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Estimation of Radionuclide Concentrations and Average Effective Dose from Some Selected Imported Foodstuff

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Abstract: Radionuclide concentrations in imported food products depend on the geological and mineralogical characteristics of the soil from which the products are derived and this is a major cause of concern in radiation monitoring. The analysis of three naturally occurring radionuclides that are: ^{226}Ra, ^{232}Th and ^{40}K in fourteen selected imported food samples was carried out in this research using sodium iodine detector. Reasonable quantities of each of the samples were packed in cylindrical containers and kept for a month to attain secular equilibrium. The activity concentrations of the analyzed samples ranged from 48.76 ± 5.03 to 85.45 ± 3.20, from 10.10 ± 1.70 to 21.10 ± 2.20 and from 8.06 ±1.4 to 10.54 ± 3.64 Bq/kg and their average values were 65.32 ± 4.14, 11.23 ± 2.18 and 9.68 ± 2.08 for ^{40}K, ^{226}Ra and ^{232}Th, respectively. For ^{232}Th, ten samples were seen to be below detention limit BDL. The mean effective dose was estimated to be 4.17 µSv/y. The result of the radiation dose was less than the average value of 1mSv/y for general public, making the foodstuff analyzed radiologically safe for consumption.

Keywords: Imported foodstuff, Radionuclides, Monitoring, Effective dose, Consumption.

Introduction

Foods are substances whether in liquid, solid, frozen, dried or dehydrated form that are consumed by humans to provide essential nutrients (vitamins, minerals and fats) for growth and development. They are ingested by organisms and assimilated into their cells to provide energy. Food remains the most critical need for human existence. It has been estimated that at least one-eighth of the mean annual effective dose due to natural sources is caused by the consumption of foodstuff [1, 2]. Radionuclide concentrations in imported food products depend on the geological and mineralogical characteristics of the soil from which the products are derived and this is a major cause of concern in radiation monitoring. Food consumed by humans may be contaminated through naturally occurring radioactivity, nuclear power plant accidents, winds or rainfall, as well as through nuclear weapons which are deposited on plants, soil or water and can enter the food chain through the absorption *via* plant roots, putting human beings at risk after ingestion of the contaminated food, leading to acute health effects, such as nausea and vomiting, as well as to chronic health effects, such as increase in the risk of cancer [3]. The aim of this work, therefore, is the estimation of radionuclide concentrations and average effective dose through ingestion from some selected imported foodstuff.

Materials and Methods

Food Sampling and Preparation

Fourteen samples of imported foodstuff were selected for analysis as these are foods commonly taken by Nigerians. The samples

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were dried by placing them in the oven for 24 hrs at 110 ^{0}C, to ensure that moisture is completely removed. Then, some foodstuff, like rice, cornflakes, oat, beans, … etc. were ground and sieved to give room for uniformity in size. The samples were then weighed with a weighing balance and 100g of nutmeg, cocoa, … etc., which were already homogenized, were sealed and packed in plastic containers of 8cm height and 6cm diameter. The containers were later sealed using paper- tape to avoid any possibility of radon leakage. All the fourteen samples were kept for at least 4 weeks (28 days) to attain secular equilibrium between radon and its daughters [4] prior to gamma spectroscopy analysis. After the preparation, the radionuclide concentrations in the samples were measured.

Measurement of Radionuclides with Gamma - Ray Spectroscopy

The analysis of all the samples was carried out using a well-calibrated NaI (TI) and well-shielded detector couple to a computer resident quantum MCA2100R multichannel analyzer for 36,000s. The background sample measurement by the detector was achieved by filling an empty thoroughly clean plastic container with distilled water and counting for the same reasonable period as the sample and the peaks were resolved for the natural radionuclide.

1460KeV gamma-radiation of ^{40}K was used to determine the concentration of ^{40}K in the sample. The gamma transition energy of 1764.5KeV ^{214}Bi was used to determine the concentration of ^{238}U, while the gamma transition energy of 2614KeV ^{208}TI was used to determine the concentration of ^{232}Th and ^{137}Cs was detected by its 661.6KeV gamma energy. The efficiency calibration of the detector was carried out using a reference standard mixed source traceable to Analytical Quality Control Service (AQCS, USA), which has certified activities of the selected radionuclides and has a geometrical configuration identical to the sample containers. The activity concentration in the sample was obtained using the expression in [5, 6].

$$C\left(\frac{Bq}{kg}\right) = \frac{C_n}{\varepsilon \rho_\gamma M_s} \qquad (1)$$

where C is the activity concentration of the radionuclide in the sample, C_n is the count rate under each photopeak due to each radionuclide, ε is the detection efficiency for the specific gamma energy, ρ is the absolute transition probability of the specific gamma energy and M_s is the mass of the sample.

Results and Discussion

The results of the activity concentration (Bq/kg) of the primordial elements targeted in the samples are shown in Table 1.

Potassium has the highest concentration when compared with other radionuclides from the foodstuff samples.

