Physical Properties and Processing Quality of Durum Wheat Fractions Recovered from a Specific Gravity Table[1]

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ABSTRACT

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Thirteen samples of Canada Western Amber Durum wheat of varying grade from the 1989 harvest were fractionated on a specific gravity table. The fractions recovered exhibited a broad range of physical properties reflected by variable test and kernel weights and proportions of shrunken, broken and sprouted kernels. The most severely sprouted, broken, and damaged kernels were concentrated in the least dense fractions. This allowed the isolation of denser fractions with greatly reduced α-amylase activity and improved visual quality compared with the unfractionated wheat. The only negative quality attribute of the denser fractions was lower protein content. The superior end-use quality of the denser fractions was confirmed by milling and by evaluation of spaghetti making of representative fractions. For each wheat series evaluated, from the least to the most dense fraction, milling yield improved progressively, with a concomitant improvement in semolina color and a decrease in semolina ash content and speckiness. The denser fractions also exhibited improved spaghetti color.

Specific gravity tables fractionate samples on the basis of density differences. They operate on a principle similar to that of dry stoners, except that the pitch of the porous deck can be changed laterally as well as longitudinally (National Association of British and Irish Millers 1976).

Specific gravity tables are effective in removing light foreign material from seeds (Peske and Boyd 1985). More recent reports (Winter 1987, Hook et al 1988, Helman 1989, Munck 1989) propose using specific gravity tables to segregate low-grade European bread wheat to recover portions with improved test weight and reduced α-amylase activity. Recently, we showed that specific gravity tables can be used to recover milling-grade wheat from low-grade Canada Western Red Spring wheat (Tkachuk et al 1990, 1991). In this article we report on the physical properties and processing quality of gravity table fractions recovered from a diverse set of commercially grown Canada Western Amber Durum (CWAD) wheats.

MATERIALS AND METHODS

Wheats

The Grain Inspection Division of the Canadian Grain Commission supplied 13 durum wheat samples (50 kg each) in November 1989. Some of the samples were selected from the division's 1989 new crop survey of individual farmers' deliveries; others were selected from rail carlots sampled during unloading at terminal elevators in Thunder Bay, Ontario, and Vancouver, British Columbia.

Gravity Table Fractionation

The samples were cleaned to export standards with a Carter C-989 dockage tester (Simon-Day Ltd., Winnipeg, MB) and then fractionated in 40-kg lots with a specific gravity separator (SY 300, Spiroll Kipp Kelly, Inc., Winnipeg, MB). This specific gravity table has a capacity of 580 kg/h and can produce up to five fractions.

The principle of specific gravity table separation is described elsewhere (Tkachuk et al 1991). Ideally, settings should be adjusted slightly between samples to optimize separation, but the relatively small size of our samples made that impractical. Instead, we used constant settings that stratified all the wheat samples in a reasonably uniform layer. Settings were as follows: eccentric, 7; air gate, 3; side raise, 1; end raise, 5; speed, 6.5; hopper, 4. The fractions collected in the current study are designated in order of increased density as F1-5.

Wheat Physical Characterization

Unfractionated samples and individual fractions of the specific gravity table were inspected by inspectors from the Canadian Grain Co. Commission. They assigned a grade to each sample and determined the proportion of kernels that were broken, shrunken, or sprouted (lightly, moderately, and severely).

Test weights were determined singly with a Schopper chondrometer using a 1-L container (Dexter and Tipples 1987); kernel weights were determined as described by Dexter et al (1987).

Milling

Samples were milled as collected from the gravity table without further cleaning into semolina in single 1-kg lots. Samples were prepared for milling as described by Dexter and Tipples (1987) and milled with a four-stand Allis-Chalmers mill in conjunction with a laboratory purifier (Black 1966) according to the procedure outlined by Dexter et al (1990). Semolina yield and total milling yield (semolina and flour combined) were expressed as the proportion of wheat to first break on a constant moisture basis. Flour was considered a by-product and was discarded. Semolina specks were estimated as described by Dexter and Matsuo (1982). Total specks that would be visible in pasta were counted; black specks were then counted separately.

