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The influence of roasting and malting on the total and extractable mineral contents of human weaning mixtures prepared from Indian raw materials

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Four weaning foods were formulated using locally available cereals and pulses such as wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), green gram (*Vigna radiata* L.) and jaggery. Cereals and pulses were mixed in the proportion of 7 : 3. Roasting and malting were the processing techniques used in developing weaning foods which resulted in a significant increase of HCl-extractable minerals, an index of their bioavailability to humans. The effect was more pronounced on malting. Both the processing techniques improved HCl-extractability of calcium, iron, phosphorus, zinc and copper. The higher HCl-extractability of the minerals may be ascribed to the reduced content of phytic acid in the processed weaning foods.

INTRODUCTION

Hunger and malnutrition continue to cause enormous worldwide human suffering. The most serious nutritional deficiencies are various forms of protein energy malnutrition (PEM), particularly affecting young children. Iron deficiency is extremely prevalent globally. It is the most common cause of anaemia in the paediatric population with an incidence between 17 and 44% in children between the ages of 6 and 36 months (Lanzkowksy, 1985). Many studies have demonstrated that poor levels of development, cognitive function and behaviourial differences in children are associated with iron deficiency. Calcium deficiency is responsible for improper development of bones in growing children leading to various deformities of the skeletal system.

Breast milk, though indispensable for an infant, is not sufficient to sustain adequate child growth after 6 months of life. Thus supplementation with other foods becomes a necessity. In response to the growing needs of infants, several brands of nutritionally sound formulae are available in the market. But, in spite of these efforts, these processed protein foods remain out of reach of the majority due to their expensiveness. The solution of the malnutrition problem lies in the production of economical and acceptable protein processed food mainly from local resources.

Cereals and pulses constitute important sources of dietary calories and protein for many segments of the world's population, especially in developing countries. They are processed and cooked in a variety of ways, depending on taste and cultural preferences. Besides being good sources of protein and energy, they are good sources of minerals in the human diet. Because of the presence of antinutritional factors such as phytic acid and polyphenols (Chauhan *et al.*, 1986), the HCl-extractability of minerals, an index of their bioavailability from cereals and pulses, may be poor (Nolan & Duffin, 1987) as they complex with divalent cations. The solubility of minerals from foodstuffs, subjected to an in-vitro gastric simulated condition is indicative of their bioavailability from the foodstuffs (Lock & Bender, 1980; Wien & Schwartz, 1985; Kim & Zemel, 1986). The levels of phytic acid (Sutardi & Buckle, 1985; Mahajan & Chauhan, 1987) and polyphenols decline (Khokhar & Chauhan, 1986; Dhankhar & Chauhan, 1987) and availability/solubility of minerals improve (Chompreeds & Fields, 1984; Novert *et al.*, 1985; Mahajan & Chauhan, 1987) following germination of several plant foods.

In view of the importance of cereals and pulses, four weaning mixtures were developed, using roasting and malting, and analysed for total and extractable minerals. This paper reports on the effect of roasting and malting on extractability of Ca, P, Fe, Zn and Cu from weaning foods prepared by utilizing locally available cereals and pulses.

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MATERIALS AND METHODS

Materials

The seeds of wheat (WH-283), dehusked barley (Karan-351) and green gram (K-851) were obtained from the Department of Plant Breeding, Haryana Agricultural University, Hisar, India. Jaggery was procured from the market in a single lot. It is a type of unrefined brown sugar prepared from cane juice. The seeds were freed from dust, broken seeds and other foreign materials.

Development of weaning foods

Wheat, barley and green gram were steeped in double their amount of water at ambient temperature for 12 h. The soaked cereals and pulses were wrapped in damp muslin cloth and allowed to sprout at room temperature (37°C) for 48 h (cereals) and for 24 h (pulses). Then the sprouts were fan-dried overnight. Sprouted cereals and pulses were roasted in an oven at 70°C for 2 h to develop a malt aroma. Grains of wheat, barley and green gram were roasted in a skillet until a uniform light brown colour was produced.

The malted and roasted ingredients were ground in a cyclone mill (mesh size 0·5 mm) separately. The flour thus obtained and powdered jaggery were thoroughly blended.

The proportions of these ingredients (cereal, pulse and jaggery) were selected in such a way that each weaning food could provide 300 kcal, 6–9 g protein and 6–9 mg iron per day and also amino acid make up, similar to that of an egg. The following weaning foods were developed.

I. Roasted wheat (70 g); roasted green gram (30 g); jaggery (25 g).
II. Malted wheat (70 g); malted green gram (30 g); jaggery (25 g).
III. Roasted barley (70 g); roasted green gram (30 g); jaggery (25 g)
IV. Malted barley (70 g); malted green gram (30 g); jaggery (25 g).

Chemical analysis

The weaning foods were analysed for moisture, total nitrogen, ash, fat, crude fibre and calories by employing standard methods (AOAC, 1980). A factor of 6·25 was applied to convert N into crude protein.

