CEREAL CHEMISTRY

VOL. 41 MARCH, 1964 NO. 2

THE MINERALS OF WHEAT, FLOUR, AND BREAD[1]

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ABSTRACT

Ten commercial hard wheat blends from various growing areas, flours milled from these wheats, and bread made from the flours were analyzed for mineral elements of nutritional importance. Patent flours contained lower proportions of all minerals than the original wheat: magnesium, manganese, and cobalt less than 20%, phosphorus, potassium, zinc, iron, copper, and sodium between 20 and 32%, calcium 40%, and molybdenum 52%. In bread, sodium and calcium were present in higher concentration than in wheat. The concentration of cobalt in bread averaged 85% of that of wheat, iron and molybdenum 65%, potassium and copper 40 to 45%, zinc 28%, magnesium 19%, and manganese 13%.

Many quantitative studies have been made of the mineral composition of wheat, and there are reports of the mineral elements in flour, mill streams, and bread, as well. Bailey (1) has reviewed the literature prior to 1943. More recent research in the United States has been concerned with the relationship of mineral composition of wheat to variety and growing conditions (2,3) and to the location of the mineral elements within the wheat kernel (4). None of these studies has been concerned with the changes in content of mineral elements from wheat to bread. Consequently, data available to nutritionists have been compiled from many sources.

This paper presents quantitative data on the amounts of nutritionally important mineral elements found in commercial wheat blends from the principal hard wheat regions of the United States, commercially milled flour from each of these wheats, and bread made from each of the flours, together with a limited study of the distribution of these mineral elements in commercial flour mill streams. It represents a part of the nutrition research conducted at the American Institute of Baking (5–8).

[1]Manuscript received October 7, 1963. Contribution from the American Institute of Baking, Chicago, Illinois. This research was supported by a grant from the Max C. Fleischmann Foundation.

Materials and Methods

Sample Description. Flours, mill products, and the wheat blends from which they were milled were obtained from commercial flour mills. Bread was made from the flours at the American Institute of Baking, using the sponge and dough procedure and a representative baker's formula. The following ingredients were used, in parts per 100 parts flour by weight: compressed yeast 2.5; yeast food (composition: potassium bromate 0.11%, potassium iodate 0.10%, sodium chloride 19.4%, ammonium sulfate 7.0%, monocalcium phosphate 50%, and starch 23.4%) 0.5; sodium chloride 2, sucrose 6, nonfat dry milk 4, lard 3, water 68, calcium propionate 0.11, and an amount of commercial enrichment wafer to meet the Standards of Identity for enriched bread. Breads were sliced and dried at room temperature. Wheats and breads were ground in a hammer mill to pass a screen with 0.024-in. openings (equivalent to U.S. Standard Sieve No. 30).

Descriptive data supplied by the mills for the wheats and flours, together with our values for ash in the breads, are given in Table I.

TABLE I
DESCRIPTION OF SAMPLES

A. WHEAT, FLOUR, AND BREAD[a]

Sample No.	Wheat and Source	Flour Yield[a]	Flour Patent[a]	Ash[b]		
				Wheat	Flour	Bread
		%	%	%	%	%
1	HRS Mont., N.D., S.D., Minn.	71.8	98.5	2.03	0.53	2.99
2	HRS Mont., N.D., S.D., Minn.	72.2	80	2.09	0.45	2.94
3	HRW Kans., Colo.	73.7	95	1.86	0.49	2.94
4	HRW Kans., Colo.	74.4	96	1.95	0.48	2.96
5	50% HRS, 50% HRW	..	95	1.90	0.48	2.99
6	50% Baart, Wash., 50% HRW	72.3	88	1.84	0.47	2.93
7	50% Baart, Wash., 50% HRW	72.4	90	1.82	0.48	2.97
8	50% Baart, Wash., 50% HRW	74.8	83	1.85	0.46	2.90
9	HRW Texas, Okla.	72	..	1.96	0.47	2.98
10	HRW Texas, Okla.	72	..	1.87	0.50	3.07

B. WHEAT AND COMMERCIAL FLOUR MILL PRODUCTS[c]

Product	Proportion of Cleaned Wheat[a]	Moisture as Received	Ash[b]
	%	%	%
Wheat	100.0	10.3	1.96
Farina	1.51	13.2	0.43
Patent flour, 80.1% patent	60.68	13.6	0.43
First clear flour	11.14	13.1	0.86
Low grade flour	2.42	11.4	1.93
Red dog	0.48	10.2	4.15
Shorts	9.13	12.6	5.88
Bran	14.59	8.5	7.27
Germ	0.07	8.3	3.98

[a] Data supplied by mills.
[b] Dry basis.
[c] Blend of HRS and HRW. Flour yield 75.8%.

