Elemental Analysis of Nigerian and Nigerien Foods Using Neutron Activation and Estimation of Daily Intake

A.R. Usman[1,4], M.U. Khandaker[1], N.F. Isa[2], and Y.A. Ahmed[3]

[1] Department of Physics, University of Malaya, 50603 Kuala Lumpur, Malaysia
[2] Department of Physics, Bayero University, Kano, Nigeria
[3] Center for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria
[4] Department of Physics, Umaru Musa Yar'adua University, Katsina, Nigeria

Abstract— **Realizing the importance of individual elements to human body, 14 different food samples (mainly cereals: beans, millet, sorghum and rice) collected from two different countries; Nigeria and Republic of Niger, were analyzed using Instrumental Neutron Activation Analysis (INAA) for the determination of the elemental content. Despite the commercial activity of uranium in the Republic of Niger, the concentration of Uranium, Arsenic, Chromium etc. in the studied samples show below detection limit. Elevated concentrations of K, Ca and Mg were found from the sampled beans of this work. Daily intake per person of all assessed elements were estimated and compared with Recommended Daily Intake (RDI) to establish the accumulation information of mineral, toxic and radioactive elements in the body of people of Nigeria and Niger Republic. Assessed elemental concentrations were compared with the available literature data on relevant cereals, and found reasonable agreement. Analytical quality control service (AQCS) reference material (lichen) from International Atomic Energy Agency (IAEA) was also irradiated and analyzed in this work for ensuring quality control of the method and facility (nuclear reactor) used.**

Keywords— **Cereals, Katsina, Maradi, NAA, Mineral, Toxic and Radioactive elements.**

I. INTRODUCTION

The need to have a detailed and accurate information on the elemental concentrations of our foods cannot be over emphasized. This is because, trace elements form an important component of the biotic environment for their roles in the health of human being, animals and plants. Taking of right food with the correct proportion of nutrients is the ideal requirement of the body. Most of our dietary compositions are now understood to be either essential to, or complimenting the proper usage of nutrients in human body [1, 2]. Cereals, one of the major food category, is the staple food of the sub-Sahara region of northern Nigeria and Niger republic. This is largely produce due to soil type and amount of annual rainfall in the regions. The main crops being cultivated in Niger Republic are millet, sorghum (guinea corn), and beans. Rice is mainly cultivated through irrigation farming around the River Niger and River Komadougou of the country [3]. On the other hand, maize, millet, sorghum and beans are the main cultivated edible crops in Nigeria.

In order to determine elemental content of the selected crops, this study employed (thermal) neutron activation analysis for its advantages over several others techniques that includes ability to detect many elements in a wider range of matrix, freedom from reagent blank, high accuracy and improved sensitivity [4, 5, 6,]. The study was carried out using Nigerian Research Reactor (NIRR-1) situated at the Center for Energy Research and Training (CERT), Ahmadu Bello University (ABU), Zaria – Nigeria. NIRR-1 was designed as a Miniature Neutron Source Reactor (MNSR) such that it has a configuration of tank-in-pool structure, a fuel of highly enriched uranium (90.2 %), light water serving as both moderator and coolant, metallic beryllium (Be) surrounding core of the reactor as reflector, rated power of 31kW and a corresponding thermal neutron flux 1.0 x 10^{12} $cm^{-2}s^{-1}$. Details of the reactor structural and configurations can further be found elsewhere [1]. Present study broadly bears the followings as some of its major goals. First is to determine and compare all the detectable elements in the selected food items of Nigeria and Republic of Niger, including the risk elements since these regions are major producers of the itemized food products. The second goal arose from considering that Republic of Niger has uranium exploration commercial activities and thus aimed to find if those activities have (through leaching, human activities and wind) led to sufficient migration of related parent and daughter elements to the selected regions, and consequently contaminated the distant soil and crops. The third is to use the obtained data to calculate elemental contribution of dietary intake to the people of these communities. This would ultimately increase more available data on this subject from these regions, especially Republic of Niger.

