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^{226}Ra, ^{232}Th and ^{40}K CONTENTS IN SOME NATURAL AND CARBONATED FRUITS COMMONLY CONSUMED IN PLATEAU STATE, NORTH CENTRAL NIGERIA AND THEIR ANNUAL EFFECTIVE DOSE TO HUMAN POPULATION.

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Abstract

The purpose of this study was to use a thallium-doped sodium iodide scintillator detector to determine the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in certain naturally and artificially carbonated ripened fruits in Plateau State, North Central Nigeria. In naturally ripened fruits, the activity contents ranged from 14.2646 Bq/kg to 43.553 Bq/kg, 36.016 Bq/kg to 77.773 Bq/kg, 64.2964 Bq/kg -184.5337 Bq/kg, whereas carbonated fruits the activity contents ranged from 16.8618 Bq/kg -59.2042 Bq/kg, 49.345 Bq/kg -55.7937 Bq/kg, 85.4247-289.3227 Bq/kg, 39.33732 Bq/kg-52.24704 Bq/kg, and 162.7373Bq/kg respectively. All of the samples revealed activity levels of ^{232}Th that were higher than the world average of 30 Bq/kg, according to UNSCEAR 2000. Except for Avocado, where the activity concentration is greater than the allowed limit of 35 Bq/kg, the average values for 226Ra and 40K were calculated to be less than the UNSCEAR 2000 permissible limit of 35Bq/kg and 30Bq/kg, respectively For all carbonate fruits, the activity concentration for ^{232}Th is greater than 35 Bq/kg, and for carbonated mango and avocado, the activity concentration for ^{226}Ra is greater than 30 Bq/kg. However, the annual effective dose in all fruit samples (natural and artificially ripened fruits) was computed and shown to be significantly lower than the suggested limit of 1mSv by the International Commission of Radiological Protection (1996).

1. INTRODUCTION

Estimating human population exposures to various sources of radiation, whether natural or man-made, is a major and ongoing issue for everyone. Radionuclides are naturally occurring materials that can be found in the soil, water, air, and food. Plant roots absorb radionuclides from the soil, radioactive particles in the air settle on crops, and radionuclides accumulate in animals that eat plants, feed, or drink water that contains radioactive material. However, in nature, the issue of radiation exposure has become an unavoidable part of life on the planet as a result, human civilizations have been concerned about environmental protection and management in order to ensure that creatures are safe from the impacts of ionizing radiation [1]. Radionuclides are usually released in trace amounts into the environment, depending on the geology of the area, and then transported to the vegetables and fruits we eat, which are an important part of a healthy diet, and variety is just as important as quality, so it is directly related to the survival of all living organisms, and its quality cannot be compromised [2]

A diet rich in vegetables and fruits can help lower blood pressure, prevent heart disease and stroke, prevent some types of cancer, reduce the risk of eye and digestive issues, and have a beneficial influence on blood sugar, which can help control appetite[3]. These advantages are only obtained by eating naturally ripened fruits rather than those that have been artificially ripened. The terrible aspect is that many fruit vendors utilize chemicals like CaC_2 to help ripen fruits, and these chemicals are extremely harmful to the human body, posing major health risks. Calcium carbide is a caustic and hazardous compound that contains trace amounts of arsenic and phosphorous hydride. Diarrhea, thirst, weakness, burning sensation in the throat, shortness of breath, and ulcer skin are some of the symptoms of arsenic and phosphorous poisoning. CaC_2 is also recognized to have cancer-causing characteristics and the general public is unaware of the potential radiological dangers of eating artificially ripened fruits on a daily basis. Furthermore, there is a scarcity of precise radiological information on our environment, particularly in third-world nations like Nigeria about naturally ripened and artificially ripened crops. The work is significant and relevant because radiological evaluation of our agricultural produce (fruits) is required, particularly when uneducated men/vendors in Plateau State, North Central Nigeria, use calcium carbide as a ripening agent, which the United States has banned. The United States' Food and Drug Administration (FDA) tests food for contaminants, including radiation, and imposes strict limits and restrictions on foods imported from other countries to ensure public safety. In Nigeria, the National Agency for Food and Drug Administration and Control (NAFDAC) has warned farmers, traders, and the general public to refrain from ripening fruits with radiation. Although it is now considered a criminal offense, the practice of using calcium carbide, which is reported to be exceedingly detrimental to one's health, continues unabated.

