

Small-Scale Reconstitution of Durum Semolina Components

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ABSTRACT

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Pasta prepared by extrusion from 25 g of semolina has been compared with that made from a standard laboratory extruder and found to have similar quality. Durum semolina was fractionated into its starch, gluten, water soluble, and residue fractions. The freeze-dried components were reconstituted and the properties of the reconstituted semolina (ReSem) have been measured. Examination using a 2 g-mixograph and micro-

extension tester has shown that ReSem behaves similarly to the original semolina. ReSem and semolina were made into pasta using a small-scale pasta extruder and were of comparable cooking quality. The fractionation and reconstitution of durum semolina on this scale is a useful technique to evaluate the contribution of semolina components to pasta quality.

The protein properties of durum semolina are important in determining pasta quality (Matsuo et al 1972; D'Egidio et al 1990). Less attention has been given to the other components until recently (Delcour et al 2000a,b). With starch comprising $\approx 70\%$ of the pasta, it is likely that the starch affects pasta quality, particularly considering the contribution of starch properties to quality in Japanese udon noodles (Oda et al 1980). However, in a product where the protein plays a major role in quality, it is difficult to measure the influence of starch or other components unless the protein composition and content of the raw material are similar. Using semolina or flour from grain it is hard to achieve this situation, as environmental or genetic effects can alter the protein properties, which in turn will mask the contribution of starch or other components of interest to quality.

Addition and reconstitution have been used for many years in studying the effects of flour components on bread quality (Finney 1943; MacRitchie 1985; Bekes et al 1994). The first approach has been to utilize a control or base flour and add some of the component being tested, such as glutenin or even a glutenin subunit, to this flour (Bekes et al 1994). This is satisfactory when there is a major effect of the component and significant differences between the effects of materials being compared. With starch, this is not the case, and reconstitution is a more satisfactory approach. This is based on building the flour up from its components and directly comparing the effect of different materials in a system where the remaining components are identical. In this way, the contribution of all components or fractions may be studied (Matsuo et al 1986; Bekes et al 1994; Sissons et al 1998).

While a great deal of attention has been directed to the reconstitution of the components of bread doughs, there have been few reports on the use of this technique in pasta doughs. Pasta is usually prepared from durum semolina, a coarse fraction from milling, and this highlights the difficulty of reconstituting semolina. The act of separating the components breaks down the particle structure and the reconstituted material is much finer than semolina. Thus, it would be necessary to ensure that any variation in quality of pasta after reconstitution is not due to a change in the particle size of the materials from which it was made. A further problem lies in obtaining sufficient material to use in reconstitution studies. Laboratory-

scale pasta machines require relatively large amounts (>1 kg) of semolina to operate efficiently and reliably. Often, only small amounts of components are available, insufficient for these machines. There have been reports recently of reconstitution of pasta components, but these have used relatively large quantities of the fractions (Delcour et al 2000a,b).

Here we discuss the fractionation of semolina into its components, and the reconstitution of these components on a small scale. There were two aims of this work. The first was to validate a small-scale extruder by comparing its products to pasta from a standard-scale laboratory extruder. The second was to test whether small-scale reconstitution would be valid as a method to test the contribution to pasta quality of different starch and protein components to pasta quality. This work describes a comparison of the rheological and the cooking quality of the pasta of these reconstituted semolinas with those of the original semolina. The results of this validation are presented here.

MATERIALS AND METHODS

Fractionation

The commercial durum semolina used as the source for reconstitution experiments was obtained from Goodman Fielder (Tamworth, Australia). Semolina was mixed with distilled water (60% w/w) at 15°C by hand for 10 min to form a dough. After resting the dough for 5 min, 800 mL of water was added and the dough piece was hand-kneaded for about 10 min. The gluten ball was separated from the liquid fractions by filtration over a nylon screen (150 μ m pore size). The gluten was further washed with nine 100-mL water washes for 5 min each until minimal starch appeared in the wash water, producing gluten essentially free of starch. Some solid material remained on the nylon screen and this is called residue

