Effect of Fumigation on Wheat in Storage. III. Vitamin B-6 Components of Wheat and Wheat Products

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ABSTRACT

The amounts of pyridoxine, pyridoxal, and pyridoxamine have been determined in whole-wheat grain, bran, shorts, low-grade flour, patent flour, dough, bread, and rolls from stored wheat samples periodically fumigated with methyl bromide, a mixture of ethylene dichoride and carbon tetrachloride, or phosphine, and from wheat samples stored without fumigation at ambient and refrigerated temperatures. Fumigation and length of storage had no effect on the vitamin B-6 content of wheat grain, its milling fractions, or the doughs and baked products made from it. The B-6 content of bran was 13.7 γ per g.; shorts, 11.8; wheat grain, 3.7; low-grade flour, 1.6; patent flour, 0.5; bread dough, 0.7; bread, 0.6; roll dough, 0.6; and rolls, 0.5. Sixty-two percent of the original B-6 of wheat grain is in the bran, 27% in shorts, 3% in low-grade flour, and 10% in patent flour. Pyridoxine constituted over 70% of the B-6 in whole-wheat grain, bran, and shorts, over 50% in low-grade and patent flours, and less than 20% in doughs, breads, and rolls. During baking, 81% of the B-6 in dough was retained in breads and 83% in rolls.

Emphasis has been placed on the need for additional reliable data on the vitamin B-6 content of foods to aid in the assessment of the adequacy of human diets with respect to this important vitamin (1). The Food and Nutrition Board has recommended a daily allowance for vitamin B-6 of 1.5 to 2 mg. (2). No information is available on the effects caused by fumigation of grain during storage on the vitamin content of wheat, wheat milling fractions, and wheat products. Highly reactive chemical fumigants and the aeration procedures used to remove them could reasonably be expected to alter the vitamin content. This study was part of an extensive 3-year study on the effect of fumigation of wheat in storage as measured by vitamin content of wheat grain, milling fractions, baked products, and the eating-quality characteristics of the baked products. Information on wheat procurement, storage, and fumigation treatments; periods and methods of sampling the treated wheat; milling of wheat; and physical measurements of flour was given in the first paper of this series (3). The physical and eating qualities of breads and rolls were given in the second paper (4). In this phase of the study, the pyridoxine, pyridoxal, pyridoxamine, and total unchromatographed B-6 contents of wheat grain, bran, shorts, low-grade flour, patent flour, bread and roll doughs, and baked breads and rolls were determined following the various treatments and times of storage. Two previous studies from this laboratory (5,6) reported the B-6 components of some wheats and wheat products. This paper presents values for pyridoxine, pyridoxal, and pyridoxamine as determined by microbiological assay of chromatographed fractions of extracts for fumigated wheat, milling fractions, doughs, breads, and rolls.

MATERIALS AND METHODS

Early Triumph wheat was used for this study. The wheat was divided into five batches–two for controls and three for fumigation treatments. One control was held at ambient temperatures and the second was held at 32°F. Methyl bromide, a mixture of ethylene dichloride and carbon tetrachloride, and phosphine were the three fumigates used. Details were reported previously (3,4).

Three individual preparations of the breads and rolls were made for each storage period, as described previously (4). Each batch was analyzed for all B-6 components. The portion of the doughs, breads, and rolls to be used for chemical analysis was freeze-dried and samples were kept refrigerated in sealed cans until analyzed. For extraction, 1-g. samples were used for whole-wheat grain, bran, shorts, and low-grade flour, and 2-g. samples were used for patent flour, doughs, and baked products. All samples were extracted in 200-ml. 0.44N HCl by autoclaving at 15 lbs. steam pressure for 2 hr. Microbiological assay with *Saccharomyces carlsbergensis* was used for the B-6 determinations. Procedures for the chromatographic separation and the microbiological assay were those used by Polansky et al. (5). Analyses for the B-6 components were done on the first four, the eighth, and the last (12th) storage periods. A total of 570 samples were analyzed.

RESULTS AND DISCUSSION

No significant differences were found in the total B-6 content of wheat grain and each milling fraction owing to the fumigation treatments or to the length of storage time, as shown by an analysis of variance. Average values for pyridoxine, pyridoxal, and pyridoxamine, and for total solids for wheat grain, bran, shorts, low-grade flour, and patent flour are given in Table I. Only the averaged values for all treatments are reported, since the B-6 content was not affected by the three fumigations or by length of storage.

