Nutrient Composition of Selected Wheats and Wheat Products. IV. Vitamin B-6 Components

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ABSTRACT

The amounts of pyridoxine, pyridoxal, and pyridoxamine have been determined in ten consumer products purchased in ten cities representing five geographical areas of the U.S. Eleven known wheats, and flours and products made from these wheats,also were analyzed. Data for consumer products from the various geographical areas appeared to be consistent for each product. The whole-wheat products contained much higher amounts of vitamin B-6 than the refined products. In the wheat to flour to products studies, durum wheat contained more B-6 (4.3 γ per g.) than hard or soft wheats (3.4 γ per g.). In milling the hard and soft wheats to flour, generally 10 to 25% of the B-6 was retained, whereas in milling semolina from durum wheat, about 28% was retained. Pyridoxine accounted for three-fourths of the B-6 in wheat samples, over half in flours, about two-thirds in macaroni, and less than half in baked products. The increase in B-6 in some of the breads and also the change in proportions of the three components from that of flour was probably due to recipe ingredients and possibly to fermentation in the case of breads.

More than three times as much wheat as other grains was used for human consumption in 1967 (1). The effects of present-day production, including milling and baking processes, on nutrient content of wheat products are of interest to those concerned with wheat products used for foods. The recommended daily allowance for vitamin B-6 is 1.5 to 2 mg. per day (2). Most whole grains and their products contain 2 to 4 γ of B-6 per g. (3) and are considered one of the better sources of the dietary vitamin. In general, the refined products contain less than 1 γ B-6 per g. (3), but must be considered for their contribution because of the amounts consumed. This study was part of an intensive study on content and distribution of a number of nutrients in wheats and wheat products (4). In this phase of the study the pyridoxine, pyridoxal, and pyridoxamine contents of these wheats and wheat products were determined. Very few reliable data were available on the B-6 components in wheat and wheat products, except for those included in a study on grains and cereal products (3).

For the determination of vitamin B-6 in the low concentrations in which it occurs in wheats and particularly in refined wheat products, generally the microbiological assay with *Saccharomyces carlsbergensis* is used. *S. carlsbergensis* has been found to respond in growth to all three forms of B-6, but to a lesser degree to pyridoxamine than to pyridoxine and pyridoxal (5). Pyridoxine, pyridoxal, and pyridoxamine have been chromatographically separated on ion-exchange columns from hydrolyzed extracts and each form assayed microbiologically (3). Data obtained by these procedures compare well with those obtained by rat bioassay for total B-6 in a few selected food samples, of which one was a whole-wheat flour (6). This paper presents values for pyridoxine, pyridoxal, and pyridoxamine as determined by microbiological assay of chromatographed fractions of extracts for ten types of wheat products available to the consumer in ten cities in the United States, and for known hard, soft, and durum wheats representative of the major wheat-producing and -milling areas of the U.S., flours milled from them including conventional and air-classification milling processes for soft wheat, and selected prepared products made from each of the flours. Values for thiamine, riboflavin, and niacin as well as other nutrients such as amino acids, fatty acids, tocopherols, and a number of mineral elements will be reported in similar papers.

MATERIALS AND METHODS

Detailed descriptions of the samples and how they were collected and prepared were given in the first paper of this series (4). Samples were kept in sealed cans at 0°C. until analyzed. One-gram samples were used for whole wheats and whole-wheat products, and 2-g. samples for refined products. All samples were extracted in 200 ml. 0.44N HCl by autoclaving at 15 lb. steam pressure for 2 hr. The procedures for the chromatographic separation and the microbiological assay were those used by Polansky et al. (3). As described in that procedure, samples were analyzed independently on at least two different assay periods.

RESULTS AND DISCUSSION

Pyridoxine, pyridoxal, and pyridoxamine values for the ten consumer products purchased in each of the ten cities are given in Table I. The data are reported in γ per g. of product on dry weight basis. There were no great differences in the B-6 content for the same product purchased from the different locations. Whole-wheat products ranged from 2 to 4 γ of B-6 per g.; the refined products contained considerably less, 0.3 to a little over 0.7 γ B-6 per g. The whole-wheat products would likely be considered as making significant contributions to dietary vitamin B-6.

