Nutrient Composition of Selected Wheats and Wheat Products. XI. Summary

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ABSTRACT

The nutrient content of a variety of wheats and wheat products as well as of some consumer-available wheat products from U.S. markets has been determined. Data for the vitamins thiamine; riboflavin; total and free niacin; vitamin B-6 and its three components, pyridoxine, pyridoxal, and pyridoxamine; α-, β-, γ-, and δ- tocopherols, and α- and β- tocotrienol, are presented for hard red wheats, bread flour, and white bread; for durum wheats, semolina, and macaroni; and for soft wheats, cake flour and cake, and straight-grade and cut-off flours and crackers. Data are also given for the fatty acids, 14 mineral elements, individual amino acids, and carbohydrate fractions. The nutrients of wheat products were expressed as percentages of the nutrient concentration in whole wheat, thus permitting comparisons in losses or gains. Recipe ingredients and enrichment mixtures plus preferential selection of the endosperm in flour resulted in a considerable range of values in relation to whole wheat.

Wheat and wheat products comprise about 82% of the flour and cereal products consumed by the population and they make important contributions to the nutrients of the national food supply, including approximately 16% of the protein and calories, 30% of the carbohydrates, more than 20% of the iron, and 10% of the phosphorus. Smaller contributions are made to lipid, calcium, and B-vitamin supplies (1). Results of a recent survey by the U.S. Department of Agriculture (2) have shown an increase in the consumption of bakery products other than bread; however, the nutrient composition of these foods has received little prior attention. This study was undertaken to determine the nutrient composition of selected wheat products available to the consumer in five geographical regions of the U.S. (3), and of wheat grains of known history, flours from these grains, and typical food products made from these flours: bread by conventional sponge-dough procedures and by continuous dough-mix, macaroni, cake, or crackers. Thus, information on the uniformity of nutrient composition of wheat products throughout the country and the degree to which the processes of milling and baking produced changes in the nutritive value of wheat products were studied in order that data might be available for estimates of contributions of these products to nutrients in the American diet.

PROCEDURES

Three laboratories participated in the study. The American Institute of Baking procured materials, prepared samples for analysis, and determined total solids, ash, and protein; the mineral elements calcium (Ca), magnesium (Mg), iron (Fe), phosphorus (P), sodium (Na), and potassium (K); the vitamins thiamine, riboflavin, free and bound niacin; and the 18 commonly occurring amino acids. Total lipids and the fatty acid composition of the extracted lipids were determined at Purdue University. The Human Nutrition Research Division determined the carbohydrate

fractions, reducing and nonreducing sugars, starch, lactose, pentosans, and other fractions of carbohydrate classification; the three forms of vitamin B-6: pyridoxine, pyridoxal, pyridoxamine; the individual tocopherols comprised in vitamin E; and trace mineral elements which occurred in sufficient amounts to be measured by atomic-absorption spectroscopy, including copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni), manganese (Mn), tin (Sn), and zinc (Zn).

The ten consumer-available wheat foods selected for analysis in New York, Boston, Atlanta, Charlotte, Chicago, Minneapolis, Seattle, San Francisco, Los Angeles, and Dallas, were all-purpose flour, biscuit mix, whole-wheat cereal to-be-cooked, shredded-wheat cereal, wheat-flakes cereal, enriched white bread made by conventional sponge-dough-mix and by continuous dough-mix procedures, whole-wheat bread, hamburger rolls, and cake-type doughnuts. The different brands of the products were obtained from each market at the same time and made into composite lots from which samples were prepared. One hundred samples resulted. There were 11 wheats used for the processing studies, 20 flours milled from these wheats, and 25 products prepared from the flours, including conventional and continuous dough-mix breads – a total of 56 samples. Altogether, 156 samples were analyzed in the different laboratories.

The data from which these summaries have been derived have been published or accepted for publication in CEREAL CHEMISTRY (3-12). This paper brings together the volume of data from nine publications by research scientists specializing in related fields of analytical food chemistry. The data on wheat products have been summarized in terms of percentages of the nutrient constituent of whole-wheat grain, which also made possible the derivation of average nutrient content on a dry-weight basis.