Analytical Procedure. A search of the literature revealed that numerous methods have been suggested for the determination of major and minor mineral elements in plant products. Preliminary experiments, including recovery studies, were conducted to test the suitability of several of these procedures for the cereal products under investigation. As the result of these studies, the following procedures were selected.

Moisture and Nitrogen. Moisture was determined by the air-oven method (9) and nitrogen by a conventional Kjeldahl method. The factor used for conversion to protein was 5.7.

Ashing and Digestion. For the determination of all other elements except phosphorus, samples were ashed at 500°C. in a muffle furnace. The ash was dissolved in hydrochloric acid, evaporated to dryness, and taken up in hydrochloric acid. The solution was then diluted with water, filtered, and made up to volume quantitatively with water. For phosphorus, samples were digested with nitric and perchloric acids (10). Redistilled water was used throughout.

Phosphorus. This was determined photometrically as a phosphovanadomolybdate by the procedure of Rickey and Avens (10).

Calcium and Magnesium. A modification of the method of Patton and Reeder (11), in which calcium and magnesium are titrated with ethylenedinitrilo tetraacetate (EDTA) using Erichrome Black T indicator, was used. To prevent interference by the large amount of phosphorus present, calcium was first precipitated as the oxalate, the precipitate was ashed and dissolved in hydrochloric acid, and the analysis continued as directed after addition of a small, quantitatively determined amount of magnesium salt to improve the sensitivity of the end point. Magnesium was precipitated as magnesium ammonium phosphate from the filtrate of the calcium oxalate precipitation. This was filtered off and dissolved in $0.5N$ hydrochloric acid, and the analysis was continued as directed.

Sodium and Potassium. The flame photometer was used, according to the general procedure of Clifford and Winkler (12) modified as required by the instrument, a Coleman Model 21. Large amounts of both calcium and phosphate cause interference and they were quantitatively precipitated as calcium triphosphate. Readings were made on the filtrate.

Minor Mineral Constituents. Iron, manganese, zinc, copper, cobalt, and molybdenum were determined by photometric methods (13). For iron the *o*-phenanthroline procedure was used (14). Manganese was determined as permanganate (14). Because of the very small amounts of copper, molybdenum, and cobalt, these elements, together with zinc, were determined by use of larger samples (25 g.). The separation procedure of Strafford, Wyatt, and Kershaw (15) was used.

Copper and Molybdenum. These elements were separated from others by complexing with diethylammonium diethyldithiocarbamate and extracting with chloroform. Copper was determined in an aliquot of the solution of carbamate complex (15). After evaporation of the chloroform and destruction of organic material by digestion with sulfuric, nitric, and perchloric acids as described above, the molybdenum salt was dissolved in hydrochloric acid and molybdenum determined as a thiocyanate (16).

Zinc and Cobalt. Diphenylthiocarbazone (dithizone) in toluene was used to extract zinc and cobalt from the solution (15). Zinc and most of the cobalt were extracted at pH 8, after which a further extraction was made at pH 9.0–9.5 for complete removal of cobalt. Zinc dithizonate was decomposed with dilute hydrochloric acid, which extracted zinc into the aqueous layer while cobalt dithizonate remained in the toluene layer.

Zinc was determined as a complex with 2-carboxy-2′-hydroxy-5′-sulfoformazyl-benzene (Zincon) by the method of Rush and Yoe (17). Toluene was evaporated from the cobalt dithizonate solution, organic matter removed by digestion with sulfuric, nitric, and perchloric acids. The cobalt salt was dissolved in hydrochloric acid and determined as an *o*-nitrosocresol complex by the method of Gregory, Morris, and Ellis (18).

