# EFFECT OF SEMOLINA EXTRACTION RATE ON SEMOLINA CHARACTERISTICS AND SPAGHETTI QUALITY[1]

J. E. DEXTER and R. R. MATSUO, Canadian Grain Commission, Winnipeg, Manitoba

## ABSTRACT

Cereal Chem. 55(6): 841-852

Two Canadian durum wheats were milled experimentally in an Allis-Chalmers mill to yield a semolina extraction range of about 58 to 76%. Semolina granulation of both wheats decreases slightly with increasing extraction rate, resulting in slightly higher starch damage. Spaghetti processing absorption is not affected, however. Percent ash and protein content increase with extraction rate for both wheats. In each, the farinograph indicated a slight weakening of pasta dough characteristics as extraction rate increased, but spaghetti cooking quality was not affected. Pigment loss during processing increases significantly with increasing extraction rate, resulting in lower spaghetti pigment content. At high extraction, spaghetti also becomes browner and duller. At comparable extraction rates the difference in quality between the two durum wheats remains relatively constant for each quality parameter examined. Milling for coarser semolina granulation does not affect spaghetti cooking quality and results in slightly improved spaghetti color.

Flour yield is known to have a marked effect on flour properties (1). Recently Orth and Mander (2) showed that flour extraction rates affect loaf volumes of some Australian wheats. They suggested that, when screening experimental lines in wheat breeding programs, optimum flour yield should be determined for each wheat type to allow realization of maximum breadmaking potential.

Data on the variation in semolina composition and spaghetti-making quality at different extraction rates have not been available. This study evaluates the effect of semolina extraction rate under laboratory conditions on semolina composition, pasta dough rheological properties, and spaghetti quality for two Canadian durum wheat (*Triticum durum,* Desf.) cultivars.

---

[1] Paper No. 400 of the Canadian Grain Commission, Grain Research Laboratory, Winnipeg, Manitoba, Canada, R3C 3G9.

0009-0352/78/000095$03.00/0

## MATERIALS AND METHODS

### Wheat Samples

Two Canadian amber durum wheat cultivars, Hercules and Wakooma, grown during the 1974 crop year were chosen for the study. Table I gives some of the wheat quality data.

TABLE I
Wheat Quality Data[a]

| Property | Hercules | Wakooma |
|---|---|---|
| Grade (CW)[b] | 2 | 3 |
| Hectolitre weight (kg) | 82.9 | 82.7 |
| 1,000-kernel weight (g) | 42.0 | 42.5 |
| Protein (%) | 13.7 | 14.6 |
| Ash (%) | 1.57 | 1.83 |

[a] Expressed on 14.0% mb.
[b] CW = Canada Western.

TABLE II
Data for Coarse Semolina and Flour From Two Durum Wheats[a]

| Property | Hercules Coarse Semolina | Hercules Flour | Wakooma Coarse Semolina | Wakooma Flour |
|---|---|---|---|---|
| Milling yield (%) | 69.9 | 76.7 | 69.7 | 76.1 |
| Protein (%) | 12.8 | 13.1 | 13.5 | 13.7 |
| Ash (%) | 0.71 | 0.70 | 0.80 | 0.77 |
| Starch damage (Farrand units) | 11 | 53 | 15 | 59 |
| Yellow pigment (ppm) | 4.40 | 4.64 | 5.08 | 5.16 |
| Pigment loss (%) | 17.7 | 20.7 | 20.3 | 22.1 |
| Particle size distribution (%) | | | | |
| Held on sieve, 40 mesh | 14.6 | ... | 16.7 | ... |
| Held on sieve, 60 mesh | 57.9 | ... | 59.1 | ... |
| Held on sieve, 80 mesh | 15.4 | ... | 14.8 | ... |
| Held on sieve, 100 mesh | 4.0 | ... | 3.4 | ... |
| Through 100 mesh | 7.6 | 100 | 5.5 | 100 |
| Spaghetti color | | | | |
| Brightness (%) | 48.6 | 48.6 | 45.2 | 45.7 |
| Purity (%) | 58.3 | 59.0 | 60.5 | 61.8 |
| Dominant wavelength (nm) | 577.2 | 577.0 | 578.0 | 577.9 |
| Spaghetti cooking quality[b] | | | | |
| Normal time | 16.6 | 15.0 | 21.4 | 19.6 |
| Overcooked 5 min | ... | ... | 15.8 | 18.9 |
| Farinogram[c] | | | | |
| Mixing time (min) | 4.75 | 6.00 | 5.25 | 6.00 |
| Maximum consistency (BU) | 640 | 710 | 640 | 720 |
| Tolerance index (BU) | 80 | 40 | 60 | 40 |

[a] All analytical results expressed on 14% mb.
[b] No value indicates that the majority of strands tested did not recover from compression.
[c] Performed at 31.5% absorption (14% mb).

