International Journal of Food Contamination
a SpringerOpen Journal

REVIEW **Open Access**

Estimated the radiation hazard indices and ingestion effective dose in wheat flour samples of Iraq markets

Ali Abid Abojassim*, Husain Hamad Al-Gazaly and Suha Hade Kadhim

Abstract

In this research, Uranium (^{238}U), Thorium (^{232}Th) and Potassium (^{40}K) specific activity in (Bq/kg) were measured in (12) different types of wheat flours that are available in Iraqi markets. The gamma spectrometry method with a NaI(Tl) detector has been used for radiometric measurements. Also in this study we have calculated the radiation hazard indices (radium equivalent activity and internal hazard index) and Ingestion effective dose in all samples.
It is found that the specific activity in wheat flour samples were varied from (1.086 ± 0.0866) Bq/kg to (12.532 ± 2.026) Bq/kg, for^{238}U, For ^{232}Th From (0.126 ± 0.066) Bq/kg to (4.298 ± 0.388) Bq/kg and for ^{40}K from (41.842 ± 5.875) Bq/kg to (264.729 ± 3.843) Bq/kg. Also, it is found that the of radium equivalent activity and internal hazard index in wheat flour samples ranged from (3.4031) Bq/kg to (35.1523) Bq/kg and from (0.0091) to (0.1219) respectively. But The range of summation of the Ingestion effective dose were varied from (0.0317) mSv/y to (0.5734) mSv/y. This study prove that the natural radioactivity, radiation hazard indices and Ingestion effective dose were lower than the safe.

Keywords: Wheat flour; Natural radioactivity; Iraq market and gamma spectroscopy

Review

The world is naturally radioactive and approximately 82% of human-absorbed radiation doses, which are out of control, arise from natural sources such as cosmic, terrestrial, and exposure from inhalation or intake radiation sources. In recent years, several international studies have been carried out, which have reported different values regarding the effect of background radiation on human health.

Introduction

Natural radioactivity is caused by the presence of natural occurring radioactive matter (NORM) in the environment. Examples of natural radionuclides include isotopes of potassium (^{40}K), uranium (^{238}U and its decay series), and thorium (^{232}Th and its decay series). In addition to being long-lived (in the order of 1010 years), these radionuclides are typically present in air, soil, and water in different amounts and levels of activity. Natural radionuclides are found in terrestrial and aquatic food chains, with subsequent transfer to humans through ingestion of food. As such, international efforts were brought together collaboratively to apply adequate procedures in investigating radionuclides in food (IAEA, International Atomic Energy Agency, Measurements of Radionuclides in Food and Environment 1989), and to set essential guidelines to protect against high levels of internal exposure that may be caused by food consumption (ICRP 1996; UNSCEAR 2000).

Since wheat flour is one of the essential foods that is consumed in Iraqis daily lives, the desire to establish a national baseline of radioactivity exposure from different types of wheat flour samples that available in Iraq markets is very critical. Wheat flour is a powder made from the grinding of wheat used for human consumption. Wheat flour, the “Staff of Life”, has been an essential commodity to human existence through the centuries and is currently the most widely consumed staple food. Moreover, numerous studies were conducted worldwide to investigate natural radionuclides in food consumed in different parts of the world (Hosseini et al. 2006; Jibiri & Okusanya 2008; Ababneh et al. 2009; Desimoni et al. 2009). For a systematic treatment, a methodical approach is undertaken that focuses on a wheat flour type of food per study. Because wheat flour is popular among all ages, the current study

* Correspondence: ali.alhameedawi@uokufa.edu.iq
Department of Physics, Kufa University, Faculty of Science, Kufa, Iraq

focuses on investigating the natural radioactive content in all times of food.

Material and methods

Sample collection and preparation

Twelve samples of the most available types of flour were collected from the local markets in Iraq to measure natural activity. The types of samples are listed in Table 1. After collection, each flour sample was kept in a plastic bag and labeled according to its name. All of wheat flour samples were weighed and then dried in an oven at 105°C overnight and reweighed to find the water content. The samples were crushed and were made to pass through a 0.5-mm sieve. Sieved samples were weighed and a mass of 600 g of each sample was placed in a plastic container. The plastic containers were hermetically sealed with adhesive tape for 30 days for secular equilibrium to take place (Nasim et al. 2012).

