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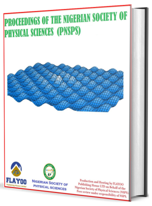

Radionuclide intake due to food drying surfaces: implications for individual ingestion effective dose in Ogbomoso, Southwestern Nigeria

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ABSTRACT

Measurement of low-level radionuclide transfer from food drying surfaces is of radiological importance in environmental protection, especially in West Africa where farmers commonly preserve their foodstuffs by a low cost method of sun-drying on surfaces such as rock, asphalt, concrete, wood, metals, or roofing sheets which are reported sources of natural radionuclides. The transfer coefficient of natural radionuclides from drying surfaces into food samples is therefore a concern for dietary intake for the consumers. The radioactivity measurements of commonly used food drying surfaces in Ogbomoso, as well as cassava flour sun-dried on these surfaces were performed via gamma-ray spectrometry. Cassava flour was sun-dried on fabric raised 1 meter above the ground to serve as control sample ($CF_{control}$). Activity concentrations of ^{40}K, ^{238}U, ^{232}Th in rock, asphalt, concrete and cassava flour dried on these surfaces were determined using a lead-shielded NaI(Ti) detector crystal. Food consumption data and the measured activity concentrations in dried cassava flour were used to estimate ingestion effective dose of radionuclide intake from cassava flour due to these drying surfaces. Annual ingestion effective doses ($mSvy^{-1}$) in cassava flour dried on concrete, rock, asphalt and fabric were estimated to be 0.72, 0.59, 0.42 and 0.26, respectively. Radionuclide addition was observed in cassava flour dried on concrete, rock and asphalt with transfer variation maximum in rock surface and minimum in asphalt surface. Result of this study is useful for radiometric data analysis in the study area especially on food safety regulations.

Keywords: Cassava flour, Radionuclide, Ingestion effective dose, Transfer variation.

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1. INTRODUCTION

Sun-drying of food products is a common practice among local farmers especially in Africa, of which farmers as well as food consumers utilize diverse drying surfaces to dry their foodstuffs [1]. Cassava, being a valued agricultural produce, provides about 40% of all dietary intakes of many developing countries of Africa [2]. Cassava flour is commonly dried on surfaces such as rock, concrete, asphalt or metals, of which can lead to radiological contamination of food products due to radioactive elements

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naturally present in those surfaces. Naturally occurring radionuclides are transferrable through natural processes including food processing techniques, food drying methods and so on. Deposition of radionuclides into food products can be a significant route to human exposure when such food products are ingested. Ref. [3] reported the possibility of incurring more radionuclide ingestion dose from food diets produced by roasting techniques. Ref. [4] assessed radionuclide transfer in food chain and revealed radionuclide addition in cow milk due to ingestion of contaminated pasture. Ref. [5] reported radionuclide transfer factor for ^{238}U and ^{232}Th greater than the recommended values. Measurement of low-level radionuclide transfer from food drying surfaces is of radiological importance in environmental protection. Metric data obtainable from radiological studies such as, soil-to-plant transfer factor, radionuclide addition due to food preparation techniques, as well as radionuclide transfer coefficient due to drying surfaces is useful for transfer model in environmental radiation protection. This study aimed to investigate natural radionuclide transfer of selected drying surfaces to cassava flour and implication on ingestion effective dose.

2. MATERIALS AND METHOD

Cassava flour sun-drying is prominent in Iregba-Oja, being a central region where farmers in the neighbouring villages can conveniently process their farm produce and sell to the consumers. Cassava flour is commonly sun-dry on rock, asphalt and concrete surfaces in this region of Ogbomoso. Therefore, Iregba-Oja, located in Ogbomoso, Soutwestern Nigeria was chosen as the study area. Figure 1 presents the map of the study area.

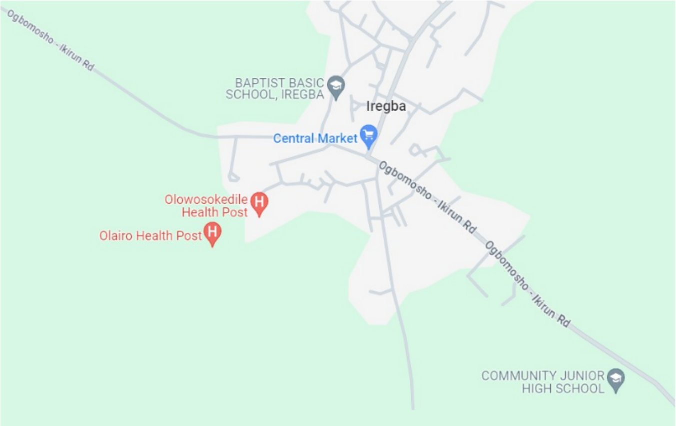

Figure 1. Map of Iregba-Oja, Ogbomoso.

