WFL Publisher
Science and Technology
Meri-Rastilantie 3 C, FI-00980
Helsinki, Finland
e-mail: info@world-food.net

Journal of Food, Agriculture & Environment Vol.5 (1) : 8-11. 2007

www.world-food.net

Aluminium exposure from vegetables and fresh raw vegetable juices in Kenya

Lydia W. Njenga [1*], David M. Maina [2], David N. Kariuki [1] and Francis K. Mwangi [1]
*[1] Department of Chemistry, [2] Institute of Nuclear Science and Technology, University of Nairobi, Box 30197, 00100 GPO, Nairobi, Kenya. *e-mail: njengalydia@yahoo.com*

Received 21 September 2006, accepted 4 January 2007.

Abstract

Drinking of fresh vegetable raw juices for both cleansing and cure therapy has become very common in Kenya. Fresh raw vegetable juices have been recommended because they can boost the required minerals and vitamins in the body. This work was carried out to evaluate the amount of labile aluminium content in fresh raw vegetable juices and compare it with the total aluminium in vegetables. In addition, another objective was to determine the amount of aluminium leached out from aluminium pots during cooking. Out of 18 different vegetables analyzed, total aluminium ranged from 0.096 to 1.06 mg g^{-1}; carrots contained the lowest values while parsley contained the highest values. Labile aluminium in fresh raw vegetable juice ranged from 0.003 to 0.181mg ml^{-1} and this gave 1 to 30% of the total aluminium. The amount taken per day during juice therapy, either as a detoxifier or a cure, ranged from 0.95 mg day^{-1} to as high as 40.22 mg day^{-1}, but levels as high as 321.78 mg can be consumed depending on the volume of the juice consumed per day. The total aluminium consumed during juice therapy was found to be higher than that recommended by WHO. Aluminium pots were found to leach out some aluminium and the amount leached out was found to depend on the storage time and the age of the pot.

Key words: Aluminium in vegetables, Nairobi, Kenya, vegetable juices, total and labile aluminium.

Introduction

Aluminium is an environmentally abundant element to which we are all exposed. It is the third most abundant element in the earth's crust and is widely used in the production of medicines, cooking and storage utensils. It is also used in food additives, water purification and in industry. Aluminium is released to the environment by both natural processes and anthropogenic sources with the former being a greater contributor for potential neurotoxin or chronic exposure. Although aluminium is abundant in nature, it has no known biochemical role, but in the last decade, aluminium toxicity and its effect on general environment have been given increased attention. Of late, there has been evidence that it can be a potent neurotoxic agent to humans and has been regarded as a factor in human disorders of the nervous system [1-3] and in iron adequate microcytic anemia [4].

Human beings are exposed to aluminium from airborne dust, water, food, aluminium cookware, aluminium packaging and aluminium containing medicines. According to FAO/WHO [5], the provision tolerable weekly intake (PTWI) of aluminium is 7 mg kg^{-1} body weight for adults and 2 mg kg^{-1} body weight for children. Aluminium in the diet for an adult ranges from 9 to 36 mg day^{-1} with an average of 20 mg day^{-1}, although consumption of up to 1000 mg day^{-1} has been recorded [1, 6, 7]. The main source of the aluminium is the food we consume. Green leafy vegetables have been found to contain concentrations ranging from 0.1 to 25.2 mg kg^{-1} on a dry weight basis (DW), with lettuce recording the highest concentrations [6]. Cereals have also been noted to contain values ranging from 0.04 to 400 mg kg^{-1} while tea and herbs are found to accumulate high amounts of aluminium [6]. According to Scott [6], brewed tea may contain from 2 to 5 mg l^{-1} of aluminium while ground coffee beans contain 51.7 mg l^{-1}. Food additives like baking powder and medical products, like antacids, may also increase aluminium intake. Aluminium-containing antacids are widely used as non-prescription medications. Most of the antacids contain aluminium hydroxide ($Al(OH)_3$), and although it is insoluble, in the small intestines where the pH is around 2, it will be hydrolyzed and become soluble changing into a form that is absorbed by the body. Aluminium in the diet may also be increased as a result of leaching from the aluminium-based cooking utensils and packaging materials. Leaching from the utensils into the food depends on factors, such as the age of the utensils, the pH of the food, the form and composition of the food, duration of contact and presence of some ions, like fluoride and citrate [8-10]. Several surveys have been reported on the aluminium content in diets consumed in various parts of the world: China [11], France [12], Germany [13], Italy [9], Spain [16, 17], UK [18] and USA [19, 20].

