Pasta Containing Regrinds: Effect of High Temperature Drying on Product Quality

KEXUAN FANG[1] and KHALIL KHAN[1,2]

ABSTRACT

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Low, high, and ultra high temperature dried (LTD, HTD, UTD) pasta regrinds were used at several replacement levels with semolina to produce spaghetti and elbow macaroni. Products were dried at 40 (low), 73 (high), and 90°C (ultra high) and evaluated for quality factors such as color, firmness, cooking loss, and cooked weight. Blending decreased firmness and increased cooking loss. HTD or UTD significantly improved firmness and cooking loss. HTD also improved spaghetti and elbow macaroni color, whereas UTD improved elbow macaroni color but adversely affected spaghetti color. Variation in regrind granulation did not significantly affect the quality of the products. However, the temperature at which regrinds were dried influenced the finished products. Low-temperature regrinds (LTR) produced significantly better firmness of the spaghetti and elbow macaroni and less cooking loss of the elbow macaroni. Increasing the regrind drying temperature slightly improved product color. A sensory panel found spaghetti containing up to 30% HTD regrinds (HTR) acceptable. Also the control and 10 and 20% of LTR were more acceptable than 30% of LTR or 10, 20, or 30% of HTR.

In the pasta industry, about 5 to 10% of dry goods become regrinds (Donnelly 1980). Regrinds are those dried pasta products which, due to breakage, checking or cracking, and trimming of long goods, are reground to small particle size. These regrinds are blended with semolina to produce short or long pasta products.

Annual pasta consumption in the United States is about 4.8 billion pounds (National Pasta Association 1992). Therefore, regrinds can amount to 240–480 million pounds of pasta production that end up as blended products. However, only two reports discussing the effect of regrinds on pasta quality were found in the literature. One report detailed the effect of blending regrinds with semolina on the conventional low temperature dried (LTD) spaghetti quality parameters of color, cooked weight, cooking loss, and cooked firmness (Donnelly 1980). Donnelly concluded that increasing amounts of regrinds decreased cooked firmness and color scores, and increased cooking loss. The second report concerned the effect of regrinds on pigments, starch damage, and stickiness of high temperature dried (HTD) (72°C) spaghetti (Grant 1989). Grant suggested that blends without regrinds had a higher amount of pigment, and that adding regrinds increased starch damage and stickiness. No published information was available for those high or ultra high temperature dried pasta regrinds (HTR and UTR) that may influence the HTD, UTD, or conventional dried pasta products.

Several advantages of HTD or UTD (60–120°C) pasta, such as improved color, better firmness, less cooking loss, reduced stickiness, increased resistance to cracking, shorter drying time, reduced floor space and energy cost, and lower bacteria count, have been reported in the literature. Wyland (1981) reported that increasing the drying temperature (from 40 to 80°C) improved spaghetti color, increased firmness values, and decreased cooking loss and cooked weight values. Braibanti (1980) suggested that during HTD, the gluten was partially coagulated. This gluten structure retained the starch longer during cooking, leading to less starch loss. Dexter et al (1981) found that high temperature (HT) at the initial stages of drying yielded a spaghetti with significantly improved color intensity compared to LTD spaghetti, whereas HT during the latter stages of drying yielded a spaghetti with improved strength and cooking quality without sacrificing color quality. Ibrahim (1982) reported that, in some cases, HTD slightly improved the yellow color of spaghetti. An increase in temperature from 60 to 80°C resulted in a progressive increase in cooked spaghetti firmness and progressive decrease in cooked weight and cooking loss. Grant (1989) reported that HTD (72°C) decreased cooking loss regardless of variety, sprout damage, or length of cooking, but did not appear to affect cooked spaghetti weight. Grant also reported that the incorporation of spaghetti regrinds increased stickiness. However, HTD decreased stickiness in similar samples. Aktan (1990) reported that the mean color score for spaghetti dried at 90°C was significantly higher than those for spaghetti dried at 40, 60, 70, and 80°C. Aktan and Khan (1992) reported that cooked weight increased, cooking loss decreased, and firmness generally increased as drying temperature increased.