Results and Discussion

Amounts of the various mineral elements found in wheat (Table II) are in the range of those reported by other investigators (1–4). The variation in amounts of individual elements in the wheat samples does not appear to be related to growing area or total ash. Previous investigators have reported that amounts of the elements are related to soil and fertilizer composition (2,3).

Flours milled from these wheats were all of approximately 72% extraction, but ranged from 98.5 to 80% patent (Table I). Neither total ash nor the content of any of the mineral elements was directly related to the reported degree of refinement of the flour. Comparison of the mean values for the minerals in flour (Table III) with those for minerals in wheat in Table II shows that the individual elements are not present in flour in proportion to their concentration in wheat. Only 11.5% of the cobalt, 14% of the manganese, and 15% of the magnesium of the wheat are found in the flour. Phosphorus, potassium, zinc, iron, copper, and sodium are present in flour to the

TABLE II
Mineral Composition of Wheat, Dry Basis

Sample No.	K	P	Mg	Ca	Na	Zn	Fe	Mn	Cu	Mo	Co
	%	%	%	%	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1	0.435	0.486	0.197	0.043	32	46	46	57	5.2	0.40	0.018
2	.452	.473	.193	.042	35	38	43	57	5.5	.43	.028
3	.507	.450	.162	.049	80	33	41	47	5.0	.30	.046
4	.436	.426	.153	.053	57	33	38	43	4.7	.32	.027
5	.530	.410	.175	.047	45	37	46	51	3.8	.50	.017
6	.423	.384	.158	.034	49	30	45	40	5.3	.48	.021
7	.424	.402	.229	.034	44	30	43	45	5.5	.61	.031
8	.451	.379	.153	.049	41	31	46	30	8.0	.66	.025
9	.390	.430	.229	.053	36	39	42	43	5.6	.59	.016
10	0.489	0.490	0.181	0.045	33	36	43	45	4.6	0.53	0.031
Mean	0.454	0.433	0.183	0.045	45	35	43	46	5.3	0.48	0.026

TABLE III
Mineral Composition of Flour, Dry Basis

Sample No.	K	P	Mg	Ca	Na	Zn	Fe	Mn	Cu	Mo	Co
	%	%	%	%	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1	0.099	0.134	0.037	0.016	8.6	12.0	14.4	6.4	2.1	0.30	0.005
2	.086	.118	.031	.016	9.3	8.0	9.9	5.1	1.9	.26	.003
3	.123	.110	.026	.022	13.5	7.0	8.2	5.8	1.8	.21	.005
4	.123	.108	.023	.022	13.7	8.4	7.9	5.1	1.9	.16	.002
5	.085	.128	.019	.014	5.3	8.0	15.5	8.3	1.6	.20	.001
6	.097	.120	.038	.012	5.9	5.7	8.6	3.5	1.7	.34	.003
7	.084	.137	.023	.012	6.3	6.3	10.5	4.0	1.5	.39	.001
8	.118	.134	.019	.015	9.6	6.6	8.1	7.6	1.5	.35	.001
9	.097	.109	.043	.026	19.7	7.7	5.7	8.0	1.5	.18	.002
10	0.139	0.164	0.025	0.023	6.2	7.8	15.8	10.8	1.8	0.14	0.005
Mean	0.105	0.126	0.028	0.018	9.8	7.8	10.5	6.5	1.7	0.25	0.003

