequently exacerbate such time-dependent browning, as well as increase the amount of noticeable bran flecks in the end product. Such was the case in a study by Miskelly and Moss (1985), in which straight-grade flours gave raw noodles that were yellower, but duller, than those prepared from patent flours. Changes in biochemical composition of different mill streams may also affect the textural properties of cooked raw noodles, but the extent to which this occurs is largely unknown.

At the Grain Research Laboratory (GRL), we are presently devising standardized tests for measuring noodle quality. The purpose of this study was to determine the effect that flours of different levels of refinement, produced by a laboratory mill, had on noodle quality traits. This study would also assess, in particular, whether using a straight-grade flour would give quality rankings similar to those of patent flours. A third purpose of the study was a preliminary examination of differences in cooked noodle quality of Canadian wheat flours. Wheat samples representing

---

[1] Paper 1404, Canadian Grain Commission, Grain Research Laboratory, Winnipeg, MB, Canada.

the five major common wheat classes grown in western Canada were milled; individual mill streams were composited on the basis of increasing ash content to produce patent flours with an extraction rate range of ~30–70% and straight-grade flour with 75% extraction. Noodles were prepared from these flours and assessed for color and textural properties at 2 hr and after storing overnight (24 hr).

MATERIALS AND METHODS

Wheat Samples

The wheats employed in this study were 1991 cargo composites representative of: Canada Western Red Spring (CWRS), Canada Western Red Winter (CWRW), Canada Prairie Spring red seed-coat (CPS-R), Canada Prairie Spring white seed-coat (CPS-W), and Canada Western Soft White Spring (CWSWS). The wheats were inspected by Canadian Grain Commission inspectors, and all qualified for the No. 1 grade.

Analytical Methods

Protein content (N × 5.7) was determined by the Kjeldahl method, as modified by Williams (1973). Ash content and farinograph properties were determined by standard procedures (AACC 1983). Moisture content was determined with a rapid moisture tester (C. W. Brabender Instruments, South Hackensack, NJ), as outlined in the instruction manual. Wet gluten and the Zeleny sedimentation tests used ICC methods 137 and 116, respectively (ICC 1980). Starch damage was determined by the Farrand method (1964). PPO was determined by the method of Marsh and Galliard (1986).

Milling

A 30-kg sample of each wheat class was cleaned and conditioned overnight at optimum temper moisture content: CWRS 16.5%, CWRW 15.5%, CPS-R 15.5%, CPS-W 15%, and CWSWS 14%, as described by Dexter and Tipples (1987). The wheats were milled in 10 lots of 3 kg, with a five-stand Allis-Chalmers laboratory mill. The CWRS, CPS-R, and CWRW wheats were milled by the GRL sifter flow of Black et al (1980), in conjunction with the GRL bran finisher (Black et al 1961). The softer textured CPS-W and CWSWS wheats required an additional break passage before being sent to the bran finisher.

Individual flour streams from the replicate millings of each wheat were composited and blended. Yields were calculated as a proportion of clean wheat on a constant moisture basis. A portion of each was retained for analytical and rheological testing; the remainder was used to prepare five flours of varying degrees of refinement from each wheat (addition of streams in order of ascending ash content). The actual extraction rate of the corresponding flours, differing slightly from wheat to wheat because of variable stream releases, approximated 30, 50, 60, 70, and 75%. The component streams of the flours also varied from wheat to wheat because of the range in wheat hardness. For example, as expected from numerous previous reports comparing the stream characteristics of soft and hard wheats (Ziegler and Greer 1971), the break flour streams of the soft white spring wheat were much lower in ash content than were the corresponding break flours of the harder wheats.

Noodle Preparation

Laboratory preparation of noodles was similar to that described previously by this laboratory and others. A Hobart N50 mixer (Hobart Canada, North York, ON) was used to mix the ingredients. An Ohtake laboratory noodle machine (Ohtake, Tokyo, Japan) was used to prepare the noodles (Oh et al 1983, Miskelly and Moss 1985, Shelke et al 1990, Kruger et al 1992). A solution of 1% *Kansui* (9:1, sodium and potassium carbonates) was added to 250 g of flour in a Hobart N50 mixer over a 30-sec period

