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Determination of Natural Radioactivity of the *Hibiscus sabdariffa* Linn (Roselle) Used in Côte d'Ivoire (Ivory Coast)

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Abstract

In this work, ten medicinal and nutritional leaves samples of *Hibiscus sabdariffa* Linn imported from Mali and Burkina Faso in Côte d'Ivoire and sold on the market were collected. The analysis of these plants using High Purity Germanium detector (HPGE) gamma spectrometry showed the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K varied respectively in the range of (1.74 - 0.11) × 10^{-3} Bq/kg, (6.72 - 0.61) × 10^{-4} Bq/kg and (4.65 - 0.54) × 10^{-3} Bq/kg1 in the leaves of *H. sabdariffa*. The Average Annual Committed Effective Dose (AACED) values from leaves this plant varied from 251.492 × 10^{-6} to 68.133 × 10^{-6} mSv/y. These values found are below 0.30 mSv/y, the world average value for an individual. These results show that there is no radiological risk in consuming "bissap" leaves.

Keywords

Natural Radioactivity, HPGe Gamma Spectrometry, Activity Concentration, Medicinal and Nutritional Plant, Côte d'Ivoire

1. Introduction

Hibiscus sabdariffa Linn is to the family of the plant called *malvaceae* and it is usually called "bissap" in Burkina Faso, Senegal, Togo, Mali and Côte d'Ivoire [1]. The fruit of the plant is used in nutrition for making juice extract [2] in Africa. It is also well known traditionally that fruits including juice from *H. sabdariffa* are rich in vitamin C. These leaves are also used to treat diseases like kidneystone, liver damage, hypertension and leukemia [3]. The works of Mensah and Golomeke have allowed discovering that extracted juice of *H. sabdariffa* has antioxidant properties [4]. In Côte d'Ivoire, the most populations drink "bissap" juice, it is said to be rich in vitamin B6, calcium, potassium and other several elements that are yet to be isolated and characterized. In order to assess the radiological risks linked to the consumption of this plant and its derivatives by the population, we focused this study to determine the natural radioactivity levels from this plant and also evaluated the Average Annual Committed Effective Dose (AACED) due to the ingestion of radionuclides from *H. sabdariffa*.

2. Methodology

Sample preparation

Samples of leaves of *H. sabdariffa* imported to Côte d'Ivoire were collected from the local markets of Côte d'Ivoire (**Figure 1**), these different varieties of leaves shown in **Table 1**. Samples were dried in the range of 25˚C at ambient air and grinded into a fine powder with a particle size < 1 mm, 500 mg of each samples were put into standard Marinelli beaker and the activity concentrations for the natural radionuclide's in the measured samples were computed. Samples were placed in Marinelli beaker sealed off and kept for one month, the time to achieve radioactive secular equilibrium between ^{226}Ra and ^{222}Rn and daughter nuclei. In order to determine the background distribution due to naturally occurring radionuclide's in the environment around the detector, an empty Marinelli beaker container was counted in the same manner as the samples.