It is clear from the literature that the use of HTD or UTD may result in higher quality of pasta products. However, there is little information about the quality of the products that incorporated regrinds. Therefore, the purpose of this study was to investigate the effect of blending HTR, UTR, and conventional temperature dried pasta regrinds with semolina on the quality of spaghetti and elbow macaroni products dried at high (73°C), ultra high (90°C), and conventional (40°C) temperatures. Effect of particle-size distribution of regrinds on product quality and physicochemical properties of regrinds also were investigated. Both instrumental and sensory testing methods were used to evaluate the products.

MATERIALS AND METHODS

Regrind Samples

Three samples, low (52°C) and high (72°C) temperature dried pasta regrinds (LTR and HTR) and partly ground ultra high (88°C) temperature dried pasta regrinds (UTR), were obtained from two U.S. pasta processors. These regrinds were produced from 100% durum wheat semolina. The partly ground UTR was processed by sieving off the fine particles, grinding the coarse particles, and then mixing all particles to produce UTR (particle size similar to LTR and HTR). Fine UTR (finer that LTR and HTR) and coarse UTR (coarser than LTR and HTR) were also produced. A laboratory hammer mill (model 66-B, Jacobson Machine Works, Inc., Minneapolis, MN) was used for the grinding process.

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[1] Graduate student and associate professor, respectively, Cereal Science, North Dakota State University, Fargo, ND 58105.

[2] Corresponding author. E-mail: kkhan@prairie.nodak.edu

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Semolina Sample

Enriched durum wheat semolina from North Dakota Mills (Grand Forks) and its extruded products represent the control (100% semolina) samples.

Blending Procedures

To investigate the effect of blending on product quality, blends were prepared by mixing LTR, HTR, and UTR samples, respectively, with semolina at 10, 15, 20, 25, and 30% replacement levels for spaghetti, and 15, 25, 35, and 50% replacement levels for macaroni processing.

To investigate the effect of granulation of regrinds on product quality, blends were prepared by mixing UTR, fine UTR, and coarse UTR, respectively, with semolina at the 25% replacement level for both spaghetti and macaroni processing. A Cross-Flow Blender (Patterson Kelley Co., East Stroudsburg, PA) was used for both procedures.

Quality Evaluation of Regrinds and Semolina

Particle-size distribution was obtained on a Ro-Tap shaker (model RX 29, W.S. Tyler Inc., Mentor, OH), using 100 g of sample and shaking for 1 min (Donnelly 1980). Speck count was determined by spreading each sample on a flat surface and counting the visible specks (bran or black particles) in three different 1-in^2 areas enclosed by a special framed glass plate. The average of the three readings was converted to the number of specks/10 in^2 (64.5 cm^2). High speck count (>40 specks/10 in^2) carries over into the pasta, resulting in a product with poor appearance and consumer appeal (Vasiljevic and Banasik 1980).

Moisture, protein, and ash contents were determined using standard methods 44-15, 46-11, and 08-01 (AACC 1983), respectively. Samples were dry-ashed according to method 923.23 and iron content was determined according to method 965.09 (AOAC 1990). Falling number and damaged starch were determined using standard method 56-81B (AACC 1983) and the method of Gibson et al (1993), respectively. Sodium dodecyl sulfate (SDS) sedimentation test was performed according to the micro-sedimentation procedure of Dick and Quick (1983). Machine-washed wet gluten was determined using standard method 38-11 (AACC 1983). Hand-washed wet gluten was determined by standard method 38-10 (AACC 1983), with the following modification for regrind samples: 10 g of regrind were blended with 25 g of semolina and mixed with 21 ml of water, rather than using 25 g of semolina and 15 ml of water. Regrind and semolina color were determined by using the Minolta color difference meter (model CR310, Minolta Co., Ramsey, NJ) and converting the *L* (brightness) and *b* (yellowness) values to color scores using a chromaticity diagram (Debbouz 1994).

Mixograms were obtained using standard method 54-40A (AACC 1983), except that water was put into the bowl before using the regrind sample. An overall empirical classification incorporating peak height and general curve characteristics was assigned. A scale of 1–8 was used (Vasiljevic and Banasik 1980). The higher the number, the stronger the curve type.

