Kragujevac J. Sci. 45 (2023) 15-20. UDC 632.118.3:539.166:637.141.8:641.87:159.938.363.6
doi: 10.5937/KgJSci2345015C *Original scientific paper*

GAMMA SPECTROMETRY ANALYSIS AND HEALTH RISK ASSESSMENT OF EDIBLE LIQUIDS

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(Received April 14, 2023; Accepted June 02, 2023)

ABSTRACT. Examination of radioactivity in edible liquids is very important because large amounts are taken into the body during the day. This scientific paper presents a comprehensive study on the gamma spectrometry analysis and health risk assessment of edible liquids. The study involved samples of various liquid products such as alcoholic beverages, juices, and milk. Milk is an important part of our regular diet for everyone, from newborns to adults, so we determined the active concentrations of radionuclides for both milk from farms directly and milk bought in a supermarket. The gamma spectrometry analysis was performed using a high-purity germanium detector to determine the concentration of natural and artificial radionuclides. The radioactivity of each sample is presented as the mean value of the measured sample from five different manufacturers. In conclusion, the gamma spectrometry analysis and health risk assessment of edible liquids demonstrated that the concentration of radionuclides in the selected liquid food products was not a major health concern. However, continuous monitoring and evaluation are recommended to ensure that the safety of the products is maintained within the permissible limits.

Keywords: edible liquids, gamma spectrometry, radioactivity concentrations

INTRODUCTION

Natural and anthropogenic radionuclides present in edible liquids can pose a risk to human and environmental health. For this reason, it is essential to identify them and know their concentration in everyday products. The radioisotopes we find in nature emit gamma radiation, which we call terrestrial background radiation, representing the main external source of irradiation of the human body (ALTIKULAÇ *et al.*, 2015). As a result of the anthropogenic activity of one of the most important artificial radionuclides, ^{137}Cs, with a half-life of 30.1 years, has a strong affinity for binding to the soil and is therefore a permanent environmental pollutant (ZHANG *et al.*, 2022). The presence of radionuclides in food and drinks is a global concern due to the potential health risks associated with their consumption. This has led to an increasing need for studies to monitor and evaluate the concentration of radionuclides in various food products. In recent years, there has been growing interest in gamma spectrometry analysis and health risk assessment of radionuclides in food products, including liquid foods such as alcoholic beverages, juices, and milk. These food products are an essential part of the human diet, and the presence of radionuclides in them can lead to health risks such as cancer and genetic mutations (KHANDAKER *et al*., 2016).

Milk and dairy products are very important foods in the diet of humans and infants and as such must be safe and tested (MITROVIC *et al.*, 2016; HOWARD *et al*., 2017;). Wine is an alcoholic beverage, such as beer, that is frequently consumed with meals (DESIDERI *et al.*, 2010). Consuming contaminated wine will raise a person's internal radioactivity and chemical contamination, which will enhance the health concerns related to radiation exposure and metal pollution. The exact health effects will depend on which radionuclides and metals have been ingested and, on their amount (CARIDI *et al*., 2019). This study aims to determine the activity concentrations of natural and artificial radionuclides in nine different liquids that we use in our daily diet. Additional tests, such as investigations with clear objectives are required for the quality assurance of wines, such as the measurement of ethanol or sugar content, the concentration of organic acids, minerals, and trace elements (for their impact on wine technology as well as their hazardous effects) could be done in further research. These tests are needed before we can say with certainty that the use of alcoholic beverages is safe.

MATERIALS AND METHODS

Sample collection and preparation

Samples were purchased at food stores in Kragujevac, Serbia. The list of edible liquids and their manufacturer is given in Table 1.

Table 1. Specifications of the edible liquids and their manufacturer brought from Serbian markets.

Liquid	Manufacturer
Rose vine	Plantaže
Black vine	Plantaže
White wine	Plantaže
Light beer	Nikšićko
Dark beer	Nikšićko
Domestic milk	-
Processed milk	Moja kravica
Homemade juice	-
Soda	Coca Cola
Homemade liquor	-

Liquid samples were placed in Marinelli bakers, which have a volume of 450 mL. After sealing the containers with silicone, to achieve secondary equilibrium, the samples were stored in a freezer for 35 days (DA SILVA *et al.*, 2018). The samples were weighed using a digital scale with a sensitivity of ± 0.01 g.

