Comparison of Experimentally Milled Durum Wheat Semolina to Semolina Produced by Some Canadian Commercial Mills[1]

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ABSTRACT

A milling scheme for producing 70% extraction durum wheat semolina in an Allis-Chalmers laboratory mill is described. The granulation, ash, starch damage, color, and spaghetti-making quality of laboratory-produced semolina were compared to those qualities in semolina milled from the same wheat by three Canadian commercial mills. Results showed the laboratory product to be very similar to commercially produced semolina. Each commercial mill also provided semolina mill streams, which were subjected to extensive quality testing. The streams were found to exhibit a wide range of analytic, rheologic, and spaghetti-making properties.

The aim in durum wheat milling is to produce a product with a bright yellow color, a low speck count, and uniform granulation. Because of these constraints, semolina yield is never as high as flour yield. In commercial mills, durum semolina yield varies from about 63–68%. With laboratory mills, semolina yields are normally somewhat lower. The first experimental durum mill reported by the Grain Research Laboratory consisted of a two-stand Allis-Chalmers experimental mill and a small scale purifier (Binnington and Geddes 1936). The scheme used five breaks and two purifications and yielded only 32% semolina. A few years later, the flow was modified so that semolina yield was increased to 50% (Board of Grain Commissioners 1940). More recently, Black (1966) described a laboratory purifier that, used in conjunction with a three-stand Allis-Chalmers laboratory mill, gave a semolina yield of 55–60%.

A number of schemes for semolina milling with a Buhler laboratory mill have been reported (Black and Bushuk 1967, Gasiorowski and Obuchowski 1975, Sollberger 1970). Discussions

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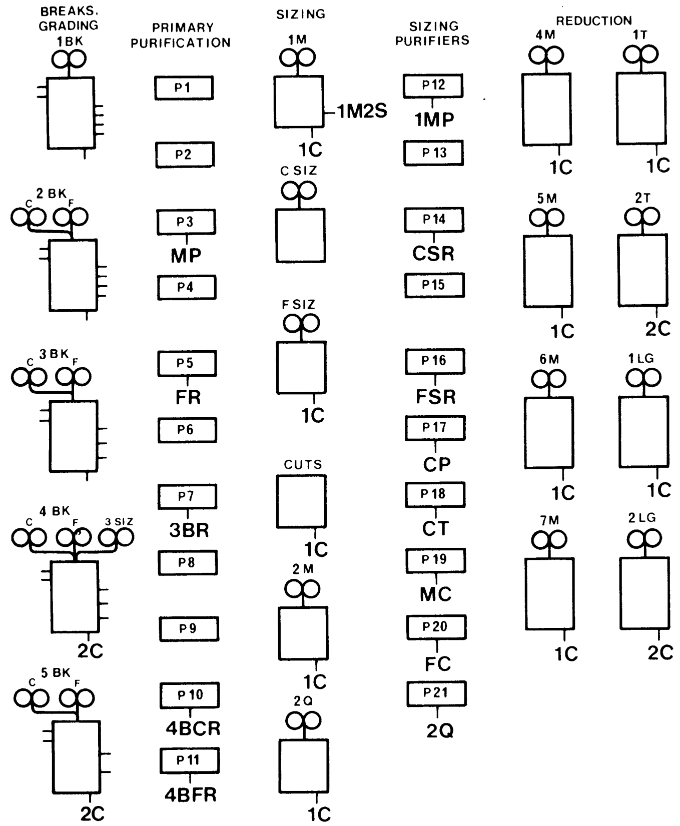

