Evaluation of radioactivity of cereals and legumes using a nuclear impact detector CN-85

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Abstract

The research aims to evaluate the radioactivity in elected samples of cereals and legumes which are wide human consumption in Iraq using Nuclear Track Detectors (NTDs) model CN-85. The samples were prepared scientifically according to references in this field. After 150 days of exposure, the detector were collected and chemically treated according to scientific sources (etching chemical), nuclear effects have been calculated using the optical microscope. Radon ($^{222}\text{Rn}$) concentration and uranium ($^{238}\text{U}$) were calculated in unit Bq/m$^3$ and (ppm), the results indicate that the highest concentration of radon and uranium was in yellow corn where the concentration of radon was $137.17 \times 10^2$ Bq/m$^3$ and uranium concentration $2.63$ (ppm). The lowest concentration of radon and uranium was in Oats, where the concentration of radon was $24.27 \times 10^2$ Bq/m$^3$, and uranium concentration $0.466$ (ppm). The concentrations of other cereals and legumes varied between these two values. These different in radon and uranium concentrations due to different in geological nature of the different agricultural soils, and the different absorption of plant roots for certain elements present in the soil solution. These values for the concentration of radon and uranium for cereals and legumes are within the permitted globally and as issued by the International Atomic Energy Agency (IAEA).

Key words

Radon, uranium, grains and pulses.

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Introduction

Contamination occurs in the food chain when food is exposed to radioactive material or radioactive materials were mixed with irrigation water, soil and air, for example from an reactor accident, as happened in the Chernobyl reactor explosion in Russia. Countries far away from the scene have been exposed to radiation, not just direct injury, it went beyond that from dairy, beef, grain crops, pulses and other agricultural and animal products in the Netherlands and Sweden, and that such infected products if used by the wrong hands it up to any spot in the world where it can cause damage endless without felt by the individual [1].

Food radiation contamination is a shift and change in the physical and chemical structure of food. It is possible to produce toxic compounds or become some radioactive and when eaten by humans cause many diseases, especially cancer [2].

The fall of some radioisotopes on the soil and plants leads to the entry of the human body or animal through the food chain, the radioactive material is transferred from the soil to the plant tissue by root or adsorption by the leaves through the metabolic processes carried out in the paper [3].

Radon is considered $^{222}\text{Rn}$ (radiant colorless gas, taste and smell) of the natural radiation that is generated as a result of spontaneous decomposition of sources of the element radium $^{226}\text{Ra}$, and that the presence of radium in an area in nature depends on the presence of uranium $^{238}\text{U}$, and radon the only metal that is in the case of gaseous, which is seven and a half times heavier than the air and is everywhere and at all times, and its derivatives constitute about half of the radioactive dose that affects the general public from natural sources combined [4].

Detection of radon or uranium in grains and legumes at higher than normal limits indicates a clear threat to human life. Cereals and legumes (plant proteins). The basic meal for most individuals, especially for low-income people because of the economic price cheapness compared to other food, perhaps the most important characteristic of the containment of many vitamins and important elements of the body and the most important fiber, all types of cereals and legumes share a number of benefits, including prevention of cancer, maintaining the health of bones, protecting the digestive system. Preventing high cholesterol in the body, maintaining the ideal weight, controlling blood sugar, preventing anemia, maintaining kidney health, reduce high levels of stress, regulate the hormones in the body being rich in useful compounds in addition to supplying the body with energy, where the body provides many vitamins such as: vitamin C,B1,B2 and B3, as well as it provides the body with many elements such as iron, magnesium, phosphorus, potassium, and sulfur [5].

The long-term measurement method was used to measure the concentration of radon and uranium using solid state nuclear track detectors (SSNTD’s). This method is more efficient in measuring the concentration of radon and its wolves and the concentration of uranium was found [6], where detector are placed in closed spread chambers cylindrical shape and placed in front of the sample to measure the concentration of radon and close tightly to prevent leakage or exchange of air with the ocean, and after the spread of radon inside the room solves the emission of alpha particles and a balance between him and his children, and then allow the detector exposure to the sample [7].
The nuclear track detector CN-85 used in this research, which is the organic reagents and the chemical composition (C6H8N2), has a particularly good sensitivity to alpha particles and other heavy particles, the detector intensity 1.52 g.cm⁻³ [8].

