Quality of Bread Fortified with Ten Micronutrients[1]

A. S. EMODI and L. SCIALPI, Development Department, Hoffman-La Roche Inc., Nutley, NJ 07110

ABSTRACT

The quality of bread fortified with the vitamin and mineral supplements suggested by the Food and Nutrition Board of the National Academy of Sciences/National Research Council was studied. Bread was fortified with the full vitamin and mineral supplement. Micronutrient stability during baking and storage was excellent. No-off flavor was noticed by 10 trained taste panelists in bread stored for five days at room temperature or for four weeks at freezer temperature.

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The Food and Nutrition Board of the National Academy of Sciences (NAS/NRC) suggested in 1974 that cereal-grain products be fortified with six vitamins and four minerals. In view of the many changes in consumption patterns, food technology, and marketing and the new information concerning the nutritional status of the U. S. population, the Board's proposal was a timely upgrading of the enrichment program of cereal-grain products. Furthermore, because about 26% of daily caloric intake comes from cereal-grain products, these products can improve the nutritional level of population groups that need improvement most. Currently, many cereal-grain products are fortified only with thiamin, niacin, riboflavin, and iron, with calcium as an optional nutrient. The new recommendation also includes vitamin A, pyridoxine (B_6), folic acid, calcium, magnesium, and zinc. Table I shows the current fortification levels and the proposed NAS/NRC levels for flour. The levels in bread are calculated from those in flour, using the factor 0.625.

The feasibility of fortifying flour, bread, rice, and corn products with the suggested nutrients was reported earlier (Rubin et al 1977). At a workshop held in 1977 in Washington, however, the possibility of an off taste in bread caused mainly by the additional minerals was suggested. This article reports studies done in cooperation with Quality Bakers of America Cooperative, Inc., to determine if the micronutrients impart objectionable flavor to bread.

MATERIALS AND METHODS

Materials

Two different lots of bakers' patent flour were used for our studies. Lot 1, used for the first experiment, contained 0.44% ash, 11.5% protein, and 13% moisture. Lot 2, used for the second experiment, contained 0.42% ash, 11.6% protein, and 13.6% moisture.

The vitamins and minerals were supplied by Roche, as reported by Rubin et al (1977). Flour was fortified with micronutrient premixes received from Roche, and bread was baked and evaluated by Quality Bakers of America Cooperative, Inc. All micronutrients were added to achieve the recommended level, except vitamin A, which provided a 15% excess.

Baking Method

Bread was made by the continuous method; baking time was 18 min at 425°F. The baking formula is shown in Table II.

Micronutrient Analysis

The vitamin assay methods were described previously (Rubin et al 1977). Iron, calcium, magnesium, and zinc were assayed with an atomic absorption spectrophotometer (Varian Techtron AA-5). Weighed amounts of samples were digested with concentrated nitric acid, diluted, filtered, and nebulized into the flame. To avoid interference, the final solutions for calcium and magnesium determinations contained about 1% lanthanum.

Bread Quality

Taste was evaluated and bread scored at Quality Bakers of America cooperative, Inc. Bread samples were tasted by a 10-member panel trained to detect flavor changes in bakery products. The triangle test was used. Scores were obtained by judging the eating, external, and internal characteristics of the samples. The rating scale was: poor, 40; fair, 60; good, 80; excellent, 100.

RESULTS AND DISCUSSION

Our first study was to determine the no-effect level of magnesium and calcium because of the indication that, at suggested levels, these two minerals affect the taste and quality of bread. Flour was fortified by adding the full vitamin and mineral levels suggested in the proposal, except for calcium and magnesium which were added at one-third and two-thirds of the recommended level (Ca 300 and 600 mg/lb, Mg 66 and 133 mg/lb). The control contained the current enrichment of thiamin, niacin, riboflavin, and iron.

Analysis showed that the bread was highly over-fortified with minerals (Table III). The calcium content was 872 mg/lb for the bread fortified at the 2/3 level and 658 mg/lb for the bread fortified at the 1/3 level, instead of the expected levels of 417 mg/lb and 232 mg/lb, respectively. On the average, it had increased by about 430 mg/lb. Calcium propionate and calcium acid phosphate used as preservatives account for only about 110 mg of calcium per pound. The reamining 320 mg/lb, therefore, must be contributed by other ingredients. Similarly, magnesium and zinc were also somewhat higher than would be expected from the flour content, suggesting that some of the ingredients might contain these minerals, too.

The retention of the vitamins during he baking process was good. Only vitamin A showed a minor (7–10%) loss.

The data show that flour already contained about 50% of the recommended magnesium and zinc levels (Table III), suggesting that the natural mineral content of cereal-grain products must be considered before addition of micronutrients, especially those that might cause off-flavor. Our addition of the two-thirds and one-third levels of calcium and magnesium and the full levels of zinc and iron resulted in a bread (Table III) that contained about 50% more calcium and magnesium and about 80% more zinc than suggested in the proposal. These minerals cause off-flavor even at smaller concentrations. Iron (40 mg/lb of flour) was included, as proposed in the NAS/NRC recommendation. On November 18, 1977, however, the FDA withdrew its amendment and restored the provision for 13.0–16.5 mg of iron per pound of flour.