Fig. 1. Simplified schematic flow sheet for a commercial semolina mill. Only those sections involved in the production of collected mill streams are shown. **BK** = break roll, **P** = purifier, **C** = coarse, **F** = fine, **M** = middlings, **Q** = quality, **T** = tailings, **LG** = low grade. Semolina streams: **MP** = medium purifier, **FR** = fine repurifier, **3BR** = third break repurifier, **4BCR** = fourth break coarse repurifier, **4BFR** = fourth break fine repurifier, **1M2S** = first middlings second scalp, **1MP** = first middlings purifier, **CSR** = coarse sizing repurifier, **FSR** = fine sizing repurifier, **CP** = cuts purifier, **CT** = cuts tailing, **MC** = medium cuts, **FC** = fine cuts, **2Q** = second quality. Flours: **1C** = first clear, **2C** = second clear.

on commercial milling of durum semolina have been published by Sebestyen (1970a, 1970b) and by Nelstrop (1972). Shuey et al (1977) attempted to calculate the total extraction of durum wheat products milled from a laboratory Buhler mill on the basis of semolina, flour, and the semolina and flour recovered from the dust and dregs. None of these studies compared the quality of laboratory semolina to that of the commercial product.

Recently we modified the long milling flow for a three-stand Allis-Chalmers laboratory mill described by Black (1966) to produce semolina with coarser granulation and higher yield (Dexter and Matsuo 1978b). The question arose whether the laboratory product differed significantly from commercially milled semolina. This study was therefore undertaken to compare laboratory and commercial semolina by examining the quality characteristics of the respective semolinas and of spaghetti made from them. In addition, semolina streams were collected from the commercial mills and from the laboratory mill and their properties determined.

MATERIALS AND METHODS

Commercial Milling Flow

Semolina and semolina streams were obtained from three commercial mills. Results for only one of these mills will be described in detail, however. A schematic representation of the commercial milling flow is presented in Fig. 1, showing the origin of the mill streams we examined.

At the time the samples were collected, the following wheat blend was being milled: 1 CW AD (12.3% protein), 35%; 1 CW AD (14.1% protein), 15%; 2 CW AD (12.3% protein), 50%. The semolina extraction rate on a clean wheat basis was as follows: semolina, 63%; 1st clear flour, 13%; 2nd clear flour, 6%; millfeed, 18%.

Laboratory Milling Flow

The long milling flow for the three-stand Allis-Chalmers laboratory mill described by Black (1966) was modified with additional purification steps, greater air flow at specific purification steps, and wider roll gaps on the break rolls. The milling flow is presented in Fig. 2. Five additional purification steps (P) were added (P4, P8, P10, P11, and P12) for better particle size

TABLE I
Characteristics[a] of Semolina and Mill Streams

Semolina	Protein (%)	Wet Gluten (%)	Wet Gluten/ Protein	Ash (%)	Yellow Pigment (ppm)	Particle Size Distribution (% held on US sieve No.) 40	60	80	100	Throughs	Starch Damage (Farrand Units)
Commercially-milled	12.3	28.5	2.32	0.70	6.74	20.1	62.2	15.1	1.7	0.4	12
Stream											
Medium purifier	11.7	26.1	2.23	0.55	5.48	55.5	42.9	0.7	0.1	0.3	6
First middlings second scalp	11.4	29.5	2.59	0.49	5.86	2.6	31.6	56.6	8.1	0.6	19
First middlings purifier	11.2	27.8	2.48	0.52	5.81	34.9	63.0	1.4	0.1	0.1	9
Fine repurifier	12.5	29.0	2.32	0.66	5.91	3.5	91.4	4.5	0.1	0.2	9
Coarse sizing repurifier	11.3	28.6	2.53	0.53	5.41	43.5	55.5	0.3	···	0.1	7
Fine cuts	12.4	30.3	2.44	0.69	5.86	···	44.6	45.5	7.7	1.8	19
Cuts purifier	12.9	32.1	2.49	0.76	5.87	···	17.2	68.6	12.4	1.3	16
Fine sizing repurifier	13.1	29.1	2.22	0.83	6.15	2.4	91.2	5.6	···	0.1	11
Medium cuts	11.5	26.4	2.30	0.55	5.26	5.0	94.0	0.5	···	···	13
Cuts tailings	13.1	32.4	2.47	0.76	5.86	···	18.7	67.6	12.0	1.2	9
Third break repurifier	13.1	27.2	2.08	0.89	5.86	34.1	64.5	0.7	0.1	0.2	18
Fourth break coarse repurifier	13.1	26.8	2.04	0.94	6.06	4.9	91.1	3.3	0.1	0.2	13
Fourth break fine repurifier	14.3	35.9	2.51	1.10	6.36	···	21.1	53.6	14.7	10.0	22
Second quality	12.5	27.2	2.18	0.93	5.96	30.0	67.6	2.0	0.1	0.1	12
Flour											
First clear	13.3	31.9	2.40	1.00	6.13	0.1	0.8	2.7	15.8	79.7	48
Second clear	14.1	35.5	2.52	1.69	6.17	0.1	0.5	0.7	2.2	93.8	62
Laboratory-milled	12.7	33.9	2.67	0.64	5.77	15.7	58.5	15.1	3.7	6.6	17

