Radon concentrations and radiological risks in canned meats using etching technique

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Abstract. This study evaluated the radon gas concentration of different samples of fresh canned meat available in Iraqi markets. A solid-state nuclear track detector (CR-39) uses a chemical etching technique for 1 hour at a temperature of 98°C in NaOH (6.25 N) concentrations. All radon, radium, and uranium concentrations were in an average value of 0.0461±0.0093Bq/kg 0.0041±0.00083 Bq/kg, and 0.0510±0.0103Bq/kg respectively. Also, radiological risks of annual effective doses were determined and found with Average values of 0.5066±0.1006 µSv/year, and also, excess live cancer risk was 1.773±0.3522. At the same time, all these values for infants, children, and adults were all within a safe limit. SPSS program version 26.0 showed descriptive statistics, histogram distribution and box plot, which shows that all values with normal distribution and some sample values were outliers. Finally, all values were within acceptable limits according to many international health organizations WHO, EPA, and ICRP and did not poss any hazard on human healt.

1 Introduction

People worldwide rely on meat as a significant source of critical nutrients in their diets. Due to population growth and changing lifestyles, there is a direct need for processed canned meat, which is driving up the consumption of meat products. Because they are readily available and appropriate for working families, canteens, and cafeterias, canned meat products are frequently served for meals. They are also simple to prepare for activities like camping and other situations where a refrigerator might not be accessible.

The primary source material is either chopped or comminuted beef or poultry. Spices, soy protein, starch, nitrite, salt, ascorbates, and phosphate are possible additions. The historical practice of preserving meat emerged from the necessity to preserve perishable food. Originally, meat preservation methods involved the use of salt. Certain varieties of salt impart a visually appealing reddish-pink hue to the meat. Commercial food preservation became increasingly important with the worldwide population's demographics starting to shift in the middle of the nineteenth century. From the business of killing animals to the business of processing and storing meat, the meat industry has evolved. With the introduction and rapid

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expansion of supermarkets, meat preservation became essential because it could be shipped over great distances without sacrificing its nutritional content, texture, or color.

There are several ways in which humans are exposed to radionuclides. They come into contact with radionuclides through soil, aerosol depositions, and plant and animal sources. Humans are most affected downstream by radiation. Cheese's inherent nutritional components—proteins, minerals, and vitamins—make it a vital part of the average person's diet. The two main methods of radionuclides reaching the human body are ingestion and inhalation. Consuming food or water can be linked to radioactive intake and passing through open wounds. Alpha-emitters in fresh canned meat samples have been investigated in different ways utilizing a range of experimental approaches in different regions of the world. The objectives of this study were to measure the radon concentrations in fresh canned meat samples from different countries found in Iraqi markets using CR-39 detectors and compare the results to those allowed within the global limit.

2 Materials and methods

2.1 Collection samples

Thirty - two fresh canned meat samples were collected from different markets places in Iraq. The fresh canned meats were from different origins (Local, Arabian, and foreign), such as Thailand (8 samples), Turkey (6 samples), Iran and Brazil (3 samples), Iraq, Vietnam, and Lebanon (2 samples), and other countries (Indonesia, Morocco, Jordan, United Arabia Emirates, China, and Syria) including (1 sample), (see Table 1). The fresh canned meat samples were put in a plastic container with information like the brand name, location, sample code number, and exposure duration written on it. Following sample collection, the samples were delivered to Kufa University at the nuclear laboratory for analysis of the alpha emitters [1-15].

Table 1. Details information of each different Fresh Canned Meat sample.

Sample Code	Sample Name	Country
FCM 1	California garden (tuna)	Thailand
FCM 2	Valencia Garden (tuna diet)	Thailand
FCM 3	Durra (tuna white)	Thailand
FCM 4	Salsa (spicy tuna)	Vietnam
FCM 5	Jood (corned meat hush)	Turkey
FCM 6	Shabuam (chicken chunk)	Iran
FCM 7	Al- nawgal (tuna chunk)	Vietnam
FCM 8	Mahfe (tuna fish/ diet)	Iran
FCM 9	Jood (chicken luncheon meat)	Turkey
FCM 10	Khosh (sardine fish)	Indonesia
FCM 11	Siblou (sardines fish)	morocco
FCM 12	Al taghziah (chicken hot dog)	Lebanon
FCM 13	Ghadeer (beef luncheon)	Jordan
FCM 14	Amrajona (luncheon chicken)	turkey
FCM 15	Basma (chicken luncheon meat)	turkey
FCM 16	Al-Taghziah (beef luncheon meat)	Lebanon
FCM 17	Siblou (tuna salad)	Thailand
FCM 18	Shakib (tuna fish)	United arab emirates
FCM 19	Nawras (tuna fish spicy)	Iran

