that iron is or is not associated with a specific subcellular component or biochemical is valuable, not only because it tells us something about the form of iron, but also because it will facilitate future isolation efforts. The investigator can then use appropriate techniques for isolation of either organelles, particles, or compounds, and perhaps more importantly it will enable the investigator to maintain the materials' integrity during isolation.

The maize sections showed a positive staining reaction to the Prussian Blue test for ferric iron along the outer region of the scutellum and in the aleurone layer. Cotyledons of the blackeyed peas also reacted in the Prussian Blue test, showing the most intense color along the peripheral area. Hyde et al. (1963) observed that the peripheral cells of pea cotyledons contain relatively little starch, but numerous large spherical structures which probably represent stored proteins. He also noted that toward the center of the cotyledon the number of protein bodies per cell decreases, while the number of starch grains increases.

The histo- and cytochemical examinations indicating the high concentrations of iron in the aleurone layer and scutellum of maize as well as at the periphery of the cotyledon of blackeyed peas were confirmed with the aid of the x-ray analysis (EDAX and SEM).

The maize germ analysis gives evidence of a high concentration of Fe. Maize endosperm shows only a slight indication of the presence of Fe.

Further study has been done to chemically characterize iron in seeds and grains. This work dealt with the iron–protein complex, phytoferritin, and the iron–phytate complex, ferric phytate. These findings will be reported in a future paper.

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Mineral Composition of U.S. and Canadian Wheats and Wheat Blends

Klaus Lorenz and Robert Loewe*

The mineral compositions (K, Mg, Ca, Fe, Mn, Zn, Na, and Cu) of 65 samples of hard and soft wheats, collected from mills in the U.S. and Canada after the 1975 harvest, were determined. Average values of each mineral in the different wheat classes are presented. Comparisons in mineral content between hard and soft wheat were made, and correlation coefficients were calculated between percent protein and percent ash in wheat, and each of the mineral elements determined.

An expansion of the cereal fortification program in the United States has been proposed by the Food and Nutrition Board of the National Academy of Sciences in 1974. The proposal suggests additional fortification of cereal grain products with nutrients for which there is a risk of deficiency within certain population groups (National Academy of Sciences, 1974).

Canada is also considering an expanded cereal enrichment program after results of the Nutrition Canada Survey indicated less than adequate levels of certain nutrients in the diets of some Canadians.

To study the feasibility of expanded cereal product fortification, the American Bakers Association formed an Inter-Industry Committee. In Canada, the Technical and Nutrition Committee of the Bakery Council of Canada accepted the task (Ranum and Kulp, 1976).

Before some definite recommendations for changes in cereal product fortification can be made, however, it was felt that analysis of the nutrient composition of wheat varieties, grown presently in different parts of the U.S. and Canada, and their milling fractions are needed. It is realized that the mineral composition of various wheat varieties has been reported by many cereal researchers. However, with the introduction of new wheat varieties and modifications in agronomic practices, changes in mineral composition are possible.

This paper presents the mineral composition of hard and soft wheats from different areas of the U.S. and Canada and of wheat mixes blended by various mills for milling into flours for specific bakery applications.

MATERIALS AND METHODS

a. Sample Identification and Chemical Analyses. Sixty-five wheats and wheat mixes were collected after the 1975 harvest by representatives of the Pennwalt Corporation and the Research Products Company. The number

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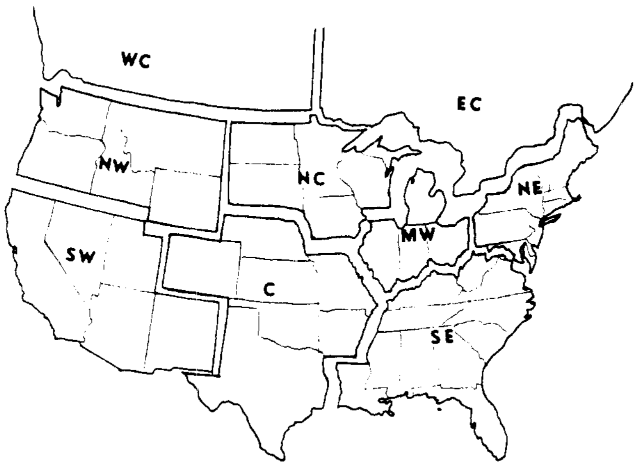

Figure 1. Division of the U.S. and Canada into specific areas for wheat sampling purposes.

