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Measuring the Natural Radioactivity of Local Wheat Flour and Comparing it with the Imported Wheat Flour Using Gamma-Ray Spectroscopy

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Abstract
In this study, twenty samples of wheat flour were collected from local markets. Thirteen of these samples were local flour with different commercial names, and seven were imported flour with different commercial names. Three radionuclides (U-238, Th-232, K-40) were detected in all the wheat flour samples with a multichannel buffer (MCB) detector. The value of the specific activity of the local flour for the element U-238 ranged between 4.34 and 11.88 Bq/kg, with an average value of 7.98 Bq/ kg, as for the element Th-232, its specific activity ranged between 3.22 and 4.84 Bq/ kg, with an average value of 3.94 Bq/kg. For the element potassium K-40, the specific activity ranged between 220.45 and 290.65 Bq/kg with an average value of 248.63 Bq/kg. The average specific activity of imported flour for the element uranium U-238 ranged between 1.25 and 4.38 Bq/ kg, with an average value of 2.48 Bq/kg. As for the element Th-232, its specific activity ranged between 0.22 and 2.88 Bq/kg, with an average value of 1.51 Bq/ kg. As for the element potassium K-40, its specific activity ranged between 152.23 and 161.32 Bq/ kg with an average value of 158.19 Bq/kg. The radioactivity dose calculated for all samples is 0.424 $mSv.y^{-1}$, which is lower than the allowable limit of 1 $mSv.y^{-1}$. It was shown through this study that the radioactivity level of local flour was higher than that of imported flour.
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Article Info.

Keywords:
Potassium, Uranium, Specific Radioactivity, Local Flour, Gamma Ray.

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1. Introduction
Standard radioactivity is formed through the presence of normal radioactive sources, or what is known as Natural Occurring Radioactive Material (NORM). These materials are mostly natural radioactive sources that cause soil pollution, including the isotope element of cesium Cs-137, that cause soil pollution, including the isotope element of cesium Cs-137 [1, 2]. Through scientific studies, radioactive levels were studied and compared with internationally permissible values. One of the most important materials, in which radioactive levels must be monitored is wheat flour. It is obtained by grinding wheat [3, 4]. Wheat flour is one of the most materials consumed on a daily basis, as it is considered the main source of food in the world. Large mills are used for grinding grains so the radioactivity chains exist naturally. It is usually concentrated in the air, water, and soil, at different levels from one country to another and from one region to another. It contains radionuclides that intake by the human body through eating these materials, such as ham, bread, and pastries, which people are largely consumed [5, 6]. In general, most of the food of the people, and the Iraqi people in particular, contains bread and pastries of all kinds in their meals [7, 8]. The most prominent natural radionuclide of terrestrial origin that is present in the soil is the element potassium K-40. This element is found in human food and in the normal human body in a natural form. There are also uranium chains U-238 and thorium Th-232. Thorium 232 is commonly found in foodstuffs [9, 10]. The highest natural percentages

of radionuclides are that of potassium (K-40). Regarding the previously mentioned series, their value of specific activities are changes according to the place and time of the region from which the model is taken.

There are many scientific studies that examine samples and models of foodstuffs, including wheat [11]. These studies measured radioactive levels in wheat. The International Food Agency (IFA) and the World Health Organization (WHO) set the natural limit of radiation in foodstuffs and through this it bans the buying and selling of foodstuffs that exceed the natural limit of radiation [12]. There are strict guidelines and instructions to protect people from danger and high levels of radiation, especially in areas that have been exposed to wars and bombing with depleted uranium, where agricultural areas are greatly affected by harmful radiation [13].

