Phytic Acid in Durum Wheat and Its Milled Products[1]

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ABSTRACT

Phytic acid content of whole kernels and of milled products (bran, dust, semolina, and flour) was determined for six durum wheat varieties grown in 1976 at three North Dakota locations. Phytic acid levels in the whole wheat kernel were not significantly influenced by variety or environment, although trends were noted between locations. Significant differences were determined for phytic acid levels among milled products. Significant differences were also found in phytic acid levels among mill fractions due to location and variety, with significant interactions between location and variety and between location and mill fraction. Phytic acid, a nutritionally undesirable metal-chelating agent, is located primarily in the mill by-products bran and dust and is present in relatively low levels in the major pasta-product ingredients, semolina and flour.

Phytic acid, a normal constituent of whole wheat, is the hexaphosphoric acid ester of myoinositol. The primary role of phytic acid may be that of a phosphorus store that is gradually utilized during germination (Nahapetian and Bassiri 1976). Numerous studies indicate that it reduces the physiological availability of dietary Mg, Ca, Zn, and Fe in monogastric animals (Bassiri and Nahapetian 1977). However, the extent of phytate influence on Fe absorption is still uncertain (Anonymous 1967, Morris and Ellis 1976, Ranhotra et al 1974).

In his studies on phytic acid in milled wheat commercial products, Hay (1942) found that phytic acid phosphorus content was directly proportional to fiber content and that certain white wheats appeared to have lower phytic acid content than red ones. This variation in phytic acid content among wheat varieties was also noted by Nahapetian and Bassiri (1976). They found significant variations in phytic acid concentration over a two-year test period with seven Iranian and five other varieties of *Triticum aestivum* L. At the present time, limited data is available on the phytic acid content of the wheat class *Triticum durum* Desf. and its milled products. Lolas et al (1976) examined the phytic acid-total phosphorus relationship in 38 varieties of wheat. This list included two samples labeled "durum" and "amber durum" with no variety identification specified.

Durum wheat production and past utilization has increased significantly in the United States, (Donnelly 1980, Donnelly and Gilles 1976). Because durum wheat semolina is the material of choice for the production of quality pasta products, the present study was conducted to determine the effect of variety and environment on the phytic acid content of durum wheats and their milled products.

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MATERIALS AND METHODS

Durum Wheat Varieties

Six durum wheat varieties selected for this study were: Botno, Cando, Crosby, Rolette, Rugby, and Wells. They represent a selection of commercial varieties released and produced in North Dakota. These particular samples were grown in drill strips (45.75 × 1.22 m) in 1976 at three North Dakota agricultural experiment station locations: Dickinson, Minot, and Fargo. In this study, the samples were not replicated.

Protein

Wheat protein content was determined by the Kjeldahl procedure, using the standard AACC method (1976).

Test Weight

Test weight (in pounds per bushel) was determined using the standard AACC method (1976).

Milling

All wheat samples were milled on a Buhler experimental mill especially flowed for milling durum wheat and equipped throughout with corrugated rolls. Semolina was purified on a Miag

TABLE I
Test Weight and Protein Content of Durum Varieties Grown at Three Locations in North Dakota in 1976

	Location					
	Dickinson		Minot		Fargo	
Variety	Test weight (lb/bu)	Protein[a] (%)	Test weight (lb/bu)	Protein (%)	Test weight (lb/bu)	Protein (%)
Botno	61.2	17.0	62.3	15.2	63.6	14.0
Cando	60.7	15.9	62.3	13.8	63.6	12.9
Crosby	60.2	17.0	61.9	15.0	63.2	14.1
Rolette	61.9	16.1	62.5	15.5	63.3	15.5
Rugby	60.7	17.0	62.8	15.5	63.6	13.9
Wells	59.7	17.6	61.9	15.4	63.8	13.3

[a]Expressed on a 14% moisture basis; N×5.7.

TABLE II
Yield (%)[a] of Milled Fractions[b] from Durum Varieties

Variety	Dickinson S	Dickinson F	Dickinson B	Dickinson D	Minot S	Minot F	Minot B	Minot D	Fargo S	Fargo F	Fargo B	Fargo D
Botno	51.8	7.2	20.2	14.2	52.0	7.4	19.4	14.5	56.1	7.1	19.0	12.6
Cando	51.6	7.2	20.7	14.8	52.4	7.0	19.9	14.7	55.9	7.2	19.6	11.9
Crosby	51.5	7.0	20.9	14.9	54.0	6.9	19.9	12.6	54.3	6.9	19.1	13.1
Rolette	50.2	6.7	19.1	14.6	54.0	7.6	20.6	12.6	54.3	8.1	18.5	11.5
Rugby	51.6	6.6	20.3	14.9	52.1	7.0	20.3	14.5	56.5	7.3	19.5	11.7
Wells	50.0	7.9	21.9	13.9	51.0	7.6	20.8	13.3	53.8	7.7	20.4	12.5

[a]Based on total weight of unmilled wheat.
[b]S = semolina, F = flour, B = bran, and D = dust.

