Measurement of the Radioactivity Levels for Some Food Products Imported to Iraq and Estimation of the Risk to Consumers

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Abstract

In this study, Uranium (^{238}U), Thorium (^{232}Th), Radium (^{226}Ra) and Potassium (^{40}K) activity concentrations were measured in 34 samples of biscuit, pastry, dessert, cakes and nestles manufactured in Turkey, Ukraine, Poland, Spain, France, Russia, Turkmenistan, Iran, Jordan, Algeria, India, Morocco, Kingdom of Saudi Arabia, Emirates, in addition to locally produced biscuit sample manufactured in Iraq using gamma-ray spectrometry system. The average activity concentrations were 69.09±24.89 Bq/kg for ^{238}U, 26.75±11.13 Bq/kg for ^{232}Th, 4.86±1.16 Bq/kg for ^{226}Ra and 178.84±58.39 Bq/kg for ^{40}K. The effective doses arising from ingestion of naturally occurring radioactive materials in the investigated food samples ranged from 0.068±0.02 mSv/y for adults (age > 17 y) to 0.191±0.05 mSv/y for children (age 1–2 y), with a mean value of 0.12 mSv/y. It was found that the estimated potential radiation doses for investigated population groups were below the dose constraint of 0.3 mSv/y. The corresponding average radiation risk for all population groups (6×10^{-6} per year) was found to be significantly lower than that considered acceptable in the relevant International Atomic Energy Agency (IAEA) safety standards (10^{-5} per year). The results presented in current study confirm that the potential radiation doses and radiological hazards associated with intake of the natural radionuclides in the imported and locally produced food species is acceptable and well within permissible limits. Hence, the imported and locally produced food species investigated in this study were considered safe for human consumption with respect to radiological hazards.

***Key words**: Naturally occurring radioactive materials, gamma-ray spectrometry system.*

Introduction

Food may contain naturally occurring radioactive materials and radionuclides of artificial origin. The sources of these radionuclides in food are[(1)]:

- Radionuclides in the uranium and thorium decay series, and ^{40}K, all of which are present throughout the environment;

- Radionuclides released from nuclear facilities: these are primarily of artificial origin, but may also be of natural origin, particularly in the case of uranium mining and processing activities;

- Fallout from the testing of nuclear weapons (^{137}Cs and ^{90}Sr);

- Accidental discharges of radionuclides.

The presence of radionuclides in food may be as a result of direct deposition from the atmosphere onto crops, root uptake from the soil, or transfer through aquatic pathways. Hence, international efforts were brought together collaboratively to apply adequate procedures in investigating radionuclides in food and to set essential guidelines to protect against high levels of internal exposure that may be caused by food consumption[(2)]. The aim of this study is to investigate radioactivity levels for some types of food products imported to Iraq, in addition to locally produced food and estimation of the potential radiation dose and risk to consumers.

Materials and Methods

2.1 Sampling and Analysis

Total of 34 of food samples were collected from local markets in Baghdad city in January 2020 for gamma-ray spectroscopy analysis. The radiological investigation involves measuring radioactivity levels for biscuit, pastry, dessert, cakes and nestles samples manufactured in Turkey, Ukraine, Poland, Spain, France, Russia, Turkmenistan, Iran, Jordan, Algeria, India, Morocco, Kingdom of Saudi Arabia, Emirates, in addition to locally produced biscuit sample manufactured in Iraq. These food species are one of the essential foods that are consumed daily by Iraqis. After collection, each sample was kept in a plastic bag and labeled according to its country of origin and name. All of the food samples were crushed, dried using an oven at 65°C for 60 min and then weighed using digital balance. A mass of 0.5 kg of each sample was placed in a plastic Marnili beaker. The plastic Marnili beakers were hermetically sealed with adhesive tape for 30 days to attain secular equilibrium between ^{226}Ra and its decay products(2). Radioactivity levels in imported food samples were measured in February 2020 using a gamma-ray spectrometry system, which includes a multichannel analyzer equipped with high purity GeLi(Tl) detector (efficiency 30%). The detector is shielded by a cylindrical lead shield in order to reduce the ambient background level. The activity concentrations of radionuclides in Bq/kg were estimated using equation below(3):

