MACROMINERAL AND MICROMINERAL DISTRIBUTION IN BREAD PRODUCED BY CONVENTIONAL AND CONTINUOUS (MECHANICAL DEVELOPMENT) METHODS

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ABSTRACT

Cereal Chem. 55(6): 1050-1055

Total ash, calcium, potassium, sodium, magnesium, phosphorus, and four microelements—iron, copper, manganese, and zinc—were determined in bread baked by conventional and continuous methods. The contents of macroelements and microelements were determined at various stages of the baking process as well as in the whole loaf, crumb, and crust. The amount of macroelements and microelements was greater in bread made by the continuous baking system than that made by conventional baking, especially of sodium, potassium, iron, manganese, and zinc. The differences in amounts were most probably due to variation in formulas used with the two methods of baking.

Bread is a widespread food commodity throughout the world. From a nutritional viewpoint, bread is considered a source of such multinutrients as carbohydrate, protein, minerals, and vitamins. The nutrients present in bread depend not only on the flour but also on the baking formula. Reports on the distribution of minerals as affected by the method of bread processing are limited. Czerniejewski et al (1), Waggle et al (2), and Zook et al (3) all reported similar results on analyses of minerals in wheat, flour, and bread prepared from flour.

The objective of this article is to assess the distribution of macrominerals and microminerals in flour dough at different stages of processing and bread crumb and crust using two baking methods, namely, the conventional and continuous systems.

MATERIALS AND METHODS

Flour Sample

Flour used in this study was obtained from the North Dakota State Mill and Elevator. The flour was bleached, enriched, and malted (extraction 73%).

Bread Samples

Bread was produced using both the conventional and continuous (mechanical development) procedures.

Conventional Baking Method

Bread was baked using a straight-dough procedure with a 3-hr fermentation, 55-min proof period and a baking time of 20 min at 430° F (221.1° C). The baking formula used was as follows, with ingredients expressed on flour weight basis:

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0009-0352/78/000115$03.00/0

Flour	1,700 g
Salt	2%
Sugar	5%
Shortening	3%
Yeast	3%
Nonfat dry milk (NFDM)	2%
Water	62%

After the 3 hr of fermentation, the dough was divided (into loaves), shaped into balls, allowed to rest for 10 min, and then sheeted, molded, and placed into bread pans. Samples of dough were collected after mixing, fermentation, and the final proofing stage; frozen; and freeze-dried. Bread samples were allowed to cool, and portions of the crumb, crust, and whole bread were frozen and freeze-dried. The freeze-dried samples were ground in a Wiley mill to pass through a 40-mesh sieve and stored in polyethylene screw-cap containers in cold storage at 38° F (3° C) before analyses.

Continuous (Mechanically Developed) Baking Method

The same flour was used to produce bread by the continuous method with a Wallace and Tiernan Laboratory continuous unit (Baker Process Co., Belleville, NJ) using the procedure that D'Appolonia (4) described. The baking formula used was as follows, with ingredients expressed on flour weight basis:

Flour	5,000 g
Salt	2.25%
Sugar	8.00%
NFDM	2.00%
Shortening	3.25%
Yeast food	0.50%
Compressed yeast	2.75%
Potassium bromate	60 ppm
Potassium iodate	12 ppm
Water	64%

Differences in formulation between the two types of bread were essential because of the differences in processing techniques. For each method of baking, two loaves of bread were produced from every batch of flour (five batches).

Moisture

Moisture content in all samples was determined in duplicate according to the AACC method (5). All results were reported on moisture-free basis.

Mineral Analysis

For all elements, two portions of each sample were analyzed in duplicate.

For macromineral analysis, samples were prepared by mixing 100 mg of sample with 3 ml of 60% $HClO_4$, followed by gentle boiling for 30–40 min. At the end of the boiling period, the solution, which was colorless, was cooled and diluted to volume (100 ml). For calcium and magnesium determinations, samples were diluted ten-fold with 1% lanthanum solution to overcome interference. Standard solutions were prepared for calcium and magnesium with a blank containing the same concentration of lanthanum. Measurements were made with an atomic absorption spectrophotometer (Varian Techtron, Model 250) (6). Sodium and potassium were determined with Flame Spectrophotometer Model SP900 (The Unicam Inst., L.T. Cambridge, London) according to specifications in the manual. Total phosphorus was determined by the method that Allen (7) described.