There are variations in the activity concentrations of radionuclides among the different food samples. The activity concentration of ^{40}K ranged from 48.76 ± 5.03 Bq/kg to 85.45 ± 3.20 Bq/kg with a mean value of 65.32 ± 1.77 Bq/kg, ^{226}Ra ranged from 10.06 ± 2.24 Bq/kg to 21.10 ± 2.03 Bq/kg with a mean value of 11.23 ± 0.85 Bq/kg and ^{232}Th ranged from BLD to 10.54 ± 3.64 Bq/kg with a mean value of 9.68 ±1.59, as shown in Table 1. Samples 7 and 2 exhibited the first and second highest concentration of ^{40}K with values of 85.45 ±3.2 Bq/kg and 74.84±1.02 Bq/kg, respectively. The first and second highest concentrations of ^{226}Ra were found in samples 14 and 5 with their corresponding values as 21.10±2.03 and 12.04±1.38 Bq/kg, respectively. The first and second highest concentrations of ^{232}Th were 10.54±3.64 and 10.45±1.2 Bq/kg for samples 5 and 7, respectively. From all the measured samples, ten samples of ^{232}Th had values below the detection limit. The study revealed that the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K for all samples under study were much lower than the activity concentration values in food, which are usually in the range 40- 600Bq/kg [7]. The trend of activity concentrations of the radionuclides was in the order of magnitude ^{40}K > ^{226}Ra > ^{232}Th in all the sample studied.

TABLE 1. Activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th (Bq/kg) in the food samples.

S/N	PRODUCT NAME	Origin	^{40}K	^{226}Ra	^{232}Th
1	Nutmeg	USA	65.59±3.19	10.49±2.50	BDL
2	Quaker Oat	U.K	74.84±1.02	10.10±2.01	BDL
3	Titus Fish	Cotonou	72.34±6.29	10.19±3.01	BDL
4	Olotu Beans	South Africa	65.22±5.03	11.25±1.09	BDL
5	Horlicks Cocoa	U. K	68.03±5.88	12.04±1.38	10.54±3.64
6	Thailand Rice	Cotonou	55.02±3.90	10.10±1.70	BDL
7	K. Cornflakes	South Africa	85.45±3.20	10.10±2.20	10.45±1.2
8	Creamcraker B.	U. K	63.08±3.19	11.25±0.09	BDL
9	Instant Coffee	South Africa	65.47±2.45	10±2.24.06	BDL
10	Ginger	U.S.A	65.38±6.64	10.12±1.53	BDL
11	CereIlac	U. K	65.31±6.29	10.13±1.85	BDL
12	Frisco Gold	Netherland	48.76±5.03	10.12±3.23	BDL
13	Horlicks milk	U. K	55.10±5.88	10.12±3.13	8.06±0.66
14	White Oat	U.S.A	64.84±2.45	21.10±2.03	DBL
	Mean +S.D.		65.32±1.77	11.23±0.85	9.68±1.59

BDL: Below Detection Limit.

Annual Effective Dose from Ingestion of the Food Samples

The effective dose helps estimate the doses from radionuclides through ingestion from different sources of radioactivity. It is based on the risks of radiation-induced health effects [6].

The annual effective dose due to the intake of radionuclides from foodstuff is calculated using the metabolic model developed by [8, 9]:

$$D_{rf}\left(\frac{Sv}{y}\right) = R_f \sum\left(C_r\, A_{rf}\right) \quad (2)$$

where D_{rf} is the annual effective dose in Sv/y, C_r is the effective dose conversion factor 0.28 E-06, 0.23 E-07 and 0.006 E-06 Sv/Bq, for ^{226}Ra, ^{232}Th and ^{40}K, respectively. A_{rf} is the activity concentration of the radionuclide in the ingested foodstuff. R_f is the consumption rate (kg/y) and the values are presented in Table 2.

The effective dose (μSv/y) varied from 0.01 in Olotu beans to 15.88 in rice. The estimated values for baby foods, which are cerelac, friscogold, horlick milk, white oat and beans, are extremely small compared with effective dose values for rice, cornflakes and creamcraker. The mean effective dose was estimated to be 4.17(μSv/y).

TABLE 2. Consumption rate and annual effective dose.

S/N	Product Name	Consumption rate (kg/y)	Annual effective dose (μSv/y)
1	Nutmeg	4.90	3.11
2	Quaker Oat	0.03	0.02
3	Titus	11.2	7.49
4	Olotu Beans	0.02	0.01
5	Horlicks	2.00	1.37
6	Rice	28.23	15.88
7	Cornflakes	20.67	15.40
8	Creamcraker	18.55	11.82
9	Instant Coffee	0.04	0.03
10	Ginger	5.00	3.13
11	Cerelac	0.03	0.02
12	Frisco	0.03	0.02
13	Horlicks milk	0.03	0.02
14	White Cat	0.03	0.03
	Mean		4.17

Source: Food Balance Sheet, Nigeria, 2006.

Conclusion

This research has helped identify and measure the primordial radionuclides present in the imported foodstuff consumed by Nigerians, in order to determine the activity concentrations and assess the health impact from the consumption of the foodstuff. Furthermore, it has also helped ascertain the level of health risks that might be involved for countries consuming the foodstuff.

The variations of radionuclide concentrations from one sample to another might stem from the heterogeneity of the environment from where the foodstuff originated.

The health impact assessment of the present study revealed that the consumption of the analyzed imported foodstuff does not pose any radiological effects to Nigerians consuming them. Nonetheless, there is a need for regular monitoring of the imported foodstuff so as to avoid the accumulative effect of doses.

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