There have been many accidents in nuclear facilities which led to the radioactive contamination of air, water, and soil. Through this, it was necessary to identify and know some of the countries that own nuclear facilities and examine samples of food imported from them in order to avoid the possibility of receiving a high level of radiation that causes vascular diseases and genetic deformities in the long term [14, 15]. The half-life ($T_{1/2}$) of these nuclides is very long and can reach hundreds of years. Therefore, the effect of the radionuclides remains and continues for a long period of time in the soil and is difficult to treat using simple methods. Supervisory teams concerned with such matters should be informed so that they can conduct a radiological examination of the suspicious soil and submit proposals to remove radioactive contamination in those areas, especially agricultural ones [16].

2. Materials and Methods

Twenty samples of wheat flour were tested and assessed in this study. 13 samples were locally produced from wheat flour. The remaining samples (i.e., 7 samples) were from imported wheat flour. The samples were weighed at a rate of one kilogram per sample with a precise balance. The samples were numbered and coded, as shown in Table 1. After completing the weights for all samples, the samples were kept in the laboratory for one month in a dark place to avoid sunshine, to achieve radioactivity balance and the disbanding of radon gas. After a month, a radiological examination was carried out using multichanal buffer (MCB) radiological detection system [17].

The laboratory radioactivity background resulting from weather conditions was recorded and subtracted from the results. The samples were placed in standard Marinelli beakers; the detector was used to register radioactivity of each sample for two hours. The energies of the natural elements on the spectrum were determined, and the specific activity of each sample was calculated using mathematical equations and through a computer program that was previously install [18].

3. Experimental Work

Specific activity levels of samples were measured using Gamma spectrometer which consists multichannel analyzer that classified as a scintillation detector with Canberra sensor (2″× 2″) crystal element, as shown in Fig. 1.

Detector intrinsic efficiency is the ratio of the number of photons detected to the number of photons incident on the detector surface. Efficiency is the mostly significant of all detectors, so an exact efficiency calibration of a gamma-ray spectrometry system is essential [18]. The gamma spectrum was examined by means of the Canberra detector, Table 2. An energy standardization for this detector was achieved with Co-60 radioactive sources of 37000 Bq radioactivity from USNRC and National Certificate Skilled Measures, “Gamma Source”. The MCB ORTEC detector has fourteen pins to connect with another piece, as shown in Figs. 2 and 3.

Table 1: The codes of all flour samples.

Code Sample	Name of samples	Origin
Y1	Ardh- al falaah	Iraq
Y2	Al-Faris	Iraq
Y3	Al- khansaa	Iraq
Y4	Al-Zahaa	Iraq
Y5	Al-Ryaaf	Iraq
Y6	Baghdad	Iraq
Y7	Daaz	Iraq
Y8	Al-Rafiden	Iraq
Y9	Al- Baydhaa	Iraq
Y10	Al-Dora	Iraq
Y11	Al-Tajee	Iraq
Y12	Al-Niser	Iraq
Y13	Al- Ressafa	Iraq
Y14	Beshler	Turkey
Y15	Fakher	Kuwait
Y16	Altunsa	Turkey
Y17	Jehan	Turkey
Y18	Al-Knooz	Turkey
Y19	Al-Baker	UAE
Y20	Napoietuna	Italy

Figure 1: Canberra detector (BICRON).

Figure 2: 14-Pins of ORTEC.

Figure 3: Digi BASE ORTEC.

The detector is connected via a coaxial cable. The intended resolution is 7.9% for energy of 661.66 keV of Cs-137 in normal conditions. Comparative efficacy at 1.33 MeV Co-60 was 22% and at 1.274 MeV Na-22 was 24% [19]. The detector was protected by a cylinder-shaped lead shield to attain the lowest background. In this study, the radioactivity K-40 is the most frequent and strongest radiation with energy of 1460.06 keV. The correction of calibration efficiency for this structure was performed using standard sources from the International Atomic Energy Agency (IAEA) as a function of gamma-ray energies. The activity concentrations of U-238 and Th-232 were calculated assuming secular equilibrium with their decay products. The gamma transition with lines of Bi-214 (1765 keV) were used to calculate activity concentration of radioisotope in the U-238 series. The activity absorptions of radioisotope in the Th-232 series were determined by means of gamma transition lines of Tl-208 (2614 keV). The measuring time for each sample was at 2 hr. The detector has relative efficiency of 73.8% at 1.33 MeV for Co-60, and its resolution (FWHM) was 1.18 keV at 122 keV for Co-57, and at 1332 keV of Co-60 was 1.97 keV. The comparative efficiency of the detector was determined for each energy standards covering energy values in the range 186 -1332.5 keV [20], and K-40 with 1460 -1461 keV.

