Mineral and Vitamin Contents of Saudi Arabian Pearl Millet Flour and Bread

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ABSTRACT

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The contents of nine mineral elements, β-carotene, and seven vitamins of B-complex series were studied in pearl millet (*Pennisetum americanum*) flour and bread obtained from Jizan, Saudi Arabia. On a wet basis, the mineral concentrations (mg/100 g) in the flour and bread were, respectively: Na, 17 and 102; K, 420 and 239; Ca, 22 and 23; P, 338 and 250; Mg, 44 and 37; Fe, 3.35 and 3.09; Zn, 1.88 and 0.96; Cu, 0.68 and 0.55; and Mn, 3.09 and 1.89. The concentration of β-carotene (<0.01 mg/100 g) was low in both. The levels of vitamins in the flour and bread were, respectively, (mg/100 g): thiamine, 0.27 and 0.17; riboflavin, 0.15 and 0.11; pyridoxine, 0.27 and 0.24; niacin, 0.89 and 0.87; pantothenic acid, 1.40 and 0.71; folic acid (μg/100 g), 34.9 and 18.3; and vitamin B_{12} (μg/100 g), 0.07 and 0.05. For adults of both sexes, in terms of the Recommended Dietary Allowances of the Food and Nutrition Board, 100 g of fresh millet bread can contribute approximately 3% of Ca, 6% of Zn, 11–12% of Mg, 31% of P, 17–31% of Fe, 2% of vitamin B_{12}, 5% of folic acid, 5–6% of niacin, 6–8% of riboflavin, 11–12% of pyridoxine, and 11–15% of thiamine.

Millets are small-seeded, annual cereal grasses that are well adapted to hot climates (Hulse et al 1980). At least four varieties of millets are extensively grown in certain parts of the world. These are pearl millet (*Pennisetum americanum*, also called *Pennisetum glaucum*, and *Pennisetum typhoideum*), proso millet (*Panicum miliaceum*), finger millet (*Eleusine coracana*), and foxtail millet (*Setaria utalica*). Pearl millet is the most widely grown of all the millets. Whereas in affluent societies millets are used mainly as animal feed, in developing countries most of the millets are consumed directly by humans. In areas where millet is the staple diet, a large portion of the requirements for protein, energy, and micronutrients are derived from millet. Millet, along with sorghum, is also a staple for a segment of the population in northern Yemen and in the northern and southern regions of Saudi Arabia, principally because of traditional dietary habits. Several reports have appeared in the literature on the chemical composition and nutritive value of millets from different parts of the world (Adrian and Sayerse 1957, Uprety and Austin 1972, Rehman et al 1974, Khan and Eggum 1978). However, the minor constituents of millets and of millet breads, such as mineral and vitamin contents, have received scant attention, particularly when compared to those of other cereals.

The present study was therefore undertaken to investigate nine nutritionally important mineral elements, β-carotene, and seven water-soluble vitamins of B-complex series in millet flour available in Saudi Arabia and in the bread made from it locally by the traditional method.

MATERIALS AND METHODS

Materials

Four samples of pearl millet were purchased from the local market in Jizan, in the southern province of Saudi Arabia. The grains were cleaned and ground manually in a traditional stone mill. The flours received after each of the three successive grindings were thoroughly mixed and passed through a 0.5-mm sieve. Subsamples from each of the four flour samples were withdrawn and stored in glass jars in a freezer until analyzed (within one week) for the mineral, β-carotene, and vitamin contents. The remaining flours were employed in the preparation of breads.

Baking of Millet Bread

Millet bread is homemade and is not prepared commercially. Therefore, the millet bread for this study was prepared by the traditional method practiced by housewives. For this purpose, 2-kg of millet flour was mixed well with 30 g of table salt and kneaded by hand in a metal vessel for 15–20 min in 1,240 ml of water until a uniform dough was obtained. The dough was left to sit for 60 min, then pieces (300 g each) were scaled off, rounded, and flattened (2–3-cm thickness) with the palm of the hand. The loaves were baked in an earthen oven called a *tannour* for 15 min (300° C). After baking, the breads were cooled to room temperature and finely ground in a laboratory micromill (Technilab Instruments, model 502) to pass 0.5-mm screen. The samples were immediately freeze-dried and stored in glass jars in a deep freeze (−40° C) for further analysis.