[a]14% moisture basis.

separation and bran removal. Stocks were purified with greater air flow at P3, P4, P7, P8, P11, and P12. Roll gaps were widened (first break = 1.29 mm, second break = 0.41 mm, third break = 0.20 mm) to produce semolina with coarser granulation. The fourth, fifth, and sixth breaks were used essentially as sizing rolls. Frosted reduction rolls used in the long milling flow (Black 1966) were not used. Flour (stocks passing through the 10XX sieve) and fines (stocks held on the 10XX sieve) were accumulated and added to the final product.

In our standard milling procedure, a 1,000-g sample was washed and tempered overnight to 16.5% moisture. Mill room conditions were controlled at 22°C and 60% rh. The milling procedure gave reproducible yields, as shown for 10 replicates: mean semolina yield, 69.5%; range of yield, 68.6–69.8%; standard deviation, 0.343%; coefficient of variability, 0.49. The percentage of stocks that made up the finished product for a representative sample was as follows: after first series of purifications (P1–P4), 42.4%; after second series (P5–P8), 40.6%; after third series (P9–P12), 10.3%; overs of 10XX, 3.7%; throughs of 10XX, 2.9%.

Semolina streams were collected from the laboratory mill after every second purification (ie, at P2, P4, P6, P8, P10, and P12), and the throughs and overs of the 10XX sieve were combined to yield another fraction. To obtain a sufficient quantity of each mill stream for detailed analysis, approximately 10 kg of wheat was milled.

To permit us to directly compare the laboratory product to the commercial product, each commercial mill provided a sample of the wheat being milled on the day the semolina streams were collected. Each of these wheats was milled by the laboratory procedure.

Analytic Methods

Ash, protein, and yellow pigment contents were determined as described by Dexter and Matsuo (1978b).

Particle Size Distribution

U.S. standard sieves Nos. 40 (420μ), 60 (250μ), 80 (177μ), and 100 (149 μ) were used in conjunction with a Ro-tap sieve shaker to obtain particle size distribution. One hundred grams of each stream was shaken for 2 min, and the separated fractions were weighed.

