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EXCESS LIFETIME AND HEREDITARY CANCER RISK DUE TO NATURAL RADIOACTIVITY IN SOME TYPES OF SPICES SAMPLES IN IRAQI MARKETS

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Abstract

In present study, natural radioactivity of 238U, 232Th, and 40K in selected samples of spices existing in the Iraqi market were estimated using gamma-ray spectroscopy with NaI(Tl). Also, it was determined some radiological risks parameters such as, radium equivalent (Raeq) and internal hazard index (Hin) in the present study. The results show that, the average value of specific activity for of 238U, 232Th, and 40K were 10.63±1.15 Bq.kg-1, 9.82± 0.67 Bq.kg-1 and 243.28±5.65 Bq.kg-1 respectively. While, the average value of Raeq and Hin were 43.35 Bq.kg-1and 0.144, respectively. The average value of AED total in the samples under study were 0.011 mSv/y which it is lower than acceptable limit according to UNSCEAR (2008). The results of natural radionuclides and radiological risks parameters in most the spices samples were far below the accepted of the world limit. Therefore, it can be concluded that spices samples may be used for eating without any health effects.

Keywords: 238U, 232Th, 40K, Gamma-Ray Spectroscopy with NaI(Tl), Spice Samples, and Iraqi Markets.

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Introduction

Food contains natural and manmade radionuclides that contribute to an effective internal dose after intake.It has been calculated that food consumption accounts for at least one eighth of the mean yearly dosage due to natural sources [1].Average radiation exposures to various organs of the body are also essential concerns for long-term health.Three long-lived naturally occurring radionuclides found in the earth's crust are ^{232}Th, ^{238}U, and ^{40}K.They enter the human body mostly through the food chain and inhalation of suspended dust in the air. These metals accumulate in vital organs and produce radiation doses when inhaled or swallowed. Thorium, uranium, and potassium accumulate in human lungs, liver, and skeleton tissues, respectively. Large amounts of these radionuclides deposited in specific organs cause radiation damage, metabolic alterations, and morphological changes. This leads to weakened immune systems, the development of numerous diseases/cancers, and a rise in mortality rates. The potential harmfulness is based on their long half-lives and chemical behavior (^{232}Th: 1.4×10^{10} yr, ^{238}U: 4.47×10^{9} yr and ^{40}K: 1.28×10^{9} yr). ^{232}Th is mainly radiotoxic, ^{238}U is both radiotoxic as well as chemically toxic whereas ^{40}K is radiotoxic as well as nutritionally important element [2]. Because of the health concerns connected with indoor radiation exposure, numerous governmental and international organizations, including the International Commission on Radiological Protection (ICRP), the World Health Organization (WHO), and others, have taken considerable measures to reduce such exposures [3]. Spices and herbs are prized for their various flavors, colors, and scents, and are among the world's most versa. The main objective of this study is therefore to determine the activity concentration levels of ^{226}U, ^{232}Th, and ^{40}K in some spices, consumed by the population of Iraq, to ensure that food safety is not compromised and that the external and internal effective doses are within the specified safety limits. The purpose of this work is to measure the natural radioactivity of ^{238}U, ^{232}Th, ^{40}K in spice samples collected from Iraqi markets using NaI(Tl) gamma ray spectroscopy.

1. Methodology of Research

1.1. Collections of Samples

This study includes 19 types of spice samples, these samples were collected from different sites of Iraqi markets. The Spice samples were labeled with special codes. The information complete about samples was written, as shown in Table 1.

