

Comparative Assessment of Radioactivity Concentration in Sweet Potatoes from Different Geopolitical Zones of Nigeria

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Abstract—Evaluation of the specific activity of radioactivity in tubers is an important tool in the assessment of human internal exposure to radiation through ingestion. In this research, the activity concentrations of natural radionuclides 40 K, 238 U and 232 Th in sweet potato samples taken from different farm lands in the six geopolitical zones of Nigeria were determined by means of gamma spectrometry. Using standard calibrated NaI (TI) and shielded detector coupled to a computer resident quantum MCA2100R Multichannel analyzer for 36,000 s. The activities were estimated to be 526.39 ± 51.40 , 8.55 ± 1.76 and 1.14 ± 0.42 Bq/kg respectively for 40 K, 238 U and 232 Th. The estimated daily intake through potato diet are 6.6622, 4.6860, 4.6748, 2.75103, 2.7453, and 2.3983 Bq.d⁻¹ for South-East (Abia), South-South(Edo), South-West(Oyo), North-Central (Kwara), North-West (Sokoto), and North-East (Adamawa) respectively.. Findings showed that potato plants uptake and transport radionuclides from the soil by the root system. It also showed that 40 K is the most radionuclides contaminant presents in the farm soil where the potato plants were grown. The daily intake of radionuclides was also observed to be highest in 40 K. This may be due to the use of phosphate rich fertilizer in the farmlands where they were grown. The overview of the research showed that the annual effective doses due to potato diet, at this present rate, pose no significant threat to the public.

Keywords—Key words: Natural radionuclides, potatoes, effective dose, ECLR

I. INTRODUCTION

Mining and exploration activities taking place for many years in Nigeria have brought a challenge of pollution of water supplies, depleted land quality for agricultural practices and abnormally high quantities of soil natural occurring radioactive elements [1]

Terrestrial radiation differs from one location to another place owing to variation of soil radionuclide concentration. Locations with natural background radiation above normal are called high background radiation and some of these areas are found on the Jos- Plateau axis. The earth, of course, has varied quantities of radioactivity owing to chain delay of soil natural radionuclides 238 U and 228 Th and 40 K [2].

Man made activities like mining, geological formations and features of soil relative to radioactivity are important factors that enhance the base levels of natural radiation [3]. Naturally occurring radionuclides of 228Th and 238U have cogent contributions in the ingestion dose and are available in the biotic system of air, soil, water, plants and animals [4]. Distribution of radionuclides in different parts of the plant depends on the chemical characteristics and several other factors of the plants and soil [4].

Radionuclides are radioactive Isotopes with unstable nuclei, known by excess energy contained to be imparted either to a newly created radiation particles within the nuclei or through internal conversion. A radionuclide undergoes radioactive decay during this process, resulting to emission of γ (gamma) - ray(s)

with subatomic particles such as α (alpha) or β (beta) particles [5]. Radiations are particles with energy or wave that travel through a vacuum or matter, containing medium that are not required for their propagation [6]. Absorption of this energy from radiation in biological matter may cause excitation and ionization [7, 8, 9]. Radiation is available in the environment and it has ever been penetrating from the outer surrounding space, even from within our body systems and the ground - Terrestrial Radiation. Radioactivity level from the natural radionuclides is known generally as the background radiation, which depends on the amount of the radioactive materials available in the surrounding environment. Pollution of the surrounding environment by either natural sources or human activities may cause the background radiation to be high. This Radiation has effects on human or biological bodies depending on the absorbed dose. High level radiation dose can affect the genetic cell (DNA) of human while low dose can have no appreciable immediate impact. The biological effect of radiation are grouped as either deterministic or stochastic [9].

