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Aluminium Content of Egyptian Breads

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ABSTRACT

Bread, flour, bran and other bread-making ingredients were collected from 13 villages in Egypt during September–December 1984. The aluminium content, as measured by instrumental neutron activation analysis, ranged from 18·1 to 224 μg/g of bread in fellahi from Edfina on the Mediterranean coast and bettaw from Beni Suef, about 90 miles south of the capital Cairo, respectively. Aluminium in the ingredients ranged from 16·9 μg/g in white wheat bran to 91·4 μg/g in corn bran. Some trends were noted but not statistically tested. In general, the aluminium content of the bread seemed to be higher the further south the village was located. Corn-containing breads had higher levels of aluminium than wheat-based breads. The use of dung as a fuel for bread baking was associated with higher levels of aluminium in the bread. Daily intake of aluminium from bread in Egypt is 5 to 20 times greater than the estimated average daily intake from common American diets.

INTRODUCTION

Interest in the Al content of foods dates back at least to 1879 when Penney published the Al content of flour and wheat from various locations around

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the world, including Egypt. Hopkins and Elsen (1959) and Eden (1958) reported that the Al content of plant products may reflect differences in plant varieties, soil conditions, pH of the soil and water used for irrigation.

Currently the literature has no definite answer as to whether a high concentration of Al in brains of people with Alzheimer's disease is a result of or a contribution to the disease. Martyn *et al.* (1989) have indicated that the risk of Alzheimer's disease is higher in districts where mean Al content, in the water supply, exceeds 0·11 mg/litre compared to other districts with Al concentrations less than 0·01 mg/litre. Another recent study, by Ward and Mason (1989), reported that Al concentration in brain tissue ranged from 3·6 to 12·7 μg/g for individuals with Alzheimer's disease compared to 0·38 to 4·8 μg/g for controls. Also Crapper *et al.* (1976) examined ten post-mortem cases of the disease (for a total of 585 areas sampled) and found that the Al concentration in the brain ranged from 0·4 to 107 μg/g compared to $1{\cdot}9 \pm 0{\cdot}7$ μg/g for seven normal human brains (for a total of 208 areas sampled). However, these data are at variance with the work published by Ehmann *et al.* (1982), which shows no significant difference in Al concentration between Alzheimer's and control brains on a bulk sample basis. Greger (1985) reported that Al may be implicated in conditions such as dialysis dementia, osteodystrophy, Alzheimer's disease and amyotrophic lateral sclerosis. Because of the association of Al with these conditions there has been renewed interest in the amount of Al in diets.

According to Smith (1928), a 7-day diet for one person can provide 3·3018 g of Al or an average daily intake of 0·4717 g. Greger (1985) has recently evaluated the Al content of the American diet and proposed an estimated average Al intake of 26·5 mg/day, an amount almost 20 times smaller than that reported by Smith. In a recent review of Al intake, Lione (1983) noted improvement in methods of analysis for Al, which have been developed in the decade 1973–83, and that up to 25% of some Al salts may be absorbed from the gastro-intestinal tract. The same study also indicated that Al may be concentrated in bone, parathyroid and brain tissue. Further, high levels of Al can produce neurotoxicity in cats and rabbits. Also Al may alter the metabolism of Ca, P and Fe in humans, leading to development of osteomalacia or a P-depletion syndrome. It should be indicated that Al was detected in cigarette ash (Iskander, 1986), air particulates collected from ambient air in six US cities (Thompson, 1979), and room dust, ventilator dust and tap water (Crapper *et al.*, 1976). Persigehl *et al.* (1977) indicated that accumulation of Al in human organs may depend on environmental factors, such as the degree of industrialization.

Bread is the major component of the diet of rural Egyptians. Bread and cereals provide up to 70% of the calories and about two-thirds of the protein (Anon., 1966; Nawar, 1979). The concentration of Al in imported, handpicked and washed Egyptian wheats was reported by Penney (1879) as 366, 108 and 30 μg/g, respectively. Smith (1928) found Egyptian wheat to contain 327 μg Al/g. Although Ca, P and Fe contents of Egyptian breads have been recently reported by Tabekhia and Toma (1979), information on Al is very limited. This lack of information, coupled with the observations of the widespread use of Al vessels for preparation of food in Egypt and the practice of using sand to scour the cooking vessels, prompted this study.

