Changes in Spaghetti Protein Solubility During Cooking[1]

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Cereal Chem. 56(5):394-398

ABSTRACT

Three durum wheats and a hard red spring wheat possessing diverse cooking quality were processed into spaghetti in a DEMACO laboratory extruder and cooked for 3–28 min. Although cooking quality decreased for all four wheats over the complete range of cooking times examined, the samples did not rank in the same order at each cooking time. The amount of residue in the cooking water, cooked weight, and degree of strand swelling did not appear to be related to cooking quality. For all four wheats, protein extractability in dilute acetic acid rapidly decreased during cooking up to about 12 min. At each cooking time examined the two poorer quality wheats exhibited significantly greater protein extractability than the two better quality wheats. Osborne protein solubility fractionations showed this to be mainly due to a greater proportion of extractable gluten protein for the poor quality wheats. However, gel filtration elution profiles of acetic acid extracts for the four wheats at each cooking time revealed no significant quantitative differences in their pattern of protein denaturation. The relationship between cooked spaghetti protein extractability and spaghetti cooking quality was confirmed for 18 durum wheat lines of differing spaghetti cooking quality.

Variations in spaghetti cooking quality are due mainly to protein content (Dexter and Matsuo 1976, Matsuo et al 1972) and gluten characteristics (Dexter and Matsuo 1977a, 1978a; Matsuo 1978; Matsuo and Irvine 1970; Walsh and Gilles 1971; Wasik and Bushuk 1975). Previously we showed that if dough development is defined as formation of a continuous network of protein sheets and fibrils, then at the dough-water content of paste goods, full gluten development does not occur (Dexter and Matsuo 1979, Dexter et al 1979, Matsuo et al 1978). Absence of full gluten development would explain why no significant differences could be found in the way that the solubility of semolina proteins was altered by spaghetti processing for wheats of diverse spaghetti-making quality (Dexter and Matsuo 1977c). Scanning electron microscopy studies of cooked spaghetti and cooked noodle structure suggested that the manner in which the proteins were modified during the cooking process might account for cooking quality differences (Dexter et al 1978, 1979).

In this investigation we examined the changes in spaghetti protein solubility that occur at various cooking times for three Canadian durum wheat (*Triticum durum* Desf.) samples representing a range of spaghetti cooking quality and for a Canadian hard red spring wheat (*T. aestivum* L. em Thell) sample. In addition, Wasik's (1978) suggestion that the proportion of cooked spaghetti protein insoluble in acetic acid may be related to cooked spaghetti firmness was investigated for a series of durum wheats of diverse spaghetti cooking quality.

MATERIALS AND METHODS

Three amber durum wheat samples (Pelissier, Stewart 63, and a 1 CW AD grade sample) and a 1 CW hard red spring wheat sample, all from the 1977 crop, were obtained from the Inspection Division of the Canadian Grain Commission for a detailed study of changes in spaghetti protein solubility at various cooking times. The wheats (10-kg samples) were milled into semolina in a Buhler laboratory mill (Black 1967) and processed into spaghetti in a DEMACO S-25 laboratory-scale continuous extrusion press (De Francisci Machine Corporation) as previously described (Matsuo et al 1978), except that extrusion temperature was increased to 60°C to improve extrusion properties and to yield a product with better surface characteristics. Some quality data for the four wheats and their milled products are summarized in Table I. Farinograms were obtained at 31.5% absorption using the rear sensitivity setting (Irvine et al 1961).

To test the relationship between cooked spaghetti protein solubility and spaghetti cooking quality, 11 amber durum wheat lines from the 1976 Cooperative Test (composites of samples grown at eight stations across Western Canada: Morden, Portage La Prairie, Glenlea, Indian Head, Regina, Saskatoon, Swift Current, and Lethbridge) and seven amber durum wheat lines from the 1976 B Test (composities of samples grown at Glenlea, Regina, and Swift Current) were chosen, to give a range in spaghetti cooking quality. The wheats were milled in an Allis-Chalmers laboratory mill (1,000-g samples) as described by Black (1966) with some modifications (Dexter and Matsuo 1978b) to obtain a semolina extraction rate of 70%. Spaghetti was prepared by a microprocedure described by Matsuo et al (1972). The samples are described in Table II.

