Nutrient Composition of Selected Wheats and Wheat Products. VI. Distribution of Manganese, Copper, Nickel, Zinc, Magnesium, Lead, Tin, Cadmium, Chromium, and Selenium as Determined by Atomic Absorption Spectroscopy and Colorimetry

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ABSTRACT

Magnesium and eight trace mineral elements, manganese, copper, nickel, zinc, lead, tin, cadmium, and chromium, were determined by atomic absorption spectroscopy in 11 known wheats or wheat blends, 20 commercially prepared flours from these wheats, and 25 specially prepared products from the flours. The same minerals were determined in ten consumer products from ten different cities. There was significant variation among the five hard wheats in their content of nickel, zinc, lead, tin, cadmium, and chromium. The concentrations of all elements but lead were lower in the Baker's patent flour than in the hard wheats. Flour was the major source of manganese, copper, zinc, magnesium, and lead in breads, but only one-half or less of the chromium, nickel, tin, and cadmium in bread could be attributed to the contribution of the flour. Manganese, copper, zinc, cadmium, and chromium varied significantly in the four soft wheat samples, most of the variation being contributed by a single low mineral wheat. In general, the more highly refined short patent (cake) flours were lower in mineral content than the straight-grade and cut-off flours from the soft wheats. The concentrations of manganese, copper, zinc, and magnesium were about the same or lower and nickel, tin, cadmium, and chromium higher in the cake and crackers than in the respective flour from which they were made. Approximately 20 to 30% of the mineral content of the two durum wheat samples was recovered in the semolinas prepared from them. The mineral content of macaroni was almost entirely accounted for by the contribution of the semolinas. There was relatively small difference between the mineral content of bread prepared by conventional sponge-dough and continuous-mix procedures. Air classification vs. conventional milling had no significant effect on the mineral content of flour. Although there were significant variations in the lead, cadmium, and chromium concentrations in most of the market samples of consumer products, there was no discernible effect of geographic location on the general mineral content of these products. Whole-wheat consumer products contained greater concentrations of manganese, copper, zinc, magnesium, and chromium than did products made from white flour. The selenium content of a small group of wheat blends and products was determined by a colorimetric method. The selenium concentration of the hard wheat samples exhibited about a twofold variation, but little variation was found in the selenium content of bread.

This study is part of a broad program undertaken to provide data on the multinutrient composition of wheats and wheat food products. In addition to data on magnesium and trace element composition reported here, information was sought on proximate analysis, macro mineral elements, selected carbohydrate fractions, amino acid and fatty acid composition, and the vitamins thiamine, riboflavin, niacin, and B-6, and tocopherol components.

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The objectives of this phase were threefold. The first was to develop methodology to determine trace minerals and magnesium in single samples of wheats and wheat products by atomic absorption spectroscopy. A method for the determination of nine elements has been achieved by the use of a multi-element standard containing a constant level of sodium, and where required, adding lanthanum and correcting for light scatter (background) (1). Data on manganese, copper, nickel, zinc, magnesium, lead, tin, cadmium, and chromium contents are presented here.

The second objective was to use the developed procedures to determine the minerals and the changes in distribution of the minerals caused by processing 11 known wheats, 20 commercially prepared flours from these wheats, and 25 products (breads, cakes, crackers, and macaronis) prepared from these flours. Differences in mineral content due to newer methods of baking bread (conventional sponge-dough vs. continuous-mix) and to newer methods of separating flour (air-classified cake and cracker flour vs. conventional milling) were to be ascertained.

The third objective was to determine if regional differences in mineral content existed among ten selected available consumer wheat products purchased from ten cities in five regions throughout the U.S.

Reports on the distribution of minerals in wheats as related to the composition of products from their flours are limited to a study by Czerniejewski et al. (2) on the content of 11 mineral elements in ten commercial hard wheat blends, the flours prepared from them, and conventional sponge-dough bread prepared from the flours. Waggle et al. (3) reported results of analyses for 15 minerals in flours and millfeeds prepared from nine different wheat samples.

MATERIALS AND METHODS

Samples

The sampling plan, collection, preparation, description, and distribution of the samples as well as the extent of the nutrient data sought were reported (4) in the first paper of this series.

Analytical Procedures

All precautions for trace element analyses were observed. Water was distilled, then deionized. Hydrochloric acid was redistilled. Spectrographically certified reagents were used when available, otherwise the purest grade manufactured. Blanks and standard samples were used in all procedures. The main points of the analytical procedures are given here.