MATERIALS AND METHODS

Samples of bread, flour and bran were collected during the period from September to December of 1984. The samples represent 13 villages from Aswan in the south to El-Alemain in the north (Fig. 1), and include six different varieties of Egyptian breads (Table 1). The differences in formulations, baking procedures and fuel used may have an effect on the Al

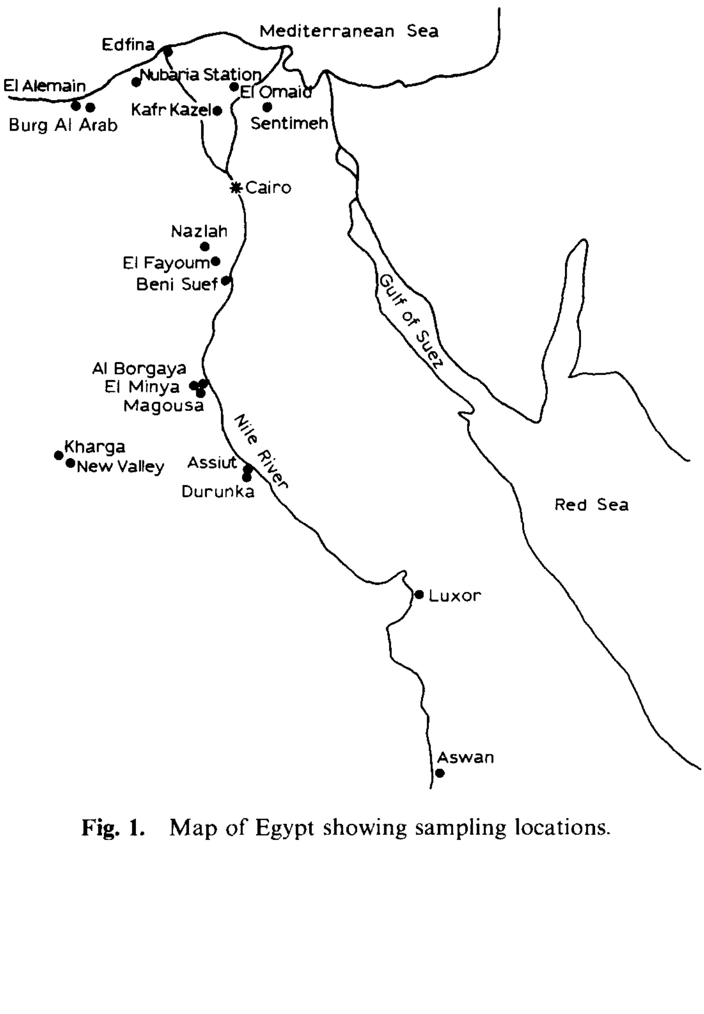

Fig. 1. Map of Egypt showing sampling locations.

TABLE 1

Sample Locations, Bread Type, Number of Loaves in Composite Samples, Corn Flour (as per cent of total flour used in bread formulation), Use of Dung as a Fuel and the Concentration of Al (in μg/g)

Sample location	*Bread name*	*Number of loaves*	*Corn flour (%)*	*Use of dung*	*Al conc. (μg/g)*
Balady					
Burg Al-Arab	Bakuun	1		no	31·2 ± 1·1
Kafr Kazel	Mabbotot	2	25·0	yes	48·9 ± 1·5
Kafr Kazel	Kabbouri	2	25·0	yes	65·5 ± 2·2
Nazlah	Manottot	2		yes	48·9 ± 0·78
Beni Suef	Balady	3		yes	224 ± 3·8
Amh					
Edfina	Fallahi	2		no	18·1 ± 0·45
El-Omaid	Amh-nashif	2	25·0	no	27·6 ± 0·61
El-Omaid	Amh-tari	2		no	28·7 ± 1·9
Nubaria Station	Amh-nashif	1	20·0	yes	92·6 ± 1·4
Shamsy					
Beni Suef	Shamsy	3		no	38·9 ± 1·7
Other wheat-based breads					
Edfina	Rokak	3		no	23·8 ± 0·60
El-Alemain	Majordag	2		no	35·2 ± 1·5
Durunka	Faish	2		no	47·2 ± 0·85
Durunka	Rushda noodles	1		?	81·8 ± 1·6
Aswan	Fiti	2		no	137 ± 1·2
Bettaw					
Beni Suef	Bettaw	2	24·2	no	75·7 ± 2·3
Al-Borgaya	Bettaw	2	98·2	no	74·6 ± 0·82
Magousa	Bettaw	2	91·2	yes	113 ± 1·4
Mashouah					
Sentimeh	Rokrouk	3	53·3	yes	62·8 ± 1·9