Bran was a good source of vitamin B-6 (13.7 γ per g. on a dry-weight basis) and shorts contained nearly as much (11.8) (Table I). Whole-wheat grain had 3.7 γ B-6 per g.; low-grade flour, 1.6; and patent flour, only 0.5. The yields during milling and the percentages of pyridoxine, pyridoxal, and pyridoxamine of the original B-6 content of wheat for each milling fraction are given in Table II. Only 10% of total

TABLE I. AVERAGE PYRIDOXINE, PYRIDOXAL, AND PYRIDOXAMINE VALUES FOR FUMIGATED WHOLE-WHEAT GRAIN AND ITS MILLING FRACTIONS
(dry weight basis)

	Total Solids %	Vitamin B-6			
		Pyridoxine γ/g.	Pyridoxal γ/g.	Pyridoxamine γ/g.	Total γ/g.
Wheat grain	88.7	2.71	0.52	0.46	3.69
Bran	89.2	10.29	1.68	1.73	13.70
Shorts	89.8	8.60	1.51	1.73	11.84
Low-grade flour	88.2	1.09	0.30	0.25	1.64
Patent flour	87.6	0.28	0.14	0.11	0.53

TABLE II. PERCENTAGES OF TOTAL PYRIDOXINE, PYRIDOXAL, AND PYRIDOXAMINE CONTENT OF FUMIGATED WHOLE-WHEAT GRAIN RETAINED IN EACH MILLING FRACTION

	Yield from Wheat %	Vitamin B-6			
		Pyridoxine %	Pyridoxal %	Pyridoxamine %	Total %
Bran	17.03	63.1	53.8	63.0	61.8
Shorts	8.02	26.2	25.0	30.4	26.6
Low-grade flour	7.53	3.0	3.8	4.3	3.3
Patent flour	67.14	7.0	19.2	15.2	9.8
Total	99.72	99.3	101.9	113.0	101.4

B-6 originally found in wheat was retained in the patent flour, whereas the yield of patent flour from wheat was 67%. Patent flour comes from the endosperm, which is about 83% of the wheat kernel but low in B-6. Apparently B-6 tends to be concentrated in the outer coating and germ of the wheat kernel. The bran contained 62% of the original wheat B-6, but only 17% of the wheat kernel is in this fraction. One-hundred-one percent of the total vitamin B-6 was recovered from the four milling fractions. The microbiological assay for pyrodoxamine seems to be the most variable and would probably be responsible for the higher total percentage of pyridoxamine in the milling fractions.

One-half to three-fourths of the vitamin B-6 in whole-wheat grain and its milling fractions was pyridoxine. The B-6 in whole-wheat grain was 73% pyridoxine; in bran, 75%; shorts, 73%; low-grade flour, 67%; and patent flour, 53%. The percentages of total B-6 as pyridoxine, pyridoxal, and pyridoxamine in the wheat and milling fractions are given in Table III. Included in this same Table are percentages of total B-6 as pyridoxine, pyridoxal, and pyridoxamine for doughs, bread, and rolls. The doughs contain over 50% of their B-6 as pyridoxal, indicating the addition of vitamin B-6 from recipe ingredients other than flour. The baked bread and rolls contain between 30 and 40% of their B-6 as pyridoxal and 40 to 50% as pyridoxamine. The increase in pyridoxamine and the decrease in pyridoxal in the bread and rolls as compared to doughs would indicate that transamination occurs during baking (7).

TABLE III. PERCENTAGES OF TOTAL VITAMIN B-6 AS PYRIDOXINE, PYRIDOXAL, AND PYRIDOXAMINE IN FUMIGATED WHEAT GRAIN, BRAN, SHORTS, LOW-GRADE AND PATENT FLOURS, DOUGHS, BREADS, AND ROLLS

Product	Pyridoxine %	Pyridoxal %	Pyridoxamine %
Wheat grain	73	14	13
Bran	75	12	13
Shorts	73	13	14
Low-grade flour	67	18	15
Patent flour	53	26	21
Bread dough	15	55	30
Bread	19	32	49
Roll dough	16	58	26
Rolls	19	38	43

TABLE IV. AVERAGE PYRIDOXINE, PYRIDOXAL, AND PYRIDOXAMINE VALUES OF BREAD DOUGHS AND BREADS MADE FROM FUMIGATED WHEAT
(dry weight basis)