FCM 20	Goldfish (chicken luncheon meat)	Iraq
FCM 21	California garden (light chunks tuna)	Thailand
FCM 22	Heinz (corned beef)	Brazil
FCM 23	Altunsa (chicken luncheon)	Turkey
FCM 24	Albacore (white meat tuna)	Thailand
FCM 25	Al-Fhkar (chicken luncheon meat)	Iraq
FCM 26	Al-Tazaj alzahabi (chicken luncheon meat)	Turkey
FCM 27	Salsa (sardines)	China
FCM 28	Bordon (corned beef loaf)	Brazil
FCM 29	Laziza (chicken luncheon meat)	Syria
FCM 30	Corned beef Exeter	Brazil
FCM31	Fulla (light meat tuna)	Thailand
FCM 32	Americana (shredded light tuna meat)	Thailand

2.2 Preparation of the samples

To propagate samples for measurement, many steps must be taken, including weighing the sample, which weighs 30 gm, on a sensitive, highly accurate scale, enclosing it in a plastic container with the dimensions 7 cm in length and 2.25 cm in radius, and stored for 30 days to get balance equilibrium, as shown in Figure 1.

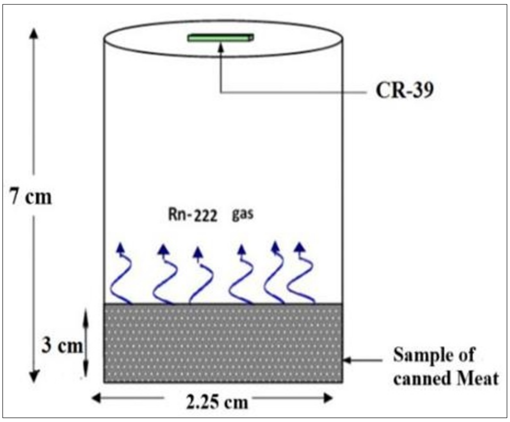

Fig. 1. The container used in the study

Exposing samples for about two months and storing them in the fridge. To measure the levels of radon, a CR-39 detector was fastened to the top of a plastic cup holding fresh canned meat samples. The CR-39 detector was put in a beaker with the pre-made chemical agent solution to perform the chemical etching.

After the detector was immersed, the beaker was heated in a water bath (type HH-420, Germany) for 1 hour at a temperature of 98°C. The beaker is now tightly closed to prevent any evaporation-related fluctuations in NaOH (6.25 N) concentrations. Then the detectors are carefully cleaned with distilled water and given 15 minutes to dry as shown in Figure 2 (a and b). Final step, radon levels were measured after being inspected under a microscope.

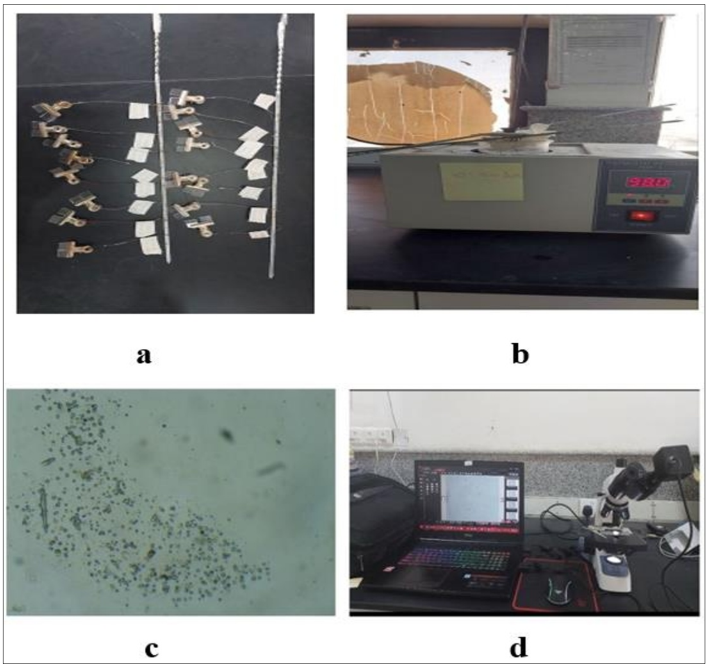

Fig. 2. Detection of tracks with a microscope.

