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Assessment of Radiation Dose from Natural Radionuclides Content of Powdered Milk in Malaysia

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Abstract

Powdered milk is an essential dietary consumed by all age ranges which provides necessary nutrients, most important for the growth and development of infants, children, and the elderly. Natural radionuclides are present in various food sources including powdered milk and commonly found are ^{40}Potassium, ^{226}Radium, and ^{232}Thorium. This study investigates the levels of these radionuclides in Malaysian powdered milk and the resulting radiation dose to consumers. This study aims to determine the types of radionuclides in powdered milk, assess the activities of radionuclides, and compare the mean annual effective dose of powdered milk that was selected based on age level categories. X-ray diffraction (XRD) and X-ray fluorescence (XRF) were used to analyze the existence and evaluate the levels of radionuclides in the sample. As a result, the elements Potassium (K) and Sulfur (S8) were found in the sample by using X-ray diffraction (XRD). The element Sulfur (S8) is found in samples A, B, C, D, E, and G. All these samples show the same reading, volume 1796.72 with a density of 1.76 µg/cm^3. From XRD, the total activity of radionuclides can be calculated, with the highest value being 30.39958 (Bq) for sample F. While the lowest value was 24.452176 (Bq). Among the samples that had been analyzed, Sample B showed a low level of radioactivity while Sample F showed the highest. However, its value is still lower than the International Commission on Radiological Protection (ICRP) public dose limit which is 1mSv per year. Future studies could explore processing methods that might affect the levels of natural radionuclides in powdered milk and how to reduce the level of radionuclides.

1. Introduction

Natural radionuclides that are commonly found in powdered milk such as ^{40}Potassium, ^{226}Radium, and ^{232}Thorium [1], [2]. Radionuclides or radioactive materials are defined as a class of compounds in which an atom's nucleus is unstable. The radioactive elements found in the crust of the earth, the radioactive decay product of these elements, and the radionuclides resulting from interactions between cosmic radiation and light are all considered natural radionuclides. In the nuclear fuel cycle, radionuclides play a critical role [3]. Radiation, also known as electromagnetic waves, is defined as a source of energy that moves through space at the speed of light. Uranium, Thorium, and Radium are three basic radionuclides found on Earth [4]. When ^{238}Uranium has gone through the decay process, it will produce ^{222} Radon. ^{222} Radon is a natural radioactive gas, which is colorless, odorless, and tasteless making it difficult to detect without specialized equipment [1], [2]. Food is one of the reasons humans are exposed to radiation besides getting it naturally from the environment through breathing. Milk is one of the ingredients that are frequently consumed by humans for baking and cooking, also being an important link in the food chain and a significant supply of nutrients for the average person's diet. Radionuclides, including ^{226} Radium and ^{232} Thorium including their offspring, readily integrate into soft body tissues after ingestion and can cause complex, lifelong health problems that can affect the consumers [5]. They also can increase the risk of cancer. As an example, lung cancer may result from extended exposure to low-intensity radiation, specifically because of ^{222} Radon and its short-lived alpha emitting decay products, ^{218} Polonium and ^{214}Polonium [6]. Other than that, thyroid cancer is also one of the main effects of consuming radioactive materials, which can cause severe circumstances, resulting in defects in the reproductive system, heart failure, and slight changes in DNA. This happens because some isotopes can trigger human health. When absorbed by the body, these isotopes can mimic necessary elements or cause various disruptions to cellular functions.

Specifically, this study that identifies higher radioactivity levels can be a valuable tool for prevention. By tracking the source of contamination within the production chain, powdered milk producers can implement targeted mitigation strategies. These results may also help regulate the amount of radioactive material that is allowed in powdered milk, thus strengthening existing regulatory regulations. The last important factor is consumer education. It is possible for consumers to reduce potential hazards by being aware of the safety measures in place and making educated decisions.

2. Materials and Method

Seven samples consisting of five brands were collected from supermarkets in Johor. Two main instruments have been chosen to determine the elemental composition and the radioactivity in powdered milk, which are XRD and XRF. The collected samples were weighed and packed with a mass of 7 g and each sample was prepared into two small, sealed bags then seven bags were run using XRD while another seven samples were run using XRF. The presence of elements was determined by XRD by sending X-ray beams through it, which interact with the atoms in the sample and produce diffracted beams as the technique [7]. The samples were put on the plates and compressed before being put in the instrument. This step was repeated for the XRF instrument too. The use of XRF is to find the energy of an element in the sample. This is because the process by which certain high-energy radiation excites atoms by ejecting electrons from their innermost orbitals is known as XRF. Emission of x-ray fluorescence radiation occurs when the atom relaxes, that is when outside electrons fill inner shells [8].

