Estimation of the radiation hazard indices in most types of Pasta spread in the Iraqi markets

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Abstract. pasta (Macaroni) is a dry, hollow pastry, made from cereals such as wheat, rice, barley, etc. It is a diet rich in carbohydrates for different age groups. In this research study examines the emergence of the long-lived gamma radiation emitters in the various types of pasta available in the Iraqi market. We found concentration of (²³⁸U), (²³²Th) and (⁴⁰K) measured in (20) Various types for pasta that could be obtained in the Iraqi market. ( Radium equivalent ),, (internal hazard index), and (absorbed dose rate) were also calculated for all studied samples. radiometric measurements by using the gamma spectrometry NaI(Tl) detector. The specific activity in Macaroni samples were wide-ranging from (0.232±0.195) Becquerel /kg to (22.869±2.005) Becquerel /kg and at a rate (6.081) Becquerel /kg for ²³⁸U. For ²³²Th From (0.018±0.36) Becquerel /kg to (114.269±1.40) Becquerel /kg and at a rate (21.672) Becquerel /kg and for ⁴⁰K from (58.724±2.28) Bq/kg to (1145.99±10.57) Becquerel /kg and at a rate (663.092) Becquerel /kg. Also, Where we found that the internal risk index as well as the radium equivalent in the samples (pasta) ranged from (0.0135) to (0.8031) Becquerel /kg and at a rate (0.2672) Becquerel /kg and for the equivalent radium, the values were from (4.780) Becquerel /kg to (274,515) Becquerel /kg, and at a rate (177.262) Becquerel /kg. This study showed that risk indicators calculated in this study are safe and do not constitute any health threat to humans.

Keywords. Gamma Spectroscopy, Macaroni food, pasta, Iraq.

1. Introduction
Pasta is dry Macaroni. It's formed in different forms. It's made with unyielding wheat, it is usually cut in short lengths. The curved macaroni may be referred to as prod macaroni. Some macaroni shapes can make by home machines. Macaroni is commonly made by large-scale extrusion commercially [1]. The word “Macaroni”, In north America, It is used synonymously with elbow noodles, as it is the most used variety in pasta and cheese formulas. While the name "Maccheroni” refers to the straight square and square noodle "short length noodles" in Italy. Maccheroni may also refer to long noodle dishes such as "Maccheroni alla chitarra” and "frittata di Maccheroni”, ready with long pasta similar to spaghetti [1]. The name originates from the Italian "Maccheroni” or "makke’ro:ni”’, which is the plural form of "Maccherone” [2]. The texture specifies the type of pasta, so these types are different from each other, therefore; are on two types: “rigatoni” and “tortiglioni” [3] .Sampling food and measuring the concentrations of radionuclides in it provides more health information to the consumer whether it is
valid or not. If, for example, $^{131}$I is launched in Almarai, and its concentration in the produced milk will provide significantly more meaningful data than in air, sedimentation or silage samples [4,5]. However, $^{131}$I measurements in pasture grass may be very important in providing an important mark of the expected concentration in milk. A comprehensive understanding of agricultural practices such as fertilizer, approved irrigation method, and the nature of food consumption must be taken into consideration when sampling food. [6]. This information can be obtained from national food papers or from competent local specialists. Care must be taken when taking samples regarding manpower requirements, expenditures and the need to avoid overloading in laboratory facilities in general. [5, 7].

Natural radioactivity may be result in the environment in a number of ways, including the presence of a natural radioactive substance "NORM". The most effective and common potassium isotopes $^{40}$K, uranium $^{238}$U and its decay chain, and thorium $^{232}$Th and its chain of decay. In addition to being long-lived (about 1010 years), these radionuclides are naturally present in water, air and soil in various quantities and activities. [8]. Natural radionuclides travel from soil to crops, to livestock, and from water to fish, and thus the nuclides find their way to humans by swallowing these various foods, applying adequate procedures in investigating radionuclides in food may require international efforts cooperatively [9] to lay down basic guidelines for defense against high levels of internal exposure caused by food consumption [10].

Since pasta is one of the usual foods consumed at the table in everyday life, it is necessary to determine the baseline for radiation exposure from various types of pasta samples. [11]. Macaroni has been a staple food for humans for more than 200 years and remains the most consumed [12]. Moreover, many studies have been conducted all over the world to examine the natural radionuclides in foods consumed because of their critical importance to human health. [13]. The current study focused on calculating the concentrations of natural radionuclides in different types of pasta because they are commonly used among different age groups [14].