TABLE I
Flour Quality Characteristics of Samples

Flour[a]	Level of Refinement[b]	Mill Extraction Rate (%)	Moisture (%)	Ash (%)	Protein (%)	Wet Gluten (%)	Farinograph Properties Absorption (%)	Farinograph Properties Development Time (min)	Farinograph Properties Stability (min)	Zeleny Sedimentation (ml)	Starch Damage (Farrand Units)	PPO[c] (units/g)
CWRS	A	28.5	14.7	0.36	12.2	37.7	61.5	3.75	33	55.0	26	0
	B	50.5	14.9	0.41	12.9	39.2	63.3	2.5	29	55.5	28	0
	C	60.4	15.0	0.42	13.6	41.5	64.4	6	29.5	58.0	28	4.6
	D	68.1	14.9	0.45	13.6	41.9	63.5	5.75	28.5	56.5	27	6.6
	E	75.4	15.1	0.49	13.9	42.0	64.9	6	22	56.5	28	6.0
CWRW	A	31.6	13.7	0.33	9.9	28.9	56.6	1.75	28	51.0	26	6.6
	B	51.4	13.6	0.36	10.0	28.8	56.9	1.75	11	49.0	23	0
	C	63.1	13.7	0.37	10.1	28.9	56.6	1.75	10.5	47.0	22	20.6
	D	71.8	13.6	0.38	10.4	30.3	56.3	1.75	12	48.0	21	7.3
	E	76.9	13.5	0.45	10.5	30.0	56.4	1.75	11	46.0	19	39.8
CPS-R	A	31.4	14.4	0.33	9.6	30.9	58.1	4	9	41.0	23	3.3
	B	49.3	14.2	0.39	9.7	30.3	58.2	3.5	7.5	40.0	21	6.0
	C	61.3	14.4	0.41	9.8	31.8	57.9	3.25	7	40.0	24	17.9
	D	69.0	14.4	0.42	10.2	32.0	58.1	4	8.5	40.0	22	24.5
	E	75.5	14.2	0.45	10.3	31.3	58.2	3.5	7	40.0	23	25.9
CPS-W	A	28.0	13.8	0.37	10.1	32.9	58.6	3.5	5	40.0	15	5.3
	B	46.2	13.8	0.39	10.1	33.0	58.8	3.5	5	40.5	19	54.4
	C	60.1	14.0	0.40	10.6	34.7	59.0	3.75	6	42.5	15	23.9
	D	69.8	14.2	0.40	10.7	34.8	59.4	3.5	5.5	43.5	17	34.5
	E	75.3	13.8	0.44	11.0	35.7	59.2	3.5	5.5	45.0	16	74.3
CWSWS	A	29.8	13.6	0.38	8.9	31.8	52.7	1	1.5	21.0	3	20.6
	B	52.5	13.5	0.38	9.6	33.8	53.6	1	2	24.0	4	16.6
	C	63.0	13.4	0.40	9.6	33.6	53.7	1.25	1.5	24.0	5	21.2
	D	67.8	13.3	0.43	9.6	30.2	53.6	1.25	1.5	24.5	8	31.8
	E	73.8	13.2	0.49	9.9	33.9	54.3	1.25	2	26.0	8	16.6

[a] 13.5% flour moisture basis. CWRS = Canada Western Red Spring, CWRW = Canada Western Red Winter, CPS-R = Canada Prairie Spring red seed coat, CPS-W = Canada Prairie Spring white seed coat, CWSWS = Canada Western Soft White Spring.

[b] A–D = patent flours (30, 50, 60, and 70% extractions respectively). E = Straight-grade flour (75% extraction).

[c] Polyphenol oxidase.

with slow speed mixing (setting 1) to achieve a final absorption of 32%. Mixing was continued for 30 sec at slow speed, followed by 1 min at high speed (setting 2), and an additional 3 min at slow speed. Then, the ingredients were passed through the Ohtake laboratory noodle machine with a 3.00-mm clearance between rollers, at a roller temperature of 28°C. The sheet was passed through the machine twice more at this gap setting, once with folding, and once without. The sheet was then processed through the noodle machine with the roller gap successively reduced 15% for each of the next six passes (gaps of 2.55, 2.15, 1.85, 1.57, 1.33, and 1.10 mm). Before cutting, a portion of the sheet was retained for color testing. The remainder was cut into strips (~2.3–2.4 mm wide) with a No. 12 cutter.

Color Measurement

Raw noodle sheet color was measured with a Labscan II spectrocolorimeter (HunterLab, Reston, VA) using the CIE 1976 L^*, a^*, b^* color scale with a D65 illuminant. L^* is a measure of brightness; a^* and b^* indicate the red-green and yellow-blue chromaticity, respectively. Positive values of a^* and b^* indicate increased redness and yellowness. Noodle sheets were stored in plastic bags at 24.5°C, and readings were made at 0, 1, 2, 3, 4, and 24 hr. Measurements were made in triplicate at two locations on the surface of the sheet.