RESULTS AND DISCUSSION

Total solids, protein, fat, and ash of hard red wheats, soft wheats, and durum wheats and their products are shown in Table I. Durum is genetically different from hard red and soft wheats obtained for this study and showed somewhat greater contents of protein, fat, and ash. The flours all showed lesser amounts of these constituents than did their respective whole wheats, and the composition of breads, cakes, crackers, and macaroni depended on the recipe ingredients. Bread made by either conventional or continuous dough-mixes did not appear greatly different. Straight-grade flour from soft wheat was less refined than the patent flour used for cakes, as indicated by ash content. Cut-off flour, about 18% milling yield, was a less refined product than straight-grade. The fat content of both cake and crackers showed the addition of shortening in the recipe.

Data on the vitamin content are summarized in Tables II and III. The vitamin contents of hard red wheat and soft wheat were very nearly the same. Durum wheat had somewhat greater concentration of the B-vitamins than the other wheats. Bread flour averaged about 20% of the vitamins of hard red wheat, and semolina averaged 48% of those of durum. Patent or cake flour averaged 16%; straight-grade, 20%; and cut-off, 47% of the vitamins of soft wheat. Bread by conventional dough-mix procedure averaged almost 50%; and by continuous dough-mix procedure, 42% of the vitamins of whole wheat. Added ingredients in bread raised riboflavin over that of whole wheat and contributed to thiamine and niacin.

TABLE I. COMPOSITION OF WHEATS AND WHEAT PRODUCTS

Samples	Total Solids %	Dry Weight		
		Protein N X 5.83 %	Fat %	Ash %
Hard red wheat	89.0	14.8	2.86	1.87
Flour, patent	86.4	13.7	1.41	.49
Bread				
Conventional mix	62.7	13.9	4.73	3.39
Continuous mix	63.6	12.9	4.51	3.42
Soft wheat	89.3	11.7	2.88	1.73
Flour				
Patent	88.6	9.7	1.36	.42
Straight grade	87.2	10.6	1.79	.56
Cut-off	88.6	11.3	1.84	.56
Cake	73.7	6.4	18.14	2.71
Crackers				
From straight grade	95.4	9.4	12.23	3.32
From cut-off	95.2	10.3	12.63	3.32
Durum wheat	89.5	15.6	3.58	2.03
Semolina	85.6	15.2	1.90	.83
Macaroni	90.4	14.9	1.64	.82

The mechanical process of milling and the separation of various physical components of the wheat berry have an effect on nutrient content of the flour product. Sensitivity to heat and oxidation, as well as limits of analytical specificity, contributed to the variability. The recipe ingredients made additional changes in nutrient content of the food product from that of the original wheat grain and the flours. Gamma and delta tocopherols were not found in whole wheats or their flours but appear in those products where shortening was added. Expressing the data in terms of percentages of their wheat-berry component showed the need for individual nutrient evaluation of the processed food items. The data on nutrients other than the vitamins continued to show these observations.

The fatty acids of wheat, Table IV, showed a relatively large amount of linoleic acid. Linoleic was also the largest constituent of the fatty acids of the flours; but in bread, cake, or crackers, shortening greatly altered relationships. The contributions of the wheat constituent were important to the content of unsaturated fatty acids of the product.

Since the nutritional requirement for vitamin E is influenced by the intake of polyunsaturated fatty acids, it is of interest to compare the relative amounts of these two nutrients in the various fractions and products. Harris and Embree (13) estimated that to meet nutritional requirements, the minimum ratio of vitamin E to polyunsaturated fatty acids is 0.6 mg. per g. Ignoring the contributions of the non-α forms, this ratio equaled or exceeded 0.6 mg. only for hard wheat (1.06), soft wheat (0.89), and wheat cereal requiring cooking (0.6). In other words, most wheat products do not have adequate amounts of α-tocopherol to balance their polyunsaturated fatty acid content.