In biological systems, aluminium normally exists as Al^{3+} and its absorption, distribution and subsequent toxicity is influenced by its associated ligand and the stability of the Al-ligand complexes. While most of the aluminium is excreted, intestinal absorption of aluminium is enhanced by the presence of some ligands such as fluoride, citrate and lactate which form soluble complexes. Also, due to some similarity in the ionic radii of Al^{3+} with Mg^{2+}, Ca^{2+} and Fe^{3+}, deficiency of the latter three ions might enhance aluminium intestinal absorption [6, 21, 22]. High aluminium content, on the other hand, decreases the intestinal absorption of iron, fluoride, phosphorus, magnesium and calcium ions.

In Kenya, a lot of research has been done on the levels of trace elements in food, water and other matrices but very little is known on the concentration of aluminium in these matrices. This lack of an aluminium database calls for studies on the aluminium content of the various foods consumed in Kenya. The rise in consumption of fresh raw vegetables in Kenya could exacerbate the aluminium toxicity problem in the country. These juices are recommended due to their nutritional value, detoxification capabilities, excellent sources of vitamins and minerals as well as therapeutic effects. Since green leafy vegetables have been reported to contain high levels of aluminium, it is important that the amount of aluminium consumed per day from fresh raw vegetable juices be established for purposes of educating the consumers. The main objective of this study was to determine total aluminium content in vegetables, labile aluminium in fresh raw vegetable juices and also determine the amount of aluminium leached from cookware. The results from this study are envisaged to form a good source of information for advising consumers of raw vegetable juices of the possible presence and levels of aluminium.

Materials and Methods

Sample collection and preparation: Vegetable samples were purchased from different supermarkets and open air markets within Nairobi.The vegetable samples were washed thoroughly under running water to remove all the soil and other foreign materials. They were then rinsed with distilled water and placed on a clean surface to drain off the water. The samples were chopped into small pieces and divided into two groups; one for total aluminium and the other for labile aluminium. Samples for the analysis of total aluminum were dried overnight in an oven at 110^{o} C. They were then ground into fine powder and stored in sealed plastic bags.

Samples for the determination of labile aluminium were prepared using a juice extractor. The chopped samples were fed into the juicer and all the juice extracted leaving the pulp fiber behind. To avoid cross sample contamination, after every extraction, the juicer was thoroughly washed with running water, rinsed with distilled water and dried before using it for the next sample.

Of each dry sample 0.4 g or a 5 cm^3 sample of the vegetable juice was digested using a mixture of $HNO_3 + HClO_4 + H_2SO_4$ at a ratio of 6:3:1.

Aluminium from the cookware: 500 cm^3 of deionized water was put into a new stainless steel pot (BW1), covered and boiled for five minutes. It was then immediately transferred into a plastic container and left to cool. The same procedure was repeated using: a) a new aluminium pot (BW2); b) a three-year-old aluminium pot where the aluminium concentrations in three cases were investigated i) immediately after boiling and cooling (BW3), ii) after standing in the pot for twelve hours (BW4) and iii) after standing in the pot for 72 hours (BW5); c) a three-year-old pot containing 300 g of cut tomatoes. The hot mixture was filtered and the filtrate analyzed for aluminium content (BW6). d) A three-year-old pot was first washed and scrubbed using steel wool (BW7).

The aluminium levels were determined using atomic absorption spectrophotometer at a wavelength of 309.4 nm. The detection limit of the instrument was 0.04 µg l^{-1}.

Results and Discussion

The aluminium content leached from the cookware is reported in Table 1. From the data, new aluminium pots (BW2) were found to release 3.2 mg l^{-1} aluminium while a 3-year-old aluminium pot leached out 10 mg l^{-1} aluminium. This was in agreement with previous studies of Rajwanshi *et al.* [10] where an increase of 4.06-9.22 mg l^{-1} in aluminium level was reported. When an old pot was scrubbed with steel wool (BW7) and then used to boil water for 5 minutes, there was only an increase of 1% in the aluminium level.

Table 1. Leaching of aluminium from containers during cooking.

