DURUM WHEAT AIR-CLASSIFIED FLOURS AND THEIR EFFECT ON SPAGHETTI QUALITY[1]

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ABSTRACT

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Samples of durum wheat, with different percentages of vitreous kernels (40 and 95%) were milled into flour. Each flour stream was pin milled and air-classified into a high-protein fine fraction and a medium-protein coarse fraction. A total of 7.3% of the fine flour with approximately 16% protein or over was obtained from air-classified flour fractions from the 95% vitreous wheat sample, and 7.8% of the high-protein flour was produced from the 40% vitreous wheat sample. Ash contents averaged higher in the fine flour fractions. Spaghetti processed from the fine fractions showed lower color scores and had a higher cooking loss. Differences in vitreous kernel content did not affect spaghetti quality. The coarse fraction of air-classified flour was processed into high-quality spaghetti. The fine fraction could be used to increase the protein content of noodles and other pasta products.

The best pasta is produced from high-quality durum wheat. Durum wheat is marketed on the basis of vitreousness (an indication of hardness) and on the test weight of docked grain. The high vitreous wheat generally mills to higher amounts of semolina and lower amounts of flour as compared to less vitreous durum wheat.

Durum flour produced during durum milling is a secondary product. It is used for making noodles and sometimes as a cost-reducing measure in making pasta. Through the process of flour fractionation by air classification, durum flour can be upgraded in protein and could be used to increase the protein content of pasta or noodles (1).

In air classification, the centrifugal force of the rotor is opposed by the counter air flow to separate flour particles on a density and particle-size basis. Due to the differences in density and greater friableness of the matrix protein, a fine-particle, lower density, protein-rich fraction can be obtained.

A number of researchers have reported on the use of air classification to fractionate cereal grain flour. Garcia *et al.* (2) separated corn and wheat germ into five fractions by air classification and reported shifts of carbohydrate and mineral content. Peplinski *et al.* (1,3) reported fractionating durum and hard red spring wheat into high-, medium-, and low-protein fractions by air classification. The fine durum flour fractions showed high protein and ash contents. Shuey and Gilles (4) also separated spring wheat into high-protein, medium-protein, and low-protein fractions by air classification. Using the air-classification technique, Wu and Stringfellow (5) obtained fractions from oat groats which ranged from 4 to 88% protein.

Although there is a need to increase dietary protein of cereal grain by plant breeding or by processing methods, the use of the residue fraction as the result of pin milling and air classification remains a problem.

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A study was undertaken to determine the amount of protein-rich durum flour which can be obtained from pin milled and air classified flours. The flours represented various mill streams obtained from high and low vitreous kernel content durum wheat. The quality of the pasta produced from the various air-classified mill stream fractions also was investigated.

MATERIALS AND METHODS

Sample Preparation

The 95% vitreous durum wheat (95% VDW) was a composite blend of durum samples obtained from the 1973 North Dakota crop survey. The 40% vitreous durum wheat (40% VDW), grown in 1973, was a blend of a large number of smaller samples obtained from the North Dakota State Mill and Elevator, Grand Forks, N. Dak. Since these are statewide grown samples of comingled varieties, the effect of varieties and environment would not influence the results. The wheat grade was evaluated by the federally licensed North Dakota Grain Inspection Service, Fargo, N. Dak.

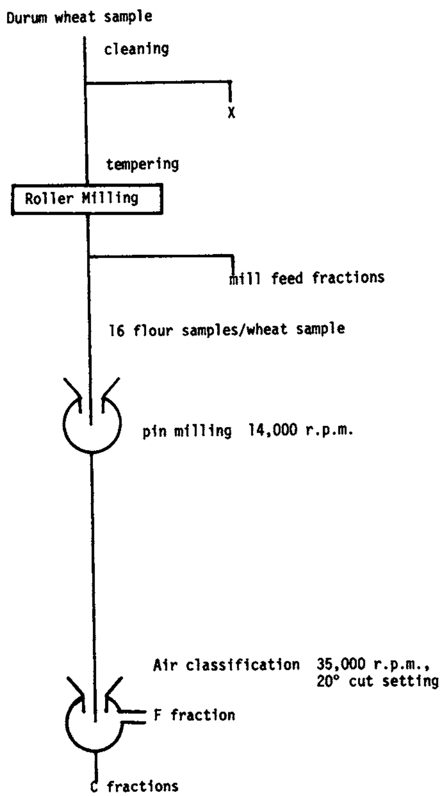

Fig. 1. Processing flow sheet illustrating the treatment of each sample of wheat.