### TABLE III
### Effect of Semolina Extraction on Semolina Characteristics From Two Canadian Durum Wheat Cultivars

| Cultivar | Extraction (%) | Particle Size Distribution (%) Held on 40 | Held on 60 | Held on 80 | Held on 100 | Throughs | Starch Damage (Farrand Units) | Protein (%) | Wet Gluten (%) | Yellow Pigment (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| Hercules | 57.7 | 0.1 | 40.9 | 44.4 | 8.8 | 5.4 | 17 | 12.6 | 33.0 | 4.48 |
| | 59.6 | 0.2 | 39.2 | 45.3 | 9.3 | 5.7 | 17 | 12.7 | 34.1 | 4.47 |
| | 61.8 | 0.2 | 39.2 | 44.5 | 9.2 | 6.5 | 17 | 12.7 | 33.5 | 4.40 |
| | 63.8 | 0.4 | 40.0 | 44.4 | 8.9 | 6.2 | 18 | 12.7 | 33.2 | 4.52 |
| | 65.8 | 0.2 | 42.0 | 42.8 | 8.6 | 5.9 | 17 | 12.7 | 32.9 | 4.49 |
| | 67.8 | 0.2 | 39.9 | 45.2 | 9.0 | 5.4 | 17 | 12.8 | 32.1 | 4.64 |
| | 68.8 | 0.2 | 38.4 | 42.9 | 9.0 | 9.1 | 18 | 12.9 | 33.7 | 4.64 |
| | 72.0 | 0.2 | 37.7 | 42.1 | 8.8 | 10.8 | 19 | 12.9 | 33.4 | 4.48 |
| | 74.0 | 0.3 | 38.6 | 40.0 | 8.6 | 12.2 | 20 | 12.8 | 33.7 | 4.54 |
| | 75.9 | 0.3 | 38.0 | 40.0 | 8.6 | 12.5 | 20 | 13.0 | 32.6 | 4.72 |
| Wakooma | 57.7 | 0.2 | 40.0 | 44.4 | 8.8 | 6.2 | 23 | 13.2 | 34.3 | 5.19 |
| | 59.7 | 0.2 | 39.9 | 44.6 | 9.0 | 6.1 | 24 | 13.3 | 33.8 | 5.28 |
| | 62.0 | 0.2 | 40.3 | 43.6 | 9.1 | 6.5 | 24 | 13.3 | 33.1 | 5.17 |
| | 63.7 | 0.2 | 41.2 | 43.7 | 8.8 | 5.9 | 24 | 13.4 | 33.5 | 5.28 |
| | 65.7 | 0.4 | 42.0 | 43.0 | 8.6 | 5.6 | 24 | 13.5 | 33.3 | 5.28 |
| | 67.7 | 0.4 | 40.9 | 43.7 | 8.8 | 5.8 | 25 | 13.6 | 33.3 | 5.25 |
| | 69.8 | 0.2 | 38.6 | 42.7 | 9.0 | 9.1 | 26 | 13.4 | 33.2 | 5.23 |
| | 71.8 | 0.2 | 37.3 | 41.3 | 8.8 | 11.9 | 27 | 13.6 | 33.7 | 5.27 |
| | 74.0 | 0.3 | 37.1 | 40.6 | 8.7 | 12.8 | 26 | 13.7 | 32.9 | 5.32 |
| | 76.0 | 0.2 | 37.0 | 40.9 | 9.0 | 12.6 | 26 | 13.6 | 33.4 | 5.29 |

**Semolina**

*Milling.* Wheat samples were washed, tempered to 16.5% moisture and allowed to condition for 18 hr; 1,000-g samples were milled in a modified Allis-Chalmers laboratory mill with a laboratory purifier (3). The long-milling flow described by Black (3) was modified to yield a semolina extraction range from 57.7 to 76%. Frosted reduction rolls were not used in the flow, and more purification stages were added. Only stocks from the first and second drawers of the purifier were taken for the lowest extraction semolina. More stocks from other drawers were used for extractions to 68%, and a portion of the 10XX sieve overs was added for higher extraction.

