Minerals and Protein Contents in Hard Red Winter Wheat[1]

E. DIKEMAN,[2] Y. POMERANZ,[3] and F. S. LAI,[3] U.S. Grain Marketing Research Laboratory, U.S. Department of Agriculture, Agricultural Research Service, Manhattan, KS 66502

ABSTRACT

Cereal Chem. 59(2):139–142

Twenty-five and 29 cultivars/selections of hard red winter wheat were grown at 23 locations in the Great Plains in 1973 and 1979, respectively. Equal weights of each of the 1973 cultivars/selections were composited for 10 locations and of the 1979 cultivars/selections for nine locations. In addition, equal weights of cultivars/selections from 23 locations were composited for 10 cultivars/selections for 1973 and nine cultivars/selections for 1979. The 38 composite samples were analyzed for ash, protein, P, K, Mg, Ca, Zn, Fe, Mn, and Cu. Ranges of all components were much wider for location composites (across cultivars/selections) than for cultivar/selection composites (across locations). Irrigation reduced total ash and K contents and increased Mn content. Large compositional differences were found in location composites for the two years. When components were expressed as percent of sample, eight correlation coefficients were statistically significant (in both years) for the cultivar/selection composites (ash with Zn and P; protein with P, Mg, and Zn; Zn with P and Mg; and Cu with P). Four were significant for the location composites (ash with P and Mg and protein with Ca and Mg). When mineral components were expressed as percent of ash, the significant correlations were Zn with protein, K with P, and Mn with Mg for the cultivar/selection composites and Ca with protein for the location composites. The only significant correlations irrespective of how mineral content was expressed were Zn with protein for the cultivar/selection composites and Ca with protein for the location composites.

Several studies have related mineral composition in wheat to nutritional value and such factors as variety, location, and climate. Toepfer et al (1969, 1972) and Zook et al (1970) compared the mineral component data of wheats with mineral values of their products as part of a nutritional survey. Lorenz and Loewe (1977), who correlated protein with mineral components in commercial wheat blends of hard and soft wheats, found significant correlations between protein and Ca, Fe, K, and Cu and between ash and Ca, Mg, Na, K, Mn, and Cu.

Schrenk (1955) studied the effects of soil and weather, location, and fertilization on mineral composition of three hard red winter (HRW) wheat cultivars, including 13 locations and fertilizer combinations of Ca and P and of Ca, Mg, and P. The available nutrients in the soil showed a distinct correlation with rainfall data. The major mineral elements (K, P, Mg, and Ca) of wheat varied less than the minor elements (Na, Fe, Mn, and Cu).

El Gindy et al (1957) using one HRW wheat, one soft red winter wheat, and one white wheat, found that fertilizer treatment affected total ash and that element distribution in the flour fractions varied greatly among varieties. They found no consistent relationship among elements. Rasmusson et al (1971) found that varietal differences in P, K, Ca, and Mg in wheat were large and that Ca, P, and K contents appeared to be heritable.

This study investigated the association between protein and ash in HRW wheat and the effect of the associations on mineral composition. Cultivar/selections and location composites were tested to evaluate genotypic and phenotypic compositional differences among HRW wheats grown in the Great Plains of the United States.

MATERIALS AND METHODS

Samples

Wheat composites were prepared from the 1973 and 1979 HRW Southern Regional Performance Nursery samples. Each cultivar/selection composite represented equal quantities (50 g) of grain from a cultivar/selection grown at 23 locations for 1973 and 1979. Each location composite represented equal quantities (50 g) of grain from 25 different cultivars/selections grown at that one location in 1973 and 29 cultivars/selections for 1979. The locations and the cultivars/selections listed in Table I were selected to represent a wide range of growth conditions and composition; of the 100 composites, 38 were selected at random for analysis. These 38 composites were 10 and nine location composites and 10 and nine cultivar/selection composites from 1973 and 1979, respectively. All composites were ground on a stainless steel Wiley mill to pass a 20-mesh sieve (840-μm) and mixed thoroughly.

