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Radiological Comparative Analysis of Differently Reared Chicken Meat from Gold Mining and Non-Gold Mining Corridors

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Abstract: This study was carried out to determine the distinction between activity concentration of naturally occurring radionuclide (^{40}K, ^{226}R and ^{232}Th) in free-range and cage type chicken meat reared and consumed in Ede, a non-mining area and Ilesha (Iperindo) a gold mining area of Osun State, south western Nigeria. Measurement was carried out by means of gamma spectroscopy technique centered on NaI(Tl). This was with a view of to determine the health implication of the populace. The mean activity concentration of ^{40}K, ^{226}Ra and ^{232}Th were evaluated on chicken meat and organs were evaluated to be 51.14Bq/kg, 68.25Bq/kg and 55.99Bq/kg for free range type in Ede; also 54.69Bq/kg, 74.05Bq/kg and 69.12Bq/kg for free range in Ilesha (Iperindo). The mean activity concentration of ^{40}K, ^{226}Ra and ^{232}Th also evaluated in chicken meat and organs of cage type in Ede were found to be 39.81Bq/kg, 72.47 Bq/kg and 49.11Bq/kg in addition to that of Ilesha cage type were 42.00 Bq/kg, 126.04 Bq/kg and 93.92 Bq/kg respectively. The global average activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in food consumption by UNSCEAR was 412 Bq/kg, 32 Bq/kg and 45 Bq/kg. However, comparison with these values, obviously showed that the means activity concentration of ^{226}Ra and ^{232}Th in chicken meat and organs in both categories reared and consumed in Ede and Ilesha exceeds the standard limit, but the mean activity concentration of ^{40}K was found lower. Estimation of annual effective dose through ingestion of radionuclides was also evaluated. The mean annual effective dose due to the ingestion of the three natural radionuclides through consumption of heart, beef, gizzard and liver in Ede both free and age type were found to be 35.69 ± 6.5 μSvyr^{-1}, 32.96 ±3.16 μSvyr^{-1}, 25.58 ± 8.18 μSvyr^{-1} and 30.54 ± 0.61 μSvyr^{-1} respectively while that of Iperindo were 36.48±0.72 μSvyr$^{-1,}$ 49.54±10.86 μSvyr$^{-1,}$ 58.88±29.28 μSvyr$^{-1,}$ and 36.18± 0.14 μSvyr^{-1} respectively. The evaluated mean annual dose from the highlighted radionuclide's in chicken meat and organs of both types in two study areas were lower than the FAO dose limit of 72.1 μSvyr^{-1}

Keywords: Natural radionuclide's, Gold mining, chicken meat, comparative Analysis, corridors.

1 Introduction

The Composition of human diet varies from place to place as well as from individual to individual. Food is a major source of energy for metabolic activities in human body when ingested. However, the composition of balance diet in food include, carbohydrate, fats, protein, vitamins, minerals and water which are essential and should be regularly consumed for human growth and for proper function of all part of the body. Out of these composites, protein is a complex compound made up of carbon, hydrogen and oxygen just like carbohydrate and fat, and in addition nitrogen. This source of protein includes meat, fish, egg, dairy product pulses, nuts and seeds [1]. Meat is the flesh of animals or birds (chicken meat) used as food, and serve as source of protein in balance diet. The supply of meat in Nigeria comes from five major sources. These are beef, poultry, goat meat, pork and mutton. Beef contributes the highest percentage 36%, poultry takes the second 31%, goat meat 20%, pork and mutton takes 5% [2].

Natural radionuclide's originated in the earth crust, and include ^{40}K,^{232} Th and ^{226}Ra. The naturally occurring radionuclides constitute 85% of radiation dose received by man [3]. Plants are grown on soil and receive nutrients from soil through transpiration. Following a food chain, nutrients

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(potassium (k), phosphorus (p), nitrogen (N), magnesium (mg) and sulphor (s) accompanied with naturally occurring radionuclide are carried from soil to plants through transpiration. These are translocated to all parts of the plants. Small animal like rabbit, rat, goat and birds feed on these plants as source of food [4].