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As a result, the focus of this study is on natural radionuclides (uranium, thorium, and potassium) in naturally and artificially ripened fruits, with a comparison of activity concentrations and radiological risk among age groups in Plateau State of North Central Nigeria were majority of the fruits are grown and consumed in the research area.

2. The study Area

Plateau State is located in Nigeria's North Central Zone, one of the country's six geopolitical zones[4]. It covers a total area of 26,899 square kilometres and has a population of roughly three million people. It is situated between 08°24'N and 008°32' and 010°38' east longitude. The Jos Plateau is assumed to be a region of newer granite that intruded through an older granite rock to form the surrounding states.

3. MATERIAL

Ten samples were gathered from various sites (five naturally ripe and five unripe fruits, i.e. ripe and unripe of the same tree). The orange, mango, pear, banana, and plantain samples used in this study represented the majority of fruits consumed in the study area. The samples were taken directly from the tree during the fruiting season. For 2-3 days, the unripe were placed in a polythene bag with a ripening agent (calcium carbide). All of the samples were washed, sliced, and dried at room temperature before being oven dried at 600 degrees. The dry sample was pulverized and sieved until it was a uniform powder. To achieve secular equilibrium, the powdered materials were maintained in a sealed tight polyethylene beaker for 30 days. To prevent radon-222 from escaping, each case's packing was triple sealed. The sealing technique included smearing Vaseline jelly on the inner rim of each jar lid, filling the lid assembly gap with candle wax to prevent the gaps between lid and container, and tightening the lid-container seal using masking adhesive tape.

4. Activity concentration analysis

The experiment used a 76x76mm NaI (Tl) detector crystal optically linked to a photomultiplier tube (PMT). The assembly includes a preamplifier and a 1kilovolt external source. The detector is surrounded by a 6cm lead shield with cadmium and copper sheets, which is designed to decrease the effects of background and scattered radiation.

Camberra Nuclear Products' Maestro data gathering software was used. For each sample, the samples were measured for a total of 29000 seconds. The following equations (1) and (2)) were used to calculate the activity concentrations in each sample using the peak area of each energy in the spectrum:

$$C\ (Bq.kg^{-1}) = \frac{C_n}{C_{fk}} \quad (1)$$

Where,

C = activity concentration of the radionuclides in the sample given in $BqKg^{-1}$

C_n = count rate (counts per second)

C_{fk} = Calibration factor of the detecting system.

$$CPS = \frac{Net\ count}{Live\ Time} \quad (2)$$

Where,

CPS is count per second.

Two calibration point sources, Cs-137 and Co-60, were used to calibrate the system for energy and efficiency. These were counted for 30 minutes with the amplifier strength that yields 72 percent energy resolution for the 661.16KeV of Cs-137. To verify the calibration (Ti-208), the IAEA gamma spectrometric reference materials RGK-1 for K-40, RGU-1 for Ra-226 (Bi-214 peak), and RGTh-1 for Th-232 were utilized. The spectral energy windows employed in the study contain gamma energies of 1764.0, 2614.5, and 1460.0 Kev for 226Ra, 232Th, and 40K, respectively, and energy windows of 1620-1820, 2480-2820, and 1380-1550 Kev for 226Ra, 232Th, and 40K

5. Radiological Risk Assessment

Standard radiation indices are used to quantify the impact of radiation on the health of people exposed to radiation and the environment.

6. Annual Effective Dose

The yearly effective dose is a measurement of the risk of long-term ionizing radiation effects on the human body, organs, and tissues, taking into account their radiation sensitivity in Sieverts (Sv).

According to [5], the annual effective dose attributable to food ingestion was calculated using a metabolic model that may be calculated using formulae [6,7,8].

$$D_{rf}\ (sv/y) = \sum (C_r A_{rf}) \times R_f \quad (3)$$

Where

Drf is the annual effective dose,

Cr is the effective dose conversion factor of the nuclides. (See table 3).

Arf is the activity concentration of the radionuclides in the ingested food (f, Bq/kg)

Rf is the consumption rate of the food item f,kg/y committed effective doses per unit intake by ingestion of natural radionuclides. (See table 4).

7. RESULTS AND DISCUSSION

The measured results for five natural ripe fruits and five artificial (carbonated) ripe fruits obtained at various places around plateau state, north central Nigeria, are summarized in Tables 1 and 2.