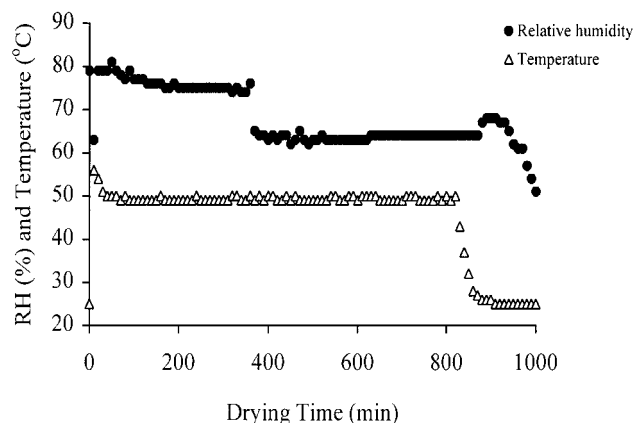


Fig. 1. Actual temperature and relative humidity values recorded during the pasta drying cycle.

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fraction. The filtrate passing through the screen was centrifuged at $3,000 \times g$ for 10 min to separate the starch from the water-soluble components (pentosans, albumins, and globulins). All fractions were stored at -20°C overnight, then lyophilized in a freeze-dryer (Dynavac model FD3A Sydney, Australia) and are referred to as gluten fraction (GF), water soluble fraction (WSF), starch fraction (SF), and residue fraction (RF). The dried WSF was stored in an evacuated desiccator because of its very hygroscopic nature. Moisture was assayed by oven-drying a sample for 1 hr at 130°C according to Approved Method 44-16 (AACC 2000). Protein content ($N \times 5.7$) was determined according to Approved Method 46-13.

Reconstitution

All fractions were ground using a pestle and mortar and recombined in proportion to their recovered amounts based on an average yield across several batches. This mixture, as well as the semolina, was passed through a metal sieve (1 mm pore size) to reduce the particles to a uniform size to improve homogeneity. Under visual observation, the recombined semolina material (ReSem) had a smaller particle size than the original semolina. An additional pasta sample (FD) was made from the commercial semolina that had been freeze-dried with the ReSem.

Dough Functional Properties

Mixing tests were conducted with a prototype 2-g mixograph (TMCO, Lincoln, NE) with water absorption calculated from the semolina protein and moisture content (Approved Method 54-40A). The masses of semolina and water were adjusted to provide 3.5 g of dough. Four replicates of mixograph determinations were made (Rath et al 1990). Parameters included mixograph dough development time (MDDT), peak dough resistance (PR), bandwidth at peak dough resistance (BWPR), and resistance breakdown (RBD).

TABLE I
Yield, Protein, and Moisture Contents of Semolina Components After Fractionation^a

Fractions	Yield (%)	Protein (%)	Moisture (%)
Semolina		11.8	13.6
Gluten (GF)	11.4 ± 0.3	78.1	4.6
Starch (SF)	56.2 ± 2.1	0.9	2.9
Residue (RF)	13.0 ± 2.6	9.7	4.3
Water soluble (WSF)	4.6 ± 0.1	19.5	3.5

^a Data are mean ± standard deviation of seven fractionations. Yield is percentage of weight of semolina. Protein ($N \times 5.7$) Kjeldahl and oven moisture contents from a pool of seven fractionations.

Breakdown was calculated as the change in the value of the resistance during the 3 min after peak resistance, and expressed as a percentage of the relevant value at the peak resistance (Bekes et al 1994). Doughs for extension testing were mixed to peak dough development in a 2-g mixograph using 3.5 g of dough. Extension was made in duplicate on a micro-extension tester with a 19-mm gap and 6-mm hook operating at 1 cm/sec. Dough samples for extension testing (1.7 g/test) were molded into cylinders ≈6 mm in diameter with a prototype molder, mounted on a sample carrier, and rested at 30°C ($>90\%$ rh) for 45 min before extension testing (Gras and Bekes 1996). Recordings of the dough resistance and the sample carrier position were taken at 100 readings/sec and recorded using LabTech Notebook software (Laboratories Technology Corp., Wilmington MA). Maximum resistance to extension (R_{max} in Newtons) and extension before rupture (Ext in cm) were calculated using specially written software (Rath et al 1994).

