

Effect of Roller Mill Extraction Rate on the Chapatti-Making Quality of Canadian Flours¹

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ABSTRACT

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The effect of roller mill extraction rate on the chapatti-making potential of Canadian wheat from six different classes was assessed. Objective measurement of texture including pliability, puncturability, and tearing force, in conjunction with color, discerned significant differences due to flour extraction rate as well as wheat class. The 85% extraction yield was determined by sensory panelists to yield the best chapatti. Analyses of objective measurements, HunterLab values L^* , a^* , and b^* , in conjunction with sensory assessments, suggested that the optimum chapatti have a brightness (L^*) of 75–79, redness (a^*) of 1.5–4.0, and a yellowness (b^*) >17. Sensory scoring compared with objective measurement indicated

that a tearing force of <4.0 kg was necessary to achieve optimum panelist evaluation of tearing and chewability. The primary reasons for a fair rating were attributable to either a too white and nonwheaty taste for the low extraction flours or, in the case of the 95% extraction material, dark chapattis with a slightly off flavor. No chapatti prepared from any of the wheat classes or varying extraction rate flours resulted in an unacceptable rating. Evidence suggests that removal of low-extraction millstreams, up to 40%, from a 85% extraction yield flour did not have a detrimental effect on chapatti quality.

Chapattis are circular, unleavened flat breads that have served as the staple food of the Indian subcontinent and parts of the Middle East for centuries (Nurul Islam and Johansen 1987). The common practice of small sacks of grain being ground at a local village stone mill to yield 95% extraction *chakki* flour has the advantage of providing an excellent source of nutrition and high dietary fiber. Leelavath et al (1986) reported that chapattis prepared from flours ground on a traditional stone mill yielded a product superior to those prepared from flours produced on pin, hammer, or roller mills. It was felt that the higher starch damage caused by the stone mill resulted in increased water absorption, yielding chapattis that were softer and more pliable. However, the increasing industrialization and subsequent urbanization of the population has increased the demand for convenience foods (Raghavan 1994). In recent years, flours have been increasingly produced at various levels of refinement by large-scale roller mills that have the capacity for high throughput and allow the miller the opportunity to selectively blend millstreams to meet their various clients' needs.

The objective of this study, therefore, was to evaluate the effect of a wide range of extraction levels and millstream blends on the relative chapatti-making quality of different classes of Canadian wheats. A secondary objective was to determine how removal of high-purity millstreams influenced the end-product quality of such flours.

MATERIALS AND METHODS

Flour Samples

Wheat representing six different classes of Canadian wheat grown on the western prairies—Canadian Prairie Spring White (CPSW), Canadian Prairie Spring Red (CPSR), Canadian Western Soft White Spring (CWSWS), Canadian Western Red Spring (CWRS), Canadian Western Red Winter (CWRW), and Canadian Western Extra Strong (CWES)—were purchased from grain dealers in western Canada in 1994. All wheats were graded as No. 1

by licensed inspectors of the Canadian Grain Commission. Approximately one ton of each wheat was milled on the Canadian International Grains Institute (CIGI) pilot mill using a commercial flow to yield flours of approximately 85% extraction rate. Stream selection was used to prepare different flour blends for each class on the basis of extraction yield: 0–60, 0–75, 0–85, 0–95, and 0–95 fine. Additional flour blends were prepared by omitting increasing amounts of the initial high-quality streams: 20–85, 40–85, and 60–85%. Flours blended at the 95% yield were prepared by adding bran, overs of a No. 60 wire (0.341 mm but <0.60 mm) to the 0–85% flour. The designation of 0–95% fine represents addition of bran that had been remilled to produce particles able to pass through a No. 60 wire screen (0.341 mm). The range in analytical properties of the millstreams for individual wheat classes are shown in Table I.

Analytical Methods

Protein content ($N \times 5.7$) was determined by the Kjeldahl method, as modified by Williams (1973); ash content, starch damage, and farinograph data were determined by standard procedures of the AACC (1995). Wet gluten was determined by ICC standard method 137 (ICC 1980) using the Glutomatic system, whereas flour color was evaluated with a Simon Series IV flour color grader following the procedure described by the manufacturer. The relative reflectance of a flour-water slurry is listed in arbitrary scale units; the lower the number, the brighter the color. Polyphenol oxidase levels were determined using the method of Marsh and Galliard (1986) as modified by Hatcher and Kruger (1993).

Chapatti Preparation

Chapatti preparation was performed as described by Dhaliwal et al 1996, in which 100 g of flour and water, derived from a 500 BU farinograph trace, were mixed for the optimum time indicated by the farinograph analysis using a GRL mixer (Grain Research Laboratory, Canadian Grain Commission). The dough was rested for 15 min before being cut into four equal sections. A section of the dough was then placed on a rolling board with a thickness guide of 1 mm. The dough was rolled in one direction, inverted, and the sheet rolled in a perpendicular direction. A 15-cm diameter stainless steel cutting template was pressed onto the dough sheet to produce a uniform chapatti. The raw chapatti was immediately placed on a preheated 225°C griddle. The chapatti was cooked for 40 sec on one side, turned over, and cooked on the other side for 70 sec. The cooked chapatti was quickly transferred (<10 sec) to

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an adjacent oven (National, Lincoln, NE) maintained at 275°C and allowed to puff for 20 sec before removal and cooling at room temperature for 10 min. After cooling, the chapatti was placed in a resealable plastic bag and stored for 2 hr before either instrumental or sensory evaluation.

