Canadian Journal of Pure and Applied Sciences
Vol. 15, No. 1, pp. 5141-5159, Feb 2021
Online ISSN: 1920-3853; Print ISSN: 1715-9997
Available online at www.cjpas.net

ASSESSMENT OF RADIOACTIVITY CONCENTRATIONS AND ITS' HEALTH DETRIMENT OF IMPORTED CANNED FOOD PRODUCTS IN NIGERIA

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ABSTRACT

High purity Germanium detector (HPGe) have been used to investigate the radioactivity concentrations of ^{226}Ra, ^{232}Th, ^{40}K , ^{210}Pb and ^{137}Cs in 22 brands of imported canned food products in Nigeria categorized into staple foodstuffs, beef and seafood. The results obtained for staple food stuffs shows a mean activity value of 12.33±3.68, 12.35±4.62,51.48±15.12, 2.65±0.18 and 0.61±0.27 Bq kg^{-1} for ^{226}Ra, ^{232}Th, ^{40}K, ^{210}Pb and ^{137}Cs respectively, while in beef food products, it is 14.41±4.79, 14.12±4.83,50.44±14.80, 1.11± 0.07 and 0.32±0.20 Bq kg^{-1} respectively, and for seafood products it is 17.95±5.71, 16.24±5.48,61.65±18.07, 1.17±0.13 and ND Bq kg^{-1} respectively. The overall results indicate that the natural radio activities in the three categories of canned foodstuffs examined are well below the UNSCEAR and other regulatory bodies recommended permissible limits. The presence of ^{210}Pb and ^{137}Cs in some samples potent some degree of heavy metal contamination of those foodstuffs. All the five radiological risk parameters evaluated are well below International recommended permissible levels. The computed dose to essential organs and tissues indicates a highest dose level of 0.2 mSvy^{-1} which is well within the 1mSvy^{-1} recommended permissible level of the public. The calculated collective effective dose equivalent revealed that 97,463,16 of the total population are exposed to radiation from ingestion of the canned foods with adults most impacted. The total health detriment indicates radiological risk ratio of 1:2238 for infants, 1:2583 for children and 1:4238 for adults. From the estimated cost-detriment, it is obvious that the economic benefits which is directly proportional to cost of purchase and importation put at about nine billion US dollars annually derived from consuming these imported canned food products is far above the health detriment.

Keywords: Nigeria, radioactivity surveillance, canned food, health detriment.

INTRODUCTION

The public concern and anxiety of possible irradiation due to intake of radioactive contaminated food products globally after the Fukushima Daiichi nuclear power plant accident of March 12th 2011, occasioned by tsunami that released substantial amount of radioactive substances into Daiichi water and terrestrial environment is worthy of note (Jibiri and Okusanya, 2008; Murakami and Oki, 2012; Eun-Kyeong *et al*., 2016). This have necessitated many countries of the world to institute control and monitoring mechanism for food products imported from Japan in particular and other counties affected due to trans-boundary radiation pollution effects. The Hong Kong Centre for Food Safety (CFS), IAEA (International Atomic Energy Agency) and other radiation and radioactive sources regulatory bodies including researchers have also stepped up surveillance on radioactivity and radiation levels of imported food products worldwide, which include: vegetables, fruits, milk, meet, aquatic products, milk powder and other processed foods from foreign countries. The post-assessment monitoring program of the environment and foods is normal and routing in any country of the world for her food safety, security and sustainability. Similar routine monitoring and post-assessment of food products from Europe after the 1986 Chernobyl reactor accident have been reported in literatures (Mlwilo *et al*., 2007; Jibiri and Okusanya, 2008).

Naturally Occurring Radioactive Materials (NORMs) abound in the earth's troposphere and in tissues of living organisms. These naturally occurring radionuclides such as ^{238}U, ^{232}Th and ^{40}K can be found in elevated amount; in soil, public and domestic water supplies, oil & gas facilities and waste and the air we breathe, thereby subjecting human beings to some degree of radiation exposure (Varier, 2009; Ali *et al*., 2014; Sowole and Olaniyi, 2018). Moreso, the artificial sources of radionuclides that are essentially due to industrial activities, medical and military activities, have over the years increased the radiation burden on man through the

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food chain. The complex pathway of radionuclides into man include; inhalation and external exposure to radiation, food consumed through the food chain (UNSCEAR, 2000; Ononugbo *et al*., 2017). Radioactivity contamination are observed in terrestrial environment and aquatic food chains, consequently they are transferred to man through the inhalation and intake of food (Murakami and Oki, 2012; Alrefae *et al*., 2014). Beside the NORM naturally present in human due to it genetic make-up, elevation of radioactivity concentrations above normal levels are directly linked to the amount and type of food ingested (FAO, 1987). This linear relationship between food intake and radiological health hazard have raised international concern toward radioactivity implications from the consumption of food (FAO, 1987; IAEA, 1989; Venturini and Sordi, 1999; Al-Masri *et al*., 2004; FSA, 2004; Mlwilo *et al*., 2007; Chau and Michalec, 2009; Gharbi *et al*., 2010**;** WHO, 2011; Alrefae *et al*., 2014; Ononugbo *et al*., 2017). Ingested radionuclides accumulate in tissues and organs of the body, for example ^{238}U accumulates in human kidney and lungs, ^{232}Th concentrate in liver, skeleton tissue and lungs while ^{40}K accumulates in muscles (Tawalbeh *et al.*, 2012). It have been reported that greater parts of the average annual effective dose due to natural sources is attributed to the intake of food (UNSCEAR, 2000; Badran *et al*., 2003; Mlwilo *et al*., 2007; Jibiri and Okusanya, 2008; Ononugbo *et al*., 2017). Excess accumulation of these radionuclides in any organ of the human body can impact negatively on the health of the individual, induces various forms of diseases and has been reported to contribute to the increase in mortality rate (Agbalagba *et al*., 2016).

Radioactivity studies over the years have been directed toward evaluating the level of spatial distribution radionuclides in the environment to obtain vital radiological data that are essential for the establishment guidelines relating to radiation protection. But this goal will not be completely achieved if the radiation levels from the ingestion of food is not analyzed, quantified and estimated (Tang *et al*., 2003; Rahman and Voigt, 2004; Choi*et al*., 2008; Awudu *et al*., 2012; Jha *et al*., 2012; Murakami and Oki, 2012; Assyikeen *et al*., 2015).

Studies have shown that 12.5% of the annual dose received by man due to natural sources radiation can be attributed to the intake of food, with ^{238}U and ^{232}Th series contribute about 30 % –60 % to the internal radiation dose (UNSCEAR, 2000, Badran *et al*., 2003). These can come through the consumption of aquatic staple foodstuffs, fruits, vegetable and beef depends on the radionuclide concentration on the food. The physiochemical properties of the radionuclides can also have a strong influence on their environmental behavior and resulting exposure pathways.

Literatures abound globally on the assessment of radioactivity concentration in food products (FAO, 1987; Yu *et al*., 1997; McDonald *et al*., 1999; Venturini and Sordi, 1999; Badran *et al*., 2003; Al- Masri *et al*., 2004; FSA, 2004; Hernandez *et al*., 2004; Hosseini *et al*., 2006; Mlwilo *et al*., 2007; Chau and Michalec, 2009; Shnthi *et al*., 2009; Zaid *et al*., 2010; WHO, 2011; Awudu *et al*., 2012; Giri *et al*., 2013; Al-Ghamdi, 2014; Alrefae *et al*., 2014; Harb, 2015; Eun- kyeong *et al*., 2016; Al-Absi *et al*., 2019). In Nigeria, some research work on the evaluation of radionuclide content in staple foodstuffs and vegetable products have also been reported (Olomo, 1990; Osibote *et al*., 1999; Farai, 1993; Maziya-Dixon *et al*., 2004; Arogunjo *et al*., 2005; Eyebiokin *et al*., 2005; Jibiri and Agomuo, 2007; Jibiri and Okusanya, 2008; Sowole, 2011; Agbalagba *el al*., 2016; Ononugbo *et al*., 2017; Sowole and Olaniyi, 2018). But despite Nigeria been the highest importer of canned food products in Africa, spending over nine billion US dollars annually on importation of canned food product alone, the country has no clear radionuclides content policy and guidelines for radioactivity level screening of imported food products at point of entry (FOS, 2006). A thorough literatures examination reveals a pretty inadequate studies on the radioactivity concentration of imported canned food products, with just two known studies carried out in Nigeria in the last one decade, and none put into cognizance the anthropogenic activities in those assessed foodstuffs (Jibiri and Okusanya 2008; Alrefae *et al*., 2014; Agbalagba *et al*., 2016). The paucity of research studies and literatures on radioactivity content of imported processed canned food products into Nigeria lay credence to this current study to fill the gap and to satisfy the minimum national requirement for the establishment of a baseline value for radioactivity exposure rate for the public from the consumption of these categories of food products.