Noodle Cooking

Twenty noodle strands (50 mm in length, ~5 g) were added to 200 ml of gently boiling, distilled water in a 250-ml beaker. The noodles were cooked to optimum cooking times, determined in preliminary experimentation by squeezing noodles through a hinged-glass plate at different cooking times until the noodle core disappeared. Optimal cooking times (min) for the different wheat classes were: 9.0 CWRS, 7.5 CWRW, 7.0 CPS-R, 7.0 CPS-W, 6.0 CWSWS. After cooking, the noodles were cooled in running tap water for 1 min. The drained noodles were then stored in a covered plastic container at 24.5°C for 10 min before textural analyses. All cooking was performed in triplicate.

Measurement of Cooked Noodle Texture

Textural measurements of cooked noodles were made on an Instron Universal Testing Machine (IUTM, model 4201, Instron, Canton, MA) with fixtures and procedures similar to those described by Oh et al (1983, 1985a). In this study, the IUTM was interfaced to a personal computer using a DMA board (Scientific Solutions, Solon, OH) and Labtech Notebook software (Laboratories Technologies, Wilmington, MA). Textural measurements included maximum cutting stress (MCS), resistance to compression (RTC), and surface firmness. The MCS and RTC measurements correlate highly with sensory perception of firmness and chewiness (Oh et al 1983). It was possible to determine the thickness of the noodles instrumentally, based on the difference between the gauge length and the initial contact with the noodle. The mean width of the noodles (10 noodles stacked side by side) was carefully measured with a ruler. MCS and RTC analysis was done on five sets of three noodles each, and the data was processed and averaged by computer to give a single result for each. The coefficient of variation of the MCS, RTC, and surface firmness analyses of a single sample averaged 3.1, 2.8, and 5.1%, respectively.

Statistical Analysis

Statistical analysis was performed using a personal computer and a StatRelease 6.03 statistical program (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Effect of Flour Refinement on Flour Quality Characteristics

The flour quality characteristics of the five wheat samples used in this study at the different levels of flour refinement are shown in Table I. Presumably, factors such as the quantity and quality of protein influence the textural results. Protein contents of the CWRW, CPS-W, and CPS-R samples were very similar, whereas that of the CWRS was higher and that of the CWSWS was lower. With decreasing flour refinement, substantial increases in protein, ranging from 0.6 to 1.7%, are found within a class. These were concomitant, in general, with increases in wet gluten. However, comparison of the lowest flour refinement stream with the highest flour refinement stream indicates a slight drop in the ratio of wet gluten to protein, reflective of the increased presence of non-gluten proteins associated with the aleurone. Starch damage within a class remained essentially constant, regardless of the level of flour refinement. PPO enzymes were fairly low for all classes of wheat, with the exception of CPS-W. Such enzyme levels generally increased with increasing ash, which is consistent with the known location of these enzymes in the aleurone and bran layers (Kruger 1982, Marsh and Galliard 1986, Hatcher and Kruger 1993). α-Amylase levels (not shown) were very low for all wheat classes, indicating the absence of sprout damage.

Effects of Flour Refinement on Raw Cantonese Noodle Color

We have observed in previous studies in this laboratory that the brightness of noodle sheets is strongly affected by water absorption. To avoid this, wheat flours in this study were all processed at the same flour-water absorption. The flours had no difficulty passing through the sheeting rolls of the laboratory Ohtake machine, although transducer readings of roll pressure were considerably higher with the CWRS wheat flours, reflecting a higher protein level and dough strength (Table I).

Optimally, raw Cantonese noodles should be bright, have a pale yellow color, and be free of off-color tinges such as red, green, or brown. The ability to withstand color deterioration over time is also a desirable quality consideration. The changes in Cantonese noodle color (L^*, a^*, and b^* values over time) for the samples from the different wheat classes employed in this study are shown in Figures 1–3. For all classes of wheat, raw noodle brightness (L^*) decreased with time; the overall decrease became increasingly greater for flours of decreasing flour refinement. On the other hand, b^* (yellowness) increased most