Ashing

Each wheat series (hard, soft, durum) and each consumer product was considered a separate experiment. Each series was ashed and analyzed in randomized complete blocks. Each block was replicated once, usually after a lapse of 2 months, using a second set of subsamples and random numbers. Samples of approximately 55 g. (range 48 to 62 g.) were dry ashed overnight in 100-ml. platinum dishes at 480°C. The residue was treated with excess 6N HCl, dried, and re-ashed overnight. This procedure was repeated until no visible carbon remained. Breads, rolls, and cakes required a single re-ashing; wheats and whole-wheat products required re-ashing.

Extraction

Ashed samples were extracted in dilute hydrochloric acid and made to a volume of 50 ml., except for most wheats and all shredded wheat samples which were made to 100 ml. Extraction of the ash from these large samples into such small volumes was facilitated by holding the partially extracted samples in volumetric flasks on a steam bath overnight.

Multi-Element Standards

Six levels of multi-element standard were individually prepared and the same standard was used for all analyses. The composition of the first and sixth levels of the multi-element standard is given in Table I. Each level of standard was diluted 1 to 100 for magnesium determinations.

Instrumentation

Samples were run on a maximum versatility Jarrell-Ash Atomic Absorption spectrometer equipped with a recorder and operated as shown in Table II. Standards, blanks, and samples were aspirated from porcelain boats with two deionized water rinses between readings. A set of standards was run at the beginning and at the end of each series of samples (10 to 30 samples). Two nonconsecutive readings were recorded for samples and backgrounds. Background was read at a nonabsorbing wave length close to the analytical wave length for the element in question. The wave length used for the background reading was always checked for nonabsorbance by the element being determined. The principal source of background interference was light scatter by the high solids content of the solutions.

An aliquot of the extracted sample solution was diluted as required to give an

TABLE I. COMPOSITION OF BASIC MULTI-ELEMENT STANDARD[a]

Element	Lowest Concentration p.p.m.	Highest Concentration p.p.m.	Element	Lowest Concentration p.p.m.	Highest Concentration p.p.m.
Mn	0.24	2.0	Cd	0.025	0.225
Cu	0.08	0.72	Sr	0.6	5.0
Ni	0.2	2.0	Cr	0.46	5.5
Zn	0.02	0.18	Co	0.1	1.0
Mg[b]	10.0	100.0	Sn	0.05	1.0
Fe	0.16	3.0	Se	0.1	1.0
Pb	0.5	4.0	Ba	0.1	1.0
Al	0.5	5.0	K	62.0	290.0
Mo	0.5	5.0	P	59.0	290.0
B	0.5	5.0	Na	1,400	1,400
Ca	3.0	24.0			

[a]Lowest and highest concentrations of all elements were in the low and high standard respectively and intermediate levels proportionately distributed in each of the four other standards. All standards contained 1,400 p.p.m. of sodium.

[b]Standards were diluted 1 to 100 for Mg analysis.

TABLE II. PARAMETERS USED IN OPERATING THE ATOMIC ABSORPTION SPECTROMETER[a]

Element	Cathode Lamp Current ma.	Burner Table Height mm.	Wave Length Total Å	Wave Length Background[b] Å	R 106 Photomultiplier Tube Current v.	Air p.s.i.	H_2 p.s.i.	Analytical Range p.p.m.
Mn	13	25	2,795	...	460	22	23	0.22–1.8
Cu	8	16	3,247	...	460	36	24	0.08–0.72
Ni	19	32	2,320	2,324	460	23	23	0.2–2.0
Zn	10	14	2,139	...	500	16	14	0.02–0.18
Mg	6	20	2,852	...	460	6	9	0.1–1.0
Sn	10	8	2,863	2,850	680	20	23	6.0–50.0
Cd	11	32	2,288	2,265	560	32	14	0.015–0.150
Pb	8	26	2,170	2,202	580	26	15	0.40–3.5
Cr	10	35	3,577	...	460	19	24	0.50–5.0

[a]Jarrell-Ash maximum versatility spectrometer equipped with single-element hollow cathode lamps, triple Beckman total consumption burners, five optical passes, 100 μ fixed entrance and exit slits, grating blazed for 3,000 Å.