A deterministic effect or tissue reaction of ionizing radiation is directly related to the absorbed dose and it has a threshold of dose which includes reddening of skin while stochastic effect has no threshold of dose; it is dependent on molecular mechanisms involved, it can be observed in hereditary defect or cancer. Industrial wastes from manufacturing companies involved in recycling secondary steel metals can release various harmful particles that may be associated with radioactive contamination. These emitted substances do not only pollute water or degrade the soil and vegetation, but increase also the occurrence and prevalence of some disease conditions in the populace [10]. The main objective of this investigation is to assess the natural radioactivity concentration and evaluate the radiation hazard parameters for the sweet potatoes samples collected from different regions of Nigeria. Sweet potatoes botanically known as *Ipomoea batatas* tuber has been ranked as the most commonly consumed carbohydrate-rich meal in the world and one of the most important crops in some low income nations aside rice, wheat, cassava and corn [11]. It is a commercial crop with over 90% of global production farmed in developing nations. Sweet Potatoe is valued to be a superfood compared to other crops, with high nutritional value and may be a better choice for consumption compared to other potatoes like Irish potatoes (*Solanum tuberosum*) [12].

The people of Offa, a town in North-Central Nigeria are known to be a high consumer of sweet potatoes. Above 50% of the Nigerian populace are estimated to consume sweet potato once a week as part of their diets in a boiled, roasted or fried form [10]. However, despite a dietary preference for sweet potatoes in Africa, America and Caribbean countries, studies have shown that complex carbohydrate-rich foods may cause high glycemic indices resulting in potential harmful health effects and development of some chronic diseases. Excess consumption of high glycemic index foods may cause hyperinsulinemia, insulin resistance, uncontrollable weight gain and obesity, heading to insulin-resistant syndrome [13]. Current investigation revealed a positive correlation between the consumption of meals with high glycemic index and increased risk of chronic diseases such as type 2 diabetes, heart related diseases, and cancer [14].

This study, however examined radioactivity concentration measurement of sweet potatoes and its annual effective dose in human.

II Materials and Methods

Collection of samples was conducted based on the premise that they constitute a high percentage of the diet in the locals. A total of six (6) tuber crops samples were collected directly from farm lands within six states of different geopolitical zones in Nigeria as shown in figure 1. The six states in focus were chosen from each region and the states are listed as follows: Kwara State (North Central), Oyo state (South West), Edo state (South South), Imo State (South East), Sokoto State (North west), Adamawa State (North East). At the collection points, samples were discretely and carefully placed in a pre-labelled polythene bags to avoid mix-up as well as cross contamination. The sample collected on sites are shown in figure 2. The potatoes were transported to the laboratory, washed with distilled water and were sliced into chips using stainless kitchen knife, which were initially washed and rinsed with distilled water. The samples were air dried for about 8-10 weeks as shown in figure 3. The dried potato chips were grinded to fine powder using Silver Crest electronic grinder. Then, each 30 grams sample was weighed into petri dishes of equal size, using an electronic weighing balance (G&G electronic scale: JJ500) and tape-sealed for 28 days before gamma spectrometric analysis, to allow attainment of secular equilibrium of the parent and daughter nuclides. This is described in figure.4 and table 1 showing the description of samples 1 to 10 from North Central (NC1-10), North East (NE1-10), North West (NW1-10), South West (SW1-10), South South (SS1-10) and South East (SE1-10).

