Measurement of Radioactive Potassium-40 to Specify Potassium Element in Wheat and Its Derivatives for Wasit Governorate – Iraq

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Abstract. The total potassium (element) concentration in percentage ratio (K%) has been calculated for wheat and its derivatives (wheat flour, bran, yeast samples) of Wasit mills, and wheat flour samples that used in bakeries distributed in Wasit governorate by measured K-40 radioactive isotope using gamma spectroscopy adopted with high pure germanium coaxial detector. The overall average values of the above investigated samples were; 0.190%, 0.159%, 0.122%, 0.111%, and 0.251%, respectively. In addition, the natural occurring radioactive materials for all samples have been investigated. Except potassium – 40 (K-40), all the measured radioactive isotopes were below the minimum detectable activity of gamma spectroscopy, therefore, even if a more accurate measurement system is used, the specific radioactivity (S.A) of these isotopes are within the international permissible levels. Then, the ingested radiation annual effective dose of the intake K-40 (Eff D) has been calculated, and the results showed that all values within the international allowed values.

Keywords: Potassium; Radioactivity; Wheat; Flour; Bran; Wasit; Mills; Bakeries

Abstract:

1. Introduction

The human body needs a lot of minerals; although it is present in very small quantities, the human body needs it in the formation of bones and blood. In addition to its role in maintaining the normal functions of cells, its work together with vitamins to form the enzymes necessary for vital processes in the Human body, if the enzyme lacks any of the mineral elements becomes ineffective and unable to function properly. Metals are classified into two categories: major metals, which are the minerals the body needs in large amounts (more than 100 mg per day), such as calcium, phosphorus, potassium, sodium, chlorine, and magnesium, and secondary minerals, which the body needs in very small amounts, such as zinc, iron, manganese, iodine, fluorine, selenium, and chromium [1]. Potassium (K) is one of the main metals in the human body. Its importance lies in the transfer of nerve cells through the exchange of sodium and potassium ions through the cellular membranes of the nerves.
and lowers blood sugar. It also helps to prevent muscle spasms. However, potassium has many benefits for human health and improves the life [2-3].

The amount of potassium in eaten natural food ranges from 2000 mg to 4000 mg per day. Potassium is abundant in many foods such as: wheat flour, avocados, bananas, and etc. It is worth mentioning that excess potassium is taken out by the kidneys, so people with kidney problems should have less potassium intake of less than 2000 milligrams per day [4]. Symptoms of potassium deficiency include several health problems [5-6]. The increase in potassium in the body is not a big problem in healthy people, but it may be a major problem in people suffering from kidney failure, which leads to the disruption of the role of kidney in the release of potassium, which increases the concentration in the blood (Hyperkalemia) [7].

Potassium has three isotopes; K-39, K-40, and K-41. From bioenvironmental point of view, the most significant is K-40, because it's radioactive. There is of the order of 140 g of potassium in an adult who weighs 70 kg, and 0.0169 g consists of the K-40 isotope. This amount of K-40 disintegrates at the rate of 266000 atoms per minute. Of every 100 disintegrations, 89 result in the release of beta particles with maximum energy of 1.33 MeV, and 11 result in gamma photons with energy of 1.46 MeV. All of the beta particles and about 50 % of the gamma rays are absorbed in the body, giving annual doses of 16 mrad from the beta particles and 2 mrad from the gamma rays [8]. Besides, there are several techniques that can measure the concentration of potassium in different samples, but in this paper the measurement of potassium-40 concentration was adopted by using gamma spectroscopy with high-purity germanium coaxial detector (HpGe), and then calculating the total potassium concentration based on the abundance of potassium-40 and the results of references [9-10]. Gamma spectroscopy was used because it's high precision, especially when using HpGe detector.

On the other hand, bread that made from wheat flour is an important part of the Iraqi table, where the consumption rate of up to 9 kg/month (This is what the Iraqi Ministry of Trade provides within the ration items of the Iraqi people). Flour is supplied through mills approved by the government, which in turn relies on imported Australian wheat, which should not exceed 35% (within the wheat for milling, this is done by the Iraqi Ministry of Trade) and local wheat with 60 to 69%. There are also many families that buy ready-made bread from bakeries, which depend on the wheat flour imported, especially from Turkey.

In this paper, the concentration of potassium in the wheat and its derivatives samples and wheat flour used in bakery that spread in Wasit Governorate - Iraq will be measured using gamma spectroscopy with HpGe detector.

2. The Experimental Aspects

2.1 Samples collection
In this work, samples were collected from Wasit province [11], which is located in central Iraq. Wasit province has an area of 17153 square kilometers and constitutes 4\% of the total area of Iraq. It is famous for the production of foodstuffs, especially grains such as wheat, barley, dates, etc., and has a rich fish wealth. The population of Wasit Governorate in 2006 was estimated at 1,032,838. The urban population reached 530,962 people, representing 51.4\% of the total population. Although this study included the province of Wasit, but one can be generalized results on all provinces of Iraq (except Kurdistan) for the great similarity in dietary habits between the Iraqi provinces. However, twenty seven samples were collected from nine mills of Wasit province. Three different samples were collected from each mill; bran, cleaned wheat, and the produced wheat flour. Twenty samples of flour used in bakeries, which are Turkish type, were collected from almost all districts of Wasit province. Finally, six samples of the yeast (bread developer), popular in Iraqi markets, were collected.