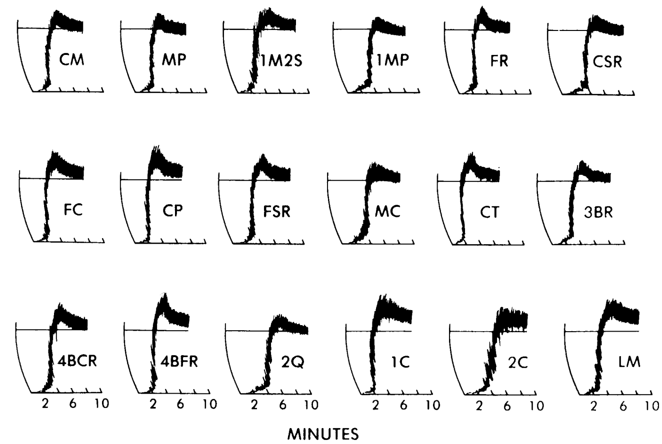

Fig. 3 Pasta dough farinograph curves for the commercial semolina streams. All farinograms were obtained at 31.5% absorption (14%) mb). **CM** = commercially-milled semolina. Semolina streams: **MP** = medium purifier, **1M2S** = first middlings second scalp, **1MP** = first middlings purifier, **FR** = fine repurifier, **CSR** = coarse sizing repurifier, **FC** = fine cuts, **CP** = cuts purifier, **FSR** = fine sizing repurifier, **MC** = medium cuts, **CT** = cuts tailings, **3BR** = third break repurifier, **4BCR** = fourth break coarse repurifier, **4BFR** = fourth break fine repurifier, **2Q** = second quality. Flour: **1C** = first clear, **2C** = second clear. **LM** = laboratory-milled semolina.