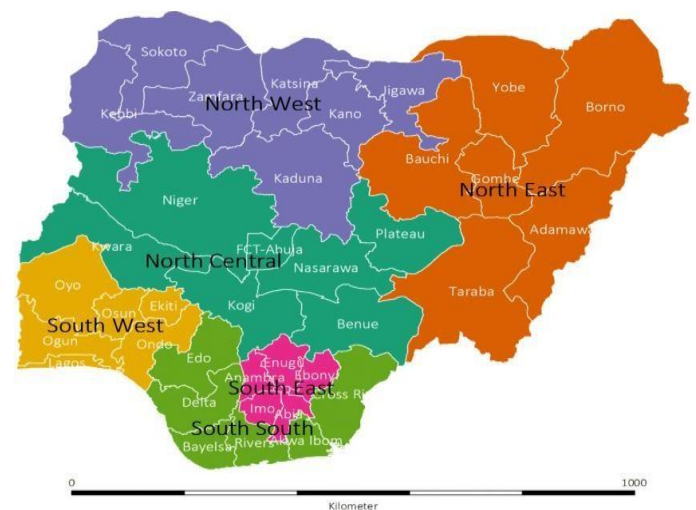


Fig 1. Nigeria Map showing the Regions and the States



Fig 2: Sweet Potatoes Collection on sample sites



Fig 3: Dried potatoes chips under room temperature



Fig.4: Samples weighed in petri dish kept for secular equilibrium

Table 1: Description of Sample

SAMPLE CODE	LGA	Farm Location	Crop Type	Discription
NC1-10	Offa	Ojoku	Tuber	Sweet Potato
NE1-10	Gombi	Gombi	Tuber	Sweet Potato
NW1-10	Bodinga	Bodinga	Tuber	Sweet Potato
SW1-10	Lagelu	Ibadan	Tuber	Sweet Potato
SS1-10	Etsako West	Auchi	Tuber	Sweet Potato
SE1-10	Ikwuano	National Root Crop Research Institutes, Umudike	Tuber	Sweet Potato

2.1 Radioactivity Measurement

Storing and gamma spectrometric analysis of the samples, as shown in figure 5 was carried out at the Radiation/Health Physics research laboratory of Ladok Akintola University of Technology, Ogbomoso, Oyo State. The activities of natural radionuclides in the samples were analyzed by 7.6 cm × 7.6 cm NaI(Tl) - detector of model 802 series, produced by Canberra Inc. The detector has a resolution of about 8% at 0.662 MeV, which is capable of distinguishing the gamma ray energies of the radionuclides of interest in this study. The interference of background radiation was minimized by the use of a 15 mm lead - shield that reduced the interference by 95%. Output of the Sodium Iodide - detector was connected to a Canberra series Multichannel Analyzer (MCA) with computer based MAESTRO - ORTEC program employed for acquisition and analysis of the gamma spectra data. Prior to sample analysis, energy and efficiency calibrations of the gamma-counting system, using standard IAEA sources, were performed for various energies of interest in the selected sample geometry following the processes described in IAEA - 1989. The background was obtained through the counting of empty container with the same geometrical shape as the one housing the samples and deducted from the gross count. Each sample including background was counted for 36,000 sec to obtain the gamma spectrum with good statistics. The activity of ²³⁸U, ²³²Th, and ⁴⁰K were obtained by employing the gamma - ray photo peaks corresponding respectively to energy of 1120.3 KeV (²¹⁴Bi), 911.21 KeV (²²⁸Ac) and 1460.82 KeV (⁴⁰K). The activity concentrations of the radionuclides thus were determined using the total net counts under the selected photo-peaks, the measured photo-peak efficiency, gamma intensity and weight of the samples using the following expression [8,1].

$$C \text{ (B. kg-1)} = \frac{C_n}{\epsilon P_y M_s} \quad (1)$$

Where: C is the activity concentrations of radionuclides in the sample, C_n is the total net count rate under each photo peak, P_y is the absolute transition probability of the specific gamma energy, ε is the efficiency of the detector for the specific gamma energy and M_s is the mass of the sample in kilogram (kg).



Fig 5: Experimental setup for sample radionuclides detection

2.2 Estimation of Radium equivalent activity (Raeq)

Since ⁴⁰K, ²³⁸U and ²³²Th are not equally distributed in a sample, the radium equivalent activity, Raeq is used in radiological study as a single activity concentration of ⁴⁰K, ²³⁸U and ²³²Th radionuclides present in a sample. The assumption is based on the fact that 4810 Bq/kg of ⁴⁰K, 370 Bq/kg of ²³⁸U and 259 Bq/kg of ²³²Th produce the same gamma dose effect (UNSCEAR, 2000).

