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Determination of K-40 radionuclide content and the resulting radiation doses in some foodstuffs and drinking water in KSA

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ABSTRACT

The activity of K- 40 radionuclide content and the resulting radiation doses in some foodstuff and drinking water in KSA are measured. To the first time, a quantitative study is given here to determine the concentration of the natural potassium in various samples under investigations. High resolution gamma ray spectroscopy was employed. Our standard sample was prepared using pure KCl, thus radiation content of the samples can be estimated directly by relative method. Data for every sample was collected for 7000s. The content of K- 40 in the samples varies from 0.50 to 110 Bq/kg, which produce an equivalent dose up to 85.5 μ Sv/y.

KEYWORDS

Natural radioactivity;
Foodstuffs;
Gammy-ray spectrometry.

INTRODUCTION

Certain foodstuff used in Arab area such as: olive oil, honey, she-camel milk and *ZAMZAM* water were investigated here. Soft-ware equipped with the detector electronic system was used to analyze the data, and to give the required results.

A comparative study of our results with different results in other areas of the world was done.

There are a few radioisotopes that exist naturally in our environment. Some of these isotopes were present when the earth was formed; others are continuously produced by cosmic rays. Four were produced when the earth was formed, these are: K- 40 (half-life of 1.277×10^9 y), U – 238 (half-life of 4.51×10^9 y), U – 235 (half-life of 7.1×10^8 y) and Th–232 (half-life of 1.4×10^{10} y) While, C-14 (half-life of 5280 y) is produced continuously in the upper atmosphere by cosmic rays. We focus here on K – 40 since it is the largest contributor to our natural background radiation. There are many isotopes of potassium; most of the stable isotopes on earth are K – 39, while the radioactive isotope K – 40 represents 0.0117 % of the natural potassium. K- 40 decays by two ways:

1- Via beta minus decay (89.28 %) to the ground state of Ca- 40, average energy 0.561 MeV, max. 1.31 MeV.
2- Via electron capture (10.72 %) to the excited state of Ar-40.

When the excited state of Ar - 40 decays to the ground state of Ar - 40, a gamma photon of energy equals 1460.83 KeV is emitted (with a rate of 0.9953 %)[8]. The specific activity of K- 40 isotopes is 31 KBq / kg of natural potassium. The natural potassium content of the body is 0.2%, so for a 70 kg man, the amount of activity resulting from K- 40 will be about

4.26 kBq. This element distributes throughout the human body. Body burden decreases with age and muscle-wasting diseases[4]. The daily intake of element in food and fluids is 0.33g. The conversion factor due to ingestion is 5.02×10^{-9} Sv / Bq, and due to inhalation is 3.34×10^{-9} Sv / Bq. Thus, this isotope delivers a dose of 180 μ Sv / y to the gonads and other soft tissue and 140 μ Sv / y to bone (NCRP, 1987a). Stable potassium constitutes 2.59 % of the earth's crust with 380 ppm in sea water; the K – 40 levels in soil varies from 0.037 to 1.1 Bq/g. K – 40 is the predominant in normal food and human tissue[4].

Radioactivity in the diet of a man consists of fallout radionuclides and natural radionuclides mainly due to K – 40 and the two primordial radioactive series with U – 238 and Th – 232 as parents. The decline in the atmospheric weapon tests programme since 1962 has significantly decreases the fallout radioactivity in foodstuff levels since 1968. This enabled us to easily measure radioactivity in foodstuff by Gamma spectrometry[14]. Contamination of the food chain occurs as a result of direct deposition of radionuclides on plant leaves, root uptake from contaminated soil or water, and animals ingesting contaminated plants, soil or water[2]. Several papers in different parts of the world were reported[12]. Several papers and reports on the radiation level in some foodstuffs used in Saudi Arabia were reported[1]. In this paper we give the recent radiation level in food stuffs.

EXPERIMENTAL

Sampling

Samples from different areas in KSA were collected. Three types of samples were used: solid, powdered and liquid samples. All samples were collected from local market, while *ZAMZAM* water was taken directly from the well laying underneath *QA'BA* directly. Solid samples such as: wheat, barley, rice, beans, lentils, etc were prepared in a form of fine powder suitable to be used by Marinelli beaker. These samples were crushed into fine powder and were put in 0.5 l Marinelli beakers. Powder and liquid samples were used directly and were put in the mentioned above Marinelli beakers. The net weight of the samples were measured and recorded for further analysis. The standard sample was pure KCl (99.95 %) (Of 0.5 l in volume) and provided by chemistry department, faculty of science, Taif university.