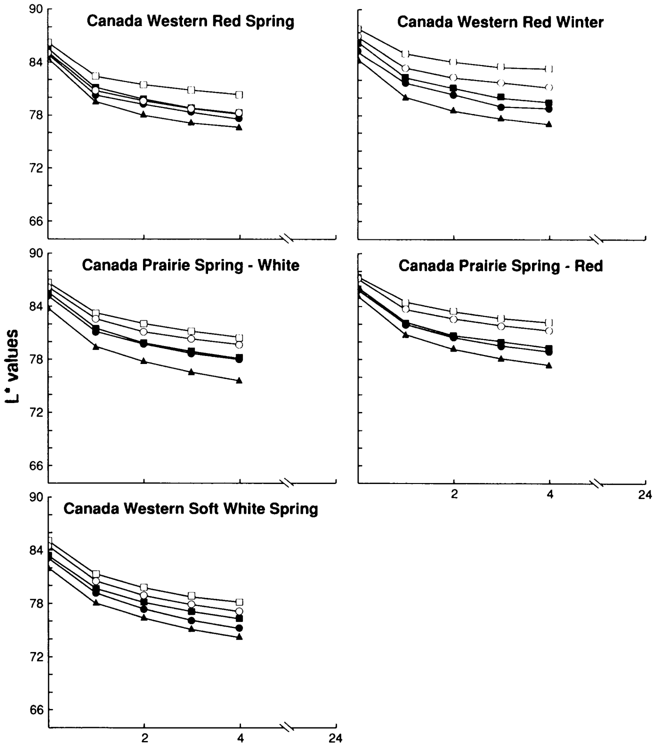

Fig. 1. Change in brightness (L^*) of raw Cantonese noodles over time for different classes of Canadian wheat with different flour refinement levels: □ = flour A (30% extraction), ○ = flour B (50%), ■ = flour C (60%) ● = flour D (70%), ▲ = flour E (75%) straight-grade flour.

in the first hour for all classes and then remained constant. The increase was slightly greater with higher extraction flours, particularly for the CWSWS wheat classes, where substantial increases in yellowness were observed. For the CWRS, CWRW, and CWSWS wheat flours, redness (a^*) increased with time. The CPS-W and CPS-R flour, on the other hand, showed the opposite behavior, decreasing in redness (increasing in greenness) up to 4 hr. Only after standing overnight was this trend reversed. Within a class, decreased flour refinement (increased ash) generally amplified the changes that were observed.

Because raw Cantonese noodles may not always be consumed on the day of preparation, laboratory assessments are frequently made not only on the same day (2 hr), but also on the next day (24 hr) (Miskelly 1984, Kruger et al 1992). Within a particular wheat class, the relative ranking of the brightness and yellowness at 2 and 24 hr were in the same general order at the different levels of flour refinement. Statistically, interaction effects between wheat class and flour refinement were very low. Furthermore, the differentiation of color values was no better at any particular flour refinement level. The practical significance of this is that any particular blending of flour mill streams for laboratory assessment of noodle color is likely to provide the correct intrinsic ranking of wheat cultivars; no particular flour refinement level gives greater discriminability. Note, however, that the presence of bran flecks becomes more apparent with higher extraction flours, particularly for wheats with red seed coats.

Although there were no large differences in color between the wheat classes, the CWSWS produced the least bright, but yellowest, dough sheet overall at both 2 and 24 hr ($P < 0.05$). Because brightness decreases with increasing protein content (Miskelly 1984, Kruger et al 1992), decreased brightness in the low-protein CWSWS is likely due to its finer particle size. Increased yellowness can be attributed to elevated levels of either PPO or flavonoids, both of which are concentrated in the branny layers. The latter is more likely, as PPO levels were not excessive in the different CWSWS wheat flours. In addition, the rate of decrease in brightness, an indication of elevated PPO (Kruger et al 1992), did not correlate with PPO activity for CWSWS, in contrast to CPS-W wheat, which had a Pearson correlation coefficient of −0.96 ($P < 0.001$) for this relationship.

Effect of Flour Refinement on Cooked Noodle Texture

Cooked noodles from the different wheat classes at different extraction rates were assessed for various textural attributes according to IUTM procedures devised by Oh et al (1983, 1985a). MCS (firmness), RTC (chewiness), and surface firmness were tested. A sample of CWRW wheat flour was included in each day's testing as a control sample. In preliminary experiments, it was found that the length of time after preparation of the raw alkaline noodles had substantial effects on the texture of the cooked noodle (Fig. 4). The MCS progressively decreased, whereas the surface firmness and RTC increased slightly. Changes in the firmness of the noodle could be due to time-dependent biochemical changes (alteration of starch and protein by enzymes, alkali, etc.). Increased RTC and surface firmness over time is harder to explain, but starch retrogradation or surface drying of the noodle are possible causes. To maintain consistency, the time of noodle cooking and testing was fixed at 1–2 hr after noodle preparation for the MCS test, and >2 hr for the RTC and surface firmness tests.