Retention of Nutrients

Retention of mineral elements and vitamin contents was calculated by the procedure of Murphy et al (1975), using the following formula:

$$\text{Percent retention} = \frac{\text{Nutrient content/g of bread} \times \text{bread wt containing 100 g of flour after baking} \times 100}{\text{Nutrient content/g of flour} \times 100 \text{ g of flour}}$$

Chemical Analysis

Moisture and mineral analyses in duplicate were performed on representative samples withdrawn from each of the four millet flour and bread samples. Moisture in samples was determined according to AOAC method 14.004 (1980). For mineral assays, 1–2-g samples were ashed according to method 14.006 of AOAC (1980), and the ash was dissolved in 20% HCl. Nine mineral elements were determined in the ash. Sodium and K were analyzed with a flame-photometer (Beckman, Klina flame); Ca, Mg, Fe, Zn, Cu, and Mn were determined with a Perkin-Elmer model 603 atomic absorption spectrophotometer, and P was determined spectrophotometrically by the procedure of Watanabe and Olsen (1965). Absorbance of standard solutions of metals was verified by values given in the manufacturer's reference manual. To avoid interferences, the final diluted solutions for Ca and Mg contained 1% lanthanum.

For β-carotene and vitamin analyses, the four millet flours as well as bread samples were thoroughly mixed. Representative samples were withdrawn from the composite samples and analyzed in duplicate. The concentration of β-carotene was determined by the method (43.014) of AOAC (1980). For the assays of vitamins, standard methods of AOAC (1980) were used for thiamine (method 43.024), riboflavin (method 43.168), niacin (method 43.150), and vitamin B_{12} (method 43.134). Pyridoxine (B_6) was determined by the procedure of Atkin et al (1943), pantothenic acid by the method of Neilands and Strong (1948), and folic acid according to the method of Hurdle et al (1968).

RESULTS AND DISCUSSION

Mineral Analysis

The mineral composition of millet flour and bread is shown in Table I. The amounts of Na and K in the flour were, in general, comparable to those reported for sorghum (Hulse et al 1980), wheat (Watt and Merrill 1963), and corn (Hussain and Baker 1974). The P content was higher than that in sorghum, wheat, corn, and rice (Hulse et al 1980), which is in line with the report of Desai and Zende (1979) that pearl millet was richer in P than many other cereal grains. The concentration of Ca was low compared to legumes and oilseeds, but such low concentrations are typical of the cereal grains (Watt and Merrill 1963). The 1:15 ratio of Ca to P in millet flour was imbalanced compared to the 2:1–1:1 ratio suggested by the Food and Nutrition Board (NAS/NRC 1980) and implies that Ca might have to be added to millet flour during processing for use in human nutrition if millet is the major portion of the whole diet in the absence of Ca-rich foods such as milk and milk products. Magnesium content of millet flour was generally two to three times lower than that found in many other cereal grains (Hulse et al 1980, Watt and Merrill 1963). The Fe content of millet flour was comparable to that of sorghum and wheat (Watt and Merrill 1963) but higher than that of corn (Hussain and Baker 1974). Even though Desai and Zende (1979) reported a higher Fe content of 8.5–10.5 mg/100 g in millet, the result for Fe obtained here is well within the range reported by Hulse et al (1980). The levels of Zn, Cu, and Mn were comparable to concentrations that have been reported for sorghum (Hulse et al 1980) and wheat (Ghanbari and Mameesh 1971, Lorenz et al 1980) but were higher than those reported for corn (Hussain and Baker 1974).

When concentrations of the mineral elements in millet are expressed in terms of the Recommended Dietary Allowances (RDAs) for adult males 19–22 years of age (NAS/NRC 1980), a 100-g serving of millet bread can contribute approximately 31% of the RDA for P and Fe, 11% of Mg, 6% of Zn, and 3% of Ca (Table II). For adult females, 31% of the RDA for P, 17% of Fe, 12% of Mg, 6% of Zn, and 3% of Ca is met. Recommended Dietary Allowances for the remaining minerals studied have not yet been set, although safe levels of daily intakes have been recommended that are the same for adult males and females. Based on the lowest levels recommended, a 100-g millet bread can supply approximately 9% of Na, 13% of K, 28% of Cu, and 76% of Mn.

Vitamin Analysis

The data on vitamin analysis are presented in Table III. When expressed in milligrams per 100 g (wet weight), the amount of β-carotene in millet flour (<0.01 mg) was lower than that of sorghum (Hulse et al 1980). Pearl millet cannot be considered a good source of β-carotene because it supplies less than 0.3% of the RDA per 100 g. This observation is similar to those in reports published previously (Desai and Zende 1979, Hulse et al 1980). Among the B vitamins, the levels of thiamine and riboflavin were in complete agreement with the data of Desai and Zende (1979), but the niacin content was lower than values reported by these authors.