To assess the effect of granulation, both wheats also were milled to flour and coarse semolina. The milling procedure for the coarse semolina was similar to the long-milling flow described, but to obtain a coarser granulation the second break rolls were spaced at 0.007 in. (0.178 mm) instead of 0.004 in. (0.102 mm).

*Quality.* Table II presents quality data for the flour and the coarse semolina from each wheat. All of the analytical determinations were performed in

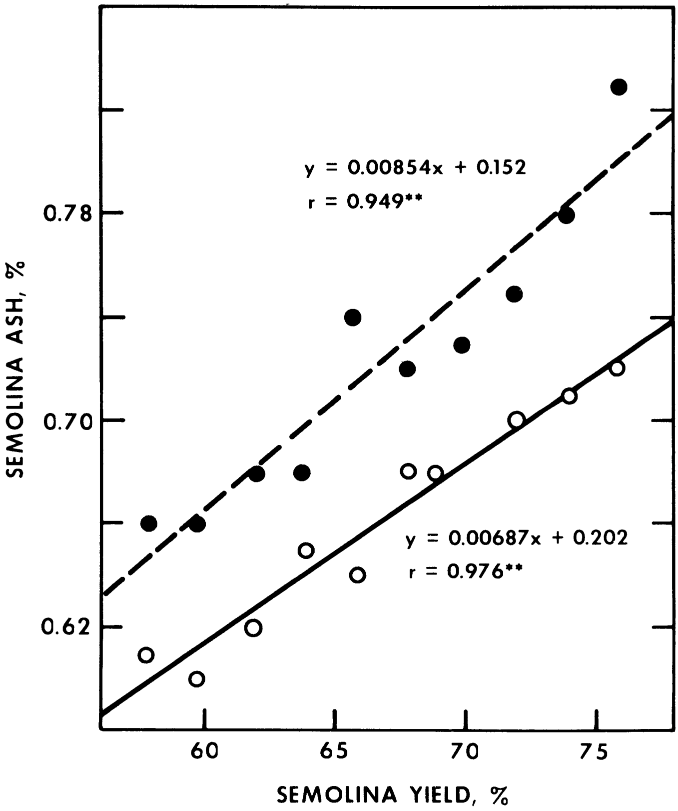

Fig. 1. Relationship between semolina extraction rate and semolina ash content for Hercules (o) and Wakooma (•).

duplicate, and data are expressed as an average of the two results on 14% moisture basis.

Protein contents were determined by the Kjeldahl method (N × 5.7) of Williams (4), farinograms were obtained in a 50-g bowl at 31.5% absorption using the rear sensitivity setting as described by Irvine and co-workers (5), and starch damage was determined as described by Farrand (6).

To determine wet gluten, 10 g of semolina and 5 ml of distilled water were mixed by hand for about 2 min. The dough was then washed for 10 min in a Theby Gluten Washer using a salt phosphate buffer (pH 6.7), followed by 2 min of hand washing. The resulting gluten was worked between the fingers until it became tacky and was weighed.

