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Study of K-40, Ra-226, Ra-228 and Ra-224 activity concentrations in some seasoning and nuts obtained in Rio de Janeiro city, Brazil

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Abstract

This work presents an investigation of the activity concentration (AC) of naturally occurring radionuclides in 26 samples of seasoning and nuts utilized for Brazilian population. The samples were measured using gamma spectroscopy technique with a high-purity germanium detector. The analysis shows that K-40 AC was measured in all samples, and its AC ranges from 21.0 Bq/kg to 1288 Bq/kg. The highest K-40 AC was measured for *cheiro verde*, a Brazilian seasoning made of chives (*Allium schoenoprasum*) and parsley (*Petroselinum crispum*), while annatto, made with the fruit of *Bixa orelhana*, presented the lowest AC. Brazil nut (*Bertholletia excelsa*) presented the highest AC for Ra-226 and Ra-228 with 24 Bq/kg and 25.7 Bq/kg, respectively, and black pepper (*Piper nigrum*) presented the highest Ra-224 AC, with 33.9 Bq/kg. Behavior of radionuclides present in the seasoning samples and dose percentage due to ingestion was evaluated. The highest effective dose for members of the public due to idealized intake of 1 kg of seasoning was 23.5 µSv/y due to Brazil nut and the lowest effective dose was found for annatto: 0.13 µSv/y. The Syrian seasoning was the only sample that presented a measurable amount of Cs-137, (6.1 ± 1.1) Bq/kg for AC and 0.08µSv/y for effective dose.

Keywords: naturally occurring radioactive; seasoning; nuts; gamma spectrometry; effective dose.

Practical Application: To establish a database, in order to provide subsidies for the direct and indirect Public Administration (Federal, State, District and Municipal Organs and Authorities) to develop strategies for limiting dose control or to develop actions that prevent future consequences due to human factors, whether industrial or cultivated.

1 Introduction

Rio de Janeiro city is the second most populous city in Brazil with almost 7 million inhabitants, the local market offers a great diversity of foods, nuts and seasonings, national and imported. Seasonings are used worldwide, some have a common use as salt and sugar, besides others used locally as *cheiro verde*, a mixture of chives (*Allium schoenoprasum*) and parsley (*Petroselinum crispum*) used in Rio de Janeiro, Brazil.

According to the International Food Safety Authorities Network (2011), plants used as food commonly have K-40, Th-232 and U-238 and their progenies. In a variety of concentrations, naturally occurring radionuclides are present in every part of the earth and in the tissue of all living beings. Natural radionuclides can be found almost everywhere; in soil, water and atmosphere, subjecting human beings to a daily exposure. The K-40 is responsible for about 60% of the total annual effective dose due to ingestion (United Nations Scientific Committee on the Effects of Atomic Radiation, 2008). Therefore, it is a radionuclide of relevance both in the environmental point of view and radiological protection (Zhu, 2001).

Gamma-ray spectrometry using high-purity germanium detectors (HPGe) is a procedure widely used for determining the concentrations of natural and artificial radionuclides in environmental samples. As a nondestructive technique, this method possesses advantages in multi-element analysis, simplified sample preparation (i.e., does not require any chemical separation process), and applicability for precise quantitative determination of the radioactive content in a sample. The most accurate method to determine the activity concentration of radionuclides is to use an adequate standard source with similar geometrical dimensions, density, and chemical compositions to the sample under study (Díaz & Vargas, 2008).

This study aims to determine activities concentrations for the radionuclides K-40, Ra-226, Ra-228, Ra-224 in nuts and seasoning samples obtained in Rio de Janeiro City, Brazil, using a hyper pure germanium detector (HPGe) and the LabSOCS software for the calculation of self-absorption correction.

2 Materials and methods

2.1 Sample analyses

The nuts and seasoning samples analyzed were acquired in informal street commerce of Rio de Janeiro city, Brazil. The samples analyzed are listed in Table 1, along with their botanical names and the physical characteristic in which they were analyzed.

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Table 1. Samples, their physical characteristic and their botanical names.

