ELSEVIER

Food Chemistry 70 (2000) 57–61

Food Chemistry

www.elsevier.com/locate/foodchem

Risk of increased aluminium burden in the Indian population: contribution from aluminium cookware

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Received 19 August 1999; received in revised form 21 December 1999; accepted 21 December 1999

Abstract

Aluminium (Al) is a well-established potential neurotoxin in addition to its role in the aetiopathogenesis of certain disorders related to bone and blood. Food and water are the major sources of Al ingestion in normal population groups. Al content of certain cooked foods was therefore analysed to assess its daily burden in the Indian population. Significant levels of Al were detected in most of the cooked foods analysed. Green leafy vegetables and pulse preparations (dhal/sambar) contribute greatly to total daily Al intakes. Storage of food in Al vessels also raises Al content significantly. It thus appears that total intake of Al in Indian population groups, who regularly use Al cookware and storage utensils, may be higher than that reported elsewhere.

Keywords: Aluminium; Cooked food; Leaching; Daily intake; Indian population

1. Introduction

The neurotoxic potential of Al is undisputed. Individuals with renal insufficiency are particularly susceptible to Al toxicity; Al causes a neurological syndrome, commonly known as dialysis encephalopathy (Alfrey et al., 1972). Generally, the accumulation of Al in the body is reported to cause disorders related to bone, brain and blood (Alfrey, Len Gendre & Kaehny, 1976; McDermott, Smith, Ward, Parkinson & Kerr, 1978; Ward, Feest, Ellis, Parkinson & Kerr, 1978).

Food and water are the two major sources of oral Al ingestion in normal population groups. Al absorption is known to occur, albeit to a limited extent, even in healthy individuals with intact renal function (Gorsky, Dietz, Spencer & Osis, 1979; Greger & Baier, 1983). Besides the Al present in foods per se, humans may also be exposed to additional Al contributed by cooking utensils and storage and packaging containers made of Al (Levick, 1980; Lione, 1983; Trapp & Cannon, 1981; Underwood, 1977). Although there is currently no definitive evidence in humans indicating Al toxicity through routine dietary ingestion of this metal, there is continued interest and concern about the Al content of foods and diets, and their possible relationship with Al toxicity, particularly in the ageing population.

While the Al content of most western foods and diets has been reported, there is a lack of precise information on Indian foods and diets. Rao and Rao (1993) have estimated the Al content of a few selected raw foods but no estimates of daily intakes of Al through diets containing those foods have been provided.

A study was therefore undertaken to analyse the Al content of the commonly consumed foods in cooked form and to assess the daily burden of Al, through diet, of the Indian population. Since Al vessels are the most commonly-used cooking utensils in rural and semi-urban India, the contribution of Al, from old and new cooking utensils, to total daily intake of Al, was also examined.

2. Materials and methods

Food preparations were classified as vegetables, leafy vegetables, roots and tubers, pickles, chutneys (semi-solid pastes), dhal/sambar (split pulse/lentil soups), cereals, milk, curds, etc. Some of the commonly-used vegetables such as kovai (Coccinia *indica*), ladies finger

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PII: S0308-8146(00)00068-6

(Hibiscus *esculentus*), banana (Musa *paradisiaca*), French beans (Phaseolus *vulgaris*), cabbage (Brassica *oleracea* var *capitata*), cauliflower (Brassica *oleracea* var *botryhis*), brinjal (Solanum *melangena*), potato (Solanum *tuberosum*), yam (Amorphophallus *eomapanulatum*), leafy vegetables such as spinach (Spinacea *oleracea*), amaranth (Amaranthus sps), gogu (Hisbiscus *sabdarrifa*), bassella (Bassella *alba*) and chutneys made from ginger (Zingiber *officinale*), tamarind (Tamarindus *indica*), tomato (Lycopersicon *esculentum*) and mint leaves (Mentha *piperia*), were analysed for their Al content. Red gram (Cajanus *cajan*) was the pulse chosen for dhal/sambar preparations (liquid pulse preparation) and rice (Oryza *sativa*) was selected as the representative cereal. Some of the common spices such as cumin (Cuminum *cyminum*), mustard (Brassica *campestris*), chilli (Capsicum *annuum*), turmeric (Curcuma *longa*), pepper (Piper *nigrum*), cinnamon (Cinnamonum *zeylanicum*), cloves (Eugenia *caryophyllata*), coriander (Coriandrum *sativum*) and cardamom (Elettaria *cardamomum*) were used in vegetable, dhal/sambar and chutney preparations. They were also individually analysed for their Al concentrations.