A total of seven samples were prepared from the collected brands for each category. Then, the preparation of the sample will be done before running it in the machine. The data were presented in a graph, Intensity (counts/sec) against 2theta, which can be used to identify an unknown sample's composition. The same sample is reused for the next step, which involves radioactivity analysis of elements found in powdered milk.

3. Equations

All types of elements have their radioactivity value. The total activity of these samples can be calculated by substituting the value of the decay constant (λ) and net count per second (N) in the following Equation (1).

$$A = \lambda N \tag{1}$$

For the annual effective dose, E can be calculated using Equation (2).

$$E = \text{Specific Activity } \times \text{Annual Consumption } \times \text{DCF} \tag{2}$$

where Specific Activity refers to concentration (Bq/kg), Annual consumption is consumption rate (kg/y) and DCF refers to the Dose Conversation Factor [9].

4. Results and Discussion

The elements that have been found in the collected powdered milk are presented in Table 1.

Table 1 *Presence of Potassium K, Sulfur, and Urea with FOM%*

Sample	Potassium (FOM%)	Sulfur (FOM%)
Sample A	0.19	0.29
Sample B	0.16	-
Sample C	0.00	0.00
Sample D	0.00	0.00
Sample E	0.14	0.50
Sample F	0.26	-
Sample G	0.66	1.56

The values of potassium K and sulfur were shown in the Figure of Merit (FOM) percentage. FOM indicates the degree to which the measured XRD pattern from the experiment and the standard pattern found in a reference database for well-known materials match each other. The smaller the value, the better the matching. From Table 1, it shows that brands Sample C and Sample D have the smallest value, 0.00% which means potassium K, was identified as the most likely phase present based on the smallest FOM value. This suggests that potassium K is the dominant crystalline component in the sample. The same goes with Sulfur where its FOM value is 0.00%. Sample G was the biggest value, which is 0.66% and 1.56% for potassium and sulfur respectively. This shows that it is difficult to identify a good match for the crystalline phase present in sample G.

The presence of Thorium (Th) and Uranium (U) elements can be identified via the value of impulse at a specific number of elements – X-ray absorption and emission energies (keV) as shown in Figure 1. X-ray absorption and emission energies of elements can be explained as conditions where an atom absorbs X-rays at an energy level near or above its core level binding energies. It gives information on the structural, magnetic, and electronic characteristics of specific components and elements in materials. The energy of thorium is 12.81 keV, while uranium is 13.61 keV. Analysis of XRD's result indicates that the relative intensity of these elements contained in samples is 100 respectively. Different value of impulse shows the quantity of an element found within the sample. From Fig. 1, the impulse readings for the Thorium element are 21, 19, 24, 15, 23, 30, and 22, respectively. Uranium's impulse values are stated as 18, 17, 24, 18, 16, 24, and 23. Most specimens had greater values of Thorium than Uranium.