TABLE I
Locations and Cultivars/Selections Used to Prepare Composites

Locations			Cultivars/Selections	
	City			
State	1973	1979	1973	1979
CO	Akron	Akron	Atlas 66/Conn/2/Lcr	Century II[a]
	Burlington	Burlington	Baca[a]	CO533305
	Fort Collins	Julesburg	Bronze[a]	CO611264
	Julesburg	Fort Collins	Buckskin[a]	CO611265
	Springfield	Springfield	Burgas 2	CO741232
IA	Ames	···	Centurk[a]	IL74-3506
IL	Urbana	Urbana	Homestead[a]	IL74-3603
KS	Colby[a]	Colby[a]	Kankay	Kharkof[a]
	Hays	Hays[a]	Kharkof[a]	KS75210[a]
	Garden City	Hutchinson	KS70H134	KS75216[a]
	Manhattan[a]	Manhattan[a]	OK66V2619	KS76H3591-2
MO	Columbia[a]	Columbia[a]	OK66V2621	KS76H5028-3
NE	Clay Center[a]	Alliance	OK66V2629	OK753312
	North Platte	Sidney[a]	Sage[a]	NE75414
	Sidney[a]		Scout 66[a]	OK748084
NM	Clovis[a,b]	Clovis[a,b]	SD7117	OK753664
	Clovis[a,c]	Clovis[a,c]	Sentinel[a]	OK754615
		Farmington	S Scout/Agent	Palo Duro/Ctk
OK	Goodwell	Goodwell	Trison[a]	Plainsman V[a]
	Lahoma[a]	Lahoma[a]	TX69A330-1	Rocky[a]
	Stillwater	Stillwater	TX69A367	Sage[a]
TX	Bushland[a,b]	Bushland[a,b]	TX69A460-1	Scout 66[a]
	Bushland[a,c]	Bushland[c]	TX69A525-1	TX71A494-2
	Chillicothe	Chillicothe	TX69A565	TX71A916-3
		Dallas	TX69A571	TX71A968-6
				TX71A983-4
				TX73V165
				TX73V203[a]
				TX73V388

[a] Location or cultivar/selection composite used for analysis.
[b] Dryland.
[c] Irrigated.

[1] Cooperative investigations between USDA-ARS and the Kansas Agricultural Experiment Station, Kansas State University. Contribution 81-363-J of the Kansas Agricultural Experiment Station.

Mention of firm names or products does not constitute endorsement by the USDA over others of a similar nature.

[2] Research assistant, Department of Grain Science and Industry, Kansas State University, Manhattan 66506.

[3] Research chemist and research chemical engineer, U.S. Grain Marketing Research Laboratory, Manhattan, KS 66502.

TABLE II

Ash, Protein, and Elemental Contents (dry matter basis) of Cultivar/Selection Composites for 1973 and 1979[a]

Composite[b]	Ash (%)	Protein[c] (%)	P (%)	K (%)	Mg (%)	Ca (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)
					1973					
Baca	1.90 d	15.0	0.428 c	0.476 b	0.144 a	481 bc	27.4 b	49.7 a	51.4 c	4.25 d
Bronze	1.99 b	17.0	0.469 a	0.480 b	0.151 a	409 d	31.8 a	46.3 a	55.4 bc	5.29 b
Buckskin	1.82 g	15.7	0.433 bc	0.458 c	0.140 b	510 ab	26.1 c	53.0 a	55.0 bc	4.89 b
Centurk	1.92 c	15.2	0.431 bc	0.487 b	0.144 a	520 a	26.4 c	52.4 a	54.6 bc	5.34 b
Homestead	1.87 e	16.2	0.449 abc	0.429 d	0.147 a	487 bc	28.0 b	49.8 a	63.2 a	5.29 b
Kharkof	2.01 a	16.2	0.450 abc	0.518 a	0.150 a	538 a	29.3 b	51.7 a	54.0 bc	5.20 b
Sage	1.88 e	15.8	0.430 c	0.451 c	0.149 a	476 c	26.5 c	47.8 a	58.4 ab	4.95 c
Scout	1.84 f	15.1	0.415 d	0.478 b	0.143 a	481 bc	26.4 c	49.8 a	59.3 ab	4.97 c
Sentinel	1.90 d	16.3	0.453 ab	0.420 d	0.150 a	488 bc	27.9 b	54.0 a	59.0 ab	5.34 b
Trison	1.92 c	15.8	0.470 a	0.450 c	0.143 a	476 c	29.2 b	44.1 b	50.0 d	5.84 a
Average	1.91	15.8	0.443	0.465	0.146	487	27.9	49.7	56.0	5.14
					1979					
Century II	1.98 a	17.7	0.496 a	0.465 cd	0.173 a	635 b	27.8 a	38.2 b	50.5 a	5.64 a
Kharkof	1.99 a	17.1	0.430 ab	0.582 a	0.156 bc	625 b	27.9 a	43.2 ab	45.3 b	5.10 bc
KS75210	1.80 b	16.2	0.419 ab	0.493 bcd	0.158 bc	460 d	25.9 ab	46.5 a	48.6 ab	4.95 bcd
KS75216	1.69 f	16.3	0.385 b	0.506 bc	0.150 bc	510 c	22.9 d	41.5 ab	48.9 ab	4.52 de
Plainsman V	1.71 e	18.3	0.445 ab	0.461 d	0.162 b	490 c	25.3 bc	38.7 b	51.4 a	5.34 ab
Rocky	1.75 d	15.6	0.385 b	0.521 b	0.146 c	495 c	23.3 c	32.7 c	42.0 c	4.80 cde
Sage	1.77 c	16.1	0.433 ab	0.484 bcd	0.159 b	710 a	25.6 b	43.0 ab	50.0 a	4.37 f
Scout 66	1.74 d	15.8	0.400 b	0.444 e	0.150 bc	515 c	23.6 c	39.2 b	47.5 ab	4.68 cde
TX73V203	1.74 d	15.1	0.392 b	0.504 bc	0.140 d	515 c	23.4 c	38.4 b	42.2 c	4.80 cd
Average	1.80	16.5	0.421	0.496	0.155	551	25.1	40.2	47.4	4.91