Farinograms were obtained using standard method 54-21 (AACC 1983). Absorptions were adjusted so that the resulting farinograph peaks touched the 500 BU line.

Pasta Processing

The procedure described by Walsh et al (1971) was used to prepare spaghetti (average diameter 1.50 mm) and elbow macaroni (average diameter 4.30 mm, with hollow diameter 2.00 mm) from the semolina control and blends. A constant 31.5% water (based on semolina) was used (0.5% additional water was used for those of incorporated regrinds). The LT (40°C) and HT (73°C) drying cycles described by Debbouz (1994), and the modified Braibanti UTD (90°C) drying cycle were used. All samples (1,000 g) were processed in replicate on two different days on the DeMaco continuous semicommercial scale vacuum pasta extruder with die 43131 for spaghetti and die 33319 for elbow macaroni (D. Maldari and Sons Inc., Brooklyn, NY).

Instrumental Evaluation of Spaghetti and Elbow Macaroni

Color of raw spaghetti and elbow macaroni was determined using the Minolta color difference meter and converting the *L* (brightness) and *b* (yellowness) values to color scores using a spaghetti color map, according to the procedure at the Department of Cereal Science, North Dakota State University (Walsh 1970, Debbouz 1994).

Spaghetti cooking quality, expressed by cooked weight, cooking loss, and cooked firmness, was determined on all samples (Method 16-50, AACC 1983). Cooked weight was the weight of 10 g of dry spaghetti after cooking 12 min or 10 g of dry elbow macaroni after cooking 8 min in 300 ml of boiling distilled water. Results were expressed in grams. Cooking loss was the solids lost to the water during the cooking, reported as a percentage basis of the dry pasta. Firmness was measured using two strands of spaghetti and one elbow macaroni and expressed as grams centimeters.

Sensory Evaluation of Spaghetti

Nine experienced panelists from the Department of Cereal Science, North Dakota State University, were trained to do the sensory evaluation of the spaghetti products. A minimum of five panelists has been suggested for descriptive and discrimination testing. Panelists were supplied with deionized, distilled water, napkins, and spittoons at their individual booths in a distraction-free room. In the training session, panelists became familiar with the terminology and scorecard used in this study. Attribute intensities were rated on unstructured 15-cm lines anchored 1 cm from each end. Panelists were given samples during training to correspond to the extremes (anchors) for each attribute to be evaluated (Jacobi and Setser 1985). Six samples of the HTD spaghetti containing 10, 20, 30% LTR and HTR, respectively, along with the control (100% semolina), were evaluated in triplicate. All samples were dried using the HTD (73°C) cycle described by Debbouz (1994).

Samples were cooked in 1,000-ml beakers on a hot plate (type 2200, model HPA22 45M, Thermolyne, subsidiary of Sybron, Dubuque, IA) using a 1:15 ratio of spaghetti to water. For sensory evaluation, 45 g of spaghetti in 8-cm strands were cooked in rapidly boiling distilled water to optimum (defined in preliminary cooking tests as the time when the center core in the strands disappears). This was ≈5 g of spaghetti per panelist. Spaghetti was immediately assessed for appearance moistness, mouthfeel dryness, off-flavor, and firmness. Spaghetti clumping and general acceptability were assessed ≈7 min after cooking, the average time required for the panelists to complete their assessment of the other attributes (Malcolmson 1991).

Statistical Analysis

Instrumental data were analyzed using analysis of variance (ANOVA). Degrees of freedom (DF): regrind type (RT) (spaghetti DF2; macaroni DF2); blending level (BL) (spaghetti DF4; macaroni DF3); drying cycle (DC) (spaghetti DF2; macaroni DF2); RT × BL (spaghetti DF8; macaroni DF6); RT × DC (spaghetti DF4; macaroni DF4); BL × DC (spaghetti DF8; macaroni DF6); RT × BL × DC (spaghetti DF16; macaroni DF12); total (spaghetti DF44; macaroni DF35).

Sensory data were analyzed for spaghetti using ANOVA. DF: replications (DF2); treatments (DF6); judges (DF8); total (DF16).