Sample identity	Concentration (mg l^{-1})
BW1	ND
BW2	3.2
BW3	10.0
BW4	10.3
BW5	10.4
BW6	11.3
BW7	10.1

ND not detected

This increase is attributed to the destruction of the protective layer of Al_2O_3 exposing the metal, which in turn reacts with water thereby increasing the aluminium content. Acidic foods cooked in aluminium pots have been reported to increase the leaching of aluminium [10]. In the present work, when tomatoes were boiled in water making the water acidic (pH 4.75), the aluminium content leached out increased from 10.0 to 11.3 mg l^{-1}. It was noted that storage time did not have a great effect on the leaching out of aluminium. When water samples were left standing in the aluminium pot for 72 hours the aluminium content increased by 0.4 mg l^{-1} (1%). Casdoph and Walker [23] reported that when water containing 1 mg l^{-1} fluoride at pH 3 was boiled for 10 minutes in an aluminium pot, almost 200 mg l^{-1} aluminium was released and this level increased to 600 mg l^{-1} after prolonged heating.

Vegetables have been reported to contain high fluoride levels [24] and this will increase the aluminium leaching during the cooking process. Thus, it is expected that the cookware may contribute highly to total aluminium intake. Preliminary work carried out on surface and borehole water samples showed low aluminium levels; 0.05 mg l^{-1} in borehole water (Table 2), indicating that their contribution to the total aluminium intake is very minimal.

Table 2. Aluminium concentrations in surface and borehole water samples.

Water Sample	Description of water sample	Concentration (mg l^{-1})
1	Surface water	nd
2	Borehole water	0.5
3	Borehole water	0.4
4	Surface water	nd
5	Borehole water	0.4
6	Surface water	nd
7	Borehole water	nd
8	Borehole water	nd

nd – not detected

Analysis of total and labile aluminium in vegetables and in fresh raw vegetable juices is presented in Table 3. The data shows that, for the total aluminium, levels ranged from 0.096 mg g^{-1} in carrot to 1.062 mg g^{-1} in parsley while aluminium in fresh raw vegetable juices ranged from 0.002 mg l^{-1} in cabbage to 0.181 mg l^{-1} in methi (*Methe piperita*). It was observed that the percentage of labile to total aluminium varied from only 0.56 to 30%. The rest is suspected to be in the bound form. Amaranthus (*Amaranthus hybridus*), managu (*Solanum nigrum*) and pumpkin (*Cucurpita pepo*) leaves have been reported to contain high concentration of silica [25]. Silica has also been reported to correlate to aluminium toxicity in water[3], and vegetables are known to have high levels of silica. Therefore, due to high silica in vegetables, toxicity of aluminium in vegetables may be expected to increase. Although parsley recorded the highest total aluminium, only 6% was found to be labile. There was no correlation found between total and labile aluminium.

Table 3. Aluminium content in vegetable and fresh raw vegetable juices.

Species	Fresh vegetable mg g^{-1} (DW)	Juice, mg ml^{-1}
Carrot (*Daucus carota*)	0.096	0.011
Lettuce (*Lactuca sativa*)	0.154	0.007
Courgette (*Cucurbita mudullosa)*	0.182	0.003
Celery (*Apium graveolens*)	0.219	0.015
Beetroot (*Beta vulgaris*)	0.223	0.008
Capsicum (*Capsicum annuum)*	0.229	0.005
Spinach (*Spinacea oleracea)*	0.284	0.085
Cucumber (*Cucumis sativus)*	0.356	0.005
Kale (*Brassica inegriofolia*)	0.356	0.067
Cabbage (*Brassica oleracea L.* Capitata group)	0.358	0.002
Broccoli (*Brassica oleracea* L. Gemmifera group)	0.476	0.058
Coriander (*Coriandrum sativum L*)	0.611	0.069
Managu (*Solanum nigrum*)	0.679	0.064
Amaranthus (*Amaranthus hybridus)*	0.706	0.078
Methi (*Methe piperita*)	0.862	0.181
Pumpkin (*Cucurpita pepo)*	0.929	0.074
Parsley (*Petroselinum sativum)*	1.062	0.065

DW Dry weight

Table 4 presents the levels of aluminium that may be consumed per day during vegetable juice therapy. For unmixed juices, aluminium levels range from 0.95 to 40.22 mg in cabbage and spinach respectively when one glass is taken per day. The amount of aluminium increases with the increase in the amount of juice taken per day and levels as high as 321.78 mg can be consumed if one takes 8 glasses of juice. According to Walker [26], as a rule the minimum amount of fresh raw vegetable juices taken per day by a person undergoing juice therapy (detoxification) should be one pint (473 cm^3) and this is equivalent to 16 ounces. An individual may also drink a combination of juices from several vegetables (Table 4) as long as the total is one pint. Normally, 0.946 to 3.786 litres or more of vegetable juice per day are recommended [26] depending on whether it is being taken for detoxification or for curative purposes.