Because of civilization, rapid industrial revolution and the digital age we found ourselves, many individuals now result to consumption of processed canned foods more than ever before, basically due to inability to make out time for cooking freshly prepared foods, as it help to save time and requires less stress. Processed canned foods also served as major source of foods for the military officers and personnel during war periods, the students in colleges, and higher institution of learning, refugees, internally displaced persons and offshore workers in high sea, depend greatly on canned food. However, some of these canned foods have been reported to contain some level of NORMs above recommended permissible limits which can impair human health due to accumulative effects (Jibiri and Okusanya, 2008; Alrefae *et al*., 2014; Agbalagba *et al*., 2016). Since the manufacturers of canned food products do not indicate the presence and levels of artificial and naturally occurring radioactive substances present in the sealed food nor the level of radiation that it might triggered due to the processes involved in packaging, storage and transportation. It is therefore imperative to experimentally and analytically determine the presence, the levels and the health implications of radioactivity concentration in these canned foods. This research work is therefore aimed at evaluating the anthropogenic (^{210}Pb and ^{137}Cs) and NORMs (^{226}Ra, ^{232}Th, ^{40}K) levels in the canned food products imported and widely consumed by Nigerian, compare the activity concentration in the three categories of canned foods: staple foodstuffs, beef products and seafood products. The study explore all known applicable radiological risk parameters to attain an empirical and justifiable inference on the risk or otherwise of consuming these canned food production to Nigerians. The total health detriment to man and total cost of health detriment in monetary terms will also be evaluated to establish if the food items investigated worth consuming.

MATERIALS AND METHODS

Experimental Methods

Collection and Preparation of Samples

Canning is a method of preserving food from spoilage in which the food contents are processed and sealed hermetically and then sterilized by heat in an airtight container. The canned food product samples were collected from different local markets, stored and supermarkets in Nigeria. Researchers ensure that samples collected carried the regulatory Agency; "National Agency for Food and Drug Administration and Control (NAFDAC)" in Nigeria registration number and ensure that the products will not expired in two months' time as at the time of collection. To ensure a widespread representation, 22 different canned food products were selected which covered 10 different brands: sweet corn, green peas, mushroom, vegetable, tomato, beans, beef, sausage, hotdog, and fish (tuna, sardine, geisha, and skipper) as presented in Table 1. These were further classified into three namely: staple foodstuffs, beef food products and seafood products.

Samples preparation for analysis follows standard practice as reported in literatures (IAEA, 1989; Mlwilo *et al*., 2007; Alrefae, 2014). The preparation involved freeze-drying process that removed the moisture and reaching a constant weight while preserving vital contents (Alrefae, 2014; Al-Absi *et al*., 2019). Samples were oven dried at a temperature range of 60 - 75^{0}C for a period not least 24 hrs to attain constant weight. Samples were then homogenized and sieved using a 0.5 mm mesh sieve for similar sample matrix. The prepared samples were then powdered, packet into Marinelli beaker and sealed for a period not less than 28 days to allow for equilibration before gamma analysis (Mlwilo *et al*., 2007; Alrefae, 2014). The density of each sample were taken to correct for differences in the densities of the samples.

Table 1. Brand names and country of production of the different canned food products examined.

Sample no.	Country of origin	Brand name	Type	Sample Net weight wet (g)
1.	Lebanon	Ailaghziah Beef Hot Dog	Hot Dog	380
2.	Thailand	Trio Golden sweet corn (whole kernels)	Sweet Corn	340
3.	China	Trio Green peas	Green peas	400
4.	Morocco	Milo sardine	Sardine	125
5.	Holland	Zwan Hotdog sausage	Sausage	400
6.	Lebanon	Golden county minced beef delight	Beef	400
7.	Italy	Montex luncheon beef	Beef	400
8.	South Africa	Cattleman Corned beef	Beef	300
9.	Thailand	Trio tuna chunks	Tuna	170
10.	China	Trio mushroom (whole)	Mushroom	400
11.	Lebanon	Skipper (fish)	Fish	185
12.	China	Geisha (Mackerel in tomato sauce)	Mackerel	155
13.	USA	Food town cream style golden sweet corn	Sweet corn	418
14.	South Africa	Koo vegies	Vegies	410
15.	South Africa	Koo baked beans in tomato sauce	Baked beans	400
16.	UK	Heinz beans	Beans	415
17.	South Africa	Braai relish tomato	Tomato	410
18.	Thailand	Sweet kernel corn in vacuum	Corn	350
19.	South Africa	All gold Tomato puree	Tomato	410
20.	Greece	Macedonia vegetable	Vegetable	210
21.	N/A	CSB sausage	Sausage	190
22.	N/A	White Tuna	Tuna Sausage	220

Gamma Spectroscopy

The detection and measurement of the radionuclides were performed with the aid of a lead-shielded (100mm) coaxial High Purity Germanium (HPGe) p-type (model: BE2020 and Serial number: b15168). The detector has energy resolution of 2.62 at 1.33MeV of ^{60}Co photopeak gamma-ray source with efficiency of 27.9% at similar energy peak. The obtained background spectra from unfilled container counted for 28800 seconds was used to determine the background activities of the radionuclides and their minimum detection limit. The energy and efficiency calibrations of the HpGe spectrometer system and analytical procedures adopted in this research work are well reported in literatures (IAEA, 1989; Mlwilo *et al*., 2007; Alrefae, 2014). Energy calibration of broad Energy Germanium detector was done with point sources of ^{241}Am, ^{137}Cs and ^{60}Co. The reference material used for the efficiency calibration was IAEA-414 with a cylindrical geometry of equal dimensions as the sample vessels.

Gamma Vision software was deployed for the spectra analysis, the samples ^{226}R activity levels were obtained using its progenies (^{214}Bi) of photopeak energy of 609.3 keV γ- lines. The ^{232}Th activity levels were determined using ^{208}TI emissions at 911 keV, similarly, ^{40}K activity levels were quantified by 1460 keV emissions. Finally, ^{137}Cs was likewise determined using the 662 keV $\gamma - ray$ peak, as one of the indicator isotopes for any potential environmental contamination due to release of artificial radionuclides. Self-attenuation correction factor for each sample in relation to the standard was determined using direct gamma transmission technique to correct for the efficiency of the standard used for the evaluation of the radioactivity level in the samples. The radioactivity content C (Bq kg^{-1}) was determined from the net peak area using the formula (Jibiri and Okusanya, 2008; Arefae *et al*., 2014).

$$C = \frac{N_C}{\varepsilon . P_\gamma . M_S} \quad (1)$$

Where C represent the specific activity levels, N_c represents net gamma count rate (counts per second), εrepresents the detector efficiency of the γ-ray, and M_s represents the sample mass in (kg), $P_\gamma$is the emission probability of the radionuclide.

The minimum detectable activity (MDA) of the measuring system describes the operational capability of the system without the influence of the sample, which is expressed as (Kitto *et al*., 2006; Arefae *et al*., 2014).

$$MDA = \frac{2.71 + 4.66 S_b}{\varepsilon P_\gamma M_S} \quad (2)$$

where S_b= net background countstandard error. The MDA values for the counting system were computed as; 0.33 for ^{226}Ra, 0.28 for ^{232}Th and 3.68 Bq kg^{-1} for ^{40}K.

RESULTS

The results of the measured activity concentration of the natural (^{226}Ra, ^{232}Th, ^{40}K) and artificial (^{210}Pb and ^{137}Cs) occurring radio nuclides identified in the canned food samples investigation and their estimated errors are presented in Table 2.

Table 2. Specific activity concentration of the different canned food products.