Traditional South Indian recipes were employed for the preparation of food items. Certain dishes (pickles/chutneys) were stored for 24 to 72 h at room temperature (as is a common practice) before analysis of Al. The utensils used were stainless steel (control vessels), old (10 years) and new (1 to 15 days) Al vessels.

Table 1
Aluminium content of cooked food (mg/100 g)[a]

Sample No.	Food	Stainless steel vessel (control)	Old Al vessel		New Al vessel	
			Al content	% increase (of control)	Al content	% increase (of control)
1	Rice	0.32	0.50	55	0.85	165
Vegetables						
2	Kovai	0.66	1.21	97	2.38	259
3	Ladies finger	1.03	0.97	–	1.40	35
4	Banana	2.71	2.75	1.6	2.81	3.9
5	Beans	1.05	1.17	8.0	1.30	23.4
6	Cabbage	0.81	1.02	25.7	1.31	61.9
7	Cauliflower	1.28	1.59	24.9	1.90	48
Roots and tubers						
8	Potato	1.08	1.46	35.4	1.68	55.8
9	Yam	1.57	4.80	206	4.80	205
Pulses (red gram) sambar/dhal						
10	Plain sambar	5.78	6.96	20.4	11.24	94.5
11	Mixed veg. sambar	6.65	7.23	9.1	8.81	32.5
12	Plain dhal	0.94	1.50	60	1.93	106
13	Tomato dhal	1.06	0.97	–	2.02	90
Leafy vegtables (as dhal)						
14	Spinach	5.54	6.0	8.1	7.34	32.5
15	Amaranthus	11.07	21.70	96	30.7	178
16	Gogu	9.03	10.84	19.6	10.56	16.7
17	Basella	3.79	4.39	15.8	4.85	28.1
18	Milk (boiled)	0.08	0.08	–	0.08	–
19	Curds (set overnight)	0.07	0.07	–	0.30	352
20	Tea decoction	0.38	0.38	–	0.54	42
21	Water (mg/100 ml)					
	Boiled for 20 min	0.06	1.5	–	0.16	–
	Boiled for 40 min	0.06	8.8	–	2.0	–
22 *Spices (mg/100 g)*						
	Pepper	3.45				
	Tamarind	3.55				
	Cumin	5.25				
	Asafoetida	15.10				
	Fenugreek	1.25				
	Coriander	0.64				
	Mustard	1.15				

[a] Each value is an average of two observations. Plant variety is as given in the text.

The cooked food preparations were processed and analysed for Al by atomic absorption spectrometry (Varian Techtron VA-6 Model). Five grammes of the diet were weighed into a silica crucible and heated in a muffle furnace at 200°C for 2 h, after which the temperature was raised to 500°C for 8–10 h to completely destroy the organic matter. The ash was dissolved in 1 ml of HCI (6 M) and the volume was then made up to 10.0 ml with deionized water. Samples were transferred into polypropylene tubes and stored at 4°C until further analysis. Samples for the analysis of Al contained 2 mg of potassium/ml, to suppress the ionization effect. The instrumental parameters for Al were: wavelength 309.3 nm, lamp current 5 mA, spectral band pass 0.5 nm and air acetylene flame. The detection limit of Al for the instrument was 0.2 ng/ml. An internal standard (Sigma Al standard) for Al was included in the estimations and its percentage recovery was estimated. The recovery was found to be between 95 and 97% for all samples.