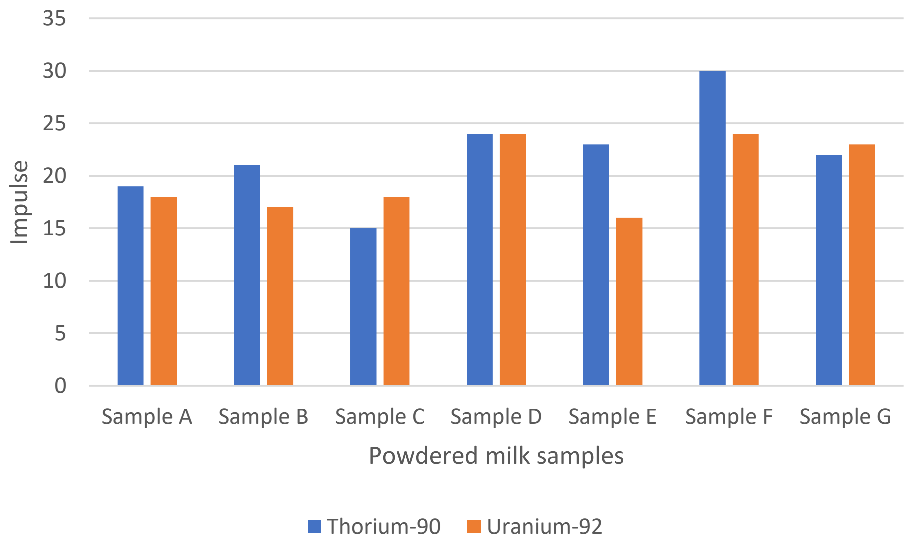

Fig. 1 *Comparison of total activity of radionuclides in powdered milk samples*

Fig. 2 shows the comparison of the total activity of radionuclides in each sample. The lowest value was 24.52963 Bq (Sample B), 25.45218 Bq (Sample A), 27.04030 Bq (Sample C), 28.48645 Bq (Sample D), 29.10415 Bq (Sample G), 29.80830 Bq (Sample E) to the highest value which is 30.39958 Bq (Sample F). From the chart, the trends show that the total activity of radionuclides for all samples was>20 Bq and < 31 Bq.

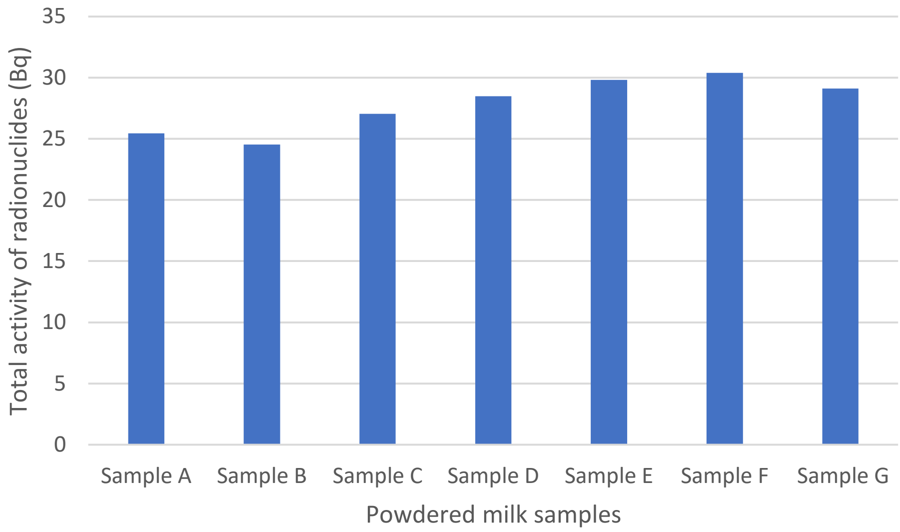

Fig. 2 *Total activity of radionuclides in powdered milk samples*

The annual effective dose of powdered milk in every sample is compared to the ICRP value as shown in Table 2. The ICRP recommends a dose limit of 1 mSv/year for the public, including infants, excluding natural background and medical exposures.

Table 2 *Value of annual effective dose of each sample*

Sample	Annual effective dose mSv/year
Sample A	0.0048
Sample B	0.0093
Sample C	0.0070
Sample D	0.0074
Sample E	0.0031
Sample F	0.0032
Sample G	0.0031

Based on Table 2, calculated annual effective doses from consuming powdered milk products with varying specific activities. The highest value of the Annual Effective Dose was Sample B (0.0093) while the lowest value of the Annual Effective Dose was Sample G and Sample E (0.0031) are significantly below the ICRP recommended limit of 1 mSv/year for the public. This indicates that the radiation exposures associated with these powdered milk products are well within safe limits according to ICRP guidelines for infants, children, and adults. These comparisons show that even at different specific activities, the radiation exposure from consuming powdered milk remains far below regulatory limits, ensuring safety across different age groups [9].

5. Conclusions

Based on the assessment of radionuclides in powdered milk across different age categories several key conclusions can be drawn. Firstly, the analysis identified Potassium (K) and Sulfur (S8) as the predominant elements detected via X-ray diffraction (XRD) in various powdered milk samples in Malaysia. These elements contribute to the natural radioactivity observed in the samples. Regarding the specific activity of radionuclides, the highest recorded value was 30.39958 Bq in sample F, while Sample B exhibited the lowest activity at 24.452176 Bq. Despite these variations, all measured activities were found to be below the international public dose limit recommended by the International Commission on Radiological Protection (ICRP). Even with the highest activity observed in Sample F, the estimated annual effective doses for infants, children, and adults consuming these powdered milk products remain significantly below regulatory limits, ensuring that radiation exposure from these products is well within safe levels. In conclusion, while differences in radionuclide activities were noted among the powdered milk samples analyzed, all fell within acceptable limits set by regulatory authorities. This underscores the importance of continued monitoring and adherence to safety standards in food production to safeguard public health across different age demographics.

