Relationship between Durum Wheat Protein Properties and Pasta Dough Rheology and Spaghetti Cooking Quality

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Thirty durum wheat lines were evaluated for pasta dough farinograph properties, protein characteristics, and spaghetti cooking quality. Farinograph properties were strongly influenced by gluten strength. Farinograph bandwidth was found to be a better indicator of spaghetti cooking quality than the traditionally used mixing time and tolerance index. Protein solubility fractionations revealed that insoluble residue protein was the protein fraction most responsible for variations in gluten strength, farinograph properties, and spaghetti cooking quality. The intrinsic viscosity of whole gluten dissolved in a dissociating medium was significantly correlated to the proportion of residue protein, gluten strength, farinograph properties, and cooking quality. Intrinsic viscosity measurements and gel filtration profiles of lactic acid soluble gluten proteins in a dissociating medium suggested that differences in the soluble gluten proteins may also be a durum wheat gluten quality factor.

Durum wheat is the raw material of choice for the manufacture of high-quality spaghetti and other pasta products. Pasta dough made from durum wheat semolina has rheological properties ideally suited to the pasta manufacturing process. When cooked, durum wheat pasta resists disintegration and retains a firm texture.

Differences in spaghetti cooking quality appear to be attributable mainly to protein content and gluten strength (Dexter et al., 1980; Grzybowski and Donnelly, 1979). There is some evidence that durum wheats with high ratios of glutenins to gliadins may possess cooking quality superior to those with low ratios (Dexter and Matsuo, 1977a,b; Wasik and Bushuk, 1975). It is well-known that gluten properties have a marked influence on farinograph mixing properties at pasta absorption (Irvine et al., 1961), but the relationship between farinograph properties and spaghetti cooking quality has not been established conclusively. Matsuo and Irvine (1970) suggested that weak farinograph mixing properties are related to poor cooking quality while Walsh and Gilles (1971) could not establish a trend between mixing strength and cooked spaghetti firmness.

The purpose of the present study was to examine further the interrelationships between pasta dough rheological properties, spaghetti cooking quality, and protein properties. Thirty durum wheat lines possessing a wide range in spaghetti-making quality were evaluated for mixing properties and cooking quality, and their gluten proteins were assessed for gluten strength, solubility in various protein extractants, and intrinsic viscosity in a dissociating medium.

EXPERIMENTAL SECTION

Plant Material. Thirty durum wheat (*Triticum turgidum* L.) lines consisting of 22 developed in Canada (Coulter, Macoun, Hercules, Wakooma, Wascana, Stewart 63, and 16 lines from the Canadian breeding program), 5 from the United States (Ramsey, Rolette, Ward, Cando, and Edmore), 1 from Algeria (Pelissier), 1 from South America (Quilafen), and 1 from France (D64-47) were grown at Indian Head, Saskatchewan, and Swift Current, Saskatchewan, during 1978. One 500-g portion of each wheat from each location was milled into semolina in a three-stand Allis-Chalmers laboratory mill equipped with a laboratory purifier as previously described (Dexter and Matsuo, 1978b).

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Quality Evaluation. Quality analyses were performed in duplicate on each line at each station. Semolina protein content was determined by the Kjeldahl procedure (N × 5.7, 14% moisture basis) as modified by Williams (1973). Gluten strength was assessed by the gluten breaking strength procedure of Matsuo (1978).

Farinograms were obtained as described by Irvine et al. (1961). Fifty grams of semolina (14% moisture basis) was mixed with distilled water (31.5% absorption) in a small stainless steel farinograph bowl (59-rpm drive) while using the rear sensitivity setting. Mixing time was the time required to reach the peak of the curve, tolerance index was the decrease in consistency measured in Brabender units (BU) which occurred 4 min past the mixing time, and bandwidth was measured in Brabender units (BU) 4 min past the mixing time.