[b]To correct for light scatter and other nonspecific absorption.

optimum concentration for the manganese, copper, zinc, and magnesium absorbance reading. Generally, no dilution was made for the other elements except to adjust the HCl normality and sodium and lanthanum concentrations of the final solution. For lead, 1 ml. of concentrated acetic acid was added per 10 ml. of final solution. The normality of HCl in the final solution for all the elements was reduced to 0.5N or less by dilution, or addition of a calculated amount of concentrated ammonium hydroxide. Sodium ion was not added to ashed solution from breads, cakes, and crackers if they were not diluted for analyses. All other solutions were made to about 1,400 p.p.m. sodium final concentration by the addition of sodium chloride. Lanthanum was added to give respective final concentrations for manganese of 4,000 p.p.m.; magnesium, 1,000 p.p.m.; lead, 2,000 p.p.m.; and chromium, cadmium, and tin, 5,000 p.p.m.

Verification of Atomic Absorption Procedures

Confirmation of the atomic absorption procedures developed was obtained by recoveries and by comparisons with data obtained by chemical methods of analysis. Three increments of two to four minerals were added to weighed samples prior to ashing for the recovery experiments. Results of the recovery experiments and of the data obtained by the two procedures are shown in Table III. Recoveries were excellent and agreement between the two procedures was good.

Statistical Analysis of Results

The data were reduced by analysis of variance using the statistical models reported by Inkpen and Quackenbush (5).

RESULTS AND DISCUSSION

Data obtained on the 11 known wheats, their flours, and the products prepared from the flours are summarized (mean and standard deviation) on a dry weight basis in Table IV.

TABLE III. VERIFICATION OF ATOMIC ABSORPTION PROCEDURES

Element	Recoveries %	Results by Two Methods[a] Chemical[b] p.p.m.	Atomic Absorption p.p.m.
Mn	102±2	4.50	4.40
Cu	99±7	1.36	1.39
Ni	95±7	0.096	0.101
Zn	97±6	6.07	6.15
Mg	103±5	480[c]	550
Cr	102±5	4.35	4.13
Pb	89±5	0.295	0.252
Sn	90±10	8.90[d]	9.56
Cd	92±8	0.073	0.110

[a]Test material for Pb and Cd comparisons was shredded wheat; a water sample prepared by the Department of Health, Education, and Welfare for a collaborative study of atomic absorption methods was used for Cr comparisons. White flour was the test material for the other elements.

[b]Methods from Sandell, E. B., Colorimetric Determination of Traces of Metals (3rd ed.). Interscience: New York (1959).

[c]Chemical magnesium analysis by F. N. Hepburn, American Institute of Baking, Chicago, Ill.

[d]Because of the low sensitivity of the colorimetric method, Sn was added to the flour sample before dry ashing.

Hard Wheat Series

There were statistically significant variations in the nickel, zinc, lead, tin, cadmium, and chromium concentration of the five hard wheat blends. One sample, H-3-W (4), was highest in manganese, magnesium, and chromium, and was above the mean concentration of all other elements except copper and lead. The other four blends exhibited no tendency to be consistently high or low in any of the elements. The flours tended to vary in mineral content depending upon the wheat blend from which they were milled. The flour H-3-F, from the wheat cited above, contained the highest concentration of manganese, nickel, zinc, magnesium, lead, and cadmium, and was above the mean for copper and chromium. The flour prepared from wheat H-1-W was below the mean concentration of all elements but cadmium. The significant variations in the mineral content of the flours did not carry over to the breads. There was a marked increase in the nickel, tin, and cadmium concentration of breads over that in the flours. The chromium concentration was also higher in breads than in flours, whereas the other elements remained about the same or decreased slightly in concentration. Breads prepared by continuous mix tended to contain slightly less of the minerals than the conventional sponge-dough prepared breads.

Soft Wheat Series

The Pacific Coast soft white wheat blend, S-3-W (4), was considerably lower in manganese, copper, zinc, and magnesium than the other three soft wheats. It was also lowest in concentration of cadmium and lower in lead, chromium, and tin than the respective mean value for all the soft wheats. Copper, zinc, and chromium in the soft patent flours and copper, nickel, zinc, chromium, and tin in the straight-grade flours reflected the tendency of this one wheat sample to be generally low in mineral concentration. This wheat sample accounted for most of the variation among the minerals of the soft wheats.