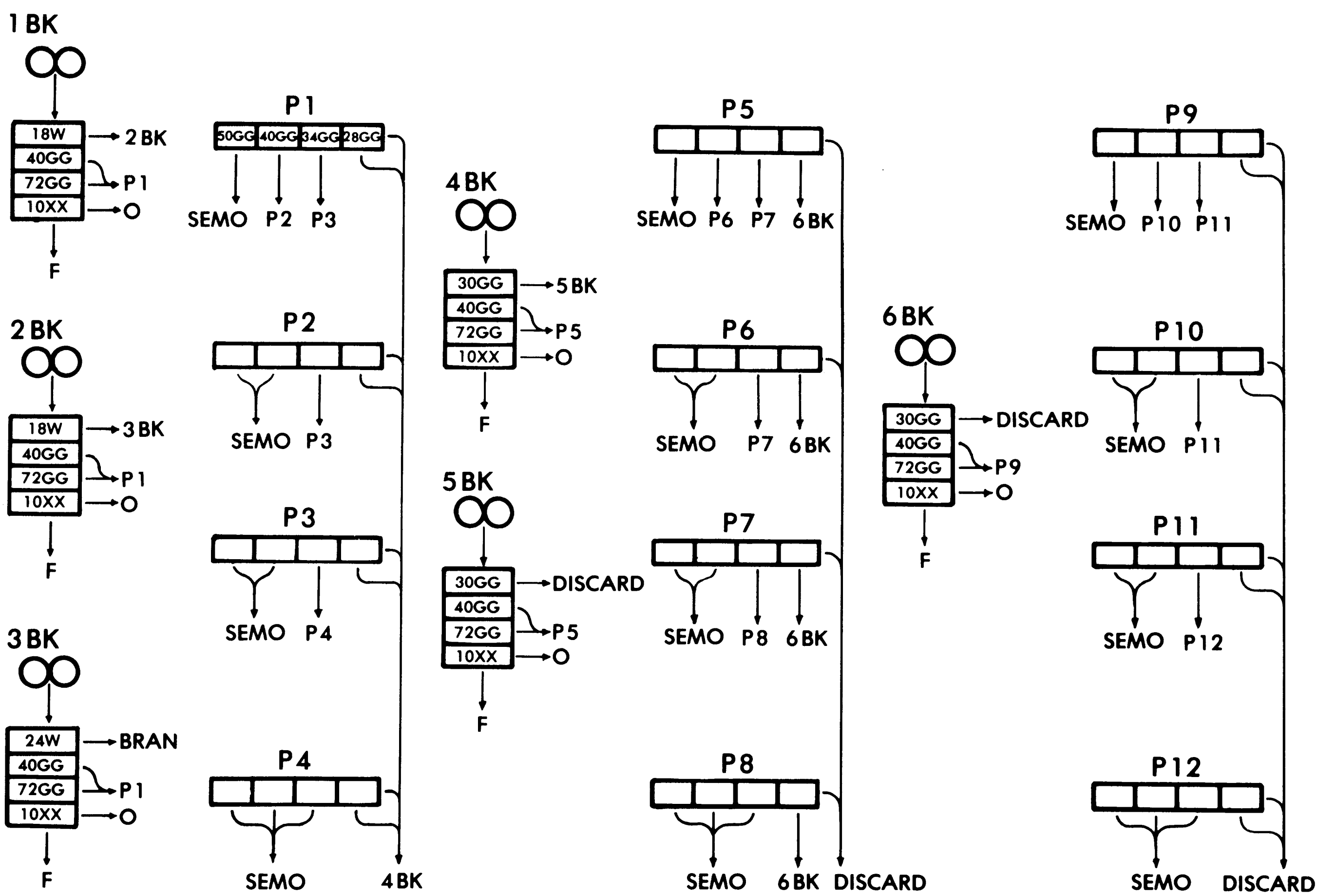

Fig. 2: Simplified schematic flow sheet for the Allis-Chalmers laboratory mill system. **BK** = break roll, **P** = purifier, **O** = fine overs, **F** = flour.

Starch Damage

Starch damage was determined on a 5-g sample by Farrand's method (1964).

Farinograms

Farinograms were obtained by the method described by Irvine et al (1961). Absorption for all samples was 31.5%.

Spaghetti Processing

Fifty grams of semolina, with sufficient distilled water to achieve the required absorption, was mixed in a 50-g farinograph bowl and processed into spaghetti as described by Matsuo et al (1972). Samples were dried in a cabinet controlled at 39° C with decreasing rh for a period of 29 hr.

Spaghetti Color

Spaghetti color was determined on whole strands of spaghetti in a Beckman Color DB-G spectrophotometer as described by Dexter and Matsuo (1977a).

Cooking Quality of Spaghetti

Spaghetti samples were cooked and their cooking quality assessed as described by Dexter and Matsuo (1977b). Cooked weight of spaghetti and the proportion of solids lost during cooking were determined as described previously (Dexter and Matsuo 1979).

RESULTS AND DISCUSSION

Semolina and Semolina Stream Characteristics

Semolina and mill streams from all three commercial mills were evaluated for quality, but because similar trends were found in each case, results are presented only for samples from one mill (Table I). The major difference in granulation between laboratory-milled semolina (LM) and commercially-milled semolina (CM) is the proportion of flour, which accounts for the higher starch damage of LM. The slightly higher protein content of LM is probably a reflection of the slightly greater extraction rate of the laboratory system (Dexter and Matsuo 1978b). Although the mill streams were not enriched, the CM was enriched with a mixture containing niacin, reduced iron, thiamin mononitrate, and riboflavin. The normal level of addition of the enrichment mixture accounts for the higher pigment and ash contents of CM compared to LM. Semolina samples from the other two mills (which were not enriched) were similar to the laboratory semolina in all physical and chemical characteristics examined.