Table 2: General specifications of Canberra detector.

System	specifications
Crystal Volume	2×2 inch
Working power	1000 V. dc.
No. of station	1024 Channels.
FWHM for (Co-60)	1.33 MeV
Relative efficiency	22 %
Including time	Two hr.
Resolution	Two keV
Diameter of mineral	Six cm
Dimension of crystal	Five cm
Distance since window	0.5 cm
model	302

The counting rate is proportional to the amount of radioactivity in a sample, so the specific activity (Ac) can be determined from the follows in Eq. (1) [21]:

$$Ac = \frac{C - B.G}{\varepsilon\%\ MI\gamma t} \qquad (1)$$

where Ac is the Specific activity (Bq/kg), C is the Area under photo peak, ε% is the Percentage of the energy efficiency, Iɣ is the Percentage of gamma emission, t is the time (second), M is the Mass of sample (kg), B.G. is the Back ground of the lab.

The dose rate for the radionuclides was calculated using Eq. (2) [22, 23]:

$$D\ (\mu Sv.h^{-1}) = 0.0007\ (0.462\ C_{Ra}+0.604\ C_{Th}+0.0417\ C_{k}) + 0.034 \qquad \textbf{(2)}$$

After the radiological balance of the samples was completed, each sample was weighed separately at a rate of one kilogram. The background radiation was measured, in order to calculate the radioactivity of the samples. After that, one kilogram was placed in the Marnelli beaker inside the shield measuring system Canberra detector, as shown in Fig. 4.

Figure 4: Flour sample in Marnelli Beaker inside the shield.

4. Results

The specific acitivities of the radionuclides of the local flour samples are listed in Table 3 and those for the imported flour samples are shown in Table 4.

Table 3: The specific activity for local flour.

Code of Samples	Specific activity (Bq /kg)		
	U- 238	**Th- 232**	**K-40**
Y1	5.35 ± 0.05	3.24 ± 0.03	290.65 ± 2.9
Y2	4.34±0.04	3.88 ± 0.03	280.32±2.8
Y3	4.65±0.04	3.22 ± 0.03	260.33±2.6
Y4	8.36±0.08	4.33 ± 0.04	255.32±2.5
Y5	9.31±0.09	4.66 ± 0.04	240.22±2.4
Y6	8.74±0.08	4.22 ± 0.04	243.66±2.4
Y7	7.34±0.07	3.84 ± 0.03	241.84±2.4
Y8	10.54±0.10	4.17 ± 0.04	230.55±2.3
Y9	11.36±0.11	3.55 ± 0.03	220.45±2.2
Y10	11.88±0.11	3.65 ± 0.03	251.32±2.5
Y11	8.44±0.08	4.84 ± 0.04	247.332.4
Y12	6.31±0.06	4.11 ± 0.04	248.66±2.4
Y13	7.20±0.07	3.58 ± 0.03	221.32±2.1
Min. value	4.34±0.04	3.22 ± 0.03	220.45±2.2
Max. value	11.88±0.01	4.84 ± 0.04	290.65±2.9
Average	7.98±0.07	3.94 ± 0.03	248.63±2.4

Table 4: The specific activity for imported flour.