RESULTS AND DISCUSSION

Physicochemical Properties of Regrinds

Particle-size distribution for each regrind sample and control semolina are presented in Table I. HTR, UTR, and especially

LTR, have higher percentages of fine particles than the semolina. Regrind samples of fine UTR and coarse UTR have highest percentages of most fine and coarse particles, respectively.

Quality parameters of regrinds and semolina are presented in Table II. Protein and iron contents for all regrind samples were similar, but higher than those for the semolina (Table II). The iron contents for regrinds were higher than those for the semolina, but color scores were lower. The lower color scores for regrinds may be due to the extrusion, drying, and grinding processes used to produce the regrinds. Iron content that may play a role in reducing the color may be introduced during these processes. The moisture content for regrinds, especially the fine LTR, also were lower. This may be due to the grinding process. No differences in ash contents were found among the regrind and semolina samples.

Speck count for regrind and semolina samples were within the acceptable range of speck count (<40 specks/in^2) (Table II). Speck counts of >40 specks/in^2 are generally thought to produce pasta products with poor appearance and consumer appeal (Vasiljevic and Banasik 1980).

Although machine washing regrinds did not produce wet gluten, hand washing the LTR pasta that had semolina incorporated produced a significantly larger amount of wet gluten than washing the same amount of the semolina without regrinds (Table II). No differences in producing wet gluten between HTR and UTR were found. This suggested some gluten-forming proteins were present in the LTR which were able to interact somehow with the gluten proteins in the semolina (Table II).

Inspection of mixograph data showed that the mixograph score for LTR was higher than those for HTR or UTR (Table II). However, estimating the difference in gluten strength between HTR and UTR was difficult due to the irregular curves of the HTR and UTR (neither HTR nor UTR produced gluten dough).

SDS-sedimentation data (Table II) show a higher value for LTR than the semolina. This may be due to the higher levels of starch damage in the LTR samples. Farrand (1964) reported a similar result when flour sedimentation values were analyzed in relation to the different levels of starch damage. He suggested that the conventional interpretation of sedimentation values in terms of protein quality may be seriously influenced by the level of starch damage.

Starch damage levels for all regrind samples (LTR, HTR, and UTR) were higher than the semolina. Regrinds with a higher level of damaged starch also showed higher farinograph absorption. For example, LTR was higher than HTR and UTR, and HTR was higher than UTR, in the levels of damaged starch and farinograph absorption (Table II). This agreed with the findings of Dexter et al (1985), who reported that >90% of the variability in farinograph absorption was attributable to flour starch damage. Farrand (1964) reported a similar result when he examined the effect of starch damage on flour properties. Seyam et al (1974) reported that the semolina absorption was increased, probably due to the increase in starch damage, by 0.5% for the fine and very fine granulation.

Falling number values for all samples except LTR were higher than the semolina (Table II), indicating the absence of sprout damage in the raw materials. The value for LTR was lower than for HTR, UTR, and semolina, but higher than the minimum value of 300 sec, which may indicate the presence of sprouting. Donnelly (1979) suggested that falling number values <250–300 units generally indicate the presence of sprouting in the parent wheat.

TABLE I
Particle-Size Distribution of Regrinds and Semolina[a]

		Regrinds[c]				
U.S. Sieve (mm)	**Control[b]**	**LTR**	**HTR**	**UTR**	**Fine UTR**	**Coarse UTR**
20 (0.86)	0	0.1	0	0	0	1.0
40 (0.38)	16.2	1.5	10.2	11.7	0.2	44.4
60 (0.23)	70.3	28.9	47.0	46.8	29.0	35.6
80 (0.18)	8.7	27.8	17.3	15.5	20.1	8.5
100 (0.14)	2.6	20.1	9.8	8.2	17.7	4.1
t (<0.14)[d]	2.0	19.9	15.2	17.3	32.6	6.1

[a] Values (average of two measurements) represent percent of sample not entering through sieve.

[b] Enriched durum wheat semolina from North Dakota Mills, Grand Forks.

[c] LTR, HTR, UTR = low, high, ultra-high temperature regrinds, respectively.

[d] Through sieve no. 100.

