Evaluation of the radiological hazard in some dried fruit and grain samples in Iraqi Markets by Using of gamma ray Spectroscopy

Athraa Naji Jameel

Physics Department, College of Education, Mustansiriyah University, Baghdad, Iraq

E-mail: athraanaje@yahoo.com

Abstract. The activity concentrations of 226Ra, 232Th and 40K have been measured by using of gamma spectroscopy for fifteen samples fall under the consumed food group (six type of dried fruit and nine types of grain) at local markets in Baghdad. The average of activity concentration values of 40K, 232Th and 238U were 324.4±28.5 Bq/Kg, 3.66±0.20 Bq/kg and 3.44±0.58 Bq/kg, for the dried fruit samples, 302.3±98.9, 4.8±1.5 and 4.29 ±1.4 Bq/kg, respectively. For the grain samples, radiation hazard indices, the annual effective dose, internal and external risk, lifetime cancer, and the doses of ingestion, were all doses values within the international borders allowed. Thus, Food the dried fruit and grain in Baghdad is safe for human consumption and it has no heath effect.

Keywords: Radioactivity, Dry fruit, Excess Life Time Cancer Risk, ingested effective dose.

1. Introduction

Natural happening radioactive matter (NORM) is found in soil. NORM may be moved from soil to plants. Thus, every type of meals may also have a few quantity of radioactivity in it. Most types of food have the following isotopes and their daughter products, 238U, 232Th and 40K [1]. The primary pathways for the transfer of radionuclides to humans are meals crops. Natural radionuclides are transmitted and cycled by natural processes and the various extreme environmental booths by entering into ecosystems and human meals chain [2]. Radiation doses acquired due to the intake of meals may be calculated from the quantity of radionuclide deposited on foodstuffs, the activity concentration of particular radionuclide in meals according to unit deposition, the intake rate of the meals merchandise and the dose according to unit activity ingested [3, 4]. Most people around the world rely on grains, legumes and foods from cereals in their diet. The normal amounts of radioactivity in our daily food are important to estimate. However, a study of the concentration of natural radioactivity in foodstuffs was conducted in different countries [5, 6]. There are many Global research interested by popularity of radioactive pollutants in exported and imported meals and The appearance of match potassium 40K in all meal samples and the intake of match potassium 40K in exported and imported meals over those years did not target any radiation dose above the global recommended limit [7-9].

In addition, plant absorption varies from species to species; thus the consumption of different meal items is a secondary supply of variability [10, 11]. Therefore, the objective of the present study is to
evaluate the activity concentrations of $^{40}$K, $^{238}$U and $^{232}$Th in different foodstuffs in the region and to estimate the effective dose of ingestion for individuals consuming local foodstuffs in the area.

2. Materials and methods

2.1. Preparation of Samples

Six samples of the different dried fruit and nine samples of the grain were collected from the Iraqi markets. Samples have been placed in an oven for dried it and crushed to attain a homogeneous powder. The homogenized samples were packed into Marinelli Becker and sealed for 30 days to achieve a secular equilibrium. Table 1 shows the name, code and the country for the dried fruit and grain samples.

2.2. Measurement of samples

$^{238}$U, $^{232}$Th, and $^{40}$K analysis in dried fruit and grain samples using a 100 percent relative efficiency crystal dimension NaI (Tl) detector of 3x3. Manufactured by Ortic in the U.S.A., the module has 4096 channels and a working voltage of 695V. Samples are measured for 24 hours (86400 s). Made in the United States of America (U.S.A.). Three standard sources ($^{60}$Co, $^{133}$Ba, and $^{137}$Cs) were chosen from the samples. These isotopes were placed at a distance of 4cm from the top of the detector inside the shielding. The spectrum of standard elements used to calibrate the NaI(Tl) system as shown in Figure 1 and the efficiency curve between the energy and efficiency of all energy from standard sources as shown in Figure 2 are shown.