TABLE IV
Mineral Composition of Bread, Dry Basis

Sample No.	K	P	Mg	Ca	Na	Zn	Fe	Mn	Cu	Mo	Co
	%	%	%	%	%	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.
1	0.184	0.208	0.041	0.123	0.850	13.1	30.9	5.2	2.6	0.32	0.021
2	.168	.174	.036	.123	.840	10.1	28.1	4.7	2.3	.34	.022
3	.200	.179	.031	.123	.850	8.6	24.6	4.7	2.2	.14	.020
4	.195	.172	.025	.129	.867	10.1	28.5	4.8	2.4	.15	.023
5	.196	.180	.034	.134	.860	10.0	22.7	8.1	2.2	.31	.021
6	.201	.162	.039	.124	.830	9.3	31.8	3.4	3.0	.58	.021
7	.199	.181	.031	.115	.848	7.9	28.4	4.8	2.1	.32	.028
8	.200	.180	.035	.125	.860	8.3	28.7	7.3	2.1	.37	.020
9	.180	.210	.048	.138	.890	9.6	22.0	7.3	2.2	.39	.020
10	0.189	0.189	0.023	0.137	0.887	9.9	27.3	8.8	2.2	0.30	0.025
Mean	0.191	0.183	0.034	0.127	0.858	9.7	27.3	5.9	2.3	0.32	0.022

TABLE V
Mineral Composition of Commercial Flour Mill Fractions, Dry Basis

Description	Ash	K	P	Mg	Ca	Na	Zn	Fe	Mn	Cu	Mo	Co
	%	%	%	%	%	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.
Farina	0.43	0.115	0.065	0.021	0.019	5.0	6.6	5.4	4.6	1.6	0.17	0.004
Patent flour	0.48	0.122	0.105	.027	.021	5.2	6.4	7.4	6.0	1.5	.19	.004
First clear flour	0.86	0.190	0.196	.065	.030	7.5	15.3	20.4	9.0	2.7	.32	.012
Low grade flour	1.93	0.434	0.294	.156	.046	8.5	44.5	43.6	35.8	5.5	.39	.023
Wheat	1.96	0.455	0.380	.167	.045	12.8	31.0	37.3	49.0	4.0	.33	.024
Germ	3.98	0.889	0.923	.268	.048	23.2	100.8	66.6	137.4	7.4	.67	.017
Red dog	4.07	0.903	0.781	.342	.110	30.5	105.3	131.4	121.4	14.2	.70	.074
Shorts	5.64	1.293	1.307	.541	.133	37.2	100.1	145.7	164.7	13.3	.79	.099
Bran	7.28	1.671	1.570	0.688	0.128	30 6	99.4	141.3	136.5	15.2	0.83	0.109

extent of 20 to 32% of their amounts in wheat. Calcium and molybdenum are in flour to the extent of 40 and 52%, respectively, of their concentration in wheat.

The bread, which was made by a formula typical of bakery practice in the United States (19), contained a greater concentration of most of the mineral elements than the flour from which it was made (Table IV). This would be expected because of the mineral contributions of the salt, yeast food, nonfat dry milk, calcium propionate, and the iron of the enrichment wafer. The one exception was manganese, which had an average concentration of 5.9 p.p.m. in bread and 6.5 p.p.m. in flour. On the dry basis each part by weight of flour yields approximately 1.1 part of bread of this formula. Thus the manganese in the bread is entirely accounted for by that in the flour. The concentration of magnesium, zinc, copper, and molybdenum in bread averaged 120–135% of their concentration in flour, that of phosphorus was 145%, and potassium 170%. The concentration of calcium and cobalt averaged approximately 7 times and iron 2.6 times that in the flour.

Only sodium and calcium had a higher concentration in bread than in the original wheat. Cobalt in bread averaged approximately 85% of its concentration in wheat, iron and molybdenum 65%, potassium, phosphorus, and copper 40 to 45%, zinc 28%, magnesium 19%, and manganese 13%.

In Table V, which presents data on the distribution of the mineral elements in commercial flour mill fractions, the products are arranged in order of increasing ash. Values for patent flour are in good agreement with those of Table III, and the data confirm and extend the findings of Sullivan and Near (20). With increase of ash content of the fractions, the concentration of each of the mineral elements increases, although not to the same extent. For example, bran, which contains 15 times as much ash as patent flour, contains less than 10 times as much calcium, sodium, copper, and molybdenum, between 13 and 16 times as much potassium, phosphorus, and zinc, 19 to 23 times as much iron and manganese, and 25 to 27 times as much magnesium and cobalt. These results suggest that some of the commercial mill fractions such as red dog, shorts, and bran, which are produced in rather high proportions from the wheat, could serve as special dietary sources of mineral nutrients.

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