II. METHODOLOGY

Through careful selection, a total of 14 food samples comprising two each of sorghum (guinea corn), millet, beans and rice were collected from cities of Bakori, Funtua, Katsina, and Charanci Local Governments of Katsina state

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in Nigeria and Some parts of Maradi in Republic of Niger after the best harvesting period of the samples. In order to ascertain the locality of the samples, the purchase was mostly directly from the farmers. The dried and grinded samples were then packed into separates polythene bags. A small portion of each powdered sample was prepared, weighed using high precision balance (METTLER AE 240) and packed using 8 ml polyethylene vials. An air drier was used to heat seal the vials. Each sample was prepared in twice for short and long irradiations. With the help of rabbit carriers, the samples and standard were sent into the reactor through the pneumatic transfer system which uses pneumatic pressure. NIRR – 1 irradiated the samples with a thermal neutron flux of $2.5x10^{11}$ $ncm^{-2}s^{-1}$for 5 minutes and $5.0x10^{11}$ $ncm^{-2}s^{-1}$ for 6 hours for short and long irradiations, respectively. The whole system was equipped with electronic timers which help in monitoring the exact irradiation and decay times. The samples were then taken to a measurement room consisting of a high purity germanium (HPGe) detector, connected to a PC-based Multi-Channel Analyzer (MCA).

A. Calculation of Dietary Intake for People of Nigeria and Niger Republic

The Estimated Daily Intake (EDI) were based on mg per person per day. We used the published data of [8]2009 for per capita average consumption of millet, sorghum, rice and beans as 95, 101, 58, and 24 g/day, respectively by Nigerians. The same source shows that people of Niger Republic consume 425, 124, and 88 g/day of millet, sorghum and beans, respectively. The EDI is compared with the Recommended Daily Intake (RDI) to have an insight of the daily contribution and loading of the studied elements in the bodies of people of these regions.

III. RESULTS AND DISCUSSIONS

Quantitative information of this work is presented in the Tables 1 and 2. Table 2 represents the EDI and RDI of

Table 1 Analytical Results for Various Elements from 7 Biological Samples in This Research.

Elements (ppm)*	Nigeria (average Values)				Niger Republic (average Values)		
	S1(Sorghum)	R (Rice)	B1 (Beans)	M1 (Millet)	M2 (Millet)	B2 (Beans)	S2 (Sorghum)
^{27}Mg	884 ± 89	305 ± 67	1297 ± 101	556 ± 72	893 ± 82	1167 ± 98	757 ± 72
^{28}A1 (ppm)	43 ± 5	54 ± 5	23 ± 2	66 ± 6	29 ± 3	29 ± 3	39 ± 4
^{49}Ca (ppm)	291 ± 75	280 ± 73	1489 ± 249	448 ± 93	455 ± 94	1333 ± 223	310 ± 73
^{56}Mn (ppm)	15 ± 1	6.1 ± 0.3	14.4 ± 0.6	11.6 ± 0.5	12.8 ± 0.6	27.3 ± 1.2	21 ± 1
^{24}Na (ppm)	8 ± 1	56 ± 3	41 ± 2	12 ± 1	13 ± 1	33 ± 2	5.9 ± 0.4
^{42}K (ppm)	4297 ± 305	1842 ± 138	15420 ± 1079	5198 ± 3698	4510 ± 325	16310 ± 1142	3866 ± 278
^{82}Br (ppm)	4.3 ± 0.2	0.24 ± 0.02	0.54 ± 0.04	1.27 ± 0.07	11.7 ±1.1	2.3 ± 0.1	7.5 ± 1.2
^{140}La (ppm)	0.06 ± 0.01	BDL	0.11 ± 0.02	0.11 ± 0.01	0.08 ± 0.01	0.09 ± 0.01	BDL
^{65}Zn (ppm)	60 ± 6	18 ± 3	44 ± 6	40 ± 5	32 ± 6	57 ± 7	31 ± 6
^{86}Rb (ppm)	6 ± 1	15 ± 2	20 ± 2	13 ± 2	9 ±2	23 ± 3	7 ± 1
^{232}Th(ppm)	0.4 ± 0.1	0.3 ± 0.1	0.4 ± 0.1	0.6 ± 0.1	0.4 ±0.1	0.3 ± 0.1	0.5 ± 0.1

*ppm – parts per million (i.e., PPM = $\mu g\ g^{-1}$=$mg\ kg^{-1}$), BDL – below detection limits, NA – not analyzed.