Spaghetti Cooking Tests

All spaghetti cooking tests were performed in duplicate. Spaghetti cooking quality was assessed for all samples on the GRL Spaghetti Tenderness Testing Apparatus (Matsuo and Irvine 1969, 1971) as previously described (Dexter and Matsuo 1977b). The greater the value for the cooking quality parameter, the better the cooking quality. Cooked weights, amounts of solids lost, and strand diameters were determined for the four samples prepared in the DEMACO at each cooking time. Cooked weight was determined for 10 g of spaghetti that had been cooked for the desired time and drained on a sieve for 5 min. Cooking water was recovered quantitatively, freeze-dried, and weighed, and the proportion of solids lost to the cooking water was determined after adjustments for moisture variations. Strand diameters were expressed as the average for 20 strands.

Protein Extraction

One-gram samples of ground freeze-dried cooked spaghetti were extracted in 17 ml of 0.05*M* acetic acid for 15 min in a Potter and Evejhem homogenizer (Tanaka and Bushuk 1973) and centrifuged. The pellets were resuspended and centrifuged, the two supernatants combined, freeze-dried, and weighed, and the protein content (N × 5.7) was determined by a micro-Kjeldahl procedure (Mitcheson and Stowell 1970). The precision of duplicate extractions was about 5%.

Protein Solubility Fractionations

Some samples were fractionated into protein solubility classifications by a modified Osborne procedure (Chen and Bushuk 1970). Each fraction was freeze-dried, weighed, and the protein content (N × 5.7) determined by a micro-Kjeldahl procedure

[1]Paper 416 of the Grain Research Laboratory, Canadian Grain Commission, Winnipeg, Manitoba, R3C 3G9.

0009-0352/79/000061$3.00/0

TABLE I
Some Quality Data for the Samples Used to Determine Changes in Protein Solubility During Spaghetti Cooking

Property	Sample			
	Pelissier	1 CW AD	Stewart 63	1 CW HRS
Wheat				
Grade	1 CW	1 CW	1 CW	1 CW
Protein, (%)[a,b]	13.5	13.2	13.2	13.8
Ash, (%)[a]	1.20	1.44	1.24	1.25
Semolina yield, (%)	60.0	60.0	60.9	58.0
Semolina				
Protein, (%)[a,b]	12.2	11.7	11.7	12.0
Ash, (%)[a]	0.49	0.55	0.48	0.36
Farinogram[c]				
Mixing time, (min)	6.0	6.75	4.75	5.25
Maximum consistency, (BU)	580	560	550	660
Tolerance index, (BU)	40	20	90	50

[a] Results expressed on a 14% moisture basis.
[b] Protein computed as % N × 5.7.
[c] Farinograms performed at 31.5% absorption as described by Irvine et al (1961). BU = Brabender Units.

(Mitcheson and Stowell 1970). Precision for each solubility fraction was better than 10%.

Gel Filtration

Gel filtration was performed on a 2.7 × 85 cm bed of Sephadex G-100 with upward flow at 30 ml/hr. The column was calibrated for molecular weight by Whitaker's method (1963), using previously described standards (Dexter and Matsuo 1977c) Samples (1.2 g) were extracted for 15 min in 20 ml of 0.05*M* acetic acid (Tanaka and Bushuk 1973) and centrifuged in a Beckman L-2 ultracentrifuge for 20 min at 150,000 × *g*. Twelve milliliters of extract was injected onto the column for each run and the effluent monitored at 280 nm by an LKB 8300 Uvicord II ultraviolet analyzer.

RESULTS AND DISCUSSION

Cooked Spaghetti Characteristics

The cooking quality parameter for all four wheats decreased over the complete range of cooking times, reflecting a continual loss of firmness and elasticity (Fig. 1). The samples did not rank in the same order at each cooking time, although after the samples were cooked past their optimum time (13 min), the rankings stabilized; Pelissier and 1 CW AD samples were clearly superior to the Stewart 63 and 1 CW HRS. The variation in ranking for these samples was in agreement with a recent report by Voisey et al (1978) and emphasizes that, to gain the most meaningful assessment of cooked spaghetti properties, measurements should be made at more than one cooking time.

