Bread Wheat Granular Mill Streams With Potential for Pasta Production. II. Effect of Crop Year, Wheat Classes, and Eggs on Processing Spaghetti[1]

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ABSTRACT

Granular mill streams of coarse, intermediate, and fine granulations, collected from a pilot mill specifically flowed for producing bread wheat flour, were used for egg-spaghetti production. Wheat classes of hard red spring (HRS), hard red winter (HRW), and durum from the crop years of 1974 and 1975 were investigated. Processing absorption was affected by wheat classes and degree of grinding. Of the classes tested, durum wheat egg-spaghetti had the best color and appearance, followed by HRW and HRS wheats, respectively. Granulation and/or position of the mill stream affected the egg-spaghetti color and appearance. A mill stream of intermediate granulation gave pasta with the best color and appearance. Cooking quality was not affected by degree of grinding but was affected by protein quantity and quality. All the wheat classes tested could be used for egg-spaghetti production. Farinograph and mixograph data could not be used to predict egg-spaghetti cooking quality properties. The egg-spaghetti prepared by the micro process had higher absorption and firmness and lower cooking loss than did the egg-spaghetti prepared by the macro process, but their color and cooked weight were similar. Wheat lipoxygenase did not appear to affect egg-spaghetti color.

Durum semolina is generally recognized as the best raw material for pasta production. According to Harris and Knowles (1939), durum wheat is harder, tends to be higher in protein content, and has more yellow pigment than does bread wheat.

The United States, Italy, and other countries use principally durum wheat for pasta production. Brazil, and other countries use farina instead of semolina. Often color additives or ingredients such as eggs are used with the farina to give pasta a yellow color and to improve the nutritional quality.

The macro and micro spaghetti processes have been used to study the factors affecting the quality of cooked spaghetti made from durum wheat (Cunningham and Anderson 1943a, 1943b; Fifield et al 1937; Harris 1947; Irvine 1971; Martin et al 1946; Matsuo and Irvine 1970; Walsh 1971, 1973a, 1973b). Little information is available, however, on the use of bread wheat farina for pasta production.

The objectives of this study were to determine the effect of whole eggs on the quality of spaghetti made from granular mill streams (GMS) of durum and bread wheats (1974 and 1975 crop years) and to compare egg-spaghetti produced by micro and macro (semicommercial) procedures.

MATERIALS AND METHODS

Wheat Samples

The wheats used were from the 1974 and 1975 crop years. Wheat lots included the durum variety Rolette, hard red spring (HRS) varieties Waldron and Era, commercial hard red winter (HRW), and a 50:50 blend of commercial HRW and Era. Semolina from a blend of the durum milling and processing standard blends, which represented the durum grown in North Dakota, was used as the standard.

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Milling and Purification of the GMS

The GMS were obtained from the pilot mill and purified as previously described (Fernandes et al 1978).

Characteristics of the GMS

Characteristics of the GMS were previously determined and reported (Fernandes et al 1978) and are summarized in Table I. Average particle size was determined with a Ro-Tap testing shaker (W. S. Tyler Co., Cleveland, OH) and the U.S. standard sieves 40, 60, 80, and 100. Sifting time of each 100-g sample was 1 min. The GMS rheological properties were previously reported (Fernandes et al 1978).

Selection of the GMS

In preliminary tests with the samples from the 1974 crop year, the GMS were placed in three broad classes by coarse, intermediate, and fine particle size distribution. One purified GMS of each granulation was selected on the basis of percent extraction and egg-spaghetti quality. Final tests for the selected GMS were conducted with the samples from the 1975 crop year. Because of the large amount of data obtained, only the results of the selected GMS are reported. The selected GMS were Purifier 1 (P1)—coarse, Sizing II (S2)—intermediate, and Fourth midds (4M)—fine.