Wheat and Semolina Analytical Tests

All analytical tests were performed in duplicate and adjusted to 14% moisture basis. The moisture contents of ground wheat, semolina, and flour were determined with a rapid moisture tester (C. W. Brabender Instruments, South Hackensack, NJ) as outlined in the instruction manual.

The sodium dodecyl sulfate (SDS) sedimentation volume of wheat was determined by the modified method of Dexter et al (1980). Wheat and semolina protein contents (%N × 5.7) were determined by the Kjeldahl procedure as modified by Williams (1973). Semolina ash content, Agtron color, and wet gluten were determined by AACC methods 08-01, 14-30, and 38-11, respectively (AACC 1983).

Wheat falling numbers were determined on 7-g samples from duplicate 300-g grinds (Tipples 1971). The falling numbers of semolina were determined on duplicate 7-g samples. α-Amylase activities were determined by a nephelometric technique (Kruger and Tipples 1979) on semolina and on the wheat falling number grinds.

Spaghetti Processing

Semolina samples were processed singly by the microprocedure described by Matsuo et al (1972). Spaghetti was dried by a 70°C drying program described by Dexter et al (1981).

Spaghetti Color

Spaghetti color was determined with a spectrophotometer

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[1] Contribution No. 660 of the Canadian Grain Commission, Grain Research Laboratory, 1404-303 Main Street, Winnipeg, MB, R3C 3G8.

(DU-7, Beckman Instruments, Fullerton, CA) in duplicate on whole strands of spaghetti mounted on white cardboard (Daun 1978).

Spaghetti Cooking Quality

Optimum spaghetti-cooking time was defined as the time required for the white core in the strands to disappear. Cooking tests were performed in duplicate on 10 g of spaghetti broken into 5-cm strands and cooked in 200 ml of boiling water. The cooking water was adjusted to a predetermined hardness (Dexter et al 1985) to eliminate the effect of variable hardness on cooked spaghetti stickiness and cooking loss.

Instrument measurements of firmness (tenderness index) and elasticity (compressibility and recovery) were determined at optimum cooking time and after overcooking for 10 min (Matsuo and Irvine 1969, 1971). Spaghetti stickiness was determined at optimum cooking time with a modified Grain Research Laboratory compression tester (Dexter et al 1983a). Cooking loss was estimated in duplicate at optimum cooking time as described by Dexter and Matsuo (1979).

RESULTS AND DISCUSSION

Wheat Characteristics

Samples of variable grade representing individual farmers' deliveries and rail carlots were chosen to ensure that samples were as heterogeneous as possible. The specific gravity table segregated all the durum wheat samples into fractions with a wide range of density, kernel size, and degree of sprout damage. Representative results for milling-grade and feed-grade (No. 5 CWAD) samples are shown in Tables I and II.

The detailed analyses by the grain inspectors confirmed that sprout damaged, shrunken, and broken kernels were concentrated in the least dense gravity table fractions (Table I). The effectiveness of specific gravity tables in removing sprouted wheat kernels has been demonstrated for European common wheats (Hook et al 1988, Munck 1989) and Canada Western Red Spring wheats (Tkachuk et al 1990, 1991); the current study demonstrates its applicability to durum wheat for that purpose.

The ability of the specific gravity table to recover high quality durum wheat from an admixture of good and poor quality wheat was tested with a blend of 90% No. 1 CWAD wheat and 10% of a sample downgraded to feed quality (No. 5 CWAD) because of kernels damaged by sprout and mildew. The resulting admixture (wheat 3) was downgraded to No. 2 CWAD because of kernels damaged by sprout and mildew (Tables I and II). The most severely sprouted and mildewed kernels were concentrated in the least dense fraction isolated from the admixture, about 8% by weight. A blend of the remaining gravity table fractions isolated from the admixture, about 92% by weight, was comparable in physical appearance and α-amylase activity to the original No. 1 CWAD.