The data on carbohydrates, Table V, showed rather uniformly a higher content of starch in the flours than in wheat. Lactose was found in the breads and cakes and

TABLE II. VITAMIN CONCENTRATION IN PRODUCT COMPARED TO AMOUNT IN WHEATS

Nutrient	Hard Red Wheat (dry weight) γ/g.	Concentration of Wheat-Grain Nutrient in Product: Flour %	Bread: Conventional dough-mix %	Bread: Continuous dough-mix %	Durum Wheat (dry weight) γ/g.	Concentration of Wheat-Grain Nutrient in Product: Semolina %	Macaroni %
Thiamine	5.7	23	30	30	6.7	48	48
Riboflavin	1.2	34	161	122	1.1	88	86
Niacin, total	74	28	39	36	111	35	40
free	36	44	64	61	47	47	45
Vitamin B-6	3.5	15	15	12	4.3	28	25
Pyridoxine	2.6	11	5	6	3.3	24	20
Pyridoxal	.5	28	41	26	.6	31	31
Pyridoxamine	.4	22	55	35	.4	53	58
Tocopherols	58	11	2	11	58	43	5
α-T	13	2	1	2	10	30	2
β-T	7	7	3	4	5	31	4
γ-T	...	...	...	1.9[a]	...	...	...
δ-T	...	...	...	3.6[a]	...	...	...
α-T-3	5	30	50	0	7	37	3
β-T-3	33	17	3	3	36	48	6

[a]Micrograms per gram.

TABLE III. VITAMIN CONCENTRATION IN PRODUCT COMPARED TO AMOUNT IN WHEAT

Nutrient	Soft Wheat (dry weight) γ/g.	Concentration of Wheat-Grain Nutrient in Product: Patent flour %	Cake %	Straight-grade flour %	Crackers %	Cut-off flour %	Crackers %
Thiamine	5.4	23	10	39	20	76	39
Riboflavin	1.1	29	119	40	50	55	72
Niacin, total	72	14	5	17	12	19	14
free	38	15	7	21	17	21	19
Vitamin B-6	3.3	10	7	14	10	25	21
Pyridoxine	2.5	7	3	10	5	22	12
Pyridoxal	.5	22	30	30	35	39	50
Pyridoxamine	.3	18	11	21	14	32	50
Tocopherols	54	6	185	...	...	59	35
α-T	12	3	94	...	...	59	31
β-T	7	5	...	...	...	66	38
γ-T	...	...	66[a]	...	...	...	1.0[a]
δ-T	...	...	21[a]	...	...	...	0.3[a]
α-T-3	5	14	...	...	...	34	18
β-T-3	30	6	6	...	...	61	34

[a]Micrograms per gram.

TABLE IV. FATTY ACID CONCENTRATION OF PRODUCT COMPARED TO AMOUNTS IN WHEATS

Nutrient Fatty Acid	Hard Red Wheat (dry weight) g./100 g.	Concentration of Wheat-Grain Nutrient in Product: Flour %	Bread: Conventional dough-mix %	Bread: Continuous dough-mix %	Durum Wheat (dry weight) g./100 g.	Concentration of Wheat-Grain Nutrient in Product: Semolina %	Macaroni %
Palmitic	.37	50	216	116	.50	50	46
Stearic	.02	50	2,250	1,500	.03	33	33
Oleic	.37	30	362	354	.59	33	33
Linoleic	1.17	45	68	117	1.54	46	42
Linolenic	.10	30	50	100	.12	45	33

	Soft Wheat (dry weight) g./100 g.	Concentration of Wheat-Grain Nutrient in Product: Patent flour %	Cake %	Straight-grade flour %	Crackers %	Cut-off flour %	Crackers %
Palmitic	.40	60	515	62	654	65	665
Stearic	.02	100	1,001	50	715	50	100
Oleic	.35	31	2,198	50	1,331	51	1,331
Linoleic	1.23	38	176	58	138	59	142
Linolenic	.11	27	45	45	90	54	118

was somewhat higher in bread from the conventional dough-mix than from the continuous dough-mix. This was expected since the percentage of milk solids in continuous-dough preparation procedures is limited to prevent collapse of the risen dough in the baking pan. The addition of reducing and nonreducing sugars showed in the corresponding data for breads, cakes, and crackers.

