Food Chemistry **46** (1993) 163–167

The mineral and trace element composition of vegetables, pulses and cereals of southern India

T. S. Srikumar*

Department of Applied Nutrition and Food Chemistry, Chemical Center, University of Lund, Lund, Sweden

(Received 4 March 1992; revised version received and accepted 28 April 1992)

Some cereals, pulses and vegetables commonly used in vegetarian diets in southern India were analysed for their content of minerals and trace elements. The contents of zinc, iron, manganese and potassium were higher in wheat than in rice and different pulses. Wheat, rice and pulses contained higher concentrations of zinc, copper, magnesium, selenium, calcium and iron than did vegetables. The concentrations of lead, cadmium and mercury were higher in wheat and rice than in pulses; among the vegetables amaranth leaves had much higher concentrations of these elements. Compared to other vegetables (raw plantain, brinjal, amaranth leaves), lady's finger contained higher concentrations of zinc, copper, magnesium, calcium and selenium. The estimates of daily intake of zinc and calcium seemed to be inadequate while those of copper, magnesium, selenium, manganese and iron were apparently sufficient; estimates of lead and mercury were below the tolerable daily intake level but that of cadmium was above.

INTRODUCTION

The high content of fibre and phytate in vegetarian diets may inhibit the intestinal absorption of certain minerals and trace elements (Freeland-Graves *et al.*, 1980); moreover, animal foods are better sources of selenium in several countries (Varo & Koivistoinen, 1980). In view of this a number of studies investigating the effects of vegetarian diets on mineral and trace element status have been reported (Gibson *et al.*, 1983; Freeland-Graves, 1980). In a recent study (Srikumar *et al.*, 1992*b*) it was found that the vegetarian diet of southern Indians maintained adequate magnesium, copper, selenium and maybe also zinc status, and that hair contents of lead, cadmium and mercury were higher than values reported from several European countries. The aim of the present study was to determine the contents of elements in the major food items used in the same vegetarian diet regime of southern Indians and to estimate the daily intake.

MATERIALS AND METHODS

Sample collection and handling

Some 15 kg each of three cereals, three pulses and four vegetables, all commonly used in vegetarian diets, were purchased from six different local markets in southern India during the spring of 1988 and were identified by a botanist (Table 1). Visible contaminants were hand-picked from the food samples. Wheat, rice and pulse samples were then washed 3 times with distilled water and finally rinsed twice with deionised water in an acid-washed glass beaker and dried at room temperature for at least 3 days. The samples were powdered in a high speed mill which was coated inside with TiO_2. After each milling, the inside of the mill was washed with distilled water followed by de-ionised water.

The leaves from amaranth plants were hand-picked, and the non-edible parts of lady's finger, raw plantain and brinjal were removed using a plastic knife. The edible portions of vegetables were washed and dried as described above. Homogenisation of vegetable samples was done using a laboratory homogenizer (Ultra Turrax, Janke & Kunkel, Staufen, Germany). A representative portion (approx. 5 g) of the powdered or homogenised food sample was used for moisture and ash determinations. The vegetable samples (approx. 1 kg) were then lyophilized and stored in a desiccator for further analysis. Moisture and ash were assayed according to the AOAC methods 14004 and 14006, respectively (AOAC, 1984).

Assessment of food intake

Information on the consumption of major food items consumed was obtained from 47 out of 83 subjects participating in a previous project where trace element status was studied in a vegetarian group resident in

* To whom correspondence should be addressed. at: Department of Applied Nutrition and Food Chemistry, Chemical Center, PO Box 124, S-221 00 Lund, Sweden

Table 1. Moisture and ash content of cereals, pulses and vegetables

Common name	Botanical name	Moisture[a] (%)	Ash[a] (% dry weight)
Brown rice	*Oryza sativa*	13	0·41
White rice	*Oryza sativa*	13	0·53
Wheat	*Triticum aestivum* L.	12	1·4
Green gram	*V. radiatus*	9·3	2·7
Black gram	*Vigna mungo*	7·4	2·4
Dhal	*Lathyrus sativus*	6·4	2·2
Lady's finger	*Hibiscus esculentus*	86	6·2
Raw plantain	*Musa paradisiaca*	74	4·1
Brinjal	*Solanum melogena*	93	6·6
Cheera	*Amaranthus*	83	9·7

[a] Mean of triplicate analyses.

southern India (Srikumar *et al.*, 1992*b*). The subjects filled in a questionnaire on their usual consumption of the eight foods, using a five-step scale of portion sizes.