Samples	Analyzed form	Botanical names
Annatto	Powder	*Bixa orelhana*
Basil	Dry	*Ocimum basilicum*
Bay laurel in powder	Powder	*Laurus nobilis*
Black pepper	Powder	*Piper nigrum*
Brazil nut	*In natura*	*Bertholletia excelsa*
Cacao pod	Powder	*Theobroma cacao*
Cashew nut	*In natura*	*Anacardium occidentale*
Cinnamon	Powder	*Cinnamomum verum*
Coriander in powder	Powder	*Coriandrum sativum*
Cumin	Powder	*Cuminum cymimum*
Dehydrated Garlic	Powder	*Allium sativum*
Ginger in powder	Powder	*Zingiber officinale*
Ginseng	Powder	*Panax araliaceae*
Malagueta pepper	Liquid	*Capsicum frutescens*
Oregano	Dry	*Origanum vulgare*
Parsley	Dry	*Petroselinum crispum*
Peanut	*In natura*	*Arachis hypogaea*
Rosemary	*In natura*	*Rosmarinus officinalis*
Spicy Paprika	Powder	*Capsicum annuum*
Turmeric	Powder	*Curcuma longa*
Walnut	*In natura*	*Juglans regia*

The samples were sealed in 200 mL polystyrene pots, to reach the secular radioactive equilibrium condition (at least 45 days). The non-homogeneous samples were processed and sieved in a 16 mesh screen for the appropriate use of the LabSOCS software to correct the efficiency curve due to the process of self-absorption of the photons in the sample. The Malagueta pepper was processed jointly to the oil in which it was preserved.

Were also analyzed Syrian seasoning also called *bahar* (powder), curry (powder), *chilli* (dry), *chimichurri* (dry) and *cheiro verde* (dry). *Chimuchurri* is a seasoning from South American origin, traditional of Argentina and Uruguay, is used for meats, curry is from Indian origin, Syrian seasoning (*bahar*) is from Syrian origin, *cheiro verde* is from Brazilian origin and *chilli* is a mixture of peppers. In Table 1, all samples are Brazilian origin.

2.2 Gamma spectrometer

Radiation spectra were acquired with a HPGe detector from Canberra, model GC3020, with minimum relative efficiency of 30%, and a shield of the same brand, model 747E. The counting time used for sample spectrum acquisition was 28800 seconds. Energy calibration was performed using three radioactive sources totaling five experimental points corresponding to the peaks of ^{137}Cs (0.6617 MeV), ^{60}Co (1.17 and 1.33 MeV) and ^{155}Eu (0.1218 and 0.3443 MeV).

The multichannel system used was a DSA 1000 (Digital Spectrum Analyzer), with 8192 channels, with energy range from 50 keV to 2 MeV, installed at the Laboratory of Environmental Analysis and Computational Simulation, from Nuclear Engineering Department of Rio de Janeiro Federal University (LAASC/PEN/COPPE/UFRJ).

To ensure the quality of the analysis a certified reference material of soil (089/ERA) tracked by National Institute of Standards and Technology (NIST) was used to generate the detection efficiency curve of the measurement system. The self-absorption correction of the photons in the samples due to different density values of the samples was performed by the LabSOCS software.

The activity concentration (AC) and respective uncertainties were determined according to the statistical uncertainties of the peak areas provided by the Genie2000 software. To measure the AC and minimum detectable activity (MDA), the latter based on Currie's derivation, were used Equations 1 and 2, respectively.

$$AC = \frac{N_L}{\varepsilon \cdot m(kg) \cdot t(s) \cdot P_\gamma} \tag{1}$$

$$MDA = \frac{2.71 + 4.66 \cdot \sigma}{P_\gamma \cdot t(s) \cdot m(kg) \cdot \varepsilon} \tag{2}$$

where: *AC* is the activity concentration ($Bq.kg^{-1}$); σ is the standard deviation of the count in the background spectrum; N_L is the net area under the photo peak; *m* is the mass of the sample (*kg*); ε is counting efficiency for a specific energy (γ); P_γ is the probability of emission of the measured gamma-ray (γ); *t* is counting time (*s*).