TABLE II
Quality Parameters of Regrinds and Semolina

	Means[b,c]			
Physicochemical Properties[a]	**LTR**	**HTR**	**UTR**	**Control**
Moisture, %	8.8c	11.1b	11.3b	14.1a
Protein, %	12.1a	12.3a	12.3a	11.7b
Ash, %	0.77a	0.76a	0.78a	0.72a
Iron, ppm	37a	37a	35a	32b
Color score[a]	5.3	6.0	6.5	9.0
Speck count	13	10	10	17
Machine-washed wet gluten, g	0b	0b	0b	3.25a
Falling number, sec	300d	533b	552a	407c
SDS-sedimentation test, mm	31a	25c	25c	30b
MHWWG,[d] g	12.5a	8.6b	8.6b	8.2b
Mixograph score	4	2	2	6
Damaged starch, %	11.3a	6.0b	5.7b	1.6c
Farinograph absorption, %	67.4a	60.5b	59.3c	53.5d

[a] Color score, speck count, and mixograph score are not statistically analyzable due to the scales used. Color score was obtained from converting the b (yellowness) and L (brightness) values (Debbouz 1994).

[b] Means within rows followed by the same letter are not significantly different at the $P < 0.05$ level (Duncan's multiple range test). $n = 2$.

[c] LTR, HTR, UTR = low, high, ultra-high temperature regrinds, respectively.

[d] MHWWG = modified hand-washed wet gluten determined using AACC Method 38-10 with modification by blending 10 g of regrind with 25 g of semolina and mixing with 21 ml of water.

TABLE III
Analysis of Variance Among Cooking Quality Factors

	PR > F (α = 0.05)[a]						
Quality Factors	**RT**	**BL**	**DC**	**RT × BL**	**RT × DC**	**BL × DC**	**RT × BL × DC**
Spaghetti							
Cooking loss	0.065	0.0001	0.001	0.84	0.31	0.35	0.99
Firmness	0.0001	0.0001	0.0001	0.96	0.10	0.39	0.79
Cooked weight	0.0004	0.69	0.0001	0.75	0.28	0.63	0.81
Macaroni							
Cooking loss	0.0001	0.0001	0.0001	0.20	0.43	0.99	1.00
Firmness	0.0001	0.0001	0.0001	0.77	0.43	0.96	0.99
Cooked weight	0.0001	0.025	0.0001	0.052	0.52	0.97	0.84

[a] RT = regrind type, BL = blending level, DC = drying cycle.

Instrumental Evaluation of Spaghetti and Elbow Macaroni

ANOVA (Table III) showed lack of significant interactions among regrind types, blending levels, or drying cycles for cooking loss, firmness or cooked weight at the $P < 0.05$ level.

Effect of Blending on Product Quality

Increasing the regrind blending level had a negative influence on product cooking loss, firmness, and color (Table IV). This was in agreement with Donnelly's work. The negative effect on product firmness and cooking loss may be due to the lack of gluten present in the regrinds. It was worthy to note that cooking loss of 30% spaghetti blends was significantly higher than 20 and 25% spaghetti blends, and cooking loss of 50% macaroni blends was higher than 25 and 35% macaroni blends. Our findings of color reduction also agreed with those of Grant (1989) that blends without regrinds had a higher amount of pigment. It was also found that blending did not significantly affect the cooked weight of the spaghetti (Table IV). Donnelly (1980) reported a similar result when he examined the effect of blending regrinds with semolina on spaghetti cooked weight. No significant difference was detected in cooked weight values among macaroni blends, although the control produced a lower cooked weight value than the blends (Table IV).

Effect of Product Drying Temperature on Product Quality

Increasing the product drying temperature reduced cooking loss and improved firmness (Table V). This agreed with the findings of Ibrahim (1982) that an increase in temperature from 60 to 80°C resulted in a progressive decrease in cooking loss and progressive increase in cooked spaghetti firmness. This also agreed with the findings of Grant (1989) that HTD (72°C) decreased spaghetti cooking loss. The reduction of cooking loss may be due to the partially coagulated gluten structure formed during HTD (or UTD), leading to less starch loss (Braibanti 1980). Compared to spaghetti dried at 40°C, spaghetti dried at 60, 70, and 80°C showed a large degree of protein denaturation; at 90°C, spaghetti showed a greater degree of protein denaturation (Aktan and Khan 1992). The higher firmness values for the HTD and UTD spaghetti and elbow macaroni may be due to the higher degree of protein denaturation that might occur at HTD.

