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Assessment of Health Risk of Exposure to Alpha-Emitters in Cheese Samples Collected from Iraqi Markets

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ABSTRACT

In this research, alpha-emitter concentrations of ^{222}Rn, ^{226}Ra, and ^{238}U in Iranian, Turkish, Egyptian, Saudi Arabian, and Iraqi canned cheeses that are available in Iraqi markets were measured using the CR-39 detector. Also, the health risk parameters associated with the ingestion of alpha-emitter radionuclides, such as the annual average internal effective dose (AAIED) and the risk of an excess cancer fatality per million persons (RECFPMP), were calculated. The results show that the average values of ^{222}Rn, ^{226}Ra, and ^{228}U concentrations for all samples in the present study were 3.7±0.38 Bq/m^3, 25.24±2.63 mBq/kg, and 0.025±0.002 ppm, respectively. The average values of AAIED and RECFPMP were 0.175±0.018 μSv/y and 0.674±0.070, respectively. The results show that the highest value of alpha-emitters as well as health risk parameters were found in cheese samples produced in Saudi Arabia, while the lowest results were found in Egyptian samples. They were, nevertheless, less than the permissible value and the risk value. According to the current study, the consumption of those cheese products poses no health risks.

INTRODUCTION

Naturally occurring radioactive materials, also known as NORMs, are an integral part of our lives and will remain so for the foreseeable future. Almost everything on our planet and its atmosphere, as well as the human body, contains NORMs [1]. Radioactive contamination of the natural environment is a global concern because they have adverse effects on living organisms in varying quantities [1]. Typically, radionuclides found in nature are divided into two distinct groups: cosmogenic or extraterrestrial radionuclides produced by high-energy cosmic rays and particles (from the sun, stars, and interstellar plasma) incident on the atmosphere of the earth, and terrestrial radionuclides from the crusts of the Earth. Natural radioactivity is the result of the decay of natural radionuclides ^{232}Th, ^{235}U, and ^{238}U, which are the basis for the presence of the secondary radioactive isotopes such as bismuth, lead, astatine, radon, polonium, protactinium, radium, and francium [2].

Radon is a natural radioactive gas. It has a half-life of 3.85 days, which is sufficient for it to pass into the soil or the atmosphere. [3]. People are exposed to radon everyday due to the natural decay of uranium in soil and rocks. [1]. The International Agency for Research on Cancer classified radon as a dangerous, carcinogenic material [4], and research efforts have focused on understanding the effect of this gas on human health [4]. Ingestion and inhalation are the primary ways of entering radionuclides into the human body. In addition to transitioning through open wounds [4], eating food or drinking water can be associated with the ingestion of radionuclides.

Generally, plants acquire radionuclides through roots or leaves, or through aerial depositions, while animals acquire radionuclides from consumption of these plants and from aerial depositions as well. Human beings are exposed to radionuclides in multiple ways. They receive the radionuclides from plant and animal sources,

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airborne depositions, and soil. Radiation has the greatest downstream impact on humans. The natural nutritional components of cheese, such as proteins, minerals, and vitamins, make it a highly important food item in human daily diet [5]. Cheese can be contaminated by one of the most significant and complicated pollutants, which are alpha-emitters [6]. Dairy contamination occurs primarily when milk-producing animals ingest contaminants or when contamination happens during milk production. In various parts of the world, alpha-emitters in cheese samples were studied in various ways using a variety of experimental techniques [7-10]. The objectives of this study were to measure the alpha-emitter concentrations in cheese samples from Iran, Turkey, Egypt, Saudi Arabia, and Iraq found in Iraqi markets using CR-39 detectors and compare the results to those allowed within the global limit.

METHODOLOGY

Fifty-seven cheese samples were collected from several markets in Iraq. The cheeses were produced in different country of origin, such as Iran (15 samples), Turkey (15 samples), Egypt (9 samples), Saudi Arabia (9 samples), and Iraq (9 samples). The cheese samples were placed in a plastic container, on which information data such as name of brand, country, and sample code number, as well as exposure period, were registered. After the collection process was completed, the samples were transferred to the nuclear laboratory at the University of Kufa for measurements of alpha-emitters. For the purpose of measurement, there are many steps for propagating samples as follows: drying the cheese samples for about 24 hours at room temperature, grinding using an electric mill, weighing 28 g of sample using a high-precision sensitive scale, then putting them in a plastic container with a length of 7 cm and a radius of 4.3 cm, and storing the container for 30 days to obtain radiation balance [11]. To measure radon concentrations, a CR-39 detector with a width of 1 mm and a 2.5×2.5 cm^2 (from Track Analysis Systems Ltd., UK) was fixed at the top end of a plastic cup of cheese sample. After the exposure period, which is 72 days, the chemical etching was carried out by putting the CR-39 detector in a beaker containing the prepared chemical agent solution. After immersing the detector, the beaker was heated in a water bath (type HH-420, Germany) at a temperature of 98°C for 1 hour [12]. In this step, the beaker is sealed tightly to prevent any changes in NaOH (6.25 N) concentrations due to evaporation. Once the chemical etching process is finished, the detectors are washed carefully using distilled water and then dried for 15 minutes. In this work, cheese samples were microscopically treated with TASLIMAGE technology to measure radon concentrations.