[a] Within each column, values followed by different letters are significantly different ($P = 0.05$) by Duncan's multiple range test.
[b] Each from 23 locations.
[c] N × 5.7.

TABLE III

Ash, Protein, and Elemental Contents (dry matter basis) of Location Composites for 1973 and 1979[a]

Composite[b] State	City	Ash (%)	Protein[c] (%)	P (%)	K (%)	Mg (%)	Ca (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)
						1973					
KS	Colby	1.73 h	10.3	0.412 e	0.457 f	0.142 c	350 e	27.8 e	27.6 d	42.0 c	4.67 f
	Manhattan	1.96 b	13.3	0.510 b	0.499 d	0.161 b	380 d	37.7 b	39.9 bc	62.8 ab	4.25 g
MO	Columbia	2.14 a	15.9	0.549 a	0.527 b	0.175 a	490 bc	43.3 a	60.0 a	62.2 ab	4.62 f
NE	Clay Center	1.90 d	14.7	0.475 c	0.457 f	0.159 b	407 d	37.5 b	43.4 b	54.4 ab	5.69 b
	Sidney	2.12 a	17.3	0.520 b	0.476 e	0.176 a	607 a	21.9 f	62.6 a	70.0 a	5.44 c
NM	Clovis[d]	1.81 f	12.7	0.381 f	0.514 c	0.141 c	436 cd	23.2 f	33.5 c	52.8 b	4.93 e
	Clovis[e]	1.68 i	16.7	0.383 f	0.439 g	0.140 c	536 b	14.9 g	40.9 bc	57.3 ab	6.28 a
OK	Lahoma	1.93 c	16.6	0.473 c	0.647 a	0.173 a	504 b	34.7 c	46.9 b	45.3 c	3.51 h
TX	Bushland[d]	1.87 e	15.4	0.441 d	0.501 d	0.143 c	435 cd	30.7 d	40.1 bc	51.3 b	5.25 d
	Bushland[e]	1.77 g	16.5	0.382 f	0.452 f	0.139 c	539 b	34.0 c	43.0 b	54.1 ab	5.11 d
	Average	1.89	14.9	0.452	0.496	0.155	469	30.5	43.0	55.2	4.98
						1979					
KS	Colby	1.93 a	12.3	0.404 bcd	0.472 a	0.151 b	455 c	23.2 d	32.3 e	48.8 bc	4.98 c
	Hays	1.76 c	17.6	0.371 d	0.514 a	0.146 bc	585 a	22.7 d	38.3 bcd	44.6 cd	5.45 b
	Manhattan	1.72 d	14.5	0.411 bc	0.512 a	0.152 b	515 b	23.9 d	36.9 cd	43.0 d	4.56 d
MO	Columbia	1.76 c	13.7	0.431 ab	0.492 a	0.142 c	375 d	29.5 a	41.5 b	51.7 b	5.18 bc
NE	Sidney	1.88 b	16.4	0.449 a	0.506 a	0.159 a	485 bc	18.4 e	34.8 d	58.7 a	5.85 a
NM	Clovis[d]	1.75 c	17.9	0.393 cd	0.496 a	0.148 bc	595 a	23.4 d	49.2 a	36.8 e	5.92 a
	Clovis[e]	1.62 e	15.9	0.404 bcd	0.470 a	0.149 b	460 c	22.9 d	31.7 e	47.8 bc	3.57 c
OK	Lahoma	1.51 f	16.2	0.313 e	0.443 a	0.134 d	405 d	25.2 c	39.7 bc	47.8 bc	3.57 e
TX	Bushland	1.51 f	16.4	0.316 e	0.471 a	0.135 d	480 bc	26.7 b	41.7 b	37.8 e	5.23 bc
	Average	1.72	15.7	0.388	0.486	0.146	484	24.0	38.5	46.3	5.07

[a] Within each column, values followed by different letters are significantly different ($P = 0.05$) by Duncan's multiple range test.
[b] Each from 25 cultivars/selections for 1973 and 29 for 1979.
[c] N × 5.7.
[d] Dryland.
[e] Irrigated.