TABLE 1. Spice samples in the present study

o.	Sample code	Traditional name	Country of origin
	A1	Curry	India
	A2	Kofta spice	Iraq
	A3	Fenugreek	Syria
	A4	Mint	Iraq
	A5	Soda	Iraq
	A6	Sumac	Iraq
	A7	Cumin	India
	A8	Thyme	Syria
	A9	Biryani spice	Iraq
0	A10	Kabsa spice	Saudi Arabia
1	A11	Chicken Maggi spice	Iraq

2	A12	Banging	Iraq
3	A13	Paprika	India
4	A14	Chicken Mandi spice	Yemen
5	A15	Meat Mandi spice	Yemen
6	A16	Nutmeg	India
7	A17	Meat Maggi spice	Iraq
8	A18	Rocca	Iraq
9	A19	Lemon salt	Iraq

2.2.Preparations of Samples

Spice samples were collected from several Iraqi markets. Each sample was preserved in a plastic bag and labeled with the collecting location and date. To eliminate moisture, the samples were roasted in an oven at 100°C for about 2 hours, then crushed many times with a manual mill and sieved to obtain a homogeneous powder. These samples weighed 750 grams each. The samples were then packed into Marinelli beakers (1 L) with a consistent volume to achieve geometric homogeneity around the detector. The samples were then sealed in Marinelli beakers and held for roughly a month before counting to achieve secular equilibrium between ^{226}Ra and ^{222}Rn [4].

2.3.Measurement System

In this study, Our measurements of specific activity for ^{238}U, ^{232}Th, ^{40}K were using a gamma-ray spectrometer system (ORTEC company) that contains three main part; NaI(Tl) detector with "3×3" dimension, MCA with 4096 channel, and software program (MAESTRO-32) into the PC. An energy calibration and efficiency in NaI(Tl) detector were determined using standard gamma-ray sources from USNRC and State License Expert Quantities, "Gamma Source Set", Model RSS–8. Also, it is found that the energy resolution of NaI(Tl) detector was 7.9% for 137Cs standard source (661.66 keV). The specific activity of three radionuclides was detected according to secular equilibrium property. They included: the radionuclide that belongs to the Uranium-238 series was (^{214}Bi, 1764.5 KeV); the radionuclide that belongs to the Uranium-232 series was (^{208}TI, 2614 KeV), and the radionuclide that belongs to the single series (^{40}K, 1460 Ke).We used an ORTEC gamma-ray spectrometer system, which consists of three main components: a NaI(Tl) detector with a "3" dimension, an MCA with 4096 channels, and a software application (MAESTRO-32) that runs on a PC. Standard gamma-ray sources from USNRC and State License Expert Quantities, "Gamma Source Set," Model RSS–8, were used to estimate energy calibration and efficiency in the NaI(Tl) detector. The energy resolution of the NaI(Tl) detector was also determined to be 7.9% for the 137Cs standard source (661.66 keV).The secular equilibrium feature was used to detect the particular activity of three radionuclides. The radioactivity belonging to the Uranium-238 series was (^{214}Bi, 1764.5 KeV); the radionuclide belonging to the Uranium-232 series was (^{208}TI, 2614 KeV); and the radionuclide belonging to the single series was (^{214}Bi, 1764.5 KeV) (^{40}K, 1460 KeV).

2.4.Theoretical equations

2.4.1. Specific activity (A)

The specific activity (A) was estimated using to the equation [5]:

$$A\left(\frac{Bq}{kg}\right)=\frac{N-B}{t\times\varepsilon\times I\gamma\times m}\ \dots\dots\dots(1)$$

where, N and B are the areas under photopeak for samples and background, respectively. t is counting time (18000 sec), ε is the efficiency of the detector, I_γ is the probability of gamma emission, and m is the mass of sample.

2.4.2. Radium Equivalent Activity (Ra_{eq})

The radioactive hazard associated with samples containing radionuclides such as 238U,232Th, and 40K can be assessed using a popular radiological metric known as radium equivalent activity, which has the following mathematical expression[6, 7] **:**

$$Ra_{eq}\left(\frac{Bq}{kg}\right)=A_U+1.43\ A_{Th}+0.077A_K\ \dots\dots\dots(2)$$

2.4.3. Internal Hazard Index(H_{in})

The internal hazard index controls internal exposure to 222Rn and its radioactive offspring. The following equation [8] can be used to compute it:

$$H_{in}=\frac{A_U}{185}+\frac{A_{Th}}{259}+\frac{A_K}{4810}\ \dots\dots\dots(3)$$

The specific activity of 238U,232Th ,and 40K are AU,ATh,and Ak, respectively.