2.3 Theoretical calculations

Calculations were made of the particle tracks that appeared on the detector's surface when the following connection was made. The density of the track (track/cm^2) was calculated using equation (1). Calculations were made of the particle tracks that appeared on the detector's surface when the following connection was made. The density of the track (track/cm^2) was calculated using equation (1). Microscopic processing is done manually using an optical microscope (Xsp-500e, China). Each CR-39 detector was examined under an optical microscope with a field of view with magnification (40X). To count alpha particles, the detector's surface is divided into ten viewing areas. A digital camera (KoPa MC500) is used to take multiple images for each area. The camera is connected to the microscope via a USB cable to record tracks, and it is also connected to the computer via a USB cable to count the number of tracks. as shown in Fig.2 (c and d):

$$\rho\left(\frac{Track}{cm^2}\right) = \frac{Number\ of\ Tracks}{Area\ of\ view} \tag{1}$$

The radon activity density (C) in the can air above the samples was calculated by measuring the track density on the detector under the following relation to compute the 222Rn concentration levels in the various canned meat samples:

$$C\ \left(\frac{Bq}{m^3}\right) = \frac{\rho}{K\ t} \tag{2}$$

where t is the sample's exposure duration (67 days), ρ the track density on the exposed detector (Tr/cm^2), K the diffusion constant (calibration factor or sensitivity factor), (K= 0.28±0.043 Track.cm-2 /Bq.m-3.day), which was determined using a standard source of 226Ra for exposure times: 0.5, 1, 1.5, 2, 2.5, and 3 days.

The radon activity density in the various brands of canned meats samples (CRn) in the test tube was calculated by using:

$$C_{Rn} = \frac{C.\lambda.h.t}{L} \tag{3}$$

where λ - decay constant for (222Rn), h - distance from the sample surface to the detector = 5cm., t - exposure time = 67 days, L - depth of the powder (3cm).

Also, the specific activity of radium- 226,(226CRa), is determined in the canned meat samples using parameters such as CRn, distance h, surface area, (A), of the sample in the container, and mass M of the sample, as shown in the following equation:

$$C_{Ra}\left(\frac{Bq}{kg}\right) = \frac{C\ h\ A}{M} \tag{4}$$

The uranium-238 concentrations (CU) are calculated by using the mass of the canned meat sample, the mass of uranium-238 (MU), and the secular equilibrium property between radon-222 and uranium-238 (M), by the following formula:

$$C_U(ppm) = \frac{M_U(mg)}{M\ (kgm)} \tag{5}$$

Equation (6) was used to determine AED due to alpha emitters in fresh canned meat samples which depend on many parameters such as the specific activity of radon-222, radium-226 and uranium-238 in the sample (CAlpha) in the unit (Bq/kg), the consumption rate of samples (I) in the unit (kg/y), which are equal 15, 35 and 50 for infant, children, and adults respectively , and where the values of the conversion dose factor are 3.5 nSv/ Bq for radon-222, 280 nSv/Bq for radium-226 and 45 nSv/Bq for uranium-238.

$$AED\left(\frac{nSv}{y}\right) = C_{Alpha} \times I \times CF \tag{6}$$

Finally, Excess Long Cancer Risk (ELCR) could be found by equation (7):

