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Assessment of Human Exposure to Aluminum Through Cooked Food Monitoring

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Aluminium is the third most abundant element constituting approximately 8%of the earth's crust (Brusewitt, 1984). Aluminium is found in soil, water and air. In addition to its natural occurrence, and as a result of its inherent chemical and physical properties, aluminium finds use in a wide variety of applications including packaging materials, various containers and kitchen utensils. Aluminium compounds are also used in water treatment, drugs, cosmetics as well as food additives. Aluminium can be present naturally in food because plants take it up from soil and water. Aluminium may migrate to food from aluminium cookware (Tennakone and Wickramanayake, 1987) and usually it is best not to use aluminium products to cook or store foods that are highly acidic, such as tomatoes, cabbage and many soft fruits (Tennakone and Wickramanayake, 1988). In the general population, the major concern is related to the association between the intake of aluminium and the neurorogenerative diseases such as Perkinson's disease (Ahlsoog 2003, Schapira, 2002). Higher than average levels of aluminium have also been found in the brain of Alzheimer patients (Krishnan et al, 1988; Alfrey et al 1976). Prevention strategies carried out in modern dialysis centers have strongly reduced the occurrence of dementia dialitica (Candy et al 1986). However, it has to be stressed that the pathogenesis of this form of encephalopathy still remains a challenge in terms of molecular toxicology. The starting point to this challenge is to consider cookware as possible source of dietary aluminium and later on other numerous sources of this contamination by this element. The study therefore aimed at determining levels of aluminium in foods commonly consumed and to assess the extent to which the consumers are exposed to this element.

MATERIALS AND METHODS

Three study areas were chosen on the basis of zone areas, Kampala (Urban), Jinja (semi urban) and Rukungiri (rural). The three sampling locations in each zone area were selected for both uncooked and cooked food sampling. Each sampling location comprised of eight sampling sites approximately 500m apart. The sub-samples collected from each sampling site were composited to obtain average uncooked and cooked food good quality data. Uncooked and cooked samples (each 500 g) were transferred to polythene containers. At the end of collection

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the composite samples were taken to the laboratory. In the laboratory, cooked and uncooked food (500 g each) were air dried and ground into powder to pass 80-mesh sieve. A portion of this powder (1.5 g) was placed in an acid digestion bomb (Parr No. 4745) which consists of a 25 ml Teflon crucible encased in a metal body that has a screw cap. To the sample was added 6 ml fuming nitric acid and the cap was hand-tightened. The whole assemblage was heated for 2.5 h in a laboratory oven at 150°C. After cooling to ambient temperature, the digest was transferred to a 50 ml volumetric flask filled to the mark, and immediately transferred to a polythene bottle within 30 minutes to avoid possible contamination with the constituents of glass (that is silicon, aluminium, sodium, potassium, boron and antimony). The digestion procedure was repeated for four times for each sample for the purpose of calculating standard errors. To measure aluminium in the digest or standard solutions, the method outlined by James et al, 1983. Known volume ($\leq$ 10m) was placed in a separatory funnel containing 4ml of 8-hydroxyquinoline reagent, 4ml of 1,phenanthroline solution, 5ml of H_2O, and 5 ml of sodium acetate, followed by mixing. After 15 minutes, Al-quinolate was extracted with 5.0 ml of butyl acetate by shaking at least for 20 seconds, and after standing for 15 min to allow for complete phase separation, the butyl acetate phase was transferred to a 1.00 – cm borosilicate glass cuvette. The absorbance was read at 395 nm against butyl acetate using absorption spectrophotometer model RS232C.

After this operation, total aluminium concentration was measured in each of the food items (matooke, potatoes, beans, cabbage, dodo and tomatoes), both in cooked and uncooked form. The following utensils were used as cookware: New factory made cookware, old factory made cookware and clay pot cookware. Both were used under the same conditions of experimental design; that is cooking each food item for approximately 60 minutes in each cookware.

RESULTS AND DISCUSSION

Table 1 shows aluminium content of raw food. The food items analyzed are also indicated in the same Table. It is clearly shown that aluminium concentration in food items collected from Kampala is greater than that found in food items collected from Jinja and Rukungiri. The explanation for the differences is difficult to give as these food items are grown on soils with different chemical characteristics. Table 2 shows aluminium concentration found in cooked items collected from study areas. These cooked food items were cooked by the local people under the usual cooking conditions. Most of the cooking in Kampala and Jinja is by use of aluminium pan.

