International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Foodstuffs And Cancer: Analysis Of Radionuclides And Its Radiation Levels In Common Ghanaian Maize.

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Abstract

By gamma spectroscopic measurement; the content of natural and anthropogenic radionuclides and their activity levels were determined in selected common Ghanaian maize. The purpose was to establish whether these levels and subsequently their annual effective doses from the intake of these radionuclides were within the internationally acceptable limits. Six different maize varieties were collected, processed and data on each sample analyzed using a High Purity Germanium Detector. The activity levels and annual effective doses were calculated for the samples. The most significant radionuclides obtained from the analysis were; Potassium (^{40}K), Uranium (^{238}U), Caesium (^{134}Cs), and Thorium (^{232}Th). The average annual effective doses obtained from this study were 0.0039 mSv and 0.0012 mSv for dried and ashed samples respectively. This study concluded that the radionuclide activities and the annual effective doses were within acceptable standard levels and hence these Ghanaian maize varieties suitable for human consumption.

Keywords: Assayer software; Cancer; Effective dose; Gamma spectroscopy; Germanium detector; Ghanaian maize; Radioactivity levels; Radionuclides.

1.0. Introduction

Radioactive isotopes of elements (radionuclides) are naturally present in the environment, and that includes our bodies, food and water. We are exposed to radiation (also known as background radiation) from these radionuclides on a daily basis [1].

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The uptake of radionuclides by plant roots constitutes the main pathway for the migration of radionuclides from the soil to humans, via food chain. Consuming food containing radionuclides is particularly dangerous. If an individual ingests or inhales a radioactive particle, it continues to irradiate the body as long as it remains radioactive and stays in the body [2]. Decades of research show clearly that any dose of radiation increases an individual's risk of developing cancer. However, radiation levels can be concentrated in the food chain and further consumption adds to the cumulative risk of developing cancer and other diseases [3].

Maize (or Corn) is a major carbohydrate staple plant in Ghana and is consumed in different ways by almost all ethnic groups. Some of the most popular foods prepared from maize dough is *kenkey* (local dish) or is simply boiled in water and eaten as porridge. Maize dough can be mixed with cassava or used alone to prepare *banku* (local dish). Another maize product is the roasted or grilled and boiled maize served with nuts and coconut respectively. It is used as a carbohydrate source for the preparation of alcoholic and non – alcoholic drinks. It is also used as a gel-forming agent in confectionary and as a moisture retention agent in toppings and cake icings. Oil from maize is nutritionally excellent as it is highly digestible and a good source of essential fatty acids [4]. Radioactivity can be detected in food and water; the concentrations of these naturally-occurring radionuclides vary depending on factors such as the type of food, local geology, climate and agricultural practices [5]. Scientists have identified that some chemical constituents of food either initially present in the food, formed during preparation (especially cooking), or added for preservation are capable of inducing cancers or tumours in high-dose rodent tests. Children have a higher risk of exposure to carcinogens in food as they consume more foods, drink more liquids, and take in more air than adults do. The fact that children have rapidly developing organ systems, especially the central nervous system and the brain, makes them highly susceptible to chemical interference as they are also less able to metabolize and excrete most toxic substances [6]. Some radionuclides have a tendency to concentrate in certain tissues because of their interaction with normal physiological processes. For example, caesium and strontium isotopes tend to congregate in bones, whereas the thyroid gland selectively concentrates iodine [7, 8].

2.0. Materials and Methods

The best and most convenient apparatus used for such research is the gamma ray spectroscopy technique. Gamma spectroscopy is a radionuclear method used to determine the energy and count rate of gamma rays emitted by radioactive substances. Most radioactive sources produce gamma rays of various energies and intensities. When these emissions are collected and analyzed with a gamma spectroscopy system, a gamma energy spectrum is then produced. A detailed analysis of this spectrum is typically used to determine the identity and quantity of gamma emitters present in the source. The gamma spectrum is characteristic of a gamma emitting nuclides contained in the source. The equipment used in gamma spectroscopy includes an energy sensitive radiation detector, a pulse sorter (multichannel analyzer), associated amplifiers and data readout devices. The detector used is a high purity germanium detector [9].

2.1. *Sampling and Sample Preparation*:

Six different maize samples were obtained from the Crops Research Institute (CRI) of the Council for Scientific and Industrial Research (CSIR) at Fumesua and the Asafo local market, Kumasi all in the Ashanti Region of Ghana. Each of these samples weighed 1kg. The six varieties namely: *Mamaba, Abeleehi, Obatanpa, Dodzi, Market Sample A (MS A) and Market Sample B (MS B)* were collected in their raw states. Each of the six maize varieties was divided into two parts; 0.5kg was weighed out of each sample and labeled as either dry or ash. The dry samples were in their dry state and milled. The ash samples were roasted to ashes and milled. This gave a fine powder to obtain high detection efficiency. The prepared maize samples were then transported to the Laboratory and prepared into a 1L Marinelli beaker and stored in a shielded area prior to analysis.