Al content of the prepared food was expressed as mg Al/100 g of cooked food item (mg/100 g).

3. Results

Significant levels of Al were detected in most of the foods analysed. Marked differences were noted among individual preparations with respect to their Al content. Green leafy vegetables and dhal/sambar preparations contribute greatly to total daily Al intakes. The dhal preparations containing amaranth and gogu provided 11 and 9 mg of Al per 100 g, respectively. The contribution from milk, curd and rice was found to be low or negligible (Table 1).

Table 2
Average aluminium content of cooked food (mg/100 g)[a]

Sample No.	Food material	Al content (mg/100 gm) of food cooked in		
		Stainless steel vessel	Old Al vessel	New Al vessel
1	Vegetables	1.26	1.45	1.85
	($n=6$)	(0.66–2.71)	(0.97–2.75)	(1.3–2.81)
2	Leafy vegetables	7.36	10.73	13.37
	($n=4$)	(3.79–11.07)	(4.39–21.70)	(4.85–30.7)
3	Pulses (redgram)	3.41	4.06	9.24
	($n=5$)	(0.94–6.65)	(0.97–7.23)	(1.93–22.2)
4	Roots and tubers			
	Yam	1.57	4.80	4.80
	Potato	1.08	1.46	1.68
5	Cereals (rice)	0.32	0.50	0.85

[a] Each value is an average of two observations. Al content given in the parenthesis is the range.

Table 3
Aluminium content of food cooked and stored in new Al vessels (mg/100 g)[a,b]

Sample No.	Food material	Storage time (in days)	Al content (mg/100 g)
1	Vegetables	–	1.31
	(Brinjal, French beans)		(1.21, 1.41)
	($n=2$)	One	1.59
			(1.27, 1.92)
2	Dhal	–	2.09
	(plain dhal, tomato dhal)		(1.92, 2.27)
	($n=2$)	One	(2.96)
			(1.41, 4.52)
3	Cereals (rice)	–	
		One	0.85
			1.20
4	Pickles/chutneys	–	5.92
	(tomato, mint leaves, tamarind, gogu, ginger)		(0.88–15.92)
	($n=5$)	Three	16.17
			(1.43–44.64)
		Five	43.17
			(40.72–45.62)

[a] Each value is an average of two observations.
[b] Value in parentheses is the range of Al content. Only gogu and tamarind chutneys were stored for 5 days. Normally pickles and chutneys are stored for a longer duration when compared to vegetables and cereals.

Table 4
Average computed intake of aluminium (mg/day) per consumption unit (CU) by urban and rural populations when food is cooked in stainless steel or aluminium vessel[a]

Sample No.	Foodstuffs	Urban			Rural		
		Stainless steel vessel	Old Al vessel	New Al vessel	Stainless steel vessel	Old Al vessel	New Al vessel
1	Cereals (rice) ($n=2$)	1.08	1.70	2.88	1.70	2.65	4.51
2	Pulses ($n=5$)	1.90 (0.49–3.52)	2.21 (0.51–3.83)	3.18 (1.02–5.94)	1.18 (0.31–2.19)	1.38 (0.32–2.39)	1.98 (0.64–3.70)
3	Leafy vegetables ($n=4$)	4.49 (2.31–6.77)	6.53 (2.68–13.24)	8.17 (2.96–18.73)	1.03 (0.53–1.55)	1.50 (0.61–3.04)	1.88 (0.68–4.30)
4	Other vegetables ($n=6$)	0.77 (0.40–1.65)	0.85 (0.59–1.68)	1.13 (0.79–1.71)	0.95 (0.50–2.03)	1.09 (0.73–2.06)	1.39 (0.98–2.11)
5	Roots and tubers ($n=2$)	1.04	2.50	2.59	1.10	2.60	2.69
6	Milk and milk products ($n=2$)	0.27	0.27	0.27	0.07	0.07	0.07
	Total Al[b] (mg/day)	9.55 (5.59–16.2)	14.20 (8.25–23.2)	18.22 (10.51–32.1)	6.03 (4.21–8.64)	9.29 (6.98–12.8)	12.52 (9.57–17.4)

[a] Values in the parentheses indicate the range.
[b] Based on the amount of foodstuff actually consumed by populations according to the report of the Expert Group of ICMR (National Nutrition Monitoring Bureau, 1989).

