THE ^{40}K ACTIVITY OF ONE GRAM POTASSIUM IN MILK POWDER

KEAKTIFAN ^{40}K DALAM SATU GRAM KALIUM SUSU TEPUNG

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Abstract

Potassium is a very significant body mineral, important to both cellular and electrical function which needs to be uptake daily by human from various foods. Potassium-40 (^{40}K) which is the radioactive isotope of potassium is the largest source of natural radioactivity in animals including humans and makes up about 0.012% (120 ppm) of the total amount of potassium found in nature. This paper reported measurements of ^{40}K by using gamma-ray spectrometry in fifty-one milk powder samples from two different potassium concentrations where ^{40}K activity per gram potassium was then calculated. In this study, the concentration of ^{40}K in milk powder are found in the range of 215.7 Bq.kg^{-1} to 256.9 Bq.kg^{-1}. From calculation, the ^{40}K activity found lied in between 26.83 to 31.77 Bq.g^{-1} (mean value 29.26 ± 1.20 Bq.g^{-1}) of potassium and is in good agreement with that reported in the literature, which varies from 27.33 to 31.31 Bq.g^{-1} of potassium.

Keywords: Potassium-40, gamma-ray spectrometry, milk powder, ^{40}K activity per gram potassium

Abstrak

Kalium adalah mineral badan yang sangat signifikan, penting untuk kedua-dua fungsi sel dan elektrikal yang perlu diambil setiap hari oleh manusia dari pelbagai makanan. Kalium-40 (^{40}K) iaitu isotop radioaktif kalium merupakan sumber radioaktiviti semulajadi yang terbesar dalam haiwan termasuk manusia dan membentuk kira-kira 0.012% (120 ppm) daripada jumlah kalium yang terdapat dalam alam semulajadi. Kertas kerja ini melaporkan pengukuran ^{40}K dengan menggunakan spektrometri sinar gama di dalam lima puluh satu sampel susu tepung pada dua kepekatan kalium berbeza yang mana keaktifan ^{40}K per gram kalium akan dikira. Dalam kajian ini, kepekatan ^{40}K dalam susu tepung adalah berada dalam julat 215.7 Bq.kg^{-1} ke 256.9 Bq.kg^{-1}. Dari pengiraan, keaktifan ^{40}K ditemui jatuh antara 26.83 hingga 31.77 Bq.g^{-1} (nilai min 29.26 ± 1.20 Bq.g^{-1}) untuk kalium dan berada dalam persetujuan baik dengan nilai dilaporkan dalam rujukan, iaitu dari 27.33 hingga 31.31 Bq.g^{-1} bagi kalium.

Katakunci: Kalium-40, spektrometri sinar gama, susu tepung, keaktifan ^{40}K per gram kalium

INTRODUCTION

Potassium is a very significant mineral to the body, important to both cellular and electrical function. It is one of the main blood minerals called "electrolytes" along with the others such as sodium and chloride, and it carries a tiny electrical positive charge (potential) [Elson 2011]. According to Alan (2018), potassium is one of the seven essential macrominerals to the body. The human body requires at least 100 milligrams of potassium daily to support key processes in the body. Potassium-40 (^{40}K) is a radioactive isotope of potassium which has a very long half-life of 1.251×10^9 years. It makes up about 0.012% (120 ppm) of the total amount of potassium found in nature. Potassium-40 is the largest source of natural radioactivity in the body of animals including humans. For instance, a 70 kg human body contains about 140 grams of potassium, hence about $0.000117 \times 140 = 0.0164$ grams of ^{40}K; whose decay produces about 4,300 disintegrations per second (becquerels) continuously throughout the life of the body, i.e equivalent to about 30.7 Bq.g^{-1} of potassium (Wikipedia 2018). According to literatures review by Samat et al. (1997), the ^{40}K activity varies between 27.33 to 31.31 Bq.g^{-1} of potassium.

Potassium-40 decays to ^{40}Ca by emitting a beta particle with no attendant gamma radiation (89% of the times) and the gas ^{40}Ar by electron capture with emission of an energetic gamma ray (11% of the times). So, the ^{40}K can present both external and internal health hazards. The strong gamma radiation ($E_\gamma = 1.46$ MeV) makes the external exposure to this radioisotope a concern; while inside the body, ^{40}K poses a health hazard from the beta particles emission ($E_{\beta Max} = 1.35$ MeV) and gamma rays which associate with cell damage and general potential for subsequent cancer induction (Afshari *et al.* 2009).