Mineral and trace element analysis

Some 0·5 g of powdered cereals, pulses and lyophilized vegetable samples were wet digested using a mixture (5:1) of conc. HNO_3 and 70% $HClO_4$ as described elsewhere (Srikumar & Öckerman, 1990). All analyses were done in triplicate. Concentrations of zinc, copper, manganese, sodium, potassium, calcium, magnesium and iron were determined using a flame atomic absorption spectrophotometer with a deuterium background corrector (Varian Techtron AA5, Victoria, Australia). Lanthanum chloride (1%) in water was used for dilution when analysing for calcium and magnesium. Caesium chloride (1%) in water was used for dilution while analysing for sodium and potassium. Lead and cadmium were measured with an atomic absorption spectrophotometer (Varian AA 1275) equipped with a graphite tube atomiser (GTA 95) and a deuterium background corrector. The furnace operating criteria outlined by the manufacturer were modified by using longer ramp times to avoid minor explosions due to the presence of traces of $HClO_4$ in the digested samples. Mercury was assayed using a cold vapour generation technique (Hatch & Ott, 1968). Selenium was measured with a hydride generation technique in conjunction with atomic absorption spectrophotometry, as described elsewhere (Srikumar & Öckerman, 1991). Bovine liver 1577a (National Institute of Standards and Technology, Gaithersburg, MD) was used as a reference material, and the mean element content (n = 5) deviated less than 4% from the certified value for most elements and −12% for manganese.

RESULTS AND DISCUSSION

Mineral and trace elements

The mineral and trace element concentrations of cereals, pulses and vegetables are presented in Table 2. The content of zinc was lower in rice (approx. 7 mg/kg) than in wheat (26 mg/kg) or pulses (10–13 mg/kg). Among the cereals, wheat manifested higher concentrations of most minerals and trace elements except selenium. As compared to our previous findings, both for organically and non-organically fertilized wheat samples from Sweden (Srikumar & Öckerman, 1991), the contents of zinc and copper in the present Indian wheat samples were lower, that of iron was higher, and manganese and selenium values were similar. In both brown rice and white rice, the contents of most elements were much lower than the corresponding values reported for raw rice in Swedish food tables

Table 2. Mineral, trace and toxic element composition of cereals, pulses and vegetables[a]

	Cereals[b]			Pulses[b]			Vegetables[b]			
	Brown rice	White rice	Wheat	Green gram	Black gram	Dhal	Lady's finger	Raw plantain	Brinjal	Amaranth leaves
Minerals										
Na (mg/kg)	69	18	37	26	90	51	42	29	49	57
K (g/kg)	1·8	0·93	3·9	0·84	0·92	1·3	1·7	2·9	1·6	1·9
Ca (g/kg)	0·05	0·06	0·25	1·1	0·56	0·47	0·64	0·09	0·08	0·50
Mg (g/kg)	0·33	0·20	0·97	1·5	1·4	1·1	0·30	0·24	0·14	0·17
Fe (mg/kg)	12	6·5	42	44	37	33	4·7	4·9	2·7	21
Trace elements										
Zn (mg/kg)	5·7	8·1	26	13	10	12	13	0·84	0·96	0·75
Cu (mg/kg)	2·6	1·7	3·7	6·7	2·7	2·7	0·14	<0·04	<0·05	<0·04
Mn (mg/kg)	6·9	7·4	37	12	13	10	1·4	7·3	0·86	18
Se (μg/kg)	180	120	10	130	110	130	0·73	0·26	39	0·51
Toxic elements										
Pb (μg/kg)	30	50	80	0·52	0·26	0·16	0·13	0·09	0·47	320
Cd (μg/kg)	2·4	3·2	30	0·62	0·66	1·3	0·48	0·07	0·22	1400
Hg (μg/kg)	3·1	7·4	9·2	0·68	0·72	0·94	0·39	0·83	0·59	1·3

[a] Values presented on a wet weight basis.
[b] Mean of triplicate analyses.

(Swedish National Food Administration, Livsmedelstabeller, 1986). In brown rice, the content of selenium was higher, that of iron was similar and those of other elements were lower, compared to the respective data in other food tables (Ministry of Agriculture, Fisheries and Food, UK, 1991). The content of iron in brown rice was approximately twice that in white rice, whereas the magnesium content was about 50% higher in brown rice.

