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Estimation of Radon Exhalation Rate, Radium Activity and Uranium Concentration in Biscuit Samples in Iraq

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ABSTRACT

Introduction: Radioisotopes are naturally the main sources of human exposure to external and internal radiation. Biscuit is a type of food that is widely distributed in all markets, especially in the markets of Iraq. Therefore, the current study aimed to measure the radiation level of some nuclei in biscuit samples and determine the radiation risks that may be caused by this snack.

Material and Methods: This study aimed to evaluate the concentration of alpha radiation activity in 22 different samples of biscuits collected from the markets in Iraq. The analysis of radium activity and radon exhalation rate was performed by employing alpha-sensitive CR-39 plastic track detectors.

Results: The effective radium values ranged within 23.312-200.44 Bq/kg with a mean value of 58.927 Bq/kg. Radon emission values for the mass unit was within the range of 0.172-1.515 Bq/kg.h, with a mean of 0.445 Bq /kg.h, while radon emission values for the surface unit were 3.988-34.3 $Bq\ /m^2$.h, with a mean of 10.081 Bq /m^2.h. The uranium concentrations found in these samples were within the range of 0.02-0.172 ppm with a mean value of 0.05 ppm. Moreover, there was a direct relationship between radium activity and radon exhalation rate. Additionally, the findings showed that uranium correlated positively with radium activity.

Conclusion: The results of the present study were within internationally permissible limits. Therefore there is no risk of consumption of biscuits on human health. However, we must use modern techniques and techniques to reduce radiation risk.

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Introduction

Radon is found in three radioactive isotopes in the natural environment, namely radon (^{222}Rn, 3.82 days), thoron (^{220}Rn, 55 seconds), and action (^{219}Rn, 4 seconds). Considering radon problems, it is believed that the thoron and actinon isotopes, as well as their daughters, have been ignored by researchers when studying the radon problem [1, 2]. Radon is produced directly from radium (^{226}Ra), which has a half-life of 1600 years. Direct radon is radium (^{226}Ra), with a half-life of 1600 years, which spreads widely, especially in materials that are made of metal products. The decomposition of uranium (^{238}U), whose half-life is $4.7 \times 10^9\ years$, generates radium [3]. Generally, radon enters water when the water is pumped into the well. In this case, radon flows through the groundwater by passing through the rocks and the soil which contain the radioactive materials [4].
Natural isotopes are the main sources of human exposure to external and internal radiation. In the first place, terrestrial radioisotopes, such as thorium, uranium, and potassium mostly enter the human body by eating foods; however, they are absorbed less when they are inhaled [5]. Therefore, there is a need to study natural radiation activity in the surrounding environment in order to obtain the current levels of radioactive pollutants that are discharged into the living environment or organisms [6]. The information resulting from the behaviour of natural radionuclides can be used as a parameter to assess the radiological activity of the environment [7]. Food contamination depends on a number of factors, including the type of the soil, its characteristics, the physical and chemical components of the radionuclides in the soil, the absorption of radionuclides by a particular plant, and the amount of the accumulation of certain nutrients [8]. Human exposure to high concentrations of alpha radiation primarily from radon for a long time leads to dissatisfactory effects, such as dysfunctional changes in the respiratory tract and lung cancer [9]. Radioactive material emitted from alpha particles

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damages the natural tissues of the human body due to its high attenuation. On the other hand, alpha residues, such as uranium, thorium, and their daughter are consumed in small quantities by living organisms through their food chain and environment [10]. The accumulated uranium in humans has a detrimental effect because of its chemical and radiological properties. The uranium in the earth moves to water, plants, food supplements and then to the human body. According to an estimate [11], food contributes about 15% of ingested uranium, while drinking water contributes about 85%. An exposure of about 0.1 mg/kg of body weight of soluble natural uranium results in transient chemical damage to the kidneys [12].

Biscuit is a type of food that is widely distributed in all markets, especially in the markets of Iraq. It is consumed as a snack by people of different ages. The current study was conducted on 22 random biscuit samples from the markets in Iraq, which aimed to measure the radiation level of some nuclei in these samples and determine the radiation risks that may be caused by these food samples. Ingredients of biscuits include wheat flour, sugar, wheat bran, hydrogenated vegetable oil, low-fat milk powder, soy lecithin, ammonium bicarbonate salt, sodium bicarbonate, natural vanilla flavour, and water. It is worth mentioning that these 22 samples were collected from various available brands in local markets of Iraq in order to examine the radioactive activity of some radioactive nuclei, which may cause different diseases, especially cancer. This research was also targeted toward analysing the mass and surface exhalation rates of radon, radium activity, and uranium concentration in the biscuit samples because biscuit is a very common food in Iraq. This study benefited from the sealed can technique with CR-39 solid state nuclear track detectors (SSNTDs) was used in this study to analyze the data.

Materials and Methods

This study was conducted on 22 different types of biscuits available in the market of Iraq. The samples were dried and ground into in a very soft powder. Later, we took 36 grams of each sample, and stored them for four weeks in sealed cups, to reach the balance between radium and radon. The nuclear track detectors were then installed on the inner surface of each cup cap, which was quickly replaced with the original cup cover to maintain the state of the radiation balance. Afterward, all samples were sieved in a sieve with 3 mm pores. The samples were then placed in closed cups for 65 days using the sealed can technique containing the CR-39 nuclear trace detector with the thickness of 500 μm and dimensions of $1.5 \times 1.5\, cm^2$[13,14], Which is commercially marketed as CR-39, the detector was manufactured by Per shore Molding Ltd., U.K. ,where 20 g of biscuit was placed at the bottom of the cylindrical cup with a depth of 3.5. (Figure 1).

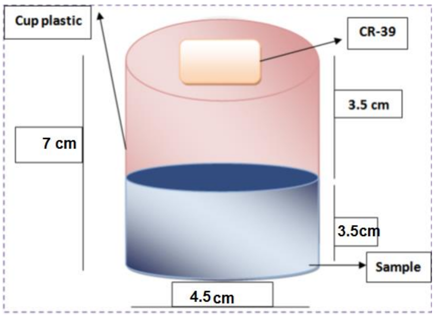

Figure 1. Experimental setup for the measurements of radium activity and radon exhalation rates in the biscuit samples.

It needs to be mentioned that the height of the cup was 7 cm and the diameter was 4.5 cm. The distance between the surface of the sample and the front face of the CR-39 remained constant at 3.5 cm, after which all the cups containing the 22 biscuit samples were closed for because decomposition of radon gas and the formation of tracks could emit alpha particles of the samples. After the sample storage period was finished, the detectors were extracted from the cultivars so that the electrochemical scraping process was performed for all the detectors. The detectors were etched in 6N NaOH solution at a temperature of 70±1°C for eight hours. For the chemical etching process, we put the detectors in a water bath (Memmert WNB22, German-made) to shape tracks resulting from the fall of the alpha particles emitted by radon and its derivatives. After this, the detectors were taken out of the water bath and then washed with distilled water. The final step was the process of counting the effects of nuclear detectors by an optical microscope (A.KRUSS, Optronic German-made). The appropriate magnification of 100X disclosed the nuclear effects of alpha particles emitted from the samples. A special lens was used to calculate the number of impacts per unit area, by dividing the surface into several squares according to the average number of effects. The tracks alpha particle on the surface of the detectors were counted manually under an optical microscope and then I went back tracks in at least 20 different locations for each detector, because the phenomenon of radiation resulting from the decomposition of radon is a random statistical phenomenon purely.

Theory

The density of the nuclear effects on the surface of the detectors can be calculated from the following equation [15]:

$$\rho = \sum_i \frac{N_i}{nA} \quad (1)$$

Where, A refers to the view section area, N_i denotes the total number of nuclear pathways, and n signifies the number of microscopic observations on the surface of the detector.

In order to calculate the levels of radon concentrations in the biscuit samples, the relationship between the radon activity density (C_{Rn}) in the aerodynamics above the samples and the density of the effects on the surface of the detectors was based on the following equation [16]:

$$\rho = KC_{Rn}T \quad (2)$$

Where, K is the calibration factor of CR-39 nuclear track detector, which equals to 0.223 Tracks.cm^{-2}.day^{-1}/Bq.m^{-3} [17]. T refers to the expose time of our samples.

In this study, an effective radiation balance (i.e., about 98%) between radium and radon had to be reached within four weeks in the decay series given that the half-life of radium and radon is 1600 y and 3.8 d, respectively. Once the auditory balance was reached, alpha-radon decomposition can be used to determine the concentration of radium activity. According to the following equation, radon concentration increases over time, after closing of the can [18]:

$$C_{Rn} = C_{Ra}\left(1 - e^{-\lambda_{Rn}T}\right) \quad (3)$$

The C_{Ra} represents the radioactive activity of the radium in the samples, λ_{Rn} signifies the constant decomposition of radioactive radon. The plastic effect detector measures the total number of the disintegration of the alpha particles in the volume unit of the can with a sensitivity K during the exposure time T calibration constant during the exposure time (T), therefore, the track density of the nuclear effects was measured by [19]:

$$\rho = KC_{Ra}T_e \quad (4)$$

The effective exposure time (T_e) can be defined as follows [20]:

$$T_e = \left[T - \lambda_{Rn}^{-1}(1 - e^{-\lambda_{Rn}T})\right] \quad (5)$$

According to the model proposed by Somogyi et al. [21], the number of radon atoms emitted from the surface of the sample is equal to the number of radon atoms in the air above the surface of the biscuit sample multiplied by the probability of decomposition. Therefore, it is given by:

$$C_s = C_{Rn}\frac{\lambda hT}{L} \quad (6)$$

Where, C_{Rn} indicates the concentration of radon in the surrounding air of the sample, λ refers to the constant decomposition of radon, h signifies the distance between the brightening of the sample and the surface of the detector, T is the total exposure time of the samples, and L indicates the height of the sample in the cup.

The radium activity of the biscuit samples can be calculated by the following formula [22-24, 19]:

$$C_{Ra}\ (Bq.\text{kg}^{-1}) = \left(\frac{\rho}{K\,T_e}\right)\left(\frac{hA}{M}\right) \quad (7)$$

Where, M refers to the mass of the biscuit samples in kg, A denotes the area of the cross-section of the can in m^2.

The radon exhalation rate for unit mass (E_M) is given by [25, 26]:

$$E_M(mBq.kg^{-1}.h^{-1}) = \frac{CV\lambda}{M[T + \lambda^{-1}(e^{-\lambda T} - 1)]} \quad (8)$$

Where, V is the effective volume of the cup in m^3.

The radon exhalation rate for a unit area (E_A) was obtained from the expression [25, 26]:

$$E_A(mBq.m^{-2}.h^{-1}) = \frac{CV\lambda}{A[T+\lambda^{-1}(e^{-\lambda T}-1)]} \quad (9)$$

Where, C indicates the integrated radon exposure expressed in Bq.m^{-3}.d.

Uranium concentrations (C_U) in biscuit samples can be calculated by using the following formula [27, 28]:

$$C_U(ppm) = \frac{W_U}{W_S} \quad (10)$$

Where, W_U is the weight of uranium in the sample and W_S refers to the weight of the samples.

Results

This study analysed 22 different samples of biscuit using a closed can technique. Table 1 shows the values of the radium activity, uranium concentrations, surface, and mass exhalation rates. As the findings of the current study indicated the values of radium activity in collected samples were within the range of 23.312-200.44 Bq/kg with a mean value of 58.927 Bq/kg. The mass exhalation rates were in the range of 0.172-1.515 Bq/kg.h with a mean value of 0.445 Bq/kg.h, while the surface exhalation rates were found to be with the range of 3.988-34.3 Bq /m^2.h, with a mean value of 10.081 Bq /m^2. h. The highest uranium concentration was 0.172 ppm in Minis Choco-Leibniz biscuit, while the lowest uranium concentration was 0.02 ppm in Mini Vanilla biscuit with a mean value of 0.05 ppm.

Figure 2 illustrates the distribution of radium activity in the different biscuit samples of Iraq, while figures 3 and 4 show a direct relationship between radium activity and radon exhalation rate in various biscuit sample $(R^2 = 1)$. This means that there was a linear relationship between radium activity and radon exhalation rate. Figure 5 demonstrates a positive correlation between uranium concentration and radium activity for the 22 biscuit samples$(R^2 = 0.9999)$. These findings provide the evidence to the fact that uranium is a good source of radium in all samples.

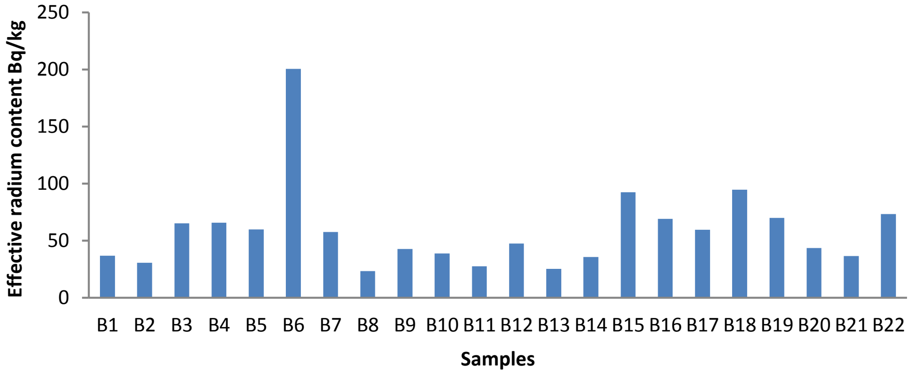

Figure 2. Radium activity for different biscuit samples (Bq/kg).

Table1. Track density, the concentration of radon, radium activity, surface and mass exhalation rates, and the concentrations of uranium for the biscuit samples.

Code	Sample Name	ρ Trak/cm^2	C_S Bq/m^3	C_{Ra} mBq/kg	E_M mBq/kg.h	E_A mBq/m^2.h	CU ppm
B1	Alshamal	316.6	21.842	36.903	0.279	6.314	0.032
B2	Petit Beurre	263.3	18.165	30.690	0.232	5.251	0.026
B3	Biscuit Narkil Shkere (Papel)	560.0	38.634	65.274	0.493	11.167	0.056
B4	Date Biscuit	563.3	38.862	65.658	0.496	11.233	0.056
B5	Stickes	513.3	35.412	59.830	0.452	10.236	0.051
B6	Minis Choco-Leibniz	1720	118.662	200.44	1.515	34.300	0.172
B7	Suamli Biscuit	493.3	34.032	57.499	0.435	9.837	0.049
B8	Mini Vanilla Biscuit	200.0	13.798	23.312	0.176	3.988	0.020
B9	Cream Biscuit With Cocao Flauour	366.6	25.291	42.731	0.323	7.311	0.037
B10	Biscuit With Cocao Cream	333.3	22.994	38.850	0.294	6.647	0.033
B11	Memories	236.6	16.323	27.578	٠.208	4.718	0.024
B12	Golden Crackers	406.6	28.051	47.393	٠.358	8.108	0.041
B13	Minw Tord namki	216.6	14.943	25.247	٠.191	4.319	0.022
B14	Fingi Biscuit	306.6	21.152	35.737	0.270	6.114	0.031
B15	sweet meal Biscuit	793.3	54.729	92.467	0.699	15.820	0.079
B16	Korovka Biscuits	593.3	40.931	69.155	0.523	11.831	0.059
B17	Petit Beurre Mange Biscuit	510.0	35.185	59.446	0.449	10.170	0.051
B18	Da Kalu	813.3	56.109	94.798	0.717	16.219	0.081
B19	New Chocolate Sandwich Biscuits	600.0	41.394	69.936	٠.529	11.965	0.060
B20	Coconut cream biscuits	373.3	25.754	43.512	٠.329	7.444	0.037
B21	Lark - Biscuits with sesame	313.3	21.614	36.518	٠.276	6.248	0.031
B22	Lark wafers with cocoa cream and hazelnut	630.0	43.463	73.433	٠.555	12.563	0.063
Minimum		200	13.798	23.312	0.176	3.988	0.02
Maximum		1720	118.662	200.44	1.515	34.3	0.172
Mean		505.572	34.879	58.927	0.445	10.081	0.050

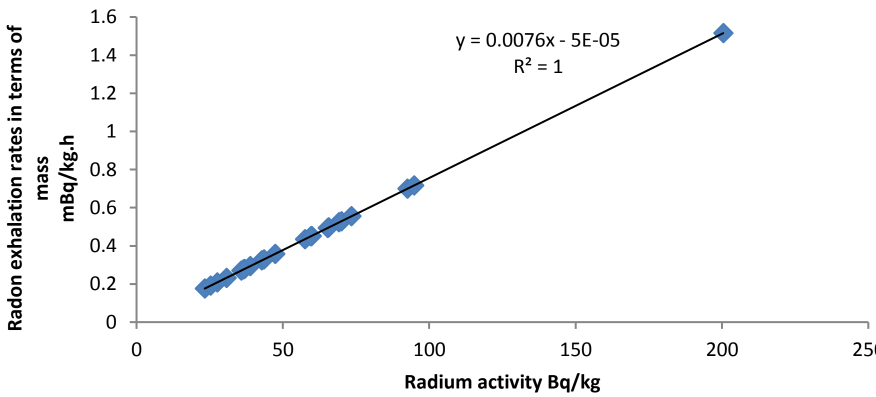

Figure 3. Correlation between radium activity and mass exhalation rate.

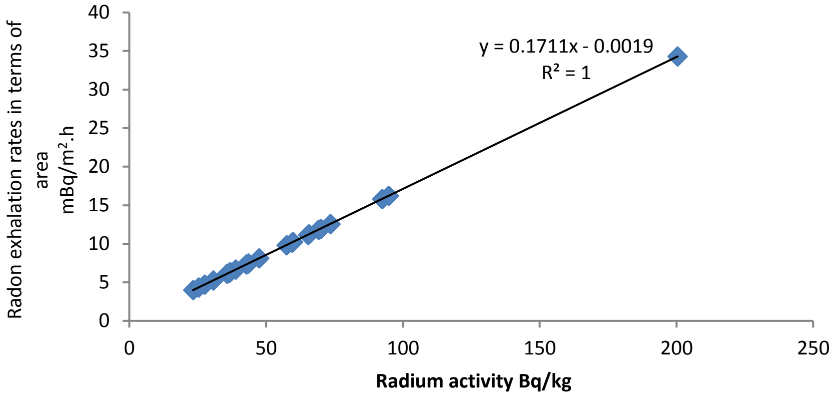

Figure 4. Correlation between radium activity and area exhalation rate.

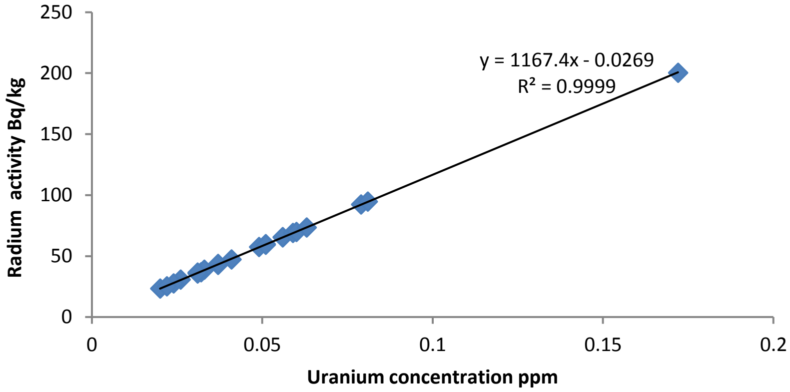

Figure 5. Correlation between uranium concentration and radium activity.

Discussion

According to the results of this study, it can be said that all results are similar to the results of other Iraqi researchers of various food items such as cereals, legumes, rice and vegetables [29-31], because many of the cereals, legumes and even vegetables involved in the manufacture of biscuits of various kinds. The mean radium (^{226}Ra) content in biscuit samples was lower than the mean of other nutrients, including wheat and barley [32]. In addition, the mean value of uranium (^{238}U) concentrations in different biscuit samples was lower than that of uranium concentrations in some kinds of wild fungi and nourished mushrooms [33]. With regard to radiation risks, the results of the present study lead us to the conclusion that eating biscuits does not pose a risk to human health if compared to other foodstuffs, because all the results of the study are within the limits allowed internationally.

Conclusion

This study addressed radium activity, radon emission rate, and uranium concentration in 22 different biscuit samples collected from local markets of Iraq by employing sealed can technique. The findings revealed that there was a direct correlation between radium activity and radon exhalation rate in terms mass and surface in those samples. In addition, uranium concentration positively correlated with radium activity in all samples. Radium activity, radon exhalation rate, and uranium concentration in this study were within internationally permissible limits. Therefore, eating biscuits poses no danger to public health; however, we must use modern methods and techniques to reduce the risks of radiation in different types of food.

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