content of the bread; thus a brief introduction of the various bread types is warranted.

Balady bread

It is a loaf with two crusts, thin layers of crumb and a pocket in the middle. Kabbouri from Kafr Kazel, manottot from Nazlah (El-Fayoum) and Bakuun from Burg Al-Arab are variations of balady bread with thicker layers of crumb and a smaller diameter loaf than traditional balady bread. Bakuun and manottot contained domestic flour and commercial yeast, and mabbotot and kabbouri contained corn flour (*Zea mays*). All ingredients were mixed and fermented in Al bowls. Manottot and balady from Beni Suef were baked with dung briquettes and corn stalks for fuel.

Amh bread

Amh is the Arabic word for wheat although amh breads (e.g. from El-Omaid and Nubaria Station) may contain corn flour as well as wheat flour. Amh breads, with the exception of the amh-tari bread from El-Omaid, were dry cracker-like breads. Nashif is the Arabic word for dry and the dry amh breads may include fallahi from Edfina and amh-nashif from El-Omaid and Nubaria Station. All three varieties were mixed in Al bowls. The fuel in Nubaria Station was dung briquettes and chopped corn stalks; in El-Omaid the fuel was stalks of corn and rice stems. The oven at El-Omaid had a metal hearth.

Shamsy bread

Shamsy or sun bread was the favourite bread of upper Egypt (south of Cairo). Shamsy was made in Beni Suef of both domestic and imported flour. It had khamiira or sourdough fermentation from commercial compressed yeast, locally produced flour and water. The water was carried from a public tap and well water. The fuel for baking was dung briquettes. The bread was baked with the residual heat rather than in an oven with fire burning as in the case of bettaw bread.

Other wheat-based bread

This may include fiti bread, a Nubian bread from Aswan made from flour, water and a little salt. It was made into a consistency like pancake batter and was baked on a vegetable oil-coated iron griddle. Water was carried from the Nile in a large can. The flour was reported to be 82% extraction local wheat flour (*Triticum aestivum*) from a local stone mill. Usually sorghum (*Sorghum vulgare*) or millet flour (both locally called dakik dhourra) would be used. Corn flour would be used if nothing else were available. The flavour of the bread was not consistent with wheat flour. Majordag bread from El-Alemain was a Bedouin bread made from wheat flour, water and a little salt. It was made into a stiff dough and was baked on a griddle. The water at El-Alemain came from a water well.

Betaw bread

The dough for bettaw bread from Al-Borgaya was mixed in an earthenware bowl and was baked on a clay hearth. The fuel was chopped rice, cotton and corn stems. The dough for bettaw from Beni Suef was also mixed in an earthenware bowl and baked on a clay hearth, while the fuel was chopped corn, cotton stems and dung briquettes. The three bettaw breads contained corn flour and fenugreek flour (*Trigonella foenugreekum*).

Mashtouah bread

This is another corn-based bread. It is different from bettaw in that it was formulated with okra flour rather than fenugreek. Mashtouah also contained both domestic and imported wheat flour. It was baked on a clay hearth and the fuel was corn stalks and briquettes of dung. The addition of okra to this bread was probably done to enhance the handling properties of the dough. The use of sand to scour the mixing bowl was observed at Sentimeh.