The theoretical part

Mechanism of occurrence of effects on the surface of the detector

The mechanism of effects on the detector surface depends on the generation of charged particles in the insulating solids have a number of effects as they pass through those substances, which can be observed using a microscope after treatment with a chemical (chemical etching) is working to show areas of damage formed. The type and shape of damage areas depend on the mass, energy and charge of the fallen particles and on the type of solid matter [9], therefore, the main effect of the particles charged on these detectors is their degradation or the cross-linking of their molecules with each other. These two effects represent major changes in the properties of the polymer (detector). The fall of radiation leads to the irritation and ionization of these molecules and thus severs the bonds between them, and damage and this damage is called the latent track [10].

The effect of ionizing radiation damaged areas show greater ability to interact with solutions alkaline like sodium hydroxide compared to correct areas because of the possession of damaged areas more energy than correct areas, so the chemical solution penetrates the irradiated areas quickly causing an impact is increasing its depth and expands in diameter with an increase etching time [11].

Propagation constant calculation

The measurement of radon concentration is based on determining the propagation constant K, which can be determined for the spread room used in this study of the following relationships [12]:

\[ \rho = KCT \]  

where:

\[ \rho \]: Intensity of track unit tr/m², \( K \): propagation constant, \( D \): density of track is represented by a unit \( Tr.Cm^{-2}.h^{-1} \).

According to the equation [13]:

\[ D = \frac{\theta}{T} = K.C \]  

It is also possible find propagation constant depending on the geometry of the propagation chamber [14]:

\[ K = \frac{1}{4}r(2\cos\theta - r/R_a) \]  

where:

\( r \): radius of the tube was used and its value 2.25 Cm, \( \theta_c \): critical angle of the detector 25°.

\( R_a \): extent of alpha particles in the air emitted from \(^{222}\text{Rn} \) 4.15 cm as in the equation [15]:

\[ R_a = (0.005E_a + 0.285)E_a^{3/2} \]  

where: \( E_a \) represents the energy of alpha particles in a unit MeV, \( K=0.793 /Cm \) length units.

Calculate the concentration of radon in the antenna space

It is possible to calculate radon concentration in antenna space of the chamber confined between the sample surface and the detector surface in the irradiation chamber in unit \( Bq.m^{-3} \) relationships [16]:

\[ D_{R_a}^{222} = \frac{C}{4}r(2\cos\theta_c - r/R_a) \]  

Calculation of radon concentration in samples

Radon concentration in samples can be found from the following relationship [14]:
\[ C_s = \lambda_{Rn} C_a \frac{ht}{L} \]  
(6)

where:

\[ C_s: \text{Concentration of radon in the samples in unit } Bq.m^{-3}. \]
\[ C_a: \text{Concentration of radon in the antenna space in unit } Bq.m^{-3}. \]
\[ \lambda_{Rn}: \text{Fixed radon decomposition equals 0.1814 day.} \]
\[ L: \text{The thickness of the sample is estimated at approximately } 1.5 \text{ cm.} \]
\[ t: \text{The irradiation time is 150 days.} \]

Radiation efficiency \( A \) of the radon obtained from samples used in Bq units can also be found using the following relationships [6]:

\[ A_{Rn} = C_s V \]  
(7)

\[ V = \pi r^2 L \]  
(8)

where: \( V \) sample size in units \( m^3 \), \( r \): radiation chamber radius used 2.25 cm.