Analytical Procedures

Moisture, ash, and protein were determined by AACC approved methods. Phosphorus was determined by the AOAC colorimetric-(Mo) blue method (1975). For mineral analysis by atomic absorption spectroscopy, 1-g samples were wet-ashed with nitric-perchloric-sulfuric acid according to the method of Liu et al (1974) adapted for digestion in a microwave oven. Absorption measurements were made in clear digests by the Perkin-Elmer model 360 atomic absorption spectrophotometer. Optimum instrument parameters were adjusted according to manufacturer's instructions. An air-acetylene flame was used for all elements except Ca and Mg, for which a nitrous oxide-acetylene flame was used. All samples were analyzed in duplicate, and two 10-sec integrated readings were recorded for each duplicate. A 0.5-g sample of NBS 1571, Orchard leaves, was digested and analyzed with each group of wheat samples to confirm the accuracy of our method. Distilled water, standards, and blanks were aspirated after every 4–6 samples. A 1,500-ppm Na^+ solution was used in the dilution for determining K to minimize ionization of K in the air-acetylene flame. A 0.2% La^{+++} solution was used in the dilution for determining Ca.

RESULTS AND DISCUSSION

Compositional data for the cultivar/selection composites (across locations) are summarized in Table II and for the location composites (across cultivars/selections), in Table III. Ranges in total protein and ash for the location composites were greater both years than ranges for the cultivar/selection composites, which was not surprising because of the well-established effects of growth conditions on gross composition of cereal grains.

Similarly, ranges in individual mineral components were wider for the location composites than for the cultivar/selection composites. Thus, on the average for the two years, ranges for location composites were higher than those of cultivar/selection composites by a factor of 2.42 for protein, 1.76 for ash, 4.11 for P, 1.17 for K, 1.41 for Mg, 1.26 for Ca, 3.67 for Zn, 2.18 for Fe, 2.19 for Mn, and 2.29 for Cu. With regard to mineral contents and coefficients of variation, our results agree in general with data reported by Schrenk (1955) except that in our study P showed larger location composite ranges than even the minor components did.

Irrigation reduced the total ash and K contents and increased Mn content; none of the other components was affected consistently. Even though location composites were, basically, from the same locations for 1973 and 1979, compositional differences between the two years were large. On the average, the 1973 location composites were higher in total ash and all mineral components except Ca and Cu; the average protein content was higher for the 1979 location composites than for those from 1973. The higher average ash and mineral contents were accompanied by consistently wider ranges in all studied components in the 1973 location composites than in those for 1979.

Several consistent (for the two years) compositional trends for location composite components were observed. For example, location composites from Bushland, TX, were low in P and Mg and high in Cu. Location composites from Columbia, MO, were high in P, Zn, Fe, and Mn; from Manhattan, KS, high in P; and from Sidney, NE, high in total ash, P, Mg, Mn, and Cu. Those trends are probably affected by soil, climate, and cultural practices. Much additional work would be required to evaluate those effects and interrelationships.

Composites for only three of the cultivars (Kharkof, Scout, and Sage) were available for both years. Expressed as percent of sample, total ash, K, and Zn were much higher in Kharkof than in Scout or Sage cultivars. The ash from Kharkof wheat was relatively rich in K, and Sage wheat ash was rich in Mg. Again, more work is needed to confirm this consistent varietal effect, independent of location and cultural practices.

Mineral components can be expressed as percent of sample or as percent of ash. In the first case, the results reflect changes in individual mineral components as they relate to changes in total ash and/or total protein. In the second, the results reflect changes in the composition of ash, irrespective of total ash content. Correlation coefficients were calculated for the cultivar/selection and location composites for ash, protein, P, K, Mg, Ca, Zn, Fe, Mn, and Cu with the individual minerals expressed by both methods. The statistically significant ones for both years are given in Tables IV and V. Expressed as percent of sample, ash correlated with Zn and P; protein with P, Mg, and Zn; Zn with P and Mg; and Cu with P for the cultivar/selection composites (Table IV). Ash correlated with P and Mg, and protein with Ca and Mg for the location composites (Table IV). Expressed as percent of ash, Zn correlated with protein, K with P, and Mn with Mg for the cultivar/selection composites. Calcium correlated with protein for the location composites (Table V).

