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Determination of Trace Elements in Ghanaian Shea Butter and Shea Nut by Neutron Activation Analysis (NAA)

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Abstract: The aim of the study is to determine the concentrations of trace elements in Ghanaian shea nut and shea butter. As part of the study, measurements of the elemental composition of shea butter and shea nut samples were carried out by Neutron Activation Analysis (NAA) using the Ghana Research Reactor-1 (GHARR-1). Samples collected from local markets in the Northern region of Ghana and the National Institute of Standards and Technology (NIST) Standard Reference Material (SRM) 1547 Peach leaves were irradiated at the GHARR-1 facility. Validation of the method was done using NIST SRM Orchard Leaves (1571) under the same experimental conditions. Six trace elements (Na, Mn, Al, Cl, Ca and K) were detected with maximum concentration of Na found to be 15±1 mg/kg in SN5, Mn; 7.4±0.8 mg/kg in SN6, Al; 259±3 mg/kg in SN1, Cl; 666±27 mg/kg in SN1, Ca; 0.21±0.04 wt.% in SN4, K; 2.0±0.04 wt.% in SN1, Ce; 3.2±0.06 mg/kg in SN2, Se; 0.12±0.004 mg/kg in SN4, and Sc; 0.40±0.02 mg/kg in SN2 . The concentrations of the trace elements were within the limit laid down for safe human consumption.

Key words: Ghana Research Reactor-1, high-purity germanium detector, mean concentrations, nutritional health, sample irradiation, trace elements

INTRODUCTION

Shea nut (*Butyrospernum paradoxum*) is an oil rich fruit obtained from tropical shea tree (*Vitellaria paradoxa*), which is indigenous to the West African savannah zone (Oluwole *et al*., 2004). The shea tree usually grows to an average height of about 15 m with profuse branches and a thick waxy and deeply fissured bark that makes it fire resistant (HORIZON, 2010).

Its fruit contains one or two nuts, which are brown and shiny. Although fruit pulp is edible, the tree is mainly important for its nut, which contains a kernel with an oil content ranging from 45 to 60%. The oil, known as shea butter, is used for cooking and the manufacture of soap, candle, cosmetics, pharmaceutical products and butter substitutes (Oluwole *et al*., 2004). As a cosmetic, it is used as a moisturizer, for dressing hair and protection of the skin against the weather. Shea butter is also applied as an ointment for rheumatic and joint pains relieves and in cases of dislocation, swelling and bruising. It is widely used to treat skin problems such as dryness, sunburn, burns, ulcers and dermatitis and to massage pregnant women and children (HORIZON, 2010).

More than 60 elements in various parts of human body have been detected. Among these, at least 25 elements are essential to human health out of which 14 are termed as trace elements. These elements with other pollutants are discharged in the environment through industrial activity, automobile exhaust, heavy-duty electric power generators, refuse burning and the use of pesticides in agriculture etc. Man, animals and plants take up these metals from the environment through air, water and food. Trace elements play important roles in chemical, biological, biochemical, metabolic, catabolic and enzymatic reactions in the living cells of plants, animals and human beings. They have great significance due to their tendency to accumulate in the vital human organs over long periods of time. The role of trace elements in body metabolism is of prime importance. Their deficiency causes diseases, whereas their presence in excess may result in toxicity to human life (Hashmi *et al*., 2007).

The content of metals and their species (chemical forms) in edible seed oils come from varying sources. The metals can be incorporated into the oil from the soil or be introduced during the production process. Lead and

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Table 1: Analysis of NIST SRM peach leaves (1547) and SRM orchard leaves (1571) in mg/kg by NAA

	NIST 1547 (Peach Leaves)		SRM 1571 (Orchard Leaves)	
Element	This work	Certified value	This work	Certified value
Na	22.50±1.5	24.00±2	87.00±4.00	82.00±6
Mn	107.00±10	98.00±3	102.00±7.00	91.00±4
Al	250.00±8	249.00±8	…	…
Cl	370.00±10	360.00±19	…	700.00 (noncertified)
Ca	1.53±0.05 (wt. %)	1.56 (wt. %)	1.97±0.07	2.09±0.03 (wt. %)
K	2.59±0.05 (wt. %)	2.43±0.03 (wt. %)	1.53±0.05	1.47±0.03 (wt. %)
Ce	...	10.00 (noncertified)	…	…
Se	0.15±0.04	0.120±0.009	0.11±0.02	0.08±0.01
Sc	...	0.04 (noncertified)	…	…

Table 2: Nuclear data and irradiation scheme used in determining trace elements in the NAA