For micromineral analysis, a wet ashing method was used for copper, iron, manganese, and zinc. Ten milliliters of HNO_3 were added to 2 ± 0.005 g of sample into a 100-ml volumetric flask. The contents were brought to a gentle boil for 30–40 min and cooled, and 4 ml of 60% $HClO_4$ was added. The solution was boiled until colorless and allowed to cool, and 50 ml of distilled deionized water was added. The mixture was gently boiled for a few minutes, cooled, and diluted to volume. The microminerals copper, iron, manganese, and zinc were determined by atomic absorption spectrophotometer (6) methods, due to high precision, accuracy, and reproducibility of these supporting methods (8–11).

RESULTS AND DISCUSSION

Previously reported ash contents of flour were 0.49–0.56% (2,3). In this study, ash contents were higher—0.619 ± 0.2% (Tables I and II)—due to enrichment.

Both the mixed dough from the conventional baking system and premixed dough from the continuous baking process were higher in ash content than their respective flours due to addition of various ingredients. Ingredients that contributed to the increase in ash content were salt, yeast, and milk, and yeast food in the case of continuous bread. The difference in formulation in the two baking systems, particularly the use of yeast food with the continuous bread process, would explain the higher ash contents in the dough and bread made by that system.

Flour is considered a poor source of calcium. Addition of NFDM increased calcium content slightly, from 18.6 ± 0.4 mg/100 g in flour to 19.6 ± 3.2 and 20.1 ± 1.3 mg/100 g in bread baked by conventional and continuous methods, respectively. Burton (12) mentioned that the Food and Nutrition Board has recommended an equal intake of calcium and phosphorus for all ages except infants (1.5:1). Therefore, we suggest that the level of calcium should be elevated to a comparable ratio of phosphorus in bread.

Concentration of sodium increased significantly from flour to dough and was carried through the final product due to addition of salt to flour. The reported results on sodium, however, were approximately 50% lower than those reported elsewhere (13).

Magnesium contents in bread baked by both systems were higher than those reported by Zook et al (3), who indicated that percentages of magnesium in bread and flour were identical.

Iron concentration increased slightly during the baking procedure (preparation and baking processes), with the same amount in the crumb and crust for both bread types. The data in this study were lower than those reported by Leichter and Joslyn (14) but similar to those reported by Adams (15) and Miller (16). The disagreement could be attributed to the level of enrichment in flour or method of baking.

TABLE I
Macromineral-Micromineral Distribution in Conventional Baked Bread[a]

Mineral	Flour	Mixed Dough	Fermented Dough	Whole Baked Loaf	Crumb	Crust
Ash (g/100 g)	0.619 ± 0.2[b]	2.44 ± 0.5	2.45 ± 0.7	2.47 ± 0.2	2.45 ± 0.6	2.50 ± 0.1
Ca (mg/100 g)	18.6 ± 0.4	19.4 ± 3.5	19.6 ± 3.5	19.6 ± 3.2	19.6 ± 3.7	19.8 ± 3.1
P (mg/100 g)	126.2 ± 14	130.4 ± 8.1	131.0 ± 7.2	132.0 ± 7.2	132.0 ± 7.5	132.0 ± 6.6
K (mg/100 g)	102.0 ± 14.5	122.0 ± 4.2	122.0 ± 4.2	122.0 ± 1.1	122.0 ± 1.2	122.0 ± 1.3
Na (mg/100 g)	2.50 ± 14.5	300.0 ± 20.1	310.0 ± 20.5	307.0 ± 20.6	310.0 ± 15.8	315.0 ± 18.6
Mg (mg/100 g)	34.0 ± 4.0	44.0 ± 6.1	44.0 ± 7.2	44.0 ± 5.0	45.0 ± 2.1	44.0 ± 2.2
Fe (mg/100 g)	2.4 ± 0.1	2.5 ± 0.2	2.50 ± 0.6	2.50 ± 0.41	2.50 ± 0.20	2.45 ± 0.61
Cu (ppm)	1.9 ± 0.1	1.9 ± 0.2	1.90 ± 0.35	1.90 ± 0.25	1.9 ± 0.20	1.9 ± 0.51
Mn (ppm)	3.7 ± 0.5	3.82 ± 0.2	3.8 ± 0.4	3.8 ± 0.5	3.8 ± 0.3	3.8 ± 0.5
Zn (ppm)	7.2 ± 0.4	7.6 ± 0.6	7.6 ± 0.2	7.6 ± 0.15	7.6 ± 0.4	7.6 ± 0.2

