Determination of Natural Radioactivity Concentration in Consumed Nuts and Seeds and Their Implications in Human Body

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Abstract The concentrations of natural radioactivity of ^{226}Ra , ^{232}Th and ^{40}K were measured in nuts and seeds samples consumed in Saudi Arabia. A high-resolution HPGe detector was used for the natural radionuclides measurement. The results indicate that ^{40}K was detected in all samples, whereas ^{226}Ra and ^{232}Th were found only in Brazil nut sample. The average concentration of ^{40}K in the investigated samples was $363.82 \text{ Bq kg}^{-1}$. The estimated annual effective dose due to ingestion of nuts and seeds was 0.068 mSv y^{-1} lower than the annual dose limit of 1 mSv y^{-1} for public exposure. This indicates that no risk is expected by the intake of the studied nuts and seeds samples. The radionuclide concentrations were compared with those reported from different countries.

Keywords Nuts, Gamma-ray Spectrometry, Ingestion Dose

outcomes. For examples, previous studies have discussed the following: the mineral contents in nuts were determined to assess the edibility of nuts [4], the nutritional composition of Brazil nuts were examined as well, the relevance of possible contaminants and metal toxicants observed in nuts for human health [5], and finally, the activity concentrations of the radionuclides ^{137}Cs , ^{40}K , ^{226}Ra and ^{228}Ra in nuts were measured and estimated annual effective radioactive dose as 27% of the annual dose limit of 1 mSv y^{-1} for public exposure [6].

This current study attempts to determine the level of radioactivity in different types of nuts and seeds which are consumed by people living in Saudi Arabia and to estimate their effective dose to the human body. The obtained data may provide both baseline levels of natural radioactivity, and background information for future research on foodstuff for radiological protection of the human.

1. Introduction

The naturally occurring radionuclides, especially ^{40}K and the radionuclides of ^{238}U and ^{232}Th series, are the major sources of natural radiation exposure to human being. In fact, about 87% of the radiation dose received by humans is caused by natural radiation sources [1]. Foodstuffs contain both natural and man-made radionuclides, which after ingestion lead to an effective internal dose. It has been estimated that at least one-eighth of the mean annual effective dose of natural sources is occurred by the consumption of foodstuff [2]. For contamination assessment of foodstuff consumed by humans, it is crucial to identify the baseline value, or the level of radiation dose of natural and synthetic radionuclides. Nuts and seeds are popular products consumed all over the world since they are rich in nutrients such as essential minerals, vitamins, proteins, carbohydrates, and unsaturated fatty acids [3]. Hence, and due to their nutritional composition, extensive research has been conducted on nuts and their

2. Materials and Methods

2.1. Preparation of Samples

Forty-four samples of nuts and seeds, including (sunflower seeds, seeds of zucchini, pumpkin seeds, Pecan, walnuts, hazelnut, cashew, pine, almonds, peanuts, pistachio, chickpeas and nuts) were collected from a retail markets in Jeddah city. These samples were selected based on popularity to the public in Saudi Arabia. The sample types and their origins are listed in Table 1. The samples were prepared according to the recommendations given by IAEA [7]. They were oven dried at 80°C for approximately 14h, pulverized into a fine powder, sieved with a 2 mm mesh, homogenized and then 200g of each sample stored in Marinelli beakers. These beakers were filled, weighed, sealed, and aged for one month to achieve an approximate secular equilibrium between ^{226}Ra and its daughters (^{214}Pb and ^{214}Bi) before performing the radioisotope analyses.

Table 1. Origin and brands of the nuts and seeds samples

Name of the sample	Sample code	Sample brand	Sample origin	Sample code	Sample brand	Sample origin
Sunflower seeds	S1	Sunflower seeds	Egypt	S13	Almonds	Brazil
Seeds of zucchini	S2	Seeds of zucchini	Egypt	S14	Peanuts	Turkey
Pumpkin Seeds	S3	White Pumpkin Seeds	Egypt	S15	Peanuts	Sudan
Pecan	S4	Brown Pumpkin Seeds	Egypt	S16	Pistachio	Iran
Walnuts	S5	Pumpkin Seeds	Turkey	S17	Pistachio	Turkey
Hazelnut	S6	Pecan	U.S.A	S18	Chickpeas	Turkey
Cashew	S7	Walnuts	U.S.A	S19	Chickpeas	Saudi
Pine	S8	Hazelnut	U.S.A	S20	nuts1	China
Almonds	S9	Cashew	India	S21	nuts2	China
Peanuts	S10	Pine	Pakistan	S22	nuts3	China
Pistachio	S11	Almonds	Syria	S23	nuts	Sri lanka
Chickpeas	S12	Almonds	Saudi	S24	nuts	India