2.2. *Analysis of Maize Samples:*

The samples were analysed using an ORTEC high resolution gamma spectrometry system. The spectrometer consists of a High Purity Germanium (HPGe) detector couple to a desktop computer with Maestro 32 multichannel buffer (MCB) configuration software for spectrum acquisition and evaluation. The detector crystal had a diameter of about 36 mm and thickness of about 10 mm. The crystal is housed in an aluminium canister with a 0.5 mm thick

beryllium entrance window. A lead shield, built with 5 cm thick lead brick surrounds the detector to prevent external radiation from entering the detector chamber from the external environment and vice versa. The detector is coupled to a Canberra 1510 signal processing unit which contains the power supply, amplifier and analog to digital converter. The Germanium detector is connected to an uninterrupted Power Supply (UPS). Background counts were taken for the same period and corrections carried out where appropriate. The samples were then putted in the detector (HPGe) and counted for 25000seconds for maximum detection by the detector and data on each sample collected. To cool the detector, the detector is mounted on a liquid nitrogen cryostat (by means of a dipstick) at 196ºC (77 K) provided in a 25L Dewar. A multichannel analyzer (MCA) shapes the voltage pulse produced by the detector. The ambient temperature around the detector varied between 16°C and 27ºC during the period of measurement.

3.0. Results

With the help of the assayer software, various peaks were obtained across the width of the channel window. Each of these peaks corresponds to the energy of a particular radionuclide in the sample. They were recorded and used in the calculation of the radioactivity of each radionuclide. The equation used in calculating the activity (A) of the radionuclide in the samples is given as:

$$A = \frac{N_{net} \times \ell^{(\lambda . t_d)}}{\rho \times T_c \times M \times \varepsilon} \qquad (1)$$

Where

N_{net} - Net counts of the radionuclide in the sample

λ - Decay constant

t_d - Delay time

ρ - Gamma yield

T_c -Total counting time

M - Mass of the sample (kg)

ε - Total counting efficiency of the detector

A - Activity

The radionuclides obtained from CRI were ^{232}Th, ^{238}U, ^{40}K and ^{134}Cs and from the market samples, an addition of ^{235}U traces. From tables 1 and 2, the average activities of the identified radionuclides showed a significant higher value for Potassium. Tables 3 and 4 also highlighted the activities concentrations and effective doses obtained for the samples analysed.

Table 1. Identified radionuclides with their average activities in the samples collected from CRI.

Radionuclides	Average Activity(Bq) ±SD for Ash Sample	Average Activity(Bq) ±SD for Dry Sample	Possible Sources
Uranium(^{238}U)	0.009904 ± 0.000119	0.011192 ± 0.003325	Rocks
Caesium(^{134}Cs)	0.001168 ± 0.000476	0.002848 ± 0.000740	Fallout
Potassium(^{40}K)	0.020819 ± 0.005849	0.063235 ± 0.000304	Natural
Thorium(^{232}Th)	0.002895 ± 0.000767	0.008821 ± 0.000746	Rocks

Table 2. Identified radionuclides with their average activities in the samples collected from the local market.

Radionuclides	Average Activity(Bq) ±SD for Ash Sample	Average Activity(Bq) ±SD for Dry Sample	Possible Sources
Thorium (^{232}Th)	0.002033 ± 0.000089	0.002993 ± 0.000262	Rocks
Uranium(^{238}U)	0.001569 ± 0.000366	0.015199 ± 0.001972	Rocks
Caesium(^{134}Cs)	0.000670 ± 0.000038	0.002439 ± 0.000016	Fallout
Potassium(^{40}K)	0.161503 ± 0.003275	0.278591 ± 0.043819	Natural
Uranium(^{235}U)	0.001442 ± 0.000120	0.008621 ± 0.000682	Rocks

*SD = Standard Deviation

The annual effective dose (mSv/yr) from ingestion of radionuclide in the maize samples was calculated on the basis of the mean activity concentrations of the radionuclides. The daily maize consumption rate was assumed to be 3 kg/day and the conversion factor or dose per unit intake by ingestion for naturally occurring radionuclides for adult members of the public was taken to be $4.5\text{x}10^{-5}$ mSv/Bq for ^{238}U, $2.3\text{x}10^{-4}$ mSv/Bq for ^{232}Th, $1.9\text{x}10^{-5}$ mSv/Bq for ^{134}Cs and $6.2 \text{ x } 10^{-6}$mSv/Bq for ^{40}K [10]. The annual effective dose (H) was computed from the expression below:

$$H = \sum_{i=1}^{4} DCF(U, Th, Cs, K) \times A \times I \tag{2}$$

Where

$DCF(U, Th, Cs, K)$ - Dose conversion coefficients of the radionuclides in Sv/Bq.

A - Specific activity concentrations of radionuclides in the maize samples in Bq/Kg.

I - Radionuclide intake in Kg/yr, assuming 3 Kg average maize intake per year for 365 days/yr (1095 Kg/yr).

Table 3. Activity concentrations and annual committed doses in dry samples.