Accumulation of radioactive elements in animals and birds tissue could pose health risk to man when ingested. Radiation from natural sources give more than 80% of the total exposure received by the average member of a population and a portion of this exposure comes from dietary ingestion [5]. Land can be contaminated as a result of industrial processes such as mining, radioactive accident, past waste disposal, number of past land use, during extraction and using material with high level of radioactive elements [6]. The assessment of concentration of thorium, uranium and potassium in the soil from tantalite mining sites have been carried out [7,8]. The mining and processing of the tantalite waste products {tailing} are indiscriminately dumped within and around the mining sites. The wastes are distributed by wind and erosion [9] and could contain high activity concentration of these radionuclides and hence lead to contamination of soil, water, air and food. Eventually this may result to internal exposure of populace, animals and birds to radiation. The exposure could be through direct ingestion of water or indirectly through food chain [10].

The activity concentration of some radionuclide in food in volcanic area had been carried out [11]. During a decay progeny and transformation of the earth crust, the naturally occurring radionuclides are deposited in the soil. They are also soluble in water and form part of the soil in addition to the soil moisture contents. Radionuclide in the soil may enter part of edible plants during translocation which are later consumed by human and animals. However, Farm birds acquire these radionuclides during consumption of these plants [12] during scavenging, hence increasing the chances of accumulating high concentration of radionuclide in their tissues. Also ingestion of radionuclide contaminated feed obtained from grasses, vegetables, grains, cereal and other food items can constitute radioactivity in tissue, ingestion of radionuclide through food consumed accounts for a considerable part of average radiation dose to various organs of the body and also represents one of the crucial considerations for long term health risk [13].

As a result of this, it is important to assess the level of naturally occurring radionuclides and their daughter nuclides in chicken meat from gold mining and non-gold mining sites. This is paramount especially in area such as Iperindo Osun State, Nigeria where chicken reared are exposed to radiation through inhaled dust and food ingested from crops grown on the land and water. In this study we determined the concentration of primordial radionuclides ^{40}K, ^{226}Ra and ^{232}Th in chicken meat using gamma spectroscopy technique centered on the NaI(Tl) detector. The study area include Ede, a non- mining area and Ilesha (Iperindo), an abandoned gold mining area, both in Osun state Southwestern Nigeria. The data obtained was used to assess radiological risk associated with ingestion of chicken meat on the populace by estimating the effective annual dose and compare with international permissible limit.

2 Experimental Section

2.1 Geological Mapping of study Areas

Ede is a town in Osun State, Southwestern Nigeria. It lies along Osun river at a point on the rail road from Lagos, 180km Southwest and intersection of roads from Osogbo, Ogbomoso and Ife. Total area of 330km^2 coordinates: 7^o 44^I 20^{II} N 4^o 26^I 10^{II} E / 7.73889^o N 4.43611^{o}E, elevation 269m. [14]. The area is within the pre-cambrian basement complex of Southwestern Nigeria predominantly composed of migmatite and granitic, gnesis, quartzite, slightly magnetized to unmagnetized metasedimentary schist and metagneous rocks, charnockitic, gabbroic and dionite which is a member of older granite suite mainly granites, granodiorite and syenites [15].

Iperindo is a town in Ilesha. It is located few kilometers South Ilesha in Osun State Southwestern Nigeria. The abandoned gold mining site has been covered by thick and dense forest, tall and thick bamboo trees with evergreen canopy and densely stunt of creeping vines. The paramount rock is the amphibolites, quartz, granite, pyrite, pyrhotile and limonite [16].

2.2 Sample Collection and Preparation

A total number of twenty chickens were obtained from the two different study areas namely Ede and Iperindo. Out of these twenty chickens five were from free range category and five were from cage type category for each of the two study areas. The free ranges were randomly selected from each of the areas while the cage types were selected from poultry raised within the study areas. The free range were characterized by scavenging in the surrounding, obtaining their food from what they could find such as insect, seeds, kitchen wastes etc. The cage types obtain their food from chicken feeds produced in the study areas and feed supplement was included [17].