2.2 Gamma spectroscopy

Each sample with different mass was measured against radioactive contamination using high-purity germanium (HpGe) coaxial detector with standard setup. Samples' measurements were made at the Iraqi Center for Radiation Protection (ICRP). The multichannel analyzer was suitably set to the range (1-4092) channels, thus providing an appropriate range for the detection process with an acceptable overall FWHM resolution. The analysis of the collected spectra passed the statistical criteria specified by the code (GENIE 2000) [12]. However, the specific activity (S.A) of the investigated sample can give by:

\[
S.A = \frac{(C_s - C_B)}{M_s \varepsilon_{eff} I} \frac{1}{T} \text{…………………(1)}
\]

where, \( C_s \) and \( C_B \) are the sample and background counts (the background was calculated by putting empty Marinelli beaker on the detector and turn on the gamma spectroscopy), \( T \) is the accumulation time, \( M_s \) is the mass of the investigated sample, which is always one kg, \( I \) is the branching ratio (the intensity of gamma line), and \( \varepsilon_{eff} \) is the efficiency of the gamma spectroscopy that estimated using standard gamma source; Eu-152 isotope. Figure 1 (a and b) shows the calculated efficiency and calibration curves of the used gamma spectroscopy. Further, for K it is convenient to give the concentration by percentage ratio; therefore, by dividing S.A on the specific disintegration of the naturally occurring radioactive K-40, which is 31.19 Bq/kg, one can obtain the concentration [10-11];

\[
K\% = \frac{S.A}{31.19} \times 100\%\text{……………………………(2)}
\]
3. Results and Discussions

First of all, all samples have been investigated against natural occurring gamma isotopes and only K-40 illustrated in spectra. S.A of Uranium and Thorium isotopes and their chains were below the minimum detectable activity of gamma spectroscopy (MDA). Therefore, even if a more accurate measurement system is used, the concentrations of these isotopes are within the permissible levels approved by environmental organizations such as International Atomic Energy Agency [13].

The results content three important variables, which are S.A of K-40, potassium concentration as percentage ratio in the tested samples and the ingested radiation annual effective dose of the intake K-40 (Eff D). Eff D can give by [14]

\[
\text{Eff D} = e(g) \times Y \times S.A \quad \text{(3)}
\]

where \(e(g)\) is the effective dose conversion factor, which is \(6.2 \times 10^{-9} \text{ (Sv/Bq)}\) for K-40 isotope [14], \(Y\) is the consumption rate of wheat flour in kg/y, which is 108 kg for Iraqi people (as mentioned above), or yeast (bread developer), and S.A is the specific activity of K-40. However, the same procedure was used by [15-16].

All the results can be demonstrated in three categories; the first one is for the mills that produce wheat flour in Wasit governorate, the second is for wheat flour that used by bakeries in almost all districts of Wasit, and the third category is for the famous yeasts (bread developers) in Iraqi markets.

Table (1) shows the results of bran, cleaned wheat, and wheat flour of the mills. The maximum values of K-40 in Bq/kg, K%, and Eff D in \(\mu\text{Sv/y}\) for bran were 83.0±16.3, 0.266, and 55.58 in Al-Kut mill and the minimum values were 50.2 ± 18.0, 0.161, and
33.61 for Al-Ghiraf mill, while the overall average values were 59.3±14.7, 0.190, and 39.70, respectively. For cleaned wheat that prepare for mill to produce flour, the maximum and minimum values were found in samples of Al-Suwaira and Al-Khulud mills, respectively. The overall average values were 49.6 ± 6.9, 0.159, and 33.21. The maximum values for produced wheat flour samples were found in Al-Kut mill; 52.0±6.0, 0.167, and 34.82, respectively, while the minimum values were detected in Al-Azizia mill; 15.0±9.0, 0.048, and 10.04. The overall average values were 38.0±8.3, 0.122, and 25.44. The results illustrated a logical behavior against the measured values where the maximum values were in bran samples while the minimum values were for wheat flour samples. However, the results of K% are within the international permissible limits, which have the range; 0.133 % to 0.171% [17]. In addition, for the results of Eff D, although there are some high values, in general all results were within the international allowed values [14].