S/N	Staple Foodstuffs	Radioactivity Concentration (Bqkg^{-1})					
		Country	^{226}Ra	^{232}Th	^{40}K	^{210}Pb	^{137}Cs
1	Trio golden Sweet corn	Thailand	17 ± 3	7 ± 3	60 ± 17	6 ± 0	ND
2	Trio Green Peas	China	14 ± 3	10 ± 3	38 ± 11	8 ± 0	2 ± 0
3	Trio mushroom	China	20 ± 6	9 ± 3	37 ± 10	3 ± 0	1 ± 0
4	Macedoni a Vegetable	Greece	17 ± 6	21 ± 6	42 ± 12	6 ± 0	2 ± 0
5	Tomato puree	South Africa	16 ± 3	14 ± 5	90 ± 26	6 ± 1	2 ± 0
6	Sweet Kernel corn	Thailand	BDL	4 ± 1	40 ± 11	ND	ND
7	Braii relish tomato	South Africa	14 ± 5	14 ± 4	71 ± 20	ND	ND
8	KOO vegies	South Africa	16 ± 5	21 ± 6	38 ± 11	ND	ND
9	KOO baked beans	South Africa	BDL	5 ± 2	50 ± 14	ND	ND
10	Foodtown sweet corn	USA	22 ± 6	11 ± 4	45 ± 13	ND	ND
11	Heinz baked beans	UK	BDL	20 ± 7	56 ± 16	ND	ND
Total	**Activity Conc.**		**136 ± 40**	**136 ± 50**	**566 ± 166**	**29 ± 2**	**7 ± 2**
Mean	**Activity Conc.**		**12 ± 3**	**12 ± 4**	**51 ± 15**	**3 ± 0**	**1 ± 0**

	Beef Food Products	Country	^{226}Ra	^{232}Th	^{40}K	^{210}Pb	^{137}Cs
1	Zwan Hotdog sausage	Holland	12 ± 3	10 ± 4	47 ± 13	7 ± 0	1 ± 0
2	Minced beef delight	Lebanon	16 ± 3	13 ± 5	56 ± 16	0.2 ±0	BDL
3	Montex Luncheon beef	Italy	15 ± 5	7 ± 3	35 ± 10	BDL	1 ± 0
4	Ailaaghazah beef hotdog	Lebanon	1 ± 0	22 ± 5	65 ± 18	ND	ND
5	Cattleman corn beef	South Africa	21 ± 9	6 ± 2	72 ± 21	ND	ND
6	CSB sausage	N/A	21 ± 6	25 ± 7	27 ± 8	ND	ND
Total	**Activity Conc.**		**86 ± 28**	**85 ± 28**	**303 ± 88**	**7 ± 0**	**2 ± 0**
Mean	**Activity Conc.**		**14 ± 4**	**14 ± 4**	**50 ± 14**	**1 ± 0**	**0.3 ± 0**
	Seafood Products	**Country**	**^{226}Ra**	**^{232}Th**	**^{40}K**	**^{210}Pb**	**^{137}Cs**
1	Milo sardine	Morocco	21 ± 5	19 ± 5	55 ± 16	6 ± 1	ND
2	Mackerel Geisha	China	24 ± 6	8 ± 3	64 ± 18	BDL	ND
3	Skipper (fish)	Lebanon	28 ± 7	20 ± 6	50 ± 14	ND	ND
4	White Tuna	N/A	BDL	18 ± 5	81 ± 23	ND	ND
5	Trio Tuna chunks	Thailand	17 ± 8	17 ± 5	59 ± 17	ND	ND
Total	**Activity Conc.**		**90 ± 28**	**81 ± 27**	**308 ± 90**	**6 ± 1**	**NIL**
Mean	**Activity Conc.**		**18 ± 5**	**16 ± 5**	**62 ± 18**	**1 ± 0**	**NIL**

Table 3. Mean radium equivalent and summary of calculated radiological risk parameters of the canned food products.

Canned food product	**Ra_{eq} ($Bqkg^{-1}$)**	**AGED (μSvy^{-1})**	**Absorbed dose rate (D_R, $nGyh^{-1}$)**	**AEDE (μSvy^{-1})**	**ELCR $\times 10^{-3}$ ($mSvy^{-1}$)**
Staple Foodstuffs ($Bqkg^{-1}$)					
Trio golden Sweet corn	32 ± 7	102.4	15.0	73.4	0.3
Trio Green Peas	31 ± 9	95.5	14.0	68.9	0.2
Trio Mushroom	35 ± 12	109.5	16.1	79.2	0.3
Macedonia vegetable	50 ± 15	151.8	22.4	109.8	0.4
Tomato Puree	44 ± 12	139.0	20.3	99.3	0.4
Sweet Kernel corn	8 ± 2	27.8	3.9	19.3	0.1
Braai Relish Tomato	39 ± 13	122.7	17.9	87.9	0.3
Koo Vegies	50 ± 14	151.8	22.4	109.9	0.4
Koo Baked Beans	11 ± 5	36.2	5.1	25.2	0.1
Foodtown Sweet Corn	42 ± 13	130.7	19.3	94.5	0.3
Heinz Baked Beans	32 ± 6	99.8	14.5	71.3	0.3
Beef Food Products					
Zwan Hot Dog sausage	31 ± 10	95.4	14.0	68.6	0.2
Minced beef delight	39 ± 11	121.0	17.7	87.0	0.2
Montex Luncheon Beef	28 ± 5	88.3	13.0	63.7	0.3
Ailaghazah Beef Hotdog	38 ± 10	116.6	17.0	83.4	0.3
Cattleman Corn beef	36 ± 11	114.2	16.7	81.8	0.3
CSB Sausage	60 ± 18	180.6	26.8	131.3	0.5
Seafood Products					
Milo Sardine	52 ± 15	159.3	23.5	115.0	0.4
Mackerel Geisha	40 ± 12	125.3	18.4	90.1	0.3
Skipper (fish)	60 ± 18	184.3	27.2	133.5	0.5
White Tuna	32 ± 9	107.5	14.7	72.0	0.3
Trio Tuna	46 ± 12	143.4	21.1	103.3	0.4
Mean Value	38 ± 12	118.3	17.3	84.9	0.3
Global Standard	370	300	59	450	0.29 ($mSvy^{-1}$)

Table 4. Age groups (infants, children and adults) annual effective ingestion dose rate due to intake of natural radionuclides in canned foods.

Radionuclides		Annual Effective Dose (µSv)		
Staple Foodstuffs		**Infants**	**Children**	**Adult**
^{40}**K**	Maximum	42.0	12.1	53.7
	Minimum	22.9	6.6	29.3
	Average	32.5	9.4	41.5
^{226}**Ra**	Maximum	182.9	179.3	166.5
	Minimum	70.0	96.8	90.0
	Average	112.9	138.1	128.3
^{232}**Th**	Maximum	87.5	68.9	50.7
	Minimum	27.4	31.4	23.1
	Average	60.1	50.2	36.9
	Accumulated Mean	205.5	197.6	206.7
Beef food Products				
^{40}**K**	Maximum	63.6	11.9	52.6
	Minimum	22.5	6.5	28.7
	Average	41.1	9.2	40.7
^{226}**Ra**	Maximum	172.9	215.0	199.7
	Minimum	67.8	107.7	100.0
	Average	135.4	161.4	149.9
^{232}**Th**	Maximum	67.1	77.0	56.7
	Minimum	32.9	37.7	27.8
	Average	50.0	57.4	42.3
	Accumulated mean	226.5	228.0	232.9
Seafood Products				
^{40}**K**	Maximum	50.2	14.5	64.3
	Minimum	27.5	7.9	35.1
	Average	38.9	11.2	49.9
^{226}**Ra**	Maximum	166.8	265.0	246.1
	Minimum	86.3	137.1	127.3
	Average	126.6	201.0	186.7
^{232}**Th**	Maximum	76.9	88.2	64.9
	Minimum	38.1	43.7	32.2
	Average	57.5	66.0	48.6
	Accumulated mean	223.1	278.2	285.2
UNSCEAR, 2000 Recommendation		**200-800**	**200-800**	**200-800**

Table 5. Age groups (infants, children and adults) dose conversion factors for ^{226}Ra, ^{232}Th and ^{40}K (ICRP, 1996).

	Dose conversion factors(nSv/Bq)		
	^{40}K	^{226}Ra	^{232}Th
Infant(0−1y)	42	4700	4600
Children(1−12y)	13	800	290
Adult(>17y)	6.2	280	230

Table 6. Conversion factor(F)for different organs and tissues (ICRP, 1996).

Organ or Tissue	Conversion Factor (***F***)
Lungs	0.64
Ovaries	0.58
Bone marrow	0.69
Testes	0.82
Whole body	0.68
Kidney	0.62
Liver	0.46

Table 7. Calculated dose rate to vital organs and tissues of the body.