The categories of chicken samples were sacrificed, defeathered, washed and the organs required for our analysis were removed. The included the heart, gizzard, liver and beef. These organs of chicken were separated placed in containers and oven dried at a temperature of 378K to constant weight. The dried samples were crushed and grinded the use of motar and pestle. A total number of sixteen grinded samples of organs were obtained of which four organs were from each chicken and the organs of the fifth chicken combined with each of the obtained samples.

Known masses of the samples were each placed in plastic container of base diameter 5.0cm which could comfortably sit on the NaI (TL) detector of diameter 5.1cm. The plastic containers and samples were her metrically sealed and kept for more than four weeks in order to allow ^{226}Ra and ^{232}Th and their short-lived progenies to attain a state of secular equilibrium [10].

2.3 Radiological Measurement

2.3.1 Determination of primordial radionuclide

The poultry samples were analyzed in Ladoke Akintola University, Ogbomosho, SouthWestern Nigeria for the determination of radionuclide contents using a computer interfaced calibrated and lead shielded NaI(Tl) detector manufactured by Scintitech Instrument, USA. The detector coupled via a multichannel analyzer (MCA) PGT 2100R, manufactured by Priceton Gamma Tech USA. In the calibration, each height of a given pulse and its corresponding channel number is directly proportional to the gamma energy producing it. This forms the basis of our measurement and calculation.

The system was tested by its linearity and calibrated with standard source sample potassium, thorium and uranium (K_2SO_4 IA EA/ RGK^{-1}, Th-ore IAEA/ RGTH $^{-1}$). These are geological certified references materials for radiometric measurement from international atomic energy agency (IAEA), Vienna. The calibration curve of known energy of the source used to determine the linear equation relating the gamma energy to the channel number is shown in fig. 1. The linearity (R^2= 0.9928) of the system used for this work was observed by plotting the gap energy for calibration used to set a straight line for the energy channel calibration which can be filled with equation [1]

$$E = K_n + \in \quad (1)$$

where E and K are constants (intercept and slope of the graph). Curve fitting was carried out and the equation obtained is given in the equation below.

$$E\,(MeV) = 0.0084_n - 0.00655 \quad (2)$$

where E is the energy and n is the channel number equation 2.

Three region of interest were created for the purpose of this work. Region one was photopeak corresponding to gamma energy 1.465 MeV of ^{40}k, region two was photopeak energy 1.765 MeV for ^{238}U while region three was photopeak with channel number 310 of energy 2.615 MeV for ^{232}Th. The energy peaks were obtained from region of interest (ROI) created in the neighborhood of observed energy. The samples were countered for 36,000 second each.

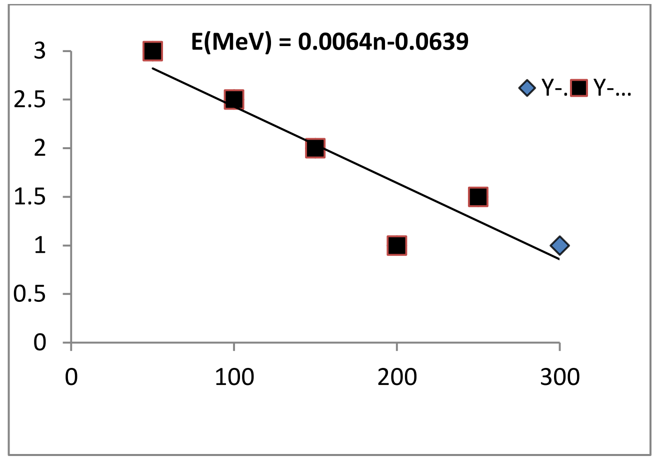

Figure 1: Calibration curve

2.3.2 Determination of Activity concentration of ^{226}Ra, ^{232}Th and ^{40}K

The detection efficiency (Ep) of the system was first determined in order to calculate the activity concentration of the radionuclides. The constant geometry of efficiency detection is given by