Code of samples	Specific activity (Bq/kg)		
	U- 238	**Th- 232**	**K-40**
Y14	1.25±0.01	0.25±0.02	152.23±1.5
Y15	2.41±0.02	0.22±0.02	155.34±1.5
Y16	2.33±0.02	1.24±0.01	160.24±1.6
Y17	3.64±0.03	2.31±0.02	158.44±1.5
Y18	4.38±0.04	2.14±0.02	160.22±1.6
Y19	1.77±0.01	2.88±0.02	161.32±1.6
Y20	1.58±0.01	1.54±0.01	159.55±1.5
Min. value	1.25±0.01	0.22±0.02	152.23±1.5
Max. value	4.38±0.04	2.88±0.02	161.32±1.6
Average	2.48±0.02	1.51±0.02	158.19±1.5

The dose for all radionuclides measured using Eq. (2) is D = 0.424 $mSv.y^{-1}$.

The obtained results of the specific activity values of the local flour samples (Table 3), showed that the min. value of specific activities of U-238 was for Y2 of 4.34 Bq/kg, while the max. was 11.88 Bq/kg for Y10. The average specific activity for U-238 was 7.98 Bq/kg; the min. value of specific activity of Th-232 was 3.22 Bq/kg for Y3 while, the max. value was 4.84 Bq/kg for Y11. The average specific activity for Th-232 was 3.94 Bq/kg; the min. value of specific activities of K-40 was 220.45 Bq/kg for Y9 while the max. value of specific activities was 290.65 Bq/kg for Y1. The average specific activity for K-40 was 248.63Bq/kg)

From Table 4, it can be noted that the min. value of the specific activity of U-238 was 1.25 Bq/kg for Y14 and the max. value was 4.38 Bq/kg for Y18, with an average value of 2.48 Bq/kg. The min. value of specific activity of Th-232 was 0.22 Bq/kg for Y15 and the max. value of specific activities was for Y19 of 2.88 Bq/kg. The average specific activity of Th-232 was 1.51 Bq/kg. As for K-40 specific activities, the min. was 152.23 Bq/kg for Y14 and the max. was 161.32 Bq/kg for Y19, with an average specific activity of 158.19 Bq/kg.

The values of specific activities for U-238 in all samples are shown in Fig. 5. The min. value of the specific activity for U-238 was recorded for the imported wheat flour sample Y14 of 1.25 Bq/kg, and the max. value was for the local flour sample Y10 of 11.88 Bq/kg. The values of specific activities for Th-232 in all samples are shown in Fig. 6. The min. value of the specific activity was 0.22 Bq/kg for Y15 of the imported wheat flour sample and the max. value was 4.84 Bq/kg for Y11 of the local flour sample. As for the specific activity of K-40 for all samples, shown in Fig. 7, the min. value was 152.23 Bq/kg for Y14 of the imported wheat flour samples and the max. value of 290.65 Bq/kg for Y1 of the local flour samples.