As cooking time was increased, the amount of solids lost to the cooking water, the cooked weight, and the strand diameter increased for all four spaghetti samples (Fig. 2). None of these parameters appeared to be related to spaghetti cooking quality. This was somewhat surprising, particularly in the case of lost solids, since it is generally believed that poor quality pasta should have a greater cooking loss than good quality pasta. This result is, however, supported by some recent reports by D'Egidio and co-workers (1976, 1978), who demonstrated that determination of residue in cooking water does not correlate well with spaghetti quality.

Strand diameters increased very rapidly during the initial 3 min of cooking from about 1.7 mm to about 2.4 mm and increased more slowly thereafter. This was in agreement with the results of Gryzbowski and Donnely (1977). However, they also reported that in some cases strand diameter contracted slightly after 15-min cooking, a phenomenon that we did not observe, although our Stewart 63 and 1 CW AD samples did appear to exhibit some decrease in the rate of strand swelling near that time.

Spaghetti Protein Solubility and Molecular Weight Distribution

All four wheats exhibited a very rapid decrease in spaghetti protein extractability in dilute acetic acid as cooking time was increased to 12 min (optimum cooking time was about 13 min), and a very limited further decrease in solubililty as cooking was continued to 28 min (Fig. 3). Throughout the complete range of cooking times, it was readily apparent that the spaghetti protein extractability of the poorer cooking quality samples, Stewart 63 and the 1 CW HRS, was significantly greater than that of the Pelissier and 1 CW AD samples. This was in agreement with Wasik's report (1978) that superior spaghetti cooking quality may be related to the proportion of insoluble protein in cooked spaghetti.

Additional information was gained on the pattern of protein denaturation during cooking for the four wheats by performing Osborne protein solubility fractionations on selected cooked spaghetti samples. The results (Fig. 4) revealed a rapid decrease in total salt-soluble proteins (albumins and globulins) and soluble gluten proteins (gliadins and soluble glutenins) up to about 12 min, concomitant with an increase in insoluble protein. As predicted by the acetic acid extractability results (Fig. 3), the Stewart 63 and 1 CW HRS had significantly less insoluble cooked spaghetti protein than did the Pelissier and the 1 CW AD samples. This appeared to be the result of a greater proportion of soluble gluten proteins in both the cooked Stewart 63 and 1 CW HRS spaghetti and, in the

TABLE II
Description of Durum Wheat Lines Chosen to Test Relationship Between Cooked Spaghetti Protein Solubility and Spaghetti Cooking Quality

Sample Description	Grade	Semolina Protein[a] (%)	CQP[b]
RL 7067[c]	2 CW	12.0	29.3
B10-1976[c]	1 CW	12.1	25.4
DT 358[d]	1 CW	12.9	26.4
Hercules[d]	2 CW	13.4	25.1
DT 427[c]	1 CW	12.2	22.3
Macoun[d]	2 CW	12.6	22.9
Coulter[d]	1 CW	12.5	22.7
DT 424[d]	2 CW	13.1	23.4
DT 428[c]	1 CW	12.6	22.1
Cando[d]	1 CW	12.0	20.5
Wakooma[d]	1 CW	13.1	21.6
Edmore[c]	3 CW	12.6	20.4
DT 359[c]	2 CW	13.5	21.2
DT 425[d]	1 CW	12.9	19.4
Wascana[d]	2 CW	12.9	19.4
DT 423[d]	1 CW	12.7	18.5
DT 354[d]	1 CW	12.4	17.9
Ward[c]	1 CW	12.6	11.3

[a] Protein computed as % N × 5.7 on a 14% moisture basis.
[b] CQP = cooking quality parameters obtained on GRL Spaghetti Tenderness Testing Apparatus (cooking time 12 min).
[c] From 1976 B Test.
[d] From 1976 Cooperative Test.

case of the HRS, a greater proportion of salt-soluble proteins as well.

Gel filtration profiles of acetic acid extracts were determined over the complete range of cooking times for all four samples. The profiles for all the Stewart 63 samples and for several samples from the other three wheats are shown (Fig. 5). As cooking time increased, proteins were progressively denatured throughout the complete molecular weight range. The pattern of change in elution profiles was quantitatively similar for all four wheats. The differences in protein extractability (Figs. 3 and 4) between the four wheats were apparently not sufficiently large to result in any readily discernible differences between samples at equivalent cooking times.