Counting system

High resolution gamma – ray spectrometer using HPGe detector was used to identify the gamma – ray line emitted by K – 40 radioisotope at 1460 KeV, technique and principle of this spectrometer is well established and can be found else were[5]. We have used Canberra HPGe detector of 50% relative efficiency coupled to Canberra Digital Spectrum Analyzer DSA2000 with an FWHM of 2 keV for the 1.332 MeV gamma ray of Co – 60. This detector is equipped with model 747 Canberra lead shield system composed of 10–cm thick low-background lead and 1 mm tin and 1.6mm copper graded linear to prevent interference by lead X – rays[3].

Calculations

Energy calibration was done using standard sources of known gamma ray energies like: Cs – 137 and Co – 60. We also used the known gamma ray energy emitted by K – 40 to identify this radioisotope in the food samples. There was no need to make efficiency calibration to our system because we use direct relative measurement, since the activity of the standard source is known, thus the peak area under the photo peak is directly proportional to the activity of standard sample.

(a) The activity of the standard sample (A_{ST}) can be given by the relation

$$A_{ST} = \frac{0.693}{\tau} \cdot \frac{N_O}{M} \cdot \frac{0.0117}{100} m_K (Bq) \qquad (1)$$

Where,

m_K is the mass of the potassium in the potassium chloride (KCL)

(b) Then, the specific activity (A_S in Bq/ kg or l) of the sample is given as

$$A_S = \frac{a_s}{a_{ST}} \cdot \frac{A_{ST}}{m_s} P_\gamma \qquad (2)$$

Where,

a_S peak area of the sample (cps)

a_{ST} peak area of the standard sample (cps)

A_{ST} the activity of the standard sample(Bq)
m_S mass of the sample under investigation (kg)
P_γ No of photons per decay

(c) Concentration ratio (R %) of natural potassium in the samples

The concentration of natural potassium in the samples is given by the relation:

$$R = \frac{\text{Specific activity of the sample}\left(\frac{Bq}{kg}\right)}{\text{Specific activity of the narural potassium}\left(31\frac{kBq}{kg}\right)} \quad (3)$$

(d) The internal doses

Using the results of the specific activities of samples and the data on food consumption pattern reported for the Kingdom Of Saudi Arabia (1999-2001), the daily intake of K – 40 radionuclide (Bq/day) can be estimated. It can be seen that the average daily intake of K - 40 is large. However, this should cause no concern because as an isotope of an essential element for metabolic activity, it is homeostatically controlled in the body (Holtzman, 1980). Knowing the dose conversion factor (CF) of K – 40 which equals 3 μ Sv year^{-1} / Bq day^{-1} (NCRP, 1987), one can calculate the annual effective dose equivalent (μ Sv year^{-1}) due to ingestion of potassium in different foodstuffs.

The daily intake (DI) can be given by the relation:

$$DI = A_S\ (Bq/kg) \times CR\ (kg/d) \quad (4)$$

Where, CR is the daily consumption rate of the foodstuff.

Therefore, the annual effective dose equivalent (DE) (μ Sv year^{-1}) is given by the relation:

$$DE = CF \times DI$$
$$= CF\ (\mu\ Sv\ year^{-1} / Bq\ day^{-1}) \times A_S\ (Bq/kg) \times CR\ (kg/d) \quad (5)$$

RESULTS AND DISCUSSION

In TABLE 1 We show the specific activities of K – 40 in the investigated samples, together with other work world- wide. We notice big variations in the concentrations of K – 40 in the different samples.

It is obvious that some of our measured values are in consistent with other values reported by many authors (TABLE 1) but wide disagreements can be seen between us and (A.F.Abdul-Fattah, S.Abdul-Majid, 1995) who reported a value of 345.54 Bq/kg for powder milk (NIDO) while our value is 39.41 Bq/kg (i.e. a factor of about 10 times less ?). Generally, it was noticed that their values were more than a factor of 10 more than ours, with the exception of Similac Milk (Infant Formula) and Infant Milk Cereal (Sahha) were the values are in good agreement. The highest concentration of the radioactive potassium was registered by Cardamom (Elettaria Hail, USA), of 110.39 Bq/kg, and other high values of Black Tea (Lipton) (63.60±0.05 Bq/kg) and Coffee (Yemen) (61.30±0.06 Bq/kg). Egyptian white Beans and Saudi chick Peas have values of 44.50±0.05 Bq/kg and 37.67±0.05 Bq/kg, respectively. Other higher values were detected for Milk powder (Nido) (39.41 ± 0.11 Bq/kg) and Milk powder (Al-Taie)(39.55 ± 0.12 Bq/kg). While, low concentrations were reported for both: Cow milk (liquid) (5.62±0.09 Bq/kg) and She Camel milk (liquid) (6.95±0.07 Bq/kg).