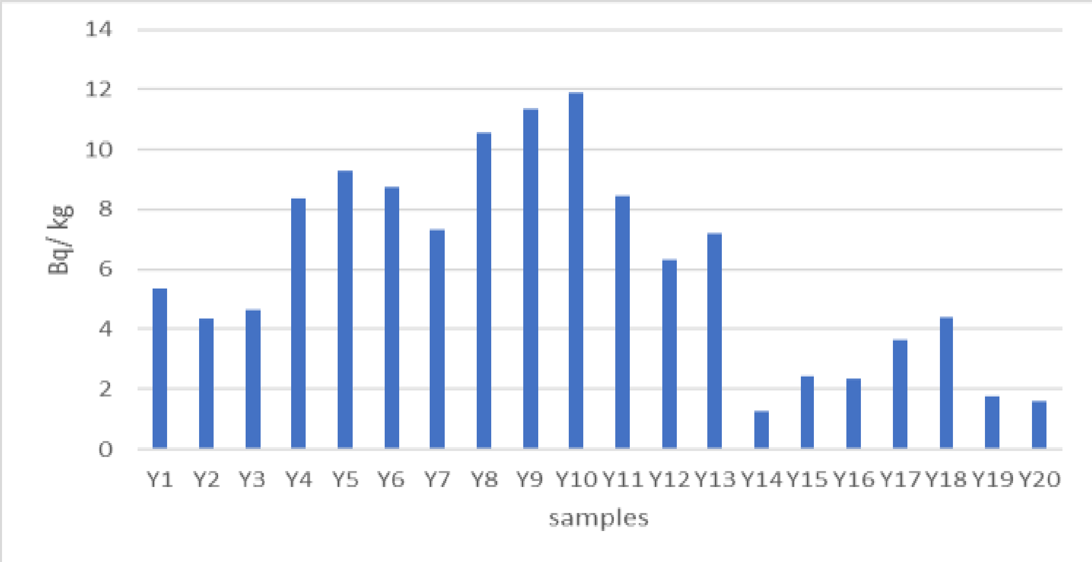

Figure 5: The specific activities for U-238 in all (Local and imported) samples.

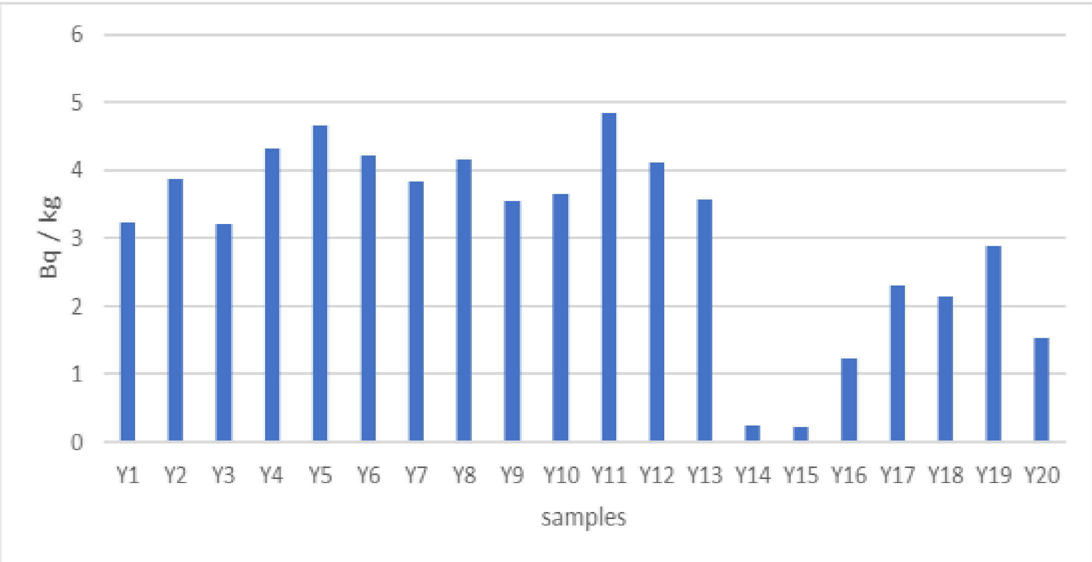

Figure 6: The specific activities for Th-232 in all samples.