Pasta Production

Small-scale extrusion method (SSE). The semolina and ReSem samples were processed into pasta (diameter of the dried pasta 1.88 ± 0.04 mm) using a small-scale extruder. The design of the extruder was based on that described in Martin et al (1946). The method used to prepare the pasta was optimized after initial studies based on Approved Method 66-42 (AACC 2000). The moisture contents of the semolina and ReSem were determined, and the two materials were hydrated to the same moisture level with deionized water to 30% absorption. Semolina (14.0% moisture base) was added to a 50-g farinograph (Brabender, Dundas Smith & Son Pty. Ltd. Pymble, Australia), bowl-heated to 40°C , and mixed briefly. Water was added to 30% absorption using an automatic dispenser and mixed for 0.5 min. The mixing was stopped and the dough was scraped down the sides of the bowl, after which the mixing recommenced for 2 min under vacuum of 65 kPa. The resulting dough was transferred to a stainless-steel rest chamber (2.5 cm i.d. \times 13.5 cm length), threaded at the bottom to take a screw cap. Cylinder temperature was maintained at 50°C by a circulating water bath through copper tubing wrapped outside the cylinder. A pressure of 7,000 kPa was applied to the dough for 9 min, after which the screw-cap was replaced with a four-hole Teflon-coated pasta die with threaded collar. The pasta was then extruded at a constant rate and cut to lengths of ≈48 cm, looped over metal rods, and hung in the drying cabinet maintained at 25°C and 85% rh. After the last sample was processed, the drying cycle commenced (Fig. 1). Pasta samples were stored at 22°C , 55% rh for at least seven days before analysis to avoid variability in optimum cooking time.

TABLE II
Effect of Water Absorption (WA) on Firmness^a and Yellowness Index (YI)^b of Cooked Pasta Prepared in Small-Scale Extruders (SSE) and Large-Scale Extruders (LSE)

Mix Time	SSE			LSE ^c		
	WA %	Firmness	YI	WA %	Firmness	YI
2	28.0	494	62.0	28.0	507	93.1
4		434	63.9			
6		439	52.7			
2	30.0	472	69.4	30.0	484	90.9
4		469	64.2			
6		469	55.6			
2	31.5	392	68.1	31.5	441	91.9
4		417	57.2			
6		443	56.1			
2	33.5	383	73.9	33.5	451	95.5
4		392	62.6			
6		420	54.7			
LSD ^d		36	7.1		57	4.1

^a Data are mean firmness (g) of pasta cooked three separate times.

^b Data are mean YI index of duplicate measurements.

^c LSE used fixed extrusion time.

^d Least significant difference ($P < 0.05$).

Large-scale extrusion method (LSE). Spaghetti (diameter of the dried pasta 1.82 ± 0.03 mm) was made using a Namad pasta extruder (Appar Laboratorio, Rome, Italy). Semolina (1.2 kg) was mixed with distilled water (30% unless otherwise specified) in a premixing chamber for 10 min, extruded under partial vacuum (8 kPa) at 50°C through a Teflon-coated die piece and dried (Fig. 1).

Evaluation of Pasta Quality

To determine color, pasta strands were placed parallel and close together and the whiteness and yellowness were measured using a Hunter Lab D25-9 reflectance colorimeter.

To determine optimum cooking time, pasta strands (≈ 10 g), broken to 7 cm lengths, were added to 250 mL of rapidly boiling water containing 0.7% (w/v) sodium chloride and 0.005% (w/v) sodium carbonate. The optimum cooking time was defined as the time taken for the white core in the middle of a strand to disappear when squashed between two microscope slides as evaluated by visual inspection. All samples were cooked to optimum cooking time.

Details of the methods used to determine firmness, resilience, and stickiness of the cooked pasta have been described previously (Wood et al 2001). Each pasta sample was cooked three times and the average of the three measurements reported. Stickiness was defined as the maximum peak force required to separate the probe from the sample surface (peak height) and the area under the peak as the work of adhesion (Smewing 1997).

To determine water absorption and cooking loss, pasta strands (10 g) were cooked to optimum cooking time, drained, cooled in 250 mL of distilled water for 2 min, drained, and weighed. Water absorption was calculated as the weight increase and expressed as a percentage of the sample weight before cooking. Cooking loss refers to the amount of solids as determined by iodine reaction (Matsuo et al 1992) lost to the water. Analyses were performed in duplicate for each sample.

Evaluation of Extrusion Methods

Commercial semolina was used for all experiments. Pasta was prepared using two extrusion and mixing systems. Pasta samples were dried under the same conditions and evaluated for color (where appropriate) and cooked pasta firmness.