Averaged B-6 values for the ten consumer products and the percentages that pyridoxine, pyridoxal, and pyridoxamine represented of the total B-6 are given in Table II on an as-purchased weight basis. Breads, rolls, and doughnuts contained less B-6 per g. than on a dry weight basis because of the higher moisture content, but still the whole-wheat bread as purchased contained five times as much B-6 as the refined products. The difference in total B-6 content of conventional-mix and continuous-mix breads was negligible on either dry weight or as-purchased weight basis. Pyridoxine made up the largest portion of total B-6 in whole-wheat products (Table II). All-purpose flour contained about 50% of its B-6 as pyridoxine, but for white breads the proportions of components changed from those of flour, showing the effects of ingredients other than flour.

Pyridoxine, pyridoxal, and pyridoxamine values for five hard wheats, and flours and breads processed from these wheats, are given in Table III. The second whole-wheat sample contained less pyridoxine and therefore less B-6 than the other four wheats. Flour milled from this wheat did not yield the lowest amount of B-6. The five hard wheats averaged 3.5 γ B-6 per g. and their flours only 0.5 γ per g. Flour 3 had the highest B-6 content, 0.65 γ per g., and both the conventional-mix and the continuous-mix bread made from flour 3 were highest in their respective bread groups. A difference in B-6 content was shown between the conventional-mix and the continuous-mix breads, which averaged 0.5 and 0.4 γ per g., respectively. The two corresponding breads from the consumer market study, previously

TABLE I. VALUES FOR VITAMIN B-6 COMPONENTS FOR TEN CONSUMER PRODUCTS FOR TEN GEOGRAPHICAL LOCATIONS (DRY WEIGHT BASIS)

Location	Flour, All-Purpose				Biscuit Mix			
	Pyridoxine γ/g.	Pyridoxal γ/g.	Pyridoxamine γ/g.	Total γ/g.	Pyridoxine γ/g.	Pyridoxal γ/g.	Pyridoxamine γ/g.	Total γ/g.
Seattle, Wash.	0.24	0.14	0.11	0.49	0.22	0.16	0.08	0.46
San Francisco, Calif.	0.39	0.22	0.11	0.72	0.23	0.17	0.09	0.49
Los Angeles, Calif.	0.31	0.16	0.13	0.60	0.19	0.15	0.14	0.48
Dallas, Texas	0.24	0.13	0.09	0.46	0.20	0.15	0.12	0.47
Chicago, Ill.	0.28	0.14	0.09	0.51	0.22	0.14	0.08	0.44
Minneapolis, Minn.	0.25	0.11	0.09	0.45	0.19	0.12	0.07	0.38
New York, N.Y.	0.26	0.14	0.13	0.53	0.24	0.15	0.08	0.47
Boston, Mass.	0.24	0.11	0.09	0.44	0.22	0.13	0.08	0.43
Atlanta, Ga.	0.27	0.11	0.07	0.45	0.22	0.18	0.09	0.49
Charlotte, N.C.	0.16	0.10	0.07	0.33	0.17	0.15	0.07	0.39
	Whole-Wheat Cereal, To Be Cooked				Shredded Wheat			
Seattle	2.97	0.50	0.28	3.75	2.50	0.31	0.25	3.06
San Francisco	2.66	0.43	0.38	3.47	2.27	0.30	0.21	2.78
Los Angeles	2.72	0.40	0.34	3.46	2.49	0.28	0.28	3.05
Dallas	2.52	0.42	0.27	3.21	2.46	0.30	0.18	2.94
Chicago	2.73	0.55	0.37	3.65	2.05	0.30	0.20	2.55
Minneapolis	2.78	0.46	0.46	3.70	2.07	0.35	0.25	2.67
New York	2.46	0.35	0.23	3.04	2.50	0.33	0.15	2.98
Boston	2.18	0.33	0.30	2.81	2.10	0.32	0.19	2.61
Atlanta	2.19	0.36	0.29	2.84	2.24	0.29	0.20	2.73
Charlotte	2.33	0.33	0.20	2.86	2.09	0.31	0.19	2.59
	Wheat Flakes				Enriched White, Conventional Mix Bread			
Seattle	1.99	0.33	0.17	2.49	0.11	0.16	0.25	0.52
San Francisco	1.88	0.21	0.10	2.19	0.09	0.16	0.20	0.45
Los Angeles	2.38	0.21	0.14	2.73	0.13	0.20	0.30	0.63
Dallas	2.32	0.21	0.18	2.71	0.11	0.18	0.19	0.48
Chicago	1.77	0.16	0.19	2.12	0.13	0.16	0.23	0.52
Minneapolis	2.15	0.23	0.16	2.54	0.18	0.23	0.34	0.75
New York	2.11	0.23	0.17	2.51	0.15	0.19	0.25	0.59
Boston	2.44	0.22	0.13	2.79	0.16	0.18	0.28	0.62
Atlanta	2.20	0.23	0.20	2.63	0.12	0.19	0.28	0.59
Charlotte	1.95	0.20	0.19	2.34	0.14	0.18	0.22	0.54