$$E_p = \frac{A}{CY_{mt}} \quad (3)$$

Where A is the net area under the photopeak, c is the activity concentration of a reference sample (Bqkg $^{-1}$), m is the mass (kg) of a reference sample and t is the period for a count of the reference sample. The efficiency was determine using a reference standard source of known activity concentration, prepared from international Atomic Energy Agency (IAEA), vienna, Austria and traceable to source Ref. No. IACA-312. The activity concentration of each radionuclide in the poultry samples were calculated base on the net photopeak and the detection efficiency.

3 Results and Discussion

Tables 1 and 2 showed the average activity concentration of ^{40}K, ^{226}U and ^{232}Th in the organs (heart, beef, gizzard and liver) in ^{40}K, ^{226}Ra and ^{232}Th of chicken types reared and consumed in Ede and Iperindo. The activity concentration of the radionuclides for the chicken type in the two study areas was lower in ^{40}K than the global activity limit of 412Bq/kg but higher in ^{226}Ra and ^{232}Th than the global limit of 32Bq/kg and 45Bq/kg respectively [18]. However, the increase in activity concentration in^{226} Ra and ^{232}Th was mostly witnessed in organs of the chicken from Iperindo (both free range and cage type).

Previous gold mining activities from Iperindo could increase the background activity concentration of the environment. The animals and birds in this area, are bound to be exposed to radiation figure 2 to 5 shows the distribution of activity concentration of ^{40} K, ^{226}Ra and ^{232}Th respectively in different organs of each specified area. Activity concentration of ^{226}Ra and ^{238}U have been reported highest in chicken meat, egg and soil water but lower in ^{232}Th [19] in French territory, and the activity concentration of ^{226}Ra is highest as obtained by [20] in Brazil but the activity concentration is highest in ^{40}K and lower in ^{226}Ra in Nigeria as determined by [10,21]. ^{226}Ra is higher than ^{232}Th in [22].

In this study, it was confirmed that the activity concentration of ^{226}Ra and ^{232}Th evaluated from chicken organs of both categories as the value of ^{226}Ra is higher than that of ^{232}Th.This could be as a result of the abundance of high mobile ^{238}U in ground water, which during a progeny produces ^{226}Ra and ^{232}Th. These could be translocated during transpiration from the ground water to the part of the root of the grain or plants which constitute the feed the chicken consumed. In addition ^{232}Th could be retained in water ingested by these chicken.

Table 1. Activity concentration (Bq/kg) of chicken organs

	Free - Range					
	^{40}K		^{226}Ra		^{232}Th	
Organ	Ede	Iperindo	Ede	Iperindo	Ede	Iperindo
Heart	30.32	36.14	90.9	98.50	78.64	46.14
Beef	107.32	120.24	81.03	88.04	47.19	63.96
Gizzard	33.61	23.09	40.57	51.42	28.07	71.14
Liver	33.30	39.27	61.39	58.23	70.04	93.24

Table 2. Activity concentration (Bq/kg) of chicken organs

	Cage Type					
	^{40}K		^{226}Ra		^{232}Th	
Organ	Ede	Iperindo	Ede	Iperindo	Ede	Iperindo
Heart	12.25	29.16	69.19	78.17	48.55	65.52
Beef	91.07	81.47	72.25	149.83	43.97	87.16
Gizzard	43.24	44.71	87.64	188.31	42.84	167.98
Liver	12.66	12.66	60.79	87.84	61.09	55.01