Element	Target isotope	Formed nuclide	Thermal cross section/(barns)	Gamma-ray energyused, keV	Half-life ($t_{1/2}$)	Irradiation time (t_i)	Counting time (t_c)/s
Na	^{23}Na	^{24}Na	0.513	1368.60	14.959 h	1 h	600
Mn	^{55}Mn	^{56}Mn	13.20	1810.72	2.5785 h	120 s	600
Al	^{27}Al	^{28}Al	0.226	1778.99	2.240 min	120 s	600
Cl	^{37}Cl	^{38}Cl	0.423	1642.96	37.21 min	120 s	600
Ca	^{48}Ca	^{49}Ca	0.610	3084.54	8.715 min	120 s	600
K	^{41}K	^{42}K	1.450	1524.58	12.36 h	1 h	600
Ce	^{140}Ce	^{141}Ce	0.576	145.40	32.501 d	4 h	36000
Se	^{74}Se	^{75}Se	51.20	264.70	119.770 d	4 h	36000
Sc	^{45}Sc	^{46}Sc	26.30	889.30	83.81 d	4 h	36000

copper are potentially present in oils through environmental contamination. The presence of trace metals such as Cu, Fe, Mn, Ni, and Zn are known to have different effects on the oxidative stability of edible seed oils (Juranovic *et al.*, 2003).

The purpose of the study is to measure the concentrations of as many elements as possible with improved sensitivity, accuracy and precision, trace the flow of elements through the shea butter supply chain, and provide better knowledge based sources of safe locally produced shea butter using Neutron Activation Analysis (NAA). The NAA technique was conveniently applied in present study to meet the necessity of providing reliable results.

MATERIALS AND METHODS

Sampling and sample preparation: The study was carried out in the year 2010 at the National Nuclear Research Institute of the Ghana Atomic Energy Commission, in Ghana, West Africa. Three samples each of the shea nut and butter were obtained from six different local markets within the Tamale metropolis in the Northern region of Ghana. Sample preparation was carried out in the sampling preparation room of the Ghana Research Reactor-1 Centre at the Ghana Atomic Energy Commission. The shea nut samples were crushed using an agate mortar and pestle to finer particles suitable for irradiation. 0.2 g of each shea nut and shea butter samples were weighed into clean polyethylene films. The films were wrapped and heat-sealed. Six replicate sub-samples were prepared for each sample. The samples were then packed into 7.0 mL volume polyethylene irradiation vials which were capped and heat-sealed. The standard reference materials were treated the same way as the samples.

Standard reference material: The Standard Reference Materials (SRM) used (NIST 1547 Peach Leaves and NIST 1571 Orchard Leaves) were obtained from the US National Institute of standard and technology and were analyzed for internal quality control. The SRMs were treated the same way as the samples.

Sample irradiation, counting and analysis: The samples and the elemental comparator standard were irradiated in the inner irradiation site of the Ghana Research Reactor-1 (GHARR-1) facility operating at half power of 15 kW at a neutron flux of 5.0×10^{11} neutrons/cm^{2}s. The scheme for irradiation was chosen according the sample matrix. After the irradiation, induced radioactivities in the samples were counted using an Ortec HPGe detector with a relative efficiency of 25% and an energy resolution of 1.8 keV at 1332.5 keV gamma-ray of ^{60}Co. The gamma-ray acquisition system consists of MAESTRO Multi-Channel Analyser (MCA) emulation software card, coupled to the detector via electronic modules. The accumulated spectra intensities were analysed both qualitatively and quantitatively.

RESULTS AND DISCUSSION

Standardization of the method was done by analysing NIST SRM Peach Leaves (1547) and then validated using SRM Orchard Leaves (1571) under the same experimental conditions as the samples. The results obtained in this work were comparable to the reported values as shown in Table 1. The precision of the reported values were