Table 2 Nigerian and Nigerien (Republic of Niger) foods; Estimation of Daily Intake and its comparison to Recommended Daily Intake

Elements	Estimated daily intake for Nigerian food (mg/day)				Estimated daily intake for Niger Republic food (mg/day)			Recommended Daily Intake (mg/day)
	Millet	Beans	Sorghum		Millet	Beans	Sorghum	
^{27}Mg	123.215	31.128	89.284	17.69	379.525	102.696	93.868	420(320)*
^{28}A1	2.185	0.552	4.343	3.132	12.325	2.552	4.836	1
^{49}Ca	141.455	35.736	29.391	16.24	193.375	117.304	38.44	1000
^{56}Mn	1.368	0.3456	1.515	0.3538	5.44	2.4024	2.604	2.3(1.8)*
^{24}Na	3.895	0.984	0.808	3.248	5.525	2.904	0.7316	2300
^{42}K	1464.9	370.08	433.997	106.836	1916.75	1435.28	479.384	4700
^{82}Br	0.0513	0.01296	0.4343	0.01392	4.9725	0.2024	0.93	8
^{140}La	0.01045	0.00264	0.00606	-	0.034	0.00792	_	375
^{65}Zn	4.18	1.056	6.06	1.044	13.6	5.016	3.844	11(8)*
^{86}Rb	1.9	0.48	0.606	0.87	3.825	2.024	0.868	400
^{232}Th	0.038	0.0096	0.0404	0.0174	0.17	0.0264	0.062	760

** Where there is difference between male and female requirement, the bracket term is for female.*

various elements for the people of Nigeria and Republic of Niger, respectively via the consumption of studied foods. A short briefing about the determined elements are given under the following sections:

A. Toxic Elements

Thorium (Th): Thorium has been detected in all the samples, with the Nigerian millet showing the highest value. When ^{232}Th is ingested as a food element, it predominantly escapes from the body via urine and feces within few days. Usually only little amount of ^{232}Th is left in the body which subsequently enters the bloodstream and finally deposited on bones for years. As ^{232}Th undergoes radioactive decay to ^{228}Ra, concurrently it emits ionizing radiation such as alpha particle with accompanying gamma radiation. Increase risk of cancer is the major concern of low to moderate exposure level of ionizing radiation. Studies have indicated that inhaling thorium dust causes an increased chance of lung and pancreatic cancers. Due to likelyhood of thorium storage in bone, the risk of bone cancer is also increased [9]. A single thorium administration of 760 mg/kg body weight per day (84nCi/kg/day = 3100 Bq/kg/day) resulted to no mortality of mice whereas a single gavage dosage of 1000 mg thorium per kg body weight per day (110 nCi/kg/day = 4070 Bq/kg/day) in form of thorium nitrate lead to the death of 4/20 mice [10].

Aluminum (Al): This study reports the presence of aluminum in virtually all the samples. Among the studied samples, Nigerian cereals show the highest mean concentrations of Al. There has not been any report of any significant role of Al in human. However, increase in evidence of its toxicity relating to its accumulation in brain and effects on nervous system has consequently led WHO to revise its earlier stand of 7 mg/kg of body weight Provisional Tolerable Weekly Intake in 2006 to 1 mg/kg of body weight [11]. Millet and several other cereals demonstrate higher level of this toxic element, above the recommended daily intake.

B. Mineral Elements

Manganese (Mn): Manganese shows highest concentration of 27.3 µg g^{-1} in Nigerien beans, 14.4 µg g^{-1} for Nigerian beans while (Nigerian) rice has the least content of 6.1 µg g^{-1} of all the samples. Mn is an essential element for metabolism of carbohydrates and lipid and also for bone growth of human beings. It also serves as an enzyme activator for some enzymes. Toxicity of manganese has also been documented, but the danger is very unlikely through dietary daily exposure except under distinct situations [11].

Calcium (Ca): This study reported highest concentrations of Ca (1489 µg g^{-1}) from Nigerian beans while the least concentration of the element is seen in rice as 280 µg g^{-1}. Calcium balance in the body is very crucial, it is not only useful to the skeleton but also plays important roles in regulating nerve excitability, muscle contraction and blood coagulation.