Mineral content of flours differed markedly with degree of refinement. Soft patent or cake flours were lowest in manganese, copper, zinc, and magnesium; straight-grade flours were either intermediate or nearer the soft patent; and cut-off flours were definitely highest in these four minerals. Nickel and lead concentrations, however, were highest in the cake flours and lowest in the cut-off flours. Tin, cadmium, and chromium concentrations varied little with degree of refinement.

Air-classified cake and cracker flours were prepared from the straight-grade flours of two of the soft wheats (the Pacific Coast white wheat was not one). The average mineral concentrations in p.p.m. of each of the two flours were as follows:

Flour	*Mn*	*Cu*	*Ni*	*Zn*	*Mg*	*Pb*	*Sn*	*Cd*	*Cr*
Cracker: straight-grade	6.4	1.8	0.20	4.8	280	0.66	4.1	0.05	0.21
Cracker: air-classified	6.0	1.5	0.14	4.7	270	0.87	3.9	0.06	0.13
Cake: soft patent	4.8	1.6	0.15	3.9	220	0.68	8.0	0.08	0.57
Cake: air-classified	5.2	1.5	0.22	3.9	200	1.53	3.3	0.05	0.39

Copper and tin in the air-classified cake and cracker flours were lower than in the straight-grade or soft patent flours from both wheats. No consistent pattern was noted among the eight flours for the other minerals.

Nickel, tin, and cadmium contents increased markedly in the cakes and crackers over that of the respective flours. Chromium concentration in cakes and in crackers was also greater than in the flours. The other four minerals were present in the cakes at a lower concentration than in the flour, and in the crackers at approximately the same concentration as in the original flour. Manganese, copper, zinc, and magnesium content of crackers appeared to be determined by the mineral content of the flour from which they were prepared.

Durum Wheat Series

The two durum wheats were similar in mineral content except for nickel, zinc, and lead. The individual sample values for these elements were: nickel: 0.20 and 0.39 p.p.m.; zinc: 37.5 and 22.8 p.p.m.; lead: 0.53 and 0.31 p.p.m. for D-1-W and D-2-W (4) respectively. With the exception of lead, the semolinas were lower in mineral concentration than the wheats. The mineral concentrations in macaroni were generally about the same as in the semolinas.

Distribution of Mineral from Wheat to Product

Table IV shows that all the elements analyzed for are present in flour at a lower concentration than in the wheat except for lead in flour from the hard wheats and semolina from the durum wheats. Calculations were made of the recovery of wheat

TABLE IV. MINERAL CONTENT OF KNOWN WHEATS, THE FLOURS MILLED FROM THEM, AND THE PRODUCTS PREPARED FROM THE FLOURS[a]

Sample	Number of Samples	Moisture %	Ash %	Manganese p.p.m.	Copper p.p.m.	Nickel p.p.m.
Wheat, common hard	5	11.0	1.87±0.10	37.9±3.4	5.1±0.5	0.47±0.08*
Flour, Baker's patent	5	13.9	0.49±0.03	4.5±0.6*	1.9±0.2	0.15±0.05**
Bread, sponge-dough	5	36.3	3.39±0.19	4.5±0.6	2.3±0.3	0.73±0.21
Bread, continuous-mix	5	35.3	3.42±0.30	4.5±0.4	2.0±0.2	0.72±0.25
Wheat, common soft	4	10.6	1.73±0.17	34.9±4.1**	4.5±0.5**	0.31±0.08
Flour, soft patent (cake)[b]	6	11.9	0.42±0.03	4.8±1.2	1.6±0.3	0.18±0.07
Cake	6	22.8	2.71±0.11	1.7±0.4	0.8±0.1	0.82±0.16
Flour, straight-grade[b]	5	11.4	0.50±0.05	6.2±0.9	1.6±0.2	0.18±0.03
Cracker	5	4.9	3.42±0.50	6.4±0.9	1.6±0.1	0.81±0.23
Flour, cut-off (cracker)	2	12.6	0.71±0.04	12.4±1.8	2.6±0.1	0.17±0.07
Cracker	2	4.5	3.09±0.34	11.9±0.6	2.4±0.1	0.85±0.39
Wheat, Durum	2	10.7	2.03±0.01	32.0±1.2	4.8±0.1	0.29±0.14**
Semolina	2	14.7	0.83±0.01	7.0±0.7	2.2±0.1	0.18±0.04
Macaroni	2	9.6	0.82±0.01	6.0±0.5	2.5±0.1	0.15±0.05

[a]Mean and standard deviation, dry weight basis.