Organs	**Effective dose rate to organs (mSvy^{-1})** Staple Foodstuffs		
	Infants	Children	Adult
Lungs	0.2	0.1	0.1
Ovaries	0.1	0.1	0.1
Bone marrow	0.2	0.1	0.1
Testes	0.2	0.1	0.1
Kidneys	0.2	0.1	0.1
Liver	0.1	0.1	0.1
Whole body	0.2	0.1	0.1
Average values	**0.2**	**0.1**	**0.1**
Organs	**Effective dose rate to organs (mSvy^{-1})** Beef Products		
	Infants	**Children**	**Adult**
Lungs	0.1	0.1	0.1
Ovaries	0.1	0.1	0.1
Bone marrow	0.2	0.1	0.1
Testes	0.2	0.1	0.2
Kidneys	0.1	0.1	0.1
Liver	**0.1**	**0.1**	**0.1**
Whole body	**0.2**	**0.1**	**0.1**
Organs	**Effective dose rate to organs (mSvy^{-1})** Seafood Products		
	Infants	**Children**	**Adult**
Lungs	0.1	0.1	0.1
Ovaries	0.1	0.1	0.1
Bone marrow	0.1	0.2	0.2
Testes	0.1	0.2	0.2
Kidneys	0.1	0.1	0.1
Liver	0.1	0.1	0.1
Whole body	0.1	0.2	0.2

Table 8. Results showing the committed effective dose.

Age Group	Committed Effective Dose C_D (mSvy^{-1})		
	Staple Foodstuffs	**Beef Products**	**Seafood Products**
Infant (0-1yr)	15.1	14.3	11.2
Children (7-12yrs)	9.9	11.4	13.9
Adult (>17yrs)	8.3	11.6	14.3

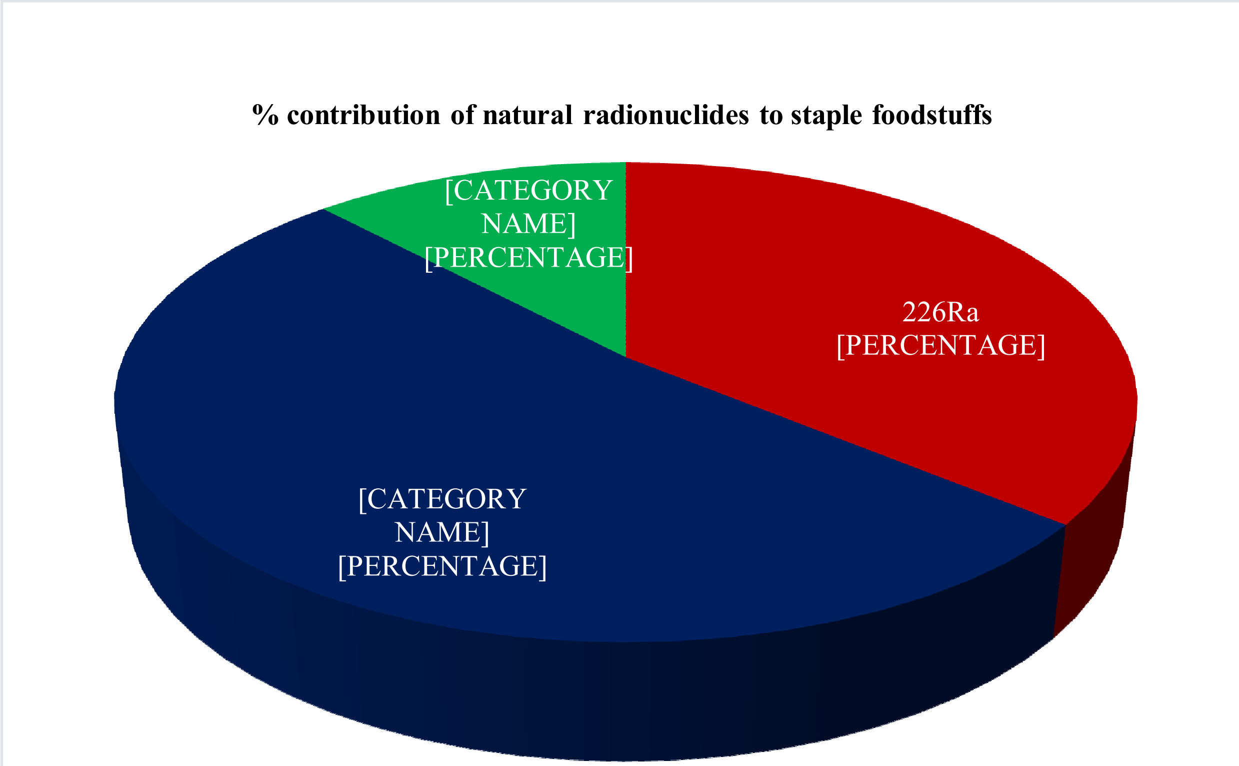

Fig. 1. Percentage contribution of natural radionuclides to the canned staple foodstuffs.

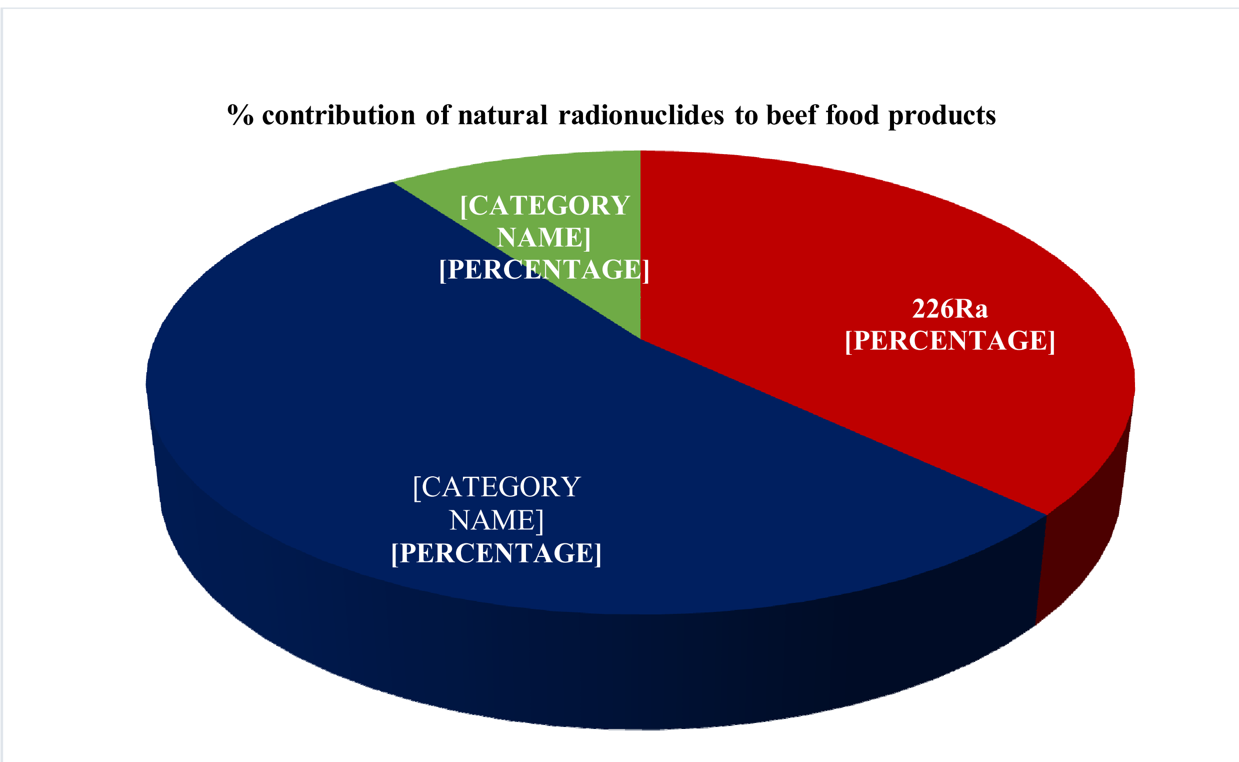

Fig. 2. Percentage contribution of natural radionuclides to the canned beef food products.