TABLE V. CARBOHYDRATE CONCENTRATION IN PRODUCT COMPARED TO AMOUNT IN WHEATS

Nutrient	Hard Red Wheat (dry weight) g./100 g.	Concentration of Wheat-Grain Nutrient in Product			Durum Wheat (dry weight) g./100 g.	Concentration of Wheat-Grain Nutrient in Product		Soft Wheat (dry weight) g./100 g.	Patent Flour %	Cake %	Crackers Flour %	Crackers %
			Bread									
		Flour %	Conventional dough-mix %	Continuous dough-mix %		Semolina %	Macaroni %					
Reducing sugar	0.55	34	1,267	1,580	0.59	63	371	0.55	50	618	50	151
Nonreducing sugar	2.92	50	13	60	3.03	58	63	3.25	51	1,064	58	8
Starch	63.2	120	99	98	61.2	120	116	66.2	121	37	119	102
Lactose	...	...	2.60[a]	2.06[a]	...	...	...	...	...	2.11[a]	...	...
Pentosans	7.62	...	...	...	7.43	...	...	7.27	...	...	...	...
Crude fiber	2.47	...	...	...	2.77	...	...	2.54	...	...	...	...
Hemicellulose	6.45	...	...	...	6.24	...	...	6.29	...	...	...	...
Cellulose	2.71	...	...	...	2.71	...	...	2.30	...	...	...	...
Lignin	.67	...	...	...	.60	...	...	.54	...	...	...	...

[a] g./100 g.

TABLE VI. MINERAL-ELEMENT CONCENTRATION IN PRODUCT COMPARED TO AMOUNTS IN WHEATS

Nutrient	Hard Red Wheat (dry weight) γ/g.	Concentration of Wheat-Grain Nutrient in Product: Flour %	Bread: Conventional dough-mix %	Bread: Continuous dough-mix %	Durum Wheat (dry weight) γ/g.	Concentration of Wheat-Grain Nutrient in Product: Semolina %	Macaroni %
Na	30	66	325	338	50	40	60
K	4,140	28	48	36	4,940	40	42
Mg	1,802	19	20	18	1,864	37	31
Ca	370	54	408	424	340	56	59
P	3,440	37	43	50	3,700	50	46
Fe	44	19	35	31	40	36	41
Cu	5.1	39	46	40	4.8	46	53
Cd	0.1	50	220	160	0.1	77	85
Cr	0.4	58	100	100	0.3	67	87
Pb	0.5	184	94	106	0.4	119	317
Ni	0.5	32	155	153	0.3	62	52
Mn	38	12	12	12	32	20	19
Se	0.50	92	82	...	...	...	...
Sn	5.6	73	173	186	6.8	88	75
Zn	24	26	32	26	30	36	35

TABLE VII. MINERAL-ELEMENT CONCENTRATION IN PRODUCT COMPARED TO AMOUNT IN WHEAT

Nutrient	Soft Wheat (dry weight) γ/g.	Concentration of Wheat-Grain Nutrient in Product: Patent flour %	Cake %	Straight-grade flour %	Crackers %	Cut-off flour %	Crackers %
Na	30	67	283	100	370	67	327
K	4,180	28	34	33	33	41	41
Mg	1,589	14	10	18	17	29	26
Ca	390	49	210	51	59	64	69
P	3,400	25	89	28	25	43	35
Fe	37	21	11	26	41	40	47
Cu	4.5	36	17	36	36	57	54
Cd	0.1	70	143	70	200	100	214
Cr	0.4	78	89	46	86	54	97
Pb	1.0	102	84	90	39	85	56
Ni	0.3	58	26	58	26	55	27
Mn	35	14	5	18	18	35	34
Sn	7.9	47	408	48	316	50	359
Zn	5	18	11	22	22	48	49

Data for mineral elements, Tables VI and VII, showed K, P, Mg, and Ca, in decreasing order, to be the main mineral elements of whole-wheat grain. All wheats were nearly the same in content of the 14 elements included in the analysis. Analyses showed that the endosperm retained Pb, Sn, Cr, Cd, and Na to a greater extent than other milling fractions excluded from the flours. In the wheat products other than flour, the recipe ingredients contributed to the mineral elements. Bread gained in Na, Ca, Fe, Cd, Cr, Ni, and Sn. Cake gained in Ca, P, Cd, Cr, and Sn. Crackers gained in Fe, Cd, Cr, and Sn. The source of additional amounts of some of these elements was not investigated as a part of this study.