Chapatti Evaluation

The procedures adopted were as outlined by Dhaliwal et al 1996.

Color: Chapatti color was measured objectively with a Labscan II spectrophotometer (HunterLab, Reston, VA) using the CIE 1976 L^* , a^* , b^* color scale with a D65 illuminant. Raw chapattis were tested at 15 and 60 min after formation, whereas cooked chapattis were evaluated at 2 hr after cooking. Measurements were recorded in triplicate at two random locations on the surface of the chapatti. Twelve chapattis were tested per experiment and the results were averaged.

TABLE I
Range of Analytical Data for Wheat Flours

Class ^a	Protein ^b (%)	Ash ^b (%)	Starch Damage (AACC units)	Farinograph Development Time (min)	Farinograph Stability (min)	Farinograph Mixing Tolerance (B.U)	Color Grade
CWSWS	9.0–12.4	0.40–1.56	3.9–4.5	1.25–2.25	1.50–1.50	120–155	-0.81–10.71
CPSW	8.9–11.4	0.42–1.59	4.8–6.2	2.25–3.50	2.50–5.00	65–90	-2.18–15.97
CPSR	10.3–12.9	0.46–1.66	6.7–8.2	3.00–3.75	2.50–5.50	55–75	-1.69–17.42
CWRW	11.6–13.8	0.37–1.61	6.3–7.2	4.25–6.75	5.50–11.00	35–55	-2.18–15.23
CWRS	11.0–12.3	0.50–1.92	8.6–10.0	3.25–5.50	6.00–10.50	20–40	-2.13–17.97
CWES	11.4–12.7	0.51–2.11	7.6–9.1	8.00–14.00	16.00–40.0	10–20	-0.46–18.00

^a CWSWS = Canadian Western Soft White Spring, CPSW = Canadian Prairie Spring White, CPSR = Canadian Prairie Spring Red, CWRW = Canadian Western Red Winter, CWRS = Canadian Western Red Spring, CWES = Canadian Western Extra Strong.

^b 14% moisture basis.