Spaghetti Cooking Quality and Cooked Spaghetti Protein Solubility

Four samples are insufficient to predict whether spaghetti cooking quality and cooked spaghetti protein extractability are

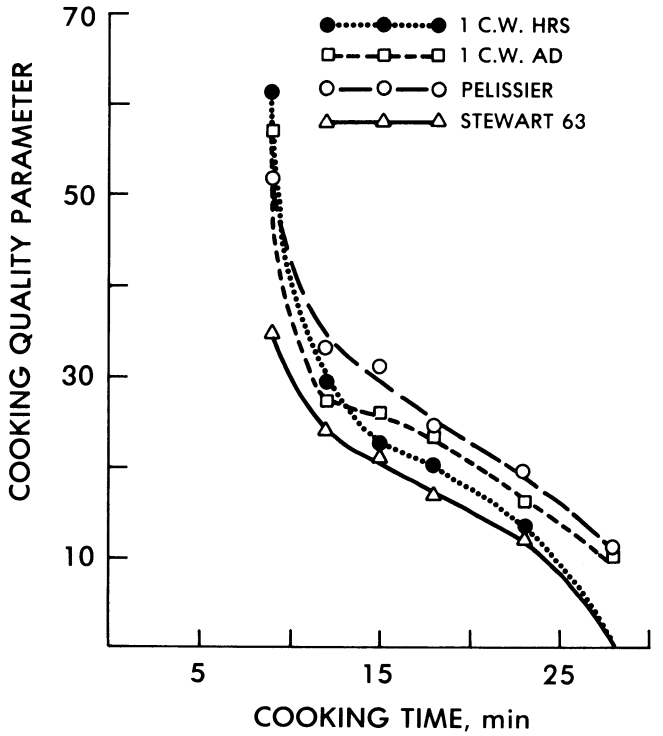

Fig. 1. Effect of cooking time on the cooking quality of spaghetti produced from three durum wheats and a hard red spring wheat.

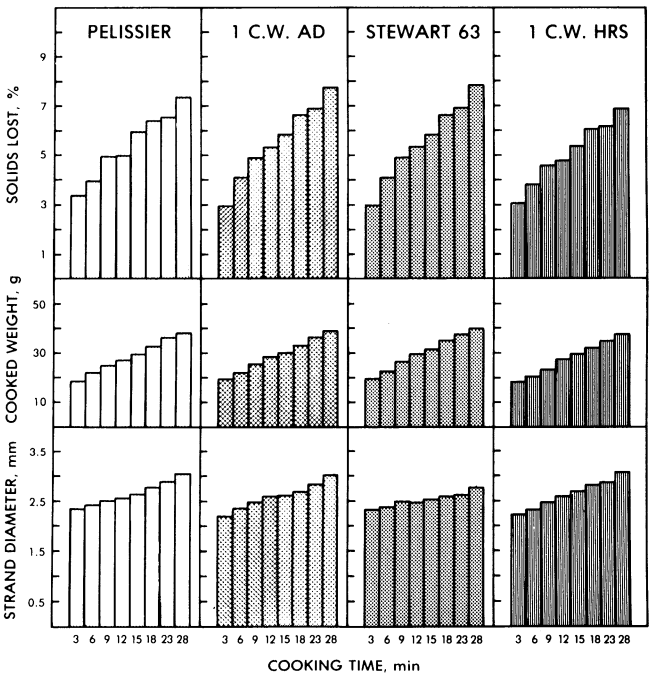

Fig. 2. Effect of cooking time on the amount of solids lost to cooking water, cooked weight, and strand diameter for spaghetti produced from three durum wheats and a hard red spring wheat. Diameter of uncooked spaghetti was 1.7 mm.