MCS

MCS results are influenced by the thicknesses of the cooked noodle (Oh et al 1983). Noodle thickness was determined, therefore, on the various cooked noodles (Table II). Within a class, thickness variations due to flour refinement were very small but, in some cases, they were statistically significant. As such, comparisons of MCS results within a class should not be affected by this factor. Between classes, variations in thickness were much more apparent. The CWRW, CPS-W, and CPS-R wheat classes were very similar in thickness; they all ranged in thickness between 2.14 and 2.22 mm. However, the CWRS wheat flour produced noodles that were thicker, ranging from 2.38 to 2.53 mm. The CWSWS wheat flour produced thinner noodles, ranging from

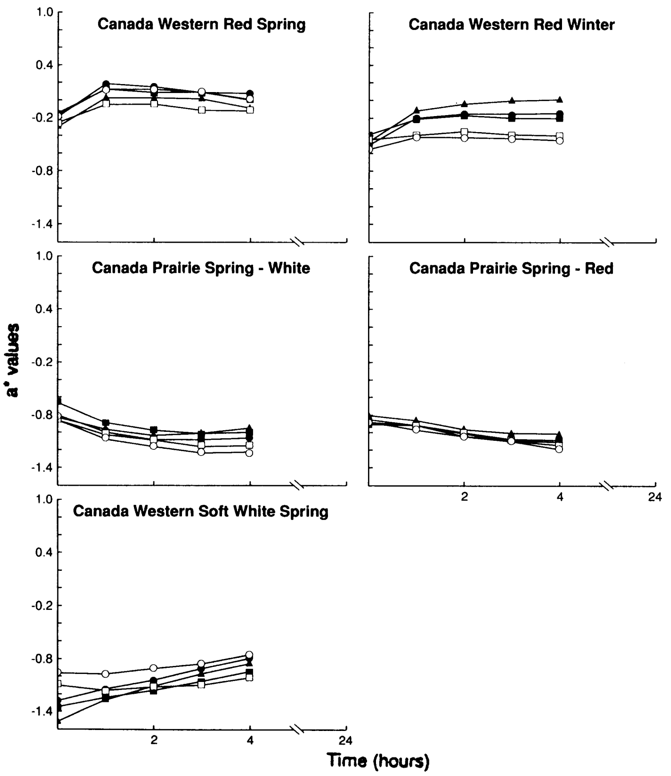

Fig. 2. Change in redness (a^*) of raw Cantonese noodles over time for different classes of Canadian wheat of different flour refinement levels: □ = A (30% extraction), ○ = B (50%), ■ = C (60%) ● = D (70%), ▲ = E (75%) straight-grade flour.

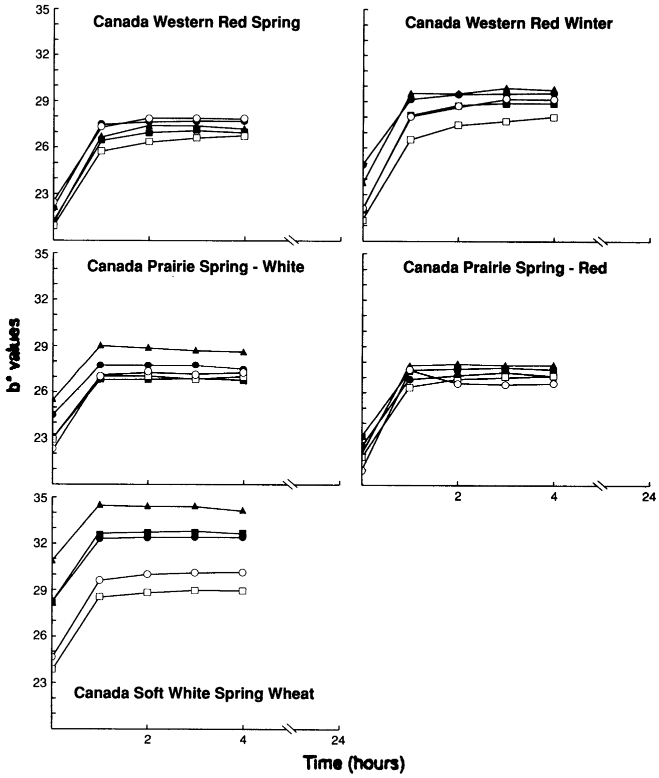

Fig. 3. Change in yellowness (b^*) of raw Cantonese noodles over time for different classes of Canadian wheat of different flour refinement levels: □ = A (30% extraction), ○ = B (50%), ■ = C (60%) ● = D (70%), ▲ = E (75%) straight-grade flour.

1.91 to 1.98 mm. Such differences are consistent with strength differences between these wheat classes (Table I). CWRS wheat would be very elastic, contrasted with the CWSWS wheat.