Table I. Sample Distribution of Hard and Soft Wheats by Mill Location

Area	No.	%	% of active milling capacity
United States			
NW Northwest	4	8	6
SW Southwest	5	10	7
NC Northcentral	5	10	11
C Central	12	25	32
MW Midwest	9	19	18
SE Southeast	7	15	13
NE Northeast	6	13	13
Total U.S.	48	100	100
Canada			
EC Eastern	12	71	
WC Western	5	29	
Total Canada	17	100	

Hard wheats	No.	Soft wheats	No.
Hard Red Winter (HW)	8	Soft Red (SR)	8
Hard Red Spring (HS)	8	Soft White (SW)	2
Hard (unclassified) (H)	1	Soft (unclassified) (S)	1
Dark Northern Spring (DNS)	1	White (W)	1
Hard Yellow Winter (HYW)	1	Ontario Soft Winter (OSW)	2
Western Red Spring (WRS)	7	Soft wheat blends	6
Alberta Red Spring (ARS)	1		
Hard wheat blends	18		

of samples taken of each wheat type and from each milling location was based on U.S. Department of Commerce production figures. The division of the U.S. and Canada into specific areas for sampling purposes is illustrated in Figure 1. The sample distribution by mill location is given in Table I.

Moisture, protein, and ash of the samples were determined by AACC approved methods (AACC, 1962) at the U.S. Department of Agriculture Soft Wheat Quality Laboratory in Wooster, Ohio.

b. Mineral Analyses. Two laboratories participated in the analyses of the samples using different digestion procedures prior to measurement of mineral concentrations by atomic absorption.

Laboratory No. 1 used a pressure digestion technique for sample preparation before analyses by atomic absorption. This procedure and its advantages over other digestion methods as well as the atomic absorption operating parameters (Perkin-Elmer Model 303) have been described in detail by Lorenz et al. (1976). The concentrations of eight minerals in the wheat samples were determined in triplicate.

Laboratory No. 2 used a dry ashing procedure as described in AACC method 40-41 (AACC, 1962) prior to determination of mineral levels using an Instrumentation Lab. Model 251 atomic absorption spectrophotometer. The laboratory contributed data of four mineral elements (Ca, Mg, Zn, Fe) in duplicate.

c. Statistical Analyses of Data. A comparison of the data from the two laboratories indicated no significant differences due to laboratory procedure for the elements Ca, Mg, Zn, and Fe, which were determined by both laboratories. The data were, therefore, pooled and analyzed using one-way analyses of variance (AOV) to establish statistically significant differences due to wheat class. Correlation coefficients were calculated between percent protein, percent ash, and each of the mineral elements determined in this study.

Table II. Mineral Composition of U.S. and Canadian Hard Wheats[a]