[b]Includes two flours prepared by air classification.

TABLE VI. MINERAL CONTENT OF CONSUMER PRODUCTS PURCHASED IN TEN CITIES[a]

Product	Total Samples Collected No.	Producers Sampled Total No.	Producers Sampled Per City Range	Producers Sampled Mode/City No.	Moisture %	Ash %	Manganese p.p.m.	Copper p.p.m.
Cereal-to-be-cooked	24	7	1–3	3	9.5	1.85±0.07	49.4±5.2	5.3±0.2
Shredded wheat	47	6	4–6	4	8.0	1.87±0.12	31.6±2.1	6.1±0.4
Wheat flakes	28	3	2–3	3	4.8	3.78±0.17	30.2±7.9	4.7±0.3
Bread, whole wheat	38	26	2–8	2	37.8	3.87±0.12	41.3±3.2	5.1±0.5
Bread, white								
Conventional dough	52	37	3–9	4	35.8	3.23±0.12	5.5±0.5	2.1±0.2*
Continuous-mix	29	17	1–4	2	36.7	3.10±0.13	5.1±0.3	2.3±0.3**
Rolls, hamburger	52	34	4–9	4	33.6	2.85±0.08	5.1±0.2	2.5±0.2
Doughnuts, cake	28	20	1–5	3	21.9	2.61±0.20	3.5±0.5	1.7±0.2
Biscuit mix	23	8	1–4	2	9.8	4.28±0.26	3.6±0.8*	1.6±0.2
Flour, all-purpose	31	19	3–4	3	12.9	0.56±0.03	4.9±0.8	1.8±0.2

[a]Mean and standard deviation, dry weight basis.

TABLE IV, Continued

Zinc p.p.m.	Magnesium p.p.m.	Lead p.p.m.	Tin p.p.m.	Cadmium p.p.m.	Chromium p.p.m.
Hard Wheat Series					
24.0±4.5**	1800±140	0.50±0.22**	5.6±0.6*	0.10±0.02**	0.38±0.06*
6.3±1.0**	340±69**	0.92±0.43**	4.1±0.4	0.05±0.01**	0.22±0.08**
7.6±1.0	370±44	0.47±0.19	9.8±1.2	0.22±0.06	0.38±0.05
6.2±1.1	330±63	0.53±0.22	10.5±1.9	0.16±0.02	0.37±0.06
Soft Wheat Series					
21.6±7.0**	1590±86	1.00±0.61	7.9±0.9	0.07±0.02**	0.37±0.15**
3.8±0.8	220±45	1.02±0.59	3.7±0.7	0.05±0.01	0.29±0.06
2.3±0.3	160±15	0.84±0.44	32.2±0.2	0.10±0.01	0.33±0.03
4.6±0.6	280±48	0.90±0.31	3.8±0.7	0.05±0.02	0.17±0.06
4.7±1.0	280±40	0.39±0.16	24.9±3.8	0.14±0.02	0.32±0.07
10.4±0.5	460±64	0.85±0.08	4.0±1.0	0.07±0.01	0.20±0.05
10.5±0.1	410±33	0.56±0.28	28.3±2.0	0.15±0.02	0.36±0.03
Durum Wheat Series					
30.2±10.3**	1860±13	0.42±0.13**	6.8±0.5	0.13±0.01*	0.30±0.05
10.8±1.0	690±26	0.50±0.03	6.0±1.2	0.10±0.02*	0.20±0.09**
10.5±1.3	580±45	0.33±0.51	5.2±0.5	0.11±0.01	0.26±0.02