(continued)

	Enriched White Bread, Continuous Mix				Whole-Wheat Bread, 100%			
Seattle	0.13	0.13	0.22	0.48	1.43	0.57	0.35	2.35
San Francisco	0.15	0.14	0.28	0.57	1.65	0.53	0.41	2.59
Los Angeles	0.18	0.15	0.30	0.63	1.72	0.49	0.44	2.65
Dallas	0.20	0.13	0.23	0.56	3.06	0.53	0.34	3.93
Chicago	0.18	0.15	0.23	0.56	2.50	0.51	0.42	3.43
Minneapolis	0.16	0.18	0.30	0.64	2.12	0.47	0.46	3.05
New York	0.17	0.15	0.27	0.59	2.46	0.65	0.32	3.43
Boston	0.16	0.12	0.24	0.52	2.05	0.46	0.31	2.82
Atlanta	0.21	0.18	0.26	0.65	2.10	0.61	0.31	3.02
Charlotte	0.16	0.15	0.19	0.50	2.44	0.52	0.26	3.22

	Hamburger Rolls				Doughnuts			
Seattle	0.09	0.17	0.21	0.47	0.20	0.20	0.09	0.49
San Francisco	0.11	0.15	0.28	0.54	0.21	0.17	0.08	0.46
Los Angeles	0.15	0.19	0.25	0.59	0.24	0.15	0.08	0.47
Dallas	0.13	0.17	0.23	0.53	0.24	0.22	0.07	0.53
Chicago	0.14	0.17	0.28	0.59	0.24	0.18	0.10	0.52
Minneapolis	0.14	0.19	0.22	0.55	0.24	0.18	0.09	0.51
New York	0.19	0.17	0.23	0.59	0.19	0.16	0.09	0.44
Boston	0.16	0.20	0.21	0.57	0.25	0.17	0.10	0.52
Atlanta	0.17	0.16	0.25	0.58	0.14	0.11	0.07	0.32
Charlotte	0.14	0.15	0.17	0.46	0.17	0.17	0.06	0.40

Averages	Pyridoxine γ/g.	Pyridoxal γ/g.	Pyridoxamine γ/g.	Total γ/g.
All-purpose flour	0.26±0.06[a]	0.14±0.03	0.10±0.02	0.50±0.10
Biscuit mix	0.21±0.02	0.15±0.02	0.09±0.02	0.45±0.04
Whole-wheat cereal	2.55±0.25	0.41±0.07	0.31±0.07	3.27±0.35
Shredded wheat	2.28±0.18	0.31±0.02	0.21±0.04	2.80±0.19
Wheat flakes	2.12±0.21	0.22±0.04	0.16±0.03	2.50±0.22
Bread, conventional mix	0.13± 0.03	0.18± 0.02	0.25± 0.04	0.56± 0.08
Bread, continuous-mix	0.17±0.02	0.15±0.02	0.25±0.03	0.57±0.06
Whole-wheat bread	2.15±0.46	0.53±0.06	0.36±0.06	3.04±0.45
Hamburger rolls	0.14±0.03	0.17±0.02	0.23±0.03	0.54±0.05
Doughnuts	0.21±0.04	0.17±0.03	0.08±0.01	0.46±0.06

[a]Standard error of the mean.