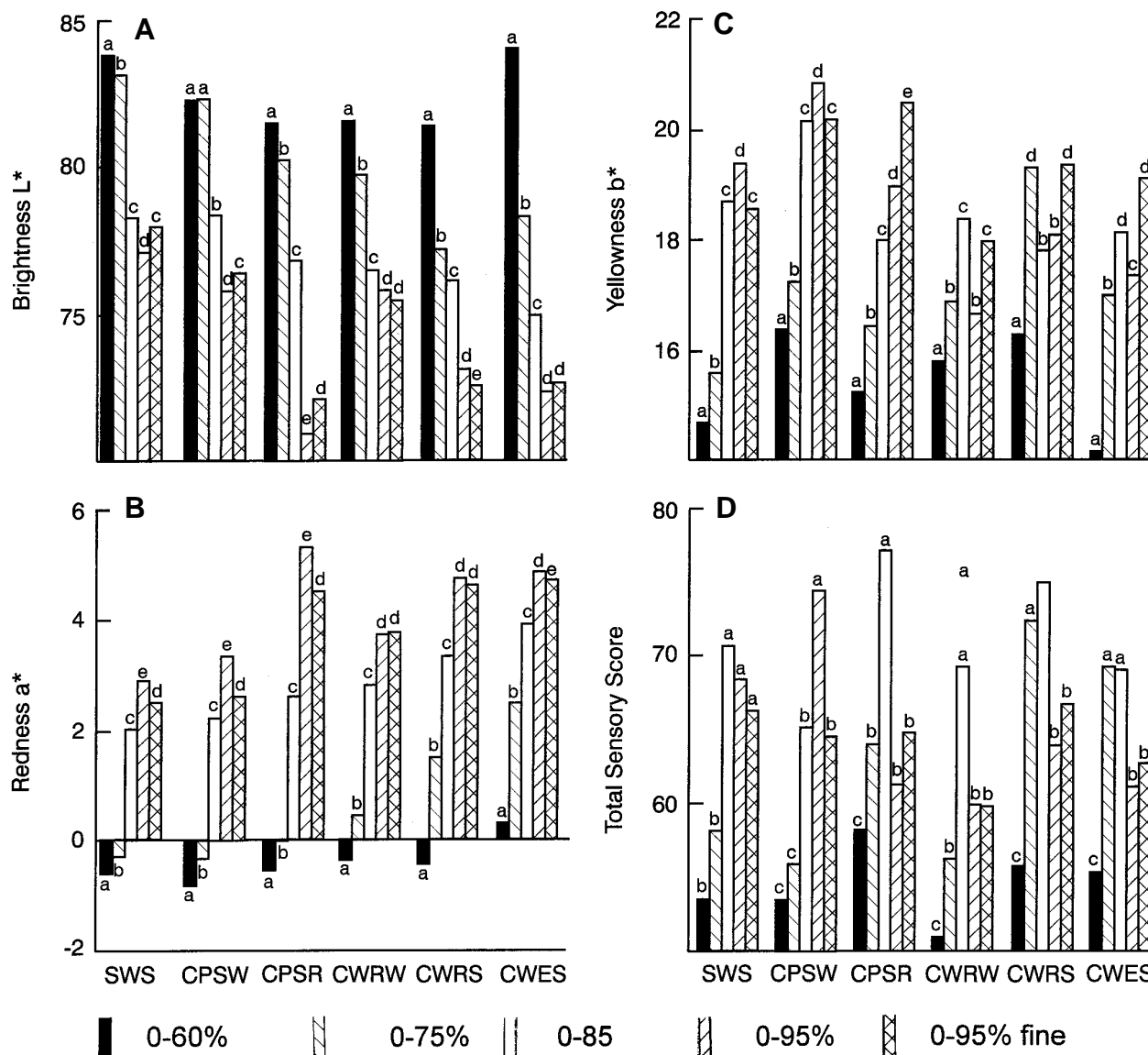


Fig. 1. Influence of roller mill extraction on cooked chapatti brightness, redness, yellowness, and sensory evaluation (A–D, respectively). Means within a class followed by the same letter do not differ significantly ($P < 0.05$). Sensory rating >69 = excellent, $60–69$ = good, $50–59$ = fair.

Texture. Pliability of chapatti strips (2.0 cm wide × 7.0 cm) were determined by a device described by Haridas Rao et al (1986). Pliability refers to the distance (cm) that the supported strip drops when extended horizontally. Twelve chapattis with three readings per chapatti were taken and an average determined for each experiment.

Tearing analyses was performed with the device similar to that used by Sidhu et al (1987) attached to a Universal Testing Machine (Instron Corp., Canton, MA). Trapezoidal pieces, 7 × 4 × 7 × 4.5 cm, were cut from the chapatti and secured to the base unit. The other end of the strip was secured to the moving head maintained at a 15° angle to the base. A 5-mm cut was made at the back edge of the chapatti between the base and moving head to ensure a clean initial point of tearing. The speed of the rising head was maintained at 25 mm/min, and the test was replicated twice on each of six chapattis and the results averaged.

The puncturing force test, which measured total penetration, was performed on three layers of chapatti according to Ramirez-Wong et al (1993). The three layers were sandwiched between two steel plates and a 5.0-mm diameter rounded plunger traveling at 50 mm/min was pushed through a 7.0-mm diameter hole. Average values represent triplicate measurements made on four chapattis for each experiment.

Sensory evaluation. The sensory evaluation of chapattis prepared from different wheat classes was conducted by seven trained panelists. Each sample was presented to the panelists in random order on two different days. Panelists scored the chapattis on the basis of taste, aroma, color, chewiness, tearing ease, and stickiness. Thus, chapattis were scored on their overall appeal on the basis of 100 points (Dhaliwal et al 1996). Taste was awarded the highest number of points (25) because if there was an undesirable taste, consumers would not be interested in the final product regardless of the other characteristics. Color and aroma were each awarded 20 points, while tearing and chewability received 15 points each. Stickiness was awarded the remaining 5 points as this was felt to be the least distinguishing feature. Total scores for each sample by all panelists were averaged. Chapattis receiving more than 70 points were rated excellent, 60–69 points rated good, 50–59 points rated fair, and breads receiving <50 were rated unacceptable.

Statistical analyses were made using the statistical program SAS (vers. 6.10, SAS Institute, Cary, NC) on a personal computer. Differences between samples were established using the general

linear model procedure, taking into account the nested design and fixed and random effects, using the probability of differentiation option to distinguish least square means.

RESULTS AND DISCUSSION

Effect of Roller Mill Extraction Rate on Chapatti Quality

Color. In general, as the flour extraction rate increased, flours tended to decrease in brightness (L^*) and increase in redness (a^*) and yellowness (b^*) (Fig. 1).

Brightness values of chapattis were quite similar among classes at an extraction rate of 60%, but significant differences were detected as the extraction level increased. The decline in brightness was inversely correlated to the ash content ($r = -0.92$ to -0.99 , $P < 0.05$) and color ($r = -0.72$ to -0.89 , $P < 0.05$) of the flour. In addition, an inverse correlation was found between brightness and protein content ($r = -0.87$ to -0.95 , $P < 0.05$). A similar phenomena has been observed in noodles (Miskelly 1984).

Variations in the red component (a^*) among classes were most pronounced between the red (CWRS, CWRW, CPSR, and CWES) and white seed coat (CWSWS and CPSW) classes at various extraction rates, with the former having higher values (Fig. 1). The elevated extraction rates caused greater bran contamination of the flour yielding a significant correlation ($r = 0.87$ – 0.96 , $P < 0.05$) between the a^* value and ash content of cooked chapattis. Significant correlations were also observed between the chapatti redness and flour protein ($r = 0.83$ – 0.93 , $P < 0.05$) or flour color ($r = 0.81$ – 1.0 , $P < 0.05$).

A desirable chapatti must have a significant yellow (b^*) component to meet the consumers desired creamy color. Yellowness (Fig. 1) increased within each class with flour yield, with the exception of CWRS where the 75% chapattis had the highest yellow component. Significant positive correlations were detected between the b^* value of cooked chapattis with flour protein ($r = 0.79$ – 0.91), ash content ($r = 0.77$ – 0.89), and color ($r = 0.72$ – 0.95) at the 95% level of significance. The influence of fine ground versus regular bran on the color components of the final chapatti was minimal and class-dependent.