[a]Data reported on moisture-free basis.
[b]Mean and standard deviation.

TABLE II
Macromineral-Micromineral Distribution in Bread Produced by Continuous (Mechanical Development) Method[a]

Mineral	Flour	Premixed Dough	Extruded Dough	Fermented Dough	Whole Baked Loaf	Crumb	Crust
Ash (g/100 g)	0.619 ± 0.2[b]	2.81 ± 0.14	2.88 ± 0.20	2.85 ± 0.25	2.86 ± 0.3	2.84 ± 0.3	2.85 ± 0.7
Ca (mg/100 g)	18.6 ± 0.4	21.2 ± 1.0	20.8 ± 1.0	21.0 ± 1.7	20.1 ± 1.3	21.0 ± 1.0	21.0 ± 1.5
P (mg/100 g)	126.2 ± 14	135.2 ± 1.0	134.4 ± 12	135.7 ± 13	135.0 ± 14	134.2 ± 11	134.0 ± 7.1
K (mg/100 g)	102.0 ± 15.6	135.0 ± 14	130.0 ± 20	130.8 ± 17	134.0 ± 15	135.0 ± 17.5	135.5 ± 16
Na (mg/100 g)	2.50 ± 14.5	345.0 ± 16.7	351.0 ± 10.5	350.0 ± 15.5	355.0 ± 17.6	345.0 ± 10.5	355.0 ± 14.8
Mg (mg/100 g)	34.0 ± 4.0	44.0 ± 2.01	44.0 ± 2.2	44.0 ± 1.25	44.0 ± 1.8	44.0 ± 1.0	44.0 ± 1.7
Fe (mg/100 g)	2.4 ± 0.1	2.8 ± 0.2	2.6 ± 1.2	2.9 ± 1.0	2.8 ± 0.1	2.82 ± 0.9	2.80 ± 0.81
Cu (ppm)	1.9 ± 0.1	2.1 ± 0.4	2.1 ± 0.2	2.0 ± 0.4	2.0 ± 0.21	2.1 ± 0.2	2.2 ± 0.1
Mn (ppm)	3.7 ± 0.5	4.5 ± 0.1	4.5 ± 0.5	4.7 ± 0.2	4.6 ± 0.2	4.6 ± 0.2	4.5 ± 0.1
Zn (ppm)	7.2 ± 0.4	8.4 ± 0.31	8.3 ± 0.55	8.4 ± 0.0	8.4 ± 0.0	8.3 ± 0.5	8.4 ± 0.1

[a]Data reported on moisture-free basis.
[b]Mean and standard deviation.

Similar data was obtained for copper in dough as well as in the bread; however, the amount was slightly higher with the continuous bread baking system. The data are in agreement with those that Zook et al (3) reported.

SUMMARY AND CONCLUSION

This study showed that the concentration of manganese was higher in bread baked by the continuous method than the conventional, with similar amounts in the crumb and crust. The data are in agreement with those that Zook et al (3) reported for bread baked by the continuous system, but slightly lower for the conventional bread.

Zinc contents in bread baked by both methods are comparable to those that Zook et al (3) reported.

Cereal grain products appear to be the best class of foods to meet the criteria of multiple nutrient fortification. Baked bread, regardless of the method of preparation, needs fortification in some minerals, especially in magnesium, zinc, and calcium.

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[Received January 26, 1978. Accepted May 4, 1978]