$$ELCR = AED \times DL \times RF \tag{7}$$

3 Results and discussion

Table 2 shows the concentrations of Radon(^{222}Rn), Radium(^{226}Ra), Uranium(^{238}U), and total Concentrations $C_{(alpha)}$ in (Bq/Kg) units of fresh canned meat samples. The minimum and maximum values of Radon(^{222}Rn) and Radium(^{226}Ra) were 0.002,0.0020 Bq/kg and 0.234,0.02095 Bq/kg in FCM26 and FCM31 with average values of 0.0461±0.0093 and 0.0041±0.00083 Bq/kg respectively. Additionally, the minimum and maximum values of Uranium(^{238}U) and total Concentrations $C_{(alpha)}$ were 0.0025,0.005 Bq/kg and 0.2587, 0.512Bq/kg in FCM26 and FCM31 with average values of 0.0510±0.0103 and 0.1012±0.0204 Bq/kg respectively. Several reported to demine recommended values of radon gas in air such as ICRP was 300 Bq/m^3. U.S.EPA was divided into three value higher levels [148 Bq/m^3, low level 74 Bq/m^3, and acceptable range level from 74 to148 Bq/ m^3 and low level 74 Bq/m^3,WHO was100 Bq/m^3, and CFR U. was 39 Bq/m3 . Therefore, all values of radon gas concentration in grain samples of the present study were lower than the recommended values according to ICRP, U.S.EPA, WHO, and CFR U. Also, it is found that all values of CRa and CU were lower than acceptable levels according to UNSCEAR.

Table 3 for infants, shows the values of annual effective dose (AED) of Radon (^{222}Rn), Radium(^{226}Ra), and Uranium(^{238}U), the minimum values were 0.257, 20.530, and 3.299 in FCM26, the maximum values were 26.945, 2155.639 and 346.442 in FCM31 with averages 5.3974±1.0720, 431.7901±85.7676 and 69.3948±13.7840 respectively. Also, the minimum and maximum values of total annual effective dose (AED_{Total}) were 0.024, 0.084, and 2.529, 8.852 in FCM26 and FCM31 respectively, with an average value of 0.5066±0.1006 μSv/year. Simultaneously, the minimum and maximum values of excess live cancer risk (ELCR) were 0.084 and 8.852 respectively, with an average value of 1.773±0.3522 in FCM26 and FCM31.

Table 4 for children, shows the values of the annual effective dose (AED) of Radon (^{222}Rn), Radium(^{226}Ra), and Uranium(^{238}U), the minimum values were 0.599, 47.903, and 7.699 in FCM26 with averages values of 2.594±2.50151, 1007.510±200.1245 and 161.921±32.162 respectively, and the maximum values were 62.873,5029.824 and 808.365 in FCM31 with the average values 12.594±2.5015,1007.510±200.1245 and 161.921±32.1628 respectively. Additionally, the minimum and maximum values of total annual effective dose (AED_{Total}) were 0.056 and 5.901 with an average value of 0.2347± 1.182 in FCM26 and FCM31 respectively. Also, the minimum and maximum values of excess live cancer risk (ELCR) were 0.197 and 20.654, averaging 4.137±0.8217 in FCM26 and FCM31 respectively.

Table 5 for adults, shows the values of the annual effective dose (AED) of Radon (^{222}Rn), Radium (^{226}Ra), and Uranium(^{238}U), the minimum values were 0.855, 68.433 and 10.998 in FCM26, the maximum values were 89.818,7185.463 and 1154.807 in FCM31 with average values 17.718±3.574, 1417.418±285.892 and 227.799±45.946 respectively. Simultaneously, the minimum and maximum values of total annual effective dose (AED_{Total}) were 0.080 and 8.430 with an average of 1.663±0.3354 in FCM26 and FCM31. Also, the minimum and maximum values of excess live cancer risk (ELCR) were 0.281 and 29.505 respectively, with an average of 5.820±1.174 in FCM26 and FCM31 respectively.

All Values of total (AED) which was less than 1.2 mSv/y and ELCR as acceptable levels according to the UNSCEAR report (United Nations Scientific Committee on the Effects of Atomic Radiation , 1988).

Statistical analysis was done by using the SPSS program version 26.0, a Descriptive Statistics for all variables: range, minimum, maximum, mean, standard deviation, a variance of radon, radium, and uranium concentrations, annual effective dose and excess live cancer risk provide in table(6), the histogram distribution with frequencies and box plot for radon, radium, and uranium concentrations show that a normal distribution for all values while the box plot shows that there some values were outliers such as FCM2, FCM16, and FCM 31, but it's also under the acceptable limits [16-30].