The Ra-224 AC was determined using the 238.6 keV energy of Pb-212 gamma radiation. The Ra-228 AC was measured using the 911.1 keV energy of Ac-228. The Ra-226 AC was determined using the 1120.3 keV energy of Bi-214. The K-40 AC was determined using its emission line 1460.8 keV.

2.3 Self-attenuation correction

The LabSOCS software makes mathematical calibrations in detection efficiency, this software includes a characterized detector and computational algorithms to make the self-absorption correction of the photons in the sample, using Monte Carlo code (Bronson, 2003). In the efficiency curve generation using the LabSOCS, the materials was simulated using the Geometry Composer from Canberra's Genie™ 2000 software package, the material of the pot was simulated for polystyrene with a density of 1.06 g/cc, chemical composition of H (7.74%) and C (92.26%). The reference material (soil, density of 1.41 g/cc) was simulated with a chemical composition based on the twelve most common chemical elements in the earth's crust, adapted by Schulze (1989): O (47%), Al (8.13%), Si (27.96%), K (2.59%), Fe (5%), Ca (3.63%), Na (2.83), Mg (2.09%), Ti (0.44%), H (0.14%), P (0.1%) and Mn (0.09%).The simulated geometry was a volume of 200 mL and the reference material was weighed to know exactly how much material was in the pot, then the efficiency curve was generated with the self-attenuation correction.

Then the gamma radiation spectra of the reference material were generated by the gamma spectrometry system installed in the LAASC. This procedure was also done in LGI (Laboratory of Gamma Spectrometry/IRD/CNEN) with the aim to verify the existence of differences between the certificate and the reference material, and also to validate the detection system. The LGI is tracked by LNMRI (Brazilian Laboratory of Metrology of Ionizing Radiations/IRD/CNEN), that is tracked by *Bureau*

International des Poids et Mesures (BIPM), and has reached a good performance in intercomparision exercises with the MAPEP (Radiological and Environmental Science Laboratory Mixed Analyze Performance Evaluation Program) conducted by the USDOE (United States Department of Energy). Based on the AC values found in the LAASC, by the LGI and presented in the certificate of the reference material, the correction factors were created. The results are shown in the Table 2.

A mean correction factor was set for each energy used for this specific geometry. The LabSOCS software makes the self-absorption corrections when it simulates each sample density, and the correction factors validate the software.

2.4 Dose assessment

The committed effective dose over one year was calculated using the relation shown in the Equation 3:

$$D_{ef} = U.C_d.D_f \quad (3)$$

where: D_{ef} is the annual effective dose ($Sv.y^{-1}$); U is the amount of food consumed in a year ($kg.y^{-1}$); C_d is the radionuclide specific concentration in the food ($Bq.kg^{-1}$); D_f is the dose coefficient according to ICRP 119.

There is no Brazilian statistical data for the amount of seasoning and nuts consumed in one year, maybe due to small consumption when it is compared to other categories of food, such as cereals, meats, beverages, etc. (Lopes et al., 2018). On the other hand, the seasonings consumption has regional and seasonal characteristics. So, the average consumption could be in disagreement the committed effective dose value for a local reality. Therefore, it was estimated the annual consumption in 1 kg for all seasonings and nuts evaluated in this work. This unit value allows a simple conversion to committed effective dose, when the local consumption is different from that proposed in the present work.

Only the average values of the AC measured in this study were used to calculate the committed effective dose. Table 3 shows the effective dose coefficients for annual committed effective dose due to the intake of K-40, Ra-226, Ra-228 and Ra-224 radionuclides.

3 Results and discussions

Nuts and seasoning samples were analyzed by gamma spectroscopy and the result is shown in Table 4. All samples presented values of AC above the minimum detectable activity (MDA) for K-40, because potassium is an essential element for the development of plants. One sample presented value above the MDA for Ra-226 and eight samples presented values above the MDA for Ra-228 and Ra-224, that is according to the results found in soils and plants in Brazil, which indicate a higher concentration of Th-232 than U-238 (Ribeiro, 2016).