It was observed that a contribution of Al to total daily intake, occurred from the Al cooking utensils and the new vessels appeared to be much more easily attacked by foods as compared to the old. It was also observed that the nature of food greatly determines the extent of Al migration from the vessels. More acidic food preparations containing green leafy vegetables, tomato dhal/sambar, etc., caused greater migration of Al into food from the utensils. Here again, the maximum effect was observed with amaranth. The increase in the Al content of the amaranth preparation when cooked in old and new Al vessels was about 10 and 21 mg per 100 g, respectively (Table 2).

It was observed that Al leached into the food when it was cooked and stored in Al vessels. As expected, acidic food preparations caused a greater leaching of Al into the food from the vessels upon storage (Table 3). Boiling of water in Al vessels, by itself caused significant time-dependent leaching of Al into the medium (Table 1). Among the spices used, asafoetida was found to have the highest Al content (15.1 mg/100 g) followed by cumin (5.3 mg/100 g) (Table 1). Some of the commonly-consumed beverages such as tea, contribute only to a minor extent to the total Al intakes (about 0.4 mg/cup of tea). It was found that, although tea leaves contain very high levels of Al, only a small proportion of it appears in the tea decoction (Table 1).

Based on the reported average amounts of nutrients actually consumed by Indian populations (National Nutrition Monitoring Bureau, 1989), the total daily intakes of Al were calculated from the data obtained from the present study on Al content of cooked foods. Intakes were found to be 9.6 (5.6–16.2), 14.2 (8.3–23.2) and 18.2 (10.5–32.0) mg of Al consumed in a day in urban populations when the foods were cooked in stainless steel, old Al and new Al vessels, respectively. The total daily intakes of Al in rural populations are expected to be 6.6 (4.2–8.6), 9.3 (7.0–12.8) and 12.5 (9.6–17.5) mg, when stainless steel, old Al and new Al vessels are used for cooking, respectively (Table 4).

4. Discussion

Data obtained on the Al content of foods clearly revealed that staple diets, based on cereals such as rice, contribute very little to total daily intakes. The same is true with regard to milk and milk-based preparations, which are normally consumed. Most of the vegetables, seem to contribute significant amounts of Al, especially the green leafy vegetables, such as amaranth and gogu. Among other ingredients of the diet, which are normally consumed, spices such as asafoetida, cumin and fenugreek contribute significant amounts of Al. Among the spices, asafoetida was found to have the highest content of Al. Although, tea leaves contain very high amounts of Al, very little is extracted into the tea decoction and hence it appears to be a minor contributor of Al to the total daily intakes.

Use of Al utensils for cooking foods is known to contribute a significant amount of Al and such a leaching of Al from the vessels into food is influenced by other factors such as pH, concentration of salt, sugar, etc. It was observed, in the present study, that boiling of water (pH 6) in Al vessels by itself resulted in a significant leaching of Al into the medium. In addition, acidic food preparations such as dhal, sambar and especially those containing green leafy vegetables, tomato, tamarind, etc. (Table 1) caused a significant leaching of Al from the vessel into the preparation. The difference in the extent of migration of Al between new and old vessels clearly shows that the new vessels are much more easily attacked by foods and therefore the extent of migration of Al from vessels gradually declines with use. Similar observations were also reported by other workers (Pennington & Jones, 1989).

Since regular use of Al utensils is quite commonly seen in rural, as well as certain sections of urban, populations, it becomes apparent that total daily intake of Al in such populations is higher than that reported for affluent populations in India or elsewhere. In fact, the calculated range of daily intakes of Al in the Indian population appears to be greater than that reported elsewhere (9 to 32 mg per day), wherever Al utensils are regularly used.