2.1. SUN DRYING OF SAMPLE

Processing and sun-drying of cassava flour was done at Iregba, Surulere Local Government Ogbomoso, Soutwestern Nigeria. Iregba is a rural settlement notable for cassava farming. Processed cassava flour was sun-dried on Concrete floor, Rock surface and Asphalt road. These three drying surfaces considered are common surfaces where farmers in the study area dry most of their processed food before consumption. Portions of Rock, Concrete and Asphalt drying surfaces (DS) were also collected and labeled as DS_R, DS_C and DS_A, respectively. The rock sample was identified as metamorphic (granite) rock with mineral constituents of quartz, mica (muscovite), feldspar. Fresh cassava flour was sun-dried on fabric (clothing material) raised 1 meter above the ground, serving as Cassava Flour control sample ($CF_{control}$). Sun-drying of cassava flour lasted for 3 days till cassava flour attained a completely dried state. Background radiation level of cassava flour before sun-drying is negligible.

(a) (b)

Figure 2. Gamma ray spectroscopy. (a) Cassava flour undergoing secular equilibrium. (b) Activity counting of cassava flour.

2.2. PREPARATION OF SAMPLES

Cassava flour dried on Concrete, Rock and Asphalt surface (CF_{exp}) were collected and labeled accordingly. CF_{exp} were grounded for homogenization and then sieved into powder with a 2mm wire mesh. Care was taken to ensure that CF_{exp} samples were not contaminated by any foreign inclusion. The same procedure was done to the collected DS_R, DS_C and DS_A on which cassava flours were dried [6]. All samples (DS_R, DS_C and DS_A, CF_{exp} and $CF_{control}$) were transferred into clean weighed cylindrical plastic containers, which could sit on the detector cap. The containers were then sealed for a period of 30 days in order for the sample to attain secular equilibrium as shown in Figure 2A.

2.3. RADIOACTIVITY MEASUREMENT

After secular equilibrium is attained, radioactivity counting was done using a lead-shielded NaI(TI) detector crystal (Model No. 802 series, Canberra Inc.) coupled to a Canberra Series 10 plus Multichannel Analyzer (MCA) (Model No. 1104) through a preamplifier, with detector resolution capable of distinguishing gamma ray energies shown in Figure 2B. Counting time was set for 10 hours (36000s) for each sample. Activity concentrations of the radionuclides in the samples were determined by the net area counts after background corrections under the photopeaks of each of the radionuclide, using the expression [7]:

$$\text{C (Bq/kg)} = \frac{Cn}{\epsilon \text{Py} Ms}. \tag{1}$$

Activity concentration of the radionuclide in the sample is denoted by C; count rate under each photopeak due to each radinuclide is denoted by C_n, ϵ is the detector efficiency of the specific gamma ray, absolute transition probability of the specific gamma ray is P_y and M_s is the mass of the sample (kg).

2.4. ESTIMATION OF GAMMA RADIATION DOSE (D)

Equation (2) was used to convert radionuclide concentration of ^{238}U, ^{232}Th and ^{40}K in DS_R, $DS_{A,}$ DS_C into doses

$$D = 0.427C_U + 0.662C_{Th} + 0.043C_K, \tag{2}$$

Table 1. Mean activity concentrations of radionuclides and absorbed dose rate (ADR) in drying surfaces (DS).

DS	^{40}K (Bq.kg^{-1})	^{238}U (Bq.kg^{-1})	^{232}Th (Bq.kg^{-1})	ADR (nGyh^{-1})
Concrete	573.69 ± 91.86	17.62 ± 5.93	20.24 ± 6.16	45.59
Rock	757.82 ± 120.03	14.33 ± 8.31	14.8 ± 8.86	48.48
Asphalt	525.74 ± 88.11	10.48 ± 9	18.6 ± 7.06	39.32

Table 2. Mean activity concentrations of the radionuclide in cassava flour and annual effective dose (AED) due to ingestions.