Magnesium (Mg): Mg is reported to have the highest concentration of 1297 µg g^{-1} from Nigerian beans and least concentration of 305 µg g^{-1} from rice. The variation is highly pronounced from one food item to the other, signifying importance of individual element for particular mineral complementation. Literatures have shown a usual reported deficiency of Mg in human and indicated nausea, growth retardation and muscle weakness as some of its symptoms and also suggested cardiac malfunction due to deficiency of the element [11].

Sodium (Na): Varying concentrations of sodium has also been reported here from one food item to the other with the highest (56 µg g^{-1}) in rice and least (5.9 µg g^{-1}) in Nigerien sorghum. Natural level of Na is usually sufficient in most foods but is still further supplemented especially in processed foods. Dietary excess of sodium results to hypertension, with the most adverse consequences seen in people of historic renal disease, congestive heart failure, or cirrhosis.

Zinc (Zn): With the exception of rice that shows lowest amount of 18 µg g^{-1} in zinc, the other food items have moderately high concentration of this element. Zn is an activator of several enzymes and stabilizes the structure of DNA, RNA and Ribosomes. Additionally, it plays a crucial role in hormonal metabolism. Diarrhea, growth retardation, skin lesions etc. have been reported as some of its deficiency syndromes.

Potassium (K): Potassium (^{42}K) was detected in high concentration in all the samples, with the most elevated value seen in Nigerien beans. Potassium is essential for human life and is considered as one of the most abundant element in our body. It serves as a regulator in the acid–base and the osmotic balance in the cell, plays a significant role in muscle contraction and transmission of nerve impulse, and also as a many enzymes' co-factor involved in the storage of carbohydrates and synthesis of protein. Despite the above advantages, potassium is also known to be radioactive and thus can have detrimental effect to health when at very high level.

Bromine (Br): Nigerian rice shows 0.24 µg g^{-1} as the least Br content. This suggest that for higher Br requirement of the body, Nigerien millet and sorghum (11.7 µg g^{-1} and 7.5 µg g^{-1}) are good choice while rice is very poor in that context. The major food sources of Br are grains, nuts, sea foods, sea salt and bread. Eusinophilic leukocytes of blood uses Br for immune defense [12]. A study suggests intake of 8 mg per day as adequate to the body and similarly, the study further cited insomnia and retarded growth as the deficiency symptoms of Br [12].

Generally, this study reports a lower concentration for the elements K, Ca, Zn and Mn, compared to the earlier data reported in [1]. Maihara et al. [13] however reported a much lower concentration of Zn in Brazilian cereals than those reported here. Arogunjo et al. [14] reported activity concentrations of ^{40}K, ^{238}U and ^{232}Th as 297.87 Bq/Kg, Nil and 5.95 Bq/Kg, respectively in Nigerian white beans of Sokoto region, and 42.29 Bq/Kg, Nil and 4.01 Bq/Kg in local rice from Ekiti state of Nigeria. The level of radioactive concentration reported in this study is below the adverse level suggested as tolerable daily intake (TDI) by [10] based on conducted studies on mice and dog. This study also indicated that beans is very rich in Mg, Ca and K as compared to other sampled cereals.

IV. CONCLUSIONS

This study detected the presence of Mg, Al, Ca, Mn, Na, K, Br, Zn, La, Rb and Th in the most staple food items of Northern Nigeria and Republic of Niger. The Estimated Daily Intake for all of the detected elements was obtained for adult population, and compared with the Recommended Daily Intake to have an insight of the daily contribution of these elements into their body. Despite the commercial activity of uranium in Republic of Niger, excessive leaching may not have yet occurred to the extent of contaminating distant soil and crops of the selected regions. This study also provides new data on cereals to the selected regions, and suggest more studies especially in Republic of Niger as only very little data was found from the region. Due to the important roles of these nutrients in biochemical processes within the body, it is thus vital that we should consider them in unison rather than in isolation for collective improvement of our health.

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CONCFLICT OF INTEREST

The Authors declared that there is no conflict of interest.

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Corresponding Author:	M.U. Khandaker
Institute:	University of Malaya
Street:	50603 Jalan University
City:	Kuala Lumpur
Country:	Malaysia
Email:	mu_khandaker@yahoo.com