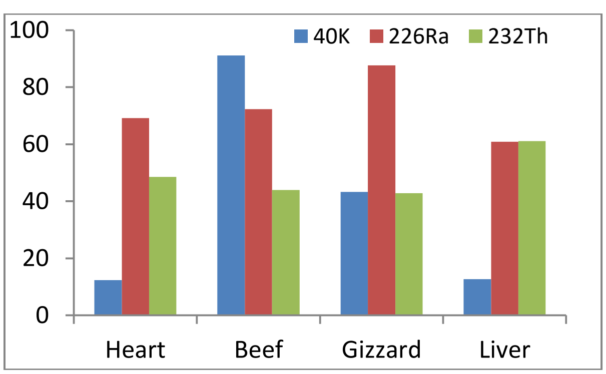

Figure 2. Activity concentration of radionuclide for Ede samples (Cage Type)

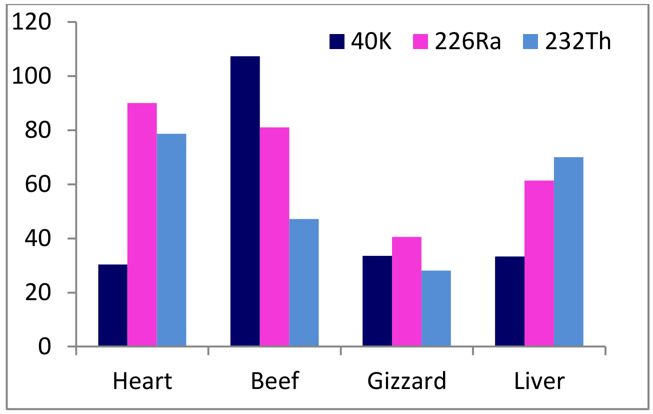

Figure 3. Activity concentration of radionuclide for Ede samples (Free Range)

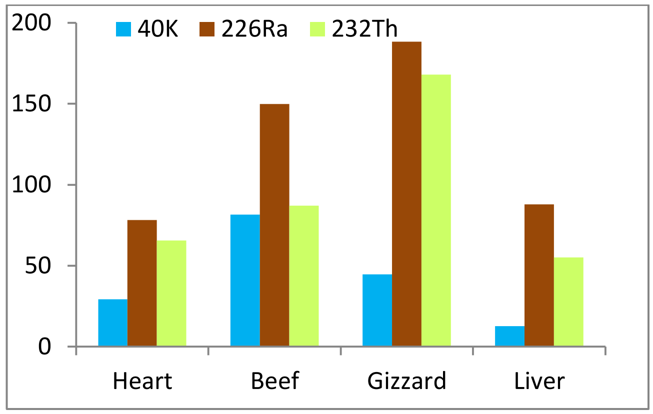

Figure 4. Activity concentration of radionuclide for Ilesha samples (Cage Type).

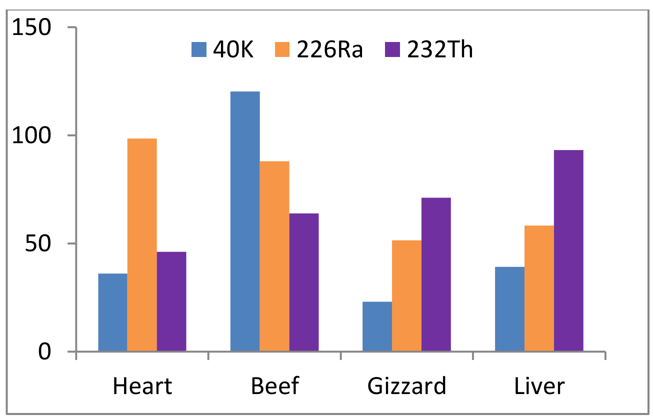

Figure 5. Activity concentration of radionuclide for Ilesha samples (Free Ranged).