2.2. Gamma-ray Measurements

The gamma-rays emitted by the food samples were measured by using High Purity Germanium (HPGe) detector gamma-ray spectrometry system of 1.85 keV resolution and 25 % relative efficiency at 1332 keV ^{60}Co gamma-ray, coupled to a computer based MCA. Spectrum analyzer carried out by using Gamma Vision V6.0 software. Counting of samples and background was done for 36000s duration. The activity concentration for ^{226}Ra was determined by using the average obtained by gamma peaks at 351.87 keV (^{214}Pb), 609.31 keV (^{214}Bi) and 1764.49 keV (^{214}Bi), while ^{232}Th from gamma peaks 238.63 keV (^{212}Pb) and 911.21 keV (^{228}Ac) and ^{40}K from 1460 keV gamma peak.

The activity concentrations of each radionuclide in the sample were calculated using the following equation [8,9]:

$$A = C / (m \epsilon P_{\gamma}) \quad (1)$$

A is the specific activity of each radionuclide in the foodstuff (Bq.kg^{-1}). C is the net count rate of nuclide (count s^{-1}). ϵ is the detector efficiency of the specific γ -ray. P_{γ} the absolute transition probability of the specific γ -ray. m is the mass of the sample (kg).

2.3. Estimation of annual effective dose.

Annual radionuclide intakes and effective doses due to ingestion of Nuts were calculated using the equation [1, 9]:

$$E_d = A_c A_i C_f \quad (2)$$

E_d the effective dose (mSv.y^{-1}), A_c is the activity (Bq.kg^{-1}). A_i is the consumption rate per year. It is assumed that the average person consumes 50g of nuts per day or about 1.83 kg/year [10]. The dose conversion factors C_f for adults as reported by [11,12], were (2.8×10^{-7} , 2.3×10^{-7} , 6.2×10^{-9}

Sv Bq^{-1}) for ^{226}Ra , ^{232}Th and ^{40}K , respectively.

3. Results and Discussion

Table 2 shows the natural activity concentration and annual dose of the Twenty-four nuts and seeds samples consumed in Saudi Arabia. The results indicate that ^{40}K was detected in all samples, whereas ^{226}Ra and ^{232}Th were found only in Brazil nut sample (S13) as 63.02Bq.kg^{-1} and 50.53Bq.kg^{-1} , respectively. These values are higher than the world median limit 45 for ^{226}Ra and 32Bq.kg^{-1} for ^{232}Th [13]; However, they are in agreement with the high levels of radium in Brazil nuts, 56 and 104.8Bq.kg^{-1} , reported by [14, 15]. A high value for the activity of ^{226}Ra is probably due to the fact that nut trees in Brazil have a large capacity to absorb radioisotopes from the soil [14]. It can be seen from Table 2 that the Chinese nuts samples (S20, S21, S22) represent the lowest values of ^{40}K . On the contrary, the highest concentrations of ^{40}K are found in nuts of Sudan (S15), Turkey (S17, S18) and Saudi (S19), which are higher than the global wide average concentration 412Bq.kg^{-1} recommended by UNSCEAR, 2008. The highest activity concentrations obtained for ^{40}K can be expected because of the potassium, which is an essential microelement for living organisms, and it is existed in all samples from the environment [1]. For all samples, the maximum detectable specific activity values for ^{40}K were $581.89 \pm 6.32 \text{Bq.kg}^{-1}$ in sample (S19) and the minimum detectable activities $25.92 \pm 2.12 \text{Bq.kg}^{-1}$ in sample (S22). The average value of ^{40}K for all samples is 363.82Bq.kg^{-1} , which is lower than the recommended average value 412Bq.kg^{-1} for ^{40}K [13]. The results in Table2 show that the variation in ^{40}K concentrations was found within the same kind of nuts and seeds samples. This variation observed can be possibly caused by two factors: the chemical and physical properties of the various farms of the producing areas and the use of many phosphate fertilizers by the farmers to get the optimum product in a short term [16].

As shown in Table 2, the calculated annual effective doses of natural radioactivity in nuts and seeds samples were varied from 0.003 to 0.541 mSv y⁻¹ with an average value 0.068 mSv y⁻¹. The current annual effective doses are lower than the recommended limit of 1 mSv y⁻¹ [11]. Moreover, for adults, the annual dose of 40K in tissues of the body is 165 µSv y⁻¹ and the total 40K effective dose from ingestion is 170 µSv [1]. Therefore, no potential harm is foreseen by the consumption of nuts and seeds in Saudi Arabia.