2.4.4. annual effective dose (AED)

The annual consumption rate (CR), specific activity (A), and dose conversion factor (CFi) of foods containing natural radionuclides were calculated using equation [9]:

$$AED\left(\frac{msv}{y}\right)=I\times\sum_{i}^{3}\ A_i\times CF_i\ \dots\dots\dots(4)$$

The values of dose conversion factor for ^{238}U, ^{232}Th, and ^{40}K were 2.80E-07, 2.30E-07, and 6.20E-09, respectively that taken from ICRP publication [10].

2.4.5. threshold consumption rate (DI_{thresh})

The threshold consumption rate (DI_{thresh}) is defined as the amount of drinking water and food ingredients consumed by a human that results in an annual effective dose (Eave.; 0.320) that is acceptable [11]. The current study's DI_{thresh} in food samples was calculated using the equation [12]:

$$DI_{thresh}\left(\frac{Kg}{y}\right)=\frac{E_{ave}}{\sum_i^3\ A_i\times CF_i}\ \dots\dots\dots(5)$$

2.4.6. Excess lifetime cancer risk (ELCR)

The excess life-time cancer risk (ELCR) is calculated using the equation below, which is dependent on the annual effective dosage value[13].

$$ELCR=AED\times DL\times RF\ \dots\dots\dots(6)$$

Where ,DL is life expectancy (70), and RF stands for fatal risk factor in (Sievert) ,which is set at 0.05 per Sievert [10].

2.4.7.Hereditary Cancer Risk(HCR)

The ICRP's (1991) cancer risk assessment methodology was used to determine the hereditary cancer risk from spice consumption. The assumed parameter for members of the public, according to the ICRP standards, is 4 x 10^{-2} Sv-1 (ICRP, 1991)[13].

$$HCR=HE\times DL\times\ RF\ \dots\dots\dots(7)$$

Where HCR is hereditary cancer risk; H_E is the effective dose (Sv/y), DL is life expectancy (70 years) and RF is risk factor (Sv^{-1}) .For stochastic effects ICRP uses a value of 0.04 for the public as risk factor (ICRP, 1991).

2. Results and Discussions

Table 2, represents the results of specific activity for ^{238}U, ^{232}Th, and ^{40}K in Spice samples that collected from different Iraqi markets. According to the results, specific activity of ^{238}U were ranged from 7.37+0.78 Bq/kg to 15.26+1.39 Bq/kg with an average value of 10.63±1.15 Bq/kg, for ^{232}Th ranged from 5.00+0.36 Bq/kg to 14.84+0.86 Bq/kg, with an average value of 9.82±0.67Bq/kg, and for ^{40}K ranged from 108.28+2.80 Bq/kg to 472.94+11.59 Bq/kg, with an average value of 243.28±5.65Bq/kg. Also from table 2, the highest values of specific activity for ^{238}U, ^{232}Th, and ^{40}K was in A2 (Kofta spice; original of Iraq) and the lowest value was in A17 (Meat Maggi spice; original of Iraq). Natural radioactivity of gamma-ray emitted from all types of spice samples in present study were compared with world limit (33 Bq/kg for ^{238}U, 45 Bq/kg for ^{232}Th, and 420 Bq/kg for ^{40}K) that reports from UNSCEAR 2008 [7]. All the results of ^{238}U and ^{232}Th were within the permitted UNSCEAR 2008 [7], also, the results of ^{40}K were within the permitted UNSCEAR 2008 [9]. These increasing the levels in ^{40}K for some samples may be because of these samples treated by high levels with chemical fertilizers that usually it is contains high concentrations of potassium-40. The specific activities of ^{238}U, ^{232}Th, and ^{40}k have different values in each sample of the study, this difference can be attributed to a difference in the geological nature of soil that grown these spice samples under study.