The chapattis were subjectively evaluated utilizing the sensory scoring system described previously by Dhaliwal et al (1996). Panelists comparing all classes rated chapattis from five flours as excellent, 14 as good, and 11 as fair (Fig. 1). However, there was

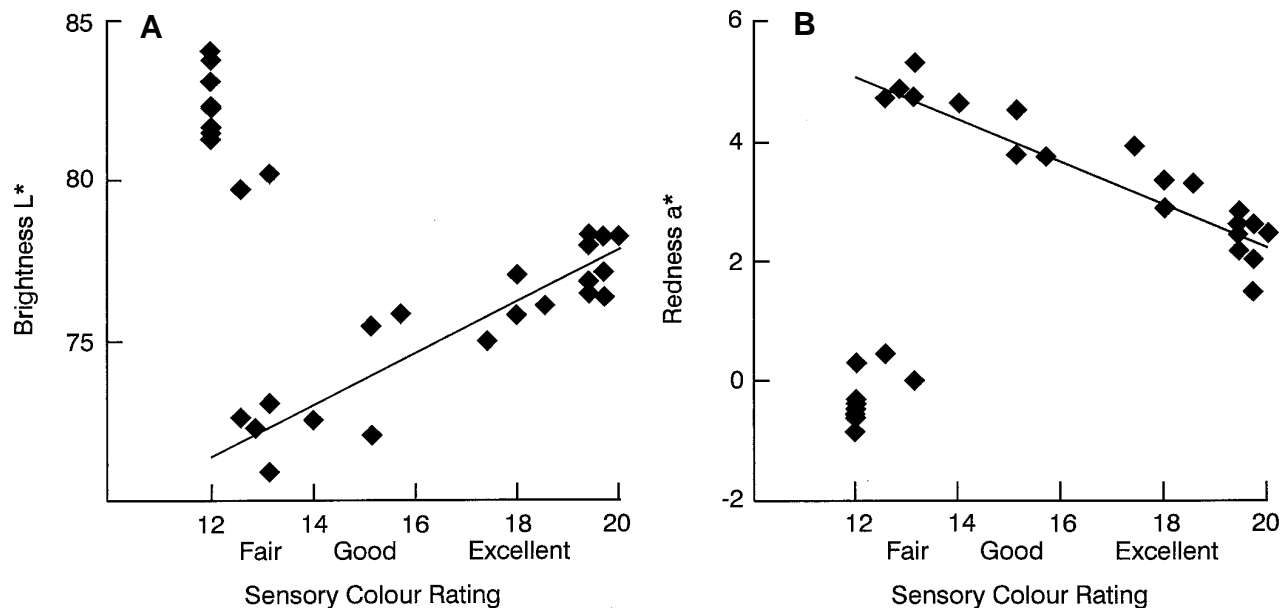


Fig. 2. Relationship between objective HunterLab brightness (A) and redness (B) with sensory perception of desirable color.

no universal consistency in rating by extraction level. The 85% extraction flours were generally determined to yield the best chapattis. A comparison of the sensory panel's subjective evaluation of chapatti color to the objective measurements are shown in Fig. 2. A good linear relationship ($r = 0.90, P = 0.0001$) between the panelists' assessment of color and brightness (L^*) measurement was evident if the points located in the upper left corner are excluded. The excluded data represent 60 and 75% extraction flours that yielded a chapatti that was too white in color. Using a sensory color score >16 to represent excellent color, the desirable limits for L^* were determined to be between 75 and 79.

A similar but inverse relationship ($r = -0.95, P = 0.0001$) was apparent between chapatti a^* values and panelist scoring. Utilizing the same criteria, the panelist's ranking of desirable chapatti color yielded optimum a^* values between 1.5 and 4.0. Chapattis with a^* values outside of these boundaries were judged to be too red or for the 60 and 75% flours, too neutral. Examination of panelists color scoring and b^* values revealed no relationship, although all chapattis ranked as excellent had a b^* value >17 .

A desirable chapatti should have a wheaty aroma and taste. Analysis of the sensory panels' organoleptic scoring for taste and aroma with L^* and a^* values revealed that significant relationships existed with chapatti color measurements. Chapatti taste was

positively correlated ($r = 0.63, P = 0.0002$) with brightness and inversely correlated ($r = -0.63, P = 0.0002$) with redness. Chapatti aroma, however, displayed the opposite trend as aroma was negatively correlated ($r = -0.65, P = 0.0001$) with brightness and positively correlated ($r = 0.69, P = 0.0001$) with redness. These conflicting relationships highlight the fine balance required to impart wheaty flavor and aroma, yet avoid the undesirable branny off-flavor to the product. The use of finely ground versus regular bran on the panelists' assessment of the 95% extraction flours found no statistical improvement with their use.

In the majority of cases, raw chapattis were darker, redder, and yellower than their baked counterparts. Analysis of the L^* , a^* , and b^* values for the raw chapattis indicated the ability to distinguish between blended flours within a class for each of the color components. The significant correlations observed between the various color components of the cooked chapatti with ash, flour protein, and flour color also existed in the raw chapattis. Although the enzyme polyphenol oxidase (PPO) is believed to play a role in product discoloration, the correlations between changes in raw chapatti L^* or a^* values over 60 min with PPO were only occasional and class-dependent. No significant correlations were detected between PPO and the observed changes in raw chapatti yellowness (b^*) for any of the classes.