Results of MCS determination are shown in Figure 5A. In general, variations in cooked noodle firmness within a class due to differences in flour refinement do exist, but they are not pronounced, except for CWRS, where decreased flour refinement results in increased cutting strength. However, CWRS also exhibited the largest increase in thickness as flour refinement decreased, which could partially account for the increased cutting stress. As shown in Table I, in going from the highest to the lowest level of flour refinement, protein increases by 1.7% and dough development time increases by 2.25 min. Oh and coworkers (1985b) also found increases in MCS values with increased protein quantity and dough strength. A 60% extraction flour (flour C) is fairly typical of that used in commercial practice. Comparing this flour refinement level with that of the straight-grade flour (flour E) reveals no significant difference in noodle firmness ($P < 0.05$) for any class but CWRS.

Overall comparisons of wheat classes indicated that the decreasing order of noodle firmness was: CWRS > CWRW > CPS-W > CPS-R > CWSWS ($P < 0.05$).

RTC

The effects of flour refinement on compressibility of the five Canadian wheat classes are shown in Figure 5B. Variations in this textural attribute within a class were insignificant with the CWRW and CPS-W wheats. Within the other wheat classes, the variations were small but significant at $P < 0.05$. As with MCS, the CWRS wheat class exhibited the largest variations due to stream composition variations, with the lowest extraction flour having less RTC.

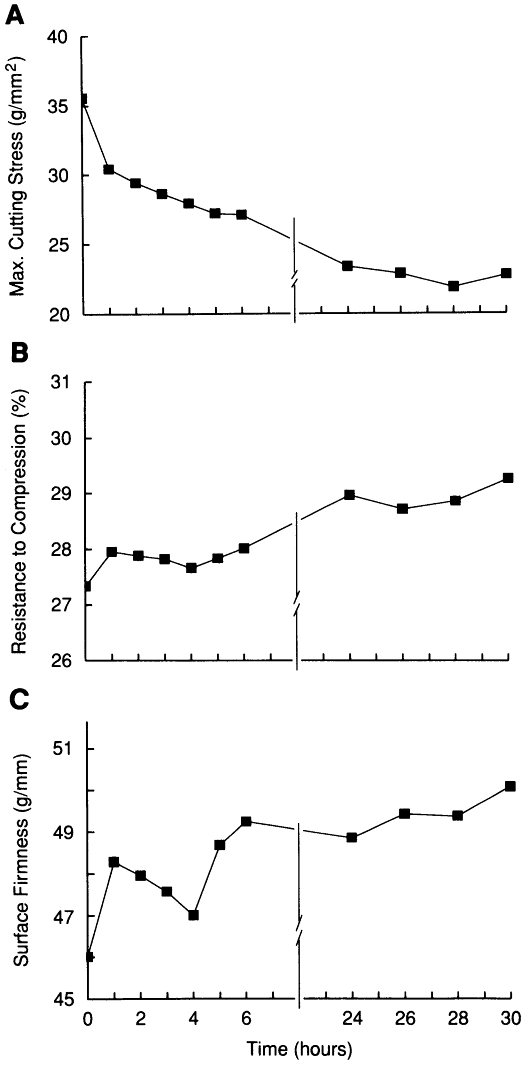

Fig. 4. Effect of length of time after noodle preparation on the maximum cutting stress (**A**), resistance to compression (**B**), and surface firmness (**C**) of cooked noodles prepared from a Canada Western Red Winter control flour.

The decreasing order of class differences in RTC were: CWRS > CWRW > CPS-W > CPS-R > CWSWS ($P < 0.05$).

Surface Firmness

With the exception of the 30% CWRS patent flour (flour A), differences in mill stream composition caused no significant effect on surface firmness within any class (Fig. 5C). Comparison of the flours from a particular class as a group ($P < 0.05$) indicated that the decreasing order of surface firmness was: CPS-W > CWRS > CWRW = CPS-R > CWSWS ($P < 0.05$).

Oh and coworkers (1985a) found that the surface firmness of cooked, white, salted noodles made from high-protein flour was poorer than that of a low-protein flour. This does not appear to be the case in the present study on alkaline noodles; the intermediate-protein CPS-W wheat had the highest surface firmness, followed by the high-protein CWRS wheat. The CWSWS wheat, on the other hand, had the lowest protein and the poorest surface firmness.

Relationship Between Flour Properties and Noodle Texture

The significant relationships between textural properties and flour quality characteristics for all the flour samples in this study are shown in Table III. The distribution of flour characteristics basically falls into three groups: high-protein CWRS wheat; medium-protein CWRW, CPS-W, and CPS-R wheats; and low-protein CWSWS wheat. The thickness, MCS (firmness), and RTC (chewiness) are highly correlated with tests indicative of protein content, protein strength, and starch damage (probably causally). Interestingly, lower correlations between surface firmness and these flour properties suggest that other flour constituent properties may be more important in affecting this textural measurement.