TABLE VIII. AMINO ACID CONCENTRATION IN PRODUCT COMPARED TO AMOUNTS IN WHEATS

Nutrient	Hard Red Wheat (dry weight) mg./100 g.	Concentration of Wheat-Grain Nutrient in Product			Durum Wheat (dry weight) mg./100 g.	Concentration of Wheat-Grain Nutrient in Product	
			Bread				
		Flour %	Conventional dough-mix %	Continuous dough-mix %		Semolina %	Macaroni %
Lysine	433	69	80	74	433	76	77
Histidine	361	85	88	81	406	88	81
Ammonia	548	106	98	93	584	111	110
Arginine	760	72	81	66	758	70	80
Aspartic acid	791	76	85	78	879	82	79
Threonine	471	86	94	85	481	86	83
Serine	834	95	98	92	860	92	93
Glutamic acid	4,984	103	100	94	5,313	108	103
Proline	1,623	110	108	103	1,643	110	109
Glycine	648	80	78	75	616	81	79
Alanine	561	79	84	79	586	77	78
Cystine	310	94	83	82	306	96	94
Valine	742	90	96	89	748	92	91
Methionine	248	103	104	96	274	94	87
Isoleucine	617	98	102	94	672	97	94
Leucine	1,068	97	103	96	1,137	97	90
Tyrosine	461	94	99	92	476	90	91
Phenylalanine	765	101	99	93	812	97	96
Tryptophan	266	83	83	71	242	90	88

The data on the 18 individual amino acids, Tables VIII and IX, showed a rather high amount of most of them in the flour. In every case, regardless of the extent of milling yield, the flours were higher than wheats in glutamic acid and proline. Cystine and methionine were among those which were high, over 90% of those in whole wheat. Bread was somewhat higher in lysine, possibly attributable to milk solids. Greatest decreases were in methionine and arginine of crackers.

Data on the ten consumer-available wheat products (Tables X to XIII) are shown in terms of percentages of the nutrients of the whole-wheat grains analyzed as part of this study. This provided a common basis for comparisons both with each other and with the products made under the grain-flour-product phase. Data from the products from ten markets were averaged for summarization. Proximate composition and vitamin concentrations are shown in Table X. Products had been enriched with thiamine, riboflavin, and niacin with few exceptions. Where fat had been a recipe ingredient, the tocopherol content was higher than in wheats. There was also the presence of γ- and δ-tocopherols in substantial quantities where none were reported in the wheat grain. The wheat products averaged in percentage of wheat vitamins as follows: wheat-flakes cereal, 117; whole-wheat bread, 92; all-purpose flour, 91; white bread, conventional dough-mix, 88, and continuous dough-mix, 86; biscuit mix, 84; wheat cereal to-be-cooked, 80; hamburger rolls, 77; shredded wheat, 66; and doughnuts, 47.

The data on fatty acids and carbohydrates are given in Table XI. From the large increases in stearic and oleic acids, the products to which shortening had been added as part of the recipe were easily identified. The relatively high average percentages of linoleic and linolenic acids—137 and 122%, respectively—would have resulted from vegetable shortening as well as from the original wheats. The carbohydrate data showed considerable reducing sugar, such as dextrose, and not

TABLE IX. AMINO ACID CONCENTRATION IN PRODUCT COMPARED TO AMOUNT IN WHEAT

Nutrient	Soft Wheat (dry weight) mg./100 g.	Concentration of Wheat-Grain Nutrient in Product					
		Patent flour %	Cake %	Straight-grade flour %	Crackers %	Cut-off flour %	Crackers %
Lysine	360	66	73	74	59	83	99
Histidine	271	82	49	88	75	99	82
Ammonia	393	102	45	109	88	115	90
Arginine	612	69	42	78	57	87	69
Aspartic acid	660	69	72	75	63	82	71
Threonine	393	76	69	81	69	93	71
Serine	652	88	62	93	81	100	84
Glutamic acid	3,440	104	46	114	95	117	108
Proline	1,168	104	50	109	97	117	94
Glycine	504	73	39	78	67	93	74
Alanine	458	53	58	74	67	91	73
Cystine	223	96	46	101	87	115	99
Valine	581	84	67	89	77	102	85
Methionine	206	89	79	95	44	111	48
Isoleucine	464	90	67	96	82	107	84
Leucine	812	91	63	95	84	107	88
Tyrosine	344	90	59	95	77	109	87
Phenylalanine	567	91	60	97	80	110	50
Tryptophan	225	68	49	70	41	77	74