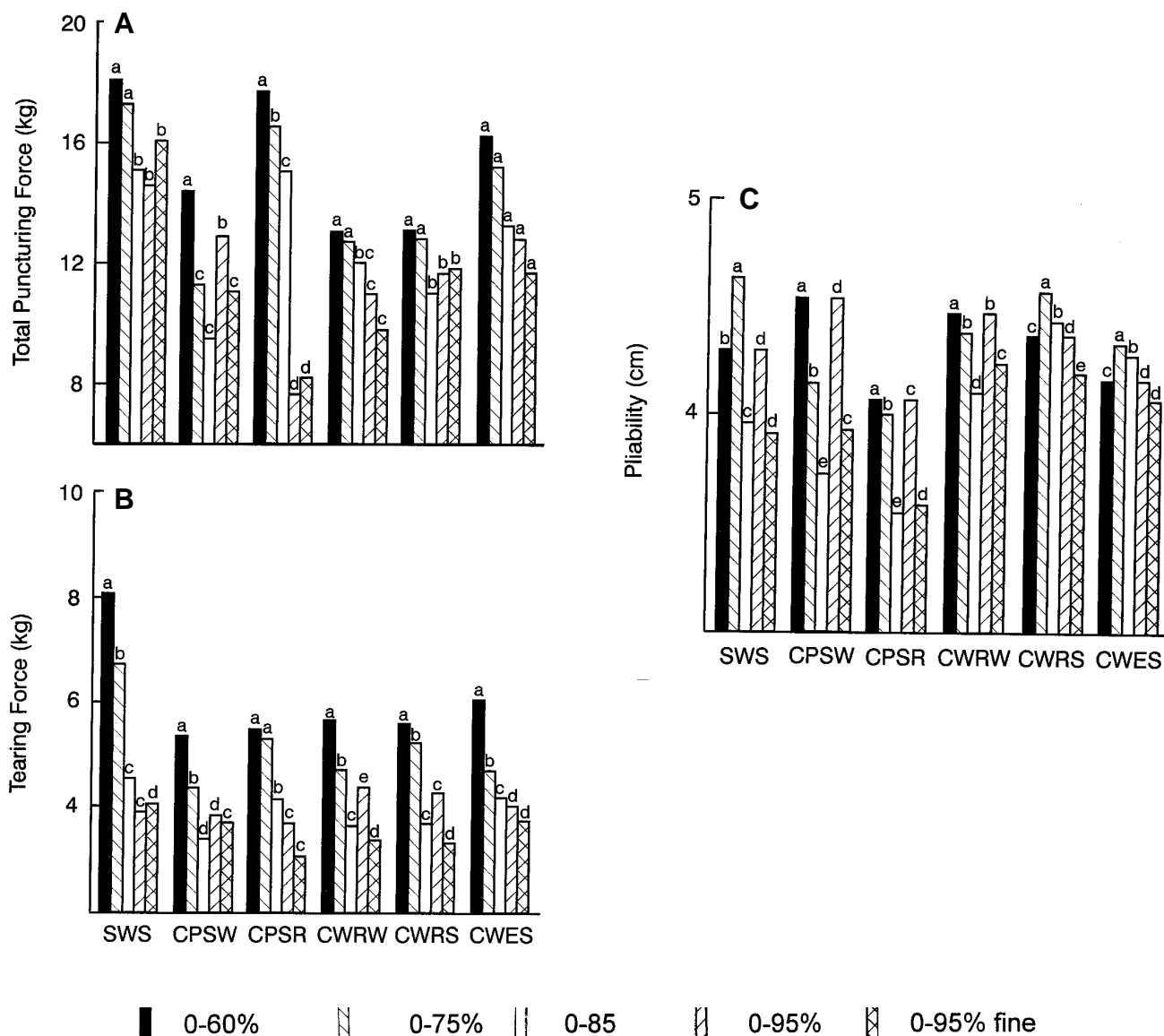


Fig. 3. Influence of roller mill extraction on total puncturing force (A), tearing force (B), and pliability (C) of cooked chapattis. Means within a class followed by the same letter do not differ significantly ($P < 0.05$).

Texture. The physical testing of the chapattis, using the Instron universal testing machine (UTM), was undertaken to establish objective force values and determine whether such testing related to differences in subjective textural attributes due to flour extraction rate. A general decline in total puncturing force within a class was observed with increasing extraction rate (Fig. 3). Maximum force requirements were found in the 60% flours with significant ($P < 0.05$) differences observed among classes at this mill extraction level. The largest range observed within a class was for CPSR with a maximum value of 17.75 kg (60% extraction) and a minimum of 7.75 kg (95% extraction). A low negative relationship ($r = -0.43$, $P = 0.015$) was detected between total puncturing force and the sensory panel's tearing score. No relationship existed with the panels' rating of chewability or overall rating.

Correlation analyses within classes (shown in Table II) indicated that total puncturing force only occasionally correlated with a number of different parameters—ash, wet gluten, absorption, farinograph development time, and farinograph stability.

An ideal chapatti should tear easily and uniformly. Examination of tearing force (Fig. 3) repeated the above trend with maximum force being required in the 60% flours for all classes and subsequently decreasing with higher flour yields. The force required for tearing the chapattis was highest in CWSWS (8 kg), which was 30% greater than any other class. Comparison of the objective tearing force with the subjective determinations by the sensory panelists indicated a significant negative relationship ($r = -0.76$, $P = 0.0001$) (Fig. 4). This negative relationship is due to the panelists scoring easily torn chapattis higher than tough chapattis. A weaker but still significant relationship was also detected between objective tearing force and the panelists' perception of chapatti chewiness ($r = -0.63$, $P = 0.0002$). Utilizing both of these subjective criteria as indicators would suggest that a tearing force of 4.0 kg is the upper limit for a desirable chapatti.