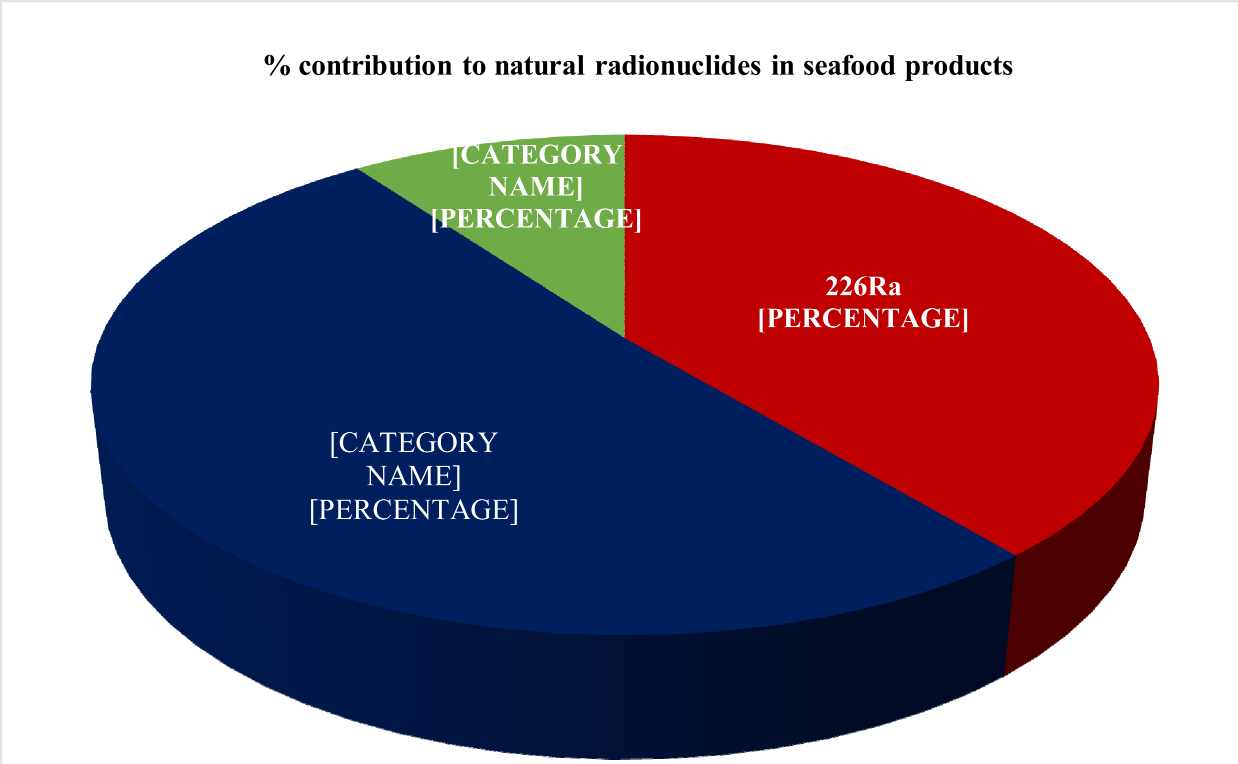

Fig. 3. Percentage contribution of natural radionuclides to the canned seafood products.

DISCUSSION

Measured Radioactivity Levels

The obtained values of the measured radioactivity levels in the canned foodstuff imported into Nigeria are presented in Table 2. The results show that ^{226}Ra, ^{232}Th, ^{40}K, ^{210}Pb and ^{137}Cs have mean radioactivity levels of 12 ± 3 Bq kg^{-1}, 12 ± 4 Bq kg^{-1}, 51 ± 15 Bq kg^{-1}, 3 ± 0 Bq kg^{-1} and 1 ± 0 Bq kg^{-1} respectively for staple foodstuffs. In beef/poultry products, the mean activity levels for ^{226}Ra, ^{232}Th, ^{40}K, ^{210}Pb and ^{137}Cs are 14 ± 4 Bq kg^{-1}, 14 ± 4 Bq kg^{-1}, 50 ± 14 Bq kg^{-1}, 1 ± 0 Bq kg^{-1} and 0.3 ± 0 Bq kg^{-1} respectively, while 18 ± 5 Bq kg^{-1}, 16 ± 5 Bq kg^{-1} and 62 ± 18 Bq kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K respectively in seafood products. The ^{210}Pb radioactivity concentration of 6 ± 1 Bq kg^{-1} was only observed in Milo sardine while ^{137}Cs activity was not detected in any of the seafood products.

An assessment of the natural radioactivity content in the three categories of canned food products examined shows that radioactivity concentration is highest in the canned seafood products and lowest in the canned staple foodstuffs. However, mean value of the canned sea food products reported in this research work is below reported values in previous study on fresh water and marine fishes and crustacean, but exceeded the values reported in Hong Kong and Kuwait canned food (Yu *et al*., 1997; Ademola and Ehiedu, 2010; Alrefae *et al*., 2014). The mean radioactivity value obtained in the canned staple foodstuffs in this research work exceeded the values reported for food spices commonly used in Nigeria and selected fruits in some part of Nigeria. It also exceeded the reported activity concentration values in vegetables and fruits in Najaf in Iraq, Qena and Alexandria in Egypt, Elazig and Rize in Turkey, South and Southwest India and the activity concentration in vegetables consumed in Jordan (Ibrahim *et al*., 2007; Shanthi *et al*., 2009; Shanthi *et al*., 2010; Korkmaz Gorrur *et al*., 2012; Adeniji *et al*., 2013; Cumhur and Mahmut, 2013; Harb, 2015; Abojassim *et al*., 2014; Abojassim *et al*., 2016; Ononugbo *et al*., 2017; Sowole and Olaniyi, 2018; Al-Absi *et al*., 2019). Moreso, the radioactivity levels recorded in the investigated staple foodstuffs is below the reported value in Bangladesh vegetables, potato of Parana in Brazil and Syrian cereals (Al-Masri *et al*., 2004; Scheibel and Appoloni, 2007). On the other hand, this obtained value for canned staple foodstuffs agreed with those values reported for staple foodstuffs in some part of Nigeria and Tanzannian (Mlwilo *et al*., 2007; Jibiri and Okusanya, 2008).

The beef food products activity concentrations recorded in this investigation are within the range of values reported in dairy food products in Brazil (Venturini and Sordi, 1999). The mean activity concentration value obtained in these imported canned beef products agreed with the reported values for imported milk products into Nigeria for ^{226}Ra and ^{232}Th but are well below the ^{40}K values reported in the dairy products (Agbalagba *et al*., 2016). The presence of the natural radionuclides in these can foods samples was expected. Specifically, detection of ^{40}K in all samples was anticipated due to its natural abundance as it was observed that the potassium samples have the highest activity concentration, because it is an important biological element circulated all over the human body and its content in man's tissue is under homeostatic *regulation* (Mlwilo *et al*., 2007). The level of activity concentration of ^{210}Pb and ^{137}Cs in categories one and two of the canned food samples examined, may be attributed to man induced contamination of the sources of these food chain. These may also find their way into these canned food stuffs in the production processes and packaging (Ram and Sarin, 2012; Paatero *et al*., 2015; Paatero *et al*., 2017). The absence of ^{137}Cs in seafood products and some staple and beef food products may be attributed to good hygiene practices in the production processing and preservation of these food products (Hafsah and Kusdianti, 2014).

Radiological Risk Parameters

Radium Equivalent (Ra_{eq})

It have been proven from literatures that ^{238}U (^{226}Ra), ^{232}Th and ^{40}K are the predominant naturally occurring radioisotopes that are commonly found in foodstuff, it is therefore pertinent to take into proper account these specific radionuclides (Jibiri and Okusanya, 2008; Arefae *et al*., 2014; Ugbede and Akpolile, 2020). In order to ascertain the gamma radiation doses index to human beings due to the internal exposure to man, radium equivalent activity index (Ra_{eq}) was introduced by National Radiological Protection Board (NRPB) (Viruthagiri and Ponnarasi *et al*., 2011). The Ra_{eq} has been defined on the basis of the preliminary estimation of the quantities of these radionuclides release that 370 Bq kg^{-1} (10pCi g^{-1}) of ^{226}Ra, 260 Bq kg^{-1} (7 pCi g^{-1}) of ^{232}Th and 4810 Bq kg^{-1} (130 pCi g^{-1}) of ^{40}K provide the same gamma ray dose (UNSCEAR, 2003; Ali *et al*., 2013). Consequently, the radium equivalent activity (Ra_{eq}) was evaluated using the formula (Xinwei, 2004; Song *et al.*, 2012).

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_k (3)$$

Where C_{Ra} is the specific activity of ^{226}Ra, which is in (Bq kg^{-1}), C_{Th} is the specific activity of ^{232}Th, in (Bq kg^{-1}), and C_k the specific activity of ^{40}K, in (Bq kg^{-1}). This equation is based on the estimation that 10 Bq kg^{-1} of ^{226}Ra equal 7 Bq kg^{-1} of ^{232}Th and 130 Bq kg^{-1} of ^{40}K produce equal gamma dose. The maximum value of Ra_{eq} must be less than 370 Bq kg^{-1}.

Table 2 present the results of the estimated radium equivalent dose rate of a mean value of 38 ± 13 Bq kg^{-1}. This mean value of Ra_{eq} obtained is below the range of values reported in some imported beef products in Nigeria (Agbalagba *et al*., 2016). Although, these values obtained are ingested directly into human body on consumption of these canned food products, still they are within the international acceptable limit for Ra_{eq} and therefore comply with radium equivalent standard for radioactivity ingestion.