Contrary to the findings of Miller and Johnson (1954), protein content of the wheat composites was not related to ash content. Our results for location and cultivar/selection composites also differ from those of Lorenz and Loewe (1977) for commercial composites (across cultivars/selections and locations). They reported significant correlations between protein and Ca, Fe, K, and Cu and between ash and Ca, Mg, Na, K, Mn, and Cu for hard wheat blends. Similarly, we did not establish large varietal differences (as compared with location differences) for P, K, Ca, or Mg, as did Rasmusson et al (1971).

The relation between Ca (as percent of ash) and protein for the location composites is of interest. Iron (as percent of ash) was significantly related to protein for the location composites in the 1973 data, but the correlation was only 0.537 for 1979. Protein content was related to Zn for the cultivar/selection composites and to Ca for the location composites, regardless of how the mineral components were computed (as percent of sample or as percent of ash).

Assessing implications of these findings will require additional studies on samples from the other main classes of wheat.

TABLE IV
Significant Correlation Coefficients in 1973 and 1979 (dry basis, percent of sample)[3]

Composites	1973	1979
Cultivar/selection		
P to ash	0.608[a]	0.670[a]
Zn to ash	0.796[b]	0.881[b]
P to protein	0.773[b]	0.783[b]
Mg to protein	0.727[a]	0.858[b]
Zn to protein	0.759[a]	0.665[a]
Zn to P	0.849[b]	0.840[b]
Zn to Mg	0.607[a]	0.749[a]
Cu to P	0.695[a]	0.751[a]
Location		
P to ash	0.934[b]	0.796[b]
Mg to ash	0.900[b]	0.768[b]
Ca to protein	0.859[b]	0.624[b]
Mg to protein	0.910[b]	0.804[b]

[a]Significant at the 0.05 level.
[b]Significant at the 0.01 level.

TABLE V
Correlation Coefficients Significant in Both 1973 and 1979 (as percent of ash)

Composites	1973	1979
Cultivar/selection		
Zn to protein	0.760[a]	0.645[a]
K to P	−0.752[a]	−0.667[a]
Mn to Mg	0.893[b]	0.932[b]
Location		
Ca to protein	0.713[a]	0.790[b]

[a]Significant at the 0.05 level.
[b]Significant at the 0.01 level.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. Approved Methods of the AACC. Methods 08-01 and 46-11, approved April 1961, and Method 44-15A, approved April 1967. The Association: St. Paul, MN.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. 1975. Official Methods of Analysis, 12th ed. Method 3-20. The Association: Washington, DC.

EL GINDY, M. M., LAMB, C. A., and BURRELL, R. C. 1957. Influence of variety, fertilizer treatment, and soil on the protein content and mineral composition of wheat, flour, and flour fractions. Cereal Chem. 34:185.

LIU, P. J., ROBBINS, G. S., and POMERANZ, Y. 1974. Composition and utilization of milled barley products. IV. Mineral components. Cereal Chem. 51:309.

LORENZ, K., and LOEWE, R. 1977. Mineral composition of U.S. and Canadian wheats and wheat blends. J. Agric. Food Chem. 25:806.

MILLER, B. S., and JOHNSON, J. A. 1954. A review of methods for determining the quality of wheat and flour for breadmaking. Kans. Agric. Exp. Stn. Tech. Bull. No. 7.

RASMUSSON, D. C., HESTER, A. J., FICK, G. N., and BYRNE, I. 1971. Breeding for mineral content in wheat and barley. Crop Sci. 11:623.

SCHRENK, W. G. 1955. Chemical composition of Kansas wheat. Kans. Agric. Exp. Stn. Tech. Bull. No. 79.

TOEPFER, E. W., HEWSTON, E. M., HEPBURN, F. N., and TULLOSS, J. H. 1969. Nutrient composition of selected wheats and wheat products. I. Description of samples. Cereal Chem. 46:560.

TOEPFER, E. W., POLANSKY, M. M., EHEART, J. F., SLOVER, H. T., MORRIS, E. R., HEPBURN, F. N., and QUACKENBUSH, F. W. 1972. Nutrient composition of selected wheats and wheat products. XI. Summary. Cereal Chem. 49:173.

ZOOK, E. G., GREENE, F. E., and MORRIS, E. R. 1970. Nutrient composition of selected wheats and wheat products. VI. Distribution of Mn, Cu, Ni, Zn, Mg, Pb, Sn, Cd, Cr, and Se as determined by atomic absorption spectroscopy and colorimetry. Cereal Chem. 47:720.

[Received April 24, 1981. Accepted October 12, 1981]