TABLE III
Phytic Acid Content (%) of Durum Varieties[a]

Variety	Dickinson	Minot	Fargo
Botno	0.98	1.03	1.04
Cando	1.16	0.95	0.98
Crosby	0.88	1.16	1.40
Rolette	0.99	1.29	1.43
Rugby	1.04	1.10	1.09
Wells	1.08	1.15	0.98
Mean	1.02	1.11	1.15

[a]Expressed on moisture free basis.

TABLE V
Analysis of Variance of Phytic Acid in Durum Mill Fractions

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value[a]
Total	287	436.19	...	
Location (L)	2	1.27	0.635	8.36**
Variety (V)	5	2.27	0.454	5.97**
L × V	10	2.34	0.234	3.07**
Mill fraction (F)	3	419.95	139.984	1,841.89**
L × F	6	5.70	0.950	12.50**
V × F	15	2.12	0.141	1.86
Error	30	2.28	0.076	

[a]** = Significant at 1% level.

TABLE IV
Phytic Acid Content (%) of Milled Fractions from Durum Wheat[a]

Variety	Milled Fraction	Dickinson	Minot	Fargo
Botno	Bran	2.77 (53.6)[b]	3.65 (61.0)	3.87 (59.5)
	Dust	1.58 (30.6)	1.63 (27.3)	1.83 (28.2)
	Flour	0.52 (10.1)	0.54 (9.0)	0.56 (8.6)
	Semolina	0.30 (5.8)	0.16 (2.7)	0.24 (3.7)
Cando	Bran	3.11 (56.1)	3.66 (60.0)	3.45 (61.6)
	Dust	1.45 (26.2)	1.58 (25.9)	1.42 (25.4)
	Flour	0.65 (11.7)	0.60 (9.8)	0.49 (8.8)
	Semolina	0.33 (6.0)	0.26 (4.3)	0.24 (4.3)
Crosby	Bran	3.19 (53.9)	3.36 (58.6)	3.63 (54.8)
	Dust	1.70 (28.7)	1.46 (25.5)	1.99 (30.1)
	Flour	0.72 (12.2)	0.68 (11.9)	0.66 (10.0)
	Semolina	0.31 (5.2)	0.23 (4.0)	0.34 (5.1)
Rolette	Bran	3.33 (53.6)	3.56 (56.6)	4.32 (60.4)
	Dust	1.83 (29.5)	1.82 (28.9)	1.91 (26.7)
	Flour	0.71 (11.4)	0.61 (9.7)	0.59 (8.3)
	Semolina	0.34 (5.5)	0.30 (4.8)	0.33 (4.6)
Rugby	Bran	2.33 (43.7)	3.59 (58.9)	3.72 (61.4)
	Dust	1.69 (34.6)	1.64 (26.9)	1.57 (25.9)
	Flour	0.63 (12.9)	0.63 (10.3)	0.55 (9.1)
	Semolina	0.23 (4.7)	0.24 (3.9)	0.22 (3.6)
Wells	Bran	3.01 (53.3)	3.06 (56.9)	3.11 (59.1)
	Dust	1.65 (29.2)	1.44 (26.8)	1.52 (28.9)
	Flour	0.66 (11.7)	0.62 (11.5)	0.45 (8.6)
	Semolina	0.33 (5.8)	0.26 (4.8)	0.18 (3.4)

[a]Expressed on a moisture free basis.
[b]Values in parentheses show percent of total phytic acid in the mill fraction.

laboratory purifier, and all stock was handled pneumatically (Seyam et al 1974).

Phytic Acid Determination

Phytic acid content was determined by the method of Wheeler and Ferrel (1971). The standard curve for Fe was prepared using 3.2*N* sulfuric acid to prevent $Fe(OH)_3$ formation. Five grams of whole ground wheat and mill dust, 2 g of mill bran, and 10 g of semolina and flour were used for measuring phytic acid content. Whole wheat and bran were ground to pass through a U.S. No. 40 sieve. Phytic acid content is expressed on a dry basis, and all values represent the mean of four analytical replications.

Sample Moisture

Moisture content of ground wheat and mill fractions were determined using the AACC air-oven method (1976).

Statistical Analyses

Analysis of variance (ANOVA) for location, variety, mill fraction, and the interaction of location and mill fraction were applied to the data.

RESULTS AND DISCUSSION

The test weights and protein levels for the durum wheat samples used in this study are presented in Table I. Lowest test weights and highest protein levels were observed for the Dickinson station, with the highest test weights and lowest protein levels observed for the Fargo station. Results from the Minot station were intermediate between these two extremes. Environment (location) obviously influenced these results: Dickinson is located in the dry, western area of North Dakota; Fargo is in the humid, eastern edge of the state; and Minot is located in the north central area slightly closer to Dickinson than to Fargo. The general differences in protein content between locations may have affected grain density sufficiently to influence the test weights obtained. In addition, location effects on kernel size and shape may have contributed to the test weight differences.