Table 1: the specific activity of K-40 isotope, the percentage of K in samples, and the ingested annual effective dose of the intake K-40 for the bran, refined wheat, and wheat flour of the mills in Wasit Governorate.

| The Mills          | The Bran | The Wheat | The Wheat Flour |
|--------------------|----------|-----------|-----------------|
|                    | K – 40 (Bq/kg) | K % | Eff D (µSv/y) | K – 40 (Bq/kg) | K % | Eff D (µSv/y) | K – 40 (Bq/kg) | K % | Eff D (µSv/y) |
| Wasit              | 54.0 ± 5.9 | 0.173 | 36.16 | 46 ± 6.3 | 0.147 | 30.80 | 30.0 ± 9.0 | 0.096 | 20.09 |
| Khayrat Al-Janub   | 53.8 ± 18.9 | 0.172 | 36.02 | 57 ± 4.7 | 0.183 | 38.17 | 30.0 ± 9.5 | 0.096 | 20.09 |
| Al-Ghiraf          | 50.2 ± 18.0 | 0.161 | 33.61 | 44.6 ± 2.1 | 0.143 | 29.86 | 51.2 ± 4.8 | 0.164 | 34.28 |
| Al-Mutanabiyy      | 62.0 ± 14.0 | 0.199 | 41.52 | 47.1 ± 3.1 | 0.151 | 31.54 | 42.3 ± 2.3 | 0.136 | 28.32 |
| Al-Kut             | 83.0 ± 16.3 | 0.266 | 55.58 | 48.3 ± 2.7 | 0.155 | 32.34 | 52.0 ± 6.0 | 0.167 | 34.82 |
| Al-Khulud          | 66.0 ± 14.6 | 0.212 | 44.19 | 40 ± 2.3 | 0.128 | 26.78 | 40.0 ± 11.0 | 0.128 | 26.78 |
| Al-Azizia          | 54.8 ± 19.0 | 0.176 | 36.69 | 41.8 ± 2.3 | 0.134 | 27.99 | 15.0 ± 9.0 | 0.048 | 10.04 |
| Al-Suwairaa        | 57.8 ± 19.5 | 0.185 | 38.70 | 70.2 ± 9.4 | 0.225 | 47.01 | 50.2 ± 18.0 | 0.161 | 33.61 |
| Abou El Hassan Ali | 52.0 ± 6.0 | 0.167 | 34.82 | 51.6 ± 2.0 | 0.165 | 34.55 | 31.0 ± 2.0 | 0.099 | 20.76 |
The second part of the results is for wheat flour used in bakeries distributed in Wasit governorate that showed in Table (2). The maximum values of K-40 in Bq/kg, K%, and Eff D in µSv/y were registered in Al–Hay bakery with values 76.0 ± 12.0, 0.244, and 50.89, whereas the minimum values were registered in Al-Dabouni bakery with values 22.0 ± 12.1, 0.071, and 14.73. The overall average values were 34.72 ± 11.0, 0.111, and 23.25, respectively. It is clear that the results of the wheat flour that used in bakeries are less than the results of the produced wheat flour in mills.

**Table 2; as in Table 1 but for wheat flour used in bakeries**

| The Bakeries       | K-40 (Bq/kg) | K %     | Eff D (µSv/y) |
|--------------------|--------------|---------|---------------|
| Sheikh Saad        | 27.2 ± 11.3  | 0.087   | 18.21         |
| Al-Hakim           | 24.4 ± 10.3  | 0.078   | 16.34         |
| Badrah             | 44.1 ± 14.3  | 0.141   | 29.53         |
| Jassan             | 27.8 ± 11.1  | 0.089   | 18.61         |
| Damuk              | 42.8 ± 5.4   | 0.137   | 28.66         |
| Dawr Al-Eummal     | 32.0 ± 2.3   | 0.103   | 21.43         |
The final part of the results are attributed to yeast samples that used from approximately all the Iraqi publics, which were showed in Table (3). The maximum and unexpected values were measured in Turkish type (Safi-instant) sample; 240.0±27.0 Bq/kg for S.A of K-40, 0.769 for K%, and 1.488 µSv/y for Eff D, which is calculated by assuming the consumption rate (Y) of yeast is 1 kg/y for Iraqi peoples. The minimum values were found in Russian type (Golden); 24.7 ± 4.4, 0.079, and 0.153, respectively.

Table 3; as in Table 1 but for yeast (flour developer) samples

| Yeast                  | K-40 (Bq/kg) | K %  | Eff D (µSv/y) |
|------------------------|--------------|------|---------------|
| Turkish type (Safi-instant) | 240.0 ± 27.0 | 0.769 | 1.488         |
| Russian type (Golden)  | 24.7 ± 4.4   | 0.079 | 0.153         |
| Chinese type (Aldanamaya) | 51.6 ± 3.1  | 0.165 | 0.320         |
| Iranian type (Razavi)  | 56.3 ± 4.6   | 0.181 | 0.349         |
| Chinese type (Angel)   | 55.3 ± 3.6   | 0.177 | 0.343         |
| Turkish type (Vega)     | 41.3 ± 5.6 | 0.132 | 0.256 |
|------------------------|------------|-------|-------|
| Overall Average        | 78.2 ± 8.05| 0.251 | 0.485 |

4. Conclusions

From the obtained results one can conclude that the consumed wheat flour is safer from radioactivity point of view where all the natural occurring gamma isotopes are below the MDA of gamma spectroscopy except K-40. K-40 was detected in all samples and their registered values are within the international allowed values, and only the maximum and unexpected value was measured in Turkish type (Safi-instant) yeast sample. In addition, all the measured values of potassium concentration are within other international measured values, therefore, the consumption of wheat flour is considered a safe and healthy in terms of it contains appropriate amounts of potassium.

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