TABLE X. COMPOSITION OF TEN CONSUMER PRODUCTS AND COMPARABLE PERCENTAGES OF WHEAT-GRAIN VITAMINS IN THE PRODUCTS

Constituent	All-Purpose Flour %	Biscuit Mix %	Wheat Cereal to-be-cooked %	Shredded Wheat %	Wheat Flakes %	White Bread: Conventional dough-mix %	White Bread: Continuous dough-mix %	Whole-Wheat Bread %	Hamburger Rolls %	Doughnuts, Cake-Type %
Proximate Composition										
Total solids	87.3	90.4	89.6	92.0	95.2	62.9	62.1	61.0	65.0	75.8
Protein (dry weight)	12.1	9.3	13.7	11.4	9.7	14.2	13.5	17.1	13.5	8.2
Fat (dry weight)	1.50	14.2	3.5	2.4	2.5	5.5	5.1	6.9	7.8	26.6
Ash (dry weight)	.56	4.28	1.85	1.87	3.78	3.23	3.10	3.87	2.85	2.61
Vitamins										
Thiamine	107	88	53	48	166	93	98	85	90	24
Riboflavin	266	227	107	85	106	240	226	182	211	96
Niacin, total	61	44	71	73	75	54	56	79	54	1
Niacin, free	117	81	74	71	93	92	102	89	94	1
Vitamin B-6	14	13	94	81	200	45	46	88	16	15
Pyridoxine	10	8	98	88	82	5	6	83	54	81
Pyridoxal	28	30	82	62	44	36	30	106	34	34
Pyridoxamine	25	22	78	52	40	62	62	90	58	20
Tocopherols	7	47	77	40	39	10	4	25	14	99
α-T	2	22	87	29	31	3	0	12	4	79
β-T	4	0	78	42	34	3	1	20	1	0
γ-T	...	17.7[a]	...	...	...	2.4[a]	0.6[a]	3.8[a]	4.0[a]	29.4[a]
δ-T	...	5.5[a]	...	...	...	1.1[a]	0.4[a]	2.1[a]	1.7[a]	9.7[a]
α-T-3	10	0	70	60	68	0	0	0	0	0
β-T-3	9	4	73	41	39	6	3	18	5	16

[a] g./100 g. dry weight.

TEN CONSUMER WHEAT PRODUCTS

Constituent	All-Purpose Flour %	Biscuit Mix %	Wheat Cereal to-be-cooked %	Shredded Wheat %	Wheat Flakes %	White Bread: Conventional dough-mix %	White Bread: Continuous dough-mix %	Whole-Wheat Bread %	Hamburger Rolls %	Doughnuts, Cake-Type %
Fatty Acids										
Palmitic	68	700	135	95	108	251	243	300	351	122
Stearic	50	9,800	100	50	100	2,700	3,050	2,800	3,900	19,200
Oleic	38	1,438	135	92	108	465	497	624	691	3,060
Linoleic	57	134	132	96	104	100	96	169	111	292
Linolenic	40	100	140	90	110	70	80	130	80	300
Carbohydrates										
Reducing sugar	64	598	127	198	1,253	1,354	1,429	1,593	1,824	736
Nonreducing sugar	51	48	106	92	278	0	0	0	0	488
Starch	121	97	102	100	70	97	97	76	91	76
Lactose	...	1.45[a]	...	...	...	2.20[a]	1.66[a]	1.80[a]	1.41[a]	2.33[a]
Pentosans	...	...	92	94	82	...	...	83	...	...
Crude fiber	...	...	87	108	80	...	...	89	...	...
Hemicellulose	...	...	93	110	63	...	...	77	...	...
Cellulose	...	...	78	108	77	...	...	92	...	...
Lignin	...	...	146	113	127	...	...	121	...	...

[a]g./100 g. dry weight.

TABLE XII. COMPARABLE PERCENTAGES OF MINERAL ELEMENTS OF WHEAT GRAINS IN TEN CONSUMER PRODUCTS

Constituent	All-Purpose Flour %	Biscuit Mix %	Wheat Cereal to-be-cooked %	Shredded Wheat %	Wheat Flakes %	White Bread: Conventional dough-mix %	White Bread: Continuous dough-mix %	Whole-Wheat Bread %	Hamburger Rolls %	Doughnuts, Cake-Type %
Na	73	...	90	...	...	...	...	...	...	...
K	29	38	103	86	88	45	38	102	36	41
Mg	17	16	102	96	78	23	20	108	23	20
Ca	65	868	124	122	95	400	378	370	384	202
P	38	161	112	104	94	52	55	117	49	111
Fe	93	65	97	82	92	79	81	107	80	30
Cu	35	31	103	119	91	42	45	100	49	37
Cd	33	158	83	100	215	158	190	158	125	98
Cr	81	144	102	141	133	117	126	158	117	58
Pb	101	48	130	136	78	82	90	84	62	90
Ni	41	144	55	129	141	98	130	164	103	137
Mn	13	10	130	83	80	14	13	109	13	101
Sn	71	212	138	152	242	160	170	140	157	71
Zn	32	28	140	121	97	37	42	114	36	30