Spaghetti was prepared by the modified micromacaroni method (Matsuo et al., 1972). Processing absorption was varied according to the requirements of each sample. Spaghetti was dried with a controlled decrease in relative humidity for 28 h at 39 °C. Spaghetti cooking quality parameters were determined on the spaghetti tenderness apparatus (Matsuo and Irvine, 1969, 1971) at optimum cooking time (13 min) and after overcooking for 10 min as described by Dexter and Matsuo (1977b).

Protein Characterization. The proteins from 10-g portions of semolina were quantitatively fractionated according to their solubilities by the modified Osborne method of Chen and Bushuk (1970). This procedure classifies the proteins into albumins (water soluble), globulins (salt water soluble), gliadins (ethanol soluble), soluble glutenins (acetic acid soluble), and insoluble residue proteins. Each fraction was freeze-dried and weighed, and the protein content (N × 5.7) was determined in duplicate by a micro-Kjeldahl procedure (Mitcheson and Stowell, 1970). Dispersibility of semolina proteins in aqueous urea solution was determined in duplicate as described by Pomeranz (1965).

Dried gluten was prepared by washing wet gluten by hand from each semolina, allowing the gluten to relax, and freeze-drying overnight. The friable puffed dry gluten was ground in a coffee grinder, and protein (N × 5.7) was determined in duplicate on 150-mg portions by the Kjeldahl procedure (Williams, 1973). The solubility distribution of the dried gluten was determined by extracting 1-g portions in centrifuge tubes with 50 mL of 0.005 M lactic acid for 2 h on a revolving wheel and centrifuging at 25000*g* for 20 min. The supernatants and the pellets were freeze-dried and weighed, and protein contents (N × 5.7)

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Table I. Means, Ranges, and Standard Deviations of Measurements

measurement	Indian Head			Swift Current		
	mean	range	SD	mean	range	SD
semolina protein, %	13.7	12.4-14.8	0.7	13.5	11.8-15.6	1.0
farinograph:						
mixing time, min	4.1	2.5-8.25	1.2	4.1	2.25-6.75	1.0
tolerance index, BU	99	40-180	36	99	20-190	37
bandwidth, BU	99	40-160	36	77	35-120	25
gluten strength, N	0.83	0.25-1.29	0.31	0.90	0.27-1.57	0.37
gluten viscosity, dL/g	0.90	0.61-1.31	0.17	1.02	0.76-1.27	0.14
specific absorbance, OD 280/prot.	61.4	54.9-72.5	3.9	61.2	55.3-65.6	3.2
protein distribution:						
albumins, %	9.5	8.4-11.9	0.8	8.4	5.8-10.4	0.9
globulins, %	7.8	6.3-11.9	1.2	7.0	5.8-10.4	0.9
gliadins, %	38.1	32.1-42.2	2.4	41.5	36.4-47.7	2.6
glutenins, %	13.5	10.3-19.7	2.7	10.9	6.7-14.8	1.8
residue, %	27.2	21.2-32.6	3.2	27.8	20.4-33.2	3.1
cooking quality parameter:						
cooked 13 min, s/m × 10^{-6}	25	14-37	5.6	17	11-31	4.9
cooked 23 min, s/m × 10^{-6}	24	0-35	8.3	18	0-32	8.0

were determined by the micro-Kjeldahl procedure (Mitcheson and Stowell, 1970).

Lactic acid soluble gluten was dissolved in AUC [0.1 M acetic acid, 3 M urea, and 0.01 M cetyltrimethylammonium bromide (Meredith and Wren, 1966)] by extracting 150-mg portions in 10 mL of solvent for 1 min on a vortex mixer. To dissolve whole dried gluten, we extracted 300-mg portions for 15 min at 4 °C with 20 mL of AUC in a Potter and Elvejhem homogenizer. The homogenate was centrifuged at 25000*g* for 20 min and filtered through glass wool to remove suspended lipid particles.