Inverse relationships were observed between the force required to tear chapattis and flour protein, ash content, wet gluten, and water absorption (Table II). A significant positive correlation was found with farinograph stability, suggesting that the viscoelastic nature of the storage proteins contributes to the ease of tearing. Only water absorption had a significant correlation with either sensory tearing ($r = 0.63$, $P = 0.0002$) or chewiness ($r = 0.66$, $P = 0.0001$).

A high degree of chapatti pliability is desirable to allow easy formation of a scoop for sauce retrieval. Maximum values for pliability (Fig. 3) were found in either the 60 or 75% flours within each class. The stronger wheat flours, CWRW, CWRs, and CWES, did not decline appreciably in pliability with increasing extraction rate although the medium to weaker flours displayed a noticeable decrease. No significant correlation was detected between pliability and any of the panelists' scoring parameters. Correlations with various flour attributes (Table II) indicated that pliability within each class correlated occasionally with ash, wet gluten, and absorption level.

The influence of finely ground bran was most noticeable in the textural measurements. In most classes, the use of the fine bran improved the chapatti's textural character by reducing the puncturing and tearing forces. Although a general decline in pliability was also detected, its impact was not detected by the sensory panel.

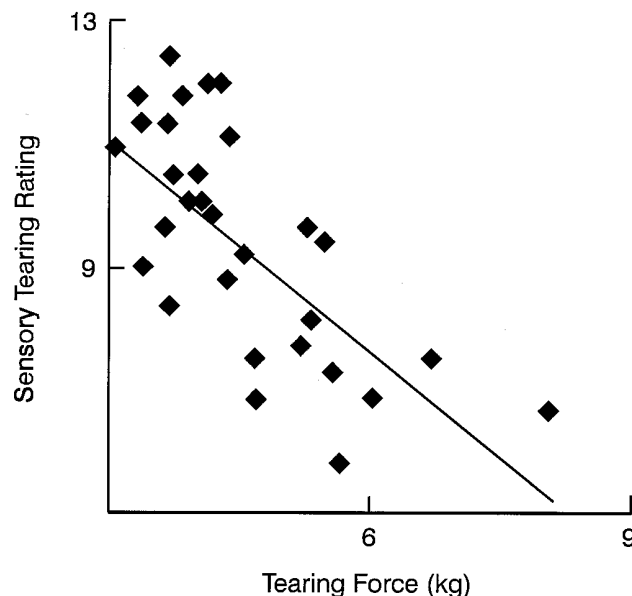


Fig. 4. Relationship between Instron Universal Testing Machine tearing force measurements and sensory panelists' tearing score.

TABLE II
Significant Correlation Coefficients ($P < 0.05$) Between Objective Textural Attributes and Flour Characteristics by Class ($N = 8$)

Class ^a	Protein (%)	Ash (%)	Wet Gluten (%)	Absorption (%)	Farinograph Development Time (min)	Farinograph Stability (min)	Farinograph MTI (B.U.)
Puncturing Force (kg)							
CWSWS	-0.94	-0.91	-0.78	-0.92	-0.70 ^b		0.62 ^b
CPSW					-0.63 ^b	0.68 ^b	-0.73
CPSR		-0.68 ^b	-0.86	-0.66 ^b		0.68 ^b	
CWRW		-0.68 ^b	-0.71	-0.69 ^b	0.64 ^b	0.82	
CWRS	-0.87	-0.89	-0.78	-0.88		0.66 ^b	-0.71
CWES						0.75	
Tearing Force (kg)							
CWSWS	-0.76	-0.83	-0.79	-0.78			0.70 ^b
CPSW	-0.85	-0.84	-0.91	-0.82	-0.73	0.88	
CPSR	-0.89	-0.90	-0.82	-0.87	0.68 ^b	0.95	-0.66 ^b
CWRW	-0.73	-0.85	-0.89	-0.89	0.85	0.96	
CWRS	-0.91	-0.90	-0.85	-0.86		0.86	-0.89
CWES		-0.85		-0.82		0.86	
Pliability (cm)							
CWSWS	-0.68	-0.75	-0.64 ^b	-0.70			0.72
CPSW	-0.90	-0.89	-0.85	-0.88	-0.92	0.86	
CPSR		-0.69 ^b	-0.68 ^b	-0.67 ^b		0.76	
CWRW		-0.67 ^b					-0.69 ^b
CWRS	-0.76	-0.84	-0.69 ^b	-0.84			
CWES		-0.67 ^b		-0.72			

^a CWSWS = Canadian Western Soft White Spring, CPSW = Canadian Prairie Spring White, CPSR = Canadian Prairie Spring Red, CWRW = Canadian Western Red Winter, CWRS = Canadian Western Red Spring, CWES = Canadian Western Extra Strong.

^b $P < 0.10$.