![Figure 1. A spectrum of standard elements use to calibrate NaI(Tl) system](image-url)
2.3. Parameters calculation

Specific Activity

It was calculated for the radionuclides $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ by the following relation [12]:

$$A(t) = \frac{N}{\epsilon \times I(E\gamma) \times m \times t} \times 100$$
Where \( N \) equals net area under peak, \( \varepsilon (E\gamma) \) is the efficiency of energy \( E\gamma \) detection. \( E\gamma \) is the net peak area adjusted for the background at energy \( E\gamma \) below the real peak. \( I(E\gamma) \) is the abundance of \( E\gamma \) energy. The sample mass in kg is \( m \), and the time in second.

**Gamma absorbed dose rates**

The calculation of the gamma absorbed dose rate by using the following equation [13, 14].

\[
D_{\gamma} \text{ (nGy/h)} = 0.462A_{Ra} + 0.621A_{Th} + 0.0417A_{K}
\]

Where the specific activities of \(^{226}\text{Ra}, ^{232}\text{Th}, \) and \(^{40}\text{K}\) are \( A_{Ra}, A_{Th}, \) and \( A_{K}, \) respectively.

**Annual effectiveDose equivalent**

The annual effective dose equivalent (AEDE) from \(^{238}\text{U} (^{226}\text{Ra}), ^{232}\text{Th}, \) and \(^{40}\text{K}\) is obtained by using the following equations [15]:

\[
\text{AEDE}_{\text{out}}(\mu\text{sV/y}) = D_{\text{out}} \times 8760 \times 0.7 \times 0.2 \times 10^{-3}
\]

\[
\text{AEDE}_{\text{in}}(\mu\text{sV/y}) = D_{\text{in}} \times 8760 \times 0.7 \times 0.8 \times 10^{-3}
\]

Where, \( D \) is absorbed dose rate measured in nGy/h. The number of 0.2 refers to outdoor occupancy factor, 0.8 is indoor occupancy factor. The number of 0.7 Sv/Gy is conversion factor.

**The Internal and External Hazard Index**

The internal hazard index (\( H_{in} \)) and external hazard index (\( H_{ex} \)) due to the radiation released by the food samples is determined as follows[16, 17].

\[
H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_{K}}{4810}
\]

\[
H_{in} = \frac{A_{Ra}}{180} + \frac{A_{Th}}{259} + \frac{A_{K}}{4810}
\]

**Life-Time Cancer Risk**

The excess lifetime cancer risk (ELCR) can be calculated from the following equation [18].

\[
\text{ELCR} = \text{AEDE} \times \text{DL} \times \text{RF}
\]

Where \( \text{DL} \) is duration of life (70 year) and \( \text{RF} \) is risk factor (0.05 Sv\(^{-1}\)).

**Ingestion effective dose**

The effective dose of ingestion due to the intake of \(^{226}\text{Ra}, ^{232}\text{Th}, \) and \(^{40}\text{K}\) in food can be measured [19].

\[
E_{\text{ing}} = \sum (A_{ig} \times C_{i}) \times g_{T,r}
\]

where, \( A_{ig} \) and \( C_{i} \) the coefficients of the consumption rate and specific activity of the radionuclide, and \( g_{T,r} \) is The radionuclide ingestion dose conversion coefficient, the required dose conversion coefficient \( g_{T,r} \) for \(^{40}\text{K}, ^{226}\text{Ra}(^{238}\text{U}), \) and \(^{232}\text{Th}, \) are \( 6.2 \times 10^{-9}, 2.8 \times 10^{-7}, \) and \( 2.2 \times 10^{-7} \) respectively [20].
3. Results and Discussion

The activity concentration was calculated in six samples of dried fruit and nine samples of grain of $^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$ as illustrated in Table 2. The average activity concentrations of $^{40}\text{K}$, $^{232}\text{Th}$, and $^{238}\text{U}$ were, $324.4\pm28.5$, $3.66\pm0.20$, and $3.44\pm0.58\text{Bq/kg}$ for dried fruit samples, $302.3\pm98.9$, $4.8\pm1.5$ and $4.29\pm1.4$, Bq/kg for grain, respectively. The values were decrease than the world average values for $^{238}\text{U}$, $^{232}\text{Th}$, and $^{40}\text{K}$, UNSCEAR, 2008 [21]. Turkey Figures and popcorn samples which have higher activity concentration, while the dried coconut and Iraq Millet samples have the lowest value. Figures 3 and 4 show the activity concentrations of $^{40}\text{K}$, $^{238}\text{U}$ and $^{232}\text{Th}$ in samples of dried fruit and grain.

