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Annual Committed Effective Doses of Primordial Radionuclides and Excess Lifetime Cancer Risk to the Consumers of Some Foodstuffs in Lagos, Southwest of Nigeria

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Abstract

Food plays vital role in the survival of man as it provides necessary nutrients to the body in order to carry out the daily activities and also to be in good health. Activity concentrations of ^{40}K, ^{238}Uand ^{232}Th in some foodstuffs from three highly rated markets in Lagos, Southwest of Nigeria have been determined by gamma spectrometry method using NaI (TI) detector coupled with a pre-amplifier base to a multiple channel analyzer (MCA). Fifteen (15) samples of maize flour, yam flour, beans, cassava flour and rice were randomly purchased from the markets: Ketu, Oyingbo and Ikeja. The highest activity concentrations for ^{40}K, ^{238}U and ^{232}Th were 153.47 ± 10.34 Bq kg^{-1}, 9.26 ± 2.17 Bq kg^{-1} and 15.36 ± 4.05 Bq kg^{-1}, respectively, all from yam flour. The mean concentrations of ^{40}K for all the samples were obtained to be 102.33 ± 7.04 Bq kg^{-1}, 5.79 ± 1.35 Bq kg^{-1} for ^{238}U and 9.15 ± 2.36 Bq kg^{-1} for ^{232}Th. The average annual committed effective dose of all the natural radionuclides to the consumers of the foodstuffs was determined to be 0.144 mSv yr^{-1} and average excess lifetime cancer risk to the consumers was determined to be 0.503 x 10^{4}. The values obtained were below the worldwide limits of 1 mSv yr^{-1} and 0.29 x 10^{-3}, respectively, which indicated that consumption of the foodstuffs had no significant negative radiological health risks to the consumers.

Keywords*:* Radionuclide, Activity concentration, Foodstuff, Dose, Gamma spectrometry.

Introduction

Food plays vital role in the survival of man as it provides necessary nutrients to the body in order to carry out the daily activities and also to be in good health. Radionuclides are generally found in different parts of the world. They are found in the soil, air and water naturally. They can be artificially made by activities of man. The highest percentage of primordial radionuclides concentrations source in plants is obtained from the soil into the plants through transportation. According to Sowole (2014), assessment of our environment radiologically is so important to ascertain safety of man from radionuclides. Ingestion and inhalation are the main pathways through which natural radionuclides enter the human body. According to Tawalbeh et al. (2012), ingested radionuclides could be concentrated in certain parts of the body. Chemical uranium toxicity primarily affects the kidney, causing damage to the proximal tubule, while this metal has also been identified as a potential reproductive toxicant (Linares et al. 2006). ^{232}Th causes effects in lungs, liver and skeleton tissues, and ^{40}K causes effects in muscles. Depositions of large quantities of these radionuclides in particular organs will affect the health condition of the human such as weakening the immune system, induce various types of diseases, and finally increase in mortality rate (Tawalbeh et al. 2012). There are several sources contributing to plant contamination which can result in direct deposition of radioactive particles from the atmosphere onto the above-ground parts, indirect absorption of radionuclides from the soil by the root system, as well as the resuspension and deposition of radionuclides in the soil.

The research work done by Giri et al. (2013) concerning foodstuffs and water ingestion by human beings in India from a uranium mining area revealed that the ingestion dose was below the dose limit of 1 mSv yr^{-1} for public exposure in planned exposure situation as recommended by ICRP (2007) indicating that there was no significant radiological health risk to the consumers. Also, the study of natural radionuclides levels was carried out by Sowole et al. (2019) along with their dose rates in some species of fish and radiological health implications they had on man as consumer. The average dose rates of ^{40}K in the fishes was calculated to be 0.0049 mGy hr^{-1}, 5.32 x 10^{-7} mGy hr^{-1} for ^{226}Ra and that of ^{228}Ra was 8.96 x 10^{-13} mGy hr^{-1}, which were below the limit of 0.4 mGy hr^{-1} recommended by NCRP (1991) as reported by Blaylock et al. (1993), and average annual dose rate to man the consumer was 0.216 mSv yr^{-1} which was below the world recommended limit of 1 mSv yr^{-1} (ICRP 2007), therefore, did not pose significant radiological health problems to the aquatic animals and the consumers.