**Calculation of uranium concentration**

In order to calculate the concentration of uranium in the studied samples \( Cu \) (ppm) (Part per million). The number of uranium atoms can be determined \( N_u \). Thus concentrating uranium in these samples by determining the number of radon atoms \( N_{Ra} \) based on the Radiation Balance Act [17]:

\[ \lambda_{Ra} N_{Ra} = \lambda_{U} N_U \]  
(9)

\[ \lambda_{Ra}: \text{Fixed radon decomposition is equal } 12.1 \times 10^{-6} \text{ S}^{-1}. \]
\[ \lambda_{U}: \text{Fixed uranium decomposition is equal } 4.9 \times 10^{-18} \text{ S}^{-1}. \]

The weight of uranium in the samples \( W_u (g) \) can be found from the equation:

\[ W_u = \frac{N_u A_u}{N_{av}} \]  
(10)

\[ A_u: \text{The mass number of uranium } ^{238}U. \]
\[ N_{av}: \text{Avogadro number is equal to } 6.02 \times 10^{23} \text{ mol}^{-1}. \]

To find the concentration of uranium in samples in ppm, we use the following relationship [6]:

\[ C_u (ppm) = \frac{W_u}{W_s} \]  
(11)

\( W_s \): The weight of the sample (g) and its amount 10 g.

**Practical part**

Food samples were collected from some cereals and legumes available in local markets (Oats, yellow corn, rice, lentils, wheat, chickpeas, white beans, red kidney beans, barley, green peas, mash, white beans, red beans, and Albaqlae), are grinded we obtain samples of homogeneous and fine powder to ensure consistent distribution of radioactive material in each sample, 10 grams of each sample were collected and placed in cylindrical irradiation chambers, the closures were sealed with a rubber payment of 22 days for a case secular equilibrium up to 98 % between radium and radon isotopes [18]. In order to prevent a leak of radon from outside the diffusion chambers, the rubber cover has been removed and replaced with another covering containing a piece of detector CN85 (With a thickness of 200 dimensions \( 1x2 \) cm²), this cover was then sealed with adhesive tape and tightly while maintaining the stability of the dimension between the detector and the face of the sample. These detectors remained inside irradiation chambers for 150 days, and then taken out and exposed to chemical etching using sodium hydroxide solution \( \text{NaOH} \) and with purity up to 98%, this process will show the intensity of the effects left by the radon on the detector, the temperature associated with this process was 60 °C and the concentration of the solution was 2.5 M, after about four hours of etching, the detectors were removed from sodium hydroxide solution, washed with distilled water and then dried and prepared under a light microscope and begin the process of detection and calculation of the number of effects arising on the face of the detector.
After calculating the number of effects shown by the reaction between the alpha particles (emitted from radon) and the detector surface facing the samples under study, the radiation background of the CN-85 detector. In the same period that the reagents used were exposed to the samples under study, one of the reagents was placed in a sealed container. The purpose of this was to calculate the radioactive background of the CN-85 reagent, to subtract the intensity of its effects from all samples.

Results and discussion

For the purpose of determining radioactive contamination in the studied samples of legumes and grains, the concentration of radon in the antenna space and its concentration within the samples were determined by a unit Bq/m³.

Table 1 shows the names of legumes and grains, and the intensity of the effects in unity (tr/m²) corresponding to it, after subtracting the radiation background from both the value and the amount $3 \times 10^8$ (tr/m²), and the concentration of radon in Antenna space and its concentration in samples in units Bq / m³ per sample.

Fig. 1 shows the concentration of radon in units (Bq / m³) of the grain and legume samples under study.

Table 1: The intensity of the effects and intensity of the radon effectiveness in the antenna space and within samples.