Ash was determined on a 4-g sample in a silica dish incinerated overnight at

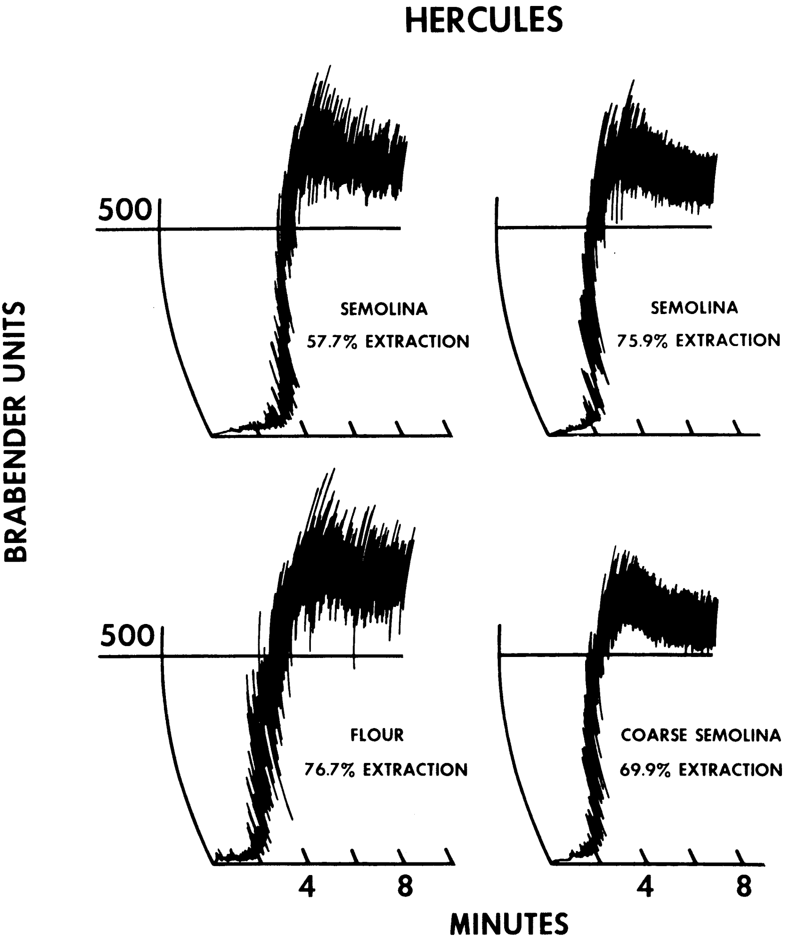

Fig. 2. Pasta dough farinograph curves for some Hercules milled products. All farinograms performed at 31.5% absorption (14% mb).

585°C. After cooling, the dish and ash were weighed, the ash brushed out, the dish reweighed, and the weight of the ash determined by difference.

Yellow pigment contents were determined on 8 g of semolina or ground spaghetti extracted overnight with 40 ml of water-saturated *n*-butyl alcohol. After filtering the extract, light transmission was determined in a spectrophotometer at a wavelength of 435.8 nm, and concentration was calculated on the basis of $\beta$-carotene.

**Spaghetti**

*Processing.* With sufficient distilled water to achieve the required absorption, 50 g of semolina was mixed in a 50-g farinograph bowl and made into spaghetti as described by Matsuo et al (7). Spaghetti was dried for 29 hr with a controlled

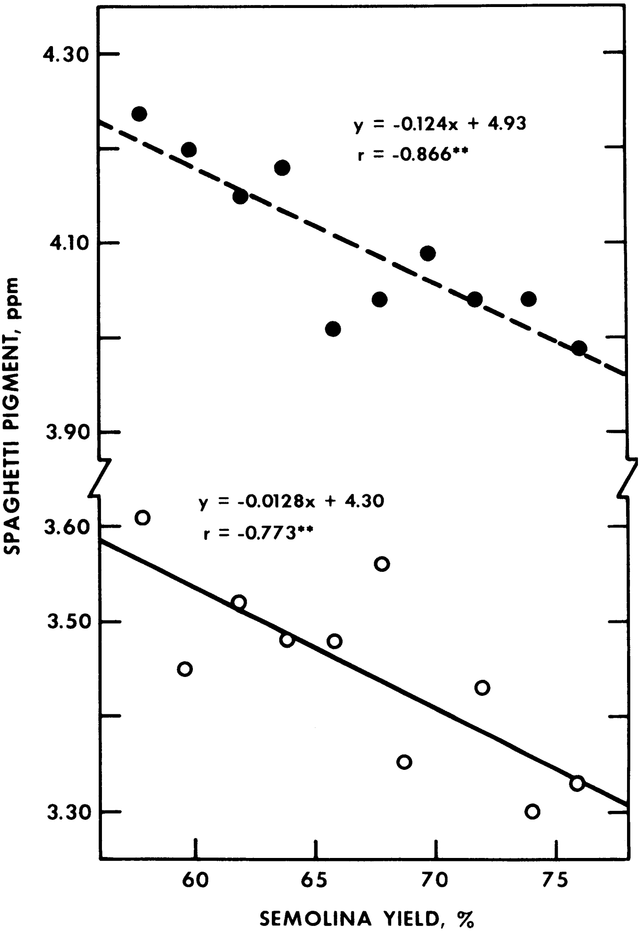

Fig. 3. Relationship between semolina extraction rate and spaghetti yellow pigment content for Hercules (o) and Wakooma (•).

decrease in relative humidity at 39° C. Each sample was processed in duplicate on separate days. Quality data are expressed as an average result for each replicated spaghetti.

*Color.* Whole strands of spaghetti were mounted on white cardboard for color measurements and placed in a Beckman Color DB-G spectrophotometer. Dominant wavelength, purity, and brightness were determined by the Ten Selected Ordinates Method (8).