The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in naturally ripened and carbonated fruits were measured. The actions that were measured, together with their errors, are displayed in Table 1 shows the radium, thorium, and potassium concentrations, which ranged from 14.2646 Bq/kg to 43.553 Bq/kg, 36.016 Bq/kg to 77.773 Bq/kg, and 64.2964 Bq/kg -184.5337 Bq/kg, respectively.

According to [2], all of the samples had activity concentrations of 232Th that were higher than the world average of 30 Bq/kg.

The average values for 226Ra and 40K were calculated to be less than the 35 Bq/kg acceptable limit except for Avocado, where the activity concentration is higher than the permitted limit of 35 Bq/kg.

Meanwhile, the activity concentration and mean values for carbonated fruits were 16.8618 Bq/kg -59.2042 Bq/kg, 49.345 Bq/kg - 55.7937 Bq/kg, 85.4247-289.3227 Bq/kg, 39.33732 Bq/kg-52.24704 Bq/kg, and 162.7373Bq/kg, respectively. Similarly, the mean value of ^{226}Ra and ^{232}Th exceeds the [2] allowable limits of 35Bq/kg and 30Bq/kg, respectively. The activity concentration for ^{232}Th is above the permissible limit of 35 Bq/kg for all carbonate fruits, and the activity concentration for 226Ra is above the allowable limit of 30 Bq/kg for carbonated mango and avocado. Infants receive a larger annual effective dose from natural and artificially ripened fruits than children and adults. The dosage conversion factor and intake rates proposed by [5] and [2].result in a greater value for infants, as shown in Tables 3&4.

However, the annual effective dosage in all fruits samples (natural and artificially ripened fruits) was clearly below the recommended limit of 1mSv [5].

8. CONCLUSION

In certain selected samples of fruits produced and regularly consumed in Plateau, North central Nigeria, activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K were determined, as well as annual effective dose. All of the samples in the study had activity levels of ^{232}Th that were higher than the world average of 30 Bq/kg. Except for Avocado, where the activity concentration exceeds the acceptable limits of 35 Bq/kg, the average values for ^{226}Ra and ^{40}K were calculated to be lower than the permissible limits of 35 Bq/kg and 400 Bq/kg. Similarly, the mean values of ^{226}Ra and ^{232}Th exceed the [2] recommended limits of 35Bq/kg and 30Bq/kg, respectively. The activity concentration for ^{232}Th is over the legal limit of 35 Bq/kg for all carbonate fruits, while the activity concentration for 226Ra is above the permissible limit of 30 Bq/kg for carbonated mango and avocado. As shown in fig, (2) and (3), all fruit samples (natural and artificially ripened) had annual effective doses below the recommended limit of 1mSv. Although the annual effective dose of fruits may not offer a significant risk to consumers, specific activities that exceed the permitted limits for some fruits that are naturally ripened or ripened with a ripening agent may have the potential to cause serious harm over time

Table:1 Activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in natural ripen fruits commonly consumed on the Plateau North Central Nigeria.

Samples ID	Samples name	Ra-226 (Bq/kg)	Error ± (Bq/kg)	Th-232 (Bq/kg)	Error ± (Bq/kg)	K-40 (Bq/kg)	Error ± (Bq/kg)
A	**Orange**	**14.2646**	**1.5184**	**36.0162**	**1.5334**	**184.5337**	**6.0063**
B	**Mango**	**15.5832**	**2.5972**	**48.4017**	**1.9659**	**157.6661**	**1.8770**
C	**Avocado**	**43.5530**	**2.8769**	**75.2566**	**1.5334**	**64.2964**	**0.1394**
D	**Banana**	**21.3769**	**2.4773**	**77.7730**	**1.5728**	**131.6029**	**3.3786**
E	**Plantain**	**28.3909**	**1.7981**	**66.4884**	**1.3762**	**139.2106**	**0.9974**
	Mean	24.63372	2.25358	60.78718	1.59634	135.4619	2.47974
	Min	14.2646	1.5184	36.0162	1.3762	64.2964	0.1394
	Max	43.553	2.8769	77.773	1.9659	184.5337	6.0063
	World average [2]	**35**		**30**		**400**	

Table: 2 Activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in artificial ripen fruits commonly consumed on the plateau North Central Nigeria.