Table 3: Mean concentrations (mg/kg) of elements in samples

Sample Id	Na	Mn	Al	Cl	Ca (wt. %)	K (wt. %)	Ce	Se	Sc
SB1	10±1.0	0.01±0.002	25±1	0.50±0.010	0.09±0.02	ND	0.40±0.02	0.02±0.001	0.015±0.001
SB2	12± 1.0	0.05±0.010	20±1	0.02±0.004	2.70±0.10	ND	1.70±0.03	0.013±0.004	0.012±0.004
SB3	7±0.2	0.14±0.020	11±1	0.11±0.010	0.10±0.02	ND	0.10±0.01	0.07±0.002	0.070±0.002
SB4	8±0.4	0.01±0.003	10±1	0.05±0.020	0.30±0.10	ND	0.08±0.004	0.03±0.001	0.030±0.001
SB5	13±0.7	0.02±0.003	18±2	1.50±0.050	5.00±0.70	ND	0.20±0.01	0.05±0.002	0.050±0.003
SB6	9±0.2	0.13±0.040	13±1	0.80±0.030	1.90±0.05	ND	0.12±0.03	0.09±0.006	0.020±0.005
SN1	13±1.0	4.40±1.000	259±3	666±27.000	0.07±0.003	2.0±0.04	1.70±0.02	0.06±0.004	0.090±0.010
SN2	14±1.0	4.10±1.000	199±2	606±27.000	0.12±0.04	1.9±0.04	3.20±0.06	0.09±0.003	0.400±0.020
SN3	9±0.7	0.70±0.080	191±2	418±22.000	0.18±0.05	1.1±0.02	2.70±0.08	0.04±0.001	0.070±0.003
SN4	10±0.5	5.20±1.000	188±3	390±22.000	0.21±0.04	1.2±0.02	2.60±0.04	0.12±0.004	0.230±0.040
SN5	15±1.0	3.10±0.100	237±2	542±32.000	0.20±0.30	1.8±0.01	2.30±0.07	0.17±0.070	0.140±0.010
SN6	12±0.8	7.40±0.800	195±4	483±19.000	0.90±1.00	1.3±0.02	3.10±0.03	0.08±0.002	0.110±0.020

ND: Not detected

calculated as a percentage relative standard deviation (% RSD) of six replicate measurements and were found to be less than ±10%. The irradiation scheme for the determination of the radionuclides and the nuclear data used are shown in Table 2.

The present study though does not contain an exhaustive number or varieties of shea butter and shea nuts from the area, may give a fair idea about the possible elemental composition of the shea butter and shea nut. The average concentration of Na, Mn, Al, Cl, Ca, K, Ce, Se, and Sc analysed in each of the six shea butter and shea nut samples are given in Table 3. It was observed that in general, the concentrations of the elements in the unprocessed shea nut were higher than that found in the processed shea butter. Sodium was recorded in various concentrations which ranged between 7 to 15 mg/kg. High concentration of chlorine was recorded in the shea nut samples ranging from 390 to 666 mg/kg, while in the shea butter samples, the concentration varied between 0.02 to 1.5 mg/kg. Similarly high potassium levels were recorded in the shea nut samples ranging from 1.1 to 2.0 wt. % and in the shea butter it was below detection limits.

A daily dietary intake of 2.5 to 5 mg of manganese by human contributes to the well-being of cells (Dara, 1993). Manganese deficiency causes diseases and excess of it causes poisoning of the central nervous system. Absorption, ingestion, inhalation or skin contact may cause manganic pneumonia (Underwood, 1997). Calcium is a major mineral found in our body. It constitutes 1.5-2% of the body weight of an adult person. For adults, daily intake of 1,000 mg is required. In children, this intake is higher. If calcium is taken in low quantities or if it does not meet the body's requirements, rickets and Osteomalacia can arise. Calcium deficiency in young girls can cause abnormal formation of bones, which can lead to problems during pregnancy and delivery of babies. After 50 years of age, calcium deficiency can lead to decrease in the bone density, and this can lead to easy fractures (Hassam, 2010). Based on recommended energy and nutrient intake, an adult needs about 1600 to 2000 mg of potassium to maintain homeostasis or balance (Mabille, 2010). Until recently, aluminium was thought to be useless to life processes. It is now thought to be involved in the action of a small number of enzymes. For a technical explanation: "it may be involved in the action of enzymes such a succinic dehydrogenase and d-aminolevulinate dehydrase (involved in porphyrin synthesis)." Even if this element is necessary for some life functions, the amount necessary is greatly exceeded by our incidental intake through drinking water, food, deodorants and some antacids. Aluminum is relatively benign, and it is used in food additives and indigestion pills. It has been linked to Alzheimer's disease and the body has a hard time ridding itself of excess aluminum (Anonymous, 2010c). Without sodium, our cells could not get the nutrients they need to survive. Sodium also allows our bodies to maintain the right blood chemistry and the correct amount of water in our blood. This element also allows our muscles to contract normally. Furthermore, our bodies need sodium to digest the food that we eat (Anonymous, 2010c). Selenium is a trace mineral, and the body only needs small amounts of it to function properly. Selenium plays an important role in the body's enzyme function, and may help to stimulate the production of antibodies (disease-fighting organisms) after vaccination. Selenium also aids in male fertility. Selenium is also considered an antioxidant, and it may work with other antioxidants such as vitamins C and E to protect the body's cells against free radicals, which can promote the development of cancer and heart disease. Men and women should consume 50 to 200 mg of selenium a day (Anonymous, 2010b). Scandium has no biological role. Only trace amounts reach the food chain, so the average person's daily intake is less than 0.1 mg. Scandium is not toxic, although there have been suggestions that some of its compounds might be cancerogenic. Scandium is mostly dangerous in the working environment, due to the fact that damps and gasses can be inhaled with air. This can cause lung embolisms, especially during long-term exposure. Scandium can be a threat to the liver when it accumulates in the human body (Anonymous, 2010a). The steady rise of cerium in the environment through its wide industrial and agricultural applications, especially the use of cerium additives in diesel vehicles could cause an increased risk of exposure to cerium in humans. The general population may be exposed to cerium mainly by oral uptake through food ingestion and by inhalation of fine particles. Studies of the daily oral intake of cerium through the ingestion pathway showed that cerium can be taken up at a rate of 5.6-8.6 mg/d. Higher intake values of 83-145 mg/d were also suggested for farmers living near an ore deposit containing about 3% of rare-earth. Oral cerium uptake is considered to be less toxic as orally administered cerium is poorly absorbed in animals. However, the EPA report on cerium compounds reviewed studies suggesting a relationship between exposure to cerium in food and the development of endomyo-cardial fibrosis; further, numerous cases have been described of workers who developed pneumoconiosis. This lung disease was associated with accumulation of cerium in the lungs after a prolonged occupational exposure to cerium fumes or dust due to the use of carbon arc lamps (Höllriegl *et al*., 2010).