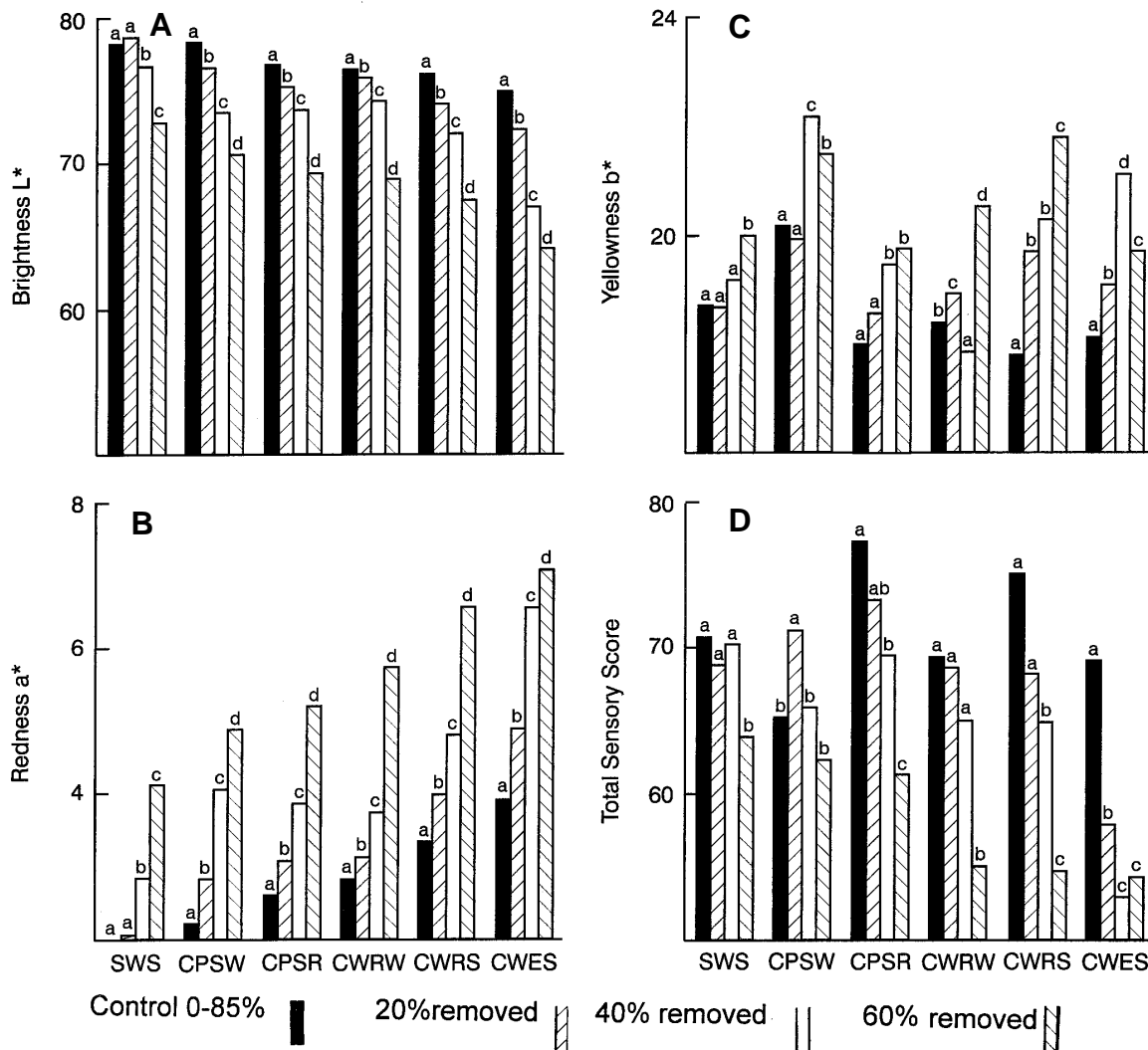


Fig. 5. Influence of mill stream removal on cooked chapatti brightness, redness, yellowness, and sensory evaluation (A–D, respectively). Means within a class followed by the same letter do not differ significantly ($P < 0.05$). Sensory rating >69 = excellent, 60 – 69 = good, 50 – 59 = fair.

