2024 International Nuclear Atlantic Conference – INAC 2024
Escola de Guerra Naval, Rio de Janeiro, RJ, May 6 - 10, 2024

ISBN: 978-65-594-1256-3

Committed Effective Dose by Ingestion Food Grown in Pedra Branca State Park

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1. Introduction

Pedra Branca State Park (PEPB) is a Conservation Unit (UC) located in the municipality of Rio de Janeiro. Administered by the State Environment Institute (Inea), it covers an area of just over 12,000 hectares and encompasses 17 neighborhoods in the West Zone. The site offers various types of activities, including hiking along its many trails, horseback riding, various observation points and diving in its waterfalls and rivers [1]. Its geological formation is made up of a group of rocks with different lithologies, involving granitoids and gneisses [2]. The presence of these rocks presupposes higher concentrations of natural radionuclides [3]. As UCs conceptually do not allow agricultural practices, however, at the time of the park's creation, family farmers already living in the region, due to historical reasons, remained in that locality. In 2003, a group of farmers transitioned from conventional agriculture to organic farming following the creation of AGROPRATA (Rio da Prata Farmers' Association), an association of family farmers. Its members then began taking actions linked to environmental preservation [4]. Organic farming encompasses an agricultural system with sustainable techniques that do not allow the use of chemical inputs (fertilizers, pesticides) either for fertility enhancement or pest control [5]. The application of fertilizers can lead to increased doses of ionizing radiation in the population because fertilizers contain natural radionuclides from the uranium and thorium series, and studies show that the raw materials used in the production of phosphate fertilizers have high concentration of uranium [6;7]. Radionuclides can be incorporated through ingestion and within the human body, they become a source of internal exposure. Therefore, identifying and quantifying the radionuclides present in food is an important step in environmental monitoring and radiological protection. From this perspective the activity concentrations of ^{40}K. ^{226}Ra, ^{228}Ra and ^{228}Th were caculated in six samples of organic fruits and vegetables grown in PEPB, at sites belonging to the trails of Virgem Maria, Furnas, and Caboclos. Radionuclide analysis was conducted using gamma spectrometry with the use of a High Purity Germanium (HPGe) detector from Canberra, with a relative efficiency of 30%, in conjunction with the Genie 2000 software package. The activity concentrations of the radionuclides were calculated based on simulated detection efficiencies, and the effective dose from ingestion was estimated based on the annual food consumption from the most recent publication by the Brazilian Institute of Geography and Statistics (IBGE) [8] and the dose coefficient from the International Commission on Radiological Protection (ICRP) [9].

2. Methodology

Six foods grown at PEPB were purchased at an organic market. In the laboratory, the edible parts were selected, processed to make them homogeneous and without any dehumidification, i.e., in natura, they were stored in a 500 mL polypropylene container, the masses were measured and the containers were wrapped in PVC film for storage in a freezer at a temperature of - 18ºC. In the event of incidents, it is recommended to analyze fresh food, since the moisture content can reach 95%, which implies efficiencies similar to those of water, with deviations of less than 1% for all energies [10]. The Fig. 1 shows the figure shows two samples prepared for analysis.

Figure 1: Organic pineapple and khaki samples

The radiation spectra were obtained using a vertical HPGe detector. The energy calibration of the detection system was carried out with sources that have gamma emissions that coincide with or are close to the areas of interest in the spectrum. The emissions tracked in this study are from the nuclides ^{212}Pb, ^{214}Bi, ^{228}Ac and ^{40}K, with gamma emission at energies of 238,6 keV, 609 keV, 911 keV and 1460 keV respectively. The certified standards used were ^{137}Cs, ^{60}Co, ^{22}Na and ^{40}K, totaling 5 experimental points of energy 661.6 keV, 1173 keV 1332.5 keV, 1274 keV and 1460 keV. The Genie 2000 software was used to simulate the values of the efficiencies according to energy, as well as the values of the corrections due to self-attenuation. The radionuclide activity concentration was calculated according to Eq.1 [11].

$$AC = \frac{N_L}{\varepsilon.m.t.P_\gamma} \tag{1}$$

Where AC is the specific activity concentration of the radionuclide (Bq.kg^{-1}); N_L is the net area under the photopeak of interest; ε is the detection efficiency of the system at the energy of interest; Pγ is the transition probability of the measured gamma ray (γ); m is the mass of the sample (kg) and t is the counting time (s).

The effective dose was calculated based on the annual food consumption published by the IBGE (2020) and the dose coefficient from the ICRP. The Eq. 2 was used to calculation.

$$Def \ = \ Df \ x \ U \ x \ AC \tag{2}$$

Where Def corresponds to the annual effective dose (μSv.year^{-1}); Df is the dose coefficient published by ICRP 119 (Sv.Bq$^{-1;}$); U is the amount of food consumed in a year (kg); AC is the specific activity concentration of the radionuclide in the food (Bq.kg^{-1}).

3. Results and Discussion

The highest activity concentration of ^{40}K was obtained for the carrot 102 ± 15 $Bq.kg^{-1}$ and the highest effective dose value, 1,48 $\mu Sv.ano^{-1}$, was for avocado. The lowest activity concentration of ^{40}K and effective dose values were obtained for the pineapple, 26 ± 05 $Bq.kg^{-1}$ and 0,0636 $\mu Sv.ano^{-1,}$ respectively. The Table I bellow shows the obtained values for all samples analyzed.

Table I: Activity concentration of ^{40}K and effective dose.

Sample	Activity concentration ($Bq.kg^{-1}$)	Effective dose ($\mu Sv.year^{-1}$)
Avocado	74 ± 12	1,480
Cabbage	81 ± 13	0,221
Carrot	102 ± 15	0,207
Khaki	33 ± 06	0,659
Pineapple	26 ± 05	0,0636
Red onion	65 ± 10	0,293

The low concentration of potassium activity in pineapple and the low dose due to ingestion can be explained by factors such as the growing season, changes in soil condition due to rainfall can affect the way this element is absorbed. These same occurrences may explain the differences between the values obtained for the other samples. It must also take into account the length of time each food has been grown and the way it interacts with the soil. For example, carrots are tuberous roots that grow underground and accumulate nutrients in the root itself. The activity concentrations of ^{226}Ra, ^{228}Ra and ^{228}Th showed values below the minimum detectable activity. The extremely low concentration of activity for these radionuclides corroborates the absence of chemical fertilizers, since these have the potential to increase the concentration of these elements.

4. Conclusions

Concentrations of ^{40}K activity were found in all the samples, while the radionuclides ^{226}Ra, ^{228}Ra and ^{228}Th showed very low values, preventing the calculation of the committed effective dose. It is fundamental to note that the products marketed by AGROPRATA are certified, which means that they are inspected by specific entities. In this sense, the results of this research provide confirmation, through the analysis carried out, of the absence of the application of artificial fertilizers. The estimated values for doses due to ingestion are within the limits established by the ICRP. Thus, the consumption of these organic foods grown in the PEPB is safe from a radiological point of view.

Acknowledgements

The authors would like to thank INEA (Instituto Estadual do Ambiente) for authorizing the research (INEA authorization nº. 27/2021).

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