TABLE VI, Continued

Nickel p.p.m.	Zinc p.p.m.	Magnesium p.p.m.	Lead p.p.m.	Tin p.p.m.	Cadmium p.p.m.	Chromium p.p.m.
0.28±0.07	33.5±3.2	1830±180	0.56±0.12**	7.8±1.4**	0.08±0.02**	0.41±0.12**
0.64±0.20*	29.0±2.4	1740±130	0.68±0.26**	8.5±1.8**	0.10±0.02**	0.56±0.09**
0.71±0.15*	23.3±2.5	1420±90	0.39±0.13*	13.6±1.2	0.22±0.02*	0.53±0.06*
0.82±0.21**	27.4±3.1	1950±190	0.42±0.11**	7.8±0.9**	0.16±0.02**	0.63±0.10
0.49±0.04	8.9±0.5	420±59	0.41±0.29**	8.9±1.0	0.16±0.02**	0.47±0.05**
0.65±0.13*	10.0±2.3*	370±66	0.45±0.25**	9.5±1.2	0.19±0.04**	0.50±0.05**
0.52±0.04	8.6±1.1	420±53	0.31±0.09**	8.8±1.0	0.12±0.02**	0.47±0.03
0.41±0.09	6.5±1.1	320±44	0.45±0.20**	5.6±0.4	0.10±0.03**	0.23±0.06**
0.72±0.09*	6.8±0.9	280±33	0.24±0.18**	11.9±1.4*	0.16±0.01**	0.58±0.10**
0.20±0.06	7.7±1.7	300±43	0.51±0.08	4.0±0.9**	0.03±0.01**	0.32±0.05**

minerals in Baker's patent flour from hard wheats, straight-grade flour from soft wheats, and semolina from durum wheats. The flour yield values reported by Toepfer et al. (4) were used in calculating the recovery in flour. The results are tabulated in Table V. In general, a greater fraction of the whole-wheat mineral was recovered in the 72% extraction straight-grade flour from the soft wheats than in the Baker's patent or semolina from the hard and durum wheats. Only 20% or less of the manganese, copper, nickel, zinc, and magnesium was recovered in the Baker's patent flour. About one-third of the chromium, cadmium, and tin from hard wheat was retained in this flour while there was a pick up of lead. Using the approximate yields of 1.1 for bread (4), 1.13 for crackers (4), and 0.94 for macaroni (6) from the respective flours, recoveries of wheat mineral in these products were also calculated. The percentages of manganese, zinc, and magnesium of wheat calculated to be in the bread were almost the same as in the flour. This indicates that flour was probably the only source of these minerals in bread. Other sources supplied a small addition of copper and almost an equal amount of chromium as that contributed by the flour. Nickel, tin, and cadmium are found in bread in considerably greater amounts than can be attributed to the flour. Similar relationships hold for the contribution of the flours to the minerals of crackers. Semolina is apparently the only source of minerals found in macaroni; however, there is an accumulation of lead.

TABLE V. RECOVERY OF INORGANIC NUTRIENT OF WHEAT IN PROCESSED PRODUCTS DERIVED FROM KNOWN WHEATS

	Percentage of element in 100 g. wheat recovered in product, dry weight basis								
Product	Manganese	Copper	Nickel	Zinc	Magnesium	Lead	Tin	Cadmium	Chromium
					Hard Wheat Series				
Flour, Baker's patent[a]	7	22	19	16	11	127	43	30	35
Bread, Conventional[b]	8	30	101	21	13	71	112	147	66
Bread, Continuous-mix[b]	8	26	100	17	12	80	120	102	63
					Soft Wheat Series				
Flour, Straight-grade[c]	13	27	45	17	13	78	36	61	44
Cracker[b]	15	29	217	21	15	39	291	205	89
					Durum Wheat Series				
Flour, Semolina[d]	10	20	30	16	16	54	36	34	27
Macaroni[b]	8	20	25	14	12	122	30	35	35

[a]Five samples, 55 to 66% flour yield (4).

[b]Yield of product from flour calculated from formula (4,6).

[c]Three samples, 72% yield of flour (4).

[d]Two samples, 42% yield of semolina (4).

Consumer Products

The consumer products represented various numbers of different producers in each city and are representative of the products sold in an area. The mineral data obtained with the hundred samples of ten products are summarized (mean and standard deviation) in Table VI. Manganese, copper, zinc, magnesium, and chromium were considerably higher in whole-wheat products than in products prepared from white flour. Nickel varied with the product. Manganese, zinc, and chromium values were higher in some of the whole-wheat products than in the known whole wheats reported in Table IV.

A few products showed significant area differences for one or more minerals. Nickel in shredded wheat was lowest in the central region, and considerable variation was found between cities within the other four regions. Nickel in the wheat flakes was higher in both western regions than in the central and eastern regions. Nickel was higher in the whole-wheat breads from the southwestern area than from the other four regions. Manganese was lowest in the biscuit mix from the northwestern area and nickel highest in the biscuit mix from the southwestern area.