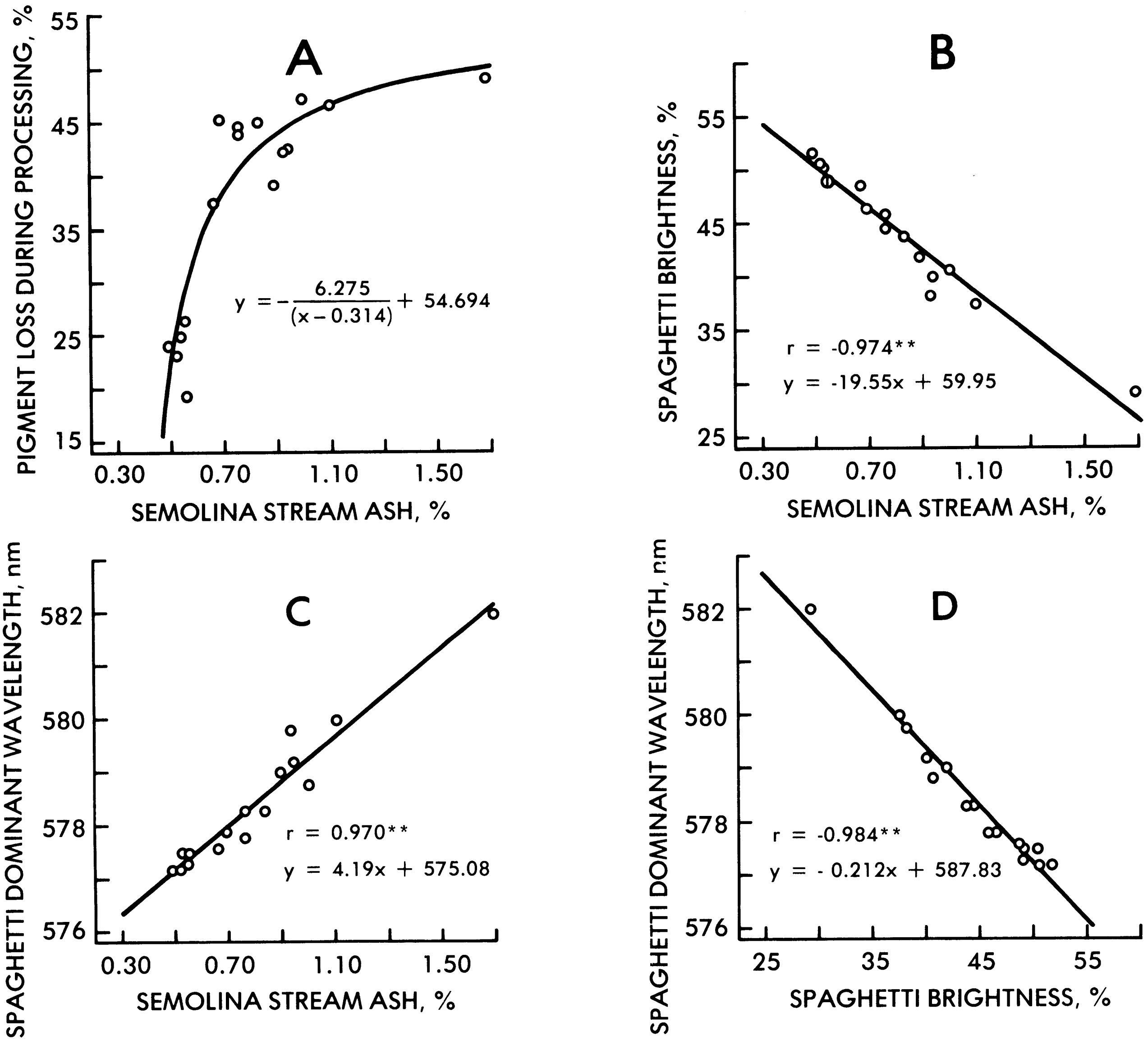

Fig. 4. Color characteristics of spaghetti prepared from commercial semolina streams. **A**, relationship between pigment loss and ash content; **B**, relationship between brightness and ash content; **C**, relationship between dominant wavelength and ash content; **D**, relationship between dominant wavelength and brightness.

The semolina streams showed a range in protein from 11.2–14.3% and in ash from 0.49–1.10% (Table I). The streams with low ash and low protein were collected early in the milling flow. Progressively higher ash and higher protein contents found in streams separated at later stages of the flow (ie, streams off the third and fourth breaks) can be accounted for by a gradient of protein and ash in the wheat kernel (Morris et al 1945). The direct relationship of pigment content with ash and protein content (Table I) demonstrates that pigment is also characterized by a gradient. The first clear and second clear flour fractions, which are not included in CM, are characterized by very high ash, protein, pigment, and starch damage.