CONCLUSION

Neutron activation analysis based on thermal neutrons from a low power nuclear research reactor, the Ghana Research Reactor-1 (GHARR-1) in combination with a high-purity germanium detector was used to analyse shea nut and shea butter samples obtained from local markets in the Northern Region of Ghana. Shea butter is the main edible oil for the people of northern Ghana, being the most important source of fatty acids and glycerol in their diet (Fobil *et al*., 2002). The concentration of the following trace elements; Na, Mn, Cl, Al, Ca, K, Ce, Se, and Sc were determined as part of existing research in establishing baseline levels of essential, non-essential and toxic elements in Ghanaian food items (Nyarko *et al*., 2006). The elemental concentrations were found to be generally higher in the shea nuts than the shea butter. It was also observed that the essential elements were in fair quantities.

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REFERENCES

Anonymous, 2010a. Retrieved from: http://www.lenntech.com/periodic/elements/sc, (Access on: 24 September, 2010).

Anonymous, 2010b. Retrieved from: http://www.lifeclinic.com/focus/nutrition/selenium.asp, (Access on: 24 September, 2010).

Anonymous, 2010c. The Role of Elements in Life Processes. Retrieved from: http://www.mii.org/periodic/LifeElement.html, (Access on: 22 September, 2010).

Dara, S.S., 1993. Environmental Chemistry and Pollution Control. 1st Edn., S. Chand and Company Ltd., New Delhi, India, pp: 184-205.

Fobil, J.N., C.A. Kipo, D.K. Abbiw and D.K. Attuquayefio, 2002. Research and development of the shea tree and its products. Research by the Cocoa Research Institute of Ghana (CRIG) into the cultivation and processing of shea nuts as an alternative to cocoa products, Bole, Ghana.

Hashmi, D.R., S. Ismail and G.H. Shaikh, 2007. Assessment of the level of trace metals in commonly edible vegetables locally available in the markets of Karachi city, Pak. J. Botany, 39(3): 747-751.

Hassam, 2010. Importance of Calcium. Retrieved from: http://hubpages.com/hub/Importance-Of-Calcium, (Access on: 22 September, 2010).

Höllriegl, V., M. González-Estecha, E.M. Trasobares, A. Giussani, U. Oeh, M.A. Herraiz and B. Michalke, 2010. Measurement of cerium in human breast milk and blood samples. J. Trace Elements Med. Biol., 24: 193-199.

HORIZON, 2010. Solutions Site Peer Reviewed Answers to Problems in Environment, Health, Population and Development. Retrieved from: http://www.solutions-site.org/artman/publish, (Access on: 17 August, 2010).

Juranovic, I., P. Breinhoelderb and I. Steffan, 2003. Determination of trace elements in pumpkin seed oils and pumpkin seeds by ICP-AES, J. Anal. At Spectrom., 18: 54-58.

Mabille, J., 2010. The Importance of Potassium. Retrieved from: http://www.healthguidance.org/entry/12820/1The-Importance-of-Potassium.html, (Access on: 22 September, 2010).

Nyarko, B.J.B., E.H.K. Akaho, J.J. Fletcher, B. Zwicker and B.A. Chatt, 2006. Simultaneous determination of short-to-medium lived nuclides in Ghanaian food items using INAA and Compton suppression counting. J. Radioanal. Nucl. Chem., 270(1): 243-248.

Oluwole, F.A., N.A. Aviara and M.A. Haque, 2004. Development and performance tests of a sheanut cracker. J. Food Eng., 65: 117-123.

Underwood, E.J., 1977. Trace Elements in Human and Animal Nutrition. 4th Edn., Academic Press Inc., New York.