Cassava flour dried on	^{40}K (Bq.kg^{-1})	^{238}U (Bq.kg^{-1})	^{232}Th (Bq.kg^{-1})	AED (mSv.y^{-1})
Concrete	143.70 ± 79.62	13.43 ± 8.33	12.19 ± 4.22	0.62
Rock	444.67 ± 136.62	13.66 ± 9.17	10.23 ± 4.05	0.86
Asphalt	315.49 ± 72.16	8.79 ± 5.53	5.41 ± 4.95	0.56
Fabric	189.10 ± 77.41	3.40 ± 5.93	1.90 ± 4.59	0.26

where D is the absorbed dose rate in nGy.h^{-1}, C$_U$ is the concentration of uranium, C$_{Th}$ is the concentration of thorium, and C$_K$ is the concentration of potassium. The constants 0.427, 0.662 and 0.043 are dose conversion factors for ^{238}U, ^{232}Th and ^{40}K [8].

2.5. INGESTION EFFECTIVE DOSE EVALUATION

Equation (3) was used to calculate radiation dose due to intake of cassava flour. The amount of radionuclide deposited on cassava flour, the activity concentration of particular radionuclide in cassava flour per unit deposition, the consumption rate of the cassava flour and the dose per unit activity ingested were used to obtain radiation dose due to cassava flour intake. The Effective dose H to a particular tissue T due to intake of radionuclide r is given by [2]:

$$H_{T,r} = \sum (U \times C_r) \times g_{T'r}, \tag{3}$$

where the U is the consumption rate (kg·y^{-1}), C$_r$ denotes activity concentration of the radionuclide r of interest (Bq·kg^{--1}), and g$_{T,r}$ denotes the dose conversion coefficient for ingestion of radionuclide r (Sv·Bq^{-1}) in tissue T.

For adult members of the public recommended dose conversion coefficient g$_{T,r}$ for ^{40}K, ^{238}U,and ^{232}Th, are 6.2x10^{-9} Sv.Bq^{-1}, 4.5x10^{-8}Sv.Bq^{-1} and 2.3x10^{-7}Sv.Bq^{-1}, respectively [2]. Consumption rate of cassava was taken to be 116.6kg.yr^{-1} .

Equation (4) was used to determine the coefficient of variation (reduction or addition) in ingestion effective dose due to drying surfaces [3]

$$K = \frac{D_{TC} - D_{TS}}{D_{TC}}, \tag{4}$$

where K is the coefficient of ingestion dose variation in cassava flour, D$_{TC}$ is the total ingestion dose in CF$_{control}$, D$_{TS}$ is the total ingestion dose in CF$_{exp}$, $K > 0$ is an indication of ingestion dose reduction due to drying surface, while $K < 0$ implies ingestion dose addition due to drying surface.

3. RESULTS AND DISCUSSION

3.1. RESULTS

The activity concentrations of radionuclides present in DS$_R$, DS$_C$ and DS$_A$, CF$_{exp}$ as well as CF$_{control}$ were determined. The mean activity concentrations and absorbed dose rate of ^{40}K, ^{238}U, and ^{232}Th measured in drying surfaces (DS) are presented in Table 1. People living around the study area receive maximum dose rate (48.48 nGyh^{-1}) from rock and minimum value (39.32 nGyh^{-1}) of the absorbed dose rate was observed in Asphalt.

Table 3. Radionuclide addition in cassava flour.

CF$_{exp}$	Coefficient of variation (K)	Ingestion dose implication
Concrete	K < 0	Radionuclide addition
Rock	K < 0	Radionuclide addition
Asphalt	K < 0	Radionuclide addition

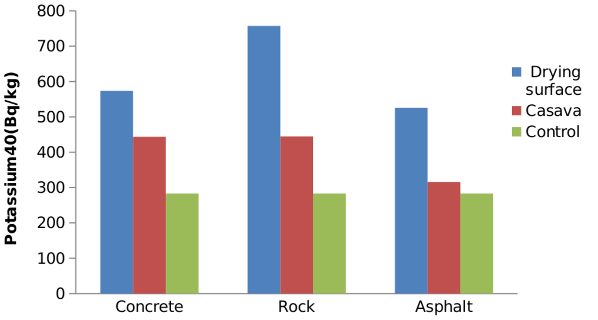

Figure 3. Activity concentration of ^{40}K in the samples investigated.