Measurement system

Natural radioactivity levels were measured using a gamma spectrometer which includes gamma multichannel analyzer equipped with NaI(Tl) detector of (3″ × 3″) crystal dimension as Figure 1. The gamma spectra were analyzed using the ORTEC Maestro-32 data acquisition and analysis system. An energy calibration for this detector is performed with a set of standard gamma ray 37000 Bq active ^{137}Cs, ^{60}Co,^{54}Mn and ^{22}Na sources from USNRC and State License Expert Quantities, "Gamma Source Set", Model RSS- 8. The detector had coaxial closed-facing geometry with the following specifications: The calculated resolution is 7.9% for energy of 661.66 keV of ^{137}Cs standard source. Relative efficiency at 1.33 MeV ^{60}Co was 22% and at 1.274 MeV ^{22}Na was 24%. The lowest limit of detection (LLD) for ^{238}U, ^{232}Th and ^{40}K were 10.86 Bq/kg, 0.569 Bq/kg and 0.0261 Bq/kg respectively. The detector was shielded by a cylindrical lead shield in order to achieve the lowest background level. An energy calibration for this detector was performed with a set of standard γ-ray 37000 Bq active ^{137}Cs, ^{60}Co,^{54}Mn, and ^{22}Na sources. In this study, the activity concentration of ^{40}K was determined directly from the peak areas at 1460 keV. The activity concentrations of ^{238}U and ^{232}Th were calculated assuming secular equilibrium with their decay products. The gamma transition lines of ^{214}Bi (1765 keV) were used to calculate activity concentration of radioisotope in the ^{238}U-series. The activity concentrations of radioisotope in the ^{232}Th-series were determined using gamma transition lines of ^{208}Tl (2614 keV). The counting time for each sample was at 18000 sec.

Table 1 Types and origin of wheat flour samples in this study

No.	Sample code	Name of Samples	Origin of samples
1	F1	Good sentences	Lebanon
2	F2	Fine semolina	Saudi Arabia
3	F3	Altunsa	Turkey
4	F4	Sirage	Turkey
5	F5	Barrash	Turkey
6	F6	Rehab	IRAQ
7	F7	Sankar	Turkey
8	F8	Super	Turkey
9	F9	Donya	Turkey
10	F10	Suphan	Turkey
11	F11	Farina	Turkey
12	F12	Sayf	Turkey

Figure 1 Block diagram of the equipment's set up of NaI(Tl) detector.

Calculation of activity

Since the counting rate is proportional to the amount of the radioactivity in a sample, the Activity Concentration (*Ac*) which can be determined as a specific activity as the follows (Maduar & Junior 2007):

$$\mathbf{A}_{\mathrm{C}} = \frac{\mathrm{C} - \mathbf{BG}}{\varepsilon\,{}^{o}\!/_{c}\,\mathrm{MtI}_{\gamma}} \tag{1}$$

Where Ac is the specific activity in (Bq/kg), C is the area under the photo peaks, ε% : Percentage of energy efficiency. I_γ is the percentage of gamma-emission probability of the radionuclide under consideration, t is counting time in (Sec.), M is mass of sample in (kg) and BG is background.

Radium equivalent activity

Radium equivalent activity (Ra_{eq}) is used to assess the hazards associated with materials that contain ^{238}U, ^{232}Th and ^{40}K in Bq/kg (Nasim et al. 2012), which is, determined by assuming that 370 Bq/kg of ^{226}Ra or 260 Bq/kg of ^{232}Th or 4810 Bq/kg of ^{40}K produce the same γ dose rate. The

Ra_{eq} of a sample in (Bq/kg) can be achieved using the following relation (Nasim et al. 2012; Singh et al. 2005; Yu et al. 1992):

$$\mathbf{Ra_{eq}(Bq/kg) = A_U + (1.43 \text{ x } A_{Th}) + (A_k \times 0.077)} \quad (2)$$

Internal hazard index

This hazard can be quantified by the internal hazard index (H_{in}) (Nasim et al. 2012; El-Arabi 2007; Quindos et al. 1987). This is given by the following equation:

$$\mathbf{H_{in} = (A_U/185) + (A_{Th}/259) + (A_K/4810)} \quad (3)$$

The internal hazard index should also be less than one to provide safe levels of radon and its short-lived daughters for the respiratory organs of individuals living in the dwellings.