Kolapo, A.A. (2014) said that many elements or compounds such as metals and metalloids will accumulate along the food chain. Their concentrations in the environment grow with the increase of urban, agricultural, and industrial emissions. The presence of metal aids their entry into the food chain and thereby increases the toxicity effects of the food in humans and animals diet. Milk is one of the most important foods for human nutrition; it is beneficial in human diet and mostly needed by infant and children during their growing age.

This paper aimed to report the activity of ^{40}K in milk powder samples measured by using gamma-ray spectrometry. As the potassium concentration for the milk powders were also being provided on the container nutrient label, the ^{40}K activity per gram potassium can then be calculated. For this study, a total of 51 milk powder samples were measured, of which 25 samples reported to contain 810 mg of K in 100 g of milk powder, and another 26 samples containing 804 mg of K per 100 g milk powder.

MATERIALS AND METHODS

Milk sample collection and preparation

A total of fifty-one cans milk powder with two different potassium nutrient contents were obtained. For each freshly opened milk can, a portion of the sample (approximately 200g) was taken and weighted. This portion of sample and the milk powder remaining in the can was dried overnight in an electric scientific oven at 85 ^{o}C. On the following day, milk powder was allowed to cool to the room temperature. The portion of sample was re-weighted to determine the moisture content and later discarded. Milk powder from the remaining inside the can was transferred and compressed into a 250 ml size marinelli beaker, sealed with thick PVC tape to inhibit radon from escaping (Zal-U'yun *et al.* 2017). The samples weight between 215 – 260 g with density between 0.67 – 0.82 g/cc. All samples were stored for a period in excessive of 30 days to establish secular equilibrium between ^{226}Ra and ^{228}Ra and their respective radioactive progenies prior to gamma counting (Dowdall and O'Dea 2002; Yang *et al.* 2005). [In this paper, only the activity of ^{40}K was reported and discussed but the measurements of gamma emitting radionuclides were carry out simultaneously.]

Gamma spectrometry counting

A sample spectrum was individually measured with the gamma ray spectrometry consisting of a high-purity germanium (HPGe) setup and multichannel analyzer of 16,384 channels. The detector used is a coaxial 3 inches diameter closed end, closed facing window geometry with vertical dipstick operated at 1,500 HV bias supply. The detector is shielded in a chamber made of lead, cadmium and copper (total thickness 11 cm) to reduce the background radioactivity. This p-type detector is designed to provide 25% relative efficiency with the FWHM resolution of 820 eV at 122 keV gamma-ray line of ^{57}Co and 1.85 keV at 1332 keV gamma-ray line of ^{60}Co. It was calibrated using procedures as reported earlier by Yii et al. (2009) using customized gamma multinuclides standard source comprising of ^{241}Am, ^{109}Cd, ^{57}Co, ^{123m}Te, ^{51}Cr, ^{113}Sn, ^{85}Sr, ^{137}Cs, ^{88}Y and ^{60}Co in the same counting geometry. Source used was manufactured by Isotope Products Laboratories, USA (source no. 1895-82). A similar geometry container filled with deionized water measured over weekend to determine the background counts.

All samples were counted for 54,000 seconds using spectrometer and corrected for density and date of sampling. Counting times are long enough to ensure a 2σ counting error of less than 10%. Some previous studies reveal that minimum counting time of 10 hours is sufficient to provide adequate counts under the various gamma-ray peaks (El-Reefy et al. 2006; Ahmed and El-Arabi. 2005; Arogunjo *et al.* 2005). The activity of ^{40}K was calculated directly *via* its energy peak (Yang *et al.* 2005; El-Reefy *et al.* 2006) using the commercial software Gamma Vision version 6.01. The minimum detectable activity (MDA) was set at 5 Bq/kg after considering the sample size and counting time of ^{40}K (Zal-U'yun *et al.* 2017).

Calculation of ^{40}K activity per gram potassium

The ^{40}K activity per gram potassium is calculated using the below equation:

$$C_{K40} = (A_K/C_K)*100 \quad \ldots \text{ eq (1)}$$

Where
C_{K40} is the ^{40}K activity per gram potassium (Bq.g^{-1})
A_K is the corrected ^{40}K specific activity calculated from the software (Bq.kg^{-1})
C_K is the potassium concentration (810
mg or 804 mg) of K per 100 g milk powder.