Farinograph mixing characteristics for the semolina streams are shown in Fig. 3. Farinograph mixing properties are affected not only by protein quality, but also by protein content and semolina granulation (Dexter and Matsuo 1977b, 1978a, 1978b), all of which show significant differences among streams (Table I). Interpretation of the mixing characteristics solely in terms of gluten properties is therefore very difficult. The results demonstrate, however, that wide variations exist in rheologic properties for the various streams.

LM appeared to have slightly stronger mixing properties than did CM (Fig. 3). This may be partially attributable to the greater protein content and slightly finer granulation of LM. However, the enrichment mixture in CM may also be partly responsible: the semolina samples obtained from the other two commercial mills, which were not enriched, possessed mixing properties that were virtually identical to LM.

Semolina streams from the laboratory mill were analyzed (results not shown), but because of the rather simple milling flow, differences between the streams were not nearly as great as were those observed between the commercial streams. The flour (combined with the fines) and P12 were the only streams with high ash content. Protein content fell into the relatively narrow range of 11.2–12.6% (for P6 and P12, respectively). Farinograph properties were more variable; mixing times ranged from 4¾ min for P2 to 7 ½ min for P12.

Spaghetti Color Characteristics

The color characteristics of spaghetti produced from the commercial semolina streams and flours are shown in Fig. 4. Pigment loss increased as ash content increased (Fig. 4A). The best fit for this relationship was a hyperbola that accounted for 85.5% of the regression equation. Just as ash content of hard red spring wheat is directly related to flour color (Holas and Tipples 1978), semolina ash content is linearly related (Figs. 4B and C) to spaghetti brightness and dominant wavelength (DWL). Brightness measures the amount of light reflected by a sample relative to that reflected by a near-perfect white surface; a low value is an indication of undesirable dullness. DWL gives an indication of brownness; samples with DWL over 577.5 nm generally tend to be

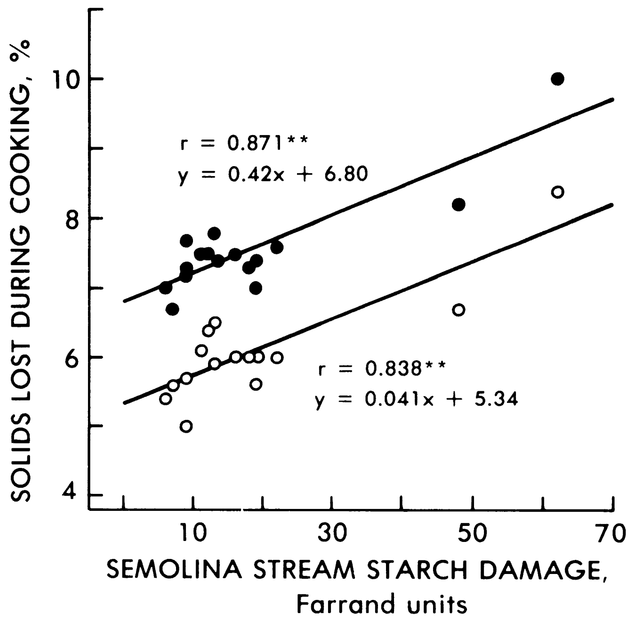

Fig. 5: Relationship between starch damage and solids lost during cooking for spaghetti prepared from the commercial semolina streams after cooking 13 minutes (o) and 23 minutes (•).

TABLE II
Cooking Quality of Spaghetti Prepared from Semolinas and Mill Streams

Semolina	Cooked 13 Min[a]: Cooked Weight (g)	Cooked 13 Min[a]: CQI[b]	Cooked 23 Min[a]: Cooked Weight (g)	Cooked 23 Min[a]: OQI[c]
Commercially-milled	27.0	14	33.9	18
Stream				
Medium purifier	26.4	13	33.4	17
First middlings second scalp	26.7	9	34.6	16
First middlings purifier	24.3	12	34.4	···
Fine repurifier	27.8	15	34.0	17
Coarse sizing repurifier	26.7	···	33.4	···
Fine cuts	26.8	19	34.0	17
Cuts purifier	26.4	23	33.8	21
Fine sizing repurifier	26.8	18	34.6	18
Medium cuts	26.4	13	34.7	···
Cuts tailings	26.0	20	33.6	24
Third break repurifier	27.6	15	33.8	17
Fourth break coarse repurifier	27.3	15	32.8	···
Fourth break fine repurifier	26.3	31	32.3	20
Second quality	27.8	···	35.1	···
Flour				
First clear	25.6	19	32.2	20
Second clear	25.6	26	31.7	27
Laboratory-milled	25.8	15	33.1	15