2. Materials and methods
Twenty models of macaroni (the majority of the types available in the Iraqi markets) have been collected for measuring unusual activity. The sorts of testers are programmed in table (1). The first step after collecting the samples is the pasta grinding process to obtain a homogeneous sample, after which it is kept with a sealed plastic container with a capacity of one liter, and then stored in the laboratory for a month and that up to countenance secular equilibrium to be reached between $^{222}$Rn and its parent $^{226}$Ra in Uranium chain [15].

| Sample code | Name of Samples   | Origin of samples |
|-------------|-------------------|-------------------|
| M_1         | Alkafeel Makaron  | Turkey            |
| M_2         | Altuns Spaghetti  | Turkey            |
| M_3         | Altuns Makaron    | Turkey            |
| M_4         | Tak-Mak           | Iran              |
| M_5         | Zer-Mak           | Turkey            |
| M_6         | Pasta             | Iraq              |
| M_7         | Samira Pasta      | Iran              |
| M_8         | Aldahabi Pasta    | Iraq              |
| M_9         | Zulfikar          | Turkey            |
| M_10        | Rezgul Co.        | Turkey            |
| M_11        | Nawras            | Turkey            |
| M_12        | OBA               | Turkey            |
| M_13        | Divella           | Italy             |
| M_14        | Madilla           | Iran              |
| M_15        | La Fonte          | Indonesia         |
| M_16        | Mak Pasta         | Iran              |
| M_17        | Zara Pasta        | Italy             |
Concentrations of radionuclides were calculated using the sodium iodide NaI(Tl) detector of (3*3) as shown in figure (1) measurements in this research and spectroscopy of samples using the MAESTRO-32 software on a Windows computer. The activity concentrations of nuclides were calculated assuming secular equilibrium with their decay products as for Potassium at the top (1460 keV) and Uranium at the transmission line of $^{214}$Bi (1765 keV), and the chain Thorium at the transmission line of $^{208}$Tl (2614 keV), the measurement time for samples was 18000 seconds.

3. Calculations

For each separate isotope, the specific activity in Bq/kg units has been calculated using the relationship (1) [16].

$$\mathcal{A}_n = \frac{(C_n - C_b)}{\varepsilon \gamma I \mu s}$$

where $\mathcal{A}_n$ has represented the specific activity of each radionuclide, $C_n$ has represented the count rate for all samples, $(C_b)$ has represented the count rate for background, $(\varepsilon \gamma)$ and $(I \mu s)$ have represented discovery efficiency and emission possibility of $\gamma$-ray respectively, $(\mu s)$ was representing the counting time and $(m_s)$ is the sample mass in kilograms.

In rocks and soil, the participation of radionuclides $^{40}$K, $^{226}$Ra and $^{232}$Th is not equal, so the radium equivalent is calculated as a common factor for the effect of these radionuclides therefor, a common factor was used for comparing its united radiological effects. This factor has represented the Radium equivalent activity ($Ra_{eq}$) [17].

$$Ra_{eq} = Ra + 1.43Th + 0.077K$$

Where $Ra$, $Th$, and $K$ are the specific activity of $^{226}$Ra, $^{232}$Th and $^{40}$K respectively.

The external ($H_{ex}$) and internal ($H_{in}$) hazard indices were calculated using Equations (3) and (4) [18].

$$H_{ex} = \frac{Ra}{370} + \frac{Th}{259} + \frac{K}{4810}$$

$$H_{in} = \frac{Ra}{185} + \frac{Th}{259} + \frac{K}{4810}$$

Their values should be greater than unity because Radioactivity may harmful for the population.

Equation (5) was used to calculate the outdoor dose ($D_{out}$) [18], and the average value should be 51 nGy/h as suggested by the UNSCEAR (2000) report.

$$D_{out} = 0.462Ra + 0.604Th + 0.0417K$$

While the indoor absorbed dose rate for agricultural soil samples have intended by using the following relation (6) [18].

$$D_{in} = 0.92Ra + 1.1Th + 0.08K$$

the recommended value of indoor absorbed dose rate should be 70 nGy/h [19]

4. Results and Discussion

Specific activity values for pasta (Macaroni) samples and their ratios are shown in table (2).