A specific gravity table can be used to isolate improved quality fractions from milling quality durum wheat, as shown by the fractions recovered from a No. 2 CWAD (wheat 5) and a No. 3 CWAD (wheat 6), both of which originally had undesirably high α-amylase activity (Tables I and II). However, the fractionation of milling-grade wheat will not always be beneficial because the least dense fractions are always lower in grade and often only of feed quality. Fractionating the No. 2 CWAD sample (wheat 5) would hardly be advantageous because the economic disadvantage of recovering 28% of the sample as lower grades would outweigh the advantage of recovering 10% of the sample as higher grades. However, fractionating the No. 3 CWAD (wheat 6) would be advantageous because recovering 65% of the sample as No. 2 CWAD would certainly outweigh the economic disadvantage of recovering 12% of the sample as No. 4 CWAD. The enhanced test weight and reduced α-amylase levels of the higher-grade wheat recovered from the No. 3 CWAD improve marketability and impart an additional incentive for fractionation.

A definite economic benefit would be gained from the gravity table separation of feed quality wheat. For the two No. 5 CWAD wheats (wheats 2 and 4) that were fractionated, about 40% was

TABLE I

Physical Characteristics of Durum Wheats and Fractions Recovered from a Specific Gravity Table

Sample	Yield (%)	CW Grade	Test Weight (kg/hl)	Kernel Weight (mg)	Shrunken and Broken Kernels (%)	Sprouted Kernels (%)[a]			
						S	M	L	Total
Wheat 1									
UF	100	1	79.1	37.7	4.5	0	0	trace	trace
Wheat 2									
UF	100	5	72.4	32.9	2.7	2.2	1.8	0.8	4.8
F1-3	56	5	71.5	30.8	3.9	1.3	1.5	3.5	6.3
F4,5	44	4	74.5	37.8	0.1	0.4	0.4	2.8	3.6
Wheat 3 (90% wheat 1 and 10% wheat 2)									
UF	100	2	78.9	38.3	4.2	0.3	0.3	0.2	0.8
F1	8	5	72.1	27.3	7.0	0.5	0.6	0.7	1.8
F2	30	2	73.1	34.8	6.0	0.2	0.2	0.4	0.8
F3	34	1	80.0	40.1	1.7	0	0.1	0.2	0.3
F4,5	29	1	82.3	45.2	trace	0	0	trace	trace
Wheat 4									
UF	100	5	76.9	42.7	1.0	11.2	6.4	8.4	26.0
F1-3	63	5	76.5	41.7	1.9	15.2	7.5	7.3	29.8
F4,5	37	4	79.8	47.9	trace	2.8	2.0	5.0	9.8
Wheat 5									
UF	100	2	79.0	38.9	2.2	1.6	1.2	1.8	4.6
F1	10	5	73.4	25.3	23.4	2.0	1.4	1.8	5.2
F2	18	3	77.3	32.4	4.9	1.6	1.6	2.8	6.0
F3	32	2	79.3	38.3	0.1	1.0	1.4	1.8	4.2
F4	30	2	80.4	43.6	0.2	0.7	0.2	2.0	2.9
F5	10	1	82.1	48.0	trace	0.1	0.1	1.4	1.6
Wheat 6									
UF	100	3	79.3	38.5	1.5	2.2	1.2	2.5	5.9
F1	12	4	75.0	31.1	15.6	5.0	2.8	2.0	9.8
F2	22	3	77.3	35.2	5.0	2.8	3.0	1.2	7.0
F3	34	2	79.7	40.4	0.2	0.6	1.2	1.3	3.1
F4,5	32	2	81.8	44.5	0	trace	1.4	0.5	1.9

[a] S = Severe, M = moderate, L = light, UF = unfractionated, CW = Canada Western, F = fraction.

recovered as No. 4 CWAD in a single pass over the gravity table, which would increase the value of the total wheat parcel by about 15%. Two or more gravity tables probably could be used in series to facilitate recovery of an even greater proportion of milling-grade wheat (No. 4 CWAD or better), thus further increasing the value of the wheat parcel.

