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Fluoride Content of Common Vegetables from Different Parts of Kenya*

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ABSTRACT

The fluoride content of some commonly eaten vegetables from various parts of Kenya has been determined using a fluoride ion-electrode. Similar species of vegetables contain variable amounts of fluoride ions, depending on location of origin, age and part of the plant. The highest content is noted in cow peas (Vigna sinensis) *while the lowest is recorded in kale* (Brassica sp).

INTRODUCTION

The earth's crust contains fluorine, mainly as cryolite (sodium aluminium fluoride), fluorspar (CaF_2) and apatite (calcium fluorophosphate). Some of the earth crust fluorides are dissolved in seawater, lakes, rivers and drinking water.

Appreciable amounts of fluorides are generally found in plants, the actual amounts depending on plant species, part of the plant and age of the plant, mature plants generally containing higher amounts than young plants (Leone *et al.*, 1956). Aluminium and fertilizer factories also discharge fluorides into the atmosphere (Garrec *et al.*, 1977).

The presence of fluoride in the soil is beneficial to the plant (Zimmerman & Hitchcock, 1956) indirectly in that fluorides reduce

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leaching of calcium and magnesium (MacIntire *et al.*, 1955), elements necessary in plant nutrition (Mengel & Kirkby, 1982). Fluoride ions do not have any direct nutritional value to the plant and excessive amounts have toxic effects (Weinsteine, 1977). The total fluoride ion content of soil is usually unrelated to fluorine available to the plants, since available fluoride is the soluble form (Weinsteine, 1977; Mackenzie, 1982).

In animals, fluoride ions have both beneficial and detrimental effects. Optimum intake of fluoride ions prevents dental caries but excessive intake of fluoride ions causes skeletal and dental fluorosis and inhibition of growth (Overton & Chase, 1954). Animals ingest fluoride ions through drinking water and foods. No fluoride-free diet is yet known (Murray, 1957). The World Health Organisation (WHO) recommends an optimal fluoride ion concentration in drinking water in the range of 0·7–1·5 mg $litre^{-1}$ (WHO, 1970), the actual amount being dependent on the average ambient temperature of the atmosphere. Most of the fluoride ion intake in foods and water is removed through urine (Griffith, 1957). If intake of fluoride ions is reduced, excretion by the kidney may continue for long periods, the levels of fluoride ions in the urine falling off with time as skeletal stores become depleted (Murray, 1957).

Recently, in Kenya, there have been debates on the apparent high levels of fluoride ions in drinking water, a ban on advertisements of fluoridated toothpastes and a subsequent 'Fluoride Seminar' in Nairobi (Likimani, 1984). Available data on fluoride contents of Kenyan waters (Thairu *et al.*, 1982) show that 21% of sources from a total of 865 boreholes and lakes Elementaita, Nakuru, Bogoria, Magadi, Turkana and Baringo contain higher than permissible fluoride ion levels. Most of the borehole waters are, however, used for irrigation. There is a high dependence of people on rivers for drinking water in Kenya. This implies (if 15% of the 39 rivers examined by Thairu *et al.* (1982) were to be taken as representative) that a fairly large percentage of Kenyans do not use acceptable levels of fluorine for the prevention of dental caries. But the levels of dental caries are not alarming. Less than 5% of Kenyans have noticeable dental fluorosis. Protection against dental caries in areas where drinking water contains less than 1 mg of fluoride ion per litre may result from food intake. On the other hand, in areas where fluoride ion contents in drinking water are already more than acceptable levels ($>$ 1·5 mg $litre^{-1}$), water may be a source of dental fluorosis. Preliminary surveys (Thairu *et al.*, 1982) of Kenyan foods show fluoride ion levels as follows: potatoes, 6·4 mg kg^{-1}; beans, 1·7 mg kg^{-1}; bananas, 0·22 mg

kg^{-1}; corn (maize), 11 mg kg^{-1}. Certainly, a diet rich in any of these could be a source of dental fluorosis. Sanni (1982) reported that commonly eaten Nigerian vegetables have fluoride ion contents between 20 and 91 mg kg^{-1}. In this paper data on the fluoride ion contents of some common vegetables from various districts in Kenya are presented.

MATERIALS AND METHODS

An Orion Digital Ion Analyser (Model 701a) fitted with an Orion Combination Fluoride Electrode (Model 96-09) was used in the analysis.

To produce constant ionic background, decomplex fluoride and adjust solution pH, a Total Ionic Strength Adjuster (TISAB II) was used. TISAB II was prepared by adding 57 ml of glacial acetic acid, 58 g of NaCl, 4 g of cyclohexylene dinitrilotetraacetic acid or 1,2-diamino-cyclohexene,*N*,*N*′,*N*′-tetraacetic acid (CDTA) to 500 ml of distilled water in a 1-litre beaker. The mixture was dissolved by using a plastic magnetic stirrer, then cooled to room temperature in a water bath. The pH of the solution was adjusted to about 5·3 by using 5M NaOH. The mixture was then transferred to a 1-litre volumetric flask, cooled to room temperature and diluted to volume using distilled water.