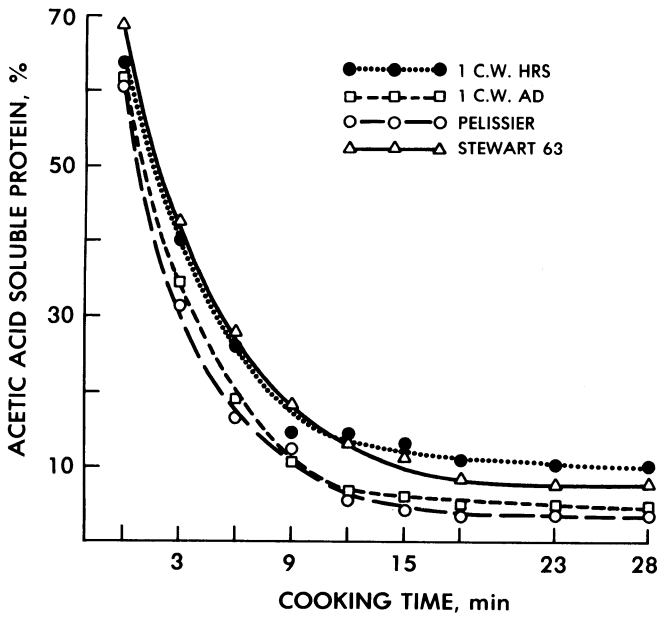

Fig. 3. Effect of cooking time on the acetic acid extractability of protein for spaghetti from three durum wheats and a hard red spring wheat.

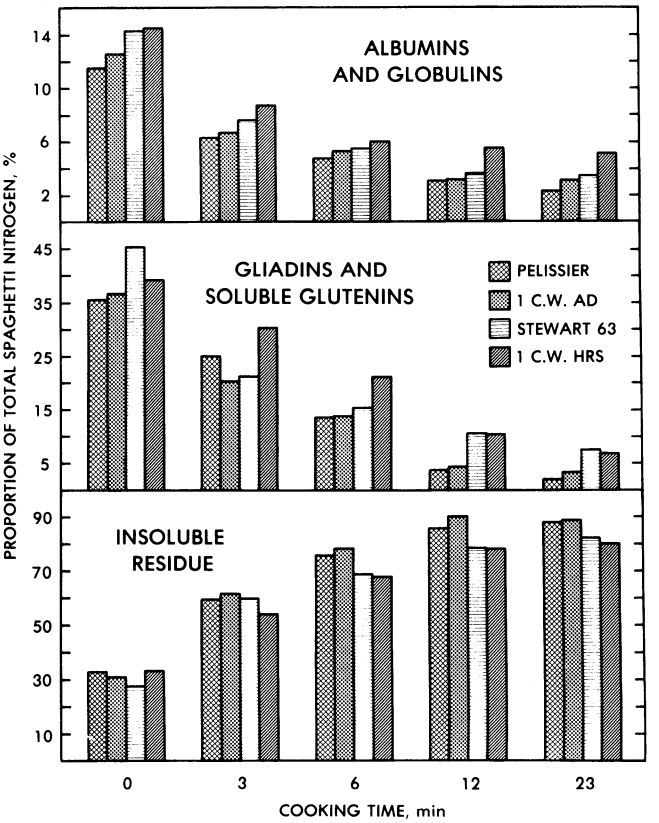

Fig. 4. Effect of cooking time on the Osborne protein solubility distribution of cooked spaghetti from three durum wheats and a hard red spring wheat.