The Raeq was estimated using equation 2 [15, 16, 17].

$$Raeq = A_u + 1.43A_{Th} + 0.077A_k \quad (2)$$

Where A_u, A_{Th} and A_k stand for the activity concentrations of ²³²Th, ²³⁸U and ⁴⁰K respectively.

2.3 The Health Impact Assessment

Natural radioactivity health impact in the samples were determined by the following parameters; Daily intake of radionuclides and Annual Effective Dose due to ingestion of tubers.

The Annual effective dose due to ingestion (AED) was determined as follows;

Table 2 :Estimated Mean Value of Daily intake Radionuclides and Annual Effective Dose

Sample Code	ACTIVITIES Concentration (Bq/kg)			AE D	EC L	RA eq	Dli m
	K	U	Th				
BODINGA	95.1 ±40.15	10.85±2.08	9.93±2.24	21.92	76.36	125.59	2.7453
ETSAKO	183. ±31.97	10.92±3.00	10.42±2.30	23.43	82.01	213.80	4.6860
GOMBI	81.0 ±40.14	10.85±2.08	9.43±2.24	20.95	73.83	109.43	2.3983
IKWUANO	274. ±28.47	11.12±2.38	10.19±1.74	21.06	82.64	303.76	6.6622
OFFA	105.09±32.37	10.69±2.064	9.43 ±2.24	20.97	73.53	125.51	2.7510
LAGELU	183. ±24.17	10.92 ±3.71	9.98 ±2.07	19.62	79.15	213.33	4.6748

$$AED \left(S_v yr^{-1} \right) = C \left(Bq kg^{-1} \right) \times M \left(kg yr^{-1} \right) \times DCF \left(S_v Bq^{-1} \right) \quad (3)$$

Where C stands for the radionuclide activity concentration.

M denotes the consumption rate per year.

DCF denotes the standard dose conversion factor, that is equivalent to 0.28 $\mu Sv Bq^{-1}$ for 226 Ra, 0.23 $\mu Sv Bq^{-1}$ for 232 Th and 0.0062 $\mu Sv Bq^{-1}$ for 40 K for the persons who live over 70 years.

2.4 Excess Lifetime Cancer Risk

The ELCR (Excess lifetime cancer risk) was calculated using the following equation

$$ELCR = AED \times DL \times RF \quad (4)$$

Where AED represents the annual effective dose equivalent due to ingestion,

DL - duration of life (given to be 70 years)

RF - Risk factor of 0.05 Sv^{-1} that is fatal cancer risk per sievert.

III Results and Discussion

Outcomes of finding are presented through table 2 and figure 6 for estimation of daily intake of radionuclides and annual effective dose

3.1 Estimation of daily intake of radionuclides and annual effective dose

To ascertain the actual gamma radiation dose arising from 40 K, 238 U and 232 Th due to sweet potato consumption among Offa residence, the Dint (daily intake) of the radionuclides and the AED (annual effective dose) were estimated using equations 3 and 4 respectively [1, 6, 18, 19] by assuming an annual potato consumption rate of 14.35 per kg per person [20, 1].