The percentage contributions of the three naturally occurring radionuclides in the canned staple foodstuffs, beef food products and seafood products samples are presented in Figures 1-3. The percentage contributions of the three naturally occurring radionuclides in the samples were evaluated on the established fact that 1 Bq kg^{-1} of ^{226}Ra, 0.7 Bq kg^{-1} of ^{232}Th, and 13 Bq kg^{-1} of ^{40}K produce the same radiation dose rates in the radium equivalent (Song *et al*., 2012). The calculated percentage contribution of ^{226}Ra, ^{232}Th and ^{40}K as presented in Figure 1 for the canned staple foodstuffs are 36%, 55%, and 12% respectively. Figure 2 present the percentage radioactivity contribution for beef products which are 37%, 53% and 10% for ^{226}Ra, ^{232}Th, and ^{40}K, respectively, while Figure 3 is the percentage contribution from seafood products which have the values of 39%, 51%, and 10% for ^{226}Ra, ^{232}Th, and ^{40}K, respectively. The results indicate that ^{232}Th contributes the highest radioactivity dose rate in all the three categories of imported canned food products examined. These reported percentage contribution are in agreement with the percentage contribution of the natural radionuclides in milk and food spices samples previously reported in literatures by (Agbalagba *et al*., 2016; Ononugbo *et al*., 2017).

Annual Gonad equivalent dose (AGED)

The gonads, the active bone marrow and the bone surface cells are classified as organs of interest in radiation protection by UNSCEAR (2003). Protecting these vital human organs from radiation exposure through ingestion or inhalation is fundamental to safeguard man from radiological health risk. The annual gonadal dose equivalent (AGED, mSvy^{-1})owing to the specific activities of ^{226}Ra, ^{232}Th, and ^{40}K was evaluated using the expression (Al-Jundi *et al*., 2006*)*:

$$AGED\ (\mu Svy^{-1}) = 3.09C_{Ra} + 4.18C_{Th} + 0.314C_K \ (4)$$

Where C_{Ra}, C_{Th}, and C_K represent the radioactivity levels of ^{226}Ra, ^{232}Th and ^{40}K respectively. If the estimated annual gonad equivalent dose of the food source is higher than the world permissible value of 0.29mSvy^{-1}, the model suggest that the food product is a potential source of radiological health risk to the consumer (Al-Jundi *et al*., 2006). In this studied canned food products, the AGED mean value is 118.3 μSvy^{-1} which is well within the 173.2 μSvy^{-1} mean value reported in imported milk in Nigeria and the global maximum permissible values of 300 μSvy^{-1} (UNSCEAR, 2000; Agbalagba *et al*., 2016). Thus the different canned food samples examined may not cause any immediate radiological health side effects going by the AGED index.

Absorbed Dose Rate (D_R)

The absorbed dose rates (D_R) is the gamma emission received by consumers of these processed food products on contact to and ingestion and it represents an even dispersal of the natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K). It is estimated using the guidelines given by and is expressed using the relation (UNSCEAR, 2000).

$$D_R(\eta Gyh^{-1}) = 0.462C_{Ra} + 0.621C_{Th} + 0.0417C_K (6)$$

where $D_R(\eta Gyh^{-1})$is the absorbed dose rate indoor, C_{Ra}, C_{Th}, C_k are the radioactivity concentrations (Bq kg^{-1}) of ^{226}Ra, ^{232}Th, and ^{40}K respectively.

UNSCEAR (2008) reported that the world recommended permissible limit value of absorbed dose for the public should be 59 ηGyh^{-1}. Table 3 column 4 presents the result of the calculated absorbed dose rate investigated canned food samples with a mean value of $17.3\eta Gyh^{-1}$. This shows that these investigated imported canned food products into Nigeria meet International standard in terms of absorbed dose rate.

Annual Effective Dose Equivalent (AEDE)

The AEDE is defined as the total tissue weighted of the equivalent doses to targeted tissues and organs of man. It denotes the stochastic health risk to the entire human body, which predict the likelihood of cancer induced sickness and genetic effects due to low levels of ionizing radiation.

The annual effective dose equivalent received was evaluated from the absorbed dose rate by applying dose conversion factor of 0.7 SvGy^{-1} and the occupancy of 0.8 (19/24) recommended by (UNSCEAR, 2000; Veiga *et al.*, 2006). The annual effective dose equivalent (μSvy^{-1}) was therefore calculated using the formula (UNSCEAR, 2000):

$$AEDE(\mu Svy^{-1}) = Absorbed\ dose\ (nGyh^{-1})\ x\ 8760hx\ 0.7SvGy^{-1}x\ 0.8\ x10^{-3} \quad (7)$$

The results of the estimated annual effective dose equivalent obtained for the canned food samples analyzed are shown in Table 3 column 5. The obtained mean activity dose level of 84.9 μSvy^{-1} shows that the mean effective dose value of these canned food samples investigated is higher than the total effective dose value of 15.9 μSvy^{-1} reported in food spices by (Ononugbo *et al.*, 2017) but less than the mean value of 135.9 μSvy^{-1} reported in imported milk samples in Nigeria, India milk and the world average permissible values of 290 μSvy^{-1} for all foods (IAEA, 1989; WHO, 1993; UNSCEAR, 1993, 2000; Giri *et al.*, 2011; Agbalagba *et al.*, 2016). The relatively low effective dose recorded occasioned by the ingestion of these imported canned food products may be attributed to the low annual intake by adult of average value of 140 kg y^{-1}, 7.7 kg y^{-1} and 2.3 kg y^{-1} for canned staple foods, beef/ poultry foods and seafood respectively (FOS, 2006; Jibiri and Okusanya, 2008; Ademola and Ehiedu, 2010; Alrefae *et al.*, 2014). This results therefore indicate that the sampled canned food products are radiologically safe going by the global recommended permissible limit of annual effective dose rate of 290 μSvy^{-1}.

Excess Lifetime Cancer Risk (ELCR)

The likely carcinogenic effects that are characterized by assessing the likelihood of cancer incidence in a given population of persons for a specific lifetime from estimated intakes of radiation dose is termed as excess lifetime cancer risk (ELCR). In other words, ELCR can be defined as the additional or extra risk of developing cancer due to exposure to a radioactive substance accumulated over the lifetime of an individual. The risk parameter stipulates that the probability of an individual dying of cancer increases by 5% for a total of one Sievert received during an individual lifetime. The ELCR was estimated using the equation (Taskin *et al.*, 2009):

$$ELCR\ (mSvy^{-1}) = AEDExaveragedurationoflife\ (DL)xriskfactor\ (RF) \quad (8)$$

Where AEDE= the annual effective dose equivalent, DL= the estimated human life duration put at 70 years and RF = (0.05 for public) is the fatal cancer risk factor which is estimated to cause stochastic effects low-dose background radiation (Sv^{-1}) (Taskin *et al.*, 2009; Agbalagba *et al.*, 2016). The presence of high levels of radionuclides in canned foods can lead to radiological contamination of such canned foods and the consumption of such contaminated foods product may increase one's chance of cancer risk. If the radioactivity in the canned foods is higher than the recommended world average of 0.29 mSv y^{-1}, it could be a source of radiation to the human body and some specific organs of the body. However the computed ELCR values obtained in these investigated imported canned food products as presented in Table 3 column 6 are relatively low compared to the values reported in food spices and milk products in Nigeria and they are in hundreds of magnitude lower than the world average value (UNSCEAR, 2000; Agbalagba *et al.*, 2016; Ononugbo *et al.*, 2017). Thus these imported canned food products are radiologically safe for consumption. However, consumers are cautioned to regulate the quantity of intake of these processed canned food products to avoid accumulative radiological health effects in future in line with As Low As Reasonable Achievable (ALARA) principle.

Annual Effective Ingestion Dose to different Age Groups

The annual effective ingestion dose to individuals due to the intake of natural radionuclides (^{226}Ra, ^{233}Th and ^{40}K) in the selected canned foods were estimated using the formula from (UNSCEAR, 2000; Zaid *et al*., 2010).

$E_D = CIE (9)$

where E_D is the annual effective ingestion dose (Sv y^{-1}), C is the specific activity concentration of radionuclides in the ingested food samples (Bq kg^{-1}) while I is the annual intake of canned food (kgy^{-1}) which depends on a given age and E is the ingested dose conversion factor for radionuclides ($SvBq^{-1}$), which varies with radioisotopes and the age of the individuals that consume the food products (ICRP, 1996).