Samples ID	Samples Name	Ra-226 (Bq/kg)	Error ± (Bq/kg)	Th-232 (Bq/kg)	Error ± (Bq/kg)	K-40 (Bq/kg)	Error ± (Bq/kg)
A''	**Carbonated orange**	**16.8618**	**2.3575**	**53.0806**	**2.2019**	**187.9123**	**2.6278**
B''	**Carbonated mango**	**48.1080**	**4.0356**	**55.7937**	**1.7300**	**289.3227**	**4.0221**
C''	**Carbonate avocado**	**59.2042**	**0.8389**	**50.4855**	**2.5557**	**85.4247**	**0.1823**
D''	**Carbonated banana**	**26.9309**	**3.9957**	**49.3453**	**2.5164**	**147.4768**	**1.6088**
E''	**Carbonated plantain**	**45.5817**	**1.1186**	**52.5301**	**1.1009**	**103.5500**	**0.3861**
	Mean	39.33732	2.46926	52.24704	2.02098	162.7373	1.76542
	Min	16.8618	0.8389	49.3453	1.1009	85.4247	0.1823
	Max	59.2042	4.0356	55.7937	2.5557	289.3227	4.0221
	World average [2]	**35**		**30**		**400**	

Table: 3 Committed effective doses per unit intakes by ingestion of natural radionuclides [5].

	Effective dose per unit intake nSv/Bq		
Radionuclide	Infants 1-2yrs	Children 7-12yrs	Adults Above 17yrs
K- 40	42	13	6.2
Ra- 226	960	800	280
Th- 232	450	290	230

Table: 4 Consumption rates for fruits [2].

Average consumption Rates kg/year		
Adult	Children	Infant
75	50	35

Table: 5 Summation of annual effective dose in natural ripen fruits samples at different age groups (Adult, children and infants)

	Annual effective dose mSv/y			
s/no	Infants	Children	Adults	
1	0.00131781	0.001212766	0.001003876	
2	0.001517691	0.001427636	0.001233126	
3	0.002743188	0.002875133	0.002241723	
4	0.002136645	0.002068326	0.00184972	
5	0.002205766	0.002190205	0.001805779	

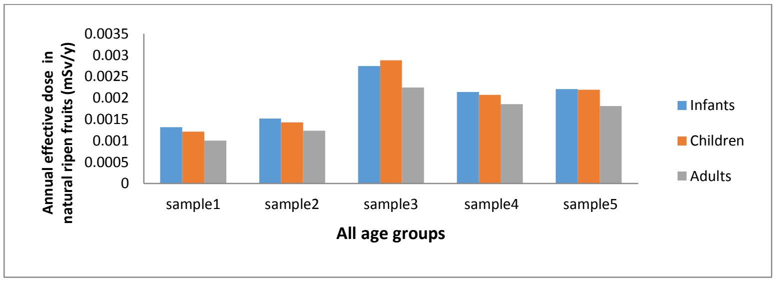

Fig 1: Summation of Annual Effective Dose (mSv/y) in natural ripen fruits by all age groups.

Table: 6 Summation of annual effective dose in artificial ripen fruits samples at different age groups (Adult, children and infants)

	Annual effective dose mSv/y			
s/no	Infants	Children	Adults	
1	0.001678807	0.001566284	0.001396579	
2	0.002920484	0.002921388	0.002168002	
3	0.002909982	0.003155734	0.002171825	
4	0.001898858	0.001888603	0.001516302	
5	0.002511113	0.002652262	0.001933256	

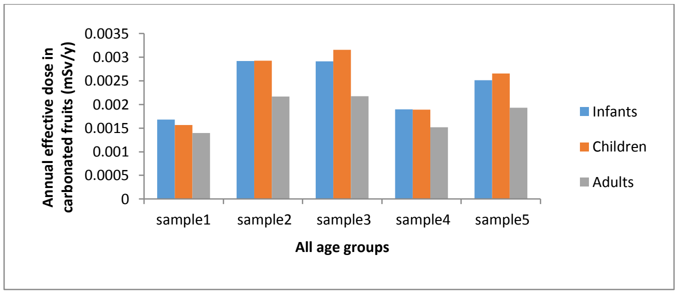

Fig 2: Summation of Annual Effective Dose (mSv/y) in artificial ripen fruits by all age groups.

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