| sample code | Specific Activity (Bq/kg) | Ratios |
|-------------|---------------------------|--------|
| $^{226}$Ra  | $^{232}$Th                 | $^{40}$K | Ra/K | Th/K | Th/Ra |
| M1          | 2.164±1.05                | 12.539±0.59 | 323.034±6.09 | 0.007 | 0.039 | 5.794 |
The specific activity resulting from $^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in pasta (Macaroni) samples as detailed in table (2) also in figures (1), (2) and (3), respectively. The specific activity of $^{238}\text{U}$ was found in the range of $(0.232\pm 0.195)$ Bq/kg to $(22.869\pm 2.005)$ Bq/kg with an average $(6.081)$ Bq/kg for $^{238}\text{U}$, For $^{232}\text{Th}$ From $(0.018\pm 0.36)$ Bq/kg to $(114.269\pm 1.40)$ Bq/kg with an average $(21.672)$ Bq/kg and for $^{40}\text{K}$ from $(58.724\pm 2.28)$ Bq/kg to $(1145.99\pm 10.57)$ Bq/kg with an average $(663.092)$ Bq/kg. The radiation hazard indices, ($R_{\text{eq}}$) and ($H_{\text{int}}$) were calculated in table (3), figure (4) and (5), Then They have varied from $(4.780)$ Bq/kg to $(274.515)$ Bq/kg with an average $(177.262)$ Bq/kg and from $(0.0135)$ to $(0.8031)$ with an average $(0.2672)$ respectively.

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| $M_2$ | $1.627\pm 0.90$ | $114.269\pm 0.36$ | $61.701\pm 3.48$ | $0.026$ | $1.852$ | $70.251$ |
| $M_3$ | $4.440\pm 1.12$ | $0.847\pm 0.59$ | $58.724\pm 3.96$ | $0.076$ | $0.014$ | $0.191$ |
| $M_4$ | $2.831\pm 0.72$ | $4.278\pm 0.53$ | $130.074\pm 5.07$ | $0.022$ | $0.033$ | $1.511$ |
| $M_5$ | $3.612\pm 0.86$ | $8.162\pm 0.59$ | $313.822\pm 5.38$ | $0.012$ | $0.026$ | $2.260$ |
| $M_6$ | $12.036\pm 1.95$ | $21.927\pm 1.40$ | $1145.991\pm 10.5$ | $0.011$ | $0.019$ | $1.822$ |
| $M_7$ | $3.609\pm 1.34$ | $0.018\pm 0.64$ | $67.484\pm 2.28$ | $0.003$ | $0.000$ | $0.080$ |
| $M_8$ | $17.457\pm 1.89$ | $19.045\pm 1.22$ | $1035.411\pm 8.84$ | $0.017$ | $0.018$ | $1.091$ |
| $M_9$ | $3.609\pm 1.07$ | $10.784\pm 0.65$ | $326.242\pm 6.08$ | $0.011$ | $0.033$ | $2.988$ |
| $M_{10}$ | $1.335\pm 0.24$ | $13.426\pm 0.51$ | $915.095\pm 7.25$ | $0.001$ | $0.015$ | $16.178$ |
| $M_{11}$ | $3.190\pm 0.42$ | $17.027\pm 0.63$ | $1145.991\pm 10.5$ | $0.076$ | $1.852$ | $70.251$ |
| $M_{12}$ | $1.715\pm 0.24$ | $11.981\pm 0.44$ | $738.844\pm 5.94$ | $0.002$ | $0.016$ | $6.987$ |
| $M_{13}$ | $6.559\pm 0.55$ | $15.818\pm 0.51$ | $804.357\pm 6.48$ | $0.012$ | $0.020$ | $1.634$ |
| $M_{14}$ | $5.393\pm 0.62$ | $18.033\pm 0.56$ | $825.347\pm 6.97$ | $0.004$ | $0.022$ | $6.068$ |
| $M_{15}$ | $2.972\pm 0.77$ | $10.445\pm 1.22$ | $1035.411\pm 8.84$ | $0.017$ | $0.018$ | $1.091$ |
| $M_{16}$ | $9.678\pm 0.62$ | $0.018\pm 0.64$ | $67.484\pm 2.28$ | $0.003$ | $0.000$ | $0.080$ |
| $M_{17}$ | $0.781\pm 0.19$ | $12.639\pm 0.49$ | $838.397\pm 6.98$ | $0.001$ | $0.015$ | $16.178$ |
| $M_{18}$ | $3.987\pm 0.43$ | $13.883\pm 0.50$ | $845.159\pm 7.01$ | $0.005$ | $0.016$ | $3.482$ |
| $M_{19}$ | $3.352\pm 0.24$ | $17.027\pm 0.63$ | $1087.881\pm 8.85$ | $0.003$ | $0.016$ | $5.337$ |
| $M_{20}$ | $1.553\pm 0.24$ | $11.981\pm 0.44$ | $738.844\pm 5.94$ | $0.002$ | $0.016$ | $6.987$ |
| Max. | $22.869\pm 2.00$ | $114.269\pm 0.36$ | $1145.991\pm 10.5$ | $0.076$ | $1.852$ | $70.251$ |
| Min. | $0.232\pm 0.19$ | $0.018\pm 0.64$ | $67.484\pm 2.28$ | $0.003$ | $0.000$ | $0.080$ |
| Mean. | $6.081\pm 0.896$ | $21.672\pm 1.31$ | $663.092\pm 12.79$ | $0.015$ | $0.185$ | $9.814$ |
Figure 1. Specific Activity of $^{238}$U in (Bq/Kg).