This research work was conducted to determine the activity concentrations of ^{40}K, ^{238}U and ^{232}Th from some foodstuffs purchased from three highly rated markets in Lagos, Southwest of Nigeria which happened to be one of the industrial areas of the country, densely populated and the cases of cancer in adults are increasing as reported by Jedy-Agba et al. (2012), Akinde et al. (2015) and IARC (2019), and also to determine annual committed effective doses, likewise excess lifetime cancer risks to the consumers.

Materials and Methods

Fifteen (15) samples of foodstuffs from three markets: Ketu, Oyingbo and Ikeja in the study area were randomly purchased due to the fact that Lagos is the smallest state in Nigeria but is the most populous and most highly industrialized region with shortage of land for farming leaving them with vegetable farming through irrigation (Adedokun et al. 2019). Foodstuffs such as crops and their processed products are transported to Lagos State from other states in Nigeria for people to buy from the markets. They were oven dried at 80 °C (Akinloye et al. 1999), ground, weighed, 145 g packed in plastic containers and carefully sealed and kept for twenty-eight days (28) to establish secular radioactive equilibrium between the natural radionuclides and their respective progenies. The method of gamma spectrometry was adopted for the analysis of the samples collected to obtain data on ^{40}K, ^{238}U and ^{232}Th. The spectrometer used was a Canberra lead shielded 7.6 cm x 7.6 cm NaI (Tl) detector coupled to a multichannel analyzer (MCA) through a preamplifier base. The resolution of the detector is about 10% at 0.662 MeV of ^{137}Cs. According to Jibiri and Farai (1998), the value was good enough for NaI detector to distinguish the gamma ray energies of most radionuclides in samples. For the analyses of ^{40}K, ^{238}U and ^{232}Th, the photo peak regions of ^{40}K (1.46 MeV), ^{214}Bi (1.76 MeV) and ^{208}TI (2.615 MeV) were respectively used. The cylindrical plastic containers holding the samples were put to sit on the high geometry 7.6 cm x 7.6 cm NaI (TI) detector. High level shielding against the environmental background radiation was achieved by counting in a Canberra 10 cm thick lead castle. The counting of each sample was done for 10 hrs because of suspected low activities of the radionuclides in the samples. The areas under the photo-peaks of ^{40}K, ^{238}U and ^{232}Th were computed using the multichannel analyzer system.

Radiological parameters determination

Activity concentrations: The activity concentrations of primordial radionuclides were determined based on the measured efficiency of the detector and the net count rate under each photopeak over a period of 10 hours using Equation 1 (IAEA 1989).

$$A = \frac{N(E_\gamma)}{\varepsilon(E_\gamma) I_\gamma M t_c} \qquad 1$$

Where:

$N(E_\gamma)$ = Net peak area of the radionuclide of interest, $\varepsilon(E_\gamma)$ = Efficiency of the detector for the γ-energy of interest, I_γ = Intensity per decay for the γ-energy of interest, M = Mass of the sample, t_c = Total counting time in seconds (36000s).

Annual committed effective dose (ACED): For ingestion of primordial radionuclides in foodstuffs, this was determined using the expression (Tettey-Larby et al. 2013):

$$ACED = C \; x \; DCF \; x \; CR \qquad 2$$

Where:

C = Concentration of each radionuclide, DCF = Dose conversion factor for ingestion of the natural radionuclides, obtained from ICRP (2012); 6.2 x 10^{-6} mSv Bq^{-1}, 4.4 x 10^{-4} mSv Bq^{-1} and 2.2 x 10^{-4} mSv Bq^{-1} for ^{40}K, ^{238}U and ^{232}Th, respectively, and CR = Consumption rate of intake of naturally occurring radioactive materials from the foodstuffs of value 144 kg yr^{-1}.

Excess lifetime cancer risk (ELCR): This was determined based on the value of the annual committed effective dose using Equation 3 (ICRP 2007):

$$ELCR = ACED \; x \; LE \; x \; RF \qquad 3$$

Where: LE is life expectancy taken to be 70 years and RF is fatal risk factor per Sievert which is 0.05 (ICRP 2007).