The effect of water quantity and dough mixing time on pasta texture was determined. Pasta was prepared using the SSE method with water absorption levels at 28, 30, 31.5, and 33.5%. For each water absorption level, dough was mixed for 2, 4, or 6 min. Correction was made for the moisture content of the semolina on a 14% moisture basis: Weight of sample to use (W_s) = $50 \times 86 / (100 - \text{moisture content of sample})$; volume of water = $(50 - W_s) + \text{desired absorption} / 2$.

The same semolina was also made into pasta using the LSE method at the same water absorption percentages but for a constant mixing time. The experiment was repeated so that for each combination of water absorption % and mixing time, there were two pasta samples, each cooked three times and tested for firmness. The white and yellow indices of only one replicate set were measured on the dried pasta. Analysis of variance (ANOVA) was used to test the effect of water absorption %, mix time, and replicate (fixed effects) on the firmness data.

To determine the effect of using a heated coil around the extruder barrel to maintain it at 50°C, pasta was made as five separate batches with the heating switched on or off. The firmness of the cooked pasta was then measured. The effect of different resting pressures and resting time on the texture of the pasta was also tested. After loading the extruder barrel with dough, it was compressed at pressures of 0, 7, 12, or 17.3 kPa and rested for 2, 4, or 9 min, then extruded. The dried pasta was evaluated for color and the cooked pasta was tested for firmness.

Five separate pasta preparations were made from commercial semolina using the small-scale method with either the vacuum turned on or off during the 2 min of mixing. In addition, two pasta prepa-

rations were made on the large-scale extruder with and without vacuum. The color of the dried pasta and cooked pasta firmness were assessed.

To determine how small a sample could be prepared, three different sample sizes were chosen: 25, 37, and 50 g of semolina, with the amount of water added accordingly to obtain 30% absorption. Three separate batches were prepared and the cooked pasta texture measured for each sample size.

Statistical Methods

Data was analyzed using S-Plus 2000 (MathSoft Inc. Data Analysis Products Division, Seattle, WA). ANOVA was used to compare statistical differences.

RESULTS AND DISCUSSION

Table I lists the yields of the four fractions and their protein and moisture contents. The yield of gluten is in the expected proportion given the protein content of the semolina used. The method of fractionation is reproducible for each batch of semolina allowing for pooling of fractions across different preparations. Gluten fraction was mainly protein with most of the remainder likely to be starch (Delcour et al 2000a). The starch fraction had $\approx 0.9\%$ protein while water soluble fraction contained $\approx 20\%$ protein by weight. Presumably, water soluble fraction also contained arabinoxylans (Delcour et al 2000a). Residue fraction comprised mainly

TABLE III
Effect of Resting Pressure of Dough in Small-Scale Extrusion Method on Cooked Pasta Firmness and Dried Pasta Yellow Index

Resting Pressure (kPa)	Firmness ^a	YI Index ^b
0	437	67.0
7,000	430	65.5
12,000	426	67.7
17,300	421	69.7
LSD ^c	31	6.6

^a Data are the mean firmness of nine individual cookings from the three resting times, except for zero pressure.

^b Data are mean YI index of duplicate readings from three resting times.

^c Least significant difference ($P < 0.05$).

TABLE IV
Effect of Vacuum During Mixing on Cooked Pasta Firmness^a and Dried Pasta Color^b of Samples Prepared Using SSE and LSE^c

	With Vacuum		Without Vacuum	
	SSE	LSE	SSE	LSE
Firmness (g)	427a ^d	620c	410b	524d
Resilience	0.68a	0.79c	0.67a	0.73d
WI	49.9a	59.3a	42.9b	56.0b
YI	56.0a	90.6a	54.4a	86.3b

^a Data are mean firmness of four (SSE) or two (LSE) extrusions.

^b Color of dried pasta, whiteness (WI) and yellowness (YI) index are means of four separate measurements.

^c Large-scale extrusion method (LSE), small-scale extrusion method (SSE).

^d Values followed by the same letter for vacuum vs. no vacuum groups are not significantly different at $P < 0.05$.

TABLE V
Effect of Dough Quantity Mixed on Firmness^a After Cooking of Pasta Prepared in a Small-Scale Extruder

Method ^b	Semolina (g)	Firmness (g)
LSE	1,200	457
SSE	25	457
SSE	37	463
SSE	50	443
LSD ^c		20

^a Data are the mean firmness of nine individual cooks.