For the mixed juices (commonly taken for curative therapy) levels ranging from 3.87 mg to 11.51 mg per pint day^{-1} can be consumed and this level may increase up to 123.5 mg day^{-1} depending on the amount of juice consumed. This indicates that the amount of aluminium taken per day could be higher than 60 mg day^{-1}, the value recommended by FAO/WHO [5]. Toxicity of aluminium may be heightened by the fact that these vegetables contain high levels of fluoride. Previous work [27] on the analysis of labile fluoride in fresh raw vegetable juices showed a range of 1.2 to 5.4 mg l^{-1}.

Fluoride complexes with aluminium to form some fluorocomplexes $(AlF_x)^{3-x}$ which upon acidification yield tetra coordinated AlF_4^-. This is easily absorbed through the walls of the stomach into the blood stream. The AlF_4^- acts as a structural analogue of phosphate (PO_4^{3-}) and may mimic it since they are isoelectronic and have similar bond length [28, 29]. Fluoride has been quoted to enhance aluminium absorption, therefore, increasing the toxicity of aluminium [6]. Since the surface water was found to contain very low fluoride concentration (below the detectable level), human exposure to aluminium in water is not very great and therefore the major bulk of aluminium comes from food eaten, especially from vegetables and aluminium cooking pots.

Table 4. Aluminium (mg) intake during juice therapy.

Vegetable type	Al mg
Carrot (16)	5.21
Lettuce (16)	3.31
Cucumber (16)	2.37
Spinach (16)	40.22
Celery (16)	7.10
Beetroot (16)	3.79
Parsley (16)	30.76
Kales (16)	31.70
Cabbage (16)	0.95
Capsicum (16)	2.37
Amaranthus (16)	36.91
Courgette (16)	1.42
Pumpkin leaves (16)	35.02
Managu (16)	30.29
Carrot (7)+ parsley (2) + celery + (4) + spinach (3)	15.44
Carrot (11)+ beet (3)+ clery (2)	5.18
Carrot (9)+ beet (3)+ lettuce (4)	4.47
Carrot (10) + beet (3) spinach (3)	11.51
Carrot (11) + cabbage (5)	3.87
Celery (11) + cabbage (5)	5.18
Carrot (7) + lettuce (5) + cucumber (4)	3.90
Carrot (8)+lettuce (5) +spinach (3)	7.63
Carrot (10)+ lettuce (6)	4.32
Carrot (7)+ celery (5)+ lettuce (4)	4.35
Carrot (7)+ cabbage (4)+celery (5)	4.47

473 cm^3 = 16 oz = 1pint
The value in brackets is the mixing ratio of the juices [26]

Conclusions

Aluminium concentrations in these vegetables are high. Therefore, consumption of these juices though good for their nutrition values may increase the amount of aluminium consumed per day. As such, when considering the total amount of aluminium taken per day, the amount of aluminium consumed during juice therapy should be taken into account.

Acknowledgement

The authors are grateful to the University of Nairobi for the financial support for this work.

References

[1] Neelan, K. U. and Kaladhar, M. 1999. Risk of aluminium toxicity in the Indian context. ICMR Bulletin **29**:1-14.

[2] Cumming A. D., Simpson, G., Bell, D., Cowie, J. and Winmey, R. J. 1982. Acute aluminium intoxication in patients of continuous ambulatory peritoneal dialysis. Lancet **1**:103.

[3] Zatta, P. 2000. Aluminum and Health: Recommendations. First International Conference in Metals and Brain. From Neurochemistry to Neurodegeneration. University of Padova, Italy, 20–23 September 2000. http:/www.bio.unip.it/~zatta/metals/documen2.html

[4] Suwalsky, M., Norris, B., Villena, F., Cuevas, F., Sotomayor, P. and Zatta, P. 2004. Aluminium fluoride affects the structure and function of cell membranes. Food and Chemical Toxicology **42**:925-933.

[5] FAO/WHO 1989. Evaluation of certain food additives and contaminants. Thirty Third Report of the joint FAO/WHO Expert Committee on Food Additives. WHO Technical Report Series (Geneva) **776**:26-27.

[6] Scott, M. 2004. Aluminium Compounds: Review of Toxicological Literature abridged Final Report. Report for National Institute of Environmental Health Sciences. North Carolina.

[7] Wan, Z. A. and Wan, A. 2004. Health hazards of aluminium. http://www.prn2.usm.my/mainsite/bulletin/sun/1995/sun37.html.