Pasta Processing

The GMS were processed into pasta either with whole eggs (egg-spaghetti) or without eggs (spaghetti). The method of incorporating the liquid was the only processing difference. For the preparation of the egg-spaghetti, 8 ml of a 50:50 whole egg/distilled water solution, which represented 3.4% whole egg solids in the pasta (db), was combined with 30 g of GMS. Then the final amount of distilled water was added, and the pasta was mixed for 2 min more. For the regular spaghetti, 30 g of GMS and an appropriate amount of distilled water were incorporated and mixed for 2.5 min. Both mixed doughs were allowed to rest for 20 min, then kneaded into a homogeneous mass by being passed for 2 min through the microkneader described by Harris (1947). They were immediately extruded with the micropress described by Walsh et al (1970) through a Teflon spaghetti die (No. 35335, D. Maldari and Sons, Inc., Brooklyn, NY). The extrusion was at a pressure of between 550 and 600 psig. Because extrusion pressure is a function of dough absorption, the pasta absorption was determined by the amount of water required to give an extrusion pressure of 550 psig. After extrusion, the pasta was allowed to rest for 10 min at room temperature to case harden. Finally, the pasta was dried in an experimental dryer with a 15-hr drying cycle, described by Gilles et al (1966). During the drying cycle, the humidity of the dryer was decreased linearly from 95 to 60% at the constant temperature of 38°C. After drying, the pasta was gradually brought to room temperature.

The macro pasta was processed on a semicommercial DEMACO pasta extruder (De Francisci Machine Co., 46 Metropolitan Ave., Brooklyn, NY) as described by Dick et al (1974). The ingredients were 1,000 g of GMS, 3.4% whole eggs (db), and distilled water.

Spaghetti Quality

The color of the dried pasta was measured with a Hunter color difference meter (Model D25, Hunter Associates Laboratory, Fairfax, VA) according to Walsh et al (1969). To convert the measured reflectance values into spaghetti color scores, the spaghetti color map of Walsh (1970) was used. The higher the color score, the better the color. Spaghetti appearance was determined visually.

The method of Sheu et al (1967) was modified and used to determine cooked weight. Ten grams of spaghetti that had been broken into about 5-cm lengths was cooked for 13 min in 300 ml of boiling distilled water containing 1.0% NaCl. The sample was then rinsed thoroughly with distilled water in a Buchner funnel, drained for 2.5 min, and weighed. Cooking loss was determned by AACC method 16–50 (1962). Firmness score was determined as described by Walsh (1971).

RESULTS AND DISCUSSION

Effect of Whole Eggs on Spaghetti Quality

The spaghetti and egg-spaghetti data are shown in Table II. Correlation coefficients were calculated between the spaghetti and egg-spaghetti only for the 1975 crop because no regular micro-processed spaghetti was made from the 1974 crop GMS material. The correlations are shown in Table III. The two types of pasta differed significantly, but the trends were similar for all the properties measured except absorption. The similarity between spaghetti and egg-spaghetti in processing absorption and cooked weight indicates that whole eggs had little effect on water absorption during mixing or cooking. Generally, the egg-spaghetti had lower cooking losses and higher firmness scores than did the regular spaghetti, probably because of the binding property of eggs (Pyler 1973).

The major advantage of using whole eggs was the definite improvement in spaghetti color and appearance; even the spaghetti produced from the GMS of the durum wheat Rolette was improved in color score and appearance. Whole eggs evidently mask the presence of specks in the final products and thereby improve the appearance of the spaghetti. This improvement indicated that pasta of acceptable color could be produced from the widely different GMS of bread wheats, but for all the varieties, regular spaghetti and egg-spaghetti from GMS of intermediate granulation were the best in color score and appearance, and their absorption and cooking quality properties were satisfactory when compared with those of the standards (Table II).