$$A = \frac{N_{net}}{\varepsilon \times I_\gamma \times m \times t} \pm \frac{\sqrt{N_{net}}}{\varepsilon \times I_\gamma \times m \times t} \quad \dots (1)$$

where N_{net} represent the net count (background subtracted) in (c/s), $\sqrt{N_{net}}$ is the random error in (c/s), ε represent the efficiency of the detector, I_γ is emitted gamma ray of the transition probability, t is the counting time (3600 sec), and m represent the sample weight (0.5 Kg).

2.2 Radiological Dose and Risk Assessment

The annual committed effective dose (CED) (mSv/y) from ingestion of the radionuclides in investigated food species was calculated using the following formula(4,5):

$$CED = \sum_i A_i \times M \times D_i \quad \dots (2)$$

where A_i is the activity concentration of radionuclide i in food group (Bq/kg), M is the food consumption rate per year (6.7 kg/y(6)), and DC_i is the age-dependent committed effective dose coefficient from ingestion of radionuclide i (Table 1). Excess fatal cancer risk probability was estimated by multiplying the committed effective dose and the detriment adjusted nominal risk coefficient of 0.04871 Sv^{-1}(4,7).

Table 1. Age-dependent committed effective dose coefficients for members of the public (Sv/Bq)(8).

Radionuclide	Age group				
	1 – 2 y	2 – 7 y	7 – 12 y	12 – 17 y	> 17 y
40K	4.2×10-8	2.1×10-8	1.3×10-8	7.6×10-9	6.2×10-9
226Ra	9.6×10-7	6.2×10-7	8×10-7	1.5×10-6	2.8×10-7
238U	1.2×10-7	8×10-8	6.8×10-8	6.7×10-8	4.5×10-8
232Th	4.5×10-7	3.5×10-7	2.9×10-7	2.5×10-7	2.3×10-7

Results and Discussion

The activity concentrations of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K measured in different kinds of imported food samples from different origins, in addition to food sample locally produced in Iraq are shown in Tables 2 and 3. The activity concentrations of ^{238}U ranged from 26.42±4.62 Bq/kg to 112.31±11.34 Bq/kg with an average value of 69.09±24.89 Bq/kg, ^{232}Th from 7.69±2.17 Bq/kg to 44.62±3.36 Bq/kg, with an average value of 26.75±11.13 Bq/kg, ^{226}Ra from 2.25±1 Bq/kg to 7.32±2.21 Bq/kg, with an average value of 4.86±1.16 Bq/kg, and ^{40}K from 102.42±6.92 Bq/kg to 296.16±16.23 Bq/kg, with an average value of 178.84±58.39 Bq/kg. ^{40}K shown relatively highest activity concentrations as compared with other radionuclides. It is well known that potassium element is essential for plants metabolism. Therefore, plants absorb more potassium from soil in varied amounts depending upon their metabolism[9]. After ^{40}K, the activity concentration of ^{238}U is relatively higher, while ^{226}Ra shows lowest activity concentration. Generally, activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K reported in current study are significantly below corresponding global average values (40, 40 and 580 Bq/kg, respectively[10]).

Figure 1 shows that there is a wide variation in the activity concentrations of radionuclides in imported food samples from different countries. Food samples imported from Ukraine have relatively highest activity concentrations, while food samples imported from Iran have relatively the lowest values, which could be attributed to the difference in the level of radionuclides activity concentrations in the soil where the food samples were imported.

Table 4 shows results of dose calculations for ingestion of different food species imported to Iraq. The committed effective dose (CED) was estimated using Eq.2 to be ranged from 0.077 mSv/y for consumption of food imported to Iraq from Algeria for 7 – 12 y age group to 0.302 mSv/y for the consumption of food imported to Iraq from Ukraine for 1 – 2 y age group. The highest annual committed effective dose was reported for the 1-2 y age group due to relatively highest dose coefficients for this age group. The average total CED arising from ingestion of the naturally occurring radionuclides in the investigated food for all population groups (0.12 mSv/y) is less than the world mean annual committed effective dose constraint of 0.3 mSv for intake of natural radionuclides[5].

The percentage contributions to the total estimated dose rate for 1–2 age group are shown in Figure 2. About 32% of the total estimated dose rate arising from ^{238}U ingestion due to its relatively highest measured activity concentration and dose coefficient, followed by ^{232}Th (about 29%) and ^{40}K (about 25%). The percentage contribution to the total estimated dose rate from ^{226}Ra is relatively low (about 14%) due to relatively low measured activity concentration.

Radiation cancer risks for all population groups were estimated in Table 5 by multiplying the annual committed effective doses and the nominal risk coefficient of 0.04871 Sv^{-1} [4,7]. The annual radiation risks were found to be generally decreased with increasing age, with average values of 9.31, 6.19, 5.35, 5.81 and 3.32 per million exposed individuals, for population groups: 1 – 2 y, 2 – 7 y, 7 – 12 y, 12 – 17 y and > 17 y, respectively. The potential contributions of cancer risk from internal radiation exposure through consumption of imported food were estimated to be low as compared with the permissible risk level of 10^{-5} per year[11]. The findings presented in current study suggest that there is no discernible increase in radiation doses or excess fatal cancer risk from ingestion of imported food in Iraq investigated in current study. The findings presented in current study are consistent with the findings presented in previous studies, which confirm that the radiological impact of radionuclides ingestion in local or imported food in Iraq is insignificant[2,3,5].

Table 2. Results of laboratory analysis for food samples imported to Iraq from foreign countries.

No.	Imported food	Type	Country of origin	Activity concentration (Bq/kg)			
				238U	232Th	226Ra	40K
1	Petit Beurre	Biscuit	Turkey	88.62±11.12	27.2±3.21	6.26±1.2	251.12±12.4
2	Eclairs mint	Mint caramel dessert	Turkey	110.71±9.72	41.62±3.76	7.32±2.2	280.2±8.72
3	Digestive Cookies ETI Whola	Pastry	Turkey	56.42±7.12	39.92±6.21	4.26±1	176.21±7.22
4	Chocopaye Bitter	Stuffed cocoa biscuit	Turkey	62.19±4.61	41.05±3.21	5.67±1.7	140.29±13.2
5	Torku No.1	Nestle	Turkey	81.52±7.21	27.26±4.62	3.42±1.2	180.86±9.61
6	Aldiva Snack Cracker	Salty biscuits	Turkey	44.93±5.13	12.62±3.11	2.25±1	110.22±4.96
7	Carame Cracker	Salty biscuits	Ukraine	105.17±8.21	32.22±4.16	6.76±2.1	260.69±11.7
8	Grona Krendelyok	Pastry	Ukraine	93.71±5.41	41.32±5.26	5.23±1.3	255.61±10.6
9	Grona Azhur	Fruit pastries	Ukraine	112.31±11.3	44.62±3.36	6.32±2.1	257.72±13.2
10	Delicia IHBR	Biscuit	Ukraine	97.62±8.14	22.72±2.21	6.05±1.4	282.33±11.2
11	Prince	Biscuit	Ukraine	105.23±10.7	34.47±4.72	5.42±1.6	296.16±16.2
12	Crunchy Sultana	Biscuit	Ukraine	104.05±9.69	39.29±2.92	5.42±1.1	220.72±9.62
13	Fit Carain	Flakes	Poland	92.42±7.54	39.44±4.26	5.62±1.9	196.42±7.62
14	Sweet joy Fica Cookies	Pastry	Poland	72.32±9.52	28.72±3.11	4.32±2.1	162.32±10.2
15	Bezgluten Domino	Biscuit	Poland	87.62±7.61	40.62±7.96	3.96±1.9	196.62±8.72
16	Bezgluten	Cocoa balls	Poland	101.32±11.4	41.11±4.22	6.46±1.7	222.71±9.21
17	Digestive Ligera Sin Sal Gullon	Pastry	Spain	72.65±8.62	22.67±4.31	4.32±2.1	196.23±8.62
18	Digestive Ligerd Sin Sal Azucares	Biscuit	Spain	43.92±7.62	32.66±5.34	3.67±1	114.22±9.55
19	Oatmeal Flakes Fitness	Oatmeal Flakes	France	56.32±6.14	27.52±4.23	4.26±1	122.71±8.27
20	Forsity	Stuffed cocoa biscuit	Russia	66.47±5.23	22.62±3.29	5.22±1.6	144.13±9.19
21	Nowruz Hasar	Stuffed wafer biscuit	Turkmenistan	54.62±7.11	18.62±1.79	4.22±1	105.23±7.22
22	Simo RHG	Biscuit	Iran	53.97±4.62	15.32±2.79	3.96±1	112.62±3.22
23	Dregstive	Biscuit	Iran	47.62±3.22	23.91±3.72	4.62±1.2	110.76±6.71
24	Alvita	Biscuit	Iran	26.42±4.62	12.61±1.67	3.22±1	102.42±6.92
25	CNC Biscuit	Biscuit	India	34.26±2.52	11.67±3.44	3.72±1	124.64±7.22
26	Cheese Cracker Priyagold	Biscuit	India	62.41±3.73	16.72±2.36	4.12±1.6	182.55±7.78
Global average concentrations(10)				-	40	40	580

Table 3. Results of laboratory analysis for food samples imported from Arabic countries and locally produced in Iraq.

No.	Imported food	Type	Country of origin	Activity concentration (Bq/kg)			
				238U	232Th	226Ra	40K
1	Well made Mini Pound	Cake	Jordan	41.24±5.62	12.42±3.14	4.96±1.2	145.34±7.64
2	Digestive Gullon	Biscuit	Algeria	56.23±6.91	8.69±2.33	6.26±1.7	165.6±10.21
3	Mega Dream Palmary	Stuffed biscuit	Algeria	38.62±5.46	7.69±2.17	4.23±1.1	112.67±7.44
4	OREO	Stuffed Wafer biscuit	Morocco	34.62±6.21	19.72±6.22	4.12±1	140.6±6.11
5	7 Days Cake Bar	Cake	Kingdom of Saudi Arabia	48.67±6.93	24.62±3.1	4.62±1.3	155.36±6.52
6	Every Day Nice Tiffany	Biscuit	Emirates	63.42±4.62	27.62±4.6	5.72±1.2	202.62±9.41
7	Glucose Tiffany	Biscuit	Emirates	68.76±7.82	34.62±2.1	5.81±1.6	212.72±4.22
8	Shamae'el	Biscuit	Iraq	62.97±5.91	15.62±2.6	3.52±1.0	140.17±8.62
Global average concentrations(10)				-	40	40	580

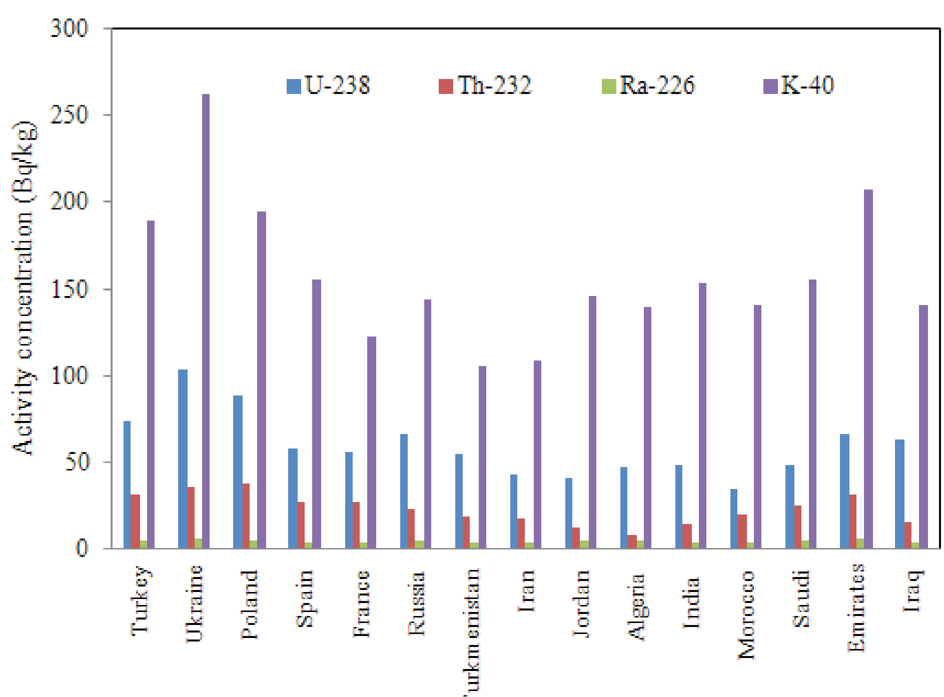

Figure 1. Average activity concentration of radionuclides in different imported food samples

Table 4. Results of dose assessment for ingestion of different food species imported to Iraq (in mSv/y).

Country of origin	Age group				
	1 – 2 y	2 – 7 y	7 – 12 y	12 – 17 y	> 17 y
Turkey	0.24	0.161	0.138	0.145	0.088
Ukraine	0.302	0.2	0.171	0.178	0.108
Poland	0.271	0.184	0.157	0.163	0.102
Spain	0.199	0.134	0.115	0.12	0.074
France	0.19	0.13	0.113	0.12	0.072
Russia	0.196	0.131	0.115	0.127	0.07
Turkmenistan	0.157	0.105	0.092	0.103	0.057
Iran	0.142	0.094	0.083	0.092	0.051
Jordan	0.143	0.092	0.081	0.095	0.046
Algeria	0.135	0.085	0.077	0.094	0.042
India	0.15	0.096	0.083	0.092	0.05
Morocco	0.153	0.102	0.088	0.096	0.054
Saudi	0.187	0.125	0.108	0.117	0.067
Emirates	0.242	0.161	0.139	0.15	0.087
Iraq	0.16	0.105	0.089	0.096	0.055
Average ± σ	0.191±0.05	0.127±0.03	0.095±0.04	0.119±0.02	0.068±0.02
Minimum	0.135	0.085	0.077	0.092	0.042
Maximum	0.302	0.2	0.171	0.178	0.108

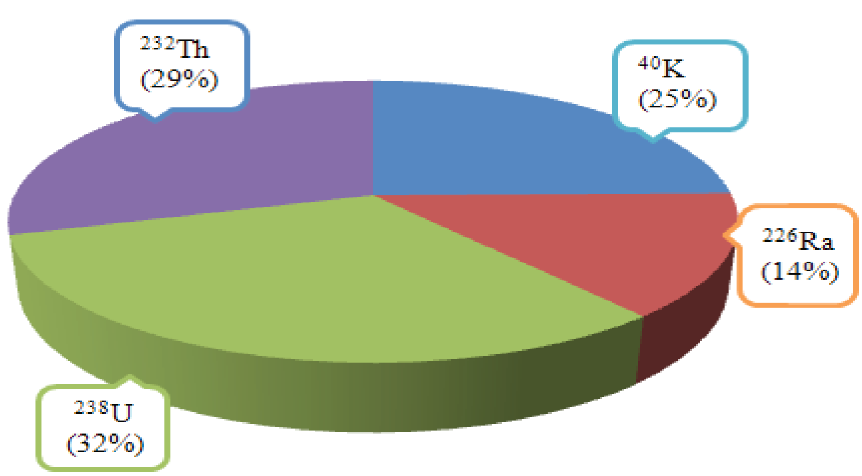

Figure 2. Percentage contributions to the total dose rate for 1 – 2 y age group

Table 5. Results of risk assessment for ingestion of different food species imported to Iraq (potential cancer incidence rate per year).