The efficiency of dissolution of whole gluten was determined by drawing off a carefully measured portion of homogenate, dialyzing against distilled water for several days, freeze-drying the protein, and performing an amino acid analysis to determine nitrogen recovery. Amino acid analyses were performed on a Durrum MBN amino acid analyser. Samples were hydrolyzed as described by Orth et al. (1974). The ammonia peak did not reflect a true value because of small amounts of urea and cetyltrimethylammonium bromide in the hydrolysates. Therefore, recoveries were computed by using an amount of ammonia estimated from the data of Tkachuk (1966).

Viscosity measurements were made on AUC extracts of whole dried gluten and lactic acid soluble gluten in an Ostwald viscometer at 25 °C. Intrinsic viscosities were calculated from the relative viscosity of each extract at several dilutions. Gel filtration was performed on lactic acid soluble gluten in AUC on a 2.5 × 36 cm bed of Sephadex G-150 as previously described (Dexter and Matsuo 1977c).

RESULTS AND DISCUSSION

The mean, range, and standard deviation of each quality measurement at each location are presented in Table I. The relatively broad range in values for each measurement reflects the diversity of the durum wheat lines. All measurements were approximately normally distributed.

Simple correlations among quality measurements were calculated for all possible pairs of quality traits at each location. The correlation coefficients for each pair were tested for homogeneity (Steel and Torrie, 1960) and if found homogeneous the data were pooled. Significant homogeneous correlations and heterogeneous correlations are summarized in Table II. Pertinent interrelationships will be discussed.

All three farinograph measurements correlated strongly to gluten strength (Table II). Strong gluten varieties show a tendency for long mixing times, low tolerance indexes, and wide bandwidths. Farinograph bandwidth correlated much better to spaghetti cooking and overcooking quality than the other two parameters. It appears likely that this is at least partly due to the greater influence of protein content on the mixing time and tolerance index compared to bandwidth. Wide bandwidths are characteristic of doughs which possess strong nonsticky gluten. This type of gluten tends to result in formation of a lumpy dough rather than a smooth homogeneous phase. As the mixing blades rotate, the dough is not sheared at all times, resulting in an irregular farinograph consistency. The strong correlation of bandwidth to cooking quality suggests that gluten stickiness may be an important cooking quality criterion in addition to gluten strength.

Previously it has been demonstrated that the proportion of residue protein present in bread wheat flour is largely responsible for bread wheat mixing properties and baking quality (Orth et al., 1972, 1976). Results from the current study reveal that residue protein also is the Osborne solubility fraction most responsible for determining durum wheat functional properties (Table II). The proportion of residue protein correlated strongly to all three farinograph parameters and to gluten strength. Residue protein was also the only protein fraction which correlated significantly to cooking quality and overcooking quality. Heterogeneous relationships were obtained between cooking quality and the proportion of gliadins and glutenins. As would be expected from the above results, specific absorbance, which is a measure of nonresidue protein, was also related to farinograph properties and negatively correlated to gluten strength and cooking quality.

Viscosity of flour or ground whole wheat suspensions has been the basis for tests for breadmaking quality (Axford et al., 1978). Therefore, we thought it might be of interest to examine the relationship between gluten viscosity and durum wheat quality. As a dissolving medium we chose AUC which has been reputed to dissolve cereal protein almost quantitatively (Bushuk and Wrigley, 1971; Meredith and Wren, 1966). More recently, however, it has been reported that AUC may dissolve as little as 75% of wheat protein (Danno et al., 1974; Payne and Corfield, 1979). Therefore, before viscosity experiments were performed, the efficiency of AUC extraction was checked by amino acid analysis of some dialyzed extracts. Nitrogen recoveries (not taking into account tryptophan and cysteine which were not determined) exceeded 90%, indicating almost quantitative extraction. The discrepancy in AUC dissolving efficiency is likely a result of the extraction procedure; Danno et al. (1974) and Payne and Corfield (1979)