Milling

The wheat samples were cleaned on commercial equipment as described by Shuey and Gilles (6) and tempered to 16.5% moisture 16 hr before milling. The samples were milled on a pilot mill which produced five break, six reduction, two sizing, break dust, tailings, low-grade, and low-quality flours, and three feed streams (6).

Sixteen of the flour streams from each of the two samples were pin milled on an Alpine Kolloplex pin mill Model 160 Z with one pass through the mill at 14,000 rpm. The pin milled flours were separated into high-protein and medium-protein fractions using an Alpine Mikroplex Spiral air-classifier Model 132 MP operating at 35,000 rpm with a cut setting of 20° and a feed setting of 5. The milling and flour fractionation flow diagram is shown in Fig. 1.

Analytical and Pasta Processing

Kjeldahl protein and ash were determined by methods 46-10 (using a 5.7 conversion factor) and 08-01, respectively (7). Starch damage was determined by the colorimetric method described by Williams and Fegol (8).

The high-protein and coarse fractions were processed using the micro spaghetti procedure described by Walsh *et al.* (9). The spaghetti was dried in an experimental laboratory macaroni dryer (10).

Spaghetti color (Method 14-22), cooked weight (Method 16-50), and cooking loss for each spaghetti sample were determined by AACC Approved Methods (7), and the firmness of the cooked spaghetti was measured by the procedure described by Walsh (11).

RESULTS AND DISCUSSION

Effect of Vitreousness on Milling Properties

The physical and chemical properties of the two durum samples are shown in Table I. The test weights of the 95% VDW and 40% VDW samples were 62.8 and

TABLE I
Physical and Chemical Characteristics of the Durum Wheat Samples

	40% VDW	95% VDW
Test weight, lb/bu	61.5	62.8
Protein[a], %	12.9	12.8
Moisture, %	10.4	8.4
Ash[a], %	1.70	1.83
1000-Kernel weight, g	33.9	35.6
Kernel distribution, %		
Large	33	44
Medium	64	54
Small	3	2
Flour extraction, %	64.2	66.6

[a]14% Moisture basis.

61.5 lb/bu, respectively. Protein content of the two samples was nearly the same, while the kernel size distribution demonstrated that the 95% VDW sample contained more large, heavy kernels than did the 40% VDW sample. Total flour extraction was 66.6% for the 95% VDW sample and 64.2% for the 40% VDW sample. The ash content of 95% VDW was 1.83% as compared to 1.70% for 40% VDW.

TABLE II
Per Cent Flour and Protein Content of the Mill Streams

Flour Stream	Flour, %		Protein[a], %		Ash[a], %	
	40% VDW	95% VDW	40% VDW	95% VDW	40% VDW	95% VDW
			Break and Sizing Flour			
1st Break	0.56	0.46	9.8	11.8	0.69	0.88
2nd Break	2.15	1.67	10.4	12.5	0.69	0.81
3rd Break	1.85	1.56	12.9	14.2	0.73	0.74
4th Break	2.07	2.23	15.7	16.0	0.82	0.86
5th Break	1.31	1.48	18.1	18.5	1.22	1.08
Break dust	1.74	1.45	11.0	12.0	0.73	0.82
1st Sizing	1.59	1.65	11.4	12.0	0.62	0.67
2nd Sizing	2.73	2.35	12.9	13.2	0.66	0.60
			Reduction and Low-Grade Flour			
1st Reduction	12.65	11.41	11.0	11.4	0.49	0.56
2nd Reduction	3.45	3.35	13.1	13.1	0.62	0.74
3rd Reduction	16.21	16.69	12.1	12.1	0.51	0.54
4th Reduction	7.99	8.14	12.5	12.9	0.59	0.58
5th Reduction	8.12	9.80	12.2	11.9	0.48	0.52
6th Reduction	5.19	5.36	12.7	13.1	0.77	0.65
Low grade	18.67	18.28	15.6	13.8	0.76	0.77
Tailing	7.02	7.12	12.8	13.4	0.66	0.66

[a]14% Moisture basis.