*Cooking Quality.* Each spaghetti sample was cooked to its normal cooking time (about 12 min) and 5 min longer than its normal cooking time. Cooking quality data were obtained on the GRL spaghetti tenderness apparatus as described previously (9,10). Results were expressed as a cooking quality

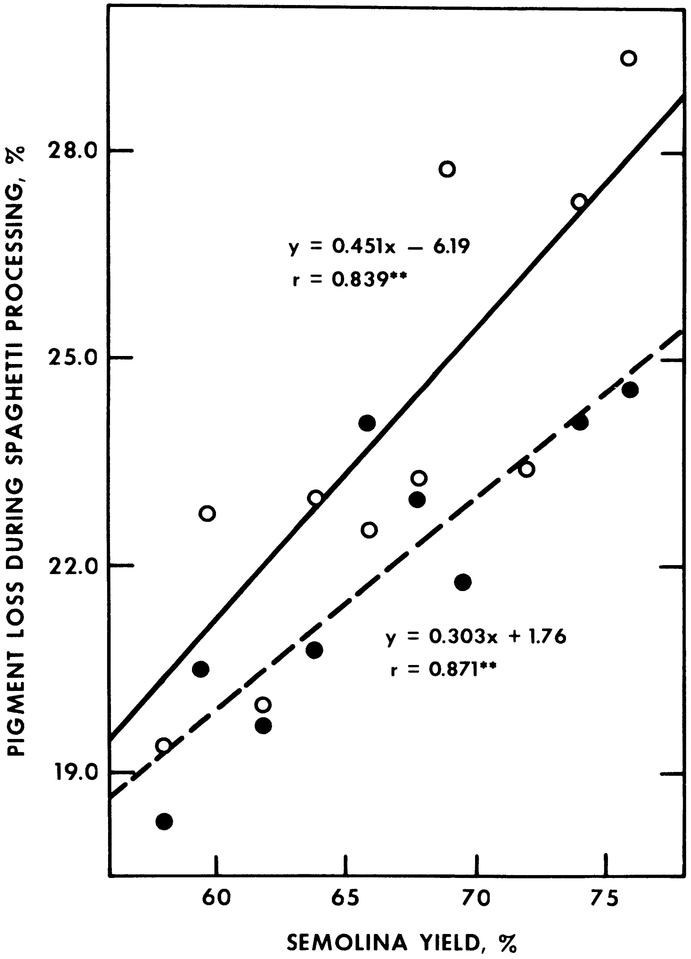

Fig. 4. Relationship between semolina extraction rate and pigment loss during spaghetti processing for Hercules (o) and Wakooma (•).

parameter (recovery/tenderness index × compressibility) (11). Because firm samples with good elasticity yield low values for tenderness index (9) and compressibility (10) concomitant with high values for recovery (10), the higher the value for the cooking quality parameter, the better the cooking quality.

## RESULTS AND DISCUSSION

### Semolina Composition

For both durum wheats, semolina granulation tends to become finer as extraction rate increases (Table III). This results in a slight increase in starch damage, but the change is not sufficient to affect the processing absorption.