^b Large-scale extrusion method (LSE), small-scale extrusion method (SSE).

^c Least significant difference ($P < 0.05$).

gluten and starch and contained $\approx 10\%$ protein. The yields and protein content of the fractions are similar to those reported for bread wheat fractionation (Toufeili et al 1999).

The evaluation of our SSE method was benchmarked against the standard LSE method used routinely in the durum wheat breeding program at Tamworth, Australia, by assessing the firmness and color of the cooked pasta.

Effect of Water Quantity and Dough Mixing Time on Pasta Texture

In commercial practice, a water absorption of 30–33.5% is used to produce pasta of optimal quality. The effect of the amount of water used to prepare the dough and the dough mixing time (SSE only) on the cooked pasta firmness for LSE and SSE pasta was investigated. For the SSE, both mixing time and water absorption affected cooked pasta firmness (Table II). There was no general

effect of mixing time on firmness. As the water absorption was increased to $>30\%$, the pasta became less firm. Pasta prepared from the LSE was mixed only one time using a standard protocol. There was no significant effect of water absorption on pasta firmness. For the SSE pasta, the yellow color was particularly sensitive to the length of mixing, decreasing on average across all absorptions by $\approx 25\%$. This is likely to be due to pigment degradation at 40°C caused by a combination of enzyme and Maillard reactions (Feillet et al 2000). There were no significant differences in yellowness index with different water absorptions for both the SSE and LSE pasta. The yellow color of the SSE pasta was inferior to that of the LSE pasta, which may be related to the surface structure or texture of the pasta. We decided to use 30% water and 2 min of mixing for all SSE pasta preparations because the pasta was closest in firmness to the LSE pasta.

Effect of Extrusion Holding Temperature, Pressure, and Resting Time on Pasta Texture

A jacket was fitted to the barrel of the SSE to maintain the dough temperature at 50°C . Although extrusion holding temperature had no effect on pasta firmness ($371 \text{ g} \pm 38$ for no temperature control vs. $378 \text{ g} \pm 29$ for 50°C temperature control), there was less variability in the firmness measurement with temperature control. We routinely used 50°C during the extrusion of pasta using SSE. To obtain a good physical appearance of the pasta a low-extrusion pressure is required, and this is inversely related to absorption, rest pressure, and die temperature. During dough resting, changes in the gluten matrix can occur which could affect the cooked pasta firmness. ANOVA indicated there was no difference in firmness of the cooked pasta or the yellowness of the dried pasta over the three resting times tested (2, 4, and 9 min). Similarly, the pressure applied during dough resting before extrusion did not affect either the pasta firmness or the yellowness index (Table III). The absence of any resting pressure above atmospheric, while not affecting pasta firmness, did result in the pasta surface being rough. Routinely, dough was compressed at 7,000 kPa for 9 min.

Effect of Vacuum During Mixing on Pasta Texture and Color

Use of the vacuum during the dough mixing (SSE method) or during extrusion is critical for achieving a good pasta firmness and dry pasta yellowness score (Table IV). The loss in firmness without vacuum was greater for the LSE, perhaps because the vacuum is applied during the extrusion of the pasta. There was

TABLE VI
Cooked Pasta Firmness^a of Semolina Samples
Prepared by LSE and SSE Methods^b

Sample	Firmness		Rank ^c	
	LSE	SSE	LSE	SSE
1180	458 ± 6	338 ± 17	1	1
1184	467 ± 27	357 ± 14	2	2
1177	492 ± 41	398 ± 32	3	3
1024	510 ± 49	455 ± 23	4	5
1150	515 ± 42	402 ± 24	5	4
1011	533 ± 62	411 ± 14	6	6
1031	562 ± 7	447 ± 16	7	8
1017	585 ± 54	486 ± 6	8	11
1206	601 ± 14	527 ± 21	9	19
1022	615 ± 16	437 ± 25	10	7
1113	652 ± 58	487 ± 11	11	12
1107	662 ± 36	534 ± 8	12	20
1106	683 ± 28	512 ± 6	13	16
1128	692 ± 24	454 ± 16	14	9
1105	706 ± 25	496 ± 12	15	14
1130	758 ± 16	511 ± 19	16	15
1133	763 ± 54	515 ± 18	17	17
1134	776 ± 65	520 ± 11	18	18
1132	783 ± 50	460 ± 8	19	10
1136	846 ± 47	492 ± 16	20	13

^a Mean values of triplicate cookings \pm standard deviation.