The average consumption rate of food for infant, children and adult which represent the different age group of 110.0 kg y^{-1}, 15.0 kg y^{-1} and 0.3 kg y^{-1} for Infants and 140.0 kg y^{-1}, 7.7 kg y^{-1} and 2.3 kg y^{-1} for children and adult for canned staple foods, beef food and seafood products respectively (FOS, 2006; Jibiri and Okusanya, 2008; Zaid *et al*., 2010). The results of the estimated annual effective ingestion dose to the different age group is presented in Table 4, while Table 5 is the conversion factors used for the three natural occurring radionuclides and the three age groups. The annual effective cumulative ingestion dose from the three natural radionuclides (^{226}Ra, ^{233}Th and ^{40}K) for infants, children and adults for staple food products are 205.5 μSvy^{-1}, 197.6 μSvy^{-1} and 206.7 μSvy^{-1} respectively, while for beef products it is 226.5 μSvy^{-1}, 228.0 μSvy^{-1} and 232.9 μSvy^{-1} respectively. For seafood products, the annual effective cumulative ingestion dose value for the three age group examined are 223.1 μSvy^{-1}, 278.2 μSvy^{-1} and 285.2 μSvy^{-1} respectively. This values obtained are in agreement with the earlier reviewed values for imported and domestic foodstuffs in Nigeria, the values reported in selected fruits at Ijebu-Ode in southwest Nigeria and other parts of Nigeria, the reported values for some vegetables in Nigeria, the reported dose intake values from canned foodstuffs from Tanzanian and fruits commonly used in Najaf Governorate in Iraq, the values reported by Harb and they are within the range of ingestion dose values reported in canned seafood consumed in Kuwait and food products in some parts of the world (Venturini and Sordi, 1999; Yu *et al*., 1997; Mlwilo *et al*., 2007; Jibiri and Okusanya, 2008; Ademola and Ehiedu, 2010; Alrefae *et al*., 2014; Harb, 2015; Abojassim *et al*., 2016; Agbalagba *et al*., 2016; Sowole and Olaniyi, 2018). The highest cumulative total annual effective ingestion dose value of 285.2 μSvy^{-1} recorded for adults seafood products is within the range of effective dose rate recommended by UNSCEAR for the general public (ICRP, 1996).

Effective Dose Rate to different Body Organs and Tissues (D_{organ}) mSvy^{-1} :

The effective dose rate to particular organ can be calculated using the relation (Agbalagba *et al*., 2016):

$$Dorgan(mSvy^{-1}) = OxAEDExF \ (10)$$

Where O = occupancy factor with a value of 0.8 and F= the conversion factor for the different organ dose (see Table 6). Table 7 present the obtained computed values of the effective dose rate assimilated by the various organs/tissues evaluated. In the staple foodstuffs, dose to infants organs/tissues are highest in lungs, bone marrows, testes, kidney and whole body estimated to assimilate 0.2 mSv dose annual from the intake of these food products. The canned beef food products examined also show that the bone marrow, the testes and whole body of infants will receive the highest dose of 0.2 mSvy^{-1} due to intake of these food products, while the bone marrow, the testes and the whole body of the children and adult were estimated to assimilate the highest dose of 0.2 mSv each annually from the consumption of seafood products investigated. This shows that ^{226}Ra and ^{232}Th are the radionuclides most absorbed into the body organs (Tawalbeh *et al*., 2012). These results obtained notwithstanding indicate that the estimated doses to different organs examined are below the international tolerable limits on dose to the body organs of 1.0mSv annually (ICRP, 1996; UNSCEAR, 2000).

Economic-Benefit to Risk Factor Analysis of Consumption of Canned Food

Economists have opined that if the benefits of demand for a goods do not far outweigh the attended risks of consuming sure goods, then it should be in the opportunity cost list. In radiation protection operates, the economic or cost benefit analysis is key in decision making on the use and disuse of a product that is radiologically laden. Applying the direct proportionality between dose and effect, it implies that the detriment to health is proportional to the effective dose-equivalent resulting from the process being evaluated (Agbalagba *et al*., 2016). The proportionality element is called the risk factor (IAEA, 2003; Ibikunle *et al*., 2016; Agbalagba *et al*., 2016). The summary of the evaluated risk analysis and health detriment effects that may possibly arise from the ingestion of imported canned staple foodstuffs, beef products and seafood products samples investigated in this study are presented in Table 8.

Committed Effective Dose (C_D)

The committed effective dose is a measure of the overall effective dose received over an average lifetime duration of 50 years resulting from ingestion of radionuclides. The three age groups of interest in this study are 0-1yr Infant, 7-12 yrs children and >17yrs adults. These were identified and assessed for committed effective dose using the formula (UNSCEAR, 2000; ICRP, 1991; Ibikunle *et al.*, 2016):

$$C_D = 50 \times E_D \quad (11)$$

The calculated value of the committed effective dose of the three age groups are presented in Table 9. The estimated values for infants and children are future base projections of the probable dose to be received by persons of these age bracket within a life span of 50 years. The estimated values for infants are (15.1, 14.3 and 11.2) $mSvy^{-1}$ for canned staple foodstuffs, beef products and seafood products respectively, while for children it is 9.9, 11.4 and 13.9 $mSvy^{-1}$ respectively. The values obtained for children are 8.3 $mSvy^{-1}$, 11.6 $mSvy^{-1}$ and 14.3 $mSvy^{-1}$ for canned staple foodstuffs, beef food products and seafood products respectively. These values obtained reveal that radionuclide consumed from food product accumulate over time especially those with very long half-life with the adult age group accumulating more doses. It is therefore advisable for adult to reduce the quantities of intake of canned food products due to the projected health implications.

Table 9. Summary of risk analysis of radiation dose from imported canned food products.

Age Group	Annual Effective Dose E_D (µSv)			Committed Effective Dose C_D ($mSvy^{-1}$)			Collective effective Dose Equivalent S_E (man-Sv)			Total Health Detriment (G) (man)			Mean THD (G) (man)	Total Cost Detriment (□) man-Sv $million
	Staple foodstuffs	Beef products	Sea food	Staple foodstuffs	Beef products	Sea food	Staple foodstuff	Beef products	Sea food	Staple foodstuffs	Beef products	Sea food		
Infant (0-1yr)	303	287	223	15	14	11	112,419	106,463	83,383	1855	1757	1376	4988	453
Children (7-12yrs)	198	228	278	10	11	14	205,408	236,531	288,401	3389	3903	4759	12051	110
Adult (>17yrs)	207	233	285	8	12	14	574,940	803,531	990,560	9487	13258	16344	39089	269

Table 10 present the National Population commission (NPC) 2006 population census figure, the projected population figure for 2015 and the computed two- third of this projected population of Nigeria, specifying the three age groups under investigation in this study. This was extracted from the National Population Commission report 2010 (NPC, 2010). The computed two- third of this projected population was adopted for the evaluation of the collective effective dose equivalent as estimated population that is may consume these food products (Agbalagba *et al.*, 2016).

Table 10. Nigeria Population Projection in different Age Group (NPC, 2010).

Age Class	Population (P_i) (NPC, 2006 Census)	Population (N_i) (2015 projection)	Two- Third of Projected Population ($\frac{\square}{\square}$ P_i)
Infant (0-1yr)	7,771,348	11,167,427	7,444,951
Children (7-12yrs)	21,763,942	31,122,437	20,748,291
Adult(>17yrs)	72,660,755	103,904,879	69,269,919

Collective Effective Dose Equivalent

The collective effective dose equivalent to the public or a given population, is the evaluation of the collective detriment or consequences and the percentage of the exposed population at risk of suffering radiologically induced illnesses. In radiation protection, the collective detriment to the public arising from activities involving exposure to radiation is advocated to be kept as low as is reasonably achievable (ALARA), economic and social effects being factor in (Agbalagba *et al.*, 2016). The estimation of the collective/ total detriment to health for the public is a step in achieving the ALARA goal. The postulation of direct variation between stochastic biological effects and dose equivalent is also applicable to the collective detriment to health being directly proportional to the collective effective dose equivalent (Ahmed and Daw, 1991). Thus the collective effective dose equivalent, S_E in a population consisting of N_i individuals is calculated using the formula (Ahmed and Daw, 1991; ICRP, 1991):

$$S_E = \sum N_i \boldsymbol{C_{Di}} \quad (12)$$

Where S_E = collective effective dose equivalent (person – Sv), N_i= the numbers of persons in a group exposed to the radiation and $\boldsymbol{C_{Di}}$is the mean Committed effective dose equivalent (μSvy^{-1}). In accordance with the NPC (2010), population projection of 183,390,767 people in 2015 living in Nigeria, the population of people within the age group of 0-1, 7-12 and >17 years was projected to be 11,167,427; 31,122,437 and 103,904,879 respectively (Ibikunle *et at.*, 2016).

In Nigeria, an average of two-third of the population are estimated to be consuming one type of imported canned food products or the other as food or ingredient for food, hence we use two-third of the population of the three age group as those expected to be exposed to radiation dose from the consumption of these imported canned food products .