The malagueta pepper was processed along with the oil in which it was preserved. The most consumed oil in Brazil is soybean oil which was also analyzed in the LAASC/UFRJ and the specific concentration for K-40 was below the minimum detectable activity (<MDA).

Table 2. Comparison of specific activities measured by LAASC and the LGI, and correction factors for use of LabSOCS software.

	K-40	Ra-226	Ra-228	Ra-224
LAASC	341 ± 13	36.5 ± 1.5	41.1 ± 2.1	34.3 ± 1.8
LGI	380 ± 25	39.6 ± 2.6	43.5 ± 3.0	41.5 ± 2.0
Certificate file	381 ± 19	77.4 ± 3.8	46.6 ± 2.3	45.7 ± 1.8
Correction Factor	0.90	0.93	0.94	0.83

Table 3. Dose coefficients (International Commission on Radiological Protection, 2012).

Radionuclides	Dose coefficient ($nSv.Bq^{-1}$)
K-40	6.2
Ra-226	280
Ra-228	690
Ra-224	65

Table 4. Activity concentration of seasonings and nuts in Bq/kg.

Samples	K-40	Ra-226	Ra-228	Ra-224
Annatto	21.0 ± 7.1	-	<3.2	-
Basil	983 ± 56	-	<11.7	<5.3
Bay laurel in powder	218 ± 18	-	-	<2.8
Black pepper	702 ± 33	-	22.7 ± 2.2	33.9 ± 3.2
Brazil nut	195 ± 11	24.0 ± 2.8	25.7 ± 1.7	13.3 ± 1.3
Cacao pod	866 ± 30	-	9.0 ± 1.5	<2.1
Cashew nut	191 ± 13	-	-	-
Cheiro verde	1288 ± 65	-	-	5.7 ± 3.0
Chilli	508 ± 27	-	-	<2.6
Chumichurri	627 ± 35	-	<8.6	5.3 ± 2.3
Cinnamon	129 ± 16	-	<6.2	2.9 ± 1.6
Coriander in powder	156 ± 13	-	5.5 ± 1.0	<2.0
Cumin	532 ± 27	-	7.5 ± 1.6	5.8 ± 0.9
Curry	442 ± 22	-	<0.41	<1.9
Dehydrated Garlic	346 ± 19	-	<3.6	-
Ginger in powder	379 ± 21	-	-	<2.0
Ginseng	366 ± 22	-	<5.2	<6.5
Malagueta pepper	55.2 ± 7.4	-	<3.1	-
Oregano	520 ± 48	-	<15.9	<7.2
Parsley	1177 ± 69	-	13.2 ± 4.2	6.3 ± 3.8
Peanut	205 ± 12	-	<2.9	<1.3
Rosemary	380 ± 28	<16.2	9.4 ± 2.3	<4.0
Spicy Paprika	453 ± 23	-	<4.5	-
Syrian seasoning (*bahar*)	377 ± 22	-	5.6 ± 1.4	7.7 ± 1.5
Turmeric	890 ± 30	-	-	2.1 ± 1.2
Walnut	136 ± 13	-	-	-

Cheiro verde (mix of parsley and chives) and parsley presented the highest specific activities of K-40. As the ratio of the mixture of parsley and chive in *cheiro verde* is not known, there is no way to estimate the AC of K-40 for the chive.