TABLE I
Mineral Content[a] of Millet Flour and Bread

Mineral	Flour	Bread	Retention[b] (%)
Na	17 ± 0.6	102 ± 5.2	831
K	420 ± 4.8	239 ± 1.0	79
Ca	22 ± 0.7	23 ± 0.6	145
P	338 ± 14.8	250 ± 8.3	102
Mg	44 ± 0.7	37 ± 0.4	117
Fe	3.35 ± 0.25	3.09 ± 0.12	128
Zn	1.88 ± 0.07	0.96 ± 0.01	71
Cu	0.68 ± 0.04	0.55 ± 0.06	112
Mn	3.09 ± 0.10	1.89 ± 0.06	85

[a] Means ± standard deviations of four samples analyzed in duplicate and expressed as mg/100 g (wet basis). Flour moisture = 13%, bread moisture = 30.6%.
[b] Calculated by the procedure of Murphy et al (1975).

However, the values of niacin, thiamine, and riboflavin were similar to those reported by Hulse et al (1980). Comparison of our data on the remaining B vitamins in millet flour with other published reports is difficult in view of the scanty information in the literature about these vitamins. In general, the contents of thiamine, riboflavin, pyridoxine, and pantothenic acid were comparable to the amounts that have been reported for sorghum, wheat, and corn (Hulse et al 1980) but were higher than those of milled rice (Kuzayli et al 1966). However, the levels of niacin and folic acid in millet flour were lower than those found in sorghum (Hulse et al 1980). The niacin content was comparable to that of wheat (bread) and corn, but lower than that of parboiled wheat (Kuzayli et al 1966). More than 90% of niacin in millet is in the bound form (Ghosh et al 1963); therefore its already low amount might have a low bioavailability. The concentration of vitamin B_{12} (0.07 μg/100 g) was low. This low concentration is not unexpected because cereals and legumes are not regarded as good sources of vitamin B_{12}. In terms of the RDAs (NAS/NRC 1980) for males (Table II), 100 g of millet bread can supply 11% of the RDA for thiamine and pyridoxine, 6% of riboflavin, 5% each of niacin and folic acid, and 2% of vitamin B_{12}. For adult females, the RDAs for thiamine, riboflavin, pyridoxine, and niacin are set lower than those for adult males (Table II). Hence, the contribution of bread (100 g) to the RDAs for these vitamins for adult females is slightly higher—15% for thiamine, 12% for pyridoxine, 8% for riboflavin, and 6% for niacin. No RDA has been established for pantothenic acid, although a safe daily intake of 4–7 mg of this vitamin is suggested for adults. Based on an intake of 4 mg per day, a 100-g serving of millet bread can account for approximately 18% of the safe daily intake of pantothenic acid.

Retention of Nutrients in the Bread

The retention of mineral elements is shown in Table I and that of vitamins in Table III. Among the minerals, the concentration of Na, Ca, Mg, Fe, and Cu increased in the bread, leading to retention values greater than 100%. However, the concentrations of Zn, K, and Mn decreased by 29%, 21%, and 15%, respectively; thus 71–85% of these minerals were retained in the millet bread after baking. The exceptionally high retention of Na may be attributed to the addition of table salt in the dough. The increase in other mineral elements might have been caused by the inorganic content of the water used in the dough. Drinking water in the Jizan area is high in the concentration of mineral elements.[1] Another possible reason for the increase in the mineral element content might be contamination from the walls of the earthenware oven on which the dough was pasted during the baking process. The higher values obtained for some of the mineral elements in millet bread is not an isolated case. Emodi and Scialpi (1980) also reported higher retentions for Ca, Mg, and Fe in wheat breads over their corresponding flours, but they did not give any reason for this. Khan and Eggum (1978) also showed higher values for Ca and Fe in various types of Pakistani breads baked from wheat, maize, sorghum, millet, and barley, as compared to their flours. We have no plausible explanation for the decrease in K, Zn, and Mn retention in the bread. In general, mineral elements showed satisfactory retention during baking of millet bread.