Comparison of Micro and Macro Process Egg-Spaghetti

The micro and macro process egg-spaghetti quality data are shown in Table II. The micro egg-spaghetti (MIS) had 4–6% higher absorption, higher firmness scores and lower cooking loss than did the macro egg-spaghetti (MAS); color and cooked weight were similar. The differences in the quality parameters reflected the processing conditions (Shuey 1975), the response of wheat classes, and the equipment. For example, the correlation between MIS and

TABLE I
Physical and Chemical Characterization of Mill Streams[a]

Variety, Stream[b]	Protein[c] (%)	Ash[c] (%)	Specks per 10 sq in.	Color Score	Starch Damage[d]	APS[e] (μ)
Crop 1974						
R-P1	14.3	0.577	60	13.0	3.84	527
R-S2	14.2	0.432	270	9.5	14.03	194
W-P1	12.3	0.321	37	8.5	2.27	529
W-S2	12.2	0.278	23	5.5	8.26	182
W-4M	13.2	0.378	316	5.0	17.64	141
E-P1	10.6	0.393	43	8.5	2.56	526
E-S2	10.7	0.352	37	5.5	10.33	184
E-4M	11.0	0.405	403	5.0	24.93	146
Crop 1975						
R-P1	10.4	0.564	7	14.5	4.02	528
R-S2	10.2	0.388	13	11.5	15.94	215
R-4M	11.1	0.523	77	10.0	39.84	160
W-P1	11.8	0.343	27	8.5	3.16	530
W-S2	11.7	0.266	10	6.0	8.49	188
W-4M	12.2	0.385	177	5.5	19.84	146
E-P1	10.6	0.402	33	8.5	4.06	527
E-S2	10.4	0.297	17	6.0	11.05	185
E-4M	11.0	0.412	173	5.5	25.45	141
HRW-P1	9.9	0.411	53	9.0	3.19	531
HRW-S2	9.8	0.296	17	7.0	9.56	190
HRW-4M	10.2	0.393	186	6.0	22.17	140
HRWE-P1	10.0	0.358	40	9.0	3.19	532
HRWE-S2	9.8	0.283	17	6.5	11.38	195
HRWE-4M	10.5	0.418	200	6.0	25.92	145
Standards						
Durum	13.2	0.663	63	12.5	5.67	314
Brazil	10.4	0.329	173	6.0	9.74	192

[a] Data from Fernandes, J. L. A. et al (1978).
[b] R = Rolette; W = Waldron; E = Era; HRW = hard red winter; HRWE = 50:50 blend of HRW and Era; P1 = Purifier, coarse; S2 = Sizing II, intermediate; 4M = Fourth midds, fine.
[c] 14.0 mb.
[d] Farrand equivalent units expressed on a dry basis.
[e] APS = average particle size.

MAS firmness scores was higher for the HRS data only (r = 0.922, $P = 0.01$), than for the combined data (r = 0.443, $P = 0.05$). This example demonstrates the influence of wheat classes. Also, the MAS doughs did not appear to be as uniformly mixed as the MIS doughs, especially when the P1 streams were used. However, correlation coefficients calculated between the MIS and MAS data showed that all the measurements except cooked weight followed the same trend (Table IV). This indicated that the study of MIS could give information about MAS.

Color, which is probably the most important spaghetti quality parameter from the consumer's point of view, was similar for both MIS and MAS. This was not expected because the MAS was processed in a vacuum and the MIS under ambient conditions. One of the main objectives in using a vacuum is to prevent oxidation of the natural pigments (xanthophyll, taraxanthin, and flavin) of amber durum wheat by lipoxygenases (Irvine and Anderson 1949, 1953b, Irvine and Winkler 1950). Red wheats (HRS, HRW, and soft red winter) usually have higher lipoxygenase activities than do some varieties of the amber durum (Irvine and Anderson 1953a). According to Matsuo et al (1970), this oxidation depends first on the amount of lipoxygenase and then on the level of linoleic acid and oxygen, as well as on the amount of time. Because eggs contain xanthophyll (Dalby 1948), and the micro processing was not performed in a vacuum, we expected that the wheat lipoxygenase might have destroyed the egg pigments. If this had occurred, the MAS should have had a higher color score than the MIS. The color scores were similar, however, and indicated that the wheat lipoxygenases did not affect the egg-spaghetti color. To test this observation, we conducted a simple experiment using the intermediate GMS S2 from the HRS variety Waldron grown in the 1975 crop year. The GMS was heated in an air oven at 75°C for 35 min to inactivate lipoxygenase (Wallace and Wheeler 1972).