CONCLUSIONS

There is a noticeable decrease in raw noodle brightness and an increase in yellowness when using flours of decreasing flour refinement. Cooked noodle textural properties, on the other hand, are not affected to any large extent by differing flour refinement. Substantial differences in noodle color and texture are found between different wheat classes. This was expected, as they have considerable differences in intrinsic flour properties. One of the more important conclusions of this study, however, is that the relative ranking of wheats in terms of raw noodle color or cooked noodle texture is mainly independent of flour refinement (inter-

TABLE II
Thickness of Cooked Noodles[a]

Flour[b]	Level of Flour Refinement[c] A	B	C	D	E	LSD[d]
CWRS	2.38 d	2.43 c	2.49 b	2.43 c	2.53 a	0.037
CWRW	2.22 a	2.20 a	2.19 a	2.17 a	2.20 a	...
CPS-R	2.17 a	2.12 c	2.16 ab	2.15 abc	2.13 bc	0.033
CPS-W	2.14 b	2.15 ab	2.18 a	2.15 ab	2.18 a	0.031
CWSWS	1.91 c	1.97 ab	1.97 ab	1.98 a	1.95 b	0.027

[a] Mean of 10 analyses each on duplicate samples. Comparisons followed by the same letter are not significantly different ($P < 0.05$) within the same row.

[b] CWRS = Canada Western Red Spring, CWRW = Canada Western Red Winter, CPS-R = Canada Prairie Spring red seed coat, CPS-W = Canada Prairie Spring white seed coat, CWSWS = Canada Western Soft Spring White.

[c] A–D = patent flours (30, 50, 60, and 70% extraction, respectively). E = Straight-grade flour (75% extraction).

[d] Least significant difference.

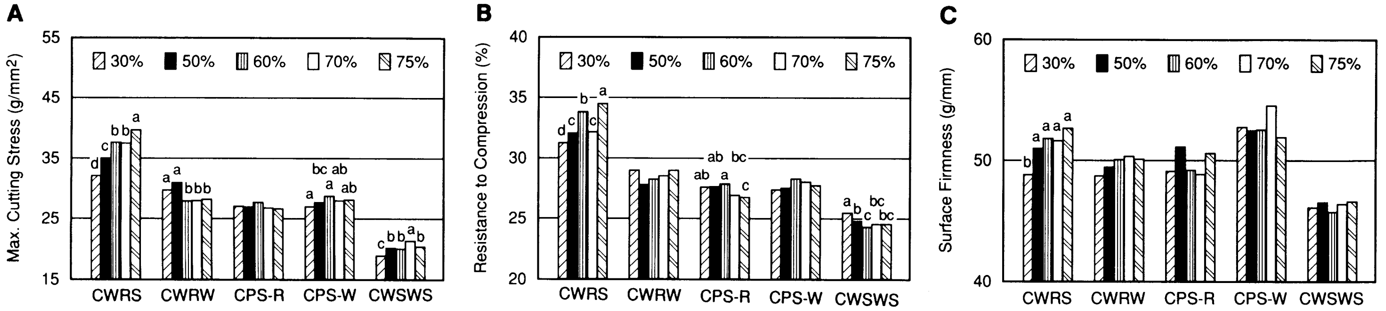

Fig. 5. Maximum cutting stress (**A**), resistance to compression (**B**), and surface firmness (**C**) of cooked noodles from different wheat classes of different flour refinement levels (30–75%). Significant differences ($P < 0.05$) within a class for each trait are indicated by lowercase letters. CWRS = Canada Western Red Spring, CWRW = Canada Western Red Winter, CPS-R = Canada Prairie Spring red seed-coat, CPS-W = Canada Prairie Spring white seed-coat, and CWSWS = Canada Western Soft White Spring.

TABLE III
Pearson Correlation Coefficients of Textural Values of Cooked Noodles[a] with Flour Quality Characteristics

					Farinograph Properties		
	Protein	Starch Damage	Wet Gluten	Zeleny Sedimentation Test	Development Time	Mixing Tolerance Index	Stability
Thickness	$0.91^{***\,b}$	0.87^{***}	0.52^{**}	0.94^{***}	0.75^{***}	-0.84^{***}	0.87^{***}
MCS[c]	0.878^{***}	0.88^{***}	0.49^{**}	0.93^{***}	0.94^{***}	-0.86^{***}	0.82^{***}
Surface firmness	0.49^{**}	0.56^{**}	NS[d]	0.90^{**}	0.68^{***}	-0.70^{***}	NS
RTC[e]	0.91^{***}	0.82^{***}	0.55^{**}	0.62^{***}	0.73^{***}	-0.80^{***}	0.86^{***}