Ingestion effective dose

The Ingestion effective dose due to the intake of ^{238}**U**, ^{233}Th and ^{40}K in foods can be evaluated using the following expression: (ICRP 1995; Janet Ayobami 2014).

$$H_{T,r} = \sum_i (U_i * C_{i,r}) * g_{T,r} \quad (4)$$

where, i denotes a food group, the coefficients Ui and $C_{i,r}$ denote the consumption rate (kg/y) and activity concentration of the radionuclide r of interest (Bq/kg), respectively, and $g_{T,r}$ is the dose conversion coefficient for ingestion of radionuclide r (Sv/Bq) in tissue T. For adult members of the public, the recommended dose conversion coefficient $g_{T,r}$ for ^{40}K, ^{226}Ra(^{238}U), and ^{232}Th, are 6.2×10^{-9}, 2.8×10^{-7} and 2.2×10^{-7} Sv/Bq respectively (IAEA 1996).

The average consumption rate of wheat flour according to report of ministry of trade in Iraq for adults is 110 Kg/y (Source : The Iraqi Ministry of Trade).

Results and discussion

The specific activity due to ^{238}U, ^{232}Th and ^{40}K in different kinds of wheat flour samples has been measured as shown in Table 2. The specific activity of ^{238}U was found in the range of (1.086 ± 0.0866) Bq/kg to (12.532 ± 2.026)Bq/kg with an average (6.603 ± 3.715) Bq/kg, ^{232}Th from (0.126 ± 0.066)Bq/kg to (4.298 ± 0.388)Bq/kg with an average (1.9465 ± 1.331)Bq/kg and ^{40}K from (41.842 ± 5.875) Bq/kg to (264.729 ± 3.843)Bq/kg with an average (133.097 ± 67.044) Bq/kg.

There is a variation in the specific activity of radionuclides in different wheat flour samples, for example (F1) which is Turkish Farina has lowest ^{238}U concentration, while (F11) which is Lebanese Good sentences has the maximum value, (F8) Turkish Super has the lowest ^{232}Th concentration while the maximum is (F7) also Turkish Sankar , and the lowest ^{40}K concentration is (F8) which is Turkish Super and the maximum is (F2) Saudi Arabia Fine semolina. The results obtained show that the specific activity of ^{238}U, ^{232}Th and ^{40}K in all wheat flour samples appeared lower than recommended limit of UNSCEAR (United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) 2008).

The radiation hazard indices (radium equivalent activity and internal hazard indices) were calculated for all samples in this study as shown in Table 3).The radium equivalent activity internal hazard indices were varied from (3.4031) to (35.1523) with an average (19.6347 ± 9.1680) and from

Table 2 Specific activity of ^{238}U, ^{232}Th and ^{40}K in wheat flour samples

Sample Code	Specific activity in (Bq/Kg)		
	^{238}U	^{232}Th	^{40}K
F1	1.086 ± 0.0866	3.411 ± 0.322	179.089 ± 3.187
F2	9.991 ± 1.715	3.340 ± 0.356	264.729 ± 3.843
F3	3.391 ± 2.241	0.796 ± 0.504	96.509 ± 2.446
F4	5.102 ± 1.861	2.462 ± 0.475	120.555 ± 5.5134
F5	2.243 ± 2.303	1.646 ± 0.394	47.805 ± 5.025
F6	6.599 ± 1.852	1.375 ± 0.655	100.892 ± 6.289
F7	11.078 ± 2.848	4.298 ± 0.388	79.767 ± 6.499
F8	BLD	0.126 ± 0.066	41.842 ± 5.875
F9	6.048 ± 1.526	1.561 ± 0.664	109.061 ± 6.643
F10	6.196 ± 3.127	1.652 ± 0.684	191.549 ± 7.006
F11	12.532 ± 2.026	2.685 ± 0.573	175.257 ± 6.510
F12	6.370 ± 2.307	BLD	190.104 ± 7.876
Average ± S.D	**6.603 ± 3.715**	**1.9465 ± 1.331**	**133.097 ± 67.044**

Table 3 Radium equivalent activity and internal hazard index in wheat flour samples

Sample code	Ra_{eq} (Bq/kg)	H_{in}
F1	28.3442	0.1027
F2	35.1523	0.1219
F3	11.9621	0.0414
F4	17.9069	0.0621
F5	8.2789	0.0284
F6	16.3357	0.0619
F7	23.3670	0.0931
F8	3.4031	0.0091
F9	16.6801	0.0614
F10	23.3093	0.0797
F11	29.8681	0.1145
F12	21.0081	0.07395
Average ± S.D	**19.6347 ± 9.1680**	**0.0708 ± 0.0341**