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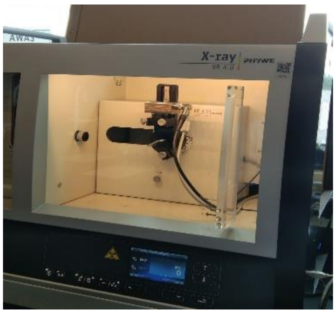
Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

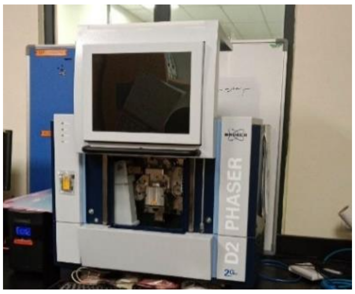
Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Adlyn Hanani Mohd Faizra, Nurul Azizatul Adawiyah A'zizi, Rabi'atul Adawiyah Yusmadi, Norazreen Sharip;* ***data collection:*** *Adlyn Hanani Mohd Faizra, Nurul Azizatul Adawiyah A'zizi, Rabi'atul Adawiyah Yusmadi, Norazreen Sharip;* ***analysis and interpretation of results:*** *Adlyn Hanani Mohd Faizra, Nurul Azizatul Adawiyah A'zizi, Rabi'atul Adawiyah Yusmadi, Norazreen Sharip;* ***draft manuscript preparation:*** *Adlyn Hanani Mohd Faizra, Nurul Azizatul Adawiyah A'zizi, Rabi'atul Adawiyah Yusmadi, Norazreen Sharip. All authors reviewed the results and approved the final version of the manuscript.*

Appendix A: XRF and XRD



X-ray Fluorescence (XRF)



X-Ray Diffraction (XRD)

References

[1] O. B. Uwatse, M. A. Olatunji, M. U. Khandaker, Y. M. Amin, D. A. Bradley, M. Alkhorayef, & K. Alzimami, "*Measurement of natural and artificial radioactivity in infant powdered milk and estimation of the corresponding annual effective dose*," Environmental Engineering Science, vol. 32, no. 10, pp. 838–846, Aug 2015.

[2] V. H. Duong, T.D. Nguyen, M. Hegedűs, E. Tóth-Bodrogi, and T. Kovács, "*Assessment of 232 Th, 226 Ra, 137 Cs, and 40 K concentrations and annual effective dose due to the consumption of Vietnamese fresh milk*," Journal of Radioanalytical and Nuclear Chemistry, vol. 328, pp. 1399–1404, 2021.

[3] National Research Council, Division on Earth, Life Studies, Commission on Life Sciences, & Committee on Evaluation of EPA Guidelines for Exposure to Naturally Occurring Radioactive Materials, "*Evaluation of guidelines for exposures to technologically enhanced naturally occurring radioactive materials*," National Academies Press, 1999.

[4] A. K. Hashim, H. A. Mezher, S. H. Kadhim, and A. A. Abojasim, "*Annual average internal dose based on alpha emitters in milk sample*," Journal of Physics Conference Series, vol. 1829, no. 1, p. 012027, Mar 2021.

[5] W. Priharti, S. B. Samat, M. S. Yasir, and N. N. Garba, "*Assessment of radiation hazard indices arising from natural radionuclides content of powdered milk in Malaysia*," Journal of Radioanalytical and Nuclear Chemistry, vol. 307, no. 1, pp. 297–303, May 2015.

[6] M. M. L. Rosa, V. A. Maihara, M. H. T. Taddei, L. T. V. Cheberle, R. P. Avegliano, and P. S. C. Silva, "*The use of total diet study for determination of natural radionuclides in foods of a high background radiation area*," Journal of Environmental Radioactivity, vol. 242, p. 106793, Dec 2021.

[7] J. Epp, "*X-ray diffraction (XRD) techniques for materials characterization*," in Elsevier eBooks, 2016, pp. 81–124, Jan 2016.

[8] M. Mititelu, L. Hîncu, E. Ozon, D. Baconi, I. Paunica, and O. Bălălău, "*Analysis of potentially toxic contaminants in milk powder*," Journal of Mind and Medical Sciences, vol. 8, no. 2, pp. 237–244, Oct 2021.
[9] J. D. Harrison, M. Balonov, F. Bochud, C. Martin, H. G. Menzel, P. Ortiz-Lopez, and R. Wakeford, "*ICRP Publication 147: Use of dose quantities in radiological Protection*," Annals of the ICRP, vol. 50, no. 1, pp. 9–82, Feb 2021.