TABLE II
Quality Data for Regular Micro Spaghetti (S), and Micro (MIS) and Macro (MAS) Egg-Spaghetti

Variety Stream[a]	Absorption[b]			Color Score			Cooked Weight			Cooking Loss			Firmness Score		
	S (%)	MIS (%)	MAS (%)	S	MIS	MAS	S (g)	MIS (g)	MAS (g)	S (%)	MIS (%)	MAS (%)	S (g/cm)	MIS (g/cm)	MAS (g/cm)
Crop 1974															
R-P1	···	29.5	25.8	···	8.5	7.5	···	31.2	32.1	···	4.9	6.8	···	6.79	4.04
R-S2	···	30.8	26.5	···	9.5	8.5	···	32.3	29.9	···	5.3	9.9	···	5.45	5.69
W-P1	···	32.8	26.1	···	6.0	7.5	···	30.4	28.9	···	3.7	8.2	···	7.69	5.91
W-S2	···	32.7	28.1	···	7.0	7.5	···	31.0	29.1	···	2.1	7.5	···	7.31	5.81
W-4M	···	32.5	27.1	···	7.0	6.0	···	30.1	29.1	···	4.1	6.7	···	7.75	6.15
E-P1	···	29.0	25.3	···	7.5	8.0	···	30.8	29.1	···	5.4	5.3	···	7.01	5.43
E-S2	···	32.7	28.5	···	7.5	7.5	···	30.4	30.9	···	3.6	8.3	···	6.55	4.35
E-4M	···	32.8	32.4	···	7.0	6.0	···	30.5	32.2	···	4.0	8.8	···	6.39	4.04
Crop 1975															
R-P1	30.5	30.2	25.2	9.5	10.0	9.5	34.9	35.4	32.5	4.3	2.4	5.2	4.21	5.69	5.33
R-S2	31.0	30.9	27.0	10.0	10.5	9.5	35.1	33.4	31.1	4.0	2.7	4.7	3.80	6.53	5.19
R-4M	31.0	31.1	28.0	9.0	9.5	9.5	34.6	31.8	31.2	4.8	3.6	7.1	4.17	7.05	4.75
W-P1	33.6	33.4	29.6	4.5	7.0	7.5	33.2	30.6	30.1	3.8	2.1	3.5	5.99	8.72	7.39
W-S2	33.5	32.6	28.7	5.0	8.0	8.0	32.9	30.1	30.0	2.2	1.9	4.4	5.59	8.38	6.89
W-4M	34.0	33.1	29.3	4.5	7.0	6.0	31.8	29.6	30.7	3.0	1.8	5.6	6.03	8.26	6.43
E-P1	32.8	32.5	28.8	4.0	7.0	7.5	34.6	30.6	30.7	2.9	1.9	3.1	5.15	7.13	6.15
E-S2	33.4	33.0	29.0	4.5	7.5	7.5	33.8	30.5	32.1	2.9	2.5	2.6	4.81	7.41	5.05
E-4M	33.3	33.6	29.5	4.5	7.0	6.0	32.7	30.4	31.2	3.2	3.5	5.2	5.01	7.43	5.45
HRW-P1	33.9	28.6	24.7	4.5	7.0	7.5	33.6	30.7	30.8	3.7	2.0	4.6	4.65	7.98	4.69
HRW-S2	33.8	33.2	29.2	5.0	8.5	8.0	32.9	30.6	30.4	2.0	1.8	3.1	4.95	6.73	5.23
HRW-4M	33.8	33.6	29.6	4.5	7.0	7.5	33.1	29.9	30.9	3.5	3.0	4.3	5.23	6.29	5.63
HRWE-P1	33.1	33.2	29.3	5.0	7.0	7.5	33.1	30.9	31.7	2.6	0.6	3.3	4.93	6.91	4.93
HRWE-S2	33.2	33.2	29.1	5.0	8.5	8.0	32.4	31.9	30.5	2.4	1.0	4.0	4.35	6.01	6.05
HRWE-4M	33.7	33.7	29.7	4.5	7.0	7.5	31.4	30.0	30.3	2.6	2.1	4.6	4.97	6.61	6.55
Standards															
Durum	32.3	31.9	···	8.5	9.5	···	34.5	31.3	···	2.3	2.4	···	5.03	7.93	···
Brazil	34.5	33.1	···	4.5	8.5	···	32.2	31.8	···	1.0	0.2	···	4.87	8.10	···