TABLE III
Analytical Data of Fine Fractions of Air-Classified Break and Sizing Flour

Fine Fraction Flour Stream	Protein[a], %		Starch Damage[b], Units		Ash[a], %	
	40% VDW	95% VDW	40% VDW	95% VDW	40% VDW	95% VDW
1st Break	16.3	18.5	161.3	112.1	2.66	3.43
2nd Break	14.6	16.4	146.2	96.2	2.52	3.45
3rd Break	16.0	18.3	125.1	98.3	2.38	2.51
4th Break	17.8	16.6	118.6	69.7	3.56	2.48
5th Break	20.1	20.4	119.4	97.0	3.53	3.15
Break dust	15.4	18.0	148.7	101.3	2.53	3.30
1st Sizing	16.3	16.0	133.6	112.7	2.92	2.68
2nd Sizing	16.7	17.9	117.3	129.2	2.73	2.54
Average	16.7	17.8	133.8	102.1	2.85	2.94

[a]14% Moisture basis.
[b]Farrand Equivalent Units, dry basis.

Table II includes the percentage of flour released for each mill stream. The 40% VDW samples released approximately 1% more flour in the first three breaks, but essentially the same amounts in the 4th and 5th breaks as compared to the 95% VDW.

The protein content of the 95% VDW flour stream was higher in all streams except in the 5th reduction and low-grade flours. Although both samples were nearly equal in total protein, there apparently was a different protein distribution within the kernel, as shown by the higher protein values for most of the 95% VDW flours and a lower protein content for its low-grade flour. The break flours had the highest ash content, with the 5th break showing the highest level for both wheats.

Flour Quality of Air-Classified Fractions

The data of the air-classified break fractions are shown in Table III. The protein content of the eight flours was higher for the 95% VDW than for the 40% VDW sample, except for the flour from the 4th break and 1st sizing flour streams. The 95% VDW sample produced 8 protein fractions over 16% as compared to 6 protein fractions over 16% from the 40% VDW sample. This reflects the amount of high-protein flour that can be recovered from the break streams of the mill.

Starch damage was higher in seven fractions (5 break streams, break dust, and 1st sizing) from the 40% VDW than from the 95% VDW sample. The 40% VDW produced fractions with starch damage that averaged 133.8 Farrand Equivalent Units (FEU) while the 95% VDW averaged 102.1 FEUs.

Flour ash was highest in the fine fraction of the 4th and 5th breaks for the 40% VDW sample and highest in the 1st and 2nd breaks for the 95% VDW sample. These ash values are high but compare to that previously reported for durum flours (1–3). The 95% VDW fractions had a higher average ash content than the 40% VDW fractions from the head-end mill streams. Ash values were not correlated with protein level.

The protein content, starch damage, and flour ash for each fine fraction from the reduction, low-grade, and tailing flours are reported in Table IV. The protein content of 40% VDW fractions ranged from 15.0 to 17.5% with an average of 16.3%. The 95% VDW fractions contained protein from 14.6 to 18.7% with an average of 17.2%. Protein content was higher in all five fractions from 95% VDW except for the 1st and 2nd reduction flour fractions. High vitreous content wheat produced more high-protein flour fractions than the 40% VDW in the tail-end of the mill as well as in the head-end of the mill, despite the fact that the original protein content of each wheat was nearly identical.

Starch damage was higher for most of the reduction and low-grade flours when compared to the break and sizing flours. These starch damage values for the flours are high compared to semolina. The pin milling may have caused part of this high starch damage.

Flour ash was highest for the break and sizing flour fractions. The average value was approximately 0.75 percentage points above the average values of the ash for the reduction and low-grade flours.

Flour yield from the air-classified fractions demonstrated that a total of 7.33% high-protein flour (15.8 or higher) could be obtained from 95% VDW, while the 40% VDW yielded 7.80% of the high protein flour.

Spaghetti Quality of Air-Classified Fine Fractions

Table V contains quality data on spaghetti produced from the fine fractions obtained from the break and sizing flour. Spaghetti color varied from 4.0 to 5.5 for the fractions from 40% VDW, and from 4.5 to 7.0 for the fractions obtained from the 95% VDW sample. Both 40% and 95% vitreous samples have nearly the same color average (4.9 and 5.2, respectively). This demonstrated that vitreousness has little effect on spaghetti color for fine air-classified fractions. These values are low when compared to 8.0 color average for commercially milled durum semolina processed by the micro spaghetti processing procedure. Color would be poor by these standards, but might be acceptable if the fractions were processed on a commercial extruder. Usually, micro processed spaghetti

TABLE IV
Analytical Data of Fine Fractions of Air-Classified Reduction and Low-Grade Flour