Three loaves of each bread type were collected and the weight was determined at the time of collection. The bread was placed in plastic bags and taken to the laboratory at the Agricultural Research Center in Cairo, Egypt. There the samples were dried in a pasta dryer overnight at 60°C, weighed again and pulverized in a blender. Most samples were processed within 24 h from collection. The ground samples were sealed in plastic bags and kept in a freezer (unknown temperature) until they were brought to the University of Idaho. The samples were kept in frozen storage (−50°C) at Idaho until they were mailed to the University of Texas for analysis. The pulverized samples were composited and a representative portion of the composite was subjected to instrumental neutron activation analysis (INAA). In some cases, in spite of all precautions, one or more of the loaves was lost due to spoilage or insect infestation. The number of loaves in each sample composite is given in Table 1. As a point of reference, white corn, yellow corn, hard wheat, soft wheat and sorghum from the US and whole fenugreek from Egypt were subjected to the same analytical procedure.

For the determination of Al by INAA, 150 to 250 mg of the composite sample was weighed in a high-purity polyethylene vial. Each vial was sealed into a larger vial to avoid surface contamination. The same procedure was applied to encapsulate the NBS Standard Reference Material, Citrus Leaves (SRM 1572, certified to contain $92 \pm 15\,\mu g$ Al/g). Neutron activation analysis requires no further treatment of the sample, thus eliminating contamination via reagents. Blank experiments were performed on the irradiation vials. At the University of Texas at Austin research reactor, samples, standards and blanks were irradiated for 180 s at an integrated thermal neutron flux of $3{\cdot}6 \times 10^{14}\,n\,cm^{-2}$. At the end of the irradiation period, the external vial was replaced with a non-irradiated clean vial, then the radioactivity due to ^{28}Al was determined using a γ-ray spectrometer.

Details on instrument specifications have been given elsewhere (Iskander, 1985).

The accuracy of the method was checked by analysing Pine Needle NBS Standard Reference Material (SRM 1575). Results obtained ($510 \pm 40\,\mu g$ Al/g) are in agreement with the certified value, $545 \pm 30\,\mu g$ Al/g. Interference by the Mg secondary activation

$$^{26}Mg(n,\gamma)^{27}Mg \xrightarrow{\beta^-} {}^{27}Al(n,\gamma)^{28}Al$$

is a thermal neutron activation reaction and correction needs to be performed. The magnitude of the correction factor depends mainly on the Mg/Al concentration ratio. Magnesium content in the samples was determined, and a correction factor of 1–3% was calculated and applied to all data reported in this paper. At the irradiation position used in this study, the fast neutron interfering nuclear reactions such as $^{31}P(n,\alpha)^{28}Al$ or $^{28}Si(n,p)^{28}Al$ were not observed. Details on corrections for interfering nuclear reactions were given by Kruger (1971).

RESULTS AND DISCUSSION

Table 1 shows the concentration of Al in the samples and other pertinent information such as the number of loaves used to composite samples and the usage of dung as fuel for baking. The moisture content of the dried samples ranges from 2% to 10%; however, Al concentration is reported on a dry weight basis. Within bread types, Table 1 lists sample locations in approximate order from north to south. It is noticed that within a bread type Al in bread declined as location moved north from Aswan to the Mediterranean Sea. This observed pattern appeared more or less consistent. Thus, for balady bread, Al concentration increased from 31·2 (at Burg Al-Arab) to 224 μg/g (at Beni Suef); for amh bread from 18·1 (at Edfina) to 92·6 μg/g (at Nubaria Station); for other wheat-based breads from 23·8 (at Edfina) to 137 μg/g (at Aswan); and for bettaw bread from 75·7 (at Beni Suef) to 113 μg/g (at Magousa).

Balady breads (manottot, bakuun and kabbouri) contain 48·9, 31·2 and 65·5 μg Al/g, respectively. The dough for kabbouri and manottot was in contact with Al bowls for a longer period of time due to its slower fermentation. Leaching of the metal may be enhanced by the acidity of the sourdough; thus manottot and kabbouri have higher Al concentrations than bakuun. It also appears that balady bread, baked using dung briquettes, shows higher Al content. Ellis and Morris (1983) indicated that metals are increased in the faeces of human subjects by 10-fold over the plant material that was in the diet. Presumably that holds true for other animals, so that the dung would be a concentrated source of metals—including Al.