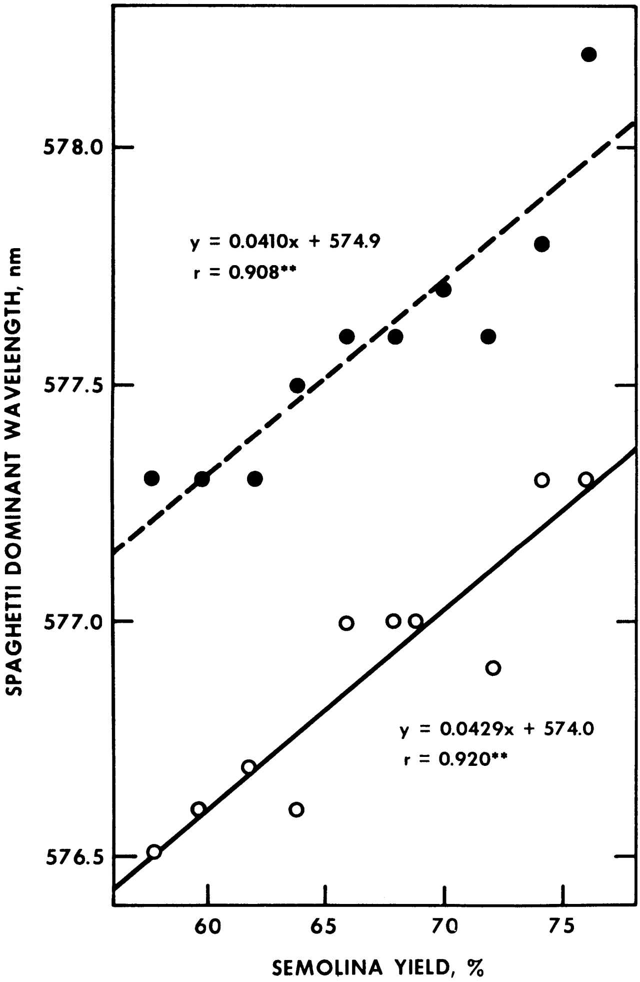

Fig. 5. Relationship between semolina extraction rate and spaghetti dominant wavelength for Hercules (o) and Wakooma (•).

Protein content becomes slightly higher as semolina extraction is increased for both durum wheats (Table III). This trend was reported for bread wheat flours of varying extraction rates (1,2) and attributed to a protein gradient in the wheat kernel (12–16). The inner endosperm is lower in protein content than the subaleurone and bran, and because the latter increase in proportion as the extraction rate increases, protein content increases. Wet gluten apparently is not related to extraction rate for either durum wheat (Table III). Thus, gluten protein nitrogen was not responsible for the observed increase in protein content.

Semolina ash content also rises as extraction rate increases for both durum wheats (Fig. 1). This reflects an increase in ash from the inner to the outer part of the kernel (12,13,17). Nearly parallel curves represent the relationship between

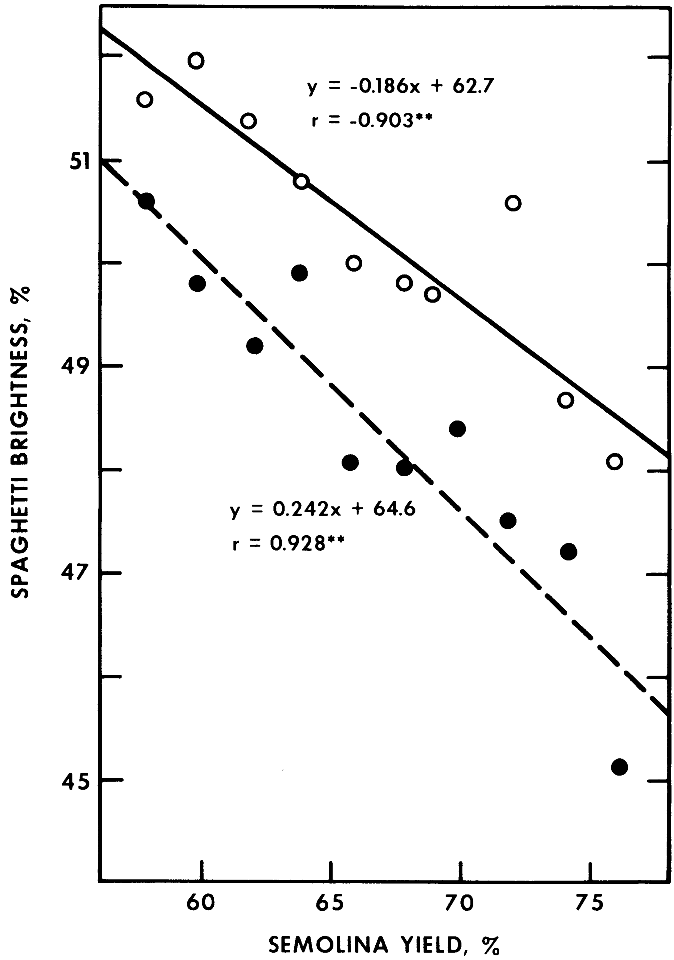

Fig. 6. Relationship between semolina extraction rate and spaghetti brightness for Hercules (o) and Wakooma (•).

semolina ash and extraction rate for the two durum wheats in this study, in agreement with previous reports on bread wheat flours (1,2). The values for semolina ash in this study are higher than those of bread wheat flours at comparable extraction rates (1,2) because the ash content of durum wheat endosperm is higher than that of bread wheat endosperm (18).