Element	Wheat[b] class	Mean	Standard deviation	95% confidence interval for mean
K (%)	HW[c]	0.349	0.062	0.321-0.377
	HS	0.334	0.089	0.295-0.372
	WRS[c]	0.249	0.036	0.232-0.265
Mg (%)	HW[c]	0.114	0.026	0.105-0.124
	HS	0.125	0.037	0.112-0.137
	WRS[c]	0.099	0.017	0.094-0.105
Ca (%)	HW[c]	0.028	0.004	0.027-0.030
	HS[c]	0.025	0.005	0.023-0.026
	WRS[c]	0.020	0.002	0.020-0.021
Fe (ppm)	HW[c]	32.7	6.1	30.5-34.9
	HS[c]	36.0	5.7	34.2-37.8
	WRS[c]	37.2	5.1	35.5-38.9
Mn (ppm)	HW[c]	42.1	3.4	40.5-43.7
	HS	44.5	6.3	41.9-47.2
	WRS[c]	38.2	4.4	36.1-40.3
Zn (ppm)	HW[c]	26.3	2.9	25.3-27.3
	HS	27.0	4.9	25.4-28.6
	WRS[c]	28.0	3.7	26.7-29.3
Na (ppm)	HW[c]	24.3	2.9	22.9-25.7
	HS	26.4	5.6	24.0-28.8
	WRS[c]	19.4	3.8	17.7-21.2
Cu (ppm)	HW[c]	4.72	1.19	4.18-5.26
	HS[c]	3.70	0.50	3.49-3.91
	WRS[c]	4.15	0.44	3.95-4.35

[a] On 14% moisture basis. [b] HW, Hard Red Winter; HS, Hard Red Spring; WRS, Western Red Spring. [c] Differences statistically different between indicated wheat classes ($\alpha = 0.05$).

RESULTS AND DISCUSSION

a. Hard Wheats. Average values for each mineral element and standard deviations for Hard Red Spring (HS), Hard Red Winter (HW), and WRS (Western Red Spring) wheats are presented in Table II. The table does not include the mineral data from any of the wheat blends since in some instances both HS and HW wheats were part of the blend. Rather than presenting the mineral composition of each of the 65 wheats and wheat blends, it was thought that it would be more meaningful to average and compare the different classes of hard and soft wheats as presented in Table II. Mineral contents of each of the samples are available upon request.

The average mineral values shown in Table II are within the range of mineral contents of wheats reported by others

Table III. Mineral Composition of U.S. and Canadian Soft Wheats[a]

Element	Wheat[b] class	Mean	Standard deviation	95% confidence interval for mean
K (%)	SW[c]	0.377	0.091	0.307-0.446
	SR[c]	0.380	0.071	0.350-0.410
	OSW[c]	0.277	0.054	0.220-0.334
Mg (%)	SW	0.116	0.036	0.096-0.136
	SR[c]	0.120	0.028	0.111-0.129
	OSW[c]	0.096	0.034	0.070-0.123
Ca (%)	SW[c]	0.030	0.007	0.026-0.034
	SR[c]	0.025	0.003	0.024-0.026
	OSW	0.027	0.003	0.025-0.029
Fe (ppm)	SW[c]	28.7	3.8	26.5-30.9
	SR[c]	33.7	6.3	31.5-35.8
	OSW[c]	27.7	4.6	24.3-31.0
Mn (ppm)	SW[c]	37.3	5.6	33.0-41.6
	SR[c]	46.0	6.3	43.3-48.6
	OSW[c]	27.1	4.8	22.1-32.2
Zn (ppm)	SW[c]	23.4	7.9	19.0-27.8
	SR[c]	26.9	4.5	25.4-28.3
	OSW	26.1	2.3	24.4-27.7
Na (ppm)	SW[c]	27.0	13.5	16.6-37.4
	SR[c]	21.1	2.2	20.1-22.0
	OSW[c]	18.4	2.4	15.9-20.9
Cu (ppm)	SW	4.40	1.01	3.63-5.18
	SR	4.30	0.92	3.91-4.69
	OSW	4.23	0.42	3.79-4.68

[a] On 14% moisture basis. [b] SW, Soft White; SR, Soft Red; OSW, Ontario Soft Winter. [c] Differences statistically different between indicated wheat classes ($\alpha = 0.05$).