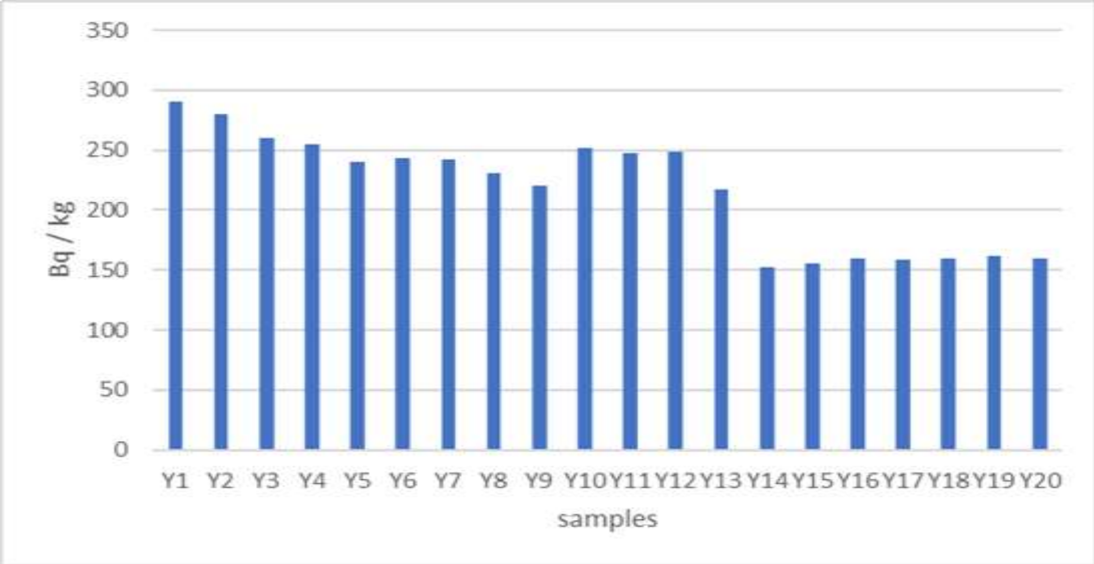

Figure 7: The specific activities for K-40 in all samples.

Using gamma spectroscopy, a flour sample gamma spectrum can be registered, as displayed in Fig. 8. Where the X-axis represents energy (E), and the Y-axis represents the percentage of counts C/R obtained and recorded by the detector. The first peak represents the background radioactivity, and the last peak is for K-40.

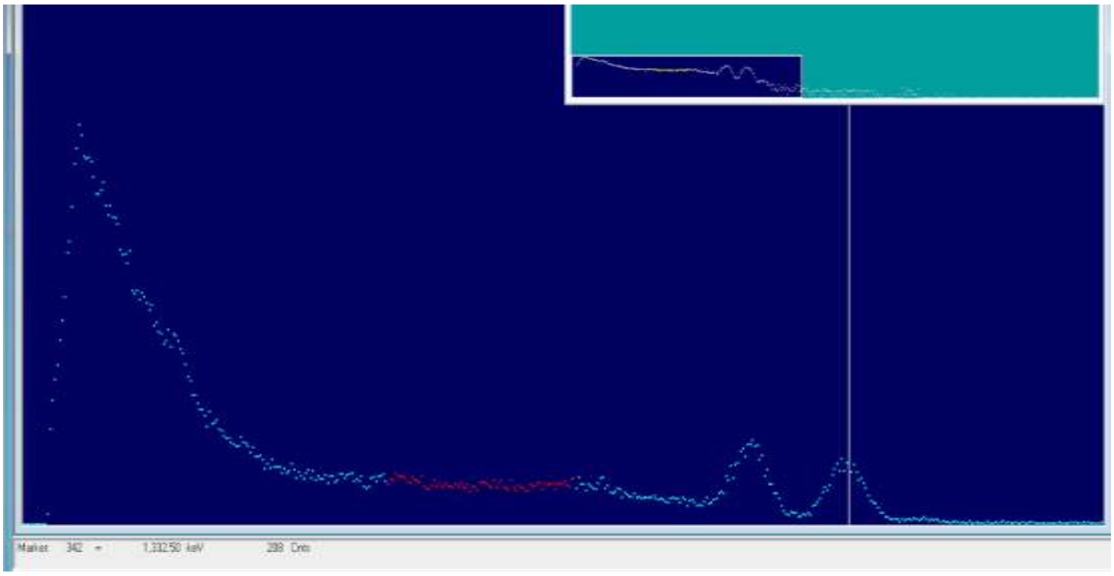

Figure 8: A gamma ray spectrum of one flour sample showing the energy peaks.