The lead, tin, cadmium, and chromium concentrations in most products exhibited significant regional differences. However, the high and low concentrations of these four minerals were distributed among the various regions. No definite trend could be noted. The possible exception was lead; the central and southwest regions were the highest in lead for all ten products.

The consumer-available continuous and conventional sponge-dough breads did not exactly follow the pattern of the breads prepared from the known wheat blends as illustrated:

Minerals	*AIB Prepared*		*Consumer Purchased*	
	Conventional p.p.m.	*Continuous p.p.m.*	*Conventional p.p.m.*	*Continuous p.p.m.*
Mn	4.5	4.5	5.5	5.1*
Cu	2.3	2.0**	2.1	2.3
Ni	0.73	0.72	0.59	0.67**
Zn	7.6	6.2**	9.9	10.0**
Mg	370	330	420	370
Pb	0.47	0.53	0.41	0.45**
Sn	9.8	10.5	8.9	9.5
Cd	0.22	0.16	0.16	0.19
Cr	0.38	0.37	0.47	0.50

Although there were some statistically significant differences between the two types of preparations, the actual magnitudes were small.

Selenium in Known Wheat Blends and Selected Products

Selenium was determined in all the known wheat blends, the flours and conventional sponge-dough breads from the hard wheats, and five whole-wheat bread samples of the consumer-available products. The colorimetric selenium determination of Cummins et al. (7) was used, incorporating suggestions on ashing by Christian et al. (8). Two separate 1-g. portions of each sample were digested and the resultant solutions combined to give a sample reading between 0 and 2 γ of

TABLE VII. SELENIUM CONTENT OF HARD WHEAT BLENDS AND FLOURS, AND BREAD PREPARED FROM THEM

Wheat Blend[a]	H-1-W	H-2-W	H-3-W	H-4-W	H-5-W	Av.
			p.p.m., dry weight basis			
Wheat	0.33[b]	0.61	0.78	0.44	0.35	0.50±0.19
Flour	0.38	0.50	0.57	0.47	0.41	0.47±0.08
Bread[c]	0.41	0.38	0.43	0.44	0.40	0.41±0.02

[a]See ref. 4 for further description of samples.

[b]Average of duplicate analyses.

[c]Conventional sponge dough.

selenium on the standard curve. In recovery trials, 2, 4, and 6 γ of selenium were added to hard wheat samples and carried through the determination. Recovery of the added selenium was about 93% for the lower levels and 82% for the highest level of added selenium.

Results of the analyses of the hard wheat blends and flour and bread prepared from them are given in Table VII. The highest selenium concentration was found in sample H-3-W from a North Dakota growing area (4). The growing areas for the samples of lowest concentration were H-1-W from Kansas and H-5-W from Texas–Oklahoma. The degree of refinement of the flour influenced the selenium concentration of the flour. Flour from wheat samples H-2-W and H-3-W were 66 and 63.5% extraction (4) and the selenium concentration was lower than in the parent wheat blend. The other three flours were 55% extraction and the selenium concentration was greater than that of the parent wheat. All the breads but one were lower in selenium concentration than the flours from which they were derived.

The soft wheats were lower in selenium than the hard wheats. The average for the four soft wheat blends was 0.28 p.p.m. The two durum wheats contained 0.90 and 0.48 p.p.m. of selenium. Five of the whole-wheat bread samples, one from each of the sampling regions, had a mean content of 0.76 ± 0.05 p.p.m. of selenium. The range for these whole-wheat breads was 0.71 to 0.83 p.p.m. The average selenium content of these whole-wheat breads was greater than that of the known wheat blends.

These wheat samples were all commercial blends. Higher selenium contents would be expected of wheat grown on a seleniferous soil and which had not been diluted with a low selenium wheat.

DISCUSSION

Statistically significant variations were found in the concentrations of some elements among the known wheat samples and the processed products from them. The consumer product series also exhibited some statistically significant variations in mineral concentrations, particularly nickel, lead, cadmium, and chromium. However, the magnitude of the variations was such that no geographical population of the U.S. should be expected to differ markedly from another in its status of mineral nutrition, solely on the basis of consumption of wheat products.

Whole-wheat products contain higher concentrations of manganese, copper, zinc, magnesium, and chromium than do products prepared from white flour.

Milling by-products and other ingredients of the wheat-flour-product study were not analyzed for minerals. Therefore, it is difficult to assign a definite pathway of loss or source of increase in the elements in going from wheat to product.

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