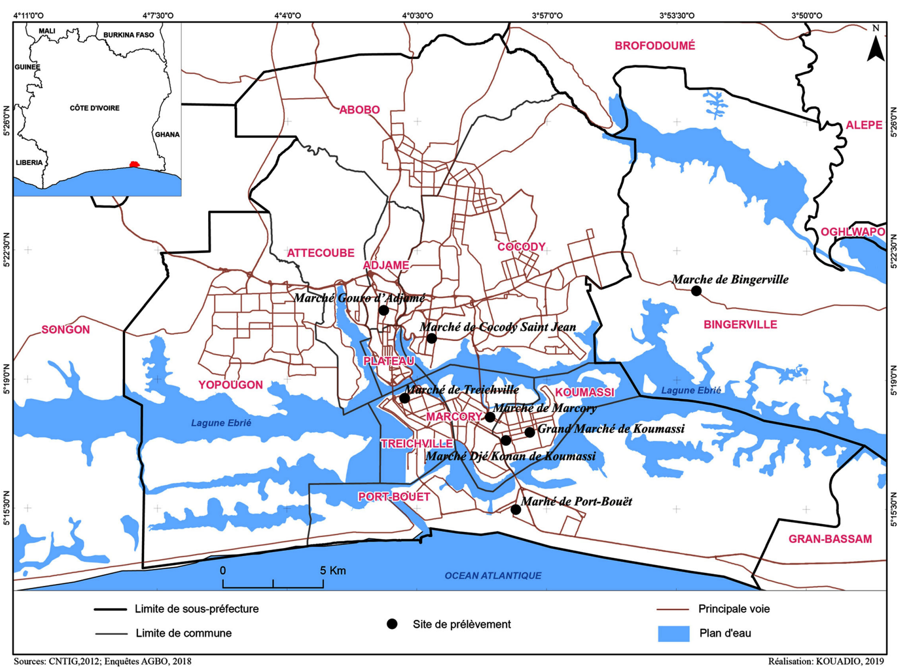

Figure 1. Map sampling shown sites sampling in black points.

Table 1. Herbal samples investigated in this study.

Samples codes	Traditional name in Côte d'Ivoire and parts used	Geographical of species Origin (Country)
S01	Bissap-leaves	Burkina Faso
S02	Bissap-leaves	Burkina Faso
S03	Bissap-leaves	Burkina Faso
S04	Bissap-leaves	Burkina Faso
S05	Bissap-leaves	Burkina Faso
S06	Bissap-leaves	Burkina Faso
S07	Bissap-leaves	Burkina Faso
S08	Bissap-leaves	Burkina Faso
S09	Bissap-leaves	Mali
S10	Bissap-leaves	Mali

Instrumentation and Calibration: Direct instrumental analysis without pre-treatment (non-destructive) was used for the measurement of gamma rays for the water samples using a High Purity Germanium detector (HPGE). The gamma spectrometry system consists of an n-type HPGE detector coupled to a computer based multi-channel analyzer (MCA). The relative efficiency of the detector is 25% with energy resolution of 1.8 keV at gamma-ray energy of 1332 keV of ^{60}Co. The identification of individual radionuclides was performed using their gamma-ray energies and the quantitative analysis of radionuclides was performed using gamma-ray spectrum analysis software, GENIE 2000. The detector is mounted in a cylindrical lead shield (100 mm) lined with copper, cadmium and plexiglass (3 mm each) to reduce the background radiation. The detector is cooled in liquid nitrogen at a temperature of −196˚C (77˚K). In order to determine the background distribution in the environment around the detector, ten empty Marinelli beakers were thoroughly cleaned and filled with distilled water and counted for 36,000 s in the same geometry as the samples. The background spectra were used to correct the net peak area of gamma rays of measured isotopes. The energy calibration of the spectrometry chain consists of establishing the relationship between channels and energy in the spectra. This was done using a set of gamma-emitting radionuclides (^{60}Co and ^{137}Cs). The main parameter necessary to quantify radionuclide activity is the full energy peak efficiency. The efficiency calibrations were carried out by counting standard radionuclides of known activities with well-defined energies in the energy range of 60 keV to −2000 keV. After carrying out these operations, we determined the specific activity of the radionuclides like uranium (^{226}Ra), thorium (^{232}Th) and potassium (^{40}K). The ^{226}Ra activity was measured by taking the mean activity of the two separate photo peaks of the daughter nuclides: ^{214}Pb at 351.9 keV and ^{214}Bi at 609.3 keV, the activity of ^{232}Th was determined using photo peaks of ^{228}Ac at 911.1 keV and the photopeak of ^{212}Pb at 238.6 keV and the activity of ^{40}K was directly determined using its gamma rays emitted at 1460.8 keV.

After measurement and subtraction of the background, the activity concentrations were calculated. The analytical expression used in the calculation of the activity concentrations in Bq/Kg for water samples is as shown in Equation (1)

$$A = \frac{Ne^{\lambda t_d}}{P \cdot T_c \cdot \gamma \cdot M} \quad (1)$$

where N is the net counts of the radionuclide in the samples, t_d is the delay time between sampling and counting, P is the gamma-ray emission probability (gamma-ray yield), γ is the absolute counting efficiency of the detector system, T_c is the sample counting time, m is the mass of the sample (kg), $\exp(\lambda t_d)$ is the decay correction factor for delay between time of sampling and counting and λ is the decay constant of the parent radionuclide.