Dexter et al (1987) demonstrated a pronounced inverse relationship of durum wheat protein content to test and kernel weights. This was reflected by a wide range in protein content within the gravity table fractions (Tables I and II). The lower protein content of the densest durum wheat fractions could be a disadvantage in years when the protein content in durum wheat is low because protein content is a primary factor determining pasta cooking quality (Matsuo et al 1972).

On the basis of SDS sedimentation volumes (Table II), the gluten quality of the lightest fractions was not diminished. In fact, the higher protein content of the lightest fractions imparted higher SDS sedimentation volumes than did that of the corresponding denser fractions.

Milling Properties

The wide range of test and kernel weights shown by the durum wheat specific gravity table fractions should be reflected by large differences in semolina milling potential (Dexter et al 1987). This was verified by milling some of the wheats (Table III). Both semolina and total milling yield increased progressively from the lightest to the densest fraction for all wheats.

The effectiveness of specific gravity tables in removing light impurities resulted in the removal of ergot bodies with the lightest durum wheat fractions. Very strict tolerances for ergot are maintained within the CWAD grades because ergot bodies are toxic. However, even the very low levels permitted in the lower CWAD milling grades (24 kernel-size pieces per 500 g of No. 4 CWAD and 12 kernel-size pieces per 500 g of No. 3 CWAD) impart black specks to semolina that detract from the appearance of pasta (Dexter and Matsuo 1982). The removal of ergot bodies in the lightest CWAD fractions virtually eliminated the presence of black specks in the denser fractions.

Semolina Analytical Properties

The specific gravity table fractions exhibited a wide range of analytical properties for semolina (Table IV). The trends in semolina protein content and α-amylase activity were consistent with the differences between wheats (Table III).

Semolina wet gluten content decreased from the lightest to the densest fractions. The ratio of wet gluten to protein content was essentially constant within each wheat fractionation series, indicating that gluten quality was relatively constant.

Semolina color showed pronounced improvement from the lightest to the densest durum wheat fraction (Table IV). Similarly, with the exception of the densest fraction from wheat 5, semolina ash content decreased progressively from the lightest to the densest fractions. These trends make even greater differences in the relative milling values of the fractions than indicated from intrinsic milling yields (Table III) because most durum wheat millers must keep their products within customer specifications for ash content and/or color.

Spaghetti Color

No consistent trend was observed in intensity (purity) of spaghetti color within or between series of specific gravity table fractions (Table V). However, spaghetti color improved progressively from the lightest to the densest fraction in accordance with shifts in semolina ash content and color (Tables IV and V). As the density of the specific gravity table fractions increased, the spaghetti became brighter and less brown (shorter dominant wavelength).

TABLE II
Analytical Characteristics of Durum Wheats and Fractions Recovered from a Specific Gravity Table[a]

Sample	Yield (%)	CW Grade	Protein Content[b] (%)	SDS[a,b] (ml)	Falling number[b] (sec)	α-Amylase[b] (units/g)
Wheat 1						
UF	100	1	13.4	42.5	340	25
Wheat 2						
UF	100	5	16.0	50.5	60	422
F1-3	56	5	16.4	49.4	60	413
F4,5	44	4	15.3	49.0	150	156
Wheat 3 (90% wheat 1 and 10% wheat 2)						
UF	100	2	13.7	39.5	280	56
F1	8	5	16.1	49.5	70	231
F2	30	2	14.7	43.5	255	81
F3	34	1	13.1	41.5	330	30
F4,5	29	1	12.2	37.5	360	25
Wheat 4						
UF	100	5	15.7	41.5	60	2,254
F1-3	63	5	15.9	40.7	60	2,200
F4,5	37	4	15.2	41.5	65	431
Wheat 5						
UF	100	2	14.6	38.0	75	226
F1	10	5	16.5	42.5	60	798
F2	18	3	15.7	41.0	65	283
F3	32	2	14.8	41.5	155	139
F4	30	2	14.1	35.5	290	61
F5	10	1	13.0	35.0	300	38
Wheat 6						
UF	100	3	13.8	36.5	60	308
F1	12	4	15.0	38.5	60	2,261
F2	22	3	14.2	38.5	60	856
F3	34	2	13.6	36.0	140	187
F4,5	32	2	13.0	34.0	270	109

[a] CW = Canada Western, SDS = sodium dodecyl sulfate sedimentation volume, UF = unfractionated, F = fraction.