To determine that our case was not an isolated incident, several different brands of enriched flour were purchased at a local supermarket and analyzed for calcium, magnesium, and zinc. The

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data (Table IV) show that the flour used for our experiments was very similar in mineral content to the commercially available brands and that the zinc and magnesium contents are indeed significant in flour. Magnesium is present at about 50% and zinc at about 40% of the recommended level. Similar data was reported by Toepfer et al (1972). These results are also in good agreement with a comprehensive survey of commercially milled wheat flour in the U.S. and Canada, published by Kulp (1978), showing 115 ± 25 mg of magnesium and 3.5 ± 0.5 mg of zinc per pound of flour. To obtain the mineral levels suggested in the current proposal, therefore, only about 110 mg of magnesium and about 7 mg of zinc should be added per pound of flour. Calcium which is present at low levels (<10%) in flour, is significantly contained in the formula additives and must, therefore, be accounted for on an individual basis. With the withdrawal of the iron proposal, iron should present no problems.

After these baseline levels were established, the experiment was repeated with unfortified flour that was first assayed for natural vitamin and mineral contents. The experimental design is shown in Table V. Vitamins were added at the recommended level. Only vitamin A provided a 15% excess. Minerals were added, accounting for the natural level, to reach the recommended levels. The assay results of bread made with these enriched flours are given in Table VI. The data show that the minerals are at about the correct levels. Vitamins are retained well in the bread. No loss occurred during baking or two-month freezer storage.

Table VII contains the scoring data of the bread. The evaluating criteria included eating characteristics such as aroma, chewability, flavor, keeping quality, and toastability; the external characteristics such as crust, general appearance, symmetry, and volume; and the internal characteristics such as crumb color, grain, and texture. None of the premixes had any detrimental effect on structure and appearance of the bread. No off-flavor was noticed in bread stored for one to five days at room temperature and four weeks at freezer temperature. Thus, our results indicate that if the natural mineral content and the calcium contributed by the ingredients in bread are considered when flour is fortified, the quality of bread will be as good as that produced today with only three vitamins and iron.

SUMMARY

We demonstrated that fortification of bread with the NAS/NRC proposed micronutrients is feasible. Bread containing the full

TABLE I
Fortification Comparisons

Nutrients[a]	Presently Used[b]		Proposed[c]	
	In Flour	In Bread[d]	In Flour	In Bread
Thiamin	2.9	1.8	2.9	1.8
Riboflavin	1.8	1.1	1.8	1.1
Niacin	24.0	15.0	24.0	15.0
Iron	13.0–16.5	8.0–12.5	40.0[e]	...
Calcium	...	...	900	562
Vitamin A[f]	None	None	1.3 (4,300 IU)[g]	0.8 (2,700 IU)
Pyridoxine	None	None	2.0	1.2
Folic acid	None	None	0.3	0.18
Magnesium	None	None	200.0	125.0
Zinc	None	None	10.0	6.2

[a]Expressed as milligrams per pound of flour.
[b]Minimums and maximums in Code of Federal Regulations, Title 21, Parts 136–137.
[c]NAS/NRC (1974).
[d]Bread is considered to contain 62.5% wheat flour based on the conversion of 100 lb of flour to 160 lb of bread.
[e]November 18, 1977, the FDA restored the provision for 13.0–16.5 mg/lb.
[f]Retinol equivalent.
[g]The originally proposed level of 2.2 mg/lb (7,300 IU) was lowered to 1.3 mg/lb (4,300 IU) (Hepburn 1976).

TABLE II
Baking Formula

Broth	%[a]	Pre-Mix Stage	%[a]
Water	68.0	Flour	100.0
Sugar	8.0	Vegetable oil	2.0
Salt, unenriched	2.25	Dough conditioner	0.25
Dairy soy blend	2.0	Bread softener	0.22
Yeast food	0.5	Broth	...
Calcium acid phosphate	0.1	Oxidation solution	12.5 ppm of KIO_3
Calcium propionate	0.1		50.0 ppm of $KBrO_3$
Yeast	2.5		

[a]On flour weight basis.

TABLE III
Micronutrient Content[a] of Flour and Bread Fortified with NAS/NRC Requirements[b]

	Flour Samples			Bread Samples		
	1	2	3	1	2	3
Vitamin A	...	5,810 IU	6,450 IU	...	3,390 IU	3,400 IU
Thiamin	3.1	3.5	3.2	1.6	1.8	1.7
Riboflavin	1.9	2.1	2.1	1.4	1.5	1.5
Niacin	27.1	31.2	32.7	18.2	21.3	22.4
Vitamin B_6	...	2.3	2.2	...	1.6	1.7
Folic acid	...	0.4	0.4	...	0.28	0.25
Iron	18.6	53.6	56.3	14.1	30.0	33.1
Calcium	104.0	667.0	372.0	481.0	872.0	658.0
Magnesium	110.0	254.0	177.0	95.0	195.0	132.0
Zinc	5.4	16.3	15.8	5.3	11.4	11.4
Moisture, %	11.0	11.4	11.0	35.8	36.4	35.7

[a]Expressed as milligrams per pound of flour.
[b]Except calcium and magnesium added at two-thirds (sample 2) and one-third (sample 3) levels, respectively. Control (sample 1) contained the current enrichment levels.