CALCULATIONS

Radon (^{222}Rn) concentrations in the airspace of the tube (C) and within the sample (C_{Rn}) were determined using Eqs. (1) and (2), respectively [13,14].

$$C\left(\frac{Bq}{m^3}\right) = \frac{\rho}{K\,T} \quad (1)$$

$$C_{Rn}\left(\frac{Bq}{m^3}\right) = \frac{C\,\lambda_{Rn}\,h\,T}{L} \quad (2)$$

where ρ is the track density, K is the calibration factor (0.28±0.043 Track.cm^{-2}/Bq.m^{-3}.day), T is the time exposure (72 days), λ_{Rn} is the decay constant for ^{222}Rn, h is the distance between the sample and the detector, and L is the sample thickness in the plastic cup. The calibration factor of the CR-39 detector was detemined using ^{226}Ra source with activity 6600 Bq which it is ^{222}Rn source. Then, slope of curve (calibration factor) was calculated using the relation between the radon exposure (at different irradiation time 0.5, 1, 1.5, 2, 2.5, and 3 days) and ρ (track density in CR-39 detectors that corresponds to irradiation time).

^{226}Ra activity within the sample (C_{Ra}) was determined using Eq. (3) [15].

$$C_{Ra}\left(\frac{Bq}{kg}\right) = \frac{C\,h\,A}{M} \quad (3)$$

where A is the surface area of the sample and M is the weight of the sample.

As shown in Eq. (4), concentrations of ^{238}U are calculated by dividing the molecular weight of uranium-238 (M_U) by the weight of the sample (M) [16-18].

$$C_U(ppm) = \frac{M_U}{M} \quad (4)$$

For the calculation of the health risk parameters for alpha-emitter radionuclides, such as the annual average internal effective dose (AAIED) and the risk of an excess cancer fatality per million persons (RECFPMP), Eqs. (5) and (6) were used, respectively [17-20].

$$AAIED\left(\frac{nSv}{y}\right) = A \times I \times CF \quad (5)$$

$$\text{RECFPMP} = AAIED \times DL \times RF \quad (6)$$

where A is the activity for radon-222, radium-226, and uranium-238 in Bq/kg, I is the daily consumption rate (in this take 22 g/day) [21], CF is the conversion factor for radon-222, radium-226, and uranium-238 ingestion by people as 3.5 nSv/Bq, 280 nSv/Bq, and 45 nSv/Bq [22], DL is the duration time (70 year), and RF is the conversion factor (0.05) [23].

RESULTS AND DISCUSSION

Table 1 presents the radon-222, radium-226, and uranium-238 concentrations in cheese samples that were produced in Iran, Turkey, Egypt, Saudi Arabia, and Iraq obtained in Iraqi markets. The range of radon concentrations in the airspace of the tube (C) in Iranian, Turkish, Egyptian, Saudi Arabian, and Iraqi samples varies from 0.58 Bq/m^3 to 9.84 Bq/m^3 with an average value of 3.22±0.73 Bq/m^3, from 0.58 Bq/m^3 to 9.84 Bq/m^3 with an average value of 4.25±0.71 Bq/m^3, from 1.16 Bq/m^3 to 5.21 Bq/m^3 with an average value of 3.00±0.50 Bq/m^3, from 0.58 Bq/m^3 to 13.89 Bq/m^3 with an average value of 4.43±1.35 Bq/m^3, and from 0.58 Bq/m^3 to 8.68 Bq/m^3 with an average value of 3.53±0.86 Bq/m^3, respectively. Also from the same table, the range of radium activity (C_{Ra}) in mBq/kg for Iranian samples were 3.96-67.13 with an average value of 21.97±5.04, for Turkish samples were 3.96-67.13 with an average value of 28.99±4.87, for Egyptian samples were 7.92-35.54 with an average value of 20.52±3.46, for Saudi Arabian samples were 3.96-94.76 with an average value of 30.26±9.22, and for Iraqi samples were 3.96-59.22 with an average value of 24.13±5.89. While, the range with average values of uranium (C_U) concentrations in unit ppm for Iranian, Turkish, Egyptian, Saudi Arabian, and Iraqi canned cheese samples were 0.004-0.065 with an average value of 0.021±0.004, 0.004-0.065 with an average value of 0.028±0.004, 0.008-0.035 with an average value of 0.020±0.003, 0.004-0.092 with an average value of 0.029±0.008, and 0.004-0.058 with an average value of 0.023±0.005, respectively. The AAIED and RECFPMP due to the ingestion of radionuclides (^{222}Rn, ^{226}Ra, and ^{238}U) were calculated for all samples in the present study as shown in Table 2. It is found that, for Iranian samples, the average values of AAIED in units of µSv/y due to ^{222}Rn, ^{226}Ra, and ^{238}U were 0.007±0.001, 0.049±0.011, and 0.095±0.021, for Turkish samples were 0.009±0.001, 0.065±0.010, and 0.126±0.021, and for Egyptian samples were 0.007±0.001, 0.046±0.007, and 0.089±0.015, while for Saudi Arabian samples were 0.010±0.003, 0.067±0.020, and 0.131±0.040, and for Iraqi samples were 0.008±0.002, 0.054±0.013, and 0.104±0.025, respectively. Furthermore, the average values of total AAIED in Iranian, Turkish, Egyptian, Saudi Arabian, and Iraqi samples were 0.153±0.034, 0.201±0.033, 0.141±0.024, 0.210±0.064, and 0.167±0.040, respectively. The average RECFPMP values associated with the intake of radon-222, radium-226, and uranium-238 in Iranian, Turkish, Egyptian, Saudi Arabian, and Iraqi samples were 0.588±0.133, 0.774±0.129, 0.547±0.092, 0.807±0.245, and 0.644±0.156, respectively.

Table 1. Results of alpha-emitters in cheese samples of the present study.

Country of Origin	Values	^{222}Rn (Bq/m^3)	^{226}Ra (mBq/kg)	^{238}U (ppm)
Iran	Range	0.58-9.84	3.96-67.13	0.004-0.065
	Average±S.E	3.22±0.73	21.97±5.04	0.021±0.004
Turkey	Range	0.58-9.84	3.96-67.13	0.004-0.065
	Average±S.E	4.25±0.71	28.99±4.87	0.028±0.004
Egypt	Range	1.16-5.21	7.92-35.54	0.008-0.035
	Average±S.E	3.00±0.50	20.52±3.46	0.020±0.003
Saudi Arabia	Range	0.58-13.89	3.96-94.76	0.004-0.092
	Average±S.E	4.43±1.35	30.26±9.22	0.029±0.008
Iraq	Range	0.58-8.68	3.96-59.22	0.004-0.058
	Average±S.E	3.53±0.86	24.13±5.89	0.023±0.005

Table 2. Results of AAIED and RECFPMP due to alpha-emitters in cheese samples of the present study.

Country of Origin	Values	AAIED (µSv/y)				RECFPMP
		^{222}Rn	^{226}Ra	^{238}U	Total	
Iran	Range	0.009-0.151	0.017-0.292	0.03-0.47	0.11-1.79	0.009-0.151
	Average±S.E	0.007±0.001	0.049±0.011	0.095±0.021	0.153±0.034	0.588±0.133
Turkey	Range	0.009-0.151	0.017-0.292	0.03-0.47	0.11-1.79	0.009-0.151
	Average±S.E	0.009±0.001	0.065±0.010	0.126±0.021	0.201±0.033	0.774±0.129
Egypt	Range	0.003-0.012	0.018-0.080	0.034-0.154	0.05-0.25	0.21-0.95
	Average±S.E	0.007±0.001	0.046±0.007	0.089±0.015	0.141±0.024	0.547±0.092
Saudi Arabia	Range	0.001-0.032	0.009-0.213	0.017-0.412	0.03-0.66	0.11-2.53
	Average±S.E	0.010±0.003	0.067±0.020	0.131±0.040	0.210±0.064	0.807±0.245
Iraq	Range	0.001-0.020	0.009-0.133	0.017-0.257	0.03-0.41	0.11-1.58
	Average±S.E	0.008±0.002	0.054±0.013	0.104±0.025	0.167±0.040	0.644±0.156

The descending order of alpha-emitters in cheese samples according to the origin of the country is Saudi Arabia > Turkey > Iraq > Iran > Egypt (Fig. 1), respectively, but according to the Nova-test, there is no significant value($p > 0.05$).

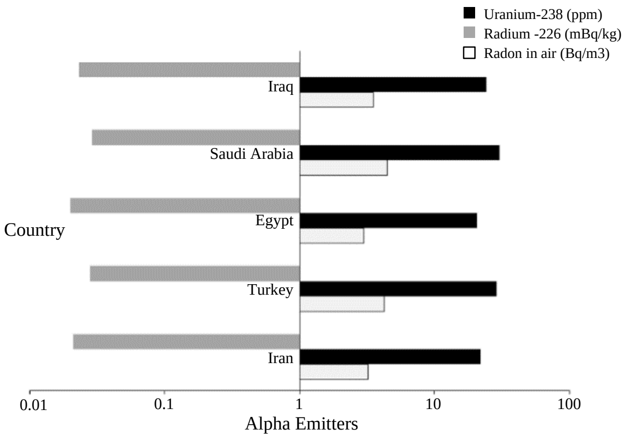

Fig. 1. Comparison of alpha-emitters in cheese originally from several countries.

The variation values in alpha-emitters can be attributed to numerous components of these cheeses as they were of animal origins. Cheese can be contaminated by radioactivity (alpha-emitters) either by the contaminants that are ingested by animals from plants, which depend on the natural soil crust, the plant itself, and the fertilizer, or because of the direct contamination of cheese by radiation, which can also be caused by the absorption of radionuclides from the atmosphere. Consequently, the radiation pollution from the plant is highly anticipated. However, the concentrations of radon for all of the measured cheese samples were less than the accepted lower limit of the action level, which is 39 Bq/m^3 according to the Code of Federal Regulations (CRF) [24]. Also, the results of other alpha-emitters (radium-226 and uranium-238) concentrations were lower than the maximum level of the world average, which equals 30 Bq/kg for radium-226 and 11.7 ppm for concentrations of uranium-226 according to the UNSCEAR [22]. For five countries in the present study, the results of AAIED and RECFPMP appeared to be in the following order: Saudi Arabia > Turkey > Iraq > Iran > Egypt (Fig. 2). Nonetheless, the results of AAIED for all cheese samples that were collected from Iraqi markets were within UNSCEAR's 0.29 mSv/y recommendation for ingestion exposure to natural sources [22,25]. RECFPMP were also below the lower limit of the range (170-230) per million persons recommended by the International Commission on Radiological Protection [25]. Therefore, the values of RECFPMP are insignificant, and therefore, it can be decided that the risk of cancer is negligible.

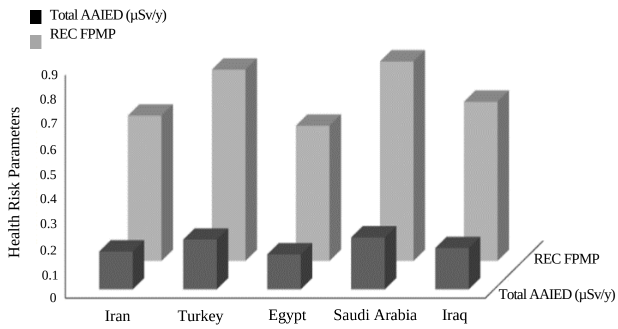

Fig. 2. Comparison of health risk parameters in different country of origin.

Finally, the average values of C, C_{Ra}, C_U, total AAIED, and RECFPMP in all of the cheese samples in the present study were 3.7±0.38 Bq/m^3, 25.24±2.63 mBq/kg, 0.025±0.002 ppm, 0.175±0.018 µSv/y, and 0.674±0.070, respectively. Indeed, the current study is considered the first attempt to evaluate the risk that is related to the presence of alpha-emitters in cheese samples in Iraqi markets. It is found that the alpha-emitters as well as the health risk parameters in the samples under study were low and insignificant from a health hazard point of view.

Table 3 shows a comparison between the specific activity results of ^{226}Ra and ^{238}U concentrations in cheese samples that were collected from Iraqi markets with several countries around the world. In the current study, the average values of ^{226}Ra were lower than the values determined in other studies presented in table, except in the Italian and Sarajevo studies, while the average values of ^{238}U were lower than the values determined in other studies presented in the same table, except in the Italian and Sarajevo studies.

Table 3. Comparison of the present study to other studies from various countries.

Country	^{226}Ra (Bq/kg)	^{238}U (ppm)	References
Slovenia	0.11	0.354	[26]
Hungary	0.2	0.2	[27]
Italy	0.015	0.002	[28]
Sarajevo	0.014	0.01	[29]
Iran	0.021	0.26	
Turkey	0.028	0.34	
Egypt	0.02	0.24	Present Study
Saudi Arabia	0.03	0.36	
Iraq	0.024	0.29	

CONCLUSION

The results of alpha particle levels (^{222}Rn, ^{226}Ra, and ^{238}U) and health risk parameters associated with the ingestion of alpha-emitter radionuclides (AAIED and RECFPMP) revealed that consumption of current cheese samples in Iraqi markets for all groups (Iranian, Turkish, Egyptian, Saudi Arabian, and Iraqi) does not result in significant changes in internal radiation dose and does not pose a health risk to those who consume these cheeses.

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AUTHOR CONTRIBUTION

All authors discussed the results and contributed to the final manuscript. R. R. Muneam carried out the experiment. A. A. Abojassim wrote the manuscript. All authors read and approved the final version of the paper.

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