Table II. Summary of Pooled Simple Correlations among Quality Measurements ($n = 60$)[a]

SP	MT	TI	BW	GS	GV	SA	Al	Gb	Gi	Gu	Re	CQ	OQ	
1	−0.50**	0.49**	ns	−0.41**	ns	ns	H	ns	ns	ns	ns	0.34*	ns	semolina protein (SP)
	1	−0.51**	0.72**	0.68**	0.48**	−0.45**	ns	−0.26*	−0.27*	−0.37**	0.74**	ns	0.38**	farinograph mixing time (MT)
		1	−0.54**	−0.68**	−0.44**	0.31*	ns	0.27*	0.35**	ns	−0.59**	−0.31*	−0.37**	farinograph tolerance index (TI)
			1	0.64**	0.47**	−0.54**	ns	ns	H	H	0.71**	0.62**	0.69**	farinograph bandwidth (BW)
				1	0.73**	−0.53**	ns	−0.30*	−0.25*	−0.48**	0.79**	0.27*	0.44**	gluten strength (GS)
					1	−0.68**	−0.31*	−0.46**	ns	−0.54**	0.71**	ns	0.38**	gluten viscosity (GV)
						1	ns	0.33**	H	H	−0.67**	−0.39**	−0.56**	specific absorbance (SA)
							1	ns	−0.28*	0.29*	ns	0.28*	ns	% albumins (Al)
								1	ns	ns	−0.42**	ns	ns	% globulins (Gb)
									1	H	H	H	H	% gliadins (Gi)
										1	−0.46**	H	H	% glutenins (Gu)
											1	0.32*	0.45**	% residue (Re)
												1	0.81**	cooking quality (CQ)
													1	overcooking quality (OQ)

[a] ns = not significant; H = heterogeneous; * and ** = correlation significantly different from zero at 0.05 and 0.01 level of probability, respectively.

Table III. Simple Correlations between Lactic Acid Soluble Gluten Intrinsic Viscosity and Some Durum Wheat Characteristics ($n = 30$)[a]

variable	simple correlation coeff
intrinsic viscosity vs.:	
gluten strength	0.53**
% gliadins	−0.60**
% glutenins	0.10 ns
cooking quality	0.14 ns
overcooking quality	0.25 ns

[a] ns = not significant; ** = correlation significantly different from zero at 0.01 level of probability.

extracted by stirring, while in the current study and in the investigations of Meredith and Wren (1966) and Bushuk and Wrigley (1971) extraction was performed by homogenizing.

Gluten viscosity was strongly correlated to gluten strength and Osborne protein distribution (Table II). Stronger glutens possessed greater intrinsic viscosities, inferring a tendency to more randomized structure. It is well-known that residue protein (insoluble glutenins) possesses a much larger molecular size than other classes of wheat protein (Dexter and Matsuo, 1978a) and is believed to form large complex aggregates through disulfide bonding or strong noncovalent forces (Khan and Bushuk, 1979). Therefore, the strong positive correlation of gluten viscosity to the proportion of residue protein and the significant negative correlations of gluten viscosity to the proportion of albumins, globulins, and soluble glutenins were as would be predicted.

Previous studies suggested that in addition to quantitative differences in gluten protein distribution, qualitative differences within the lactic acid soluble protein may be partly responsible for durum wheat gluten quality (Dexter and Matsuo, 1978a). For an investigation of this possibility, composited glutens made up of equal portions of gluten from the two locations for each durum wheat line were quantitatively fractionated into lactic acid soluble and lactic acid insoluble protein and their intrinsic viscosities determined. The proportion of lactic acid insoluble protein in the composite glutens correlated significantly to the mean values from the two locations for gluten intrinsic viscosity ($r = 0.91$**), gluten strength ($r = 0.89$**), cooking quality ($r = 0.53$**), and overcooking quality ($r = 0.66$**) for each variety, confirming the importance of the insoluble residue protein in determining durum wheat properties.