(Czerniejewski et al., 1964; Waggle et al., 1967; Zook et al., 1970; Toepfer et al., 1972). Statistically significant differences ($\alpha = 0.05$) between HW and WRS wheats were found for the elements K, Mg, Mn, and Na. In each case the WRS wheats contained lower amounts. The differences between HS and HW wheats for these same elements were insignificant. Statistically significant differences ($\alpha = 0.05$) between the three wheat classes were found for Ca and Cu. For the element Zn, significant differences were observed only between HW and WRS wheats. For Fe, average values between HW and HS and between HW and WRS wheats showed statistically significant differences ($\alpha = 0.05$).

With the exception of Fe, Zn, and Cu, the Canadian wheat samples had the lowest amounts of the minerals determined.

b. Soft Wheats. Average mineral contents and standard deviations for SW, SR, and OSW wheats are presented in Table III. Mineral contents of soft wheat blends are not included.

The average mineral contents shown are within the range of values reported by others (Waggle et al., 1967; Zook et al., 1970). For K, statistically significant differences ($\alpha = 0.05$) were found between SW and OSW and between SW and SR and OSW wheats. For Ca and Zn, only the differences between SW and SR wheats were significant, while for Mg the values for SR wheats were significantly different ($\alpha = 0.05$) from those for OSW wheats. SW and SR wheats as well as SR and OSW wheats differed significantly in Fe and Na contents. In Mn, differences between SW, SR, and OSW wheats are significant. No statistically significant differences were found in Cu content. With the exception of Ca and Zn, the Canadian soft wheats contained the lowest amounts of the minerals analyzed.

c. Comparison between Hard and Soft Wheats. A comparison between the mineral contents of all hard

Table IV. Comparison in Mineral Content between Hard Wheats and Soft Wheats[a]

Element	Wheat class	Mean	Standard deviation	95% confidence interval for mean	F ratio	F prob.
K (%)	Hard	0.308	0.078	0.294-0.321	9.79	0.002[b]
	Soft	0.347	0.081	0.326-0.369		
Mg (%)	Hard	0.114	0.030	0.110-0.119	0.38	0.540
	Soft	0.112	0.030	0.106-0.118		
Ca (%)	Hard	0.025	0.005	0.024-0.025	1.70	0.193
	Soft	0.026	0.004	0.025-0.026		
Fe (ppm)	Hard	34.49	5.70	33.71-35.26	19.86	0.000[b]
	Soft	31.31	5.37	30.17-32.45		
Mn (ppm)	Hard	41.03	5.86	40.01-42.06	0.16	0.690
	Soft	40.59	8.72	38.26-42.93		
Zn (ppm)	Hard	26.58	3.77	26.08-27.08	8.29	0.004[b]
	Soft	25.09	5.12	24.05-26.13		
Na (ppm)	Hard	22.41	4.96	21.55-23.27	1.98	0.161
	Soft	21.20	6.34	19.52-22.88		
Cu (ppm)	Hard	4.20	0.89	4.05-4.36		
	Soft	4.06	0.84	3.84-4.28	1.07	0.303

[a] All hard wheat and soft wheat blends included. [b] Differences in mineral content statistically significant between hard and soft wheat classes.

Table V. Table of Correlations

	Hard wheats[a]		Soft wheats[b]		Wheat (all classes)	
Elements	% protein vs. minerals	% ash vs. minerals	% protein vs. minerals	% ash vs. minerals	% protein vs. minerals	% ash vs. minerals
Ca	−0.4215[d]	0.2796[d]	−0.1757[c]	−0.0553	−0.2733[d]	0.2052[d]
Mg	−0.0101	0.2894[d]	−0.0409	0.0668	0.0222	0.2216[d]
Zn	0.0912	0.1213[c]	0.2069[c]	0.4801[d]	0.1840[d]	0.2018[d]
Fe	0.2956[d]	−0.0549	−0.0203	0.1077	0.3424[d]	−0.0514
K	−0.1869[c]	0.3290[d]	−0.0394	0.1471	−0.2726[d]	0.3003[d]
Na	−0.0621	0.1857[c]	0.0420	0.1388	0.0621	0.1492[c]
Mn	0.0190	0.2117[d]	−0.0066	0.2861[c]	0.0314	0.2204[d]
Cu	−0.2438[d]	−0.1503[c]	0.0275	0.4249[d]	−0.0538	−0.0169