[a] Assessed with an Instron Universal Testing Machine.
[b] Probability levels are * = 0.05, ** = 0.01, *** = 0.001.
[c] Maximum cutting stress.
[d] Not significant.
[e] Resistance to compression.

actions are small or insignificant). This suggests that a straight-grade flour may be used for comparative studies on noodle quality. The practical implication is that the same laboratory-produced, straight-grade flour can be used for preparing different end products, such as bread or noodles. At the GRL, this is particularly beneficial in a peak workload period, such as during the harvest survey, because throughput can be maximized. It is also beneficial for screening of plant breeders' lines where sample size is limited.

ACKNOWLEDGMENT

We would like to gratefully acknowledge the competent technical assistance of H. Facto.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC, 8th ed. Method 08-01, approved April 1961, revised October 1981; Method 54-10, approved April 1961, revised October 1982. The Association: St. Paul, MN.

BLACK, H. C., FISHER, M. H., and IRVINE, G. N. 1961. Laboratory milling. I. A small-scale bran finisher. Cereal Chem. 38:97-101.

BLACK, H. C., HSIEH, F.-H., TIPPLES, K. H., and IRVINE, G. N. 1980. The GRL sifter for laboratory flour milling. Cereal Foods World 25:757-760.

DEXTER, J. E., and TIPPLES, K. H. 1987. Wheat milling at the Grain Research Laboratory. 2. Equipment and procedures. Milling 180(6):16,18-20.

FARRAND, E. A. 1964. Flour properties in relation to the modern bread processes in the United Kingdom, with special reference to alpha-amylase and starch damage. Cereal Chem. 41:98-111.

HATCHER, D. W., and KRUGER, J. E. 1993. Distribution of polyphenol oxidase in flour millstreams of Canadian common wheat classes milled to three extraction rates. Cereal Chem. 70:51-55.

ICC. 1980. International Association for Cereal Chemistry and Technology. Standard 137, Mechanical determination of the wet gluten content of wheat flours (glutomatic); Standard 116, Determination of the sedimentation value (according to Zeleny) as an approximate measure of baking quality. The Association: Vienna.

KRUGER, J. E. 1982. Severity of sprouting as a factor influencing the distribution of α-amylase in pilot mill streams. Can. J. Plant Sci. 61:817-828.

KRUGER, J. E., MORGAN, B., MATSUO, R. R., and PRESTON, K. R. 1992. A comparison of methods for the prediction of Cantonese noodle color. Can. J. Plant Sci. 72:1021-1029.

LEE, C.-H., GORE, P. J., LEE, H.-D., YOO, B.-S., and HONG, S.-H. 1987. Utilization of Australian wheat for Korean style dried noodle making. J. Cereal Sci. 6:283-287.

MARSH, D. R., and GALLIARD, T. 1986. Measurement of polyphenol oxidase activity in wheat-milling fractions. J. Cereal Sci. 4:241-248.

MISKELLY, D. M. 1984. Flour components affecting paste and noodle colour. J. Sci. Food Agric. 35:463-471.

MISKELLY, D. M., and MOSS, H. J. 1985. Flour quality requirements for Chinese noodle manufacture. J. Cereal Sci. 3:379-387.

OH, N. H., SEIB, P. A., DEYOE, C. W., and WARD, A. B. 1983. Noodles. I. Measuring the textural characteristics of cooked noodles. Cereal Chem. 60:433-438.

OH, N. H., SEIB, P. A., DEYOE, C. W., and WARD, A. B. 1985a. Noodles. II. The surface firmness of cooked noodles from soft and hard wheat flours. Cereal Chem. 62:431-436.

OH, N. H., SEIB, P. A., WARD, A. B., and DEYOE, C. W. 1985b. Noodles. IV. Influence of flour protein, extraction rate, particle size, and starch damage on the quality characteristics of dry noodles. Cereal Chem. 62:441-446.

SHELKE, K., DICK, J. W., HOLM, Y. F., and LOO, K. S. 1990. Chinese wet noodle formulation: A response surface methodology study. Cereal Chem. 67:338-342.

WILLIAMS, P. C. 1973. The use of titanium oxide as a catalyst for large-scale Kjeldahl determination of total nitrogen content of cereal grains. J. Sci. Food Agric. 24:343-348.

ZIEGLER, E., and GREER, E. N. 1978. Principles of milling. Pages 115-199 in: Wheat: Chemistry and Technology, 2nd ed. Y. Pomeranz, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.

[Received June 7, 1993. Accepted October 29, 1993.]