[b] Expressed on 14% moisture basis.

TABLE III
Semolina Milling Properties of Durum Wheats and Fractions Recovered from a Specific Gravity Table

	Milling Yield,[a] %			Specks (no. per 100 sq cm)	
Sample	Semolina	Flour	Total	Black	Total
Wheat 1					
UF[b]	64.1	10.8	74.9	1	27
Wheat 2					
UF	63.3	10.1	73.4	9	35
F1-3	62.1	9.9	73.0	14	43
F4,5	64.2	10.4	74.6	5	31
Wheat 3 (90% wheat 1 and 10% wheat 2)					
UF	64.0	11.2	75.2	0	26
F1	61.2	10.9	72.1	16	51
F2	63.3	10.7	74.0	0	25
F3	64.8	11.0	75.8	0	22
F4,5	65.9	10.8	76.7	0	24
Wheat 4					
UF	63.6	10.8	74.4	2	40
F1-3	63.0	11.0	74.0	7	48
F4,5	65.6	11.2	76.8	0	39
Wheat 5					
UF	63.7	11.2	74.9	1	30
F1	59.6	11.8	71.4	5	35
F2	64.8	11.6	76.4	2	35
F3	64.4	11.6	76.0	0	27
F4	64.0	11.6	75.6	0	27
F5	66.6	10.6	77.2	0	38

[a] Proportion of clean wheat on constant moisture basis.

[b] UF = unfractionated wheat, F = fraction.

Spaghetti Cooking Quality

The beneficial effects on spaghetti texture from high-temperature drying and relatively high protein content (Dexter et al 1981, 1983a,b) were evident from the low stickiness values, low cooking losses, good firmness (low tenderness index), and good resilience (low compressibility and high recovery) of all samples (Table V). All samples exhibited very low compressibility (less than 40%) and virtually complete recovery at optimum cooking time (results not shown). Differences in tenderness index, compressibility, and recovery between samples became more evident at 10 min past optimum cooking time (Table V).

TABLE IV
Analytical Properties of Semolina from Durum Wheats and Fractions Recovered from a Specific Gravity Table[a]

Sample	Protein Content (%)	Wet Gluten (%)	Ash Content (%)	Agtron Color (%)	Falling Number (sec)	α-Amylase (units/g)
Wheat 1						
UF[b]	13.1	35.4	0.74	67.8	385	14
Wheat 2						
UF	15.7	43.0	0.79	54.2	165	153
F1–3	16.0	43.8	0.75	52.2	175	172
F4,5	14.9	40.4	0.75	59.5	275	74
Wheat 3 (90% wheat 1 and 10% wheat 2)						
UF	13.4	36.5	0.72	67.2	345	24
F1	16.0	43.5	0.81	53.8	235	101
F2	14.6	39.2	0.73	68.0	340	30
F3	13.0	35.0	0.71	71.0	385	17
F4,5	11.8	32.6	0.69	71.8	390	15
Wheat 4						
UF	15.1	39.1	0.72	58.7	60	840
F1–3	15.4	39.4	0.70	58.0	60	1,006
F4,5	14.7	37.4	0.69	62.0	170	191
Wheat 5						
UF	14.1	37.7	0.74	67.2	210	100
F1	16.6	43.0	0.82	52.8	65	369
F2	15.6	41.8	0.82	58.8	185	150
F3	14.3	39.0	0.68	67.0	270	61
F4	13.1	35.9	0.66	69.0	315	26
F5	12.2	33.3	0.72	71.5	365	16

[a] Expressed on 14% moisture basis.