The dry amh breads include fallahi from Edfina and amh-nashif from El-Omaid and Nubaria Station, and contained 18·1, 27·6 and 92·6 μg Al/g of bread, respectively. All three were mixed in Al bowls. The transfer of Al to foods cooked in Al vessels or to various solutions has been documented (Lione, 1983; Greger, 1985). Lione and Smith (1982) reported that 4 mg Al per serving can be added to some foods by cooking in Al utensils. Although the figures from the aforementioned studies appear to be insignificant, one should consider the difference in pH between the acidic sourdough and that of a meal, and the variation in the surface area between a bowl used in mixing 20 kg flour with 20 litres of water and that used for cooking a meal. It is noteworthy that, similar to balady bread, amh bread baked with dung briquettes at Nubaria Station shows higher Al than that baked with chopped corn and/or rice stalks. The amh-nashif and amh-tari breads from El-Omaid were made from different doughs and contained 27·6 and 28·7 μg Al/g, respectively. That is very close to the 24·3 μg Al found in imported flour (Table 2). The higher level of 92·6 μg found in amh-nashif from Nubaria Station may be related to the incorporation of corn flour and the use of dung briquettes as fuel.

Shamsy bread contained 38·9 μg Al/g of bread. This is similar to the Al in domestic wheat flour. The higher extraction and locally produced wheat flour contained 34·3 μg/g of Al while the 72% extraction imported flour contained only 24·3 μg Al/g. The source of the imported flour was not known. However, Egypt imports wheat from Australia, Canada, the USA and other countries. It is rather interesting that the white wheat bran contained only 16·9 μg of Al/g. If Al in the flour were coming from the water used to wash the grain or from clay contamination, then the surface layer, or

TABLE 2
Location, Description and Al Concentration in Flour Samples

Flour type	*Sample location*	*Number of samples*	*Al conc. (μg/g)*
72% Extraction wheat flour	Composite	2	24·3 ± 0·56
82% Extraction wheat flour	Composite	3	34·3 ± 0·69
White wheat bran	Beni Suef	1	16·9 ± 0·46
Corn flour	Composite	3	64·0 ± 0·47
Corn bran	Sentimeh	1	91·4 ± 0·91
Corn + 1·5% fenugreek	Al-Borgaya	1	29·8 ± 0·86
Corn + 3·0% fenugreek	Sentimeh	1	78·7 ± 1·0
Wheat + okra	Sentimeh	1	40·4 ± 0·91

bran, should have had a higher level of Al. Thus contamination of wheat grains with soil is unlikely. Greger (1985) reported that the concentration of Al was 12·8 μg/g in US wheat bran, 3·0 μg/g in US white bread and 5·4 μg/g in US whole wheat bread. This is in agreement with the fact that white bread in the US is made from flour where the bran was removed in the milling.

The high level of Al (137 μg/g) for fiti bread is in the range of Al content of breads made primarily of corn flour with no yeast or fermentation, such as the bettaw breads from Al-Borgaya, Magousa and Beni Suef with 74·6, 113 and 75·7 μg Al/g, respectively. However, the geographic effect may cause fiti from the southernmost location to have the greatest content of Al in a wheat bread. Majordag bread from El-Alemain was made using well water; however, differences between using river water at Aswan and well water at El-Alemain by itself could not make the large difference in Al content between fiti and majordag. The highest Al concentration for 1156 raw water samples examined by Miller *et al.* (1986) was 5·35 mg/litre and that for 1432 finished samples was 2·67 mg/litre. For river waters, the Al concentration was reported by Smith (1928) to range from 0·0021 to 40 parts Al_2O_3 per 100 000 (0·01–210 μg Al/ml).

It is noteworthy that bettaw bread baked on dung briquettes contained higher concentrations of Al compared to bettaw bread baked with other fuels. This may be due to contamination with ash. The same observation was noticed for balady bread. Because none of the fuels used were analysed for Al content, no strong correlation can be concluded. The three bettaw breads contained corn flour. The concentration of Al in flour including corn + fenugreek flours from different locations is shown in Table 2. The corn flour from Sentimeh contained 64 μg Al/g while the corn bran contained 91·4 μg Al/g. Fenugreek was found to contain 52·7 μg Al/g. Mixing fenugreek flour with corn flour affects Al concentration although a definite trend was not observed.

The use of sand to scour the mixing bowl was observed at Sentimeh. This practice may increase leaching of Al as the dough is exposed to a bright shiny surface. The wheat + okra flour contained about half of the Al that the corn + fenugreek flour contained, but had more than either 72% or 82% wheat flour alone.