[a]No value indicates that the majority of strands tested did not recover from compression.
[b]CQI = cooking quality indicator = recovery/tenderness index × compressibility.
[c]OQI = overcooking quality indicator = recovery/tenderness index × compressibility.

dull and brownish, whereas those with DWL below 577 are amber to lemon-yellow, the desired color for high quality pasta. As Fig. 4D shows, a very strong linear relationship exists between brightness and DWL.

CM exhibited a higher pigment loss than did LM (results not shown), probably due to oxidation of riboflavin in CM. The level of pigment was the same in LM and CM spaghetti, but brightness was significantly lower for CM, presumably because of the higher ash content due to the added iron. The semolina streams from the laboratory mill exhibited the same general color trends as did the commercial streams (results not shown), although less variation occurred between streams.

Spaghetti Cooking Quality

The spaghetti from the various streams exhibited a wide range in cooking quality (Table II). The overcooking quality indicator (OQI) was derived using a lighter compression weight than the normal cooking quality indicator (CQI) because under the heavier weight almost all the overcooked samples were completely compressed and exhibited no recovery. Thus, although OQI for some samples was higher than CQI, in all cases a decrease in cooking quality occurred as cooking time increased. The variability of the cooking results (Table II) cannot be solely attributed to protein content (Table I). For example, the coarse sizing repurified stream exhibited much poorer cooking quality at normal time than did the medium cuts, first middlings second scalp, and first middlings purifier streams, which had comparable protein levels to coarse sizing repurified. As expected, the mill stream with the highest protein content, fourth break fine repurifier, had the best overall cooking quality. However, second quality semolina, which had an intermediate protein content, cooked very poorly. Because protein quality is also known to be an important spaghetti cooking quality criterion (Dexter and Matsuo 1977a, 1977b), the assumption is reasonable that variations in gluten quality among the semolina mill streams is of some importance in determining their cooking performance.

Cooked weight (Table II) and cooking loss (Fig. 5) showed significant variations among streams but did not appear to be related to CQI or OQI. However, starch damage, a reflection of particle size distribution, appeared to have a significant influence on cooking loss (Fig. 5). At each cooking time, LM and CM yielded similar results for all the cooking quality factors examined.

The semolina streams from the laboratory mill also exhibited a wide range in cooking quality despite their relatively narrow protein range (results not shown). This provides further evidence that differences in gluten characteristics are partly responsible for variations in cooking quality between streams.

CONCLUSIONS

Results from this study have demonstrated the significant range in analytic, rheologic, and spaghetti cooking quality that exists between the various semolina streams. In general, the variations were not as great as those observed by other workers for hard red spring wheat flour streams (Holas and Tipples 1978). This could explain why, although a significant relationship between flour extraction rate and loaf volume has been demonstrated (Orth and Mander 1975), semolina extraction rate does not have a measureable effect on spaghetti cooking quality (Dexter and Matsuo 1978b).

The experimental milling scheme described in this work has been shown to yield a product with very similar properties to those of Canadian commercial semolina. Because of its excellent reproducibility, it has provided a means to assess durum wheat milling quality in the Canadian durum wheat breeding program. It has also proven valuable in studying the effect of various physical characteristics of durum wheat (kernel weight, vitreousness, hectoliter weight, etc) on semolina milling characteristics. Results of some of these experiments will be published at a later date.

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