Radioactivity measurement

A coaxial HPGe detector (GEM30-70, ORTEC) with a relative efficiency of 30% and energy resolution (FWHM) of 1.85 keV at 1.33 MeV (^{60}Co) was used to measure the specific activities of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs in the liquid food samples. The gamma-activity of each sample was measured for 48 hours, and the intensity of emission lines in the spectrum was used to determine the gamma-activity after background subtraction. The specific activity of ^{226}Ra was calculated as the weighted average activity of three separate gamma-ray lines of its decay products, ^{214}Pb (351.9 keV) and 214Bi (609.3 and 1764.5 keV). The specific activity of ^{232}Th was obtained using the gamma-ray lines of ^{228}Ac (at the energies of 338.3, 911.1, and 968.9 keV) and ^{208}Tl (at the energies of 583.0 and 860.6 keV). The gamma-ray lines at 1460.7 and 661.6 keV were used to estimate the specific activities of ^{40}K and ^{137}Cs, respectively, with a timer of 252,000 seconds set for activity and background (MILENKOVIC *et al*., 2015). The isotopes' gamma-ray net peak areas were corrected using the background spectra, and the spectrum analysis was performed using the computer program MAESTRO.

Activity concentrations were obtained using Equation (1):

$$AC = N_L / emtP_g \qquad (1)$$

where: AC is the activity concentration (Bq/kg)

N_L is the net area of photopic interest

m is the sample mass (kg)

e counting efficiency by a specific energy

P_g is the emission probability of the measured gamma-ray

t is the counting time (s).

Then, it is possible to calculate annual ingestion doses for infants and adults for given groceries $E_{ing,p}$ (Sv/a), using the equation (IAEA, 2001):

$$E_{ing,p} = C_{p,i} H_p DF_{ing} \qquad (2)$$

where: $C_{p,i}$ is e concentration of radionuclide *i* in foodstuff *p* at the time of consumption (Bq/L)

H_p is the consumption rate for foodstuff *p*, or in our case for liquids (L/a)

DF_{ing} is the dose coefficient for ingestion of radionuclide *i* (Sv/Bq).

RESULTS AND DISCUSSION

The measurement results of activity concentrations of natural radionuclides and ^{137}Cs, are presented in Table 2. The table presents the specific activities of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs in various liquid food samples, including alcoholic beverages, milk, homemade juice, and soda. Annual intakes per person have been estimated based on several websites, although it should be noted that these are rough estimates (https://pivaresrbije.rs/2021/10/12/gde-se-pivo-najvise-proizvodilo-u-eu-tokom-2020-a-ko-ga-je-najvise-konzumirao/; https://www.agro klub.rs/prehrambenaindustrija/kolika-je-potrosnja-mleka-u-srbiji-i-da-li-zato-danas-nemamo-nobelovce/45621/; https://novaekonomija.rs/csr-club/2021/coca-cola-hbc-srbija-i-bambi-ujedinjenim-snagama-grade-odrzivu-buducnost; VLAHOVIĆ *et al.*, 2012). The results show that the specific activities of these radionuclides vary widely among the different types of samples. Values of DF_{ing} for ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs are 280 nSv/Bq, 230 nSv/Bq, 6.2 nSv/Bq, and 13 nSv/Bq respectively (IAEA, 2001).

Table 2. Descriptive statistics of radionuclide concentrations in nine different edible liquids.

Sample	Annual intakes per person (L/y)	^{226}Ra (Bq/L)	^{232}Th (Bq/L)	^{40}K (Bq/L)	^{137}Cs (Bq/L)
Rose vine	1.5	13.2 ± 0.7	<MDA	398.6 ± 20.0	2.2 ± 0.1
Red vine	6	14.5 ± 0.7	-	500.6 ± 25.3	2.7 ± 0.1
White wine	6.5	16.3 ± 0.8	<MDA	488.4 ± 24.4	2.1 ± 0.1
Light beer	52	8.7 ± 0.4	3.3 ± 0.2	226.4 ± 11.3	1.2 ± 0.1
Dark beer	9	5.3 ± 0.3	5.1 ± 0.3	224.6 ± 11.2	1.6 ± 0.1
Domestic milk	25	2.3 ± 0.1	-	317.8 ± 15.9	<MDA
Processed milk	200	6.8 ± 0.3	<MDA	396.7 ± 19.8	<MDA
Homemade juice	24	2.4 ± 0.1	<MDA	166.7 ± 8.3	<MDA
Soda	91	<MDA	-	25.9 ± 1.3	-
Min		0.6	0.2	25.9	0.4
Max		16.3	5.1	500.6	2.7

*MDA – minimum detectable activity

The highest specific activities were observed in the samples of red wine, white wine, and homemade juice, with ^{226}Ra and ^{40}K being the predominant radionuclides detected. On the other hand, the domestic milk and soda samples had the lowest specific activities, with some values being below the detection limits.