Treatment	Bread Dough					Bread				
	Total Solids %	Pyridoxine γ/g.	Pyridoxal γ/g.	Pyridoxamine γ/g.	Total B-6 γ/g.	Total Solids %	Pyridoxine γ/g.	Pyridoxal γ/g.	Pyridoxamine γ/g.	Total B-6 γ/g.
Control, ambient temperature	61.92	0.11	0.39	0.23	0.73	68.14	0.11	0.19	0.30	0.60
Control, refrigerated temperature	61.87	0.11	0.41	0.22	0.74	68.05	0.10	0.19	0.28	0.57
Methyl Bromide	61.92	0.11	0.38	0.20	0.69	68.01	0.11	0.19	0.28	0.58
Ethylene dichloride-Carbon tetrachloride	62.01	0.11	0.42	0.21	0.74	68.23	0.11	0.19	0.30	0.60
Phosphine	62.00	0.11	0.39	0.22	0.72	67.98	0.10	0.19	0.30	0.59
Average	61.95	0.11	0.40	0.22	0.73	68.08	0.11	0.19	0.29	0.59
% Retention							100%	48%	132%	81%

TABLE V. AVERAGE PYRIDOXINE, PYRIDOXAL, AND PYRIDOXAMINE VALUES OF ROLL DOUGHS AND ROLLS MADE FROM FUMIGATED WHEAT
(dry weight basis)

Treatment	Roll Dough					Rolls				
	Total Solids %	Pyridoxine γ/g.	Pyridoxal γ/g.	Pyridoxamine γ/g.	Total B-6 γ/g.	Total Solids %	Pyridoxine γ/g.	Pyridoxal γ/g.	Pyridoxamine γ/g.	Total B-6 γ/g.
Control, ambient temperature	63.93	0.10	0.39	0.18	0.67	72.63	0.10	0.21	0.23	0.54
Control, refrigerated temperature	63.75	0.09	0.37	0.16	0.62	72.58	0.10	0.20	0.22	0.52
Methyl Bromide	63.81	0.10	0.37	0.16	0.63	72.30	0.10	0.20	0.23	0.53
Ethylene dichloride-Carbon tetrachloride	63.85	0.09	0.38	0.15	0.62	72.57	0.10	0.20	0.23	0.53
Phosphine	63.77	0.10	0.35	0.18	0.63	72.67	0.09	0.20	0.24	0.53
Average	63.82	0.10	0.37	0.17	0.64	72.55	0.10	0.20	0.23	0.53
% Retention							100%	54%	135%	83%

An analysis of variance showed no differences in the bread doughs or breads due to fumigation or length of storage. Average pyridoxine, pyridoxal, and pyridoxamine values of bread doughs and breads made from the various fumigated wheats are reported on a dry-weight basis in Table IV. On a dry-weight basis, bread dough contained 0.7 γ B-6 per g. and bread contained 0.6. During baking of the bread, the pyridoxine content was stable, but only 50% of the pyridoxal was retained, and the pyridoxamine content gained with a retention of 130%, again showing the effect of transamination. The vitamin B-6 content of the rolls was slightly less than that of the bread. On a dry-weight basis, roll dough contained 0.6 γ B-6 per g. and the rolls 0.5. Average pyridoxine, pyridoxal, and pyridoxamine values of roll dough and rolls made from the various fumigated wheats are reported on a dry-weight basis in Table V. Analysis of variance showed no effect in the roll dough and rolls due to fumigation or length of storage. Again, as for bread, the pyridoxine content was stable during baking, and retentions of only about 50% pyridoxal and over 130% pyridoxamine were due to transamination.

The relative changes that occur during conversion of wheat to baked product were calculated as the percentage vitamin B-6 retained or gained on a dry-weight basis. During milling of wheat to flour, only 14% of the B-6 is retained in the flour. During the flour-to-dough change, there was a gain in B-6 of 38% for bread and 21% for rolls, indicating the addition of B-6 from recipe ingredients other than flour. Eight-one percent of the B-6 was retained when the bread dough was baked into bread and 83% B-6 was retained when roll dough was baked into rolls. The bread dough contained more B-6 than the roll dough and the baked bread also contained more than rolls. During the net change from wheat to baked product, only 16% of the B-6 was retained in the case of bread and 14% for rolls.

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