The contents of calcium and magnesium were higher in pulses than in cereals, but the concentrations of lead, cadmium and mercury were lower in pulses. Compared to published element data in other food tables (Ministry of Agriculture, Fisheries and Food, UK, 1991) the present values of sodium, potassium, iron and zinc were lower, those of magnesium and manganese were similar in both black gram and green gram, that of calcium was higher in green gram but lower in black gram, and the selenium content of green gram was similar. The data for manganese and iron in dhal found in the present study were similar, calcium was found to be 34% higher and zinc 50% lower than the respective data for dhal reported by Singh *et al.* (1992).

Vegetables contained higher concentrations of potassium than of sodium which was consistent with another report (Marsh & Koons, 1983). They also had lower concentrations of copper (< 0·04 mg/kg) and zinc (0·8–1 mg/kg) than did pulses and cereals. Compared to the cereals and pulses, vegetables contained a much lower concentration of selenium. Among the vegetables, brinjal had a higher concentration of selenium. The contents of calcium, magnesium, iron, copper and manganese in brinjal were similar to values reported in other food tables (Ministry of Agriculture, Fisheries and Food, UK, 1991). The content of sodium was higher and those of zinc and potassium were slightly lower. The concentrations of potassium, calcium and iron in lady's finger were lower than those in published food tables (Food Composition and Nutrition Tables, 1981/82). Most cereals and vegetables analysed in the present study were found to be poor sources of calcium (0·5–1·1 g/kg), but rather good sources of magnesium (0·3–1·5 g/kg) and iron (20–42 mg/kg).

Toxic elements

Most cereals and vegetables analysed in the present study had comparatively high concentrations of lead, cadmium and mercury, and the concentrations were higher in white rice than in brown rice (Table 2). The concentrations of lead and cadmium in amaranth leaves were markedly higher than those found in the other food items. Srikant & Reddy (1990) found even higher concentrations of lead (12·2 ppm) and cadmium (1·10 ppm) than those reported here in amaranth leaves grown in sewage sludge in southern India.

The varied concentrations of minerals, trace and toxic elements in these food items may be explained by several factors such as element content of soil, variation in element uptake by different plants, and fertilization and processing techniques. The lower content of magnesium in white rice than in brown rice may be explained by a loss of magnesium during rice polishing (Marier, 1986). Losses of calcium, iron, zinc and manganese due to the dehulling of dhal have been reported (Singh *et al.*, 1992). Of the food items studied, those which had high concentrations of some minerals and trace elements might not necessarily be good sources of these elements, because many studies have indicated low bioavailability of certain constituents such as zinc, copper and magnesium from phytate- and fibre-rich foods (Turnlund *et al.*, 1984; Schwartz *et al.*, 1986). We have recently reported that a shift from a mixed to a lactovegetarian diet decreased the zinc, copper and magnesium status of healthy subjects, although the intake levels of these elements from both diets were similar (Srikumar *et al.*, 1992*a*). Although some food items analysed seemed to be good sources of iron, the absorption of this element from vegetable sources has been reported to be low (Hazell, 1985).

Intake of minerals, trace and toxic elements

Estimates of daily element intake from the foods analysed (Table 3) indicated that the daily intake of zinc (8 mg) was below the recommended intake, while that of copper (1·5 mg) was above this level (Bhattacharya *et al.*, 1985). The estimates of daily intake of magnesium and selenium were higher than the reported daily intake levels for Swedish subjects (Borgström *et al.*, 1979), but that of calcium was much lower. Lady's finger was a better source of zinc (0·7 mg/portion size) than other vegetables, a finding consistent with a report that this food item, purchased locally in Houston (USA), provided 0·82 mg zinc/portion size (Wolinsky *et al.*, 1988). The high selenium content found in most food items confirms our previous assumption that the southern Indian vegetarians with higher plasma selenium concentrations than Swedish subjects, live in an area rich in soil selenium (Srikumar *et al.*, 1992*b*), and supports the idea that consumption of plant foods produced in such areas can maintain selenium intake and status (Christensen *et al.*, 1988). The finding of a higher daily intake of manganese from cereals than from other food items was consistent with other studies (Varo & Koivistoinen, 1980; Hazell, 1985). The daily intakes of potassium and sodium found in the present study were lower than those reported for Swedish subjects on a mixed diet (Borgström *et al.*, 1979). The present observation that the highest percentage of daily sodium intake was via cereals was consistent with the finding for an average UK diet (Hazell, 1985).