Vegetable samples were collected between the 17th and the 20th of January, 1983. The samples were dried in an oven at $100 \pm 3\,°C$ for 8 h. Dry samples were cooled and ground to pass through a sieve of mesh size 60 then stored in a desiccator. Separations of leaves from leaf stalks were carried out prior to drying. The samples were made into solutions by using the modified method of Vickery & Vickery (1976). Two grams of dry samples were treated with 10 ml of sodium hydroxide (67 g $litre^{-1}$) heated in nickel crucibles at $100 \pm 3\,°C$ for 12 h. The crucibles were next transferred to a muffle furnace and heated at 600 °C for 8 h. After cooling the ashed sample was dissolved in 10 ml of a glacial acetic acid–distilled water (1:4) mixture, and then transferred into a 50 ml volumetric flask. The crucible was further rinsed with 20 ml of distilled water which was then added to the flask. The volume was made to 50 ml using distilled water.

Equal volumes of samples were mixed with TISAB II. Analysis was carried out in plastic containers while stirring with plastic magnetic stirring bars on a magnetic stirrer. Blanks were also analysed and the readings of the data samples appropriately corrected.

A stock fluoride solution standard of 1000 mg kg^{-1} was made by dissolving 2·211 g NaF (dried at 100 °C) in 1 litre of water. Data presented are on the dry weight basis of the vegetables. All chemicals used were of Analar grade.

RESULTS AND DISCUSSION

The most commonly eaten vegetable in Kenya (especially in towns) is 'kale' (*Brassica* sp.). Table 1 presents data on fluoride ion contents of 'kale' (*Brassica* sp.). Values range from 7 to 55 mg kg^{-1}. It is noted that fluoride ion concentration in the leaf stalk is not generally equal to that in the leaves.

Cow peas (*Vigna sinensis*) are the second most widely used vegetable. Their fluoride ion contents ranged from 12 to 115 mg kg^{-1} (Table 2). In rural areas cow peas (*Vigna sinensis*) form part of most regular meals. The ingestion of fluoride ions from cow peas is therefore considerable. Pumpkin leaves (*Curcarbita maxima*) is a widely eaten vegetable in the Central Province of Kenya and, to lesser extent, in other parts of Kenya. Samples taken from Murang'a and Meru (Table 3) show fluoride ion content of the leaf blades varies from 21 to 50 mg kg^{-1}.

TABLE 1
Fluoride Contents[a] of Kale (*Brassica* sp.)

Source	*Number of determinations*	*F^- in mg kg^{-1}*		
		Leaf blade	*Whole leaf*	*Leaf stalk*
Embu Town	3	7 (2·1)		7 (1·0)
Embu (Mungania)	3	21 (2·8)		53 (2·9)
Murang'a (Kandara)	2	21 (1·3)		12 (2·3)
Meru (Maua)	3	19 (1·8)		30 (3·0)
Kirinyaga (Mbeboi's farm)	3	17 (1·7)		12 (1·9)
Kirinyaga (Kangaita)	3	11 (1·1)		10 (2·2)
Kiambu (Town)	3	14 (1·0)		17 (0·7)
Kisii			10 (1·1)	
Kericho Tea Research Foundation 1	4		55 (1·6)	
Kericho Tea Research Foundation 2	3		26 (2·4)	
Kericho Tea Research Foundation 3	3		29 (2·4)	

[a] On a dry weight basis.
Numbers in parentheses are standard deviations.

TABLE 2
Fluoride Contents[a] of Cow Peas (*Vigna sinensis*)

Source	*Number of determinations*	*F⁻ in mg kg⁻¹*		
		Leaf blade	*Whole leaf*	*Leaf stalk*
Kitale	3		13 (1·8)	
Kisii	2		88 (1.6)	
Kapsabet	3		10 (1·3)	
Kapsabet	2		14 (1·9)	
Central Kakamega	4		115 (1·6)	
Kakamega (Prison)	3		33 (2·1)	
Kakamega (Vihiga)	3		12 (0·8)	
Kakamega (Shinyalu)	3		18 (0·9)	
Embu Town	3		25 (2·1)	
Kericho	2	25 (0·8)		22 (3·1)
Kericho	2	23 (2·4)		11 (1·5)

[a] On a dry weight basis.
Numbers in parentheses are standard deviations.

The leaf stalks, however, contain between 10 and 50 mg kg^{-1}. Higher contents of fluoride ion are noted in the leaf blades than in the leaf stalks of pumpkin leaves (*Cucarbita maxima*).