Table 4 Ingestion effective dose for adult in wheat flour samples

Sample Code	Ingestion effective dose (mSv/y)			
	^{238}U	^{232}Th	^{40}K	Sum
F1	0.0334	0.0863	0.1221	0.2419
F2	0.3077	0.0845	0.1805	0.5728
F3	0.1044	0.0201	0.0658	0.1904
F4	0.1571	0.0623	0.0822	0.3016
F5	0.0691	0.0416	0.0326	0.1433
F6	0.2032	0.0348	0.0688	0.3068
F7	0.3412	0.1087	0.0544	0.5043
F8	BLD	0.0032	0.0285	0.0317
F9	0.1863	0.0395	0.0743	0.3001
F10	0.1908	0.0418	0.1306	0.3633
F11	0.3859	0.0679	0.1195	0.5734
F12	0.1962	BLD	0.1297	0.3258
Average ± S.D	**0.1978 ± 0.1066**	**0.0537 ± 0.0317**	**0.0908 ± 0.0457**	**0.3213 ± 0.1657**

(0.0091) to (0.1219) with an average (0.0708 ± 0.0341) respectively.

The values of all the radiation hazard indices in this study (radium equivalent activity and internal hazard indices are lowest value in sample (F8) Turkish Super and the highest value in sample (F2) Saudi Arabia Fine semolina. This indicates that the internal hazard index in wheat flour samples were lower than the permissible limits of 1 recommended by UNSCEAR (UNSCEAR 2000), while the radium equivalent activity also were lower than the maximum permissible level of 370 Bq/kg recommended by UNSCEAR (UNSCEAR 2000).

Table 4 shows the results of the Ingestion effective dose in (mSv/y) for adult due to specific activity of ^{238}U, ^{232}Th and ^{40}K in wheat flour samples which it is calculated using Eq. (4). The range of summation of the Ingestion effective dose were varied from (0.0317) mSv/y (at sample F8) to (0.5734) mSv/y (at sample F11) with an average (0.3213 ± 0.1657) mSv/y, but Figure 2 shows the compare between average of the Ingestion effective dose for ^{238}U, ^{232}Th and ^{40}K in wheat flour samples which obtain the average of Ingestion effective dose due to ^{238}U was higher than due to ^{232}Th and ^{40}K because of the increased the dose conversion coefficient for ingestion of radionuclide. This indicates that the Ingestion effective dose in all wheat flour samples were lower than the permissible limits of 1 mSv/y recommended by ICRP (ICRP 1996).

Conclusion

The present study has presented the specific activity of radionuclides ^{238}U, ^{232}Th and ^{40}K using gamma ray spectroscope in different type of wheat flour that are regularly consumed by adults age in Iraq. Specific activity concentrations of these radionuclides in samples were lower than as reported by UNSCEAR. Also the radium equivalent activity and internal hazard indices values obtained when compared with the world permissible values were found to be below the standards limit which due to be radiologically hazard safe. The high value of summation of Ingestion effective was less than 1 mSv/y, the limit recommended for the public (ICRP 1996), hence wheat flour samples in Iraq markets products are safe to consumers.