An increase in product drying temperature (from 40 to 73°C) also improved spaghetti and macaroni color (Table V). This was in agreement with the findings of Wyland (1981), Dexter et al (1981), and Ibraham (1982). However, it was found that spaghetti color decreased when the products were dried at 90°C (Table V). Our results of color reduction of the UTD spaghetti and those of Aktan (1990) and Aktan and Khan (1992) differed. This may be due to product browning taking place during UTD. The addition of regrinds might also contribute to the color reduction. (Aktan and Khan did not use regrinds in their products.)

HTD produced significantly higher values of cooked weight of the spaghetti and elbow macaroni than did LTD and UTD. UTD produced a cooked weight value of the spaghetti significantly higher than LTD but lower than HTD (Table V). The effects of drying temperature on cooked weight are controversial. Wyland (1981) and Ibrahim (1982) reported decreased cooked weight with HTD, while Mok (1988) reported increased cooked weight, which is in agreement with the present study.

TABLE IV
Effect of Blending on Quality of Low, High, and Ultra-High Temperature Dried Spaghetti and Elbow Macaroni

		Means[a]			
Products	Blending (%)	Color Scores[b]	Cooking Loss (%)	Firmness (cm g)	Cooked Weight (g)
Spaghetti	0	8.8	6.1e	6.3a	29.9a
	10	8.6	6.5d	5.8b	30.4a
	15	8.6	6.7cd	5.6c	30.5a
	20	8.5	7.0bc	5.4d	30.3a
	25	8.4	7.2b	5.1e	30.5a
	30	8.4	7.7a	4.9 f	30.4a
Macaroni	0	8.1	5.3d	12.3a	28.2b
	15	8.0	5.7c	10.9b	28.6ab
	25	8.0	6.1b	10.0bc	29.0a
	35	7.9	6.4b	9.4cd	29.1a
	50	7.8	6.9a	8.8d	29.1a

[a] Means within columns followed by the same letter are not significantly different at the $P < 0.05$ level (Duncan's multiple range test). $n = 18$ for both spaghetti and elbow macaroni (statistical analysis conducted for all the long and short goods, respectively).

[b] Color is not statistically analyzable due to the color scale used.

TABLE V
Effect of Drying Cycles on Quality of Spaghetti and Elbow Macaroni

		Means[b]			
Products	Drying Cycles[a]	Color Scores[c]	Cooking Loss (%)	Firmness (cm g)	Cooked Weight (g)
Spaghetti	LTD	8.5	7.9a	4.7c	29.9c
	HTD	8.7	6.7b	5.5b	31.0a
	UTD	8.3	6.5b	5.9a	30.4b
Macaroni	LTD	7.8	6.7a	9.0b	28.4b
	HTD	8.0	6.1b	9.2b	29.8a
	UTD	8.0	5.9b	11.0a	28.6b

[a] LTD, HTD, UTD = low, high, ultra-high temperature drying, respectively.

[b] Means within columns followed by the same letter are not significantly different at the $P < 0.05$ level (Duncan's multiple range test). $n = 30$ for spaghetti and 24 for elbow macaroni (statistical analysis conducted for all the long and short goods, respectively).

[c] Color is not statistically analyzable due to the color scale used.

TABLE VI
Effect of Regrind Types on Quality of Spaghetti and Elbow Macaroni

		Means[b]			
Products	Regrind Types[a]	Color Scores[c]	Cooking Loss (%)	Firmness (cm g)	Cooked Weight (g)
Spaghetti	LTR	8.5	6.9a	5.6a	30.1b
	HTR	8.6	7.0a	5.2b	30.7a
	UTR	8.6	7.1a	5.3b	30.6a
Macaroni	LTR	7.8	6.0b	11.0a	28.4b
	HTR	8.0	6.4a	9.1b	29.3a
	UTR	7.9	6.4a	9.1b	29.1a

[a] LTR, HTR, UTR = low, high, ultra-high temperature regrinds, respectively.