Table 2. Concentrations of Radon(^{222}Rn), Radium(^{226}Ra), Uranium(^{238}U), and total concentrations C(alpha) in (Bq/Kg) units of fresh canned meat samples

code name	C(^{222}Rn) (Bq/kg)	C(^{226}Ra) (Bq/kg)	C(^{238}U) (Bq/kg)	$C_{(alpha)}$ (Bq/kg)
FCM 1	0.043	0.00387	0.0478	0.095
FCM 2	0.145	0.01297	0.1601	0.318
FCM3	0.099	0.00890	0.1099	0.218
FCM 4	0.003	0.00024	0.0030	0.006
FCM 5	0.107	0.00962	0.1187	0.236
FCM 6	0.016	0.00140	0.0172	0.034
FCM 7	0.029	0.00259	0.0320	0.064
FCM 8	0.012	0.00104	0.0128	0.025
FCM 9	0.038	0.00339	0.0419	0.083
FCM 10	0.056	0.00499	0.0616	0.122
FCM 11	0.004	0.00040	0.0049	0.010
FCM 12	0.034	0.00307	0.0379	0.075
FCM 13	0.040	0.00359	0.0443	0.088
FCM 14	0.049	0.00439	0.0542	0.108
FCM 15	0.007	0.00060	0.0074	0.015
FCM 16	0.167	0.01496	0.1848	0.367
FCM 17	0.049	0.00443	0.0547	0.109
FCM 18	0.023	0.00203	0.0251	0.050
FCM 19	0.012	0.00104	0.0128	0.025

FCM 20	0.013	0.00116	0.0143	0.028
FCM 21	0.018	0.00160	0.0197	0.039
FCM 22	0.004	0.00040	0.0049	0.010
FCM 23	0.009	0.00084	0.0103	0.021
FCM 24	0.029	0.00259	0.0320	0.064
FCM 25	0.060	0.00539	0.0665	0.132
FCM 26	0.002	0.00020	0.0025	0.005
FCM 27	0.072	0.00642	0.0793	0.157
FCM 28	0.014	0.00128	0.0158	0.031
FCM 29	0.036	0.00327	0.0404	0.080
FCM 30	0.028	0.00247	0.0305	0.061
FCM31	0.234	0.02095	0.2587	0.513
FCM 32	0.024	0.00215	0.0266	0.053
Minimum	0.002	0.00020	0.0025	0.005
Maximum	0.234	0.02095	0.2587	0.513
Average±S.E.	0.0461±0.0093	0.0041±0.00083	0.0510±0.0103	0.1012±0.0204

Table 3. Annual effective dose of Radon(^{222}Rn), Radium(^{226}Ra), Uranium(^{238}U), and excess live cancer risk (ELCR) of fresh fanned meat samples for infants

Code Sample	***AED (^{222}Rn)***	***AED (^{226}Ra)***	***AED (^{238}U)***	***AED$_{TOTAL}$ (nSv/y)***	***AED $_{TOTAL}$ (µSv/y)***	***ELCR *10 $^{-6}$***
FCM1	4.978	398.280	64.009	467.268	0.467	1.635
FCM 2	16.681	1334.443	214.464	1565.588	1.566	5.480
FCM3	11.445	915.633	147.155	1074.234	1.074	3.760
FCM 4	0.308	24.636	3.959	28.903	0.029	0.101
FCM 5	12.369	989.541	159.033	1160.944	1.161	4.063
FCM 6	1.796	143.709	23.096	168.602	0.169	0.590
FCM7	3.336	266.889	42.893	313.118	0.313	1.096
FCM8	1.334	106.755	17.157	125.247	0.125	0.438
FCM9	4.363	349.008	56.091	409.461	0.409	1.433
FCM10	6.416	513.247	82.486	602.149	0.602	2.108
FCM11	0.513	41.060	6.599	48.172	0.048	0.169
FCM12	3.952	316.160	50.811	370.924	0.371	1.298
FCM13	4.619	369.538	59.390	433.547	0.434	1.517
FCM14	5.646	451.658	72.588	529.891	0.530	1.855
FCM15	0.770	61.590	9.898	72.258	0.072	0.253
FCM16	19.247	1539.742	247.459	1806.447	1.806	6.323
FCM17	5.697	455.764	73.248	534.708	0.535	1.871
FCM18	2.618	209.405	33.654	245.677	0.246	0.860
FCM19	1.334	106.755	17.157	125.247	0.125	0.438
FCM20	1.488	119.073	19.137	139.699	0.140	0.489
FCM21	2.053	164.239	26.396	192.688	0.193	0.674
FCM22	0.513	41.060	6.599	48.172	0.048	0.169
FCM23	1.078	86.226	13.858	101.161	0.101	0.354
FCM24	3.336	266.889	42.893	313.118	0.313	1.096
FCM25	6.929	554.307	89.085	650.321	0.650	2.276
FCM26	0.257	20.530	3.299	24.086	0.024	0.084
FCM27	8.263	661.063	106.242	775.568	0.776	2.714
FCM28	1.642	131.391	21.116	154.150	0.154	0.540
FCM29	4.209	336.690	54.111	395.010	0.395	1.383
FCM30	3.182	254.571	40.913	298.666	0.299	1.045
FCM31	26.945	2155.639	346.442	2529.026	2.529	8.852
FCM32	2.772	221.723	35.634	260.128	0.260	0.910
Minimum	**0.257**	**20.530**	**3.299**	**24.086**	**0.024**	**0.084**