The levels of Al reported in these studies greatly exceed levels in bran, white bread and whole wheat bread from the US that were reported by Greger (1985) as 12·8, 3·0 and 5·4 μg Al/g, respectively. Langworthy and Austen (1904) reported that English wheat contained 0·005% Al_2O_3 (corresponding to 27 μg Al/g). Another study by Smith (1928) reported that American whole corn contained 0·167% Al; foreign red spring wheat contained 5·9–11·2 μg Al/g; yellow cornmeal and white cornmeal contained 9·7–11·2 and 9·4 μg Al/g. Davis *et al.* (1975) found from <1 to 34 μg/g of Al in

TABLE 3
Aluminium Content of US Grains and Egyptian Fenugreek

Sample	*Al conc.* ($\mu g/g$)
Soft wheat: variety a	13·3 ± 0·42
variety b	14·2 ± 0·46
variety c	11·6 ± 0·21
variety d	14·0 ± 1·06
Hard wheat	9·30 ± 0·70
Sorghum: variety a	14·7 ± 0·37
variety b	17·6 ± 0·40
White corn	6·75 ± 0·18
Yellow corn	7·70 ± 0·29
Fenugreek	52·7 ± 0·79

wheat samples representing 231 varieties and 49 growing locations in the US. In the present study the Al content of white and yellow corn, soft white wheat, hard wheat, sorghum (all from the US) and fenugreek (from Egypt) are reported in Table 3. Thus the values in US products have not changed appreciably since 1928, and are still lower than that found in Egyptian flours and breads.

An Egyptian farmer can consume up to four loaves of bettaw bread at a meal. In Beni Suef, that loaf weighs approximately 211 g and has 224 μg Al/g for a total of 47·3 mg Al/loaf or 567 mg Al/day, just from the bread. In Magousa, the bread weighs 179 g and has 113 μg Al/g of bread, giving a total of 243 mg of Al per day from the bread. The effects of long-term Al consumption at levels of 5 to 20 times that consumed in the United States are not known. Greger (1985) observed an initial decrease of P absorption by the addition of 120 mg of Al to the diets. However, higher doses, of less than 1 g/day, may interfere with P and perhaps Ca metabolism. This could be of major significance if the Egyptians at the New Village studied by Nawar (1979) are representative of all Egyptians. Nawar found a daily intake of 243 mg of Ca per day, while an earlier study by Abdou *et al.* (1965) found 449 mg. Various studies cited by Nawar (1979) reported that 13–28% of the children in different parts of Egypt had rickets. Thus ingestion of high levels of Al may interfere with the utilization of Ca and P, and may be a contributory factor to the incidence of rickets among the children in Egypt.

In conclusion, the source of the high levels of Al in the Egyptian breads has not been discerned; nor have definite patterns been observed. In addition, some valuable information about the local differences in Al content of flours was lost because of the necessity to reduce the number of samples by making composites. Those local differences could reflect the amount of Al in the grains as a result of soil and irrigation water, agronomic practices and contamination in the milling of the flour, perhaps by the addition of minerals from the grinding away of the stones in the stone mills. However, six factors seem to relate to the high levels of Al in the breads.

(1) The geographical location.
(2) The use of corn flour in the breads.
(3) The use of dung as a fuel for baking the bread.
(4) The use of additional ingredients such as fenugreek or okra.
(5) The utilization of aluminium bowls in making the Egyptian breads.
(6) The high levels of Al in the soil in Egypt (Abd Allah, 1987). Some varieties of wheat are particularly susceptible to Al toxicity; however, the varieties of wheat grown in Egypt are somewhat Al tolerant. That is the plants have the ability to accumulate the Al, in the wheat endosperm, without adversely affecting the plant's metabolism (Abd Allah, 1987).

An epidemiological study of the incidence of conditions such as Alzheimer's disease, osteodystrophy and amyotrophic lateral sclerosis in Egypt, where intake of Al from dietary sources is so high, could help unravel the relationship between Al and these conditions.

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REFERENCES

Abd Allah, M. A. (1987). Personal communication. Faculty of Agriculture, Ain Shams University, Cairo, Egypt.