[b] Means within columns followed by the same letter are not significantly different at the $P < 0.05$ level (Duncan's multiple range test). $n = 30$ for spaghetti and 24 for elbow macaroni.

[c] Color is not statistically analyzable due to the color scale used.

TABLE VII
Analysis of Variance for Effect of Regrind Granulation on Quality of Spaghetti and Elbow Macaroni

		PF > F (α = 0.05)		
Products	Quality Factors	Regrind Types (RT)[a]	Drying Cycles (DC)[b]	RT × DC
Spaghetti	Cooking loss	0.43	0.0001	0.77
	Firmness	0.15	0.0001	0.63
	Cooked weight	0.53	0.0004	0.34
Macaroni	Cooking loss	0.91	N/A[c]	N/A
	Firmness	0.98	N/A	N/A
	Cooked weight	0.48	N/A	N/A

[a] Utra-high regrind (UTR), fine UTR, and coarse UTR.

[b] Low, high, ultra-high temperature drying cycles were used to prepare the spaghetti, whereas only ultra-high temperature drying cycle was used to prepare the elbow macaroni.

[c] Not applicable.

Effect of Regrind Drying Temperature on Product Quality

Significant difference was detected in cooking loss of the elbow macaroni and in firmness of the spaghetti and elbow macaroni among LTR, HTR, and UTR (Table VI). The difference of LTR from the others may be mainly due to the fact that LTR contained a greater amount of modified hand-washed wet gluten. LTR produced significantly higher firmness values of both spaghetti and macaroni.

Determination by the modified hand-washed method of wet gluten present in a regrind might be a useful technique for predicting cooked firmness of spaghetti and elbow macaroni blends. Correlation of this wet gluten to firmness might be obtained if more regrind samples covering a wider range of wet gluten contents are available for study. LTR also produced macaroni, but not spaghetti, with a significantly lower value of cooking loss (Table VI). This may be because higher levels of regrinds (up to 50%) were incorporated into the macaroni products. Significantly lower values of cooked weight also resulted when LTR was used. The temperature at which regrinds were dried had a small impact on product color. An increase in the regrind drying temperature slightly improved the product color.

Effect of Granulation of Regrinds on Spaghetti and Elbow Macaroni Quality

No significantly different effect of the various regrind types (fine UTR, UTR, and coarse UTR) on the product quality was detected at the $P < 0.05$ level (all the PR > F values under regrind types were >0.05 as shown in Table VII). Variation in the regrind granulation did not significantly affect the quality of either the spaghetti or elbow macaroni products (Table VIII). Seyam et al (1974) studied the effect of particle size on processing and quality of pasta products. They reported that different particle size distribution of milled semolina did not appear to affect the quality of the finished pasta. However, they did not use regrinds in their study.

TABLE VIII
Effect of Regrind Granulation on Quality of Spaghetti and Elbow Macaroni

		Means[c]			
Products[a]	Regrind Types[b]	Color Scores[d]	Cooking Loss (%)	Firmness (cm g)	Cooked Weight (g)
Spaghetti	LTR	8.5	7.4	5.0	30.2
	HTR	8.5	7.3	5.0	30.4
	UTR	8.5	7.5	5.1	30.5
Macaroni	LTR	8.0	6.1	10.9	27.9
	HTR	8.0	6.0	11.0	28.5
	UTR	8.0	6.0	10.9	28.1

[a] All regrind samples were used at 25% replacement level with semolina to produce both products.

[b] LTR, HTR, UTR = low, high, ultra-high temperature regrinds, respectively.

[c] Analysis of variance for effect of regrind granulation on quality of spaghetti and elbow macaroni showed lack of significant differences among the regrind types for cooking loss, firmness, and cooked weight of the spaghetti and elbow macaroni at the $P < 0.05$ level. $n = 6$ for spaghetti; $n = 2$ for elbow macaroni.

[d] Color is not statistically analyzable due to the color scale used.

Sensory Evaluation of Spaghetti

Panel members differed significantly in their perception of spaghetti appearance moistness, clumping, mouthfeel dryness, firmness, and general acceptability. There was variation in the values they assigned to the samples, i.e., they did not assign the samples exactly the same scale values. However, their evaluation over the three replicates did not differ significantly (Table IX).