Maximum	**26.945**	**2155.639**	**346.442**	**2529.026**	**2.529**	**8.852**
Average±S.E	**5.3974±1.0720**	**431.7901±85.7676**	**69.3948±13.7840**	**506.5823±100.6238**	**0.5066±0.1006**	**1.773±0.3522**

Table 4. Annual effective dose of Radon(^{222}Rn), Radium(^{226}Ra), Uranium(^{238}U), and excess live cancer risk (ELCR) of fresh fanned meat samples for children

Code Sample	AED (^{222}Rn)	AED (^{226}Ra)	AED (^{238}U)	AED_{TOTAL} (nSv/y)	AED_{TOTAL} (µSv/y)	ELCR $*10^{-6}$
FCM1	4.978	398.280	64.009	467.268	0.467	3.816
FCM 2	16.681	1334.443	214.464	1565.588	1.566	12.786
FCM3	11.445	915.633	147.155	1074.234	1.074	8.773
FCM 4	0.308	24.636	3.959	28.903	0.029	0.236
FCM 5	12.369	989.541	159.033	1160.944	1.161	9.481
FCM 6	1.796	143.709	23.096	168.602	0.169	1.377
FCM7	3.336	266.889	42.893	313.118	0.313	2.557
FCM8	1.334	106.755	17.157	125.247	0.125	1.023
FCM9	4.363	349.008	56.091	409.461	0.409	3.344
FCM10	6.416	513.247	82.486	602.149	0.602	4.918
FCM11	0.513	41.060	6.599	48.172	0.048	0.393
FCM12	3.952	316.160	50.811	370.924	0.371	3.029
FCM13	4.619	369.538	59.390	433.547	0.434	3.541
FCM14	5.646	451.658	72.588	529.891	0.530	4.327
FCM15	0.770	61.590	9.898	72.258	0.072	0.590
FCM16	19.247	1539.742	247.459	1806.447	1.806	14.753
FCM17	5.697	455.764	73.248	534.708	0.535	4.367
FCM18	2.618	209.405	33.654	245.677	0.246	2.006
FCM19	1.334	106.755	17.157	125.247	0.125	1.023
FCM20	1.488	119.073	19.137	139.699	0.140	1.141
FCM21	2.053	164.239	26.396	192.688	0.193	1.574
FCM22	0.513	41.060	6.599	48.172	0.048	0.393
FCM23	1.078	86.226	13.858	101.161	0.101	0.826
FCM24	3.336	266.889	42.893	313.118	0.313	2.557
FCM25	6.929	554.307	89.085	650.321	0.650	5.311
FCM26	0.257	20.530	3.299	24.086	0.024	0.197
FCM27	8.263	661.063	106.242	775.568	0.776	6.334
FCM28	1.642	131.391	21.116	154.150	0.154	1.259
FCM29	4.209	336.690	54.111	395.010	0.395	3.226
FCM30	3.182	254.571	40.913	298.666	0.299	2.439
FCM31	26.945	2155.639	346.442	2529.026	2.529	20.654
FCM32	2.772	221.723	35.634	260.128	0.260	2.124
Minimum	0.599	47.903	7.699	56.201	0.056	0.197
Maximum	62.873	5029.824	808.365	5901.062	5.901	20.654
Average±S.E.	12.594±2.5015	1007.510±200.1245	161.921±32.1628	1182.025±234.7889	0.2347±1.182	4.137±0.8217

