ASSESSMENT OF EXCESS LIFETIME CANCER RISK ARISING FROM THE CONSUMPTION OF SOME CEREAL CROPS IN ALBANIA

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Abstract

In this paper, we assessed the excess lifetime cancer risk (ELCR) from the consumption of cereal crop samples. Fifteen samples of cereal crops were collected from the local markets in Tirana city. Gamma-ray spectrometry method with HPGe detector was used for the measurements of natural (^{226}Ra, ^{232}Th, ^{40}K) and artificial (^{137}Cs) radionuclide activity concentrations. Results show in decreasing order the values of activity concentration of ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs. The range of annual effective dose, calculated based on the intake of ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs in cereal crops, was found to vary from 6.49 to 67.01$\mu Sv\ y^{-1}$. This corresponds to an ELCR due to consumption of cereal crops varying from 2.3×10^{-5} to 23.5×10^{-5}, with all values lower than the world average value of 29×10^{-5} for the public members. Therefore, cereal crops do not pose any serious radiological risk and can be considered safe for consumption.

***Key words**: Gamma-ray spectrometry, activity concentration, excess lifietime cancer risk, cereal crops.*

Përmbledhje

Në këtë punim, ne vlerësuam rrezikun e kancerit të shtuar gjatë gjithë jetës (ELCR) nga konsumimi i kulturave të drithërave. Pesëmbëdhjetë kampione të drithërave ishin mbledhur nga disa markete në qytetin e Tiranës. Metoda e *spekrometrisë Gama me dedektor HPGe ishte përdorur për matjet e përqendrimit të aktivitetit të radiobërthamave natyrore (^{226}Ra, ^{232T}h, ^{40}K) dhe artificiale (^{137}Cs). Rezultatet tregojnë një rend zbritës të vlerave të perqëndrimit të aktivitetit të ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs. Interval i vlerave të dozës efektive vjetore, të llogaritur nga marrja e ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs në drithërat, ishin gjetur të variojnë nga 6.49 to 67.01μSv y^{-1}. Kjo korrespondon me vlerat e ELCR nga konsumi i drithërave të variojnë nga 2.3×10^{-5} tek 23.5×10^{-5}, me të gjitha vlerat më të vogla se vlera mesatare botërore prej 29×10^{-5} për anëtarët e publikut. Si rrjedhim, kulturat e drithërave nuk paraqesin ndonjë rrezik serioz radiologjik dhe mund të konsiderohen të sigurta për konsum.*

Fjalë kyçe: *Spektrometria gama, perqëndrimi i aktivitetit, rreziku i shtuar i kancerit gjatë gjithë jetës, kulturat e drithërave.*

Introduction

Natural radioactivity is the main source of both internal and external radiation exposures in humans, contributing approximately 80% of the total radiation dose received by the world population (UNSCEAR, 2008). The dose from background radiation or natural sources varies across countries and regions; however, the average global value is about 3 mSv/year per person (UNSCEAR, 2024). This radiation is emitted from the decay of naturally occurring radionuclides ^{238}U, ^{232}Th, and ^{40}K, which are present throughout the air, water, and soil, including the human body itself. People worldwide can also be exposed to radiation resulting from the release of radionuclides from man-made sources, such as nuclear power plants, nuclear tests, and accidents, as well as from industrial and medical waste, which have been steadily increasing (UNSCEAR, 2020). Following nuclear tests and accidents, some artificial radionuclides, such as ^{134}Cs, ^{90}Sr, and ^{137}Cs, among others, were released into the atmosphere at significant activity levels. These radionuclides, along with the decay products of ^{238}U and ^{232}Th, can also be found in various foods that we consume daily (UNSCEAR, