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Estimation of Radiation Doses, Hazard Indices and Excess Life Time Cancer Risk in Dry Legumes Consumed in Basrah Governorate/Iraq

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Abstract:

The radioactivity levels of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs were determined in 13 brands of dry legumes (7 brands of lentils and 6 brands of beans) consumed in Basrah, Iraq. This paper showed a comparison of the gamma absorbed dose rates (D), annual effective dose equivalent (AEDE) and the excess lifetime cancer risk (ELCR) for various types of dry legumes (lentils and beans) measured by SAM940-2G operating with BNC 2″x2″ gamma-ray NaI(Tl) detector along with thermoluminescence technique. For lentils samples, the minimum specific activity values of ^{238}U, ^{232}Th and ^{40}K were 0.178±0.376 Bq/kg (at sample L4), 0.180±0.433 Bq/kg (at sample L1) and 233.321±0.055 Bq/kg (at sample L1) respectively, while the maximum values of the same isotopes were 2.594±0.119 Bq/kg (at sample L6), 13.672±0.247 Bq/kg (at sample L4) and 452.134±0.043 Bq/kg (at sample L5) respectively. The averages (±SD) of ^{238}U, ^{232}Th and ^{40}K in all lentils samples were 0.952±0.808 Bq/Kg, 3.325±4.331 Bq/kg and 331.804±68.465 Bq/kg respectively. ^{137}Cs was not detected in all lentils samples. For beans samples, the minimum specific activity values of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs were 0.254±0.412 Bq/kg (at sample B3), 0.140±0.070 Bq/kg (at sample B2), 235.674±0.054 Bq/kg (at sample B2) and 0.010±0.829 Bq/kg (at sample B4) whereas the maximum values of the same isotopes were 1.043±0.412 Bq/kg (at sample B6), 2.994±0.141 Bq/kg (at sample B5), 429.390±0.044 Bq/kg (at sample B3) and 0.536±0.192 Bq/kg (at sample B1). The averages (±SD) of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in beans samples were 0.611±0.311 Bq/Kg, 1.114±0.930 Bq/Kg, 353.446±67.732 and 0.212±0.232 Bq/Kg, respectively. Various radiation hazard indices including the radium equivalent activity (Ra_{eq}), the ingestion effective dose ($H_{T,r}$), the internal hazard index (H_{in}), the external hazard index (H_{ex}), the gamma index (I_γ), the alpha index (I_α) have been determined for all 13 samples. All achieved results have been found to be under the international limit standards. Thus, selected lentils and beans brands are safe to be consumed in Basrah governorate.

Keywords: Radioactivity, Excess Life Time Cancer Risk, Thermoluminescence (TL), SAM940, Dry Legumes, Basrah Governorate

INTRODUCTION

In Health Physics, radiation dosimetry is defined as the measurement of radiation levels that impact on a human health [1,2]. The world population is subjected to the different types of radiation sources including artificial radiation (15%) and natural radiation (85%) which contains food and drinks (11%). This may give a chance to the contamination of radioactive materials [2,3]. Natural occurring radioactive matter (NORM) is found in soil. In fact, NORM can be moved from soil to plants. Thus, each sort of food may have some amount of radioactivity in it. Most types of food have the following isotopes and their daughter products; uranium-238 (^{238}U), thorium-232(^{232}Th) and potassium-40 (^{40}K) [4]. However, foodstuffs radioactivity can also be affected by man-made radiation. Caesium-137 (^{137}Cs) which made through nuclear accidents and processes is an example of anthropogenic radionuclides [5]. Dry legumes (lentils and beans) are classified as foodstuffs that frequently consumed by inhabitants of Basrah, Iraq. Safe foodstuffs and consumer protection are responsibility of governments in all over the world [6,7]. This study is critical in determining the risk of radiation on human and essential in creating rules and procedures involving to radiation protection. It is critical for measuring the radiation levels that affect Iraqi population. That is because there is always a risk from the excessive exposure of the radiation. That is why the study is significant to be done. Radioactivity measurements in foodstuffs are extremely significant for monitoring radiation risks on human health [8]. This paper is aimed to create radiological baseline data of the hazard radiation in involved dry legumes (lentils and beans) samples in Basrah/Iraq. This aim to be achieved the radioactivity levels and radiation hazard indices of consumed lentils and beans types in Basrah, Iraq are essential to be calculated and investigated.

MATERIALS AND METHODS

Sample collections and preparations

Thirteen dry legumes samples including lentils and beans were selected and then all samples were purchased from central market and different supermarkets in Basrah governorate as showing in the Table 1.

Table 1: Significant information about all lentils and beans samples involved in this study

Sample number	Sample code	Sample commercial name	Sample origin country
1	L1	Green Lentils/ Bil Bak	Canada
2	L2	Red Lentils	Egypt
3	L3	Hana	Iraq
4	L4	Zer	Turkey
5	L5	Nakhil	Turkey
6	L6	Altunsa	Turkey
7	L7	Nawras	Canada
8	B1	Nawras	Argentina
9	B2	Altunsa	Egypt
10	B3	Golden	Iraq
11	B4	Hana	Iraq
12	B5	Korjia	Ethiopia
13	B6	Zer	Kyrgyzstan

Sample preparation was made by putting each foodstuff sample in an oven for drying at a temperature of 105°C until a constant weight was reached, thus ensuring complete removal of any residual moisture. The pulverization of dried samples was made by a grinder. The crushed samples were passed through a 0.5-mm sieve to have homogenized foodstuff samples [4]. The homogenized foodstuff samples were divided into two groups. Each group has 0.5 kg of each foodstuff sample and both groups transported for sampling to the Thermoluminescence Laboratory and Nuclear Physics Researches Laboratory at the University of Basrah in Basrah/ Iraq. In Thermoluminescence Laboratory, each 0.5 kg of homogenized foodstuff sample was filled into plastic cylinder-shaped beaker with dimension of 17 cm in length and 10 cm in diameter. Three of annealed TLD-200 dosimeters were positioned in the middle of filled beaker. Labeled beakers were kept inside refrigeration at ranged temperature of (-10 and 10) °C for 3 months prior to measurement in order to collect adequate amount of gamma radiation [4,9,10]. In Nuclear Physics Researches Laboratory, each 0.5 kg of homogenized foodstuff sample was weighed and put in 0.5 kg polyethylene plastic Marinelli beakers and properly stored in the nuclear physics researches laboratory. The storage period of labeled samples was for at least one month prior to measurement in order to reach radioactive secular equilibrium between parents and their daughter [4,11].

Measurement techniques

The measurements of foodstuff samples were carried out by using two different techniques which are thermo-luminescence (TL) technique using the dosimeters of calcium fluoride dysprosium, CaF_2:Dy (TLD-200) and SAM940-2G device operating with NaI(Tl) gamma-ray detector. The lower detection limit (D_{ldl}) of TLD-200 equals to 0.291705 (arbitrary units). The calibration equation of TLD-200 is indicated as:

$$D_X = \left(\frac{\bar{M}_X - \bar{B}}{\bar{M}_C - \bar{B}}\right) D_C \ldots\ldots\ldots 1$$

It is found that $\bar{M}_C - \bar{B} = 118.684$ (arbitrary units), and D_C = 75.8 mrad. The equation 1 is used to convert the light emission obtained during the readout of TLD to the absorbed dose (D_X) of foodstuff sample. On the other hand, SAM940-2G operating with BNC 2″x2″ gamma-ray NaI(Tl) detector has 256 channels, voltage operation of 600 volts, coarse gain=1 and fine gain=1.1386. The energy calibration, resolution calibration and efficiency calibration of a BNC 2"x2" NaI (Tl) detector were determined experimentally for (32.90, 661.7, 31.63, 80.90, 356.01, 1173.20 and 1332.50) keV. The calculation of the activity level and presence of ^{238}U and ^{232}Th in all foodstuff samples was derived by arithmetical average of activities obtained from the peaks of their daughters in the foodstuff spectrum. ^{238}U derived from ^{214}Bi (609.32 keV) and ^{214}Pb (295.21 and 351.92 keV). ^{232}Th derived from ^{212}Pb, ^{208}Tl and ^{228}AC at energies of 238.63, 583.19 and 911.16 keV respectively. The activity values of ^{40}K in all foodstuff samples were determined from the single peak of potassium at 1461 keV. The present study is determined the activity values and existence of Caesium-137 (^{137}Cs) in all foodstuff samples at energy of 661.61 keV. The acquisition time for each sample was 1800 seconds.

Specific activity

The specific activity (A_s) of individual radioactivity isotope is defined as the activity per the unit of sample mass and it was calculated using the next equation [4,12]:

$$A_s\left(\frac{Bq}{kg}\right) = \frac{N}{(\varepsilon_f)(P_\gamma)(m)\,(t_s)} \ldots\ldots\ldots 2$$

Where, N = count per second (cps) equals measured count rate (N_p) in the foodstuff sample spectrum minus background count rate (N_{BGR}) in the background spectrum, ε_f = the efficiency at the peak energy, t_s = the live time of the foodstuff sample spectrum (1800 seconds), m = the sample mass (0.5kg) and P_γ = the emission probability of gamma-ray related to the peak energy.

Gamma absorbed dose rates

The mean specific activity values of ^{238}U (^{226}Ra), ^{232}Th, and ^{40}K (Bq.kg^{-1}) in the dry legumes samples are used to calculate the gamma absorbed dose rate (D). The specific activity of ^{238}U equals to the specific activity of ^{226}Ra because of achieving secular equilibrium between the parent radionuclide and its daughter. The calculation relation of the gamma absorbed dose rate which is measured by (nGy/h) is suggested by the UNSCEAR 2000 as [13]:

$$D\left(\frac{nGy}{h}\right) = 0.461\,A_U + 0.623\,A_{Th} + 0.0414 A_K \ldots\ldots 3$$

Where, A_U, A_{Th}, and A_K are the specific activities of ^{238}U,^{232}Th, and ^{40}K in Bq kg^{-1} respectively.

Annual effective dose equivalent

The annual effective dose equivalent (AEDE) from ^{238}U (^{226}Ra), ^{232}Th, and ^{40}K is obtained by using the following equations [13]:

$$AEDE_{outdoor}\left(\frac{mSv}{y}\right) = D \times 8760 \times 0.7 \times 0.2 \times 10^{-6} \ldots\ldots 4$$

$$AEDE_{indoor}\left(\frac{mSv}{y}\right) = D \times 8760 \times 0.7 \times 0.8 \times 10^{-6} \ldots\ldots 5$$

Where, D is absorbed dose rate measured in nGy/h. The number of 0.2 refers to outdoor occupancy factor, 0.8 is indoor occupancy factor. The number of 0.7 Sv/Gy is conversion factor.

Excess lifetime cancer risk

The risk of cancer due to radiation effects which is called excess lifetime cancer risk (ELCR) can be calculated from the following equation [14]:

$$ELCR = AEDE \times DL \times RF \ldots\ldots 6$$

Where, AEDE, DL and RF are the annual effective dose equivalent, the average duration of human life (70 years) and risk factor respectively. The value of risk factor in the public is 0.05 per Sievert as recommended by ICRP for stochastic effects [5,14].

The radium equivalent activity

The activity levels of ^{238}U, ^{232}Th and ^{40}K are not uniformly distributed in the foodstuff samples. Hence, the foodstuff samples would be examined by radium equivalent activity (Ra_{eq}). The Ra_{eq} which is measured in Bq/kg can be calculated by the following equation [12]:

$$Ra_{eq}\left(\frac{Bq}{Kg}\right) = A_U + 1.43\,A_{Th} + 0.077\,A_K \ldots\ldots 7$$

Where, A_U, A_{Th} and A_K are the specific activity of ^{238}U, ^{232}Th and ^{40}K in $Bq.kg^{-1}$, respectively. The acceptable maximum value of the radium equivalent activity is 370 $Bq.kg^{-1}$ [13]. The Ra_{eq} is assumed that 370 Bq/kg of ^{226}Ra, 259 Bq/kg of ^{232}Th and 4810 Bq/kg of ^{40}K yield the same gamma dose rate [4,13].

The internal and external hazard indices

The internal (H_{in}) and external hazard (H_{ex}) indices to gamma ray radiation in foodstuff samples were calculated using the following equations [6,13,15]:

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \ldots\ldots 8$$

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \ldots\ldots 9$$

Where, A_U, A_{Th} and A_K are the specific activity of ^{238}U, ^{232}Th and ^{40}K in $Bq.kg^{-1}$, respectively.

The gamma index

The gamma radiation hazard index (I_γ) which is also called the representative level index is calculated for foodstuff samples through the following formula [16]:

$$I_\gamma = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \ldots\ldots 10$$

Where, A_U, A_{Th} and A_K are the specific activity of ^{238}U, ^{232}Th and ^{40}K in $Bq.kg^{-1}$, in the foodstuff samples, respectively. The maximum value of the gamma index is unity as reported by ICRP [14].

Alpha Index

Alpha index (internal index) deals with the extraordinary level of alpha radiation. This internal index is rising because of the radon inhalation. In the current study, the alpha index was calculated by using the following equation [17] :

$$I_\alpha = \frac{A_{Ra}}{200} \ldots\ldots 11$$

Where, A_{Ra} are the specific activity of ^{226}Ra supposed in equilibrium with the specific activity of ^{238}U. The maximum value of the alpha index is unity [14].

Ingestion effective dose

The Ingestion effective dose ($H_{T,r}$) due to the intake of ^{238}U, ^{233}Th and ^{40}K in foodstuff samples is considered as radiological hazard for human health and it can be evaluated using the following expression [4,12]:

$$H_{T,r} = \sum_i \left(U_i \times A_{i,r}\right) \times g_{T,r} \ldots\ldots 12$$

where, i indicates a food type, the coefficients U_i and $A_{i,r}$ represent The annual intake of each type of foodstuffs ($kg.\,y^{-1}$) and the specific activity of the radionuclide (r) of interest ($Bq.\,Kg^{-1}$), respectively, and $g_{T,r}$ is the conversion coefficient of dose for ingestion of radionuclide r ($Sv.\,Bq^{-1}$) in tissue (T). For the public, the adult conversion coefficient of dose $g_{T,r}$ for ^{40}K, ^{226}Ra (^{238}U), ^{232}Th, and ^{137}Cs are 6.2×10^{-9}, 2.8×10^{-7}, 2.2×10^{-7} and $1.3\text{x}10^{-8}$ Sv/Bq respectively [4,12]. The annual intake values of each type of dry legumes were taken as 12 kg/y [18].

RESULTS

Table 2 and Table 3 show the specific activities of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in 7 samples of lentils and 6 samples of beans respectively. In Table 2 the minimum specific activity values of ^{238}U, ^{232}Th and ^{40}K in lentils samples were 0.178±0.376 Bq/kg (at sample L4), 0.180±0.433 Bq/kg (at sample L1) and 233.321±0.055 Bq/kg (at sample L1) respectively, while the maximum values of the same isotopes were 2.594±0.119 Bq/kg (at sample L6), 13.672±0.247 Bq/kg (at sample L4) and 452.134±0.043 Bq/kg (at sample L5) respectively. The averages (±SD) of ^{238}U, ^{232}Th and ^{40}K in all lentils samples were 0.952±0.808 Bq/Kg, 3.325±4.331 Bq/kg and 331.804±68.465 Bq/kg respectively. For ^{137}Cs, it was not detected in all lentils samples. In Table 3 the minimum specific activity values of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in beans samples were 0.254±0.412 Bq/kg (at sample B3), 0.140±0.070 Bq/kg (at sample B2), 235.674±0.054 Bq/kg (at sample B2) and 0.010±0.829 Bq/kg (at sample B4) whereas the maximum values of the same isotopes were 1.043±0.412 Bq/kg (at sample B6), 2.994±0.141 Bq/kg (at sample B5), 429.390±0.044 Bq/kg (at sample B3) and 0.536±0.192 Bq/kg (at sample B1). The averages (±SD) of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in beans samples were 0.611±0.311 Bq/Kg, 1.114±0.930 Bq/Kg, 353.446±67.732 Bq/kg and 0.212±0.232 Bq/Kg, respectively.

Table 2: Specific activity results of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in lentils samples

Sample code	Specific activity (A_s) in (Bq/Kg) (± Uncertainty)			
	^{238}U	^{232}Th	^{40}K	^{137}Cs
L1	0.232±0.058	0.180±0.433	233.321±0.055	ND
L2	0.383±0.372	1.448±0.181	396.450±0.046	ND
L3	1.595±0.154	1.794±0.171	305.475±0.050	ND
L4	0.178±0.376	13.672±0.247	277.241±0.052	ND
L5	0.858±0.226	3.377±0.150	452.134±0.043	ND
L6	2.594±0.119	2.148±0.060	309.396±0.050	ND
L7	0.825±0.105	0.657±0.106	348.610±0.048	ND
Average± SD	0.952±0.808	3.325±4.331	331.804±68.465	ND
Minimum	0.178±0.376	0.180±0.433	233.321±0.055	ND
Maximum	2.594±0.119	13.672±0.247	452.134±0.043	ND

***ND: Not detected**

Table 3: Specific activity results of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in beans samples

Sample code	**Specific activity (A_s) in (Bq/Kg) (± Uncertainty)**			
	^{238}U	**^{232}Th**	**^{40}K**	**^{137}Cs**
B1	0.526±0.716	0.486±0.036	307.043±0.049	0.536±0.192
B2	0.329±0.065	0.140±0.070	235.674±0.054	ND
B3	0.254±0.412	0.721±0.306	429.390±0.044	ND
B4	ND	0.899±0.207	360.374±0.047	0.010±0.829
B5	0.901±0.038	2.994±0.141	359.589±0.047	0.089±0.484
B6	1.043±0.412	1.445±0.092	428.606±0.044	ND
Average± SD	0.611±0.311	1.114±0.930	353.446±67.732	0.212±0.232
Minimum	0.254±0.412	0.140±0.070	235.674±0.054	0.010±0.829
Maximum	1.043±0.412	2.994±0.141	429.390±0.044	0.536±0.192

***ND: Not detected**

The gamma absorbed dose rates measured by TL technique (using equation 1) and SAM940 (using equation 3) for lentils samples were (0.302-0.387) and (0.087-0.186) mSv/y respectively, and for beans samples were (0.327-0.359) and (0.088-0.168) mSv/y respectively, as presented in Table 4. The average gamma absorbed dose rates measured by TL technique are higher than those measured by SAM940 for all samples as shown in Figure 1. The outcomes obtained appeared lower than the world average absorbed dose rates. The estimated world average absorbed dose rate of 1 mSv/y reported in UNSCEAR 2000 [13]. The annual effective dose equivalent (AEDE) values and excess lifetime cancer risk (ELCR) values for outdoor and indoor gamma exposures were determined by TL technique and SAM940 for lentils samples and beans samples. The mathematical calculations of these quantities were carried out using equations 4, 5 and 6. For lentils samples, the average values (±SD) of $AEDE_{outdoor}$, $AEDE_{indoor}$, $ELCR_{outdoor}$ and $ELCR_{indoor}$ measured by TL technique were (0.050±0.004)mSv/y, (0.200±0.016)mSv/y, (0.175±0.014) x10^{-3} and (0.701±0.054) x10^{-3} respectively and those values measured by SAM940 were (0.020±0.004) mSv/y, (0.080±0.017) mSv/y, (0.070±0.015)x10^{-3} and (0.279±0.060)x10^{-3} respectively as presented in Table 5. For beans samples, the average values (±SD) of $AEDE_{outdoor}$, $AEDE_{indoor}$, $ELCR_{outdoor}$ and $ELCR_{indoor}$ measured by TL technique were (0.048±0.001)mSv/y, (0.193±0.006)mSv/y, (0.169±0.005) x10^{-3} and (0.675±0.020)x10^{-3} respectively and those values measured by SAM940 were (0.019±0.004) mSv/y, (0.076±0.015) mSv/y, (0.067±0.013)x10^{-3} and (0.267±0.054)x10^{-3} respectively as presented in Table 6. These results show that the AEDE and ELCR obtained by TLDs are higher than that measured using the SAM940 measurements. The results obtained show that the AEDE and ELCR in all foodstuff samples appeared lower than the world average values. The estimated world average outdoor and indoor annual effective dose equivalent are 0.07 mSv/y and 0.34 mSv/y respectively, as recommended by UNSCEAR 2000 [13]. The estimated world average $ELCR_{outdoor}$ of 0.29 × 10^{-3} and $ELCR_{indoor}$ of 1.4 × 10^{-3} reported in UNSCEAR 2000 [5,13].

Table 4: The results of gamma absorbed dose rates in foodstuff samples (lentils and beans) measured by TL technique and SAM940

Sample code	**Gamma absorbed dose rates (D) in mSv/y**	
	TL	**SAM940**
L1	0.381	0.087
L2	0.382	0.153
L3	0.356	0.127
L4	0.356	0.176
L5	0.387	0.186
L6	0.340	0.134
L7	0.302	0.133
B1	0.359	0.116
B2	0.354	0.088
B3	0.345	0.161
B4	0.327	0.136
B5	0.341	0.150
B6	0.340	0.168

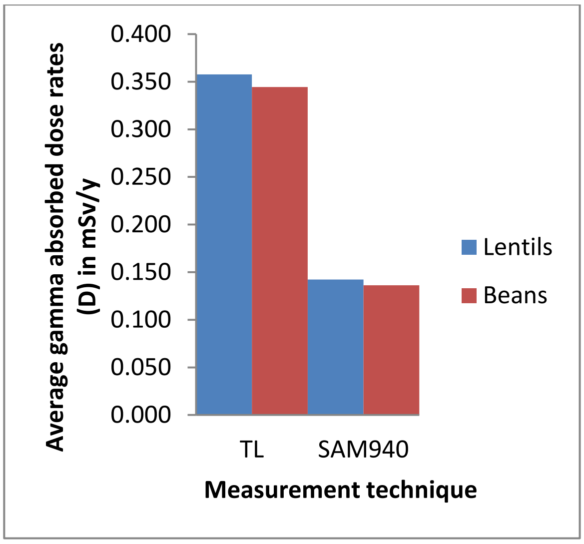

Figure 1: The average of gamma absorbed dose rates in foodstuff samples (lentils and beans) measured by TL technique and SAM940

Table 5: The annual effective dose equivalent values and the excess lifetime cancer risk values measured by TL technique and SAM940 for lentils samples

	AEDE (mSv/y) measured by TL		AEDE (mSv/y) measured by SAM940		ELCR measured by TL		ELCR measured by SAM940	
Sample code	Outdoor	Indoor	Outdoor	Indoor	Outdoor $\times10^{-3}$	Indoor $\times10^{-3}$	Outdoor $\times10^{-3}$	Indoor $\times10^{-3}$
L1	0.053	0.213	0.012	0.048	0.186	0.746	0.042	0.170
L2	0.054	0.214	0.021	0.086	0.187	0.749	0.075	0.300
L3	0.050	0.199	0.018	0.071	0.175	0.698	0.062	0.249
L4	0.050	0.199	0.025	0.098	0.175	0.698	0.086	0.345
L5	0.054	0.217	0.026	0.104	0.189	0.758	0.091	0.364
L6	0.048	0.190	0.019	0.075	0.166	0.666	0.066	0.263
L7	0.042	0.169	0.019	0.075	0.148	0.592	0.065	0.261
Average	0.050	0.200	0.020	0.080	0.175	0.701	0.070	0.279
±SD	0.004	0.016	0.004	0.017	0.014	0.054	0.015	0.060

Table 6: The annual effective dose equivalent values and the excess lifetime cancer risk values measured by TL technique and SAM940 for beans samples

	AEDE (mSv/y) measured by TL		AEDE (mSv/y) measured by SAM940		ELCR measured by TL		ELCR measured by SAM940	
Sample code	Outdoor	Indoor	Outdoor	Indoor	Outdoor $\times10^{-3}$	Indoor $\times10^{-3}$	Outdoor $\times10^{-3}$	Indoor $\times10^{-3}$
B1	0.050	0.201	0.016	0.065	0.176	0.703	0.057	0.228
B2	0.050	0.198	0.012	0.049	0.174	0.695	0.043	0.172
B3	0.048	0.193	0.022	0.090	0.169	0.676	0.079	0.315
B4	0.046	0.183	0.019	0.076	0.160	0.640	0.066	0.266
B5	0.048	0.191	0.021	0.084	0.167	0.669	0.074	0.295
B6	0.048	0.191	0.023	0.094	0.167	0.667	0.082	0.328
Average	0.048	0.193	0.019	0.076	0.169	0.675	0.067	0.267
±SD	0.001	0.006	0.004	0.015	0.005	0.020	0.013	0.054

Table 7: The results of radium equivalent activity, radiation hazard (internal, external, gamma and alpha) indices and ingestion effective dose for adult in lentils samples

Sample code	Ra_{eq} (Bg/Kg)	H_{in}	H_{ex}	I_{γ}	I_{α}	Ingestion effective dose (mSv/y)			
						^{238}U	^{232}Th	^{40}K	^{137}Cs
L1	18.456	0.050	0.050	0.079	0.001	0.001	0.000	0.017	0.000
L2	32.981	0.090	0.089	0.141	0.002	0.001	0.004	0.029	0.000
L3	27.682	0.079	0.075	0.116	0.008	0.005	0.005	0.023	0.000
L4	41.077	0.111	0.111	0.161	0.001	0.001	0.036	0.021	0.000
L5	40.502	0.112	0.109	0.170	0.004	0.003	0.009	0.034	0.000
L6	29.489	0.087	0.080	0.123	0.013	0.009	0.006	0.023	0.000
L7	28.607	0.079	0.077	0.122	0.004	0.003	0.002	0.026	0.000
Average	31.256	0.087	0.084	0.130	0.005	0.003	0.009	0.025	0.000
±SD	7.287	0.020	0.020	0.028	0.004	0.003	0.011	0.005	0.000

Table 8: The results of radium equivalent activity, radiation hazard (internal, external, gamma and alpha) indices and ingestion effective dose for adult in beans samples

Sample code	Ra_{eq} (Bg/Kg)	H_{in}	H_{ex}	I_{γ}	I_{α}	Ingestion effective dose (mSv/y)			
						^{238}U	^{232}Th	^{40}K	^{137}Cs
B1	24.863	0.069	0.067	0.107	0.003	0.002	0.001	0.023	0.000
B2	18.676	0.051	0.050	0.080	0.002	0.001	0.000	0.018	0.000
B3	34.349	0.093	0.093	0.148	0.001	0.001	0.002	0.032	0.000
B4	29.034	0.078	0.078	0.125	0.000	0.000	0.002	0.027	0.000
B5	32.871	0.091	0.089	0.138	0.005	0.003	0.008	0.027	0.000
B6	36.111	0.100	0.098	0.154	0.005	0.004	0.004	0.032	0.000
Average	29.317	0.081	0.079	0.125	0.003	0.002	0.003	0.026	0.000
±SD	6.018	0.017	0.016	0.025	0.002	0.001	0.002	0.005	0.000

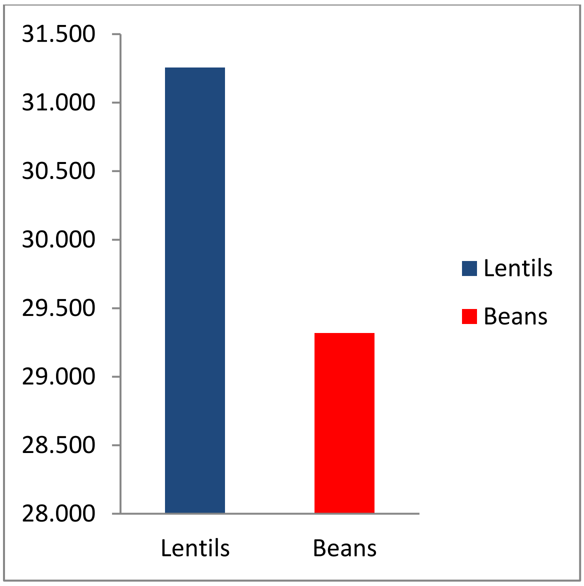

Figure 2: The average radium equivalent activity of lentils and beans samples

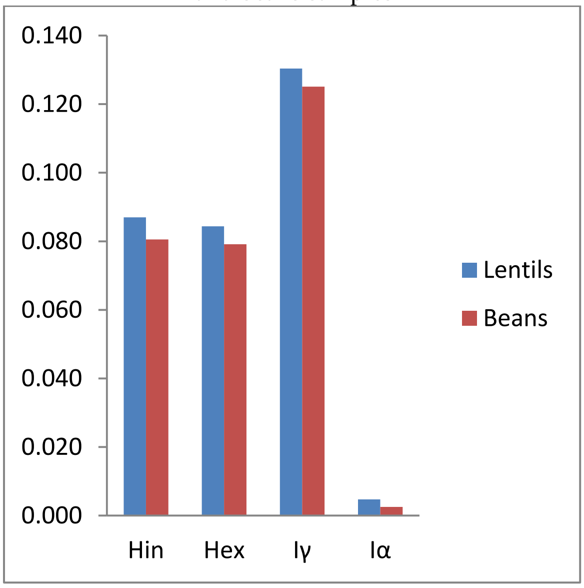

Figure 3: The average values of radiation hazard (internal, external, gamma and alpha) indices in foodstuff samples

The radium equivalent activity, internal and external radiation hazard indices, the gamma index and alpha index were calculated by applying the equations 7, 8, 9, 10 and 11 respectively. There is a variation in the values of these radiation hazard indices in all foodstuff samples as shown in Table 7 and Table 8, Figure 2 and Figure 3. The results of all radiation hazard indices are less than world limit values.