Table 2. Results of ^{238}U, ^{232}Th, and ^{40}K in spice samples in present study.

No.	**Sample code**	**The specific activity Bq/m³**					
		^{238}U		**^{232}Th**		**^{40}K**	
		Average	**±S.D**	**Average**	**±S.D**	**Average**	**±S.D**
1	A1	12.49	1.26	9.83	0.68	257.50	5.54
2	A2	11.84	1.26	9.68	0.69	472.94	11.59
3	A3	10.17	1.14	8.84	0.65	135.53	2.85
4	A4	14.30	1.50	7.04	0.64	201.13	4.83
5	A5	11.95	1.47	12.89	0.93	164.23	3.74
6	A6	12.35	1.31	9.07	0.68	376.38	6.94
7	A7	8.26	0.95	7.68	0.56	114.45	3.39
8	A8	7.46	0.90	8.54	0.59	246.52	5.50
9	A9	7.37	0.78	5.87	0.42	258.17	5.81
10	A10	10.57	1.10	9.23	0.62	119.17	3.67
11	A11	11.49	1.25	14.84	0.86	369.28	8.84
12	A12	13.05	1.33	14.17	0.84	314.28	7.13
13	A13	14.45	1.45	11.30	0.78	311.56	6.84
14	A14	6.01	0.64	5.00	0.36	309.54	7.23
15	A15	9.91	1.19	14.18	0.86	129.38	4.07
16	A16	9.82	1.08	8.40	0.61	258.84	5.81
17	A17	8.20	1.02	8.42	0.63	108.28	2.80

18	A18	15.26	1.39	12.61	0.77	210.83	4.81
19	A19	7.02	0.91	9.13	0.63	264.39	6.05
Average		**10.63**	**1.15**	**9.82**	**0.67**	**243.28**	**5.65**

The results of radium equivalent (Ra_{eq}) and internal hazard index (H_{in}) due to the specific activity of ^{238}U, ^{232}Th and ^{40}K in spices sample are showed in Table(3). The ranged of Raeq (Bq/m^3) and Hin in the samples under study were 28.1 to 62.1 and 0.099 to 0.200, respectively. While the average value of Raeq (Bq/m^3) and Hin were 43.35 and 0.144, respectively .The radium equivalent activity (Ra_{eq}) readings are determined to be within the UNSCEAR(2000) authorized maximum value of 370 Bq/kg [14]. Internal hazard indices have all value lower than the UNSCEAR (2000) acceptable value of unity [7].

Table 3. Radium equivalent internal hazard index in spices sample.

NO.	**Sample code**	**Ra_{eq} (Bq/kg)**	**H_{in}**
1	A1	46.4	0.159
2	A2	62.1	0.200
3	A3	33.2	0.117
4	A4	39.9	0.146
5	A5	43.0	0.118
6	A6	54.3	0.180
7	A7	28.1	0.098
8	A8	38.7	0.125
9	A9	35.6	0.116
10	A10	32.9	0.118
11	A11	61.1	0.196
12	A12	57.5	0.191
13	A13	54.6	0.187
14	A14	37.0	0.116
15	A15	40.1	0.135
16	A16	41.8	0.139
17	A17	28.6	0.099
18	A18	49.5	0.175
19	A19	40.4	0.128
Average		43.35	0.144

The results of AED, DI_{thresh} , ELCR and HCR due to the specific activity of ^{238}U, ^{232}Th and ^{40}K in spices sample are showed in Table (4). The average value of AED total and DI_{thresh} in the samples under study were 0.011 mSv/y and 49.70, respectively. While the average value of ELCR and HCR were 0.047×10^{-3} and 0.037×10^{-3}, respectively. The values of AED are found to be within the world average allowed maximum value of 0.320 mSv/y

UNSCEAR (2008) [9]. All values of ELCR are lower than the international permissible value of 2.5×10^{-3} [10].