Qassim Barley shows 19.70±0.08 Bq/kg, while wheat – flour gives 6.27 ± 0.12 Bq/kg. Natural honey shows 20.83±0.03 Bq/kg, while Alshifa honey (man-made) gives 2.53±0.13 Bq/kg.

Tomato paste shows high value of 34.17±0.03 Bq/kg with respect to fresh tomato of 5.40± 0.05 Bq/kg. Samples of olive oils and drinking water give very low concentrations of less than 1 Bq/kg. Drinking water from Riyadh area shows radiation free concentration, thus classified as below detected level (BDL).

In TABLE 2 We show specific activity (Bq/kg), daily intake (kg/d), activity daily intake (Bq/d), Concentration ratio (R %) of natural potassium in the samples and the annual effective dose equivalent (μ Sv/y). The total annual effective dose equivalent is 85.5 μ Sv/y which is below the acceptable level of the ingestion dose of 300 μ Sv/y as reported in UNSCEAR (2000). And the lowest recommended dose limit for public which is about 1000 μ Sv/y (Wrixon, A.D (2008). We give here the Concentration ratio (R %) of natural potassium in the samples, using radioactivity analyses. Since natural potassium is a common element in nature, thus this method can be added to other methods for determine the ratio of natural potassium in any material.

TABLE 1 : Specific activities of K – 40 in the investigated food samples, together with other work world- wide

S. No	Sample	Specific Activity (Bq/kg or l)	
		Present work	Other work
	I – Cereals		
1	Wheat-flour	6.27±0.12	9.15±1.6[11] 9.85±3.55[2]
2	Barley Qassim	19.70±0.08	
3	Indian rice (Abu kass)	4.16±0.11	17.4-46.3[13]
4	Egyptian rice (Rotana)	2.47±0.21	10.9±1.8[11]
5	USA rice (Abu Swords)	5.03±0.13	
6	Red Indian Lentil	29.41±0.04	
	2-Pulses		
7	Saudi chick Peas	37.67±0.05	
8	Egyptian white Beans	44.50±0.05	6.83±1.75[11] 171[4]
	3-Stimulants		
9	Cardamom (Elettaria Hail, USA)	110.39±0.03	
10	Coffee (Yemen)	61.30±0.06	
11	Black Tea (Lipton)	63.60±0.05	
	4-Beverages		
12	Pepsi drink	0.51±0.15	
13	Tang orange juice	0.43±0.18	
	5-Macaroni		
14	Spaghetti Pasta	7.30±0.07	
15	Al-Alali past	8.27±0.07	
	6-Dairy Products		
16	Milk powder (Nido)	39.41±0.11	345.54[1]
17	Milk powder (Al-Taie)	39.55±0.12	40[10]
18	Similac Milk (Infant Formula)	21.70±0.10	22.34[1]
19	Infant Milk Cereal (Sahha)	20.80±0.08	14.64[1]
20	Cow milk (liquid)	5.62±0.09	
21	She Camel milk (Liquid)	6.95±0.07	
	7-Sugar and Honey		
22	Natural honey	20.83±0.03	
23	Alshifa honey (man-made)	2.53±0.13	
24	AL-Osra Sugar	0.05±0.02	
	8-Vegetable Oil		
25	Olive Oil (Palestinian)	0.82±0.13	
26	AL Jouf Olive Oil (KSA)	0.57±0.15	
	9-Drinking Water		
27	Arar water	0.27±0.15	
28	Zamzam water	0.42±0.15	
29	Taif water	0.42±0.15	
30	Jeddah water	0.86±0.13	
31	Riyadh water	BDL	
	10-Miscellaneous		
32	Salt Sasa	0.70±0.11	
33	Dates	21.53±0.02	
34	Tomato fresh	5.40±0.05	
35	Tomato paste	34.17±0.03	

TABLE 2 : Specific activities (Bq/kg), daily intake (kg/d), activity daily intake (Bq/d), Concentration ratio (R %) of natural potassium in the samples and the annual effective dose equivalent (μ Sv/y).