[a] R = Rolette, W = Waldron, E = Era, HRW = hard red winter, HRWE = 50:50 blend of HRW and Era; P1 = Purifier, course; S2 = Sizing II, intermediate; 4M = Fourth midds, fine.
[b] 14.0% mb.

TABLE III
Correlation Coefficients Between Spaghetti and Egg-Spaghetti Data[a]

Spaghetti	Correlation Coefficients
Absorption	NS[b]
Color score	0.929**[c]
Cooked weight	0.674**
Cooking loss	0.630*[d]
Firmness score	0.708**

[a] 15 observations.
[b] NS = Not statistically significant.
[c] **($P = 0.01$).
[d] *($P = 0.05$).

TABLE IV
Correlation Coefficients Between Micro and Macro Egg-Spaghetti Data[a]

Spaghetti	Correlation Coefficients
Absorption	0.821**[b]
Color score	0.787**
Cooked weight	NS[c]
Cooking loss	0.681**
Firmness score	0.443*[d]

[a] 23 observations.
[b] **($P = 0.01$).
[c] NS = Not statistically significant.
[d] *($P = 0.05$).

Spaghetti was produced with and without eggs from the heated and unheated GMS. Color comparisons showed no differences between the corresponding pastas (Table V).

Apparently, the differences between the micro and macro egg-spaghetti were due to processing characteristics of the equipment and wheat classes. However, either method could be used for evaluation of the pasta-making qualities of the mill streams.

Effect of Crop Year and Wheat Classes

The data in Table II show the effect of crop year and wheat classes on the egg-spaghetti. The processing absorptions for the GMS from all the bread wheat varieties except HRW-P1 were higher than for those from the durum wheat variety Rolette. The spaghetti made from the GMS of the bread wheat varieties Waldron and Era, which contained less protein than the durum wheats, had higher absorptions than did pasta made from the GMS of the durum Rolette. This would indicate that wheat class could affect absorption, because neither protein content nor starch damage per se could account for the differences in absorption.

In general, spaghetti from the fine GMS had higher absorption than did those from the intermediate and coarse GMS. Absorption was positively and significantly correlated with particle size less than 177μ and with starch damage; it was negatively and significantly correlated with average particle size and with particle size greater than 250μ (Table VI). These correlations indicate that the degree of grinding was one factor that affected absorption.

The pasta color score was higher for the GMS from Rolette than for those from the bread wheat varieties (Table II). Within the respective particle-size classes, pasta color scores were generally slightly higher for the HRW wheat than for the other bread wheats. Egg-spaghetti made with the fine GMS of the bread wheats was brownish yellow and had the lowest color scores, probably because the ash and bran content of these wheats is high. For all varieties, color and appearance were the best for the pasta made from the intermediate GMS. The significant but low correlation of spaghetti color with speck count (−0.556, $P = 0.01$) (Table VI) indicates that specking had some effect on egg-spaghetti color. The coarse GMS contained fewer specks than did the fine GMS; yet in the pasta, the number of visible specks was higher for the coarse GMS. We attribute this high visibility to speck size, which was larger in the coarse GMS. Because of the specks, the appearance of the spaghetti made from the coarse GMS was poorer than that of the spaghetti made from the fine GMS, even though the color scores were higher for the former pasta than for the latter.