In Rukungiri, most people in rural areas use clay pots as their cooking utensils. The results of Table 2 indicate that the results are higher than those obtained in Table 1; an indication that aluminium has leached into the cooked food, with varying degree of leaching from one food items to another. The solution containing the crushed fresh tomatoes had the highest aluminium concentration followed by beans. As regards experiments carried out in the laboratory, new factory pan, old factory pan and clay pots were investigated using the same food

Table 1. Aluminium content in uncooked food items collected from Kampala, Jinja and Rukungiri.

Food items	**Aluminium detected, μg g^{-1}**		
	Kampala	**Jinja**	**Rukungiri**
Matooke	2.09 ± 0.05	2.77 ± 0.02	1.68 ± 0.02
Potatoes	4.93 ± 0.02	2.79 ± 0.05	1.86 ± 0.02
Beans	3.64 ± 0.04	2.20 ± 0.05	3.09 ± 0.05
Cabbage	6.13 ± 0.05	4.59 ± 0.04	2.78 ± 0.05
Dodo	2.10 ± 0.05	3.45 ± 0.05	1.95 ± 0.02
Tomatoes	6.04 ± 0.02	8.19 ± 0.05	4.49 ± 0.05
Total	**24.83**	**23.99**	**15.85**

Table 2. Aluminium content in cooked food items collected from Kampala, Jinja and Rukungiri.

Food items	**Aluminium detected, μg g^{-1}**		
	Kampala	**Jinja**	**Rukungiri**
Matooke	4.85 ± 0.05	3.63 ± 0.02	2.35 ± 0.02
Potatoes	5.67 ± 0.05	4.25 ± 0.05	2.04 ± 0.02
Beans	8.87 ± 0.04	6.05 ± 0.04	4.27 ± 0.05
Cabbage	8.14 ± 0.04	6.12 ± 0.05	4.01 ± 0.05
Dodo	4.25 ± 0.02	5.18 ± 0.02	2.55 ± 0.02
Tomatoes	9.58 ± 0.05	9.19 ± 0.06	5.08 ± 0.04
Total	**41.36**	**34.42**	**20.30**

items. Table 4 shows the amount of aluminium leached into food items while using a new factory pan. The results shown in this table indicate that the concentration of aluminium is greater than the concentration of aluminium found in Table 2, indicating that more aluminium is leached into the food when new factory aluminium pans are used. Table 4 shows that aluminium leached from the pan into the food in significant quantity. The reason for this is primarily due to the protective layer, which is put on pans during anodizing in the industry, which has been corroded off as the pan is used. Table 5 shows the results of aluminium concentration when clay pot cookware is used. The concentration values are lower than those indicated in Table 3 and Table 4 where new factory aluminium pan and old aluminium pan have been used respectively. The reason for these lower values may be attributed to the structure of the clay from which the pot is made. Probably, in the clay structure, aluminium is held by strong covalent bonds which are difficult to disrupt under the normal cooking conditions.

Many lot of research studies have used a variety of acids to look at the leaching reactions of aluminium from aluminium pans (Watanabe & Dawes, 1988). The studies have mostly focused on the effect of fluoride on the amount of aluminium dissolved by boiling fruit acids. Others have questioned whether aluminium leaching is enhanced by fluoride (Savory et al, 1987). In the absence of fluoride ions, it has been observed that significant leaching of aluminium is not observed. For our situation, fluoride ions were not introduced except those traces present in the food and water which is used in cooking. Our experiment was based on

Table 3. Aluminium content in new factory pan cooked food items collected from Kampala, Jinja and Rukungiri.