Table 3. Annual Effective Dose ($\mu Svyr^{-1}$)

	Free-Range		Cage Type		Mean Annual Effective Dose	
Organ	Ede	Iperindo	Ede	Iperindo	Ede	Iperindo
Heart	41.84	37.20	29.53	35.75	35.6	36.48±

					9 ± 6.15	0.72
Beef	33.06	38.68	29.86	60.40	32.90 ± 3.15	49.54± 10.86
Gizzard	17.39	29.59	33.76	88.16	25.58 ± 8.18	58.88± 29.28
Liver	31.15	36.32	29.93	36.04	30.54 ± 0.61	36.18± 0.14

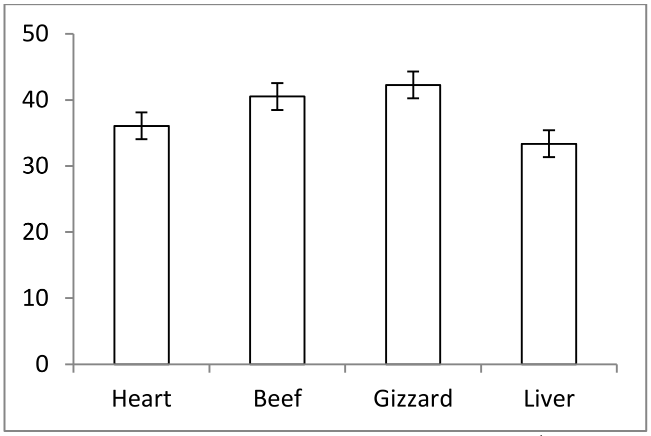

Figure 6. Mean annual effective dose (μSvyr^{-1}) due to ingestion of the three radionuclide in different organs of chicken

3.1 Annual Effective Dose

Radiation dose received due to the intake of food calculated from the amount of radionuclide on food stuff deposition, the activity concentration of particular radionuclide in food per unit deposition, the consumption rate of the food products and the dose per unit activity ingested [10]. The annual effective dose ingestion by an adult member of the public due to intake of radionuclide through ingestion of food can be calculated based on the metabolic models developed by the international commission of radiological protection [23] as follows

$$Ht = \sum (U^{l} \ x \ Cr^{i}) \ x g_{Tr} \quad (4)$$

where u denotes standard value for Nigeria (beef) consumption rate in kgy^{-1}, C is the activity concentrate (Bq/kg) of the radionuclide of type r of interest, denotes a food group and g_{tr} is the dose conversion coefficient for ingestion of radionuclide r (Sv/Bq) in tissue T.

The recommended dose coefficient g_{tr} for the public for ^{40}K, ^{226}Ra and ^{232}Th are 6.2x10^{-9}., 2.8x10^{-7} and 2.2x20^{-7} Sv/Bq respectively. [24]. Since there is no data site existing for specific consumption in the study areas, hence the average per capita of beef consumption between 1967 and 2007 for Nigeria was used, this is known to be 0.9kgy^{-1} [25] which was adopted for organs of chicken sampled. Equation 4 was used to calculate the annual effective dose due to ingestion of beef and organs of chicken.

The result evaluated for the effective dose due to ingestion of chicken was represented in table 3. The evaluated mean annual dose from the highlighted radionuclide in chicken meat of both types in the two study areas as presented on table 2 were higher than those obtained for cattle reared in mining area of Jos, Nigeria but lower than the FAO dose limit of 72.1µsvy$_{r}^{-1}$. The standard deviation from the mean value connotes the variation of the effective dose in each organ which represents the errors quoted. Figure 6 represent the chart of effective dose due to ingestion of the radionuclide in the various organs.

4 Conclusions

The activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in chicken meat and their various organs reared and consumed in Ede a non- mining area and Iperindo a gold mining area had been estimated using gamma ray spectrometry. The activity concentration of ^{40}K was lower than the global activity limit, but higher in ^{226}Ra and ^{232}Th than that of the global activity limit. The activity concentration of the radionuclides was found of higher value in Iperindo a gold mining area than Ede a non- gold mining area. Consequently long time accumulation over a period of time might result in severe radiological accident.

It is recommended that the site should be always monitored for further increase level of radionuclide and the populace protected from radiation hazard.

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