RESULTS AND DISCUSSION

Potassium-40 behaves the same as other potassium isotopes in environment, being assimilated into the tissues of all plants and animals through normal biological processes. It is the predominant radioactive component in human tissues and in most food. For example, milk contains about 74 Bq.L^{-1} of natural ^{40}K (Baeza *et al*. 2004; Argonne National Laboratory 2005). Ingestion of contaminated foods is one of the routes of uptake of potentially dangerous radionuclides for man and dairy products in particular due to importance in human diets (Baeza *et al*. 2004).

In this present study, the moisture contents in the milk powder were found to vary between 1.4 – 2.3%. Primary count rate under the photopeak of ^{40}K was analysed and calculated by the system using standard gamma radioactivity calculation equations of the commercial software Gamma Vision version 6.01. The activity concentration and the associated uncertainty (1σ) of the radionuclide was reported after normalized for one kilogram mass of each sample. To determine the ^{40}K activity per gram potassium in the sample, Equation 1 was used. Using this equation the data was calculated and reported with 1σ uncertainty. Finally, the ^{40}K activity concentration (Bq.kg^{-1}) of the milk powder samples and the calculated data are presented in Table 1 below.

As shown, the values of ^{40}K radioactivity varies from 223.4 Bq.kg^{-1} to 256.9 Bq.kg^{-1} for milk powder samples batch containing 810 mg of K. The calculated activity of ^{40}K per gram potassium ranged from 27.57 – 31.72 Bq.g^{-1} with the average of 29.46 ± 1.05 Bq.g^{-1}. Meanwhile for the batch containing 804 mg of K, the ^{40}K radioactivity ranged from 215.7 Bq.kg^{-1} to 255.4 Bq.kg^{-1} and the calculated activities of ^{40}K per gram potassium lied between 26.83 – 31.77 Bq.g^{-1} with the average of 29.07 ± 1.31 Bq.g^{-1}.

The measured activity concentrations values for ^{40}K are compared with other studies as shown in Table 2. The ^{40}K activity in these milk powder samples are found to be higher than the values reported in Iran (Afshari *et al*. 2009), Nigeria (Kolapo 2014) and Saudi Arabia (Alamoudi 2013) but lower than the values in powdered milk in Jordan (Ababneh *et al*. 2010) and comparable with some other parts of the world as shown in Table 2. The differences most probably are due to the different in potassium content in various brands of milk powder. The calculated activities of ^{40}K per gram potassium of this study are found in good agreement with that reported in the literature, which varies between 27.33 to 31.31 Bq.g^{-1} of potassium as stated by Samat *et al.* (1997).

CONCLUSIONS

The activity concentration level of ^{40}K measured in twenty-five samples for milk powder batch containing 810 mg of K are found to be lied between the range from 223.4 Bq.kg^{-1} to 256.9 Bq.kg^{-1} with mean value 238.6 ± 8.5 Bq.kg^{-1}. For the twenty-six samples of batch 804 mg of K, the concentration level of ^{40}K are found in the range of 215.7 Bq.kg^{-1} to 255.4 Bq.kg^{-1} with mean value 233.7 ± 10.5 Bq.kg^{-1}. The measured activity concentrations values for ^{40}K in present study are varies with other studies in the world. The calculated activities of ^{40}K per gram potassium ranged from 27.57 – 31.72 Bq.g^{-1} and 26.83 – 31.77 Bq.g^{-1}, respectively, for batch 810 mg and 804 mg. The overall calculated mean value of ^{40}K per gram potassium in milk powder was 29.26 ± 1.20 Bq.g^{-1}. The calculated activities of ^{40}K per gram potassium of this study are found in good agreement with that reported in literatures.

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Table 1: Potassium-40 activity concentration (Bq.kg^{-1}) measured in milk samples ± 1SD; and calculated ^{40}K per gram potassium ± 1SD