Table IV
Mineral Content[a] of Enriched Flour

	Commercial Brands				Flour Used for Experiment	Proposed
	A	B	C	D		
Calcium	120.0	101.0	113.0	114.0	104.0	900.0
Magnesium	95.0	102.0	110.0	133.0	110.0	200.0
Zinc	3.8	4.0	4.2	4.7	5.4	10.0

[a]Expressed as milligrams per pound of flour.

TABLE V
Experimental Design:
Micronutrients (mg/lb) in Flour (13% H_2O)

Micronutrient	Flour			
	1[a]	2[b]	3[c]	4[d]
Vitamin A (250 SD)	...	4,333 IU[e]	...	5,000 IU[e]
Vitamin B_1 (mononitrate)	2.9	2.9	2.9	2.9
Vitamin B_2 (type S)	1.8	1.8	1.8	1.8
Niacin	24.0	24.0	24.0	24.0
Vitamin B_6 (HCl)	...	2.0	...	2.0
Folic acid	...	0.3	...	0.3
Iron (Mallinckrodt reduced)	16.5	16.5	16.5	16.5
Calcium ($SO_4 \cdot 2H_2O$)	...	...	400.0[f]	400
Magnesium (oxide, heavy)	...	...	200	200
Zinc (oxide)	...	...	10	10

[a]Control containing current levels.
[b]Contains recommended levels of vitamins and iron.
[c]Contains recommended level of minerals but only the three currently used vitamins.
[d]Contains recommended levels of all micronutrients.
[e]Provides 15% excess.
[f]Flour will not have the recommended level of 900 mg/lb, but bread will have the recommended 562 mg/lb because formula additives yield significant amounts of calcium.

TABLE VI
Vitamin and Mineral Content (mg/lb) of Bread After Baking and Freezer Storage (−20° C)

Nutrient	After Baking				After Two Months at −20° C				Theoretical Values[e]
	1[a]	2[b]	3[c]	4[d]	1[a]	2[b]	3[c]	4[d]	
Vitamin A	...	3,130 IU[f]	...	3,250 IU[f]	...	2,870 IU[f]	...	2,690 IU[f]	2,686 IU
Thiamin	2.3	2.4	2.3	2.4	2.2	2.3	2.1	2.2	2.0
Riboflavin	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.4
Niacin	16.8	19.0	19.0	19.2	16.2	22.2	18.0	20.3	17.6
Vitamin B_6	...	1.2	...	1.2	...	1.4	...	1.3	1.4
Folic acid	...	0.3	...	0.4	...	0.3	...	0.3	0.2
Iron	12.0	12.1	13.4	13.3	12.4	12.5	13.5	13.7	10
Calcium	345	364	550	552	339	332	586	602	562
Magnesium	94	93	170	169	95	93	179	165	125
Zinc	4.8	4.9	9.4	9.6	4.9	4.5	9.3	9.2	6.2
Moisture, %	37.6	37.3	37.6	37.8	37.5	35.5	37.8	38.2	...

[a]From flour containing current levels of micronutrients.
[b]From flour containing recommended levels of vitamins and iron.
[c]From flour containing recommended levels of minerals but only the three currently used vitamins.
[d]From flour containing recommended levels of all micronutrients.
[e]Theoretical values = (nutrient content of flour and added nutrient) × 0.625.
[f]Provides 15% excess.

TABLE VII
Scoring Data of Fortified Bread

Sample	Volume (cc/g)	Numerical	Descriptive	Flavor: Days at ~25° C 1	Flavor: Days at ~25° C 5	Flavor: Freezer at ~−20° C 4 Weeks
1[a]	5.40	85	Good	Good	Good	Good
2[b]	5.30	84	Good	Good	Good	Good
3[c]	5.31	84	Good	Good	Good	Good
4[d]	5.31	83	Good	Good	Good	Good

[a]Fortified with current levels.
[b]Fortified with full vitamin levels and iron.
[c]Fortified with current vitamin and full mineral levels.
[d]Fortified with full vitamin and mineral levels.

vitamin-mineral supplement was acceptable in all characteristics. Similar findings were reported by Ponte (1979), and a commercial test marketing showed excellent customer acceptance (Milling & Baking News 1978). Some minerals are present in flour in significant amount and some are in the formula ingredients. Therefore, to achieve the NAS/NRC proposed levels, the natural micronutrient content of the flour and the nutrients contributed by the formula ingredients should be taken into account.

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