^b Large-scale extrusion method (LSE), small-scale extrusion method (SSE).

^c Ranked numerically from lowest to highest.

TABLE VII
Dough Properties of Semolina and Reconstituted (ReSem) Version^a

Sample	Mixing Properties				Extension Properties	
	MDDT (sec)	PR (AU)	BWPR (AU)	RBD (%)	R_{max} (N)	Ext (cm)
Semolina	474 ^a	329 ^a	231 ^a	5.5 ^a	440 ^a	10.85 ^a
ReSem	484 ^a	329 ^a	244 ^a	4.8 ^a	604 ^b	9.30 ^b

^a Mixograph dough development time (MDDT), peak dough resistance (PR), bandwidth at peak dough resistance (BWPR), and resistance breakdown (RBD), maximum resistance to extension (R_{max}), extension before rupture (Ext). AU = arbitrary units.

^b Values followed by the same letter in the same column are not significantly different ($P < 0.05$).

TABLE VIII
Pasta Cooking Quality of Two Semolinas and Reconstituted (ReSem) Versions^a

Sample	Protein (%) ^b	Opt. Cooking		Firmness (g)	Resilience	Stickiness (peak height/g)	Stickiness (area g/sec)	Water Absorption (%)	Cooking Loss (%)
		Time (min)	Firmness (g)						
Semolina A	11.6 ± 0.1	12.0	354	0.73	19.0	11.2	185	5.5	
ReSem A	11.8 ± 0.1	11.5	356	0.74	18.8	11.2	181	5.3	
Semolina B	11.6 ± 0.1	14.0	360	0.52	18.2	11.5	176	5.5	
ReSem B	12.5 ± 0.2	11.5	361	0.58	18.0	11.7	176	5.5	
LSD ^c		0.2	22	0.06	2.8	2.1	10	0.4	

^a Data are the mean of four different batches of pasta, each batch cooked in triplicate for measurement of texture (12 observations/sample) and cooked in duplicate for measurement of water absorption and cooking loss (eight observations per sample).

^b Protein ($N \times 5.7$) Kjeldahl duplicate analysis of sample.

^c Least significant difference ($P < 0.05$).

also a change in the resilience of the LSE pasta but no change with the SSE pasta. Only the whiteness of the SSE pasta was lower without vacuum, with no change in yellow color. For the LSE pasta, extruding without a vacuum caused a loss in whiteness and yellowness in the dried pasta, presumably due to enzymic degradation or oxidation of the yellow pigments.

Effect of Sample Size on Pasta Texture

We tested the effect of scaling down the sample size because the amount of test sample is often the limiting factor in reconstitution studies. There were no significant differences in the pasta firmness using 25, 37, or 50 g of semolina (Table V). Pasta prepared from any of these amounts of semolina using the SSE method had a cooked firmness equivalent to that produced by the LSE method, so 25 g was chosen as the optimum quantity. With 12.5 g of semolina, the extruded pasta was of poor visual appearance.

Ranking of Samples Prepared by LSE vs. SSE

Pasta was prepared from the semolina of 20 different durum wheat breeding lines by LSE and SSE to provide a range in cooked firmness. A comparison of the ranking of the cooked pasta firmness shows there was good agreement between the SSE and LSE methods (Table VI). Although the Spearman's coefficient of rank correlation between the groups is highly significant ($P < 0.001$), there were four samples (1206, 1107, 1132, and 1136) that did not rank well and cannot be explained from inspection of the full quality data. Also, the range in firmness of the SSE pasta was much narrower (196 vs. 388 g for LSE), reflecting a poorer discrimination of samples with the SSE method. This may be related to lack of vacuum in the SSE method resulting in a less firm pasta. The LSE method is better suited to the discrimination of small differences in firmness of samples. In our studies using the reconstitution method, the SSE procedure proved adequate for measuring relatively gross changes in chemical composition of the semolina. The repeatability of the SSE method determined as the firmness of cooked pasta (two batches of 10 replicate samples) is good (CV = 10.9%).