![Figure 3](image1.png)

Figure 3. The activity concentration of dried fruit and grain for $^{40}\text{K}$.

![Figure 4](image2.png)

Fig. 4. The activity concentration of samples for $^{238}\text{U}$ and $^{232}\text{Th}$. 
Tables 3 show the results of radiation hazard index values outside and inside for the annual effective dose (ADED), outside and inside hazard (H$_{ex}$, H$_{in}$), and lifetime cancer risk (ELCR). These values had been under the permissible limits (UNSCEAR, 2000)[22]. The radiation hazard index values inside the body were more than that outside the body due to the ingestion of nutrients and the rest of them within the body as shown as in Figure 3.

The highest lifetime cancer risk values in the figure and popcorn samples and the lowest value in dried coconut and millet samples as shown in Figure 5.

![Figure 5. Life-time cancer risks of the samples.](image)

For $^{238}$U, $^{232}$Th, and $^{40}$K, the effective ingestion dose was lower than the acceptable dose ingestion effective dose values of 0.3 mSv/y recommended UNSCEAR, 2008[21]. As shown in Table 4 and Figure 6, the effects of the effective dose ingestion in all samples are shown.

The average value of the dose ingested for $^{238}$U, $^{232}$Th and $^{40}$K was 0.009±0.001, 0.010±0.001, 0.02±0.01 for the dried fruit and 0.012±0.004, 0.014±0.004 and 0.023±0.007 for grain.
Figure 6. Ingestion effective dose of samples.

Table 2. A specific activity of radioactivity in some types of dried fruit and grain of $^{238}$U, $^{232}$Th and $^{40}$K.

| No. | Sample               | $^{238}$U | $^{232}$Th | $^{40}$K |
|-----|----------------------|-----------|------------|----------|
| 1   | Figs                 | 5.4       | 4.4        | 403      |
| 2   | Apricot              | 4.3       | 3.9        | 339.3    |
| 3   | Apricot              | 2.3       | 3.4        | 356      |
| 4   | Apricot              | 4.3       | 992.       | 253.4    |
| 5   | Dried coconut        | 1.04      | 2.3        | 234      |
| 6   | date                 | 3.3       | 42.        | 344.9    |
| Mean ± S.D |     | 3.44±     | 3.66±      | 324.4±   |
|       |                      | 0.58      | 0.20       | 28.5     |
| 7   | popcorn              | 5.52      | 58.        | 400      |
| 8   | Barley               | 3.4       | 4.8        | 334.8    |
| 9   |                     | 3.6       | 4.3        | 353      |
| 10  | Bulgur (crushed wheat) | 4.60   | 8.72       | 278      |
| 11  | rice                 | 5.3       | 4          | 333      |
| 12  | Millet               | 5.5       | 5.2        | 330      |
| 13  |                    | 3.585     | 4.2        | 147      |
| 14  |                    | 4.3       | 3.55       | 198      |
| 15  | Oats                 | 4.9       | 5.3        | 244      |
### Mean ± S.D