	Activity Concentrations (Bq/kg)				Annual effective dose (mSv/yr)
Sample	^{40}K	^{134}Cs	^{238}U	^{232}Th	H
MS A	0.234772	0.002423	0.017171	0.002731	0.003178181
MS B	0.322410	0.002444	0.013227	0.003255	0.003711221
Dodzi	0.183547	0.000943	0.010520	0.002010	0.002290311
Obatanpa	0.014168	0.002548	0.002045	0.001986	0.000750139
Mamaba	0.215982	0.003492	0.007677	0.002510	0.002549381
Abeleehi	0.033626	0.004408	0.207277	0.001612	0.010939552
Average	0.167418	0.002710	0.042987	0.002351	0.003903131

Table 4: Activity concentrations and annual committed doses in ash samples.

	Activity Concentrations (Bq/kg)				Annual effective dose (mSv/yr)
Sample	^{40}K	^{134}Cs	^{238}U	^{232}Th	H
MS A	0.158230	0.000134	0.002086	0.001944	0.001669395
MS B	0.164775	0.000210	0.001052	0.002122	0.001709290
Dodzi	0.067563	0.000870	0.010796	0.001231	0.001318786
Obatanpa	0.001197	0.000959	0.001047	0.000932	0.000314394
Mamaba	0.001069	0.002531	0.007076	0.001851	0.000874759
Abeleehi	0.013450	0.000314	0.020695	0.000139	0.001152601
Average	0.067714	0.000836	0.007125	0.001370	0.001173204

4.0. Discussion

The levels of radionuclides in the soil differ from one geographic area to another. The use of phosphate fertilizers on agricultural farms enhances gamma ray activity concentrations on farmlands and therefore the absorbed dose rates to the public. The most common natural radionuclides in fertilizers and soil are ^{40}K, ^{238}U, ^{235}U and ^{232}Th. Comparing the various average activities, the market samples had higher activities than that from the Crops Research Institute (CRI) at Fumesua. Been that the samples from CRI are cultivated under supervised conditions were certain factors such as fertilizer application, nature of the land, etc were taken into consideration. The market samples which were from Techiman in the Brong Ahafo Region of Ghana recorded higher activities. Again, average activity levels in the dry samples were higher than in the ash samples. The small amount of water in the maize in its dry state accounted for these differences. This confirms that water contains some amount of radionuclides. Potassium (^{40}K) recorded the highest activity with Caesium (^{134}Cs) being the lowest in most measurements. The intake of Caesium isotope by plants is inversely proportional to Potassium intake. The application of fertilizers on farmlands (such as NPK) tends to reduce Caesium by increasing the amount of potassium. This might account for the high Potassium (^{40}K) activities in the samples comparatively.

From table 5, the activity levels obtained for each of the radionuclides in this research were within the acceptable IAEA limits of 1.48Bq for ^{40}K, 0.185Bq for ^{134}C and ^{232}Th and 0.555 Bq for ^{235}U and ^{238}U.These activities corresponds to a very low absorbed dose / annual committed dose, as indicated in tables 3 and 4; which were below the standard maximum permissible dose value of one millisievert per year (1mSv/yr) for an average of five years [2, 6]. We can therefore conclude that, these Ghanaian maize samples cultivated from the Brong Ahafo Region of Ghana (food basket), were suitable for human consumption and may not pose any treat of increasing the risk of developing cancer.

Table 5: Average Activities of Radionuclides found in both dry and ash samples.

	Dry Sample	Ash Sample
Radionuclide	Average Activity	Average Activity
	Bq/kg	Bq/Kg
^{40}K	0.167	0.068
^{134}Cs	0.003	0.001
^{238}U	0.043	0.007
^{232}Th	0.002	0.001

5.0. Conclusion

Maize is a major carbohydrate staple food for the people of Ghana and is consumed in different ways by all ethnic groups. The Brong Ahafo Region of Ghana is considered as the Nation's food basket linking the southern and northern parts of the Country. The Asafo market in Kumasi is also considered as one of the biggest and busiest food distribution point in the country. A number of researches have been done to determine radionuclides in foodstuffs, their activities and to determine whether these activities are still within the acceptable limits established by the Food and Agriculture Organization (FAO) and the International Atomic Energy Agency (IAEA). The main health concern for consumers in the long term is the risk of developing cancers due to high radiation exposure. Cancer types and its target organs depend on particular radionuclides. The most significant radionuclides obtained were Potassium (^{40}K), Uranium (^{238}U) and Thorium (^{232}Th) from the market samples. Potassium (^{40}K) recorded the highest activity and Caesium (^{134}Cs) the lowest. The annual committed dose for both collection points were within safe and acceptable limits for human consumption.

Acknowledgements

We are very grateful to Prof. Mrs. Aba Andam, who supervised this work and to Mr. Isaac Odoi Danquah, who contributed greatly to this work. Also to the Radiation Protection Institute (RPI) of the Ghana Atomic Energy Commission for the use of their facilities for this study. This work is also dedicated to the memory of the late Mr. Emmanuel Kwaku Nani (a pioneer of Medical Physics in Ghana, mentor and a great friend).

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