Fine Fraction Flour Stream	Protein[a], %		Starch Damage[b], Units		Ash[a], %	
	40% VDW	95% VDW	40% VDW	95% VDW	40% VDW	95% VDW
1st Reduction	15.9	15.8	143.7	123.4	1.31	2.21
2nd Reduction	17.5	14.6	141.2	159.3	2.52	2.56
3rd Reduction	16.1	17.5	156.3	173.4	1.97	1.56
4th Reduction	15.0	17.5	191.5	182.6	2.03	1.81
5th Reduction	15.9	18.7	197.8	200.3	1.29	1.21
6th Reduction	16.5	17.5	162.6	189.0	2.54	2.29
Low grade	16.6	18.0	148.7	132.4	2.85	2.98
Tailings	16.9	18.2	163.8	157.0	2.51	2.56
Average	16.3	17.2	163.2	164.7	2.13	2.15

[a]14% Moisture basis.
[b]Farrand Equivalent Units, dry basis.

TABLE V
Spaghetti Quality of Fine Fractions of Air-Classified Break and Sizing Flours

Flour Stream	Spaghetti Color Score		Cooked Weight g/10 g		Cooking Loss, %		Firmness Score g-cm	
	40% VDW	95% VDW	40% VDW	95% VDW	40% VDW	95% VDW	40% VDW	95% VDW
1st Break	4.5	5.0	37.7	32.1	10.2	11.2	5.40	5.00
2nd Break	4.5	4.5	32.3	35.3	8.7	11.0	5.37	4.67
3rd Break	5.0	5.0	33.1	31.7	10.8	9.4	5.15	6.28
4th Break	4.0	5.0	31.3	36.5	11.2	9.7	5.65	4.04
5th Break	5.0	4.5	32.7	31.5	11.3	9.0	5.77	6.54
Break dust	5.0	4.5	32.6	32.3	9.5	9.7	4.72	5.70
1st Sizing	5.5	6.0	36.7	35.3	11.7	11.5	4.96	4.56
2nd Sizing	5.5	7.0	33.6	31.7	9.3	9.0	4.98	5.41
Average	4.9	5.2	33.8	33.3	10.3	10.1	5.25	5.28

shows a color drop of 1.0–1.5 units compared to a commercially produced product made from the same durum flour or semolina.

Spaghetti cooked weight ranged from 31.3 to 37.7 g/10 g from the 40% VDW fractions with an average of 33.8 g/10 g. The 95% VDW fractions ranged from 31.5 to 36.5 g/10 g with an average of 33.3 g/10 g. Most sample values were slightly lower than the 35–36 g normally found for pasta processed from semolina under normal commercial conditions.

Cooking loss tended to be high, and ranged from 8.7 to 11.7% for all samples. The cooking loss average was about the same for the 40% VDW samples (10.3%) as for the 95% VDW samples (10.1%). Firmness values varied from 4.04 to 6.54 g-cm and the averages for the 40% VDW and 95% VDW samples were very similar—5.25 *vs.* 5.28 g-cm, respectively. Firmness values do not appear to vary appreciably and the values compare favorably with values obtained from spaghetti made from semolina.

The spaghetti color for the reduction and low-grade flour fractions ranged from 5.5 to 8.0 with an average of 6.4 for the 40% VDW sample, and from 5.0 to 8.0 with an average of 6.3 for the 95% VDW sample (Table VI). The color was improved for these eight fractions as compared to the break and sizing fractions summarized in Table V. This color improvement may be due to the lower ash values, as shown in Table IV, compared to the values listed in Table III.

Cooked weights for the reduction and low-grade fractions were very similar to the weights obtained for the break and sizing flours. No specific trends were noted. The cooking losses for both groups of samples are shown in Tables V and VI and are very similar.

Firmness values ranged from 4.55 to 6.48 g-cm and averaged 5.09 g-cm for the 40% VDW sample and 5.52 g-cm for the 95% VDW sample. The 95% VDW fraction produced spaghetti with slightly higher firmness values than the spaghetti from 40% VDW sample.

TABLE VI
Spaghetti Quality of Fine Fractions of Air-Classified Reduction and Low-Grade Flours