Table 4. Results of AED, DI_{thresh} , ELCR and HCR in spice samples in present study.

No.	Sample code	AED mSv/y				DI_{thresh}(kg/y)	ELCR×10^{-3}	HCR×10^{-3}
		^{238}U	^{232}Th	^{40}K	Total			
1	A1	0.006	0.004	0.003	0.013	43.5	0.046	0.037
2	A2	0.006	0.004	0.005	0.015	37.8	0.053	0.043
3	A3	0.005	0.004	0.002	0.010	55.9	0.036	0.029
4	A4	0.007	0.003	0.002	0.012	46.6	0.043	0.035
5	A5	0.006	0.005	0.002	0.013	43.7	0.046	0.037
6	A6	0.006	0.004	0.004	0.014	40.6	0.050	0.040
7	A7	0.004	0.003	0.001	0.009	66.8	0.030	0.024
8	A8	0.004	0.004	0.003	0.010	57.3	0.035	0.028
9	A9	0.004	0.002	0.003	0.009	63.8	0.032	0.025
10	A10	0.005	0.004	0.001	0.010	55.0	0.037	0.029
11	A11	0.006	0.006	0.004	0.016	35.9	0.056	0.045
12	A12	0.007	0.006	0.004	0.016	36.1	0.056	0.045
13	A13	0.007	0.005	0.003	0.015	37.3	0.054	0.043
14	A14	0.003	0.002	0.003	0.009	67.3	0.030	0.024
15	A15	0.005	0.006	0.001	0.012	46.8	0.043	0.034
16	A16	0.005	0.003	0.003	0.011	50.9	0.040	0.032
17	A17	0.004	0.003	0.001	0.009	65.3	0.031	0.025
18	A18	0.008	0.005	0.002	0.015	37.7	0.053	0.043
19	A19	0.004	0.004	0.003	0.015	38.5	0.052	0.042
Average		0.005	0.004	0.002	0.011	49.70	0.042	0.034

Table 5 shows the comparison between the specific activity of ^{238}U, ^{232}Th and ^{40}K in spices sample in the Iraqi markets and some of the results of some countries of the world. The average of specific activity of Uranium-238 in spices sample of the present study were lower than that was found in Ghana and higher than another country. While, the average of specific activity of Thourium-232 in spices sample of the present study were higher than that was found in Serbia and Italy and lower than another country. Finally, the average of specific activity of Potsium-40 in spices sample of the present study were higher than that was found in Nigeria and lower than another country.

Table 5. Comparison of the activity concentrations in the spices sample.

Country	Activity concentration (Bq.kg^{-1})			
	^{238}U	^{232}Th	^{40}K	Reference
Italy	0.4	-	654.7	[15]
Brazil	-	21.7	976.3	[16]
Serbia	2.6	7.4	589.6	[17]
Nigeria	-	35.1	171.7	[18]
Ghana	31.8	56.2	839.8	[19]
Iraq	13.72	8.11	243.28	This work

3. Conclusion

The values of specific activity ^{238}U, ^{232}Th and ^{40}K in samples of spices sample are found to be lower than the world average allowed maximum values 33, 45 and 420 Bq.kg^{-1} respectively, except the activity concentration of 40K that found to be higher in samplesA2 andA17. The values for the radium equivalent activity (Ra_{eq}) are turned to be within the international average allowed maximum value of 370 Bq.kg^{-1}. The value of hazard internal is lower than the international permissible value of unity. In general terms, it can be concluded that the implemented technique shows good results when matched with other literature data. Also, it can be concluded that samples under study, which have been analyzed, are safe for human consumption because their radioactivity levels are less than the maximum permitted level.

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