The presence of radium isotopes in Brazil nuts is known for a long time from pioneering works. Even some observations were made on the possibilities of people who consume a considerable amount of the nuts, during many years, building up elevated radium body burdens (Penna-Franca et al., 1968). The mean of AC for K-40 in Brazil nut found by Armelin (2016) was (225 ± 59) Bq/kg. For Ra-226 in Brazil nut, Armelin (2016) found (44 ± 14) Bq/kg, Martins et al. (2012) found (104 ± 14) Bq/kg and Parekh et al. (2008) found (23.0 ± 1.7) Bq/kg. For Ra-228 in Brazil nut, Armelin (2016) found (153 ± 51) Bq/kg, Martins et al. (2012) found (99 ± 16) Bq/kg and Parekh et al. (2008) found (24 ± 3) Bq/kg. For Ra-224 in Brazil nut, Martins et al. (2012) found (15.8 ± 3.2) Bq/kg and Parekh et al. (2008) found (9.8 ± 1) Bq/kg. For Brazil nuts, the AC of radionuclides are comparable, and in agreement with the results from different localities of Brazil (Penna-Franca et al., 1968; Parekh et al., 2008; Martins et al., 2012; Armelin, 2016).

In a study conducted by Desideri et al. (2010) on medicinal plants, the mean of AC found for K-40 in cinnamon plants (*Cinnamomum zeylanicus*) was 240 Bq/kg, a similar value to that found in present study. For pepper (*Capsicum frutescens*) was found 793 Bq/kg, a value greater than that found in present work for malagueta pepper (C*apsicum frutescens*) and for the paprika pepper (*Capsicum annuum*), plants of the same genus, but different species. For the Ra-226 the value found was 16.6 Bq/kg for cinnamon and 3.2 Bq/kg for pepper.

The Syrian seasoning (*bahar*) presented AC of (6.1±1.1) Bq/kg for the artificial radionuclide Cs-137. This radionuclide is a long-lived fission product, which may be readily metabolized by the human body. Currently, the Cs-137 contamination in food is due mainly to worldwide fallout from atmosphere, after nuclear testing and releases caused by the accidents from nuclear power plants. Yet, there is a possibility that the Syrian seasoning may have some ingredient from an Asian region that suffered major environmental impacts after Chernobyl accident in 1986. Grain trade is one of the local economies. Table 5 shows Cs-137 AC in some spices and teas analyzed. When the literature is used as parameter, Cs-137 AC measured in this work has value above the expected. Only Di Gregorio et al. (2004) found values of Cs-137 AC for five samples of tea above the value measured in this work.

For a behavior analysis, the samples were divided into three groups depending on the vegetal part used, namely: pericarp/seeds, leaves, stems/roots. Figure 1 shows how the behavior of each

Table 5. Cs-137 AC in some spices and teas.

Foodstuffs	AC (Bq/kg)	Country	Reference
Syrian seasoning (*bahar*)	6.1 ± 1.1	Brazil	Present work
Tea	1.1-10.3	Argentina	Di Gregorio et al. (2004)
Yerba Mate	1.1-1.7	Argentina	Di Gregorio et al. (2004)
Mate Tea	≤ 2.8	Brazil	Scheibel & Appoloni (2007)
Japanese Tea	1.32 ± 0.06	Japan	Weller et al. (2018)
Soy sauce	0.023	Japan	Abukawa et al. (1998)