Table 5. Annual Effective Dose of Radon(^{222}Rn), Radium(^{226}Ra), Uranium(^{238}U), and Excess Live Cancer Risk (ELCR) of Freh Fanned Meat Samples for Adults

Code Sample	AED (222Rn)	AED (226Ra)	AED (238U)	AED_{TOTAL} (nSv/y)	AED_{TOTAL} (μSv/y)	ELCR * *10^{-6}
FCM1	16.595	1327.600	213.364	1557.559	1.558	5.451
FCM 2	55.602	4448.144	714.880	5218.626	5.219	18.265
FCM3	38.151	3052.111	490.518	3580.780	3.581	12.533
FCM 4	1.026	82.120	13.198	96.344	0.096	0.337
FCM 5	41.231	3298.470	530.111	3869.812	3.870	13.544
FCM 6	5.988	479.031	76.987	562.006	0.562	1.967
FCM7	11.120	889.629	142.976	1043.725	1.044	3.653
FCM8	4.448	355.852	57.190	417.490	0.417	1.461
FCM9	14.542	1163.361	186.969	1364.871	1.365	4.777
FCM10	21.385	1710.825	274.954	2007.164	2.007	7.025
FCM11	1.711	136.866	21.996	160.573	0.161	0.562
FCM12	13.173	1053.868	169.372	1236.413	1.236	4.327
FCM13	15.397	1231.794	197.967	1445.158	1.445	5.058
FCM14	18.819	1505.526	241.959	1766.304	1.766	6.182
FCM15	2.566	205.299	32.994	240.860	0.241	0.843
FCM16	64.156	5132.474	824.862	6021.492	6.021	21.075
FCM17	18.990	1519.212	244.159	1782.362	1.782	6.238
FCM18	8.725	698.016	112.181	818.923	0.819	2.866
FCM19	4.448	355.852	57.190	417.490	0.417	1.461
FCM20	4.961	396.911	63.789	465.662	0.466	1.630
FCM21	6.843	547.464	87.985	642.292	0.642	2.248
FCM22	1.711	136.866	21.996	160.573	0.161	0.562
FCM23	3.593	287.419	46.192	337.204	0.337	1.180
FCM24	11.120	889.629	142.976	1043.725	1.044	3.653
FCM25	23.096	1847.691	296.950	2167.737	2.168	7.587
FCM26	0.855	68.433	10.998	80.287	0.080	0.281
FCM27	27.544	2203.542	354.141	2585.227	2.585	9.048
FCM28	5.475	437.971	70.388	513.834	0.514	1.798
FCM29	14.029	1122.301	180.370	1316.699	1.317	4.608
FCM30	10.607	848.569	136.377	995.553	0.996	3.484
FCM31	89.818	7185.463	1154.807	8430.088	8.430	29.505
FCM32	9.238	739.076	118.780	867.095	0.867	3.035
Minimum	0.855	68.433	10.998	80.287	0.080	0.281
Maximum	89.818	7185.463	1154.807	8430.088	8.430	29.505
Average± S.E.	17.718± 3.574	1417.418± 285.892	227.799±45.946	1662.935±335.412	1.663±0.3354	5.820±1.174

Table 6. Descriptive statistics for all variables

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	**Statistic**	**Statistic**	**Statistic**	**Statistic**	**Std. Error**	**Statistic**	**Statistic**
C_{Rn}	32	0.232	0.002	0.234	0.046	0.009	0.052	0.003
C_{Ra}	32	0.020	0.0002	0.02095	0.004	0.0008	0.004	0.000
C_U	32	0.256	0.0025	0.2587	0.051	0.01	0.058	0.003
AED (Total)	32	2.505	0.024	2.529	0.4987	0.1006	0.569	0.324
ELCR	32	8.768	0.084	8.852	1.7460	0.352	1.992	3.969