|       | 4.29 ± 1.4 | 4.8± 1.5 | 302.3± 98.9 |

### Global Limit

UNSCEAR, 2008

|       | 33       | 45       | 412       |

| Sample | ADED(μSv/y) inside | ADED(μSv/y) outside | Hazard indexs inside | Hazard indexs outside | ELCR inside | ELCR outside |
|--------|-------------------|--------------------|---------------------|----------------------|-------------|-------------|
| D1     | 91.996            | 22.999             | 0.07                |                      | 321.77      | 80.942      |
| D2     | 90.15             | 22.538             | 0.109               | 7                    | 315.52      | 78.883      |
| D3     | 71.082            | 17.771             | 0.11                | 0.1                  | 248.78      | 62.199      |
| D4     | 70.268            | 17.567             | 0.085               | 7                    | 245.93      | 61.485      |
| D5     | 56.905            | 14.226             | 0.081               | 9                    | 199.16      | 49.791      |
| D6     | 101.62            | 25.405             | 0.063               | 0.06                 | 295.88      | 73.973      |
| Average± S.D | 78.3± 5.9 | 19.5± 1.4 | 0.008± 0.007 | 0.00 | 274.1± 19.4 | 68.5± 4.8 |
| D7     | 105.658           | 26.914             | 0.11                | 9                    | 370.84      | 92.962      |
| D8     | 92.25             | 23.062             | 0.101               | 5                    | 322.87      | 80.717      |
| D9     | 110.749           | 27.687             | 0.103               | 3                    | 387.62      | 96.905      |
| D10    | 80.02             | 20.005             | 0.126               | 6                    | 280.07      | 70.018      |
| D11    | 106.29            | 26.572             | 0.116               | 4                    | 372.01      | 93.002      |
| D12    | 91.995            | 22.999             | 0.113               | 9                    | 391.98      | 97.997      |
| D13    | 55.247            | 13.812             | 0.139               | 4                    | 193.36      | 48.342      |
| D14    | 60.893            | 15.223             | 0.077               | 4                    | 213.12      | 53.281      |
| D15    | 72.392            | 18.098             | 0.098               | 4                    | 253.37      | 63.343      |
| Average± S.D | 79.2± 7.4 | 19.9± 1.1 | 0.097± 0.031 | 0.03 | 313.5± 98.1 | 78.3± 24.5 |

Table 3. Radiometric parameters of the dried fruit and grain.

Table 4. The results ingestion of radionuclides $^{226}$Ra, $^{232}$Th, and $^{40}$K for the samples.
| code | \( \text{Eing (mSv/y)} \) |
|------|-------------------|
|      | \( ^{238}\text{U} \) | \( ^{232}\text{Th} \) | \( ^{40}\text{K} \) |
| D1   | 0.014             | 0.015             | 0.03             |
| D2   | 0.011             | 0.013             | 0.026            |
| D3   | 0.011             | 0.01              | 0.019            |
| D4   | 0.006             | 0.014             | 0.017            |
| D5   | 0.006             | 0.003             | 0.017            |
| D6   | 0.006             | 0.011             | 0.029            |
| Mean ± S.D | 0.009± | 0.010± | 0.02± |
| G7   | 0.018             | 0.014             | 0.025            |
| G8   | 0.011             | 0.012             | 0.032            |
| G9   | 0.023             | 0.015             | 0.021            |
| G10  | 0.011             | 0.018             | 0.025            |
| G11  | 0.014             | 0.018             | 0.028            |
| G12  | 0.025             | 0.018             | 0.014            |
| G13  | 0.009             | 0.014             | 0.015            |
| G14  | 0.013             | 0.011             | 0.025            |
| G15  | 0.013             | 0.018             | 0.032            |
| Mean± S.D | 0.012± | 0.014± | 0.023± |
|      | 0.004             | 0.004             | 0.007            |

4. Conclusion

Through calculations of the concentration of radioactivity for the \(^{238}\text{U},^{232}\text{Th},\) and \(^{40}\text{K}\) for the samples and the radiation hazard associated with the ingestion effective dose for the dried fruit and grain, it was found that they do not contain high radioactivity that affects the human body. Indices of radiation risk that were assessed during the analysis for all samples inside the study, all samples within the international borders allowed, and it is necessary to conduct a deep study of the other types of foodstuffs to determine their suitability for human consumption.

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