Food items	**Aluminium, detected, µg g^{-1}**		
	Kampala	**Jinja**	**Rukungiri**
Matooke	5.82 ± 0.05	4.50 ± 0.05	2.84 ± 0.02
Potatoes	6.97 ± 0.05	5.23 ± 0.05	2.53 ± 0.02
Beans	11.09 ± 0.06	7.44 ± 0.05	5.25 ± 0.03
Cabbage	10.01 ± 0.05	7.53 ± 0.05	5.00 ± 0.03
Dodo	5.14 ± 0.04	3.94 ± 0.02	3.11 ± 0.02
Tomatoes	11.69 ± 0.07	8.63 ± 0.06	7.06 ± 0.05
Total	**50.72**	**37.27**	**25.79**

Table 4 . Aluminium content in old-factory made pan cooked food items collected from Kampala, Jinja and Rukungiri.

Food items	**Aluminium detected, µg g^{-1}**		
	Kampala	**Jinja**	**Rukungiri**
Matooke	6.98 ± 0.5	5.31 ± 0.2	3.44 ± 0.2
Potatoes	8.06 ± 0.6	6.17 ± 0.5	3.06 ± 0.2
Beans	13.42 ± 1.0	8.78 ± 0.6	6.25 ± 0.4
Cabbage	11.71 ± 1.5	9.04 ± 0.8	5.90 ± 0.5
Dodo	6.32 ± 0.3	4.85 ± 0.2	3.97 ± 0.2
Tomatoes	14.04 ± 2.0	10.36 ± 1.2	8.54 ± 0.6
Total	**60.53**	**44.51**	**31.16**

natural conditions. Generally the aluminium content of cooked food collected from Rukungiri was at a minimum (total 15.85 µg/g) as compared to that collected from Kampala (24.82 µg/g) and Jinja (23.99 µg/g). This is not surprising because cookware used in Kampala and Jinja is mostly aluminium pans. Whereas in the case of Rukungiri, the cookware used is mostly clay pots. This is supported by the experiments carried out in the laboratory on new factory pans, old factory pans and clay pots. The new factory pans have protective layer of aluminium oxide and as the pans are used, they lose this layer. This explains the high content of aluminium leached from old factory pans. A thin film of α-Al_2O_3, which acts as a protective film, usually covers surfaces of new aluminium saucepans. Since the film is only a few mm thick, it can easily be disrupted by scrubbing, thus exposing the aluminium metal and, hence, attacked by acidic or basic foods. With the clay pots, the amount of aluminium leached is low. This may be due to the chemical structure of clay from which the pots are made. Clay is a mineral and contains compounds of aluminium such as; hydrated silicates of aluminium; kaolinite. Strong forces of attraction seem to hold the aluminium firmly in the minerals, thus making it rather difficult to dislodge the metal from the giant molecular structure of the clay.

There is no question that tiny amounts of aluminium do leach from aluminium cooking vessels, especially when acid foods are cooked in them. While the present results provide a useful reference point when considering pans as possible sources of dietary aluminium, it is worth remembering the numerous other

Table 5. Aluminium content in clay-pot cooked food items collected from Kampala, Jinja and Rukungiri.

Food items	**Aluminium concentration, μg g^{-1}**		
	Kampala	**Jinja**	**Rukungiri**
Matooke	5.37 ± 0.5	4.09 ± 0.2	2.59 ± 0.2
Potatoes	6.14 ± 0.5	4.70 ± 0.2	2.38 ± 0.2
Beans	9.75 ± 0.6	6.38 ± 0.5	4.54 ± 0.5
Cabbage	8.251± 0.6	6.37 ± 0.5	4.16 ± 0.5
Dodo	4.50 ± 0.2	3.49 ± 0.2	2.78 ± 0.2
Tomatoes	10.42 ± 1.0	7.69 ± 0.6	5.99 ± 0.6
Total	**44.43**	**32.71**	**22.44**

sources of the metal. These include packaging materials, tea, processed cheese, baking powder and unit acid preparations. The subject of dietary aluminium has the potential for considerable further investigation. Results presented here deal with only one small part of the problem. With all the negative evidence mounting against aluminium, educated consumers will want to take precautions in order to maintain their health and well being ofcourse, the best way to avoid excess aluminium is to cut back on aluminium intake from known sources. Use only stainless steel of cast iron cookware, clay pots and look for aluminium free antacids and deodorant. Always use filtered or spring water for drinking and cooking. Adopt safer cooking practices by not using polished cooking vessels, keeping surfaces of vessels smooth, discovering the power of steaming food, and using clay pots and eating raw food whenever you can.

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