TABLE II. AVERAGE VITAMIN B-6 VALUES AND PERCENT OF TOTAL B-6 AS PYRIDOXINE, PYRIDOXAL, AND PYRIDOXAMINE IN CONSUMER PRODUCTS (AS-PURCHASED WEIGHT BASIS)

Product	Total Solids	Total B-6	Percent of Total B-6		
			Pyri-doxine	Pyri-doxal	Pyridox-amine
	%	γ/g.	%	%	%
Whole-wheat cereal (to be cooked)	90.62	2.97	78	13	9
Shredded wheat	92.01	2.57	82	11	7
Wheat flakes	95.25	2.38	85	9	6
Bread, whole wheat	61.05	1.85	71	17	12
Bread, white, enriched, conventional	62.94	0.36	25	31	44
Bread, white, enriched, continuous	62.07	0.35	28	26	46
Rolls, hamburger	65.05	0.35	26	31	43
Doughnuts	75.85	0.35	46	37	17
Flour, all-purpose	87.27	0.44	52	27	21
Biscuit mix	90.38	0.41	46	34	20

discussed, were not different in this respect. In the controlled experiment, the difference may have been due to the difference in formulation as well as that in processing. The relative changes in B-6 content that took place on milling hard wheat to flour and making it into the two types of breads are given in Table IV. In milling wheat to flour only 15% of the B-6 is retained. This is to be expected, since the source of white flour is the endosperm part of the wheat kernel. The bran and germ contain over 90% of the B-6 in the wheat kernel. The baking change and net change include the effects of ingredient additions, fermentation, and baking. The net change showed the effect of the complete processing of the wheat to the final product, bread. Conventional-mix bread retained only 15% of the B-6 originally present in the wheat, and continuous-mix only 12%. The relative amounts of the B-6 components for hard wheats, flours, and breads are shown in Table V. The total B-6 in wheat was 75% pyridoxine, in flour only 57%, and in bread less than 40%. Increase in proportions of pyridoxal and pyridoxamine in bread over those in flour was due to recipe ingredients and possibly fermentation.

Vitamin B-6 values for four soft wheats were similar to those for hard wheats. Values for the three components for soft wheats, and for cake flours and cakes made from them, are given in Table VI. Averaged B-6 values for two types of flour, short-patent and air-classified, were the same, 0.3 γ B-6 per g., and likewise the values for cakes made from them, 0.2 γ B-6 per g. Vitamin B-6 losses during milling of the soft wheat were as high as those for hard wheat (Table VII). Cake flour retained only 10% of the B-6 from wheat; when made into cake, only about 7% of the original B-6 of wheat remained. The data in Table VIII show the relative proportions of B-6 components in soft wheat, cake flour, and cakes. As with hard wheats, the proportion of pyridoxine retained in soft wheat flours was only a small percent of that in soft wheat. The cakes were different from breads, where

TABLE III. VALUES FOR VITAMIN B-6 COMPONENTS OF FIVE HARD WHEATS, AND FLOURS AND BREADS PROCESSED FROM THE WHEATS (DRY WEIGHT BASIS)

	Hard Wheat	Total Solids	Vitamin B-6			
			Pyri-doxine	Pyri-doxal	Pyri-dox-amine	Total
		%	γ/g.	γ/g.	γ/g.	γ/g.
Wheat	H1	89.26	2.88	0.46	0.41	3.75
	H2	89.73	1.84	0.45	0.42	2.71
	H3	88.33	2.77	0.45	0.42	3.64
	H4	89.20	2.79	0.54	0.35	3.68
	H5	88.63	2.72	0.41	0.41	3.54
	Av.	89.03	2.60 ±0.38[a]	0.46 ±0.04	0.40 ±0.03	3.46 ±0.38
Flour	H1	86.04	0.22	0.13	0.09	0.44
	H2	86.16	0.35	0.15	0.07	0.57
	H3	87.22	0.39	0.13	0.13	0.65
	H4	86.41	0.24	0.12	0.07	0.43
	H5	86.08	0.27	0.13	0.10	0.50
	Av.	86.38	0.29 ±0.07[a]	0.13 ±0.01	0.09 ±0.02	0.51 ±0.08
Bread, conventional	H1	64.49	0.08	0.18	0.20	0.46
	H2	63.19	0.10	0.17	0.19	0.46
	H3	62.78	0.16	0.23	0.21	0.60
	H4	60.40	0.08	0.16	0.27	0.51
	H5	62.47	0.12	0.22	0.24	0.58
	Av.	62.67	0.11 ±0.03[a]	0.19 ±0.03	0.22 ±0.03	0.52 ±0.06
Bread, continuous	H1	63.93	0.12	0.12	0.11	0.35
	H2	62.92	0.13	0.12	0.11	0.36
	H3	63.95	0.22	0.13	0.17	0.52
	H4	63.45	0.12	0.12	0.15	0.39
	H5	63.60	0.14	0.13	0.14	0.41
	Av.	63.57	0.15 ±0.04[a]	0.12 ±0.01	0.14 ±0.02	0.41 ±0.06

[a]Standard error of the mean.