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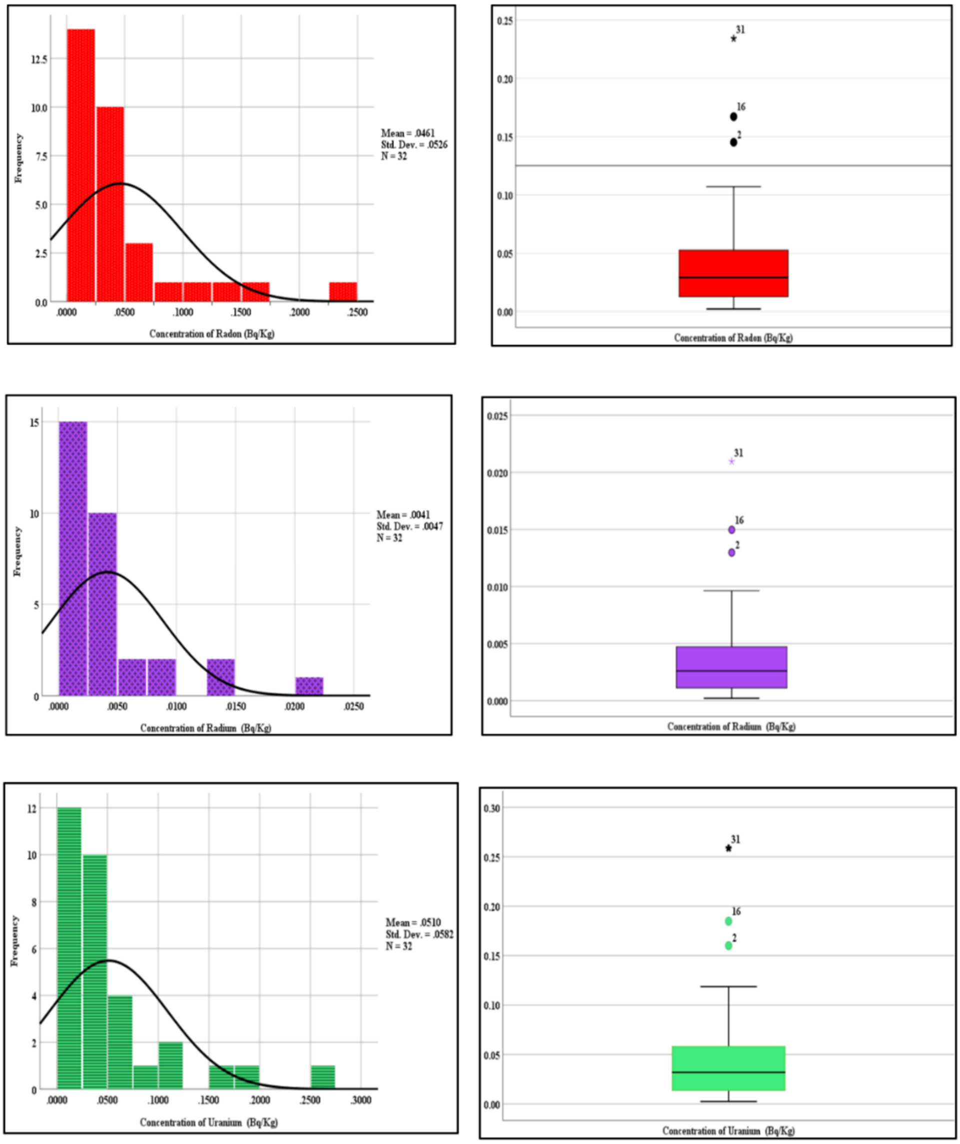

Fig. 3. Histogram distribution and box plot of radon, radium, and uranium concentrations.

4 Conclusion

Fresh canned meat samples are found to contain natural radon gas concentrations at different rates according to the type of fresh canned meat and the locations of the country. The data obtained in this study improve the suitability of the SSNTD techniques for such complex samples. So the results of alpha emitters such as ^{222} Rn, ^{226}Ra, and ^{238}U concentrations and other radiological parameters in all samples of the present study were within the acceptance of the permissible limit according to WHO, EPA, and ICRP. Finally, it can be concluded that fresh canned meat samples in this work do not pose any severe health risks to human consumption.

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