Total minerals

The samples were wet acid-digested using a nitric acid and perchloric acid mixture (HNO_3: $HClO_4$, 5 : 1 v/v). The amounts of iron, zinc and copper in the digested sample were determined by atomic absorption spectrophotometry (Lindsey & Norwell, 1969). Calcium in the digested sample was determined by a titration method (Vogel, 1962) employing hydroxylamine hydrochloride, triethanolamine, polyvinyl alcohol and using calcon as the indicator. The violet colour was titrated against 0·01 N EDTA solution to a bluish green end point. Phosphorus was determined colorimetrically (Chen *et al.*, 1956).

HCl-extractable minerals

The minerals in the weaning mixtures were extracted in 0·03 N HCl by shaking the contents at 37°C for 3 h. The clear extract obtained after filtration with Whatman No. 42 filter paper was oven-dried at 100°C and wet acid-digested as mentioned above. The amounts of the extractable phosphorus, calcium, iron, zinc and copper in the digested samples were determined by the methods described above for estimation of total amounts of the minerals.

$$\text{Mineral extractability (\%)} = \frac{\text{Mineral extractable in } 0{\cdot}03\,\text{N HCl}}{\text{Total minerals}} \times 100$$

Statistical analysis

The data were processed for analysis of variance according to the standard methods of statistical analysis (Snedecor & Cochran, 1987).

RESULTS AND DISCUSSION

Nutritional value

The moisture, protein, ash, fat and crude fibre and calorie content of the weaning foods ranged from 5·45 to 6·15%, 13·9 to 14·2 g, 4·20 to 4·61 g, 1·27 to 1·60 g, 1·33 to 1·89 g and 348·5 to 364 kcal per 100 g respectively (Table 1). All the values in these weaning foods

Table 1. Chemical composition of developed weaning foods (expressed per 100 g on dry matter basis)[a]

Weaning foods	Moisture (g)	Protein (g)	Ash (g)	Fat (g)	Iron (mg)	Crude fibre (g)	Calories (kcal)
I	5·51 ± 0·11	14·2 ± 0·32	4·49 ± 0·08	1·60 ± 0·09	16·0 ± 1·35	1·89 ± 0·02	364 ± 2·0
II	6·13 ± 0·07	13·9 ± 0·36	4·20 ± 0·03	1·48 ± 0·07	15·5 ± 2·07	1·78 ± 0·06	362 ± 3·5
III	5·45 ± 0·08	14·1 ± 0·32	4·61 ± 0·08	1·43 ± 0·08	13·9 ± 0·78	1·46 ± 0·02	353 ± 3·5
IV	6·15 ± 0·04	14·0 ± 0·39	4·36 ± 0·03	1·27 ± 0·09	13·9 ± 1·36	1·33 ± 0·05	348 ± 4·5
SE(m)	0·0006	0·15	0·06	0·03	1·37	0·05	2·47
CD ($P < 0{\cdot}05$)	0·002	0·44	0·18	0·10	4·04	0·15	7·51

[a] Values are means ± SD of six independent determinations.

Table 2. Total minerals in raw and processed weaning foods (mg/100 g)[a]

Weaning foods	Ca	P	Fe	Zn	Cu
I Processed	69·3 ± 1·94	315 ± 4·16	16·0 ± 1·35	2·77 ± 0·20	1·08 ± 0·11
Unprocessed (raw)	66·5 ± 1·42	315 ± 4·38	16·1 ± 0·77	2·63 ± 0·20	1·16 ± 0·12
II Processed	66·2 ± 2·64	316 ± 2·37	15·5 ± 2·07	2·77 ± 0·20	1·16 ± 0·12
Unprocessed (raw)	66·5 ± 1·42	315 ± 4·38	16·1 ± 0·77	2·63 ± 0·20	1·16 ± 0·12
III Processed	55·1 ± 1·02	273 ± 3·54	13·9 ± 0·78	2·35 ± 0·20	0·91 ± 0·11
Unprocessed (raw)	54·3 ± 1·17	272 ± 1·53	14·4 ± 0·78	2·49 ± 0·20	1·16 ± 0·12
IV Processed	54·9 ± 1·98	272 ± 3·35	13·9 ± 1·36	2·35 ± 0·20	1·00 ± 0·20
Unprocessed (raw)	54·3 ± 1·17	272 ± 2·61	14·4 ± 0·78	2·49 ± 0·20	1·16 ± 0·16
SE(m)	0·99	2·31	1·37	0·16	0·11
CD ($P < 0·05$)	2·91	6·78	4·04	0·47	0·32

[a] Values are means ± SD of three independent determinations.

were within the ranges prescribed by ISI for processed weaning foods. A low cost infant weaning formula based on locally available indigenous foods containing maize and green gram provided 11·5 g protein and 305 kcal per 80 g (Devadas *et al.*, 1974). On the other hand, higher amounts of protein (19·4 g) per 100 g have been found in another weaning food prepared by blending soybean, wheat, rice flour and skimmed milk (Shulk *et al.*, 1986).