In a recent report from WHO-FDA (World Health Organization, 1989), specifications with regard to provisional tolerable weekly intakes (PTWI) of Al were given as 7 mg/kg body weight, which means that for an average 50 kg body weight person, daily intakes of 50 mg of Al are tolerated. Based on this information, it appears that dietary intakes of Al in India or elsewhere do not exceed the tolerance limits. However, such recommendations are generally based on the data available from short-term toxicity studies and are therefore subject to revision as and when data become available from chronic toxicity studies. It is also pertinent to examine the applicability of such recommendations, especially in populations where widespread deficiencies of other minerals, such as calcium and iron, are common. In fact, recent evidence does suggest that Al absorption and its tissue accumulation are greatly influenced by nutrients such as iron, calcium, zinc, and dietary factors such as citrate.

5. Conclusion

The results of the present investigations revealed that major contributions of Al from Indian foods are derived through consumption of vegetables, spices and pulses, while cereals, milk and milk products contribute negligible amounts. Use of Al utensils significantly contributes Al to total daily intakes through foods. Total daily intake of Al in rural and certain sections of urban populations, where Al utensils are regularly used, appears to be greater than in urban populations where usage of Al utensils is limited.

Acknowledgements

The authors are grateful to the Director, National Institute of Nutrition (NIN), Hyderabad, for the interest in this study. The technical help of Mr. M.M. Khan and Mr. J.S. Acharya is also acknowledged.

References

Alfrey, A. C., Mishell, J. M., Burks, J., Contigulia, S. R., Rudolph, H., Lewin, E., & Holmes, J. H. (1972). Syndrome of multifocal seizures associated with chronic hemodialysis. *Transactions of American Society for Artificial Internal Organs, 18*, 257–261.

Alfrey, A. C., Len Gendre, G. R., & Kaehny, W. D. (1976). The dialysis encephalopathy syndrome. Possible aluminium intoxication. *New England Journal of Medicine, 294*, 184–188.

Greger, J. L., & Baier, M. J. (1983). Excretion and retention of low or moderate levels of aluminium by human subjects. *Food and Chemical Toxicology, 21*(4), 473–477.

Gorsky, J. E., Dietz, A. A., Spencer, H., & Osis, D. (1979). Metabolic balance of aluminium studied in six men. *Clinical Chemistry, 25*(10), 1739–1743.

Levick, S. E. (1980). Dementia from aluminum pots (letter). *New England Journal of Medicine, 304*(3), 172.

Lione, A. (1983). The prophylactic reduction of aluminium intake. *Food and Chemical Toxicology, 21*, 103–109.

McDermott, J. R., Smith, A. I., Ward, M. K., Parkinson, I. S., & Kerr, D. N. S. (1978). Brain aluminium concentration in dialysis encephalopathy. *Lancet, 1*, 901–903.

National Nutrition Monitoring Bureau (1989). *Average intake of nutrients by Indians*. New Delhi: Indian Council of Medical Research.

Pennington, J. A. T., & Jones, J. W. (1989). Dietary intake of aluminium. In H. J. Gitelman, *Aluminium in health, a critical review* (pp. 67–100). New York: Marcel Dekker.

Rao, G. V., & Rao, K. S. J. (1993). Aluminium content in selected foods. *Fresenius Environment Bulletin, 2*, 256–261.

Trapp, G. A., & Cannon, J. B. (1981). Aluminium pots as a source of dietary aluminium (letter). *New England Journal of Medicine, 304*(3), 172.

Underwood, E. J. (1977). *Trace elements in human and animal nutrition*. 4th ed. (p. 430). New York: Academic Press.

Ward, M. K., Feest, T. G., Ellis, H. A., Parkinson, I. S., & Kerr, D. N. S. (1978). Osteomalacia dialysis osteodystrophy. Evidence for a water borne etiologic agent, probably aluminium. *Lancet, 1*, 841–845.

World Health Organization (1989). In: FAO/WHO Expert Committee report on food additives, 33rd report. WHO Tech Report Series