At energy E, M is the dry-weight of samples (kg).

The average annual committed effective dose, E_{ave}, for ingestion of NORMS in the medicinal plants was calculated using the expression in Equation (2):

$$E_{ave} = I_p \cdot DCF_{ing} \cdot A_{Sp} \quad (2)$$

where DCF_{ing} is the dose conversion factor for ingestion, for each radionuclide (*i.e.*, 4.5×10^{-5} mSv/Bq, 2.3×10^{-4} mSv/Bq and 6.2×10^{-6} mSv/Bq for ^{238}U, ^{232}Th and ^{40}K respectively for an adult) [5], I_p is the consumption rate from intake of NORMS in medicinal plants and A_{Sp} is the activity concentration in the plant sample.

3. Results and Discussion

In the second column of **Table 2** of radionuclides, the highest ^{226}Ra activity is $(1.74) \times 10^{-3}$ Bq/Kg of *H. sabdariffa* leaves from samples sold at the "marché de Bingerville", the lowest concentration $(1.14) \times 10^{-4}$ Bq/Kg measured corresponds to leaves of this species at the Marcory site. An average concentration activity level of $(5.99 \pm 0.31) \times 10^{-5}$ Bq/Kg in ^{226}Ra is noted. Column three (3) of this table reports the activity concentrations in ^{232}Th, the maximum value is $(6.72) \times 10^{-4}$ Bq/Kg of *H. sabdariffa* . leaves at the Cocody site and the minimum is (6.08) $\times 10^{-5}$ Bq/Kg at the "marché de Marcory". The mean value is $(1.59) \times 10^{-4}$ Bq/Kg in ^{232}Th. The radionuclide ^{40}K has the most significant activity concentrations. The concentrations vary from $(4.65) \times 10^{-3}$ to $(5.44) \times 10^{-4}$ Bq/Kg respectively in Treichville site and "Grand-marché de Koumassi" with an average of $(1.95) \times 10^{-3}$ Bq/Kg

Figure 2 shows the histograms of the radionuclides. We note a significant concentration of ^{40}K, when detected at sites S01, S02, S03, S05, S07 and S010 in the ten (10) collection markets. We also note a lower concentration than ^{226}Ra in market S06. The regular absorption and accumulation of this radionuclide over a given period of time may be one of the reasons for its higher concentration.in plants. Chethan Rao's studies in 2012 showed that ^{40}K is an important radionuclide in plant metabolic activities [6]. The high concentration of potassium activity recorded may explain the use of the leaves of this plant for the treatment of hypertension since patients suffering from hypertension have a low concentration of potassium in their blood [7]. Among ^{226}Ra and ^{232}Th, ^{226}Ra is relatively higher, and it may be due to the fact that radium is chemically similar to calcium and calcium being one of the nutrients plants may absorb with radium, which will result in relatively more concentration of radium. The low ^{232}Th content of the plant can be explained by their insolubility and low specific activity. Ions of ^{232}Th bind weakly to soil particles that are not absorbed by the plant [8] (**Table 3**).

At the AACED level, the highest and lowest values are respectively at the Marcory site (251.492) nSv/y and the large at "marché Gouro d'Adjamé" (2.806) nSv/y. It is noted that these values are insignificant compared to the value of 0.3 mSv/y which can cause diseases to adults who regularly use *H. sabdariffa* leaves during the year. There is thus no radiological risk to consume this plant (**Table 4**).