The estimates of daily intake of lead and mercury were lower, and that of cadmium was higher, than the tolerable daily intake levels of these elements (0·43 mg lead, 0·04 mg mercury and 0·06–0·07 mg cadmium) (FAO/WHO, 1972). Compared to that of the Swedish subjects (Borgström *et al.*, 1979), the estimated daily intake levels of lead and cadmium by southern Indian vegetarians were higher and that of mercury was similar, which may explain the higher hair contents of lead and

Table 3. Estimates of daily intake of some minerals, trace and toxic elements from eight foods by adult southern Indian vegetarians

Major food items	Approximate daily intake (g/d)	Zn (mg)	Cu (mg)	Mg (mg)	Se (μg)	Ca (mg)	Fe (mg)	Mn (mg)	Na (mg)	K (g)	Pb (μg)	Cd (μg)	Hg (μg)
White rice	300	2·4	0·5	60	36	18	2	2	5	0·3	15	0·9	2·2
Wheat	100	2·7	0·4	100	1	25	4·3	4	4	0·4	8	3	0·9
Black gram	75	0·8	0·2	105	8·3	42	2·8	1	7	0·1	0·02	0·05	0·05
Dhal	50	0·6	0·1	55	6·5	24	1·7	0·5	3	0·1	0·01	0·07	0·05
Green gram	50	0·7	0·3	75	7	55	2·2	0·6	1·3	<0·1	0·03	0·03	0·03
Lady's finger	50	0·7	<0·1	15	<0·1	32	0·2	0·1	2·1	0·1	0·01	0·02	0·02
Brinjal	50	0·05	<0·1	7	2	4	0·1	<0·1	2·5	0·1	0·02	0·01	0·03
Amaranth leaves	100	0·08	<0·1	17	0·1	50	2·2	2	6	0·2	32	140	0·13
Total		8	1·5	434	61	250	15·5	10·2	30·9	1·3	55·09	144·08	3·41

cadmium previously found in the Indians (Srikumar *et al.*, 1992*b*). Their higher hair content of mercury might be due to the ingestion of this element via other sources.

The actual intake levels of some elements from the food items might vary from the present estimates calculated after chemical analysis of raw food items. Loss of iron, zinc, copper and selenium from food materials due to household cooking has been reported (Higgs *et al.*, 1972; Prasad, 1979; Umoh & Bassir, 1981). The daily element intake might also be slightly higher than the estimated amount due to the consumption of spices, herbs and other minor items. For instance, curry powder, which is commonly used by this population, contains high amounts of zinc (41 mg/kg), copper (10 mg/kg) and calcium (6 g/kg) (Ministry of Agriculture, Fisheries and Food, UK, 1991). Also, the addition of table salt during food processing will certainly increase the sodium intake.

Interpretation of the present intake data should be undertaken with caution since they are based on a limited number of food items from a single season, and using an approximate measure of daily food intake. The study implies that the daily intake levels of zinc and calcium from foods consumed in vegetarian diets of southern Indians might be inadequate while those of copper, magnesium, selenium, manganese and iron are apparently sufficient. The daily intake levels of sodium and potassium are lower than those from western mixed diets. More information on the bioavailability of these elements from the different food items is necessary for a detailed interpretation of the data.

ACKNOWLEDGEMENTS

The study was partly supported by grants from the Swedish Council for Forestry and Agricultural Research (to Dr B. Åkesson), and the Medical Faculty, University of Lund.

REFERENCES

AOAC. (1984). *Official Methods of Analysis* (14th edn). Association of Official Analytical Chemists, Washington, DC.

Bhattacharya, R. D., Patel, T. S. & Pandya, C. B. (1985). Copper and zinc in biological samples from healthy subjects of vegetarian food habit in reference to community environment. *Chronobiologica*, **12**, 145–52.

Borgström, B., Nordén, Å., Åkesson, B., Abdulla, M. & Jägerstad, M. (1979). Nutrition and old age. Chemical analyses of what old people eat and their states of health during six years of follow-up. *Scand. J. Gastroenterol.*, **14**, suppl. 52.

Christensen, M. J., Bown, J. W. & Lei, L. I. (1988). The effect of income on selenium intake and status in Utah county, Utah. *J. Am. Coll. Nutr.*, **7**, 155–67.