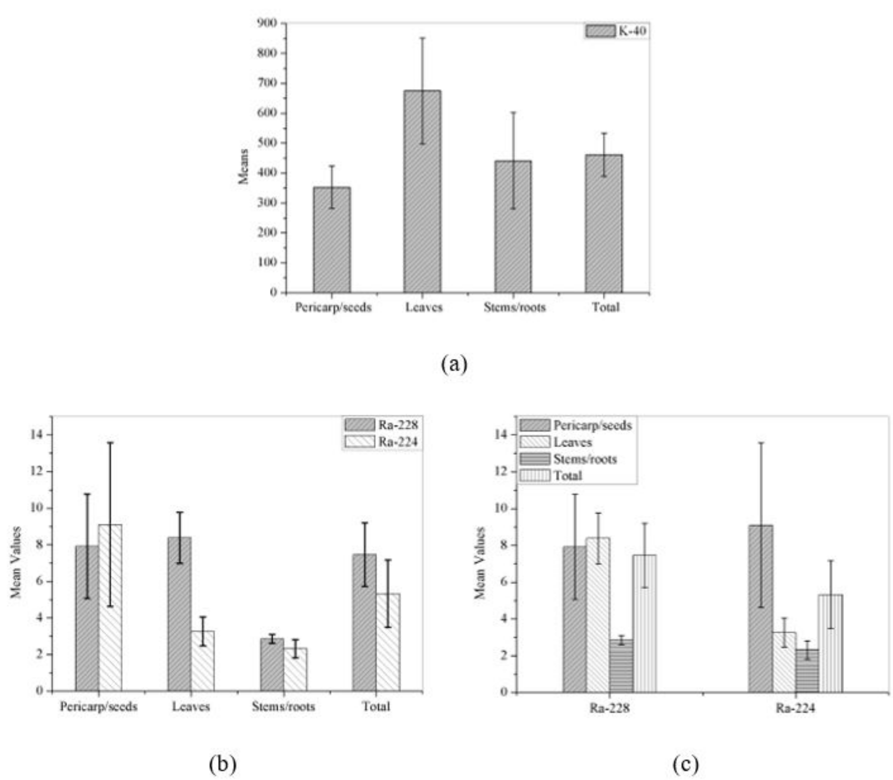

Figure 1. (a) K-40 behavior in the three categories of seasoning botanical (or vegetal) origin, plus the total mean; (b) Behavioral differences of Ra-224 and Ra-228 in each category; and (c) concentration difference of Ra-224 and Ra-228 in each category studied.

radionuclide analyzed in the samples. The ordinates axes correspond to the mean values of AC and the respective standard deviation of the mean, which configures the mean value confidence is within the range $\bar{x} \pm 1S$.

Because Ra-226 has been measurable in only one sample, this analysis does not count on the mentioned radionuclide.

Figure 1a shows that mean of K-40 AC appears slightly larger in the leaves. The potassium element is fundamental to photosynthesis, so it is acceptable to have a higher concentration of potassium in the leaves (Terry & Ulrich, 1973; Peoples & Koch, 1979; Longstreth & Nobel, 1980), and consequently, a higher concentration of K-40.

Figure 1b shows that Ra-228 AC in the pericarp/seeds and in the stems/roots is within the range of Ra-224 AC, a fact no observed in the leaves. The mean values of AC seem to suggest that, if there is a predominant vegetal structure for Ra-224, it would be in the pericarp/seed of the plants used as seasonings. Stems/roots seasoning samples had the lowest means of AC for both radios.

From Figure 1c, stems/roots showed means of AC for Ra-228 lower than other parts of the plant. It was not the same for Ra-224, whose mean values of AC for stems/roots are notoriously different than pericarp/seeds. Average ratio measured for Ra-224/Ra-228 was 1.1 for stems/roots, 0.36 for leaves and 0.79 for pericarp/seeds. It is known that the half-life of Ra-224 is 3.7 days, so the ratio of Ra-224 / Ra-228 in plants will depend directly of both mobility and decay in situ of Ra-228 (Bull et al., 2006).

Based on the specific activity conversion factors to annual effective dose due to ingestion to members of the public (adults) tabulated in Publication 119 of International Commission on Radiological Protection (2012), the effective doses of the nuts and seasonings were calculated considering the consumption of 1 kg and the results are shown in Table 6.

Cheiro verde sample (mix of parsley and chives) and parsley sample presented the highest AC of K-40 but not the highest effective dose, because the contribution of radium to the effective dose is greater than that of potassium. Table 7 shows the percentage of committed effective dose for each radionuclide studied. The radionuclide K-40 appears as the element that most contributes to the dose due to ingestion, followed by Ra-228. Although the latter appears in only 31% of the analyzed samples, its contribution is close to K-40, present in 100% of the samples. This is due to conversion factor of Ra-228, more than 111 times greater than the K-40 conversion factor, reflecting the radiobiological importance of this radionuclide.

Table 6. Effective dose for ingestion of seasoning and nuts for members of the public in μSv/y.