Rheological Properties of Semolina and Reconstituted Semolina

It is clear that semolina itself is not reconstituted, the material referred to as reconstituted semolina is actually recombined semolina components. This is true in the case of flour as well, but there is a convention that has arisen to call the recombined components reconstituted flours (MacRitchie 1985). Thus, we refer to the recombined semolina material as reconstituted semolina (ReSem) as an extension of this practice, even though the semolina particles have not been reconstituted.

The 2-g mixograph and micro-extensigraph were used to determine whether the fractionation and reconstitution procedure altered the mixing properties of the reconstituted dough compared to a dough derived from the original semolina. There were no significant changes in the key mixograph properties (Table VII). Interestingly, there were differences in the early phase of mixing (data not shown) with a wider bandwidth and steeper slope in the early phase of mixing in those samples of ReSem compared with the semolina. A possible explanation for this is that the ReSem sample has smaller particle sizes that would allow more rapid water absorption. ReSem had significantly greater R_{max} and a reduced Ext. It is possible that during the washing of the gluten to remove starch, a mechanical process might have worked the dough and induced some degree of gluten network formation. If this did happen, the dough would be strengthened and have reduced elasticity. This would affect the extensigraph parameters.

Pasta Quality from Semolina and Reconstituted Semolina

To determine whether the isolation and reconstitution of semolina components alters functionality, it is necessary to compare the product from reconstituted material with those from the original semolina. This was evident in Table VIII, where two different sets

of ReSem and the corresponding semolina from which the components were derived was evaluated. Because the total amount of protein influences some of the measured pasta quality parameters, we attempted to ensure the protein content of semolina and ReSem were as close as possible. Pasta made from semolina that had been freeze-dried showed no significant difference in all the pasta quality measures when compared with the original semolina, indicating that any changes that may have occurred during freeze-drying had no effect on the quality (data not shown). The optimum cooking time of ReSem was significantly shorter for both pasta samples than that for semolina-derived pasta, particularly for sample B. A higher protein content in the pasta generally translates to a longer cooking time, however the protein contents of the samples were closely matched, so this cannot be the explanation for these differences. In contrast, Delcour et al (2000a) reported in their studies that the optimum cooking time for pasta made from their reconstituted semolina was about 1 min longer than pasta made from semolina. They attributed this to development of a gluten network and other modifications to the gluten caused by their method of fractionation. Our mixograph results indicate no evidence for significant dough development, although the extensigraph suggests some alteration of the gluten matrix caused by the method to fractionate components.

Our assessment of the texture of the cooked pasta was made using the TA.XT2 texture analyzer. For each of the two different samples (Table VIII), there were no significant differences in pasta texture (firmness, resilience, and stickiness) between semolina and ReSem. Similarly, there were no differences in the water absorption properties of the semolina and ReSem derived pastas or in the amount of cooking loss. The resilience of sample B was much lower than sample A, and this may be due to the fact that these two samples were different semolinas. Delcour et al (2000a) reported that their reconstituted semolina had improved pasta firmness, recovery from compression, and improved surface condition when compared with the semolina. They suggested the possibility of enzymatic activity during the fractionation leading to an alteration of constituent properties. Dexter and Matsuo (1978) also found the cooking quality of their reconstituted pasta was improved over pasta derived from the original semolina. They attributed this to the higher amount of gluten in the reconstituted material as the water-soluble fraction was not returned during the reconstitution because of previous evidence that the albumins have no detectable effect on cooking quality (Matsuo et al 1972). We conclude, based on the tests employed, that there were no discernible differences in the pasta quality between ReSem and the semolina on which the fractionation was performed. These results are consistent with the similarity in the mixograph between semolina and ReSem. This model system is a useful one to investigate the functionality of components of interest, such as starch with different amylose contents and gluteins of varying strength and glutenin subunit composition.

CONCLUSIONS

Our studies have shown that pasta can be made on a small scale from both normal semolina and reconstituted semolina components without significant changes in quality. This provides the ability to determine the contribution of individual semolina components to quality by interchanging proteins and starches from different lines. It also opens the possibility of isolating starches and proteins from a wide range of sources to investigate the contribution of various components to pasta quality. In turn, the potential to identify the optimum properties of semolina components should lead to the selection by breeders of better durum cultivars with benefits to breeders, growers, processors, and consumers.

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