FAO/WHO. (1972). Sixteenth report of the joint FAO/WHO expert committee on food additives. Technical report series No. 617.

Freeland-Graves, J. H. (1980). Zinc status of vegetarians. *J. Am. Dietet. A.*, **77**, 655–61.

Freeland-Graves, J. H., Ebangit, M. L. & Bodzy, D. W. (1980). Zinc and copper content of foods used in vegetarian diets. *J. Am. Dietet. A.*, **77**, 648–54.

Gibson, R. S., Anderson, B. M. & Sabry, J. H. (1983). Trace metal status of a group of post-menopausal vegetarians. *J. Am. Dietet. A.*, **82**, 246–50.

Hatch, W. R. & Ott, W. L. (1968). Determination of submicrogram quantities of mercury by atomic absorption spectrophotometry. *Anal. Chem.*, **40**, 2085–7.

Hazell, T. (1985). Minerals in foods: Dietary sources, chemical forms, interactions, bioavailability. *Wld. Rev. Nutr. Diet.*, **46**, 1–123.

Higgs, D. J., Morris, V. C. & Levander, O. A. (1972). Effect of cooking on selenium content of foods. *J. Agr. Food Chem.*, **20**, 678–80.

Marier, J. R. (1986). Magnesium content of the food supply in the modern-day world. *Magnesium*, **5**, 1–8.

Marsh, A. C. & Koons, P. C. (1983). The sodium and potassium content of selected vegetables. *J. Am. Diet. Assoc.*, **83**, 25–7.

Ministry of Agriculture, Fisheries and Food. (1991). *The Composition of Foods*. Royal Society of Chemistry, Letchworth, UK.

Prasad, A. S. (1979). *Zinc in Human Nutrition*. CRC Press, Boca Raton, Florida.

Scherz, H. & Kloos, G. (1981). *Food Composition and Nutrition Tables*. Wissenschaftliche Verlagsgesellschaft mbH, Stuttgart 1981.

Schwartz, R., Apgar, B. J. & Wien, E. M. (1986). Apparent absorption and retention of calcium, copper, magnesium, manganese and zinc from a diet containing bran. *Am. J. Clin. Nutr.*, **43**, 444–55.

Singh, U., Rao, P. V. & Seetha, R. (1992). Effect of dehulling on nutrient losses in chickpea (*Cicer arietinum* L.). *J. Food Comp. Anal.*, **5**, 69–76.

Srikant, R. & Reddy, R. P. (1990). Lead, cadmium and chromium levels in vegetables grown in urban sewage sludge—Hyderabad, India. *Food Chem.*, **40**, 229–34.

Srikumar, T. S. & Öckerman, P. A. (1990). The effects of fertilization and manuring on the content of some nutrients in potato (var. *provita*). *Food Chem.*, **37**, 47–60.

Srikumar, T. S. & Öckerman, P. A. (1991). The effects of organic and inorganic fertilization on the content of trace elements in cereal grains. *Food Chem.*, **42**, 225–30.

Srikumar, T. S., Johansson, G. K., Öckerman, P. A., Gustafsson, J. Å. & Åkesson, B. (1992*a*). Trace element status in healthy subjects switching from a mixed to a lactovegetarian diet for 12 months. *Am. J. Clin. Nutr.*, **55**, 885–90.

Srikumar, T. S. Öckerman, P. A. & Åkesson, B. (1992*b*). Trace element status in vegetarians from southern India. *Nutr. Res.*, **12**, 187–98.

Swedish National Food Administration (1986). *Livsmedelstabeller*. Uppsala, Sweden.

Turnlund, J. R., King, J. C., Keyes, W., Gong, B. & Michel, M. C. (1984). A staple isotope study of zinc absorption in young men: effects of phytate and α-cellulose. *Am. J. Clin. Nutr.*, **40**, 1071–7.

Umoh, I. B. & Bassir, O. (1981). Nutrient changes in some Nigerian peasant foods during cooking. IV. Mineral element composition. *Nutr. Rep. Int.*, **24**, 105–7.

Varo, P. & Koivistoinen, P. (1980). Mineral element composition of Finnish foods. *Acta Agr. Scand.*, suppl. 22, 165–71.

Wolinsky, I., Lane, H. W., Warren, D. C. & Whaley, B. S. (1988). Zinc and selenium in selected and ethnic/regional foods. *J. Agric. Food Chem.*, **36**, 749–52.