Last but not least, the equation 12 is applied to calculate the ingestion effective dose of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in lentils and beans samples. The findings of ingestion effective dose are presented in Table 7 and Table 8 in units of (mSv/y). The average ingestion effective dose values of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs for adults in lentils and beans samples are shown in Figure 4. These results indicate that the ingestion effective dose in all foodstuff samples were less than the permissible ingestion effective dose values of 1 mSv/y recommended by IAEA [4,12].

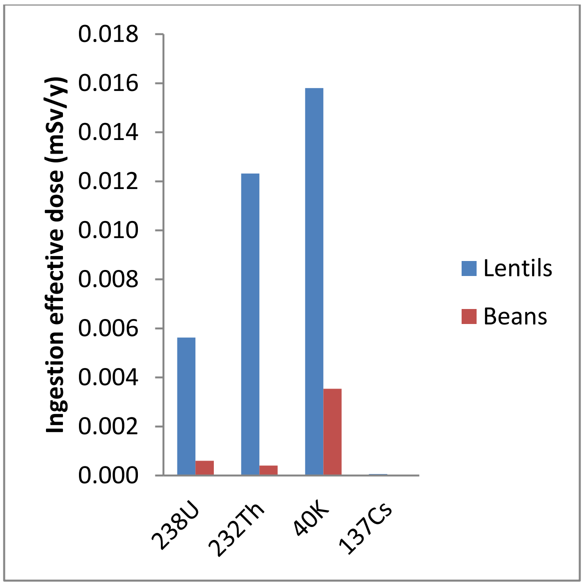

Figure 4: The average ingestion effective dose values of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs for adult in lentils and beans samples

DISCUSSION

The specific activity levels of ^{238}U,^{232}Th, ^{40}K and ^{137}Cs in lentils and beans samples were measured in Basrah governorate (Iraq). The specific activity values of ^{238}U,^{232}Th, ^{40}K and ^{137}Cs in all foodstuff samples were found lower than the global average specific activity values. The global average specific activity values of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs are 33 Bq/kg, 45 Bq/kg, 412 Bq/kg and 101 Bq/kg respectively [19,20]. The higher average specific activity of ^{40}K compared with the average activity concentration of ^{238}U, ^{232}Th and ^{137}Cs was expected because of its natural presence and the extraordinary level of potassium isotope in the sample area which contains phosphate fertilizers in which a great amount of potassium. ^{238}U and ^{232}Th are not found in some samples. The levels of background and the detection limits of technique may conceal minor peaks of ^{238}U and ^{232}Th [21]. Previous studies reported that the detection of ^{238}U and ^{232}Th is not necessary to be found in all food samples [11,22]. The existence of ^{137}Cs in some foodstuff samples may due to the Chernobyl accident fallout, the usage of contaminated foodstuff bags and nitrate fertilizers [6,23]. The difference between the results of TLDs and SAM940 techniques because TLDs obtain the gamma absorbed dose of all isotopes in foodstuff sample while SAM940 measures only the gamma absorbed dose of ^{238}U, ^{232}Th and ^{40}K in foodstuff samples. This is also clarifying the reason behind the difference between the results of AEDE and ELCR measured by TLDs and those measured by SAM940. The ingestion effective dose of all isotopes in lentils samples is higher than those in beans samples. The ingestion effective dose of ^{137}Cs is not found in all samples whereas the ingestion effective dose of ^{40}K is presented as the highest one. These results are not surprised because the ingestion effective dose results based on the results of specific activity of mentioned isotopes.

CONCLUSION

Radioactivity levels, radiation doses, radiation hazard indices and excess life time cancer risk in dry legumes were investigated. Thirteen dry legumes samples including 7 samples of lentils and 6 samples of beans were involved in this study. The findings have been shown that consumed lentils and beans in Basrah/Iraq are safe from any radiation risk. The current study suggests that other staple foodstuffs are needed to have similar study in order to create baseline data of consumed foodstuffs for preparing a radiological map of Basrah/Iraq.

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