TABLE IV. PERCENT VITAMIN B-6 RETAINED OR GAINED DURING CONVERSION OF WHEAT TO BREAD (DRY WEIGHT BASIS)

		Vitamin B-6 %
Milling change (wheat to flour)		15
Baking change (flour to bread):	conventional	102
	continuous	81
Net change (wheat to bread):	conventional	15
	continuous	12

TABLE V. PERCENT OF TOTAL VITAMIN B-6 AS PYRIDOXINE, PYRIDOXAL, AND PYRIDOXAMINE IN HARD WHEAT→FLOUR→BREAD

Product	Pyridoxine	Pyridoxal	Pyridoxamine
	%	%	%
Wheat, hard	75	13	12
Flour, hard wheat	57	25	18
Bread, conventional	21	37	42
Bread, continuous	37	29	34

TABLE VI. VALUES FOR VITAMIN B-6 COMPONENTS OF FOUR SOFT WHEATS, AND FLOURS AND CAKES MADE FROM THE WHEATS (DRY WEIGHT BASIS)

	Soft Wheat	Total Solids	Vitamin B-6			
			Pyri-doxine	Pyri-doxal	Pyridox-amine	Total
		%	γ/g.	γ/g.	γ/g.	γ/g.
Wheat	S1	89.60	2.48	0.50	0.35	3.33
	S2	87.66	2.81	0.44	0.37	3.62
	S3	90.42	2.43	0.42	0.15	3.00
	S4	89.67	2.45	0.48	0.26	3.19
	Over-all av.	89.34	2.54 ±0.15[c]	0.46 ±0.03	0.28 ±0.09	3.28 ±0.23
Flour	Short-patent	87.49	0.16	0.10	0.06	0.32
	Short-patent[a]	87.32	0.24	0.11	0.05	0.40
	Short-patent	87.17	0.11	0.08	0.02	0.21
	Short-patent	88.41	0.17	0.11	0.05	0.33
	Av.	87.60	0.17	0.10	0.05	0.32
	S1 Air-classif.	90.45	0.15	0.10	0.06	0.31
	S4 Air-classif.[b]	87.39	0.18	0.10	0.03	0.31
	Av.	88.92	0.16	0.10	0.05	0.31
	Over-all av.	88.04	0.17 ±0.04	0.10 ±0.01	0.05 ±0.05	0.32 ±0.06
Cake	Short-patent	74.16	0.10	0.16	0.02	0.28
	Short-patent[a]	73.17	0.04	0.14	0.02	0.20
	Short-patent	73.25	0.06	0.14	0.04	0.24
	Short-patent	73.41	0.09	0.11	0.03	0.23
	Av.	73.50	0.07	0.14	0.03	0.24
	S1 Air-classif.	74.30	0.06	0.12	0.02	0.20
	S2 Air-classif.[b]	73.79	0.09	0.13	0.03	0.25
	Av.	74.05	0.07	0.13	0.03	0.23
	Over-all av.	73.68	0.07 ±0.02	0.13 ±0.02	0.03 ±0.01	0.23 ±0.03

[a]Not used commercially.

[b]Experimental.

[c]Standard error of the mean.

TABLE VII. PERCENT VITAMIN B-6 RETAINED OR GAINED DURING CONVERSION OF WHEAT TO CAKE

	Short-Patent %	Air-Classified %
Milling change (wheat to flour)	10	10
Baking change (flour to cake)	75	74
Net change (wheat to cake)	7	7

TABLE VIII. PERCENT OF TOTAL VITAMIN B-6 AS PYRIDOXINE, PYRIDOXAL, AND PYRIDOXAMINE IN SOFT WHEAT→FLOUR→CAKE

	Product				
	Soft Wheat	Cake Flour[a]		Cake[a]	
		S-P	A-C	S-P	A-C
	%	%	%	%	%
Pyridoxine	77	53	53	29	30
Pyridoxal	14	31	31	58	57
Pyridoxamine	9	16	16	13	13

[a]S-P, short-patent; A-C, air-classified.

pyridoxamine increased. In cake the increase was in the amount of pyridoxal, 55% of the total vitamin B-6.