[a] HS, HW, DNS, HYW, WRS, ARS, and all hard wheat blends. [b] SR, SW, W, S, OSW, and all soft wheat blends. [c] Significant at 5% level. [d] Significant at 1% level.

wheats including the blends and all soft wheats including soft wheat blends is presented in Table IV. There were only three statistically significant differences. Hard wheats were higher than soft wheats in Fe and Zn, while soft wheats contained significantly more K than hard wheats.

d. Correlation Coefficients between Protein and Ash Content and Mineral Elements. Correlation coefficients between percent protein and percent ash in wheats and each of the eight mineral elements were calculated for all hard wheats and hard wheat blends, for all soft wheats and soft wheat blends, and for all wheat classes combined. The correlation coefficients are given in Table V.

A significant positive correlation was established between the protein content of hard wheats and hard wheat blends and Ca, Fe, K, and Cu content and between ash content of those wheats and Ca, Mg, Na, K, Na, Mn, and Cu.

In soft wheat and soft wheat blends, significant positive correlation was found between percent protein and Ca and Zn contents. Soft wheat ash was also significantly correlated with Zn, Mn, and Cu content in soft wheat.

Combining all classes of wheat, it can be seen from the values in Table V that wheat protein is significantly correlated with Ca, Zn, Fe, and K content, while percent ash shows a significant correlation with Ca, Mg, Zn, K, Na, and Mn.

A full discussion must include application of these data. Specifically, it is clear that the classes of hard and soft wheats analyzed show a number of significant differences in terms of naturally occurring mineral contents. If the intended cereal fortification program discussed in the introduction is to take place, selection of proposed fortification levels must take these naturally occurring differences into account. It must be realized that, although "typical", or average, values for these minerals may be convenient for textbook discussion, a large-scale fortification program, ultimately coming under government compliance regulations, will require a knowledge of the wide range of differences between wheat classes shown in this study and those to come.

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Effects of 1,3-Diols and Their Esters on the Rheological Properties of Dough and the Storage Stability of Bread

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Several linear 1,3 diols and their monoesters were studied in standard bread formulations. The lower 1,3-diols, especially 1,3-butanediol, exhibited antistaling properties while the higher diols were effective mold inhibitors. The esters, in amounts ranging from 0.1 to 0.5%, improved the mixing characteristics of test doughs, inhibited mold formation, and, in some instances, increased loaf volume and enhanced bread quality. The most effective esters were those whose total carbon content, diol plus acid portion, was in the range of C_{11}–C_{12}. The potential of these compounds as functional bread additives and problems to be overcome are discussed.

A variety of additives have been used as processing aids for bread doughs and other baked goods. Such materials are normally added to improve one or more of the following characteristics: mixing tolerance, dough strength, bread volume, texture, or softness. In addition, chemical additives are often employed to retard mold spoilage and thereby increase the shelf life. Among the additives used or recommended as dough conditioners are salts of steroyl lactic acid (Marnett and Tenney, 1961; Tenney and Schmidt, 1968), polypropylene glycol (Moneymaker and Forsythe, 1974), glycosides of hydroxy fatty acids (Baeuerlen and Findley, 1969), glycerides of succinic acid (Meisner, 1969), and sulfosuccinates (Whelan, 1970). Softening agents and volume improvers are usually monoglycerides (Church, 1973) although other emulsifiers may be used including the lactylate and sucrose derivatives (Pomeranz and Finney, 1973). Pomeranz and Wehrli (1969) also recommend synthetic glycosylglycerides. Salts of propionic acid or sorbic acid are the most common mold

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