Therefore, the formula for computing the collective effective dose equivalent was accordingly modified to be:

$$S_E = \sum \frac{2}{3} (N_i H_{Ei}) \quad (13)$$

An estimated number of 97,463,161 representing 53% of the total population of the country exposed to the radiation of these canned food products as a result of ingestion of these food. Table 9 presents the results of the calculated values of the collective effective dose equivalent S_E. The obtained values indicates that in staple foodstuffs, the collective dose equivalent for Infants, children and adults are 112,419 man-Sv, 205,408 man-Sv and 574,940 man-Sv respectively. The obtained values for beef food products are 106,463 man-Sv, 236,531 man-Sv and 803,531 man-Sv respectively, while for seafood products, the collective dose equivalent for Infants, children and adults are 83,383 man-Sv, 288,401 man-Sv and 990,560 man-Sv respectively. It was observed from the results that the adult population received the highest dose, followed by the children while the infants is the least exposed group to the radiation from the consumption of these imported canned food products, this is attributed to the consumption pattern or habit of these food products that is skewed to favour the adult age group followed by children with infants consuming few of the imported canned food products. This results contradicted the received dose intake order reported for milk (liquid and powder) and water that follows the consumption rate of the three examined group, which put the infants as the most exposed followed by children with adult reported to be the least exposed (Agbalagba *et al*., 2016; Ibikunle *et al*., 2016).

Total Health Detriment

The evaluation of the total or collective health detriment is of great importance to researchers, since any health detriment to any age group population in the society will impact negatively on the entire population (Agbalagba *et al*., 2016).

The gross or collective health detriment also known as the objective or total health detriment "G" (man), owning to exposure to ionizing radiation in a society or ingestion of irradiated food stuffs, is estimated using the expression (Ahmed and Daw, 1991; Ibikunle *et al*., 2016):

$$G = R_T S_E \quad (14)$$

Where R_T = Total risk factor the body organs are exposed to, it estimate the fatal radiation-induced cancers and severe hereditary effects in the first two generation with a value of $1.65 \times 10^{-2} Sv^{-1}$ according to ICRP (1991). S_E = Collective effective dose equivalent (man– Sv) (Ahmed and Daw, 1991). Table 9 present the collective health detriment for the infants, children and adult age groups calculated for the three categories of imported canned food products in Nigeria. The total health detriment (man) obtained for staple foodstuffs are; 1855 (infants), 3389 (children) and 9487 (adults), while for beef food products, the evaluated total health detriment values are; 1757 (infants), 3903 (children) and 13258 (adult), and for the seafood products, the obtained values are; 1376 (infants), 4759 (children) and 16344 (adult). These estimated total health detriment results indicate that of the 7,444,951 Nigerian infants consuming canned staple foodstuffs, beef products and seafood products, 1855, 1757 and 1376 infants respectively with a total of 4988 infants are probable to contract radiological health related sicknesses in future from intake of these investigated food products. Similarly, of the estimated population of 20,748,291 Nigerian children consuming canned staple foodstuffs, beef products and seafood products; 3389, 3903 and 4759 children respectively with a total of 12051 children prone to future radiation induce health related illnesses due to ingestion of these investigated canned food products, while of the adult population of 69,269,919 Nigerians that feeds on canned foodstuffs, a total of 39,089 are susceptible to radiological health induced diseases, going by the risk factor of $1.25 \times 10^{-2} Sv^{-1}$ (ICRP, 1991). The obtained total health detriment indicates shows a mean radiological health risk index ratio of 1: 2238 for infants, 1:2583 for children and 1:4238 for adults. These imply that for every 2238 infants in Nigeria there is the likelihood of one be ill of radiologically related sickness, while for every 2583 children one may sick of radiation induced sickness and for the adult it will be one out of 4238, showing that infants' radiological index ratio is highest, thus still most vulnerable which are in agreement with previous studies (Agbalagba *et al*., 2016; Ibikunle *et al*., 2016).

Cost of Detriment

The cost of the health detriment and collective effective dose equivalent are linear related and expressed using the formula (Ahmed and Daw, 1991):

$$\gamma = \beta S_E \quad (15)$$

Where γ is the cost of health detriment, S_E is the collective effective dose equivalent (man– Sv), while β is a constant, indicating the cost of a unit collective dose equivalent. Naturally, it would have be nice if one can arrive at a globally acceptable monetary value for the cost of radiation lethal stochastic health effects, then β will have a unique value, but this is not practically possible because of other socio-economic considerations that may come to play. Thus monetary value for radiation health effects differ from nation to nation and may change with time and season (Agabalagba *et al*., 2016). There a widespread variation of monetary value for radiation health effects β, ranging from 1000 - 100000 US dollars from extensive review of literatures (Ahmed and Daw, 1991). However, for the purpose of this study, considering Nigeria being the most populous country in Sub-Sahara Africa with a very low per capita income of below US$ 100 per day (though with little growth in recent time), we adopted US$ 1500 as assign value for human life for the cost of detriment analysis. This is not a tangible fiscal value of life, but rather it proposed to offer measure by which fair and reliable resources are assigned to radiation protection (ICRP, 1991). Table 9 present the estimated result of the total cost of health detriment computed from the collective effective dose equivalent to the different age group. The infants' age bracket was observed to have the highest cost health detriment per-caput dose with calculated total cost of health detriment of US$ 453.4 million, it was followed by the adults' age group with estimated cost effect of US$ 269.2 million while the children age group is the least with projected cost implication of US$ 109.6. From the estimated cost-detriment, it is obvious that the economic benefits which is directly proportional to cost of purchase and importation put at about nine billion US dollars annually derived from consuming these imported canned food products is far above the health detriment.

CONCLUSION

Naturally and artificial occurring radioactive materials in imported canned foods products in Nigerian markets has been examined using a High Purity Germanium detector. Artificial radionuclides (^{137}Cs and ^{210}Pb) were food in some of the food samples while in others food samples they were below detectable level. The radioactivity concentration of the sampled food products were observed to be dictated by the food category, country of origin and the sources of the food products. The activity concentration of the natural radionuclides were found to be highest in seafood products compared to the staple foodstuffs and beef food products. However, the obtained results were establish to be within the world wide ranges of values reported in the reviewed scientific literatures and international regulatory bodies recommended permissible limits for ingestion of food by the public. The present of ^{137}Cs radionuclide in some of the staple foodstuffs and beef food products, cannot be associated with the irradiation of canned food but a trace of heavy metals content in the food items which requires further study while the present of ^{210}Pb is an indicated of heavy metal contamination of the source of food chain. The radium equivalent activities obtained for all the canned food samples considered were all below the criterion limit of radiation dose (1.0 Svy^{-1}) UNSCEAR (2000). The estimated radiological hazard indices revealed that all the canned food products examined are well below their permissible levels.The estimated excess lifetime cancer risk from the naturally occurring radioactivity revealed that the chance of contracting radiologically induced health sicknesses from the consumption of the analysed canned food samples and the effective doses from the current exposure rate to the different age groups organs investigated are insignificant. It was observed from the annual effective dose computed, that the intake of the canned food samples by infants, children and adults at standard rates of their recommended intake per annum may not lead to any significant radiation dose to vital organs of the body above normal recommended value.

On the economic-benefit to risk factor analysis of the ingestion of the canned food products, the computed collective effective equivalent dose values obtained indicates that the adult population received the highest dose, while the infants' population is the least exposed group to the radiation from the consumption of these imported canned food products. The estimated total health detriment in all the food sample show a health detriment index ratio of one to above two thousand, which is adjudged to be significantly low. In the same vein, the estimated total cost of health detriment model, show that the cost benefit far outweigh the health detriment as the value recorded are be considerably low.

In general, the results obtained shows that the canned food products consumed in Nigeria are radiologically safe and may not pose any immediate and significant radiation health risk to consumers of these analyzed canned food products. Moreover, the present of ^{137}Cs and ^{210}Pb in some analyzed food samples potent some level of radiological contamination of these imported food products. It is therefore recommended that a precautionary measure be adopted in the consumption of these food items why future research be focus on increasing the number of samples for a more coverage and robust analysis.

ACKNOWLEDGEMENT

Authors wish to appreciate the Director and staff of the National Institute of Radiation Protection and Research, Nigerian Nuclear Regulatory Authority, University of Ibadan for offering to analyze the same in real time.

Funding
We the authors state that there is no funding of any kind from individual, cooperate bodies or government agencies in this research work.

Availability of Data and Material
The datasets generated and/or analyzed during the current study are not publicly available due to the policy of the countries of origin where these food products were manufactured, but are available from the corresponding author on reasonable request.

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Received: Jan 9, 2021; Accepted: Feb 1, 2021