[8] Liukkonen-Lilja, H. and Piepponen, S. 1992.Leaching of aluminium from aluminium dishes and packages. Food Additives and Contaminants **9**:213–223.

[9] Gramiccioni, L., Ingrao, G., Milana M. R., Santaroni, P. and Tomassi,G. 1996. Aluminium levels in Italian diets and in selected food from aluminium utensils. Food Additives and Contaminants **13**:767–774.

[10] Rajwanshi, P., Singh, V., Gupta, M. K. and Dass, S. 1997. Leaching of aluminium from cookware – A review. Environ. Geochem. Health **19**:1–18.

[11] Wang L., Su, D. Z. and Wang, Y. F. 1994. Studies on the aluminium content in Chinese foods and the maximum permitted levels of aluminium in wheat flour products. Biomed. Environ. Sci. **7**:91- 99.

[12] LeBlanc, J.-Ch., Guerin, T., Noel, L., Calamassi-tran, G., Volatier, J.-L. and Verger, P. 2005. Dietary exposure estimates of 18 elements from the 1st French total diet study. Food Additives and Contaminants **22**:624-641.

[13] Müller, M., Anke, M. and Illing-Gunther, H. 1998. Aluminium in foodstuffs. Food Chemistry **61**:419-428.

[14] Šèanèar, J., Stilbilj, V. and Milaèiè, R. 2004. Determination of aluminium in Slovenian foodstuffs and its leachability from aluminium-cookware. Food Chemistry **85**:151-157.

[15] Jorhem, L. and Haegglund, G. 1992. Aluminium in foodstuffs and diets in Sweden. Z. Lebensm. Unters. Forsch. **194**:38–42.

[16] López, F. F., Cabrera, C., Lorenzo, M. L. and López, M. C. 2002. Aluminium content of drinking waters, fruit juices and soft drinks: Contribution to dietary intake. The Science of the Total Environment **292**:205–213.

[17] Cabrera, C., Lloris, F., Gimenez, R., Olalla, M. and Lopez, M. C. 2003. Mineral content in legumes and nuts: Contribution to the Spanish dietary intake. The Science of the Total Environment **308**:1–14.

[18] Ysart, G., Miller, P., Crews, H., Robb, P., Baxter, M., De L'Argy, C., Lofthouse, S., Sargent, C. and Harrison, N. 1999. Dietary exposure estimates of 30 elements from the UK total diet study. Food Additives and Contaminants **16**:391-403.

[19] Pennington, J. A. and Schoen, S. A. 1995 Estimates of dietary exposure to aluminium. Food Additives and Contaminants **12**:119-128.

[20] Saiyed, S. M. and Yokel, R. A. 2005. Aluminium content of some foods and food products in the USA, with aluminium food additives. Food Additives and Contaminants **22**:234-244.

[21] Vandeervoet, G. B. 1992. Intestinal absorption of aluminium. Aluminium in Biology and Medicine. Ciba Foundation Symposium **169**:109.

[22] Yokel, R. A., Lasley, S. M. and Dorman, D. C. 2006. The speciation of metals in mammals influences their toxicokinetics and toxicodynamics and therefore human health risk assessment. J.Toxicology and Environmental Health **9**:63–85.

[23] Casdorph, H. R. and Walker, M. 1995. Toxic Metal Syndrome. Avery Publishing Group, Garden City Park, New York.

[24] Njenga, L. W. and Kariuki, D. N. 1994. Accumulation of fluoride in plants and vegetables. International Journal of BioChemPhysics **3**:170–172.

[25] Gustafsson, L. and Njenga, L. W. 1988. Determination of total fluorine in vegetables and plants by open–flame ashing and microdiffusion method. Analytical Chimica Acta **212**:133-143.

[26] Walker, N. M. 1978. Fresh Vegetable and Fruit Juices. Revised edn, Norwalk Press, Phoenix, Ar., USA.

[27] Njenga, L. W. and Kariuki, D. N. and Ndegwa, S. 2005. Water labile fluoride in fresh raw vegetable markets from markets in Nairobi, Kenya. Fluoride **38**(3):205-205.

[28] Strunecka, A., Strunecky, O. and Patocka, J. 2002. Fluoride plus aluminium: Useful tools laboratory investigation, but messengers of false information (Minireview). Physiol. Res. **51**:557-564.

[29] Lu, Y., Sun, Z. R., Wu, L. N., Wang, X., Lu, W. and Liu, S. S. 2000. Effects of high fluoride water on intelligence in children. Fluoride **33**:74-78.