In Table IX, data are given for cracker flour and crackers made from the same four soft wheats used for making the cake flours. These three cracker flours all have more B-6 than the cake flours. Cut-off flours were noticeably higher than the other two flours, and these higher values carry over to the crackers. The average B-6 value for cut-off flour was 0.8 γ per g., and for straight-grade and air-classified flours, 0.4 γ. Crackers made from cut-off flour had a B-6 value of 0.7 γ per g., and crackers made from the straight-grade and air-classified flours were 0.3 and 0.4 γ per g. respectively. It would, therefore, seem advantageous to use the cut-off flour in making crackers, since it doubles the B-6 content. The cut-off flour was less refined and would probably contain more of other nutrients, also. As can be seen in Table X, there was still a large B-6 loss during milling, cut-off flour retaining 25% of the B-6 present in the wheat and the other two flours 13 and 14%. During the baking change from flour to cracker, 70% or more of the B-6 was retained, which was also true for breads and cakes during this stage. The net change from wheat to baked product again showed a large B-6 loss. Crackers made from cut-off flour retained 20% of the original vitamin B-6 from wheat; the others retained 10 and 13%. Data in Table XI on the percentage that each component represented of the total B-6 for cracker flour and crackers show once again a reduction in the proportion of pyridoxine during milling and, as in cake, an increase in the proportion of pyridoxal in the crackers.

TABLE IX. VALUES FOR VITAMIN B-6 COMPONENTS OF FLOURS AND CRACKERS MADE FROM THE FOUR SOFT WHEATS (DRY WEIGHT BASIS)

	Soft Wheat	Flour Type	Total Solids	Vitamin B-6			
				Pyridoxine	Pyridoxal	Pyridoxamine	Total
			%	γ/g.	γ/g.	γ/g.	γ/g.
Flour	S1	Str. grade	87.54	0.25	0.14	0.06	0.45
	S3	Str. grade[a]	87.35	0.25	0.11	0.05	0.41
	S4	Str. grade	88.22	0.25	0.18	0.08	0.51
		Av.	87.70	0.25	0.14	0.06	0.45
	S1	Cut-off	87.75	0.51	0.17	0.09	0.77
	S2	Cut-off	86.77	0.59	0.18	0.09	0.86
		Av.	87.26	0.55	0.18	0.09	0.82
	S1	Air-classif.	89.41	0.17	0.13	0.04	0.34
	S4	Air-classif.[b]	90.25	0.31	0.13	0.07	0.51
		Av.	89.83	0.24	0.13	0.06	0.43
		Over-all av.	88.18	0.33 ±0.14[c]	0.15 ±0.03	0.07 ±0.02	0.55 ±0.18
Crackers	S1	Str. grade	95.34	0.12	0.16	0.04	0.32
	S3	Str. grade[a]	95.04	0.15	0.19	0.06	0.40
	S4	Str. grade	95.18	0.11	0.14	0.02	0.27
		Av.	95.19	0.13	0.16	0.04	0.33
	S1	Cut-off	94.95	0.35	0.25	0.15	0.75
	S2	Cut-off	96.08	0.26	0.21	0.12	0.59
		Av.	95.52	0.31	0.23	0.14	0.68
	S1	Air-classif.	95.16	0.12	0.18	0.05	0.35
	S4	Air-classif.[b]	95.52	0.16	0.21	0.09	0.46
		Av.	95.34	0.14	0.20	0.07	0.41
		Over-all av.	95.32	0.18 ±0.08	0.19 ±0.03	0.08 ±0.04	0.45 ±0.15

[a]Not used commercially.

[b]Experimental.

[c]Standard error of the mean.

TABLE X. PERCENT VITAMIN B-6 RETAINED OR GAINED DURING CONVERSION OF WHEAT TO CRACKERS

	Straight-Grade %	Cut-Off %	Air-Classified %
Milling change (wheat to flour)	14	25	13
Baking change (flour to cracker)	73	83	95
Net change (wheat to cracker)	10	21	13

TABLE XI. PERCENT OF TOTAL VITAMIN B-6 AS PYRIDOXINE, PYRIDOXAL, AND PYRIDOXAMINE IN SOFT WHEAT→FLOUR→CRACKERS

	Product						
		Cracker Flour[a]			Crackers[a]		
	Soft Wheat	S-G	Cut-off	A-C	S-G	Cut-off	A-C
	%	%	%	%	%	%	%
Pyridoxine	77	56	67	56	39	45	34
Pyridoxal	14	31	22	30	49	34	49
Pyridoxamine	9	13	11	14	12	21	17

[a]S-G, straight-grade; A-C, air-classified.