| Sample no. | Sample name      | $\rho \times 10^6$ (tr/m²) | $C_{\text{air}}$ (Bq/m³) | $C_{\text{sample}} \times 10^4$ (Bq/m³) |
|------------|------------------|---------------------------|--------------------------|----------------------------------------|
| 1          | Oats             | 286.6                     | 28.43                    | 24.27                                  |
| 2          | Yellow corn      | 1466.6                    | 156.24                   | 137.17                                 |
| 3          | Rice             | 655.5                     | 69.84                    | 60.831                                 |
| 4          | Lentils          | 816.6                     | 86.94                    | 75.917                                 |
| 5          | Wheat            | 1180.0                    | 117.74                   | 103.09                                 |
| 6          | Chickpeas        | 1277.7                    | 136.14                   | 119.327                                |
| 7          | White bean       | 1233.4                    | 131.4                    | 115.094                                |
| 8          | Red cowpea       | 777.77                    | 82.34                    | 72.7                                   |
| 9          | Barley           | 500.0                     | 50.57                    | 43.87                                  |
| 10         | Green bezalia    | 1122.2                    | 119.54                   | 104.67                                 |
| 11         | Mach             | 1066.6                    | 113.64                   | 99.477                                 |
| 12         | White cowpea     | 422.8                     | 44.95                    | 38.904                                 |
| 13         | Red beans        | 1200                      | 127.8                    | 112.0                                  |
| 14         | Baqlae           | 883.7                     | 88.04                    | 76.01                                  |
Fig. 1 shows the concentration of radon was higher than 137.17×10² Bq/m³ in the sample (Yellow corn). Then was 119.32×10² Bq/m³ in the sample (Chickpeas), and 115.09×10² Bq/m³ in the sample (White bean). Thus, the lowest concentration of radon was 24.27×10² Bq/m³ in the sample (Oats).

Radon activity was also found in the (Bq) unit, as well as the concentration of uranium \( C_{u}(\text{ppm}) \) during finding the weight in \( W_{u} \) samples after finding the number of uranium atoms \( N_{u} \) of the Radiation Balance Act (between uranium and radon).

Table 2 shows the names of cereals, legumes, and radiation efficiency of the corresponding radon, number of uranium atoms \( N_{u} \), weight of \( W_{u} \) per sample and then the concentration of the uranium in units of \( C_{u} \) (ppm) corresponding to each sample.

| Sample name      | \( A_{\text{Ra}}(\text{Bq}) \times 10^{14} \) | \( N_{u} \times 10^{14} \) | \( W_{u} \text{(gm)} \times 10^{-6} \) | \( C_{u} \text{(ppm)} \) |
|------------------|---------------------------------|-------------------------|-----------------|-----------------|
| Oats             | 578.59                          | 118.07                  | 4.66            | 0.466           |
| Yellow corn      | 3270.13                         | 667.37                  | 26.38           | 2.63            |
| Rice             | 1450.21                         | 295.96                  | 11.69           | 1.16            |
| Lentils          | 1809.69                         | 369.96                  | 14.59           | 1.45            |
| Wheat            | 2455.5                          | 501.1                   | 19.80           | 1.9             |
| Chickpeas        | 2751.78                         | 569.75                  | 23.33           | 2.3             |
| White bean       | 2743.74                         | 559.94                  | 22.13           | 2.21            |
| Red cowpea       | 1733.16                         | 353.70                  | 13.98           | 1.39            |
| Barley           | 1045.86                         | 213.44                  | 8.43            | 0.84            |
| Green bezalia    | 2495.33                         | 509.25                  | 20.13           | 2.01            |
| Mach             | 2371.53                         | 483.83                  | 19.12           | 1.91            |
| White cowpea     | 132.27                          | 26.99                   | 1.06            | 0.106           |
| Red beans        | 2670.09                         | 544.91                  | 21.54           | 2.15            |
The highest activity value of the radon was also in the sample (Yellow corn) and value $3270.13 \times 10^{-4}$ (Bq) and therefore the highest value in this sample in the number of atoms and weight of uranium and then the weight of uranium in unity (ppm) it was 2.63, followed by the sample (Chickpeas) the value of radiation activity $2751.78 \times 10^{-4}$ (Bq). Thus the uranium weight (ppm) in this sample was 2.3, and the lowest activity value $578.59 \times 10^{-4}$ (Bq) were in the sample (Oats) as well as the number of atoms and concentration of uranium in the unit (ppm) was the lowest value of 0.466 in this sample. The concentrations samples varied between these two values, due to the different geological nature of the soil of these samples, different absorption of plant roots for certain elements present in soil solution. These values for the concentration of uranium (ppm) for cereals and pulses are within the scope of the global permitted by the International Atomic Energy Agency (11.7) [19].

Conclusions
1-The highest concentration of radon and uranium was in the Yellow corn sample, and the lowest value was in the Oats sample.
2- These values for the concentration of radon and uranium for cereals and pulses are within the scope of the global permitted, according to the International Atomic Energy Agency.

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