The spaghetti cooking quality properties (cooked weight, cooking loss, and firmness score) apparently were not affected by the degree of grinding of the GMS; Table II shows no consistent effect of particle size. Average particle size, particle size distribution, and starch damage were not correlated with the pasta cooking quality properties (Table VI).

Among the pasta cooking quality properties, only cooking loss was significantly correlated with protein content (0.617, $P = 0.01$) (Table VI). However, when the cooking quality correlations were determined for the bread wheats only (18 observations), protein content was significantly correlated with cooked weight (−0.558, $P = 0.01$) and cooking loss (0.522, $P = 0.01$). Firmness score was not significantly correlated with protein content and varied between and within wheat classes. Moreover, regardless of protein content, pasta from Rolette generally had the lowest firmness scores (Table II). The firmness data support previous findings (Matsuo and Irvine 1970, Walsh 1973b) and indicate that protein quantity, as well as quality, affects spaghetti cooking quality properties and may be a characteristic of wheat classes.

TABLE V
Effect of Lipoxygenase Activity On Micro Egg-Spaghetti Color

Processing Conditions	Color Score[a,b]
Eggs	
Heat	7.5
No heat	7.5
No eggs	
Heat	5.0
No heat	5.0

[a] Intermediate granular millstream Sizing II from the hard red spring variety Waldron grown in the 1975 crop year.
[b] Determined by method of Walsh (1970).

TABLE VI
Correlation Coefficients Between Egg-Spaghetti Data and Physical, Chemical, and Particle Size Data of Granular Mill Streams[a]

Granular Mill Stream Characteristics	Egg-Spaghetti Absorption	Color Score	Cooked Weight	Cooking Loss	Firmness Score
Protein	NS[b]	NS	NS	0.617**[c]	NS
Ash	NS	NS	0.494*[d]	NS	−0.416*
Speck count	NS	−0.556**	NS	0.492*	NS
Dust color	−0.649**	0.695**	NS	NS	NS
Starch damage	0.459*	NS	NS	NS	NS
Absorption[e]	NS	NS	NS	0.438*	NS
Peak time[e]	−0.422*	NS	NS	NS	NS
MTI[e]	NS	NS	NS	0.477*	NS
Absorption[f]	0.472*	−0.677**	−0.582**	NS	NS
Peak distance[f]	NS	NS	NS	NS	NS
Tolerance[f]	NS	NS	NS	NS	NS
Average particle size	−0.533**	NS	NS	NS	NS
Particle size diameter					
>430μ	−0.502*	NS	NS	NS	NS
420μ–250μ	−0.495*	0.626**	NS	NS	NS
250μ–177μ	NS	NS	NS	NS	NS
177μ–149μ	0.544**	NS	NS	NS	NS
<149μ	0.535**	−0.548**	NS	NS	NS

[a] 23 observations.
[b] NS = not statistically significant.
[c] **($P = 0.01$).
[d] *($P = 0.05$).
[e] Farinograph. MTI = mechanical tolerance index.
[f] Mixograph.

In another phase of the investigation, rheological measurements obtained from the farinograph and mixograph could not predict the spaghetti cooking quality properties (Table VI).

Direct comparisons between the egg-spaghetti data of the wheats grown during the two crop years showed that, the results varied but tended to follow the same trend. Our data indicate that all the varieties and classes of wheats tested could be used as granular sources for egg-spathetti production but that the intermediate GMS were the best. Therefore, the selection of GMS from a pilot mill specifically flowed to produce bread wheat flour can yield farina of different granulations for pasta production, but a specific granular size GMS must be selected if results are to compare with commercial production.

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