In addition to the common vegetables discussed above, sampling included some miscellaneous vegetables whose fluoride data are presented in Table 4. All the vegetables encountered in the study contained fluoride

TABLE 3
Fluoride Contents[a] of Pumpkin Leaves (*Cucarbita maxima*)

Source	*Number of determinations*	*F⁻ in mg kg⁻¹*	
		Leaf blade	*Leaf stalk*
Murang'a (Kagumo)	3	50 (2·1)	50 (2·8)
Murang'a (Kiharu)	2	43 (0·7)	33 (1·4)
Meru (Maua)	3	38 (1·6)	35 (2·0)
Murang'a (Kandara)	3	30 (1·1)	24 (2·0)
Meru (Town)	2	21 (1·4)	10 (1·4)

[a] On a dry weight basis.
Numbers in parentheses are standard deviations.

TABLE 4
Fluoride Contents[a] (in mg kg^{-1}) of Miscellaneous Vegetables

Source	*Common name*	*Botanical name*	*Number of determinations*	*Whole content*
Kisii	Chinsaga	*Gynodropis gynadra*	3	25 (2·0)
Kisii (Kiberigo)	Osuga	*Solanum nigrum*	3	19 (1·3)
Kakamega (Vihiga)	Mito	*Grotalaria* sp.	3	10 (1·4)
Kericho	Cabbage	*Vigna sinensis*	3	17 (1·0)

[a] On a dry weight basis.
Numbers in parentheses are standard deviations.

TABLE 5
Dependence of Fluoride Content on the Age of Leaf of Kale (*Brassica* sp.) from Kericho Tea Research Foundation

Leaf	*Number of determinations*	*F^- in mg kg^{-1}*	
		Leaf blade	*Leaf stalk*
First	3	13 (0·6)	14 (2·0)
Second	3	15 (1·3)	33 (3·0)
Third	3	12 (1·1)	35 (2·1)
Fourth	3	30 (1·8)	80 (4·9)
Fifth	3	55 (3·5)	30 (2·1)
Old	3	215 (4·8)	11 (1·1)

Numbers in parentheses are standard deviations.

ions in varying proportions. The content of fluoride ions in the leaves varies with the age of the leaf. Data from 'kale' (*Brassica* sp.) demonstrates this (Table 5).

The accumulation of fluoride ions in the leaf blade increases with the age of the leaf. In the leaf stalk, however, there is an increment of fluoride ions up to the fourth stalk, followed by a decrement. Eating of very old leaves of 'kale' (*Brassica* sp.) could result in the ingestion of very high levels of fluoride ions.

CONCLUSION

It is not known how much of the total fluoride in vegetables is available to prevent dental caries or cause bone fluorosis. Further studies of this would be desirable.

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REFERENCES

Garrec, J. P., Lounowski, A. & Plebin, R. (1977). The influence of volcanic fluoride emissions in the surrounding vegetation. *Fluoride*, **10**, 152–6.

Griffith, G. W. (1957). Nutritional requirements and food fortification: Some medical consideration of fluoridation, *Chem & Ind.*, 7–11.

Leone, I. A., Bennan, E. & Daines, R. H. (1956). Atmospheric fluoride: Its uptake and distribution into tomato and corn plants. *Plant Physiology*, **31**, 329–33.

Likimani, S. (ed.) (1984). *Fluorosis research strategies.* Proceedings of Workshop, Nairobi, Kenya.

MacIntire, W. H., Stergers, A. J. & Shaw, W. M. (1955). Fate and effects of hydrofluoric acid added to four Tennessee soils in a 4-year lysimeter study. *J. Agric. Food Chem.*, **3**, 777–82.

Mackenzie, E. F. W. (1982). *Prevention of dental caries by the administration of fluorine in public water supplies* (1st edn.), British Water Works, London.

Mengel, K. & Kirkby, E. A. (1982). *Principles of plant nutrition* (3rd edn.). International Potash Institute, Worblanfen-Bern, Switzerland, 560–1.

Murray, M. N. (1957). Nutritional requirements and food fortification: Physiological aspects of fluorine, *Chem. & Ind.*, 5–6.

Overton, D. E. & Chase, H. C. (1954). Newburgh-Kingston caries fluorine study: Pediatric aspects—Current status, *NY State J. Med.*, 2552–7.

Sanni, S. B. (1982). The fluorine contents of common Nigerian vegetables. *J. Sc. Food Agric.*, **33**, 686–7.

Thairu, H. M., Kariuki, D. N. & Njenga, L. (1982). Distribution of fluoride in Kenya waters. *Paper presented at Environment Chemistry Workshop*, National University of Lesotho, 6–13 December, 1982.

Vickery, B. & Vickery, M. L. (1976). Suppression of interfering ions in the analysis of plants to determine fluoride using fluoride ion selective electrode, *Analyst.*, **101**, 445–54.

Weinsteine, L. H. (1977). Fluoride and plant life. *J. of Occupational Medicine.*, **19**, 49–78.

WHO (1970). *Fluorides and human health*, World Health Organisation, Geneva.

Zimmerman, P. W. & Hitchcock, A. E. (1956). Susceptibility of plants to hydrofluoric acid and sulphur oxide. *Contr. Boyce Thompson Inst.*, **18**, 263–79. (*J. Sc. Fd. Abstr.*, 1957).