Samples	K-40	Ra-226	Ra-228	Ra-224	Total effective dose
Annatto	0.13	-	-	-	0.13
Basil	6.09	-	-	-	6.09
Bay Laurel in powder	1.35	-	-	-	1.35
Black pepper	4.35	-	15.66	2.20	22.22
Brazil Nut	1.21	6.72	17.73	0.86	26.53
Cacao pod	5.37	-	6.21	-	11.58
Cashew Nut	1.18	-	-	-	1.18
Cheiro verde	7.99	-	-	0.37	8.36
Chilli	3.15	-	-	-	3.15
Chumichurri	3.89	-	-	0.34	4.23
Cinnamon	0.80	-	-	0.19	0.99
Coriander in powder	0.97	-	3.80	-	4.76
Cumin	3.30	-	5.18	0.38	8.85
Curry	2.74	-	-	-	2.74
Dehydrated Garlic	2.15	-	-	-	2.15
Ginger in powder	2.35	-	-	-	2.35
Ginseng	2.27	-	-	-	2.27
Malagueta pepper	0.34	-	-	-	0.34
Oregano	3.22	-	-	-	3.22
Parsley	7.30	-	9.11	0.41	16.81
Peanut	1.27	-	-	-	5.81
Rosemary	2.36	-	6.49	-	8.84
Spicy Paprika	2.81	-	-	-	2.81
Syrian seasoning (*bahar*)	2.34	-	3.86	0.50	6.70
Turmeric	5.52	-	-	0.14	5.65
Walnut	0.84	-	-	-	0.84
Total	**75.58**	**6.72**	**68.04**	**5.39**	**155.73**

Table 7. Percentage of effective dose by ingestion.

Radionuclides	Percentage
K-40	48.53%
Ra-228	43.69%
Ra-226	4.32%
Ra-224	3.46%

The dose due to ingestion of Ra-226 is discreet in this work because only the Brazil nut presented measurable AC for this radionuclide. Finally, Ra-224, although measurable in almost 35% of the samples, has a small conversion factor when compared to Ra-226 and Ra-228, mainly due to its low half-life, about 3.7 days.

According to United Nations Scientific Committee on the Effects of Atomic Radiation (2008) the global annual effective dose due to natural radiation sources is 2.4 mSv, of this total 0.29 mSv is due to ingestion. The sample resulting in highest effective dose analyzed in this study was Brazil nut, whose intake of 11 kg is enough to reach the annual effective dose due to ingestion. Still according to United Nations Scientific Committee on the Effects of Atomic Radiation (2008), the effective dose due to atmospheric nuclear testing and to Chernobyl accident is 7μSv/y and the effective dose due to Cs-137 found in Syrian seasoning is 0.08 μSv/y.

The concentrations of naturally occurring radionuclides in foods vary widely because of differences in the background levels in soil, the climate and the agricultural conditions that prevail. There are also differences in the types of local food, such as vegetables, fruits and fish. It is therefore difficult to select reference values from the wide ranges of concentrations reported (United Nations Scientific Committee on the Effects of Atomic Radiation, 2008). Therefore, it is important to analyze the effective dose levels in the foods consumed, to create a local database and to use this data to discuss the biological effects at low dose rates, to characterize a region by the effective dose level, since this varies from region to region, and to measure the increase in dose levels due to human action, from nuclear testing to the application of fertilizers in agriculture.

4 Conclusions

K-40 AC was measured in all samples, Ra-226 AC was measured in one sample only, namely Brazil nuts. Ra-226, Ra-228, Ra-224 AC was calculated assuming the secular equilibrium between this samples. Cs-137 AC was observed only in Syrian seasoning (*bahar*).

The sample with the lowest derived limit was Brazil nut, with consumption of 11 kg/y. The radionuclide that most contributes to committed effective dose is K-40, with almost 49% of the total. But the potassium is uniformly distributed in the body, and its concentration is mostly under homeostatic control, and do not represent a risk to human health. Different from radium isotopes studied here, that has a long half-live, and their behavior is similar to calcium element. When ingested, radio is allocated in the individual's bone structure, increasing the internal exposure, and consequently the committed effective dose.

This study contributes to establish baseline information, because it makes available data on both specific concentration of a variety of seasoning and effective dose.

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