TABLE XIII. COMPARABLE PERCENTAGES OF WHEAT-GRAIN AMINO ACIDS IN TEN CONSUMER WHEAT PRODUCTS

Constituent	All-Purpose Flour %	Biscuit Mix %	Wheat Cereal to-be-cooked %	Shredded Wheat %	Wheat Flakes %	White Bread		Whole-Wheat Bread %	Hamburger Rolls %	Doughnuts, Cake-Type %
						Conventional dough-mix %	Continuous dough-mix %			
Lysine	64	60	87	75	41	77	67	95	65	78
Histidine	73	56	90	74	60	83	73	103	78	68
Ammonia	92	67	82	71	61	102	98	111	94	65
Arginine	64	50	93	76	52	69	64	96	64	53
Aspartic acid	67	57	100	80	68	85	77	110	75	82
Threonine	77	62	96	79	69	94	86	110	85	66
Serine	81	65	89	73	64	96	86	110	88	72
Glutamic acid	91	65	83	69	59	103	96	114	98	75
Proline	92	74	85	71	61	106	100	118	101	74
Glycine	68	51	97	76	64	80	73	108	74	53
Alanine	70	56	103	83	70	86	79	114	80	60
Cystine	85	65	80	68	47	93	79	110	82	61
Valine	77	63	95	78	67	94	84	112	86	73
Methionine	88	71	97	83	70	103	92	121	94	70
Isoleucine	84	66	92	75	64	102	91	115	93	78
Leucine	85	66	94	77	65	101	91	114	92	78
Tyrosine	82	67	88	72	59	100	88	110	88	75
Phenylalanine	85	63	88	73	61	100	92	113	92	69
Tryptophan	62	54	80	80	54	75	70	94	68	64

much nonreducing sugar, such as sucrose, in these products. Lactose was found in those products where milk solids was a recipe ingredient. The lactose of white bread from the continuous dough-mix was less than that of the conventional dough-mix bread, for reasons referred to previously. The various carbohydrate classes other than starch and sugars were found only in products containing whole wheat or fractions thereof.

With the exceptions of all-purpose flour and doughnuts, the mineral elements of the other consumer products averaged over a range of 95 to 148% of those of wheat (Table XII). Values for Na, exceptionally high when salt was added, were generally omitted. Ca rated fairly high for biscuit mix, wheat cereal to-be-cooked, shredded wheat, bread, rolls, and doughnuts. As the result of enrichment, Fe was high for most products, in all probability. As noted previously for wheat products of the processing phase, Cr values—and also those for Sn—were high. Some values for Zn also were greater than those of whole wheat or flour, and must have resulted from recipe ingredients or from handling during preparation. Levels of Ni were notable for biscuit mix, 144%; shredded wheat, 129; wheat flakes, 141; continuous-mix white bread, 130; whole-wheat bread, 164; and doughnuts, 137.

Data on the amino acids, Table XIII, showed the average percentages of the amino acids of wheat grains to be as follows: whole-wheat bread, 99; white bread, conventional-mix, 83; wheat cereal to-be-cooked, 82; white bread, continuous-mix, and hamburger rolls, each 76; all-purpose flour, 71; shredded wheat, 68; and doughnuts, 62. On the average, methionine, at 89% of the wheat value, was highest; and proline, at 88%. Tryptophan, at 70%, was the low value.

Milling brought about some changes in the nutrient composition. Uniformly, the starch was one-fifth more in the flours than in the whole grain. Vitamins always decreased with the milling process, as did the fatty acids. Unsaturated fatty acids included linoleic acid as the largest constituent of the total fatty acids of wheats and the flours. The endosperm also would need to have contained much of the Pb, Sn, Cr, Cd, and Na of whole wheats, since they were also found in the flours. Glutamic acid and proline were always higher in the flours than in whole wheats. The products made with the flours usually gained in vitamins, mineral elements, and fatty acids.

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