Flour Stream	Spaghetti Color Score 40% VDW	Spaghetti Color Score 95% VDW	Cooked Weight g/10 g 40% VDW	Cooked Weight g/10 g 95% VDW	Cooking Loss, % 40% VDW	Cooking Loss, % 95% VDW	Firmness Score g-cm 40% VDW	Firmness Score g-cm 95% VDW
1st Reduction	7.0	5.5	33.1	30.0	9.2	9.4	4.55	6.48
2nd Reduction	6.5	5.5	33.8	33.4	10.2	13.1	5.37	5.07
3rd Reduction	6.5	8.0	31.5	31.3	8.8	8.8	5.75	5.85
4th Reduction	6.5	7.0	32.1	31.3	9.6	10.0	5.05	6.02
5th Reduction	8.0	7.5	32.1	30.9	9.3	8.0	5.18	6.00
6th Reduction	5.5	6.0	32.1	30.5	11.5	9.4	5.06	5.84
Low grade	5.5	5.0	36.7	31.6	11.4	12.4	4.41	5.03
Tailings	5.5	5.5	30.8	30.6	11.2	10.8	5.36	5.84
Average	6.4	6.3	32.8	31.2	10.2	10.2	5.09	5.77
Overall mill average	5.6	5.7	33.3	32.2	10.2	10.2	5.17	5.52

Spaghetti Quality of Coarse Fractions

The coarse fraction remaining after air classification (medium protein level) will make excellent quality pasta. Table VII contains the quality evaluation from some selected coarse fractions for 40% VDW sample. The average color was one unit less than the unfractionated pasta (8.5 *vs.* 9.5). Although this is a significant drop, the color is still acceptable. The cooked weight, cooking loss, and firmness values reflect excellent cooking quality. The cooked weight average was 3.9 g above the average for the fine-fraction spaghetti, the cooking loss was 3.2 percentage points less, and the firmness was 1.20 g-cm below the value for the fine

TABLE VII
Spaghetti Quality of Some Selected Coarse Fractions from Air-Classified 40% Vitreous Durum Wheat

Sample	Flour[a] Protein %	Flour[a] Ash %	Spaghetti Color Score	Cooked Weight g/10 g	Cooking Loss %	Firmness Score g-cm
1st Break	9.7	0.50	7.5	36.7	7.7	3.60
3rd Break	12.0	0.53	8.0	38.2	7.3	3.83
5th Break	16.7	0.88	8.0	37.7	6.2	4.94
Low grade	13.2	0.55	8.0	37.7	7.7	3.83
1st Reduction	10.4	0.38	9.0	36.0	7.2	3.70
3rd Reduction	11.8	0.37	9.0	36.3	6.2	3.76
5th Reduction	12.3	0.38	9.5	37.8	7.0	3.66
Sizing II	12.7	0.48	9.0	37.0	6.8	3.99
Average	12.4	0.51	8.5	37.2	7.0	3.91

[a]14% Moisture basis.

TABLE VIII
Spaghetti Quality of Some Selected Coarse Fractions from Air-Classified 95% Vitreous Durum Wheat

Sample	Flour[a] Protein %	Flour[a] Ash %	Spaghetti Color Score	Cooked Weight g/10 g	Cooking Loss %	Firmness Score g-cm
1st Break	11.4	0.64	6.0	32.7	6.6	3.89
3rd Break	13.2	0.54	7.5	37.9	5.1	4.47
5th Break	17.1	0.79	7.5	37.4	5.5	5.02
Low grade	13.2	0.56	7.5	38.1	6.9	4.07
1st Reduction	12.4	0.42	8.0	37.5	6.0	3.85
3rd Reduction	11.5	0.41	8.0	37.4	5.7	3.99
5th Reduction	11.5	0.40	8.5	36.8	5.3	3.73
Sizing II	12.8	0.43	7.5	36.7	4.9	4.35
Average	12.9	0.52	7.6	36.8	5.8	3.63

[a]14% Moisture basis.

fractions. Protein contents ranged from 9.7 to 16.7%, while ash values varied from 0.37 to 0.88%.

The 95% VDW coarse fractions exhibited qualities similar to the 40% VDW coarse fractions, as shown in Table VIII. The spaghetti color for the coarse (medium-protein) fractions averaged 2.8 units higher than that of the fine, high-protein fractions. The cooked weight was 4.6 g higher for the coarse fraction average, the cooking loss was 4.4 percentage points less, and the firmness was 1.8 g-cm less when compared to the fine fractions. The values for spaghetti produced from coarse, air-classified fractions are comparable to those for spaghetti produced from commercial semolina. Ash content of the 95% VDW coarse fractions averaged higher than the values from the 40% VDW fractions, while the protein contents were quite similar. The coarse fraction from 40% VDW produced the best color score in the spaghetti.

In summary, the fine, high-protein fractions produced spaghetti with lower color scores and greater cooking losses when compared to the coarse fractions. It is quite possible that the differences noted could be caused by the finer particle size and the higher ash content of the fine fraction. Since the coarse fraction made good quality pasta, this could be its primary use. The fine fraction could be used to increase protein content of noodles or a related product needing more protein.

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