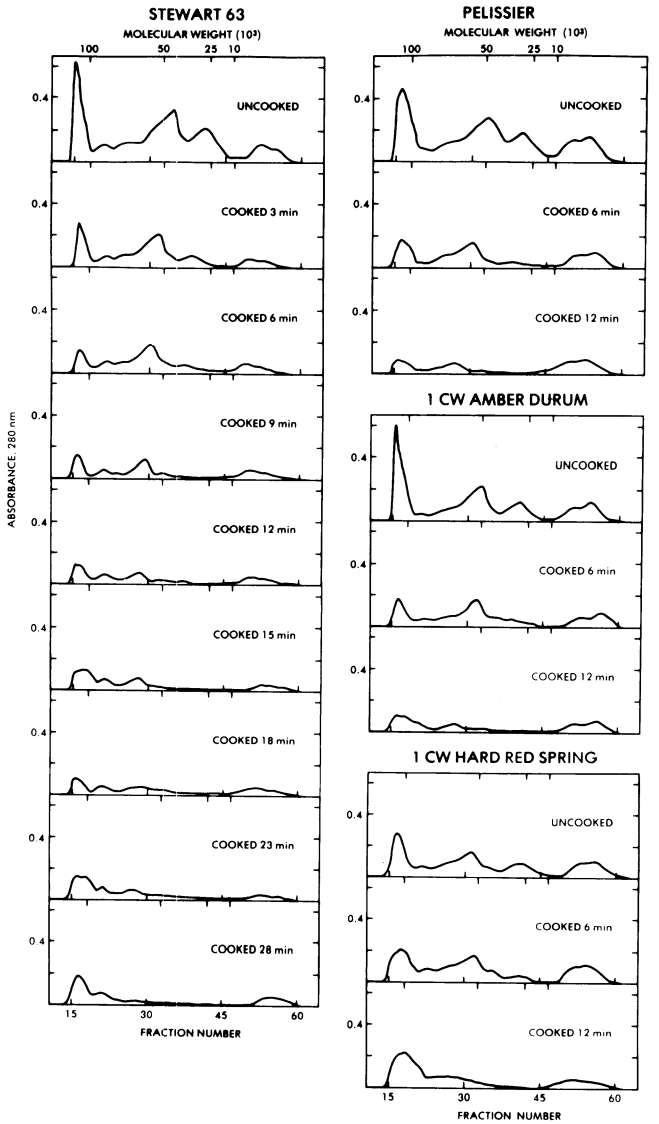

Fig. 5. Effect of cooking time on gel filtration elution profiles (Sephadex G-100) of acetic acid protein extracts for cooked spaghetti from three durum wheats and a hard red spring wheat.

related. We therefore tested this relationship for 18 durum wheat lines representing a wide range of spaghetti cooking quality (Table II). Previously we demonstrated that a linear relationship exists between spaghetti cooking quality and protein content (Dexter and Matsuo 1977b). Therefore, to eliminate the effect of varying protein content between the samples, the cooking quality parameter was determined on a unit protein basis. A similar approach is often used in bread wheat quality testing by considering loaf volume on a unit protein basis (Orth et al 1976, Tipples and Kilborn 1974).

Results indicated that although there was considerable scattering of points, a significant relationship exists between cooking quality and the proportion of insoluble protein in cooked spaghetti (Fig 6). Some scattering may have been due to environmental effects, because all the lines tested were not grown under the same conditions.

It is not clear at this time why a relationship between cooking quality and cooked spaghetti protein solubility exists. Although this phenomenon is probably of little practical significance, it may provide a valuable clue concerning the basis for spaghetti cooking quality.

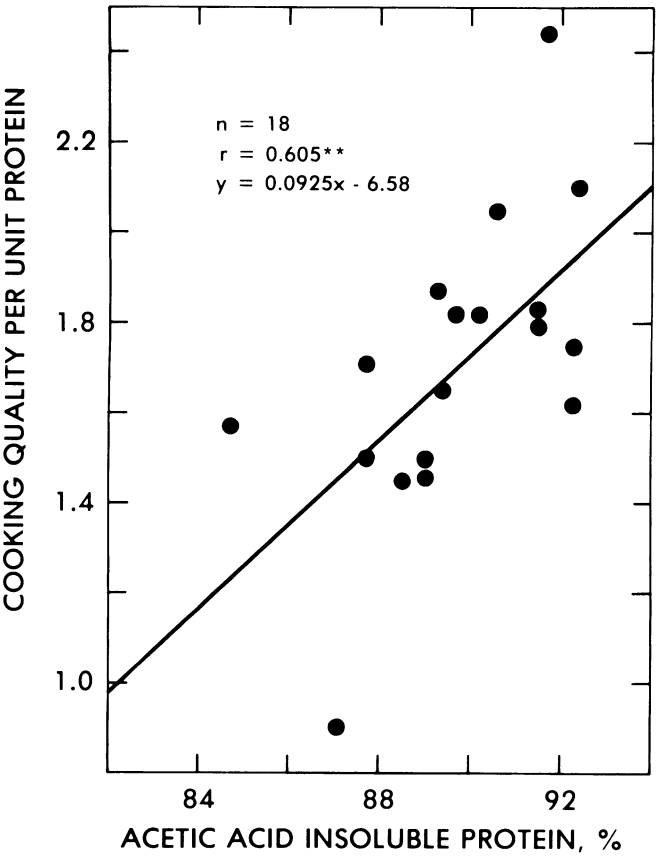

Fig. 6. Relationship between spaghetti cooking quality per unit protein (cooked 12 min) and the proportion of acetic acid insoluble protein in spaghetti.

ACKNOWLEDGMENTS

We gratefully acknowledge the expert technical assistance of B. C. Morgan, R. J. Wallis, and R. W. Daniel. We thank the Canada Committee on Grain Quality for permission to use data recorded in its minutes.

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[Received November 27, 1978. Accepted March 5, 1979]