Semolina extraction rate significantly affects the farinograph mixing properties for both durum wheats. As examples, the mixing curves for Hercules at 57.7% extraction and at 75.9% extraction are shown in Fig. 2. Decreases in mixing time are particularly noticeable as semolina extraction increases. Mixing times for the Wakooma doughs decrease from 6 min at 57.7% extraction to 5 1/4 min at 76% extraction (r = −0.821**); the Hercules dough decrease in mixing time from 5 3/4 min at 57.7% extraction to 4 1/4 min at 75.9% extraction (r = −0.648*). Usually a decrease in mixing time for pasta dough in the farinograph is associated with weaker gluten (5,19). Comparison of the mixing curves for the flour and coarse grind semolina from each durum wheat (Table II, Fig. 2) shows that the change in granulation with increasing extraction (Table III) is not responsible for the decreasing mixing time. The flour exhibits stronger mixing characteristics than the coarse semolina in both cases, a reverse trend to that observed with increased extraction. A trend of decreased dough strength with increased flour extraction rate was also reported for Australian Bread wheats (2).

### Spaghetti Color

Semolina extraction rate apparently does not affect the semolina pigment content (Table III). The negative correlation between spaghetti pigment content and extraction rate (Fig. 3) is significant, however, because pigment loss increases during processing as the extraction rate increases (Fig. 4). Since the oxidation of pigment during spaghetti processing is known to involve the lipoxidase-linoleate system (20) and lipoxidase resides mainly in the germ of

**TABLE IV**
**Effect of Semolina Extraction on Cooking Quality of Spaghetti From Two Durum Wheats**

| Hercules[a] | | | Wakooma | | |
|---|---|---|---|---|---|
| Semolina Yield (%) | CQP[b] | OQP[c] | Semolina Yield (%) | CQP[b] | OQP[c] |
| 57.7 | 16.4 | ... | 57.7 | 24.1 | 18.0 |
| 59.6 | 14.4 | 9.2 | 59.7 | 22.1 | 16.2 |
| 61.8 | 15.8 | 10.9 | 62.0 | 20.5 | 16.8 |
| 63.8 | 14.4 | ... | 63.7 | 21.5 | 16.2 |
| 65.8 | 15.2 | ... | 65.7 | 22.3 | 14.0 |
| 67.8 | 13.8 | ... | 67.7 | 23.2 | 17.2 |
| 68.8 | 15.0 | ... | 69.8 | 23.6 | 15.3 |
| 72.0 | 16.4 | ... | 71.8 | 22.3 | 16.5 |
| 74.0 | 15.0 | ... | 74.0 | 20.6 | 16.7 |
| 75.9 | 15.6 | ... | 76.0 | 23.6 | 18.0 |

[a] No value indicates that the majority of strands tested did not show recovery from compression.
[b] CQP = cooking quality parameter.
[c] OQP = overcooking quality parameter.

cereal grains (21), the relationship between pigment loss and semolina extraction rate possibly results from higher lipoxidase levels at high extraction rates.

Reflectance measurements show a progressive tendency toward greater brownness in the spaghetti (longer dominant wavelength) as extraction rate increases (Fig. 5) due to increasing amounts of nonendosperm material in the semolina. The extraction rate for either durum wheat does not affect spaghetti purity (results not shown), but as extraction rate increases, spaghetti brightness decreases (Fig. 6), an indication of increased surface dullness. The spaghetti from Wakooma (the lower grade durum wheat) is browner and duller than that of Hercules (Fig. 5, 6) at comparable semolina extraction rates.

### Spaghetti Cooking Quality

The spaghetti cooking quality does not change detectably as semolina extraction rate increases for either wheat (Table IV). Because the farinograph curves (Fig. 2) indicate a slight weakening of gluten properties with increased extraction, a tendency towards poorer cooking quality at higher extraction might be expected. Apparently, however, the change in gluten strength is not sufficient to affect cooking quality significantly in the range of extraction that we examined.

The cooking quality of the flour and coarse grind semolina from each wheat (Table II) does not differ significantly from that of the finer grind semolinas of varying extraction (Table IV). This confirms a previous report (22) that particle size does not affect spaghetti quality.

## SUMMARY AND CONCLUSIONS

Our results demonstrate that semolina extraction rate of laboratory-milled durum wheats does not alter spaghetti cooking quality but slightly affects pasta dough rheological properties in the farinograph. Pigment loss during processing increases significantly with increasing semolina extraction, resulting in decreased spaghetti pigment content. Spaghetti also becomes more brown and dull as semolina extraction increases. At comparable extraction rates the difference in quality between the two cultivars remained relatively constant for each characteristic examined.