Statistical analysis of data from panel triplicate evaluations of randomly coded samples (Table X) showed that control, 10% LTR, and 20% LTR blends were judged significantly better in general acceptability than were 30% LTR, 10% HTR, 20% HTR , and 30% HTR blends. Statistical analysis of the data (Table X) also showed that control, 10 and 20% LTR were firmer than 20 and 30% HTR, and that control was firmer than 30% LTR and 10% HTR. This agreed with the results obtained from the instrumental evaluation that LTR produced significantly higher firmness of the product.

The results of sensory evaluation of spaghetti suggested that blending regrinds up to 30% with semolina to produce spaghetti dried at high temperature may be acceptable to the sensory panel. HTD spaghetti containing 10 and 20% LTR and the control were judged significantly more acceptable to the panelists than those containing 30% LTR or 10, 20, or 30% HTR.

CONCLUSIONS

On the basis of this study, blending of regrinds with semolina to produce pasta may reduce product quality (especially long pasta product). However, HTD may provide regrind blends with

TABLE IX
Analysis of Variance Among Spaghetti Sensory Attributes

	PR > F (α = 0.05)		
Sensory Attributes	Treatments[a]	Panelists	Replicates
Appearance moistness	0.045	0.0001	0.80
Clumping	0.02	0.0001	0.41
Mouthfeel dryness	0.06	0.0001	0.37
Off-flavor	0.001	0.0001	0.07
Firmness	0.0001	0.001	0.06
General acceptability	0.0001	0.0001	0.13

[a] Control (100% durum wheat semolina) and six blends containing 10, 20, and 30% of low and high temperature regrinds, respectively.

TABLE X
Effect of Blending on Sensory Quality of High-Temperature-Dried Spaghetti

	Means[b]					
Treatments[a]	Moistness	Clumping	Dryness	Off-Flavor	Firmness	General Acceptability
Control	8.6a	10.7a	9.0a	12.0a	10.2a	11.4a
10% LTR	7.8a	8.9b	7.9a	11.1b	9.6ab	10.6a
20% LTR	8.8a	9.6ab	8.3a	10.8b	9.4ab	10.6a
30% LTR	8.0a	9.0b	7.6a	10.9b	8.6bcd	9.3b
10% HTR	8.3a	9.1b	7.5a	10.6b	8.8bc	9.1b
20% HTR	8.0a	8.6b	7.3a	10.5b	8.1cd	8.4b
30% HTR	8.0a	8.4b	7.4a	10.3b	7.7d	8.7b

[a] Control (100% semolina) and six blends containing 10, 20, and 30% of low and high temperature regrinds (LTR and HTR), respectively.

[b] Means within columns followed by the same letter are not significantly different at the $P < 0.05$ level (Duncan's multiple range test). $n = 27$ (9 panelists × 3 replicates). The higher the means, the better the sensory quality, according to the 15-cm unstructured line scale on which 1 and 14 are two extremes for each sensory attribute (1 = looks dry, 14 = looks moist for moistness attribute; 1 = strands sticky or clumping together, 14 = separate strands for clumping; 1 = mouthfeel dry, 14 = mouthfeel wet for dryness; 1 = strong off-flavor , 14 = no off-flavor for off-flavor; 1 = extremely soft, 14 = extremely firm for firmness; 1 = not acceptable, 14 = acceptable for general acceptability).

significantly improved color and cooking quality. UTD may offer almost the same advantages as HTD for short goods, but not for long goods because of its adverse effect on spaghetti color. Increasing the regrind drying temperature may have a negative influence on spaghetti and elbow macaroni firmness and elbow macaroni cooking loss, and perhaps slightly improve product color. Variation in granulation of regrinds may not appear to affect the quality of blends. HTD spaghetti containing from 10 to 30% of regrinds may be acceptable to the sensory panelists. The 10 or 20% LTR, which were blended with semolina, would produce more acceptable spaghetti dried at high temperature than 30% LTR or 10, 20, or 30% HTD pasta regrinds.

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