All the vitamins were retained well in millet bread except for pantothenic acid, folic acid, and thiamine, which all decreased as a result of baking. The magnitude of loss was 30% for pantothenic acid, 27% for folic acid, and 13% for thiamine. These data imply that, among the vitamins studied, pantothenic acid, folic acid, and thiamine were more susceptible to heat damage in millet bread. The results of vitamin retention in millet bread are compatible with those of wheat bread. Emodi and Scialpi (1980) showed that B vitamins were retained well in wheat bread during baking. Cort et al (1976) and Rubin et al (1977) also reported retention of more than 100% of vitamin B_6 in wheat bread after baking.

Based on our experience, a daily intake of 400 g of bread consumed by an adult in rural areas is a conservative estimate. Based on this amount, millet bread alone can completely meet the daily needs for P, Cu, and Mn of an adult of either sex. The need for Fe is satisfied completely in adult males but only up to 68% in adult females. Other minerals, except Ca, in the same amount of bread can furnish 24–52% of their daily recommended intakes. Among the B vitamins, the same amount of bread can satisfy 72% of the requirement for pantothenic acid in both sexes and 44 and 60% of the thiamine (B_1) for male and female, respectively. All other vitamins except B_{12} can furnish between 20 and 48% of the requirement for both sexes. These estimates are based purely on the potential of millet bread as a source of these minerals and vitamins and does not take into consideration their bioavailability.

[1] M. Jehangir. 1983. Analytical Chemistry Section, Regional Agriculture and Water Research Center, Ministry of Agriculture and Water, Riyadh, Saudi Arabia. Personal communication.

TABLE II
Recommended Dietary Allowance (RDA)[a] of Minerals and Vitamins and Percent RDA of Millet Flour and Bread

Constituent	RDA (mg/day) Adult Male	RDA (mg/day) Adult Female	Percent RDA Flour[b] Male	Percent RDA Flour[b] Female	Percent RDA Bread[b] Male	Percent RDA Bread[b] Female
Minerals						
Na	1,100–3,300[c]	1,100–3,300	2	2	9	9
K	1,875–5,625[c]	1,875–6,525	22	22	13	13
Ca	800	800	3	3	3	3
P	800	800	42	42	31	31
Mg	350	300	13	15	11	12
Fe	10	18	34	19	31	17
Zn	15	15	13	13	6	6
Cu	2–3[c]	2–3[c]	34	34	28	28
Mn	2.5–5[c]	2.5–5[c]	124	124	76	76
Vitamins						
Thiamine (B_1)	1.5	1.1	18	25	11	15
Riboflavin (B_2)	1.7	1.3	9	12	6	8
Niacin	19[d]	14	5	6	5	6
Pyridoxine (B_6)	2.2	2.0	12	14	11	12
Folic acid	400 μg[e]	400 μg[e]	9	9	5	5
Vitamin B_{12}	3 μg	3 μg	2	2	2	2
Pantothenic acid	4–7[c]	4–7[c]	35	35	18	18

[a]Food and Nutrition Board, NAS/NRC (1980). Percent RDA from 100 g of flour and bread (wet basis) for adult male and female 19–22 years of age.
[b]Moisture contents of millet flour and bread were 13 and 30.6%, respectively.
[c]Safe daily intakes according to the Food and Nutrition Board.
[d]As niacin equivalents.
[e]As folacin.

TABLE III
Vitamin Contents[a] of Millet Flour and Bread

Vitamins	Flour[b]	Bread[b]	Retention[c] (%)
β-carotene	<0.01	<0.01	...
Thiamine (B_1)	0.27	0.17	87
Riboflavin (B_2)	0.15	0.11	102
Pyridoxine (B_6)	0.27	0.24	123
Niacin	0.89	0.87	135
Pantothenic acid	1.40	0.71	70
Folic acid	34.90	18.30	73
Vitamin B_{12}	0.07	0.05	99

[a]Average of duplicate results (variation <5%) of composite samples obtained from each of the four flour and bread samples and expressed on wet basis as mg/100 g, except folic acid and vitamin B_{12}, which were expressed as μg/100 g.
[b]Moisture contents of millet flour and bread were 13.0 and 30.6%, respectively.
[c]Calculated by the procedure of Murphy et al (1975).

CONCLUSION

Pearl millet is equal to or superior to many cereals in the profile of essential mineral elements and water-soluble B vitamins. The data presented, especially that concerning the retention of microelements and B vitamins in the pearl millet bread, are seldom reported in the literature. The data should be useful to nutritionists as well as to plant breeders who make a constant effort to improve the nutritional quality by selection and breeding. Moreover, the data augment the efforts underway to compile the local food composition tables.

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