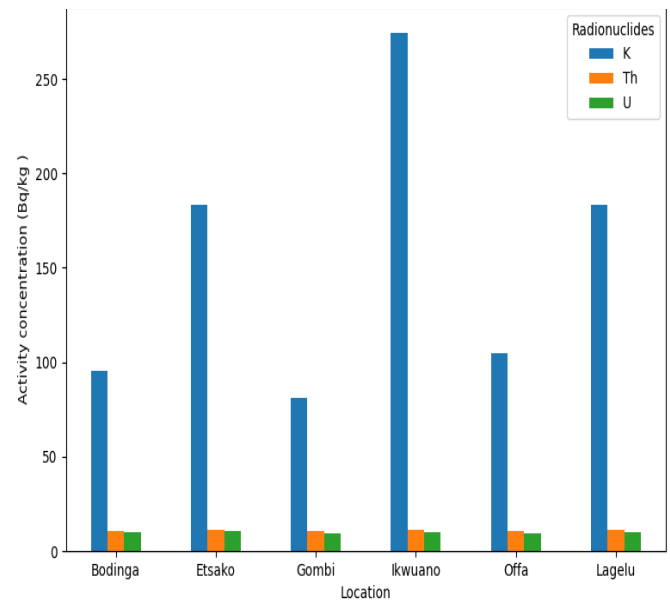


Fig 6. Activity concentrations of radionuclides in sweet potatoes

$$D_{int} = \frac{A_c \times A_{ig}}{Y_d} \quad (5)$$

$$AED = \sum_i (A_c^i \times D_{cf}^i) A_{ig} \quad (6)$$

Where A_c is the activity concentration of concerned radionuclide, A_{ig} is the per capital annual consumption rate of potato and Y_d is the total number of days (365 days) in a year. and D_{cf} signify the activity and dose conversion factor ($Sv Bq^{-1}$) of i th radionuclide respectively.

3.2 Daily intake of radionuclides and annual effective dose

The Dint and AED of respective radionuclide present in any foodstuff depend on the concentration level of the radionuclide and the annual consumption rate of such food. The estimated

Dint through potato diet (Table 2) are 2.7453 for Sokoto, 4.6860 for Edo,

2.3983 for Adamawa, 6.6622 for Abia, 2.75103 for Kwara and 4.6748 for Oyo Bq.d⁻¹. The mean values of activity concentration are 95.14 ± 40.15 , 10.85 ± 2.08 and 9.93 ± 2.24 in Sokoto, 183.42 ± 31.97 , 10.92 ± 3.00 and 10.42 ± 2.30 in Edo, 81.04 ± 40.14 , 10.85 ± 2.08 and 9.43 ± 2.24 in Adamawa 274.42 ± 28.47 , 11.12 ± 2.38 and 10.19 ± 1.74 in Abia 105.09 ± 32.37 , 10.69 ± 2.064 and 9.43 ± 2.24 in Kwara 183.42 ± 24.17 , 10.92 ± 371 and 9.98 ± 2.07 in Oyo Bq.d⁻¹ for ⁴⁰K, ²³⁸U and ²³²Th, respectively. The highest daily intake observed in ⁴⁰K is due to its wide distribution and high concentration in the potato tubers as compared to other radionuclides. Although potassium is an essential element for the human system, its high concentration in diets may result to continuous gamma irradiation of the internal body organs. This in turn may create changes in some physiological and biochemical processes of the body cells, partial or total radiation damage of some organs and genetic effects.

IV Conclusion

Sweet potatoes samples taken from each farm land of the six geopolitical zones in Nigeria have been assessed for natural radioactivity content. The assessment has thus far provided baseline information on the radionuclide's activity and internal effective doses to the residents of Sokoto, Edo, Adamawa, Abia, Kwara and Oyo which may arise due to potatoes consumption. The distribution and concentrations of the radionuclides in the studied potatoes samples have been observed to be non-uniform with ⁴⁰K displaying the highest concentration. The daily intake of radionuclides was also observed to be highest in ⁴⁰K. This may be due to the use of phosphate present in the soil of the farm lands where the tubers were grown. Offa popularly known for growing and consumption of more sweet potatoes did not have the highest ⁴⁰K unlike that of Abia as it is shown from the research, therefore the annual effective doses due to sweet potato diet, at this present rate, pose no significant threat to the public. However, with increase in consumption rate, the radionuclide intake and effective dose may likely increase. It is therefore recommended that research like be carried out on regular basis to ascertain any surge in the radionuclides values, which may occur due to change in lifestyle and increasing methods of chemical farming within the sampled areas..

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