S. No	Sample	Specific activity (Bq/kg or l)	daily intake (kg/d)	activity daily intake (Bq/d)	R (%)	DE (μSv/y)	
						individual	average
	I – Cereals						
1	Wheat-flour	6.27±0.12	0.2	1.25	0.02	3.75	3.75
2	Barley Qassim	19.70±0.08	0.02	0.43	0.06	1.29	1.29
3	Indian rice (Abu kass)	4.16±0.11	0.15	0.62	0.013	1.86	
4	Egyptian rice Rotana)	2.47±0.21	0.15	0.37	0.007	1.11	1.2
5	USA rice (Abu Swords)	5.03±0.13	0.15	0.75	0.016	2.25	
6	Red Indian Lentil	29.41±0.04	0.03	0.88	0.094	2.64	2.64
	2-Pulses						
7	Saudi chick Peas	37.67±0.05	0.02	0.75	0.121	2.25	2.46
8	Egyptian white Beans	44.50±0.05	0.02	0.89	0.143	2.67	
	3-Stimulants						
9	Cardamom (Elettaria Hail, USA)	110.39±0.03	0.006	0.66	0.36	1.98	1.98
10	Coffee (Yemen)	61.30±0.06	0.04	2.45	0.197	7.35	7.35
11	Black Tea (Lipton)	63.60±0.05	0.008	0.5	0.2	1.5	1.50
	4-Beverages						
12	Pepsi drink	0.51±0.15	0.5 l	0.257	0.00165	0.77	0.77
13	Tang orange juice	0.43±0.18	0.02	0.008	0.0013	0.024	0.02

S. No	Sample	Specific activity (Bq/kg or l)	daily intake (kg/d)	activity daily intake (Bq/d)	R (%)	DE (µSv/y)	
						individual	average
			5- Macaroni				
14	Spaghetti Pasta	7.30±0.07	0.1	0.73	0.023	2.19	2.33
15	Al-Alali pasta	8.27±0.07	0.1	0.82	0.026	2.46	
			6-Dairy Products				
16	Milk powder (Nido)	39.41±0.11	0.2	7.88	0.127	23.64	23.68
17	Milk powder (Al-Taie)	39.55±0.12	0.2	7.91	0.127	23.73	
18	Similac Milk (Infant Formula)	21.70±0.10	0.08	1.73	0.07	5.19	5.08
19	Infant Milk Cereal (Sahha)	20.80±0.08	0.08	1.66	0.067	4.98	
20	Cow's milk (liquid)	5.62±0.09	0.3	1.68	0.018	5.04	5.63
21	She Camel milk (Liquid)	6.95±0.07	0.3	2.07	0.022	6.21	
			7-Sugar and Honey				
22	Natural honey	20.83±0.03	0.03	0.62	0.067	1.86	0.7
23	Alshifa honey(man-made)	2.53±0.13	0.03	0.075	0.008	0.22	
24	Sugar (AL-Osra)	0.05±0.02	0.1	0.005	0.00016	0.015	
			8-Vegetable Oil				
25	Olive Oil (Palestinian)	0.82±0.13	0.03	0.024	0.0026	0.072	0.06
26	Olive Oil AL Jouf (KSA)	0.57±0.15	0.03	0.017	0.0018	0.051	
			9-Drinking Water				
27	Arar water	0.27±0.15	5 l	1.33	0.0007	3.99	5.87
28	Zamzam water	0.42±0.15	5 l	2.09	0.0013	6.27	
29	Taif water	0.42±0.15	5 l	2.09	0.0013	6.27	
30	Jeddah water	0.86±0.13	5 l	4.28	0.0027	12.84	
31	Riyadh water	BDL	5 l	- -	- -	- -	
			10-Miscellaneous				
32	Salt (SASA)	0.70±0.11	0.008	0.006	0.0022	0.018	0.018
33	dates	21.53±0.02	0.09	1.93	0.069	5.79	5.79
34	Tomato fresh	5.40±0.05	0.2	1.08	0.017	3.24	3.24
35	Tomato paste	34.17±0.03	0.1	3.417	0.11	10.25	10.25
	Total						85.5

CONCLUSION

The specific activities of K -40 in many foodstuffs used in the kingdom were measured using the high resolution gamma ray spectroscopy. A wide variation of these activites was reported, because of different compositions of these foodstuffs. Depending on the soil they grown on it, and the country of origin, some crops have different concentrations of Potassium than others. According to the measured values of specific activities and the annual effective equivalent doses, one can conclude that:

From among other rice samples, Egyptian rice (Rotana) has the lowest concentration of Potassium. Liquid milk of cows and the she camels has the lowest concentration of Potassium among other milk samples. Fresh tomato has a level of about one order of magnitude less than the commercial tomato bastes. On the other hand, Saudi check peas and Egyptian white beans show high concentration levels of Potassium, while the highest level of Potassium is reported in Cardamom (USA) Coffee (Yemen) and Black Tea (Lipton).

According to the previous conclusion, we recommend the using of the food stuffs that have the lowest concentration of potassium, such as egyption rice, fresh tomato and liquid milk.

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