Results and Discussion

The activity concentrations of the natural radionuclides in the foodstuffs from the study area are shown in Table 1 and Figure 1. The lowest concentrations of ^{40}K, ^{238}U and ^{232}Th from the foodstuffs were 56.75 ± 2.84 Bq kg^{-1} from beans, 2.20 ± 0.27 Bq kg^{-1} from cassava flour and 5.03 ± 1.07 Bq kg^{-1} from beans, respectively. The highest concentrations for ^{40}K, ^{238}U and ^{232}Th were 153.47 ± 10.34 Bq kg^{-1}, 9.26 ± 2.17 Bq kg^{-1} and 15.36 ± 4.05 Bq kg^{-1}, respectively, all from yam flour which could be as a result of high concentrations of these radionuclides in the soil that were transported into the crop. The mean concentrations of the radionuclides obtained for all the samples were 102.33 ± 7.04 Bq kg^{-1} for ^{40}K, 5.79 ± 1.35 Bq kg^{-1} for ^{238}U and 9.15 ± 2.36 Bq kg^{-1} for ^{232}Th. The values were lower than those obtained in foodstuffs in Ghana (Addo et al. 2013) but higher than those obtained in India (Giri et al. 2013). No artificial radionuclide was detected in all the samples. Concerning ^{40}K, ^{238}U and ^{232}Th, the lowest values of ACED were 0.0507 mSv yr^{-1} from beans, 0.0139 mSv yr^{-1} from cassava flour and 0.1666 mSv yr^{-1} from beans, respectively as shown in Table 2 and Figure 2, while the highest ACED to the consumers for ^{40}K was obtained to be 0.137 mSv yr^{-1} with mean value of 0.091 mSv yr^{-1}. Also, the highest ACED to the consumer for ^{238}U was obtained to be 0.587 mSv $yr^{-1}$with mean value of 0.037 mSv yr^{-1} and the highest for ^{232}Th was 0.509 mSv yr^{-1} with mean value of 0.303 mSv yr^{-1}. The average for all the radionuclides was determined to be 0.159 mSv yr^{-1} which was lower than that obtained by Addo et al. (2013) but higher than that obtained by Giri et al. (2013). All the values obtained in this research work were within the recommended limit of 1.0 mSv yr^{-1} (ICRP 2007) for ingestion of natural radionuclides. The lowest excess lifetime cancer risk of ^{40}K, ^{238}U and ^{232}Th to consumers were 0.1773 x 10^{-4} from beans, 0.0488 x 10^{-4} from cassava flour and 0.5831 x 10^{-4} from beans, respectively. The highest excess lifetime cancer risk of ^{40}K, ^{238}U and ^{232}Th to the consumers were determined to be 0.4796 x 10^{-4} with mean value of 0.3198 x 10^{-4}, 0.2054 x 10^{-4} with mean value of 0.1285 x 10^{-4} and 1.7805 x 10^{-4} with mean value of 1.0601 x 10^{-4}, respectively as shown in Table 2 which were below the limit of 0.29 x 10^{-4} (UNSCEAR 2000).