Milling to coarser granulation does not affect cooking quality (Tables II, IV) and results in slightly improved spaghetti color characteristics compared with finer grind semolina of comparable extraction (Table II; Fig. 5, 6). Because of our results, semolina milled from new lines in the Canadian durum wheat breeding program has been made coarser and the extraction rate increased from 58 to 70% to yield a product that more closely approximates Canadian commercial practice.

### Acknowledgments

We thank J. J. Lachance for milling the wheats, and we gratefully acknowledge the expert technical assistance of R. W. Daniel, J. W. Bradley and B. C. Morgan.

### Literature Cited

1. ZIEGLER, E., and GREER, E. N. Principles of milling. In POMERANZ, Y. (ed.). Wheat: Chemistry and technology. Vol. III, p. 115. American Association of Cereal Chemists: St. Paul (1971).

2. ORTH, R. A., and MANDER, K. C. Effect of milling yield on flour composition and breadmaking quality. Cereal Chem. 52: 305 (1975).
3. BLACK, H. C. Laboratory purifier for durum semolina. Cereal Sci. Today 11: 533 (1966).
4. WILLIAMS, P. C. The use of titanium dioxide as catalyst for large-scale Kjeldahl determination of the total nitrogen content of cereal grains. J. Sci. Food Agric. 24: 343 (1973).
5. IRVINE, G. N., BRADLEY, J. W., and MARTIN, G. C. A farinograph technique for macaroni doughs. Cereal Chem. 38: 153 (1961).
6. FARRAND, E. A. 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 (1964).
7. MATSUO, R. R., BRADLEY, J. W., and IRVINE, G. N. Effect of protein content on the cooking quality of spaghetti. Cereal Chem. 49: 707 (1972).
8. HARDY, A. C. Handbook of colorimetry. Technology Press: Cambridge, MA (1936).
9. MATSUO, R. R., and IRVINE, G. N. Spaghetti tenderness apparatus. Cereal Chem. 46: 1 (1969).
10. MATSUO, R. R., and IRVINE, G. N. Note on improved apparatus for testing spaghetti tenderness. Cereal Chem. 48: 554 (1971).
11. DEXTER, J. E., and MATSUO, R. R. Influence of protein content on some durum wheat quality parameters. Can. J. Plant Sci. 57: 717 (1977).
12. MORRIS, V. H., ALEXANDER, T. L., and PASCOE, E. D. Studies of the composition of the wheat kernel. I. Distribution of ash and protein in center sections. Cereal Chem. 22: 351 (1945).
13. MORRIS, V. H., ALEXANDER, T. L., and PASCOE, E. D. Studies of the composition of the wheat kernel. III. Distribution of ash and protein in central and peripheral zones of whole kernels. Cereal Chem. 23: 540 (1946).
14. HINTON, J. J. C. The distribution of vitamin $B_1$ and nitrogen in the wheat grain. Proc. R. Soc. London B134: 418 (1947).
15. POMERANZ, Y., and SHELLENBERGER, J. A. Histochemical characterization of wheat and wheat products. II. Mapping of protein distribution in the wheat kernel. Cereal Chem. 38: 109 (1961).
16. KENT, N. L. Subaleurone cells of high protein content. Cereal Chem. 43: 585 (1966).
17. HINTON, J. J. C. The distribution of ash in the wheat kernel. Cereal Chem. 39: 19 (1959).
18. IRVINE, G. N. Durum wheat and paste products. In POMERANZ, Y. (ed.). Wheat: Chemistry and technology. Vol. III, p. 782. American Association of Cereal Chemists: St. Paul (1971).
19. DEXTER, J. E., and MATSUO, R. R. The effect of gluten protein fractions on pasta dough rheology and spaghetti-making quality. Cereal Chem. 55: 44 (1978).
20. IRVINE, G. N., and WINKLER, C. A. Factors affecting the color of macaroni. II. Kinetic studies of pigment destruction during mixing. Cereal Chem. 27: 205 (1950).
21. LULAI, E. C., and BAKER, C. W. The alteration and distribution of lipoxygenase in malting barley and finished malt. J. Am. Soc. Brew. Chem. 33: 154 (1976).
22. SEYAM, A., SHUEY, W. C., MANEVAL, R. D., and WALSH, D. E. Effect of particle size on processing and quality of pasta products. Oper. Millers Tech. Bull. 3497 (1974).

[Received December 9, 1977. Accepted February 27, 1978]