TABLE XII. VALUES FOR VITAMIN B-6 COMPONENTS OF TWO DURUM WHEATS, AND SEMOLINA AND MACARONI PROCESSED FROM THE WHEATS (DRY WEIGHT BASIS)

	Durum Wheat	Total Solids	Vitamin B-6			
			Pyridoxine	Pyridoxal	Pyridoxamine	Total
		%	γ/g.	γ/g.	γ/g.	γ/g.
Wheat	D 1	89.12	3.37	0.57	0.39	4.33
	D 2	89.80	3.21	0.70	0.37	4.28
	Av.	89.46	3.29 ±0.08[a]	0.64 ±0.07	0.38 ±0.01	4.31 ±0.03
Semolina	D 1	85.80	0.85	0.20	0.21	1.26
	D 2	85.45	0.75	0.20	0.18	1.13
	Av.	85.63	0.80 ±0.05	0.20 ±0.00	0.20 ±0.02	1.20 ±0.07
Macaroni	D 1	90.39	0.61	0.19	0.21	1.01
	D 2	90.36	0.72	0.21	0.22	1.15
	Av.	90.38	0.67 ±0.06	0.20 ±0.01	0.22 ±0.01	1.09 ±0.07

[a]Standard error of the mean.

TABLE XIII. PERCENT VITAMIN B-6 RETAINED OR GAINED DURING PROCESSING OF WHEAT TO MACARONI

	Vitamin B-6
	%
Milling change (wheat to semolina)	28
Baking change (semolina to macaroni)	91
Net change (wheat to macaroni)	25

TABLE XIV. PERCENT OF TOTAL VITAMIN B-6 AS PYRIDOXINE, PYRIDOXAL, AND PYRIDOXAMINE IN DURUM WHEAT→SEMOLINA→MACARONI

Product	Pyridoxine	Pyridoxal	Pyridoxamine
	%	%	%
Wheat, durum	76	15	9
Flour (semolina), durum wheat	66	17	17
Macaroni	62	18	20

The two durum wheats and the semolina and macaroni made from them contained more B-6 than either the hard or soft wheat or the products made from them. The B-6 for durum wheat, semolina, and macaroni are given in Table XII. Durum wheat contained 4.3 γ B-6 per g., semolina 1.2, and macaroni 1.1. Again, as for the other wheats, there was a large B-6 loss during milling and processing to macaroni. Only 28% B-6 is retained during milling and 25% retained in processing wheat to macaroni (Table XIII). Durum wheat contained three-fourths of its B-6 as pyridoxine; semolina and macaroni each had two-thirds of its B-6 as pyridoxine (Table XIV).

Literature Cited

1. U.S. DEPARTMENT OF AGRICULTURE, ECONOMIC RESEARCH SERVICE. National Food Situation, NFS-122, Washington, D.C. (November 15, 1967).
2. NATIONAL ACADEMY OF SCIENCES-NATIONAL RESEARCH COUNCIL. Recommended Dietary Allowances, Publication 1694 (7th rev. ed.). Washington, D.C. (1968).
3. POLANSKY, MARILYN M., MURPHY, E. W. and TOEPFER, E. W. Components of vitamin B_6 in grains and cereal products. J. Assoc. Offic. Agr. Chemists 47: 750 (1964).
4. TOEPFER, E. W., HEWSTON, ELIZABETH M., HEPBURN, F. N., and TULLOSS, J. H. Nutrient compositon of selected wheats and wheat products. I. Description of samples. Cereal Chem. 46: September 1969.
5. PARRISH, W. P., LOY, H. W., Jr., and KLINE, O. L. A study of the yeast method for vitamin B_6. J. Assoc. Offic. Agr. Chemists 38: 506 (1955).
6. TOEPFER, E. W., POLANSKY, MARILYN M., RICHARDSON, L. R., and WILKES, S. Comparison of vitamin B_6 values of selected food samples by bioassay and microbiological assay. J. Agr. Food Chem. 11: 523 (1963).

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