Abdou, I., Ali, H. & Lebshtenein (1965). A study of the nutritional status of mothers, infants and young children attending MCHC in Cairo. *Bul. Nutr. Ins.*, **1**, 9–14.

Anon. (1966). Food balance sheets of UAR Department of Agricultural Economics, Ministry of Agriculture, Egypt.

Crapper, D. R., Krishnan, S. S. & Quittkat, S. (1976). Aluminum, neurofibrillary degeneration and Alzheimer's disease. *Brain*, **99**, 67–80.

Davis, K. R., Cain, R. F., Peters, L. J., Le Tourneau, D. & McGinnis, J. (1975). Final report to the National Wheat Institute, Washington, DC.

Eden, T. (1958). Climate and soils. In *Tea*. Longman Group Ltd, London, Ch. 2, p. 8.

Ehmann, W. D., Markesbery, W. R., Hossain, T. I. M., Alauddin, M. & Goodin, D. T. (1982). Brain trace element studies of aging and disease by INNA. *Trans. Am. Nucl. Soc.*, **41**, 206.

Ellis, R. & Morris, E. R. (1983). Improved ion-exchange phytate method. *Cereal Chem.*, **60**, 121–4.

Greger, J. L. (1985). Aluminum content of the American diet. *Food Technol.*, **39**(5), 73–80.

Hopkins, H. & Elsen, J. (1959). Mineral elements in fresh vegetables from different geographic areas. *J. Agric. Food Chem.*, **7**, 633–8.

Iskander, F. Y. (1985). Neutron activation analysis of an Egyptian cigarette and its ash. *J. Radioanal. Nucl. Chem.*, **89**, 511–18.

Iskander, F. Y. (1986). Cigarette ash as possible source of environmental contamination. *Environ. Pollut. (Ser. B)*, **11**, 291–301.

Kruger, P. (1971). *Principles of Activation Analysis.* John Wiley & Sons, Inc., New York, p. 328.

Langworthy, C. F. & Austen, P. T. (1904). *The Occurrence of Aluminum in Vegetable Products, Animal Products and Natural Waters.* New York.

Lione, A. (1983). The prophylactic reduction of aluminum intake. *J. Chem. Toxic.*, **21**, 103–9.

Lione, A. & Smith, J. C. (1982). The mobilization of aluminum from three brands of chewing gum. *Food Chem. Toxic.*, **20**, 945–6.

Martyn, C. N., Barker, D. J. P., Osmond, C., Harris, E. C., Edwardson, J. A. & Lacey, R. F. (1989). Geographical relation between Alzheimer's disease and aluminium in drinking water. *Lancet*, 59–62.

Miller, R. G., Kopfler, F. C., Kelly, K. C., Stober, J. A. & Ulmer, N. S. (1986). The occurrence of aluminum in drinking water. *J. Am. Water Works Assoc.*, **76**(1), 84–91.

Nawar, I. A. (1979). The structure of human diet in different income levels in an Egyptian new village in Abis Zone. IV: Calcium and phosphorus intakes. Div. of Home Economics, Dept of Agric. Extension, Faculty of Agriculture, Alexandria University, Egypt.

Penney, M. D. (1879). Alum in flour and bread. *Chem. News*, **39**, 80–1.

Persigehl, M., Schicha, H., Kasperek, K. & Feinendegen, L. E. (1977). Behavior of trace elements concentration in human organs in dependence of age and environment. *J. Radioanal. Chem.*, **37**, 611–15.

Smith, E. E. (1928). *Aluminum Compounds in Foods.* Paul B. Hoeber, Inc., New York, p. 378.

Tabekhia, M. M. & Toma, R. B. (1979). Chemical composition of various types of Egyptian breads. *Nutr. Rep. Int.*, **19**, 377–82.

Thompson, R. J. (1979). Collection and analysis of airborne metallic elements. In *Ultratrace Metal Analysis in Biological Series and Environment*, ed. T. H. Rigby. American Chemical Society, Washington, DC, Chapter 6, p. 54.

Ward, N. I. & Mason, J. A. (1989). Neutron activation analysis techniques for identifying elemental status in Alzheimer's disease. *J. Radioanal. Nucl. Chem.*, **113**, 515–26.