Batch 810 mg K per 100 g milk powder			**Batch 804 mg K per 100 g milk powder**		
Sample ID	**^{40}K activity concentration (Bq.kg^{-1})**	**^{40}K per gram potassium (Bq.g^{-1})**	**Sample ID**	**^{40}K activity concentration (Bq.kg^{-1})**	**^{40}K per gram potassium (Bq.g^{-1})**
HC01	234.2 ± 6.3	28.91 ± 0.77	**LC01**	255.4 ± 6.6	31.77 ± 0.82
HC02	241.0 ± 6.4	29.75 ± 0.79	**LC02**	236.6 ± 6.6	29.43 ± 0.82
HC03	237.1 ± 6.4	29.27 ± 0.79	**LC03**	221.8 ± 6.1	27.59 ± 0.76
HC04	238.7 ± 6.4	29.47 ± 0.79	**LC04**	233.4 ± 6.4	29.03 ± 0.80
HC05	246.8 ± 6.7	30.46 ± 0.82	**LC05**	228.9 ± 6.3	28.47 ± 0.78
HC06	232.8 ± 6.6	28.74 ± 0.81	**LC06**	225.8 ± 6.2	28.08 ± 0.77
HC07	230.8 ± 6.4	28.50 ± 0.79	**LC07**	235.4 ± 6.4	29.27 ± 0.80
HC08	236.3 ± 6.4	29.18 ± 0.79	**LC08**	239.5 ± 6.3	29.79 ± 0.79
HC09	240.1 ± 6.5	29.64 ± 0.81	**LC09**	228.1 ± 6.1	28.37 ± 0.76
HC10	255.1 ± 6.4	31.49 ± 0.79	**LC10**	244.8 ± 6.5	30.44 ± 0.81
HC11	242.3 ± 6.4	29.91 ± 0.80	**LC11**	219.6 ± 6.2	27.32 ± 0.77
HC12	226.3 ± 6.0	27.94 ± 0.74	**LC12**	215.7 ± 5.8	26.83 ± 0.72
HC13	223.4 ± 6.1	27.57 ± 0.76	**LC13**	243.4 ± 6.5	30.27 ± 0.81
HC14	256.9 ± 6.7	31.72 ± 0.82	**LC14**	234.4 ± 6.3	29.15 ± 0.78
HC15	242.3 ± 6.6	29.91 ± 0.81	**LC15**	238.3 ± 6.5	29.64 ± 0.81
HC16	243.6 ± 6.4	30.08 ± 0.79	**LC16**	236.3 ± 6.3	29.39 ± 0.78
HC17	232.6 ± 6.4	28.72 ± 0.79	**LC17**	218.3 ± 5.9	27.15 ± 0.73
HC18	246.8 ± 6.3	30.47 ± 0.77	**LC18**	238.0 ± 6.4	29.60 ± 0.79
HC19	226.5 ± 5.9	27.96 ± 0.73	**LC19**	233.4 ± 6.1	29.02 ± 0.76
HC20	240.2 ± 6.2	29.65 ± 0.76	**LC20**	242.8 ± 6.0	30.02 ± 0.75
HC21	246.1 ± 6.3	30.38 ± 0.78	**LC21**	234.3 ± 6.0	29.14 ± 0.74
HC22	240.3 ± 6.1	29.66 ± 0.76	**LC22**	226.0 ± 6.1	28.11 ± 0.76
HC23	245.2 ± 6.3	30.27 ± 0.78	**LC23**	249.5 ± 6.5	31.03 ± 0.81
HC24	228.5 ± 6.4	28.21 ± 0.79	**LC24**	250.2 ± 6.4	31.12 ± 0.80
HC25	231.8 ± 6.0	28.62 ± 0.74	**LC25**	216.2 ± 5.9	26.89 ± 0.73
-	-	-	**LC26**	230.5 ± 6.1	28.67 ± 0.75

Range	223.4 – 256.9	27.57 – 31.72	**Range**	215.7 – 255.4	26.83 – 31.77
Mean	238.6 ± 8.5	29.46 ± 1.05	**Mean**	233.7 ± 10.5	29.07 ± 1.31

Table 2: Comparison of radioactivity concentrations for ^{40}K in milk powder

Location	**Activity concentration of ^{40}K (Bq.kg^{-1})**
This study	223.4 – 256.9 (Batch 810 mg K)
	215.7 – 255.4 (Batch 804 mg K)
Iran (Afshari et al. 2009)	11.1 – 32.3
Iraq (Amin et al. 2016)	203.43 – 355.88
Jordan (Ababneh et al. 2010)	349 – 392
Nigeria (Kolapo, 2014)	17.8 – 55.1
Saudi Arabia (Alamoudi 2013)	29.46 – 146.33
Saudi Arabia (Alharshan et al. 2016)	130 – 595
Sudan (Hemada 2009)	19.25 – 375.49 (including fresh milk)
Syria (Al-Masri et al. 2004)	129 – 435