Total minerals

The developed weaning foods had 54·9–69·3 mg calcium, 272–316 mg phosphorus, 13·9–16·0 mg iron, 2·35–2·77 mg zinc and 0·91–1·16 mg copper (Table 2). The calcium, phosphorus, iron, zinc and copper contents of developed weaning foods were similar to those of raw ones. Calcium and phosphorus contents of weaning mixtures I and II were significantly ($P < 0·05$) greater than those of weaning mixtures III and IV. This may be attributed to their compositional differences. Fe, Zn and Cu contents were almost the same in the four weaning mixtures. A similar iron content (14 mg) per 100 g was reported in the developed weaning food 'Soylac' (Shulk *et al.*, 1986). On the other hand, a higher amount of calcium (290 mg) and lower iron content (7·63 mg) have been found in another mixture (Chandrasekhar *et al.*, 1988). Higher amounts of iron in developed weaning foods may be due to the addition of jaggery. Chompreeds & Fields (1984) also reported no change in total zinc, potassium and iron in soybean meal.

Extractable minerals

Significant increases in extractability of Ca, P, Fe, Zn and Cu of about 24–25, 14–17, 15–17, 4–5 and 29–33%, respectively, are observed in roasted weaning mixtures (I and III), whereas the increase in extract-ability ranged from 38 to 43, 31 to 33, 34 to 36, 18 to 19 and 50 to 51%, respectively, in malted weaning mixtures (II and IV) (Table 3). Phytate, the major phosphorus-bearing compound in grains and legumes, chelated essential divalent cations such as copper, zinc, iron and calcium, forming insoluble complexes (Vohra *et al.*, 1965). The decrease in phytic acid content, possibly through its destruction on roasting (Khan *et al.*, 1988) may indicate that the divalent cations are free from the phytate mineral complex which may account for their increased HCl-extractability in roasted weaning foods. Increased extractabilities of iron and zinc (soluble in 0·03 N HCl) in soybean meal by heat treatments have been reported earlier (Chompreeds & Fields, 1984), thus indicating a change in solubility

Table 3. Extractable minerals in raw and processed weaning foods (%)[a]

Weaning foods	Ca	P	Fe	Zn	Cu
I Processed	59·6 ± 1·39	41·4 ± 3·08	42·7 ± 1·35	44·2 ± 0·75	46·7 ± 2·71
	(24·6)	(14·4)	(17·5)	(5·75)	(33·3)
Unprocessed (raw)	47·8 ± 1·66	36·2 ± 0·93	36·3 ± 5·87	41·9 ± 3·73	35·0 ± 3·07
II Processed	68·7 ± 1·98	47·6 ± 2·99	49·5 ± 2·99	49·8 ± 2·89	56·7 ± 1·99
	(43·8)	(31·6)	(36·5)	(19·1)	(50·0)
Unprocessed (raw)	47·8 ± 1·66	36·2 ± 0·93	36·3 ± 5·87	41·9 ± 3·73	35·0 ± 3·07
III Processed	60·0 ± 2·15	43·5 ± 1·53	43·0 ± 1·35	46·7 ± 1·38	45·4 ± 2·85
	(25·6)	(17·7)	(15·4)	(4·67)	(29·5)
Unprocessed (raw)	48·1 ± 0·98	36·9 ± 0·44	37·3 ± 2·15	45·3 ± 4·75	33·9 ± 4·85
IV Processed	66·6 ± 2·08	49·2 ± 3·55	48·9 ± 1·36	52·2 ± 1·97	51·2 ± 2·99
	(38·6)	(33·3)	(34·1)	(18·4)	(51·2)
Unprocessed (raw)	48·1 ± 0·98	36·9 ± 0·44	37·3 ± 2·15	44·1 ± 3·73	33·9 ± 3·07
SE(m)	1·86	1·42	1·57	1·43	1·46
CD ($P < 0·05$)	5·59	4·27	5·04	3·05	4·48

[a] Values are means ± SD of three independent determinations.
Figures in parentheses indicate percentage increase over control values.

during heat treatment. Autoclaving improved the HCl-extractability of minerals in pearl millet (Khetarpaul & Chauhan, 1990).

The greater decrease in phytic acid content by germination can be attributed to leaching of phytate ions into the soaking medium under the influence of a concentration gradient. Such loss may be taken as a function of the change in permeability of the seed coat. Moreover, the phytase present is activated on germination (Mahajan & Chauhan, 1987). Germination has been reported to reduce phytate in various food grains (Chen & Pan, 1977; Hsu *et al.*, 1980; Khokhar & Chauhan, 1986) and to increase HCl-extractable divalent minerals (Rao & Deosthale, 1983; Beal *et al.*, 1984).

Roasting and malting, the common household technologies, are thus an affective way of improving the HCl-extractability of minerals from processed weaning foods. Consumption of such inexpensive processed weaning foods may lead to a better nutritional status of the infants.

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