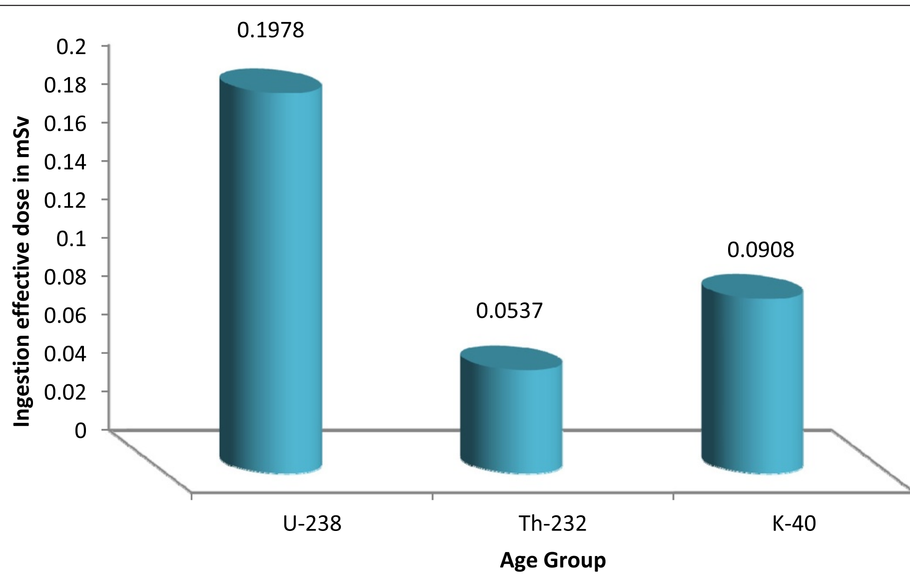

Figure 2 Ingestion effective dose in wheat flour samples.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
AAA and HHA-G carried out the Nuclear radiation studies, participated in the sequence alignment and drafted the manuscript. SHK collected and arranged wheat flour samples, also contributed to the collection of references of scientific. All authors read and approved the final manuscript.

Acknowledgements
I would like to knowledge all those contributed in declaring this issue. Special thanks to the staff of the department of physics at Kufa University.

Received: 25 June 2014 Accepted: 31 October 2014
Published online: 05 December 2014

References
Ababneh ZQ, Alyassin AM, Aljarrah KM, Ababneh AM (2009) Measurement of natural and artificial radioactivity in powdered milk consumed in Jordan and estimates of the corresponding annual effective dose. Radiat Prot Dosimetry 138:278–283
Desimoni J, Sives F, Errico L, Mastrantonio G, Taylor MA (2009) Activity levels of gamma-emitters in Argentinean cow milk. J Food Compos Anal 22:250–253
El-Arabi A (2007) ^{226}Ra, ^{232}Th and ^{40}K concentrations in igneous rocks from eastern desert, Egypt and its radiological implication. Radiation Measurement 42:94–100
Hosseini T, Fathivand AA, Abbasisiar, Karimi M, Barati H (2006) Assessment of annual effective dose from U-238 and Ra-226 due to consumption of foodstuffs by inhabitants of Tehran city, Iran. Radiat Prot Dosim 121:330–332
IAEA (1996) International Atomic Energy Agency, International Basic Safety Standard for Protection against Ionizing Radiation and for the Safety of Radiation Sources. Series No. 115, International Atomic Energy Agency (IAEA), Vienna
IAEA, International Atomic Energy Agency (1989) Measurement of Radionuclides in Food and the Environment. Technical Report Series No. 295, Vienna
ICRP (1995) Age-dependent Doses to the Members of the Public from Intake of Radionuclides - Part 5 Compilation of Ingestion and Inhalation Coefficients. ICRP Publication 72. Annex ICRP 26 (1)
ICRP (1996) International Commission on Radiological Protection, Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilations of In-gestion and Inhalation Dose Coefficients (ICRP Publica-tion 72)". Pergamon Press, Oxford
Janet Ayobami A (2014) Estimation of Annual Effective Dose Due to Ingestion of Natural Radionuclides in Cattle in Tin Mining Area of Jos Plateau, Nigeria. Nat Sci 6:255–261
Jibiri NN, Okusanya AA (2008) Radionuclide contents in food products from domestic and imported sources in Nigeria. J Radiol Prot 28:405–413
Maduar M, Junior P (2007) Gamma Spectrometry In the Determination of Radionuclides Comprised In Radioactivity Series, International Nuclear Atlantic Conference-INC. Santos SP, Brazil
Nasim A, Sabiha J, Tufail M (2012) Enhancement of natural radioactivity in fertilized soil of Faisalabad, Pakistan. Environ SciPollut Res 19:3327–3338
Quindos L, Fernandez P, Soto J (1987) Building materials as source of exposure in houses. In: Seifert B, Esdorn H (eds) Indoor Air 87. Institute of Water, Soil and Air Hygiene, Berlin, p 365
Singh S, Rani A, Mahajan R (2005) ^{226}Ra, ^{232}Th and ^{40}K analysis in soil samples from some areas of Punjab and Himachal Pradesh, India using gamma ray spectrometry. Radiation Measurement 39:431–439
United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) (2008) Report to the General Assembly. Sources and Effects of Ionizing Radiation, New York
UNSCEAR (2000) Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation Effects of Atomic Radiation. Report to the General Assembly with annexes. United Nations, New York
Yu K, Guan Z, Stoks M, Young E (1992) The assessment of natural radiation dose committed to the Hong Kong people. J Environ Radioact 17:31–48

doi:10.1186/s40550-014-0006-7
Cite this article as: Abojassim et al.: Estimated the radiation hazard indices and ingestion effective dose in wheat flour samples of Iraq markets. *International Journal of Food Contamination* 2014 1:6.