Table 1: Activity concentrations of natural radionuclides in foodstuff samples

Sample location	Sample code	Foodstuff	Activity concentration of radionuclides in foodstuff (Bq kg^{-1})		
			^{40}K	^{238}U	^{232}Th
Ketu	KFS_1	Yam flour	153.47 ± 10.34	7.92 ± 2.45	12.42 ± 3.86
	KFS_2	Beans	84.29 ± 6.91	4.82 ± 1.39	8.15 ± 2.74
	KFS_3	Maize flour	107.26 ± 8.35	5.71 ± 1.94	11.65 ± 3.25
	KFS_4	Cassava flour	126.62 ± 7.89	8.02 ± 2.53	7.47 ± 1.83
	KFS_5	Rice	79.49 ± 3.01	6.85 ± 1.74	8.34 ± 2.54
Oyingbo	OFS_1	Yam flour	126.07 ± 7.98	9.26 ± 2.17	15.36 ± 4.05
	OFS_2	Beans	56.75 ± 2.84	4.75 ± 0.83	6.09 ± 1.28
	OFS_3	Maize flour	86.02 ± 5.47	6.27 ± 1.05	9.54 ± 2.86
	OFS_4	Cassava flour	106.89 ± 9.37	2.20 ± 0.27	5.78 ± 1.06
	OFS_5	Rice	89.44 ± 6.23	5.25 ± 0.83	7.56 ± 1.74
Ikeja	IFS_1	Yam flour	115.35 ± 9.26	7.18 ± 1.52	10.05 ± 2.01
	IFS_2	Beans	65.57 ± 4.93	3.62 ± 0.25	5.03 ± 1.07
	IFS_3	Maize flour	124.75 ± 7.86	4.96 ± 0.83	9.26 ± 2.68
	IFS_4	Cassava flour	118.62 ± 8.27	6.81 ± 1.95	12.42 ± 3.16
	IFS_5	Rice	94.25 ± 6.82	3.29 ± 0.55	8.06 ± 1.24

NOTE: KFS is Ketu foodstuff sample, OFS is Oyingbo foodstuff sample and IFS is Ikeja foodstuff sample. The confidence of interval was 99%.

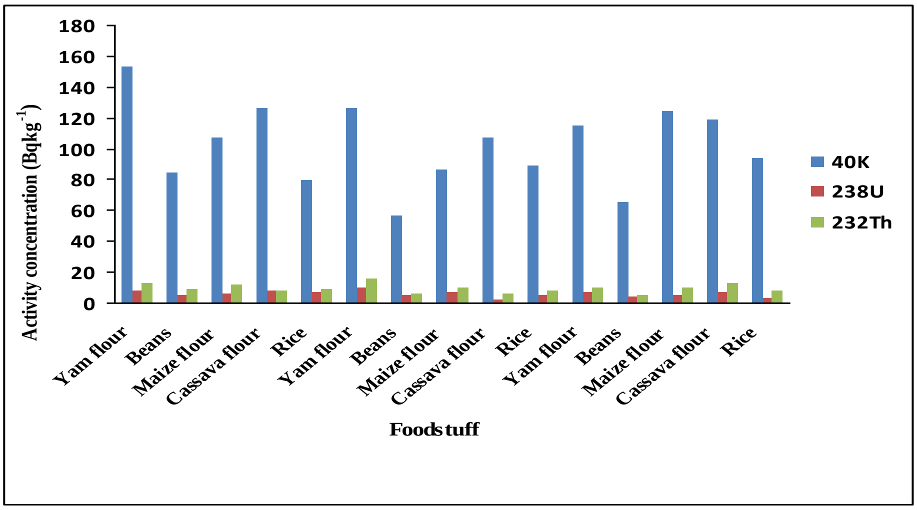

Figure 1: Activity concentrations of natural radionuclides in foodstuffs.

Table 2: Determined annual committed effective dose and excess lifetime cancer risk to consumers

Sample location	Foodstuff	^{40}K		^{238}U		^{232}Th	
		ACED (mSvyr^{-1})	ELCR x 10^{-4}	ACED (mSvyr^{-1})	ELCR x 10^{-4}	ACED (mSvyr^{-1})	ELCR x10^{-4}
Ketu	Yam flour	0.1370	0.4796	0.0502	0.1756	0.4114	1.4397
	Beans	0.0753	0.2634	0.0305	0.1069	0.2699	0.9448
	Maize flour	0.0958	0.3352	0.0362	0.1266	0.3858	1.3505
	Cassava flour	0.1131	0.3957	0.0508	0.1779	0.2474	0.8659
	Rice	0.0710	0.2484	0.0434	0.1519	0.2762	0.9668
Oyingbo	Yam flour	0.1126	0.3939	0.0587	0.2054	0.5087	1.7805
	Beans	0.0507	0.1773	0.0301	0.1053	0.2017	0.7060
	Maize flour	0.0768	0.2688	0.0397	0.1390	0.3160	1.1059
	Cassava flour	0.0954	0.3340	0.0139	0.0488	0.1914	0.6700
	Rice	0.0799	0.2795	0.0333	0.1164	0.2504	0.8764
Ikeja	Yam flour	0.1030	0.3605	0.0455	0.1592	0.3329	1.1650
	Beans	0.0585	0.2049	0.0229	0.0803	0.1666	0.5831
	Maize flour	0.1114	0.3898	0.0314	0.1100	0.3067	1.0734
	Cassava flour	0.1059	0.3707	0.0432	0.1510	0.4114	1.4397
	Rice	0.0842	0.2945	0.0209	0.0730	0.2670	0.9343
	Mean	**0.0914**	**0.3198**	**0.0367**	**0.1285**	**0.3029**	**1.0601**