No trend between lactic acid insoluble protein viscosity and gluten properties or cooking quality was apparent. However, intrinsic viscosity of the lactic acid soluble proteins (which ranged from 0.43 to 0.73 dL/g) was significantly related to mean gluten strength (Table III). This would infer a tendency to more random structure within the soluble gluten protein fraction for stronger gluten varieties and is consistent with the significant negative correlation between the mean proportion of gliadins and lactic acid soluble gluten protein intrinsic viscosity (Table III). Further confirmation of the relationship between intrinsic viscosity and the proportion of gliadins was obtained by comparing gel filtration elution profiles of the soluble gluten proteins in AUC. Some representative results are shown in Figure 1. As the intrinsic viscosity of the lactic acid soluble proteins decreased to an intermediate level, there was a noticeable increase in the size of peak II [gliadins according to the designation of Meredith and Wren (1966)] in relation to peak I (soluble glutenins). However, there was no detectable difference in gel filtration profile between samples with intermediate and low lactic acid soluble intrinsic viscosities, suggesting

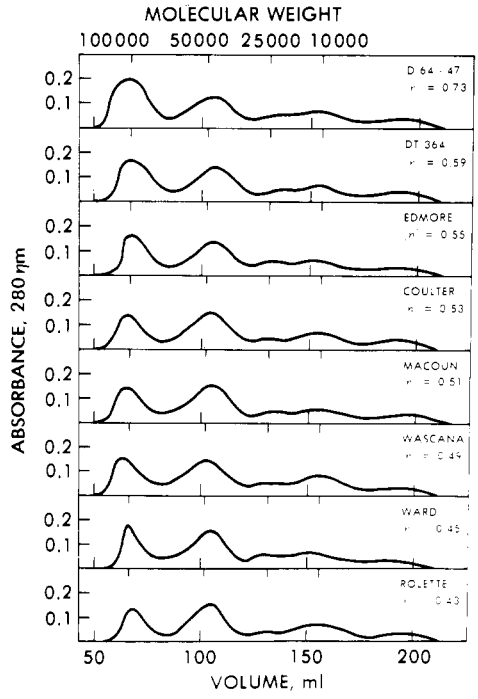

Figure 1. Representative gel filtration profiles of AUC extracts of lactic acid soluble gluten protein on Sephadex G-150.

that qualitative differences within the protein fractions may also play a role in determining gluten properties. No relationship was found between lactic acid soluble protein intrinsic viscosity and cooking quality, suggesting that variations in the nature of the soluble gluten proteins are not likely an important cooking quality factor.

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Nitrogen Fertilization Effects on Amino Acid Composition of Pecan (*Carya illinoensis*) Nutmeats

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"Desirable" pecan trees (*Carya illinoensis*) were fertilized with ammonium nitrate or nitroform at five rates up to 6.8 kg of N/tree. Effects of each N fertilizer form on amino acid composition were determined. Both forms affected amino acid composition, but in different ways. Ammonium nitrate increased the concentration of glutamate and proline relative to the nitroform fertilized samples. Regression analyses also revealed differences between the two fertilizers for lysine, arginine, aspartate, serine, glutamate, alanine, cysteine, valine, isoleucine, leucine, tyrosine and phenylalanine. These differences, though small, probably resulted from the slow release nature of nitroform that provides a more constant N supply to the developing nut than ammonium nitrate does. In addition, the free amino acid profile is presented and the prevalence of the urea cycle amino acids is shown. These data are of importance from a human nutritional viewpoint.

Pecans are a prominent nut crop in the United States with a current annual production of 250 million pounds, which is increasing yearly (Livingston, 1976). The composition of pecan nutmeats has been fairly well characterized. The average oil and protein contents are known to be 70 and 10%, respectively (Meredith, 1974). The fatty acid and mineral compositions are also known (Senter,

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