Milling yields for semolina, flour, bran, and dust are presented in Table II. Mill fraction yields are based on the total weight of tempered, unmilled wheat. Milled product percentages do not add up to 100% because of moisture loss in the milling process. The milling results indicate that lower semolina yields were associated with lower test weights and higher yields with higher test weights. A simple linear regression analysis gave a correlation coefficient of 0.80 for yield versus test weight.

Phytic acid levels for the six wheat samples grown at the three locations are shown in Table III. Standard deviations for replicated

TABLE VI

Least Square Differences Between Varieties for Phytic Acid Content in Combined Mill Fractions[a]

Rolette		Wells		Crosby		Botno		Rugby		Cando	
Wells	1.12*	Rolette	1.12*	Wells	0.66*	Rolette	0.67*	Rolette	0.87*	Rolette	0.80*
Rugby	0.87*	Crosby	0.66*	Rolette	0.46*	Wells	0.45*	Crosby	0.41*	Crosby	0.34
Cando	0.80*	Botno	0.45*	Rugby	0.41*	Crosby	0.21	Wells	0.25	Wells	0.32
Botno	0.67*	Cando	0.32	Cando	0.34	Rugby	0.20	Botno	0.20	Botno	0.13
Crosby	0.46*	Rugby	0.25	Botno	0.21	Cando	0.13	Cando	0.07	Rugby	0.07

[a]* = Significant at 5% level.

analyses were 3% or less. Phytic acid content ranged from a low of 0.88% for Crosby at Dickinson to a high of 1.43% for Rolette at Fargo. ANOVA showed that neither variety nor location had a signifiant effect on phytic acid content of the whole wheat (results not shown). However, the location means showed that phytic acid levels were slightly higher at Fargo than at Minot and that both had higher levels than Dickinson (Table III).

The phytic acid content of the milled wheat fractions are listed in Table IV. Standard deviations in replicated analyses of all semolina, flour, and dust fractions were 5% or less. Standard deviations were slightly higher for the bran fraction, 6% or less. The data and the ANOVA results (Table V) clearly show significant differences in phytic acid content between mill fractions. Phytic acid was concentrated in the bran and dust fractions. Dust is the very fine bran, semolina, and flour removed by air from the Miag purifier during semolina purification and collected in a separate cyclone collection vessel. As with the whole kernel analysis, phytic acid levels in the bran fraction noticeably increased with change of location from Dickinson to Minot to Fargo. The only exception was the variety Cando, which had slightly lower bran phytic acid at Fargo than at Minot, although the level was higher than that obtained at Dickinson. The generally higher levels may be related to the fact that phosphorus levels in the soil of the Red River Valley, where Fargo is located, are generally higher than in the soil of the higher plains to the west, where Minot and Dickinson are located.[4] Srivastava et al (1955) reported a significant positive correlation with available soil phosphorus and corresponding phytic phosphorus in wheat grains.

Dust fractions had phytic acid levels ranging from a low of 1.44% for Wells at Minot to a high of 1.91% for Rolette at Fargo. Both bran and dust can be considered by-products of the milling process; durum bran is generally used in animal feed. The two mill fractions combined account for more than 80% of the phytic acid in the total mill fractions.

Flour resulting from the milling process contained approximately 15–20% of the amount of phytic acid in the bran. Phytic acid levels in flour ranged from a low of 0.45% for Wells (Fargo) to a high of 0.72% for Crosby (Dickinson).

Semolina, the largest mill fraction and the material of choice for the production of high-quality pasta products, contained the least residual amount of phytic acid. Semolina contained no more than 6.0% of the total phytic acid in all mill fractions. Phytic acid ranged from a low of 0.16% for Botno grown at Minot to a high of 0.34% for Rolette grown at Dickinson.

ANOVA of the milled fractions (Table V) indicate that phytic acid content was significantly influenced, albeit at a low level, by variety, location, variety-location interaction, and location-mill fraction interaction, but not by variety-mill fraction interaction. The large significant effect for differences between mill fractions is the result of the large differences in phytic acid content between bran and dust and the other two mill fractions, flour and semolina.

Assessment of significant differences between varieties for phytic acid content was determined by comparing the total phytic acid content of the combined mill fractions for the combined locations, using residual value 0.076 in the least significant differences ($P = 0.05$). Results are presented in Table VI. Rolette had the highest phytic acid level and was significantly different from the other five varieties. Crosby was significantly higher in phytic acid than Rugby and Wells, whereas Botno was only significantly higher than Wells. Cando showed no significant difference in phytic acid content compared with any other variety except Rolette. Rugby was significantly lower than Rolette and Crosby but similar to Botno, Cando, and Wells in phytic acid content. Wells was also significantly lower in phytic acid than Rolette and Crosby as well as Botno but was not significantly different from Cando and Rugby.

As previously reported by Hay (1942) and O'Dell et al (1972) for other wheat classes, the results of this study showed that phytic acid is concentrated primarily in the bran. In effect, the major portion of this nutritionally undesirable metal-chelating agent ends up in the by-products of the milling process. This is also true for trace minerals, trace nutrients, and vitamins.

[4]W. C. Dahnke, Soil Testing and Department of Soils, North Dakota State University, Fargo 58105. Personal communication.

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