Country of origin	Age group				
	1 – 2 y	2 – 7 y	7 – 12 y	12 – 17 y	> 17 y
Turkey	1.17×10-5	7.84×10-6	6.72×10-6	7.06×10-6	4.29×10-6
Ukraine	1.47×10-5	9.74×10-6	8.33×10-6	8.67×10-6	5.26×10-6
Poland	1.32×10-5	8.96×10-6	7.65×10-6	7.94×10-6	4.97×10-6
Spain	9.69×10-6	6.53×10-6	5.60×10-6	5.85×10-6	3.60×10-6
France	9.25×10-6	6.33×10-6	5.50×10-6	5.85×10-6	3.51×10-6
Russia	9.55×10-6	6.38×10-6	5.60×10-6	6.19×10-6	3.41×10-6
Turkmenistan	7.65×10-6	5.11×10-6	4.48×10-6	5.02×10-6	2.78×10-6
Iran	6.92×10-6	4.58×10-6	4.04×10-6	4.48×10-6	2.48×10-6
Jordan	6.97×10-6	4.48×10-6	3.95×10-6	4.63×10-6	2.24×10-6
Algeria	6.58×10-6	4.14×10-6	3.75×10-6	4.58×10-6	2.05×10-6
India	7.31×10-6	4.68×10-6	4.04×10-6	4.48×10-6	2.44×10-6
Morocco	7.45×10-6	4.97×10-6	4.29×10-6	4.68×10-6	2.63×10-6
Saudi	9.11×10-6	6.09×10-6	5.26×10-6	5.70×10-6	3.26×10-6
Emirates	1.18×10-5	7.84×10-6	6.77×10-6	7.31×10-6	4.24×10-6
Iraq	7.79×10-6	5.11×10-6	4.34×10-6	4.68×10-6	2.68×10-6
Average ± σ	9.31×10-6± 2.5×10-6	6.19×10-6± 1.73×10-6	5.35×10-6± 1.44×10-6	5.81×10-6± 1.37×10-6	3.32×10-6± 9.94×10-7
Minimum	6.58×10-6	4.14×10-6	3.75×10-6	4.48×10-6	2.05×10-6
Maximum	1.47×10-5	9.74×10-6	8.33×10-6	8.67×10-6	5.26×10-6

Conclusions

Radioactivity levels for some imported and locally produced food species (biscuit, pastry, dessert, cakes and nestles samples) commonly consumed by human in Iraq, collected from local markets in Baghdad city were measured using gamma-ray spectrometry system. The average activity concentrations were 69.09±24.89 Bq/kg for ^{238}U, 26.75±11.13 Bq/kg for ^{232}Th, 4.86±1.16 Bq/kg for ^{226}Ra and 178.84±58.39 Bq/kg for ^{40}K. The activity concentrations of naturally occurring radioactive materials in investigated imported and locally produced food species were found to be have the following order: ^{40}K > ^{238}U > ^{232}Th > ^{226}Ra. Fruit pastries and biscuits samples produced in Ukraine recorded relatively the highest activity concentrations, whilst biscuits samples produced in Iran showed relatively the lowest values. The average annual effective dose to the public arising from ingestion of naturally occurring radioactive materials in the investigated imported and locally produced food species (0.12 mSv/y) was found to be below the radiation dose constraint of 0.3 mSv per year(5). The corresponding average radiation risk for all population groups (6×10^{-6} per year) was found to be significantly lower than that considered acceptable in the relevant International Atomic Energy Agency safety standards (10^{-5} per year)(11). These results show that the potential radiological hazards associated with intake of the natural radionuclides in the imported and locally produced food species is acceptable and well within permissible radiation dose and risk limits.

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