[b] UF = unfractionated, F = fraction.

TABLE V
Color and Cooking Properties of Spaghetti from Durum Wheats and Fractions Recovered from a Specific Gravity Table

	Color Properties[a]			Cooking Properties[b]				
Sample	B (%)	P (%)	DWL (nm)	S (N/sq m)	CL (%)	COM (%)	R (%)	TI (units)
Wheat 1								
UF	49.5	44.4	578.1	565	5.6	43	91	38
Wheat 2								
UF	40.5	46.2	578.5	555	6.6	34	100	37
F1–3	40.3	45.9	578.6	675	7.0	49	89	41
F4,5	42.7	48.7	577.9	735	6.0	40	100	36
Wheat 3 (90% wheat 1 and 10% wheat 2)								
UF	44.7	48.7	577.9	700	5.8	48	75	39
F1	39.4	47.0	579.2	550	6.1	42	99	34
F2	44.6	49.0	577.7	695	5.5	43	95	35
F3	45.9	49.2	577.6	600	5.6	45	95	38
F4,5	46.8	48.7	577.3	650	6.2	81	24	40
Wheat 4								
UF	43.1	47.0	578.3	665	8.6	52	80	42
F1–3	42.7	48.2	578.2	700	7.7	44	100	41
F4,5	45.2	48.6	577.4	760	5.3	37	100	34
Wheat 5								
UF	44.9	48.5	577.6	650	5.4	42	93	35
F1	40.3	47.1	578.7	660	6.0	38	100	32
F2	42.2	47.9	578.5	680	5.3	37	100	35
F3	45.2	48.8	577.5	710	6.3	37	98	34
F4	46.5	48.1	577.3	715	5.5	47	82	33
F5	47.3	46.2	577.2	835	5.2	41	83	37

[a] B = brightness, P = purity, DWL = dominant wavelength, S = stickiness, CL = cooking loss, COM = compressibility, R = recovery, TI = tenderness index, UF = unfractionated, F = fraction.

[b] Stickiness and cooking loss determined after optimum cooking time; compressibility, recovery, and tenderness index determined at 10 min past optimum cooking time.

The very high level of α-amylase activity associated with the least dense fractions was not detrimental to spaghetti texture, in agreement with numerous previous reports (Dick et al 1974, Combe et al 1988, Dexter et al 1990). Within each series of specific gravity table fractions from the No. 5 CWAD samples (wheats 2 and 4), the badly sprouted, least dense fractions were softer and less resilient than were the corresponding unfractionated sample and denser fraction, but cooking quality was still outstanding. The higher quality wheats showed a tendency to progressively increased softness and reduced resilience from the densest to the lightest fraction because of progressively decreasing protein content.

The least dense fractions from all samples, including the badly sprouted No. 5 CWAD samples, were less sticky than the corresponding denser fractions. This is consistent with previous reports establishing that stickiness is inversely related to protein content (Dexter et al 1983a,b) and independent of α-amylase activity (Dexter et al 1990).

The least dense samples from the No. 5 CWAD samples tended to exhibit greater cooking loss than did the denser fractions. Dexter et al (1990) concluded that cooking loss in spaghetti increases when the durum wheat falling number falls below 150 sec.

CONCLUSIONS

The current study demonstrates the suitability of specific gravity table separation for enhancing wheat quality by extending its applicability from common to durum wheat. The only negative quality aspect of specific gravity table separation of durum wheat is the lower protein content of the denser fractions.

The least dense specific gravity table fractions are always of lower grade and poorer processing quality than are the corresponding unfractionated wheats. As a result, using specific gravity tables to select fractions of improved quality from the top two grades of CWAD is not economically feasible and may limit the practicality of fractionating the lower milling grades of CWAD. However, fractionating No. 5 CWAD would undoubtedly be advantageous, particularly if two or more specific gravity tables were placed in series to enhance the quality and the proportion of milling-grade durum wheat recovered.

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