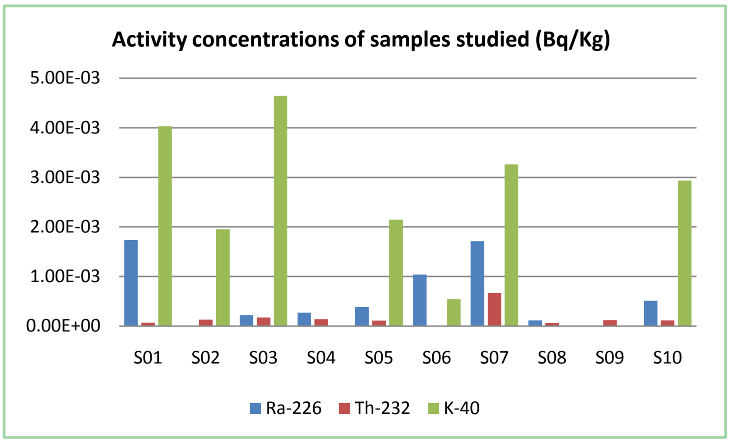

Figure 2. Activity concentrations of *H. sabdariffa* leaf.

Table 2. Activity concentrations of samples studied.

Site Codes	Radionuclides			Market
	Bq/Kg			
	Ra-226	Th-232	K-40	
S01	(1.74)E−03	(6.89)E−05	(4.04)−03	Marché de Bingerville
S02	ND	(1.28)E−04	(1.95)E−03	Marché GOURO d'Adjamé
S03	(2.23)E−04	(1.72)E−04	(4.65)E−03	Grand marché de Treichville
S04	(2.70)E−04	(1.40)E−04	ND	Grand marché de Port-Bouet
S05	(3.85)E−04	(1.12)E−04	(2.15)E−03	Marché Djè Konan de Koumassi
S06	(1.04)E−03	ND	(5.44)E−04	Grand-marché de Koumassi
S07	(1.71)E−03	(6.71)E−04	(3.26)E−03	Marché of Cocody
S08	(1.14)E−04	(6.08)E−05	ND	Marché de Marcory
S09	ND	(1.22)E−04	ND	Marché de Bingerville 2
S10	(5.11)E−04	(1.17)E−04	(2.94)E−03	Marché gouro Adjamé
Mean	(5.99)E−04	(1.59)E−04	(1.95)E−03	-

Table 3. The Average annual committed effective dose (AACED) of plant samples.

Site Codes	AACED (nSv/y)
S01	119.195
S02	15.08
S03	7.425
S04	15.37
S05	107.823
S06	38.408
S07	25,492
S08	19.114
S09	2.806
S10	68.133
Mean	33.589

Table 4. Comparison of the annual committed effective doses (Eave) due to the natural radionuclides in the medicinal plant with others countries.

Country	Range	Samples	Reference
Côte d'Ivoire	2.8 - 251.5 nSv/Y	*H.* sabdariffa_leaf	present work
Ghana	9000 - 14,000 nSv	Medicinal plants	[9]
	^{238}U: 0.7 - 9.7 nSv		
Serbia	^{232}Th: 0.3 - 2.8 nSv/y	Tea herb	[10]
	^{40}K: 1026 - 10,132.2 nSv/y		
Iraq	1380 - 1950 nSv/y	Medicinal plants0	[11]

The average annual committed effective dose due to ^{238}U, ^{232}Th and ^{40}K for this study was relatively low compared to that which was reported for medicinal plants from [9] and [10], almost similar than [11] for herbal tea.

4. Conclusion

In this work, the AACED results obtained show that there is no radiological fear to use this plant because they are far below the world value for an individual which is 0.30 mSv/y. The element potassium which has an important role in the treatment of hypertension and radium which is similar to calcium which strengthens the strength of skeletal bones, leads us to conclude that this plant has therapeutic and nutritional virtues.

Availability of Supporting Data

The datasets supporting the conclusions of this article are included within the article.

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Contributions

ADA, DL, and BO designed the experiment. ADA, BO, and DL carried out the experimental studies and collection, analysis, and interpretation of data. ADA wrote the manuscript. BO helped to draft and revised the manuscript. The authors read and approved the final manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Abbreviations

^{60}Co: Cobalt 60

^{137}Cs: Cesium 137

Bi: Bismuth

Ac: Actinium

Pb: Lead

^{232}Th: Thorium

^{238}U: Uranium

^{226}Ra: Radium

^{40}K: Potassium

NORMS: Naturally Occurring Radioactive Materials

H. sabdariffa: *Hisbiscus sabdariffa*

HPGE: High Purity Germanium detector

MCA: multi-channel analyzer

AACED: The average annual committed effective dose