5. Discussion

From the obtained results of this study, it was found that the specific activities of the imported wheat flour samples were less than those of the local Iraqi wheat flour samples. The reason for this might be due to the water and soil contamination of Iraq, which has been exposed in its modern history to several wars and extensive military operations through the bombing of some sites and vehicles with shells and missiles containing depleted uranium. Also, agricultural lands were polluted through its transmission into the air, which caused, in one way or another, an increase in the levels of natural and artificial radiation. The presence of oil facilities and the toxic fumes and gases they emit, in addition to the smoke emitted from electric generators and car smoke, have also contributed to increasing the rates of radioactive pollution in Iraq.

6. Conclusions

It was also noted that the specific activities for K-40 of the local Iraqi wheat flour samples were much higher than those of U-238 and Th-232 for the imported samples. All of the previously mentioned negative factors on the environment have caused the increase of radiation background of several areas in Iraq, and thus the occurrence of high rates of many cancerous diseases through the Iraqi individual's consumption of plants and food crops produced by his land that contain an amount of radiation. It is known that the increase of lead level in nature is a significant indicator of the presence of high concentrations of radiation in the nature. The Cs-137 radioisotope was not present in all flour samples. The total dose of natural radioactivity calculated for the flour samples taken in this work was 0.424 $mSv.y^{-1}$ as shown in Eq. (2), this dose is lower than compared with the altogether allowable limit (1 $mSv.y^{-1}$).

Conflict of interest

No conflict of interest exists, according to the authors.

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قياس النشاط الإشعاعي الطبيعي لنماذج من الدقيق القمح المحلي ومقارنته مع دقيق القمح المستورد للأسواق العراقية باستخدام منظومة التحليل الطيفي لأشعة جاما

زينب نصرالله[1] و عصام محمد رشيد[1] و عمارعبد الستارالراوي[1]
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الخلاصة

تم في هذه الدراسة استخدام عشرين عينة من دقيق القمح، تم جمع هذه العينات من الأسواق المحلية. ثلاثة عشر من هذه العينات كانت من الدقيق المحلي بأسماء تجارية مختلفة، وسبع عينات من الدقيق المستورد بأسماء تجارية مختلفة. تم الكشف عن ثلاث نويدات مشعة (U-238، Th-232، K-40) في جميع عينات دقيق القمح باستخدام كاشف المخزن المؤقت متعدد القنوات .(MCB) وتراوحت قيمة النشاط النوعي للدقيق المحلي لعنصر U-238 بين 4.34 و11.88 بكريل/كجم بمتوسط قيمة 7.98 بكريل/كجم، أما عنصر Th-232 فقد تراوح نشاطه النوعي بين 3.22و4.84 بكريل/كجم بمتوسط قيمة 3.94 بكريل/كجم. أما بالنسبة لعنصر البوتاسيوم K-40 فقد تراوح النشاط النوعي بين 220.45 و 290.65 بكريل/كجم بمتوسط قيمة 248.63 بكريل/كجم. وتراوح متوسط النشاط النوعي للدقيق المستورد لعنصر اليورانيوم U-238 ما بين 1.25 إلى 4.38 بيكريل/كجم بمتوسط قيمة 2.48 بيكريل/كجم. أما عنصر Th-232 فقد تراوح نشاطه النوعي بين 0.22 إلى 2.88 بكريل/كجم بمتوسط قيمة 1.51 بكريل/كجم. أما عنصر البوتاسيوم K-40 فقد تراوح نشاطه النوعي بين 152.23 و161.32 بكريل/كجم بمتوسط قيمة 158.19 بكريل/كجم. جرعة النشاط الإشعاعي المحسوبة لجميع العينات هي 0.424 ملي سيفرت-y-1، وهو أقل من الحد المسموح به وهو 1 ملي سيفرت y-1. وتبين من خلال هذه الدراسة أن مستوى النشاط الإشعاعي للدقيق المحلي أعلى منه في الدقيق المستورد.

الكلمات المفتاحية: البوتاسيوم، اليورانيوم، الفعالية الاشعاعية، الطحين المحلي، اشعة كاما.