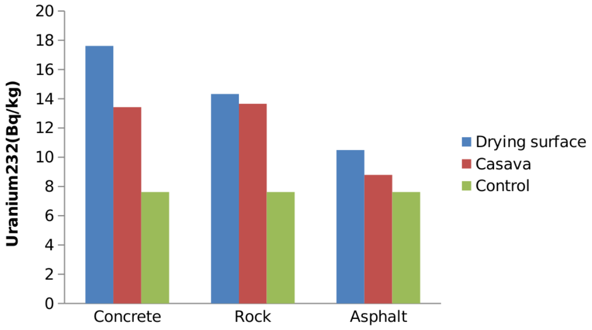

Figure 4. Activity concentration of ^{238}U in the samples investigated.

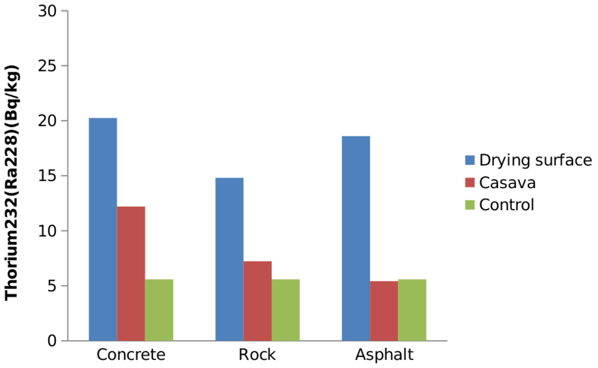

Figure 5. Activity concentration of ^{232}Th in the samples investigated.

Table 2 presents mean activity concentrations and annual effective dose due to ingestion of CF$_{exp}$ and CF$_{control}$., There is a significant difference between radionuclide concentrations in CF$_{exp}$ and CF$_{control}$. AED due to ingestion of CF$_{exp}$ is significantly high compared to AED due to ingestion of $CF_{control}$ with maximum (0.86 $mSv.y^{-1}$) and minimum (0.26 $mSv.y^{-1}$) values recorded in rock and fabric, respectively. Figures 3 to 5 compare radionuclide concentrations measured in DS, CF_{exp}, and $CF_{control}$.

Mean activity concentrations of ^{40}K (444.67±136.62 $Bq.kg^{-1}$) and ^{238}U (13.66 ± 9.17 $Bq.kg^{-1}$) is observed to be maximum in cassava flour dried on rock whereas ^{232}Th (12.19±4.22 $Bq.kg^{-1}$) showed maximum value in concrete as could be seen in Table 2. Values of potassium (^{40}K) is significantly increased when compared to ^{238}U and ^{232}Th, however, potassium is an essential element to the body which is homoestatically controlled in the human cells [8, 9]. The body content of potassium, ^{40}K is determined majorly by its physiological characteristics rather than by its intake [1, 10, 11]. It is reported that up to 30 to 60 percentage of internal radiation dose is associated to ^{238}Uand ^{232}Th of terrestrial origin [9, 10, 12]. Therefore radionuclide risk of dietary intake is of important consideration especially when food has to be sun-dried on any of rock and concrete surfaces.

The transfer coefficient of variation in the ingestion effective dose due to CF_{exp} showed that $K < 0$ which denotes the addition of dose to ingestion of cassava flour due to drying surfaces as could be seen on Table 3. This result is in line with the findings of [3] which recorded radionuclide addition due to food preparation techniques.

4. CONCLUSION

Radionuclide transfer variation of food drying surfaces has been investigated in Iregba-Oja, Ogbomoso, Soutwestern Nigeria. Results showed radionuclide addition in cassava flour dried on rock, concrete and asphalt surfaces. Annual effective dose is found to be maximum in Cassava flour dried on Rock and minimum in Cassava flour dried on Asphalt. On the standpoint of radiological health concern, this study revealed radionuclide exposure risk due to food drying surfaces. Nevertheless, obtained values of ingestion effective dose were less than the recommended $1 mSv \cdot y^{-1}$. However, further study similar to this study is recommended in regions with high background radiation.

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