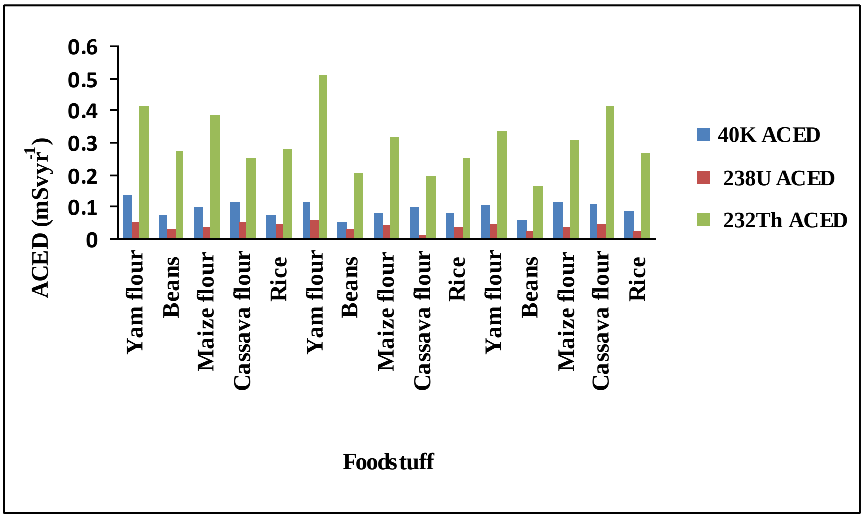

Figure 2: ACED of natural radionuclides from foodstuffs to the consumer.

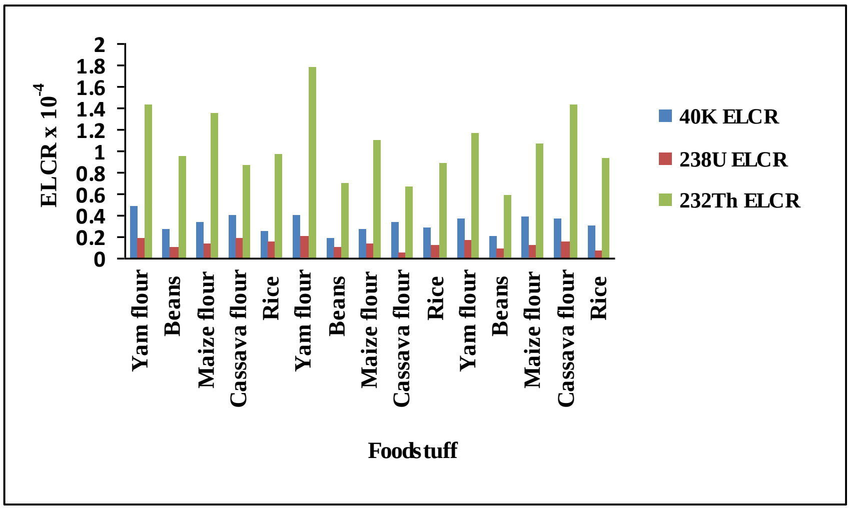

Figure 3: ELCR to the consumers of the foodstuffs.

Conclusion

Sustenance of life of human beings depends on consumption of foods which include agricultural farm products in which natural radionuclides are transported into them from the soil. Radiological assessments of some foodstuffs consumed by people in Lagos, southwest of Nigeria have indicated that the consumption of the foodstuffs by the people in the study area did not pose any significant radiological health risks to them.

Conflict of Interest

The authors declare no conflict of interest.

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