Figure 2. Specific Activity of $^{232}$Th in (Bq/Kg).

Figure 3. Specific Activity of $^{40}$K in (Bq/Kg).

Table 3. Radiological hazard indexes in the Macaroni samples.

| Sample code | $H_{int}$ | $H_{ext}$ | $R_{Ra_{eq}}$ (Bq/kg) | $D_{outdoor}$ | $D_{indoor}$ |
|-------------|-----------|-----------|-----------------------|---------------|--------------|
| M1          | 0.1273    | 0.12142   | 044.968               | 23.115        | 030.0495     |
| M2          | 0.4628    | 0.45842   | 169.782               | 78.994        | 102.6918     |
| M3          | 0.0395    | 0.02748   | 010.174               | 04.982        | 006.4767     |
| M4          | 0.0589    | 0.05121   | 018.965               | 09.634        | 012.5247     |
| M5          | 0.1163    | 0.10652   | 039.449               | 20.440        | 026.5723     |
| M6          | 0.3880    | 0.35544   | 131.633               | 68.933        | 089.6123     |
| M7          | 0.1290    | 0.11921   | 044.150               | 22.708        | 029.5206     |
| M8          | 0.0154    | 0.01473   | 005.454               | 03.013        | 003.9169     |
| M9          | 0.3832    | 0.33598   | 124.418               | 64.585        | 083.9600     |
### Table 1. Radiological Characteristics of Macaroni Samples

| Sample | Hazard Index | Mean Activity | Median Activity | Maximum Activity | Average Activity |
|--------|--------------|---------------|-----------------|------------------|------------------|
| M10    | 0.4154       | 0.35360       | 130.939         | 67.202           | 087.3621         |
| M11    | 0.2573       | 0.24924       | 092.310         | 48.696           | 063.3052         |
| M12    | 0.2806       | 0.25445       | 094.232         | 49.191           | 063.9483         |
| M13    | 0.2807       | 0.26293       | 097.376         | 51.459           | 066.8965         |
| M14    | 0.3153       | 0.30073       | 111.377         | 59.220           | 076.9859         |
| M15    | 0.2509       | 0.24009       | 088.917         | 47.235           | 061.4052         |
| M16    | 0.2273       | 0.22521       | 083.412         | 44.752           | 058.1772         |
| M17    | 0.2493       | 0.24570       | 090.997         | 48.807           | 063.4496         |
| M18    | 0.3092       | 0.30053       | 111.306         | 59.413           | 077.2371         |
| M19    | 0.2091       | 0.20450       | 075.739         | 40.434           | 052.5644         |
| M20    | 0.2651       | 0.25374       | 093.972         | 49.905           | 064.8768         |
| Max.   | 0.4628       | 0.45842       | 169.782         | 78.994           | 102.6918         |
| Min.   | 0.0154       | 0.01473       | 005.454         | 03.013           | 003.9169         |
| Mean.  | 0.2672       | 0.22519       | 177.262         | 43.136           | 056.0766         |

**Figure 4.** A radiation hazard indexes for Macaroni samples.

**Figure 5.** A radiation hazard indexes for Macaroni samples.

**Conclusions**

Nationally, the present study was extremely important to investigate the radioactivity of studied pasta samples. It was found that local consumption of pasta is safe for all ages and in different diets. From the above results above, it is possible to create a database that will serve as a baseline for other future studies on the effect of radiation from ingestion of food.

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