In general, the specific activity of ^{232}Th was found to be relatively low compared to that of ^{226}Ra and ^{40}K in most samples. This is consistent with the fact that ^{232}Th is less abundant in the Earth's crust compared to ^{226}Ra and ^{40}K.

In Figure 1 it can be seen annual ingestion doses for given liquids. Annual ingestion doses from various radionuclides in edible liquids can vary depending on the type and concentration of the radionuclide present in the liquid, as well as the volume of the liquid consumed. Radionuclides such as ^{40}K and ^{14}C are commonly found in edible liquids such as milk and juices and can contribute to the annual radiation dose received by individuals who consume these products [ICRP, 2016]. However, the doses are usually very low and generally do not pose a significant health risk to the general population. Specific activities of the detected radionuclides are below the permissible limits set by the relevant regulatory authorities.

However, further monitoring and analysis of these liquid food samples are still necessary to ensure the safety and quality of the food products consumed by the public.

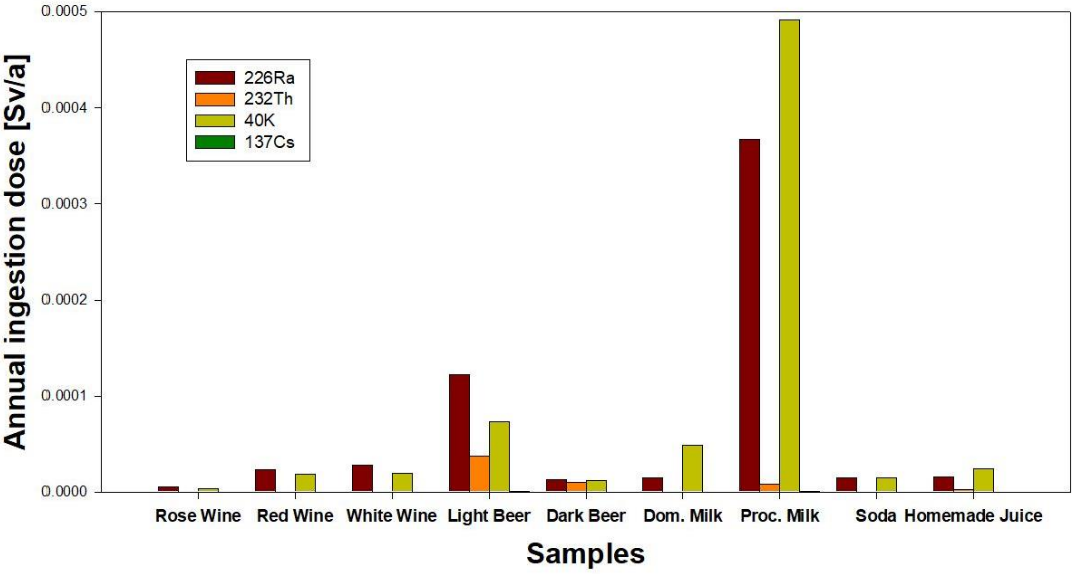

Figure 1. Annual ingestion doses from various radionuclides in edible liquids

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CONCLUSION

The present study aimed to determine the specific activities of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs in various liquid food samples, including alcoholic beverages, milk, homemade juice, and soda, and to assess any potential health risks associated with their consumption. The results indicated that the specific activities of the detected radionuclides vary widely among the different types of samples. The highest specific activities were observed in some of the alcoholic beverages and homemade juice samples, while the lowest specific activities were found in the domestic milk and soda samples. On the other hand, due to high annual consumption, the highest value of internal dose was found to be from the processed milk. To confidently debate the safety of consuming edible liquids, quality monitoring must be performed during the analysis of radioactive concentrations.

Acknowledgments

This work was supported by the Ministry of Education of the Republic of Serbiathrough the Agreements No. 451-03-47/2023-01/200122 and 451-03-47/2023-01/200378.

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