Table 3 summarises Comparison of nuts measurement results of activity concentrations of 226Ra, 232Th, and 40K with those obtained from other counties. Also, in the same table, the present concentrations of ⁴⁰K found in the analyzed nuts and seeds were comparable with results reported from other countries. In general, the variation of radioactivity concentrations in the foodstuff may differ from one country to another, depending on their climate and geological properties of the soil [1].

4. Conclusions

The study estimated the specific activity of radionuclides 226Ra, 232Th, and 40K using gamma-ray spectroscopy on samples of nuts and seeds consumed in Saudi Arabia. ²²⁶Ra, ²³²Th were detected only in Brazilian Nuts which are shown in Figure1.

Figure.1. Brazil nuts are one of the most radioactive foods

In all samples, ⁴⁰K activities were lower than the global wide average, except for samples (S15, S17, S19, S20), in which the specific activity of ⁴⁰K exceeded the permitted value as shown in Figure 2. The average value of annual effective doses was found to be within the limit of 1 mSv recommended by the International Commission on Radiological Protection in 1996 as shown in Figure 3 . Therefore, according to the obtained results, there is no health risk involved in the consumption of nuts and seeds. However, we anticipate that the consumption of Brazil nut, if the daily intake is higher than 50g, may cause some complications to the health .

Table 2. Activity concentration (Bq kg⁻¹) of 226Ra, 232Th, and 40K in Nuts and Seeds samples

Sample code no.	Name of Nuts and Seeds	Activity concentration (Bq kg ⁻¹)			Annual effective dose (mSv y ⁻¹)
		226Ra	232Th	40K	
S1	Sunflower seed	----	----	236.98±5.82	0.029
S2	Gourd seed	----	----	481.75± 6.97	0.059
S3	Melon Seed	----	----	374.20±6.56	0.046
S4	Brown Pumpkin Seed	----	----	429.83±6.14	0.053
S5	Pumpkin Seed	----	----	274.07	0.034
S6	Pecan	----	----	244.39	0.030
S7	Walnut	----	----	296.32	0.037
S8	Hazelnut	----	----	411.28	0.051
S9	Cashew	----	----	429.82	0.053
S10	Pine	----	----	426.12	0.053
S11	Almonds	----	----	396.45	0.049
S12	Almonds	----	----	444.67	0.055
S13	Almonds	63.02	50.53	389.64	0.541
S14	Peanuts	----	----	400.16	0.049
S15	Peanuts	----	----	522.55	0.065
S16	Pistachio	----	----	429.83	0.053
S17	Pistachio	----	----	544.80	0.067
S18	Chickpeas	----	----	552.22	0.068
S19	Chickpeas	----	----	581.89±6.32	0.072
S20	China nuts1	----	----	27.07	0.003
S21	China nuts2	----	----	48.58	0.006
S22	China Nuts3	----	----	25.92±2.12	0.070
S23	Sirlanka Nuts	----	----	351.95	0.044
S24	Indian nuts	----	----	411.29	0.051
Range				25.92-581.89	0.003-0.541
Average				363.82	0.068

Figure.2. Activity concentrations of 40K for the rice and the Nuts and Seeds samples, Saudi Arabia

Figure.3 Annual radio -nuclides effective dose of the investigated nuts and seeds samples consumed in Saudi Arabia

Table 3. Comparison of nuts measurement results of activity concentrations of ^{226}Ra , ^{232}Th , and ^{40}K with those obtained from other counties.

Name of Nuts and Seeds	Activity concentration (Bq kg^{-1})			Reference
	^{226}Ra	^{232}Th	^{40}K	
Melon seed	0.08	0.174	215.65	[17]
	—	—	374.20	Present work
Sunflower seed	—	—	408.17	[17]
	—	—	236.98	Present work
Walnut	—	0.128	278.35	[17]
	—	—	296.32	Present work
Brazilian Nuts	56	—	306.31	[14]
	104	—	—	[13]
	60.02	50.53	389.64	Present work
Pistachio	0.13	0.3	408.17	[17]
	—	—	429.83	Present work
Cashew Nut	—	—	285.18	[17]
	—	—	429.82	Present work
Nuts	—	0.151	282.61	[17]
	—	—	351.95	Present work

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