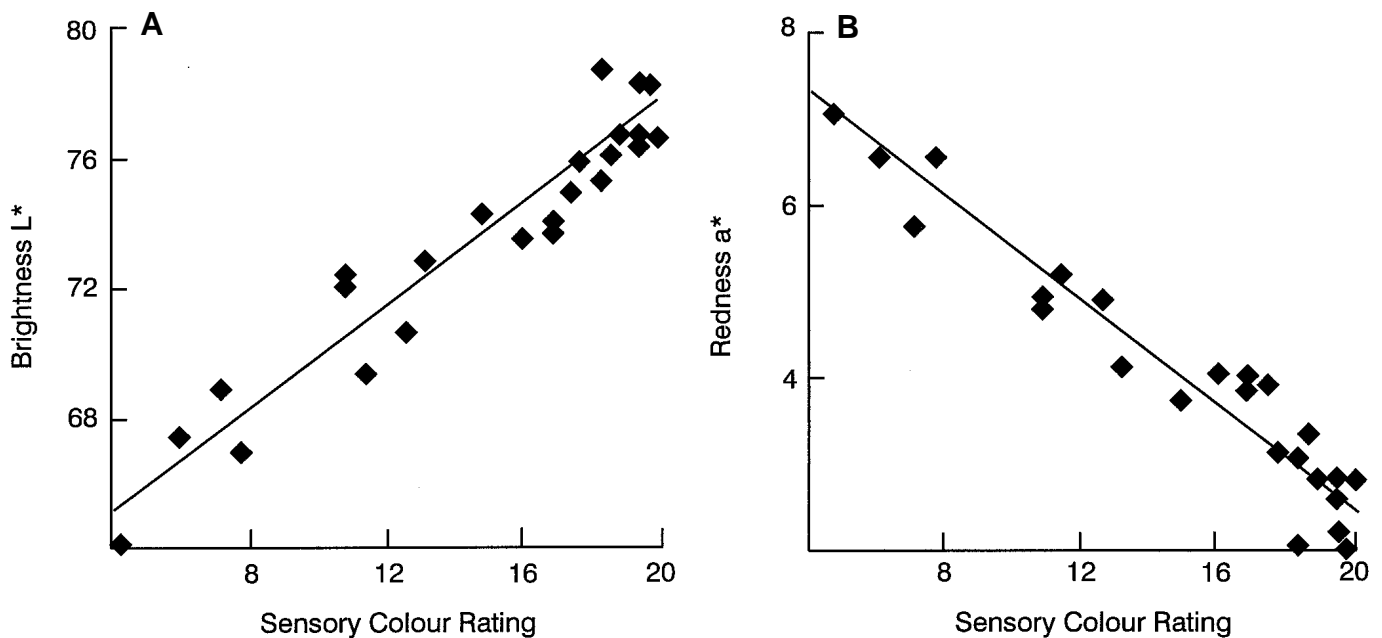


Fig. 6. Influence of stream removal on the relationship between HunterLab brightness (A) and redness (B) of cooked chapattis with sensory perception of desirable color.

Effect of High-Purity Millstream Removal

The sensory panel's preferential scoring of chapattis prepared from high-extraction flours from all wheat classes led us to consider the effect of selective removal of the high-purity, low-ash millstreams on the final product. Using the preferred 85% extraction flour as the control, the impact on chapatti color with removal of the initial 20, 40, and 60% millstreams from the flour can be seen in Fig. 5. The effect on chapatti color components L^* , a^* , and b^* values was similar for all classes, in that increasing stream removal resulted in significantly lower brightness, higher redness, and elevated yellowness. Panelists rated the 18 flours, finding 3 excellent, 10 good, and 5 with a fair rating.

The influence of stream removal on both the brightness and redness was clearly perceived by the sensory panelists, as strong correlations were detected for both L^* and a^* values with panelists' color ratings (Fig. 6). Strong positive correlations ($r = 0.95$ and $r = 0.85$, $P = 0.0001$) were found between L^* and panelists' scoring of both chapatti color and overall rating, respectively. Inverse relationships of the same magnitude ($r = -0.96$ and $r = -0.87$, $P = 0.0001$) were found between panelists' chapatti color and overall rating with a^* values. Panelists' evaluation of acceptable chapatti color reinforced the previously established L^* limits between 75 and 79, while a^* values should fall within 1.5–4.0 for optimum preference. Highly rated chapattis also had b^* values >17 with an upper limit of 21. These color criteria would suggest that a 20% patent stream removal from CWSWS, CPSW, CPSR, and CWRW 85% mill flow would still leave a highly desirable chapatti flour. Although the harder wheats, CWRS and CWES, had only slightly lower brightness values, they were unable to meet these optimum criteria primarily due to the red color component associated with their seed coat. Sensory evaluation highlighted that removal of the initial 20% material either improved or had no statistical influence on the panelists' perception of the chapatti quality. Removal of up to 40% of the initial flour still resulted in a sensory rating of good for five of the six classes while removal of the initial 20% yielded chapattis considered excellent.

Removal of the initial high-quality millstreams improved the various textural attributes of the chapattis (results not shown). Withdrawal of either 20 or 40% patent flour resulted in a more desirable lower or statistically unchanged puncturing force in 11 of the 12 samples. Elimination of the initial 20% material had no statistical influence on the tearing force, while removal of 40% of the material had a beneficial lowering of tearing force in all classes. The effect of stream removal on pliability was divided. The CPSR, CPSW, and CWRW samples had improved pliability at both levels, whereas CWSWS, CWRS, and CWES had a corresponding decrease in pliability. The sensory panel's total scoring clearly indicates, with the exception of CWES, that removal of either the initial 20 or 40% of the extraction streams from a 85% extraction yield flour resulted in an excellent or good chapatti rating. This was consistent with the beneficial effects observed by objective textural analyses.

CONCLUSIONS

Evaluation of six classes of Canadian wheat milled to produce eight different flour blends of varying extraction rate yielded a high proportion of excellent to good ratings with no unacceptable chapattis. Although low extraction flours, 60 and 75%, with corre-

sponding low ash values are desirable in a wide variety of wheat products, the chapatti requirement for a creamy yellow color and easy tearing, in addition to a wheaty aroma and taste, make low-extraction flours less suitable for chapatti production. The 85% extraction flours yielded the preferred chapatti, as three of the six classes achieved an excellent rating. Use of objective color measurement in conjunction with subjective sensory panelists' assessment yielded brightness (L^*) limits of 75–79, a^* values of 1.5–4.0, and b^* values >17 for an optimum chapatti.

Using the high-extraction 85% flours as a control, removal of 20 or 40% of the initial low ash flour streams resulted in blends that displayed improved objective textural properties and sensory evaluations of good to excellent for the majority of classes. These results suggest the ability for a roller mill with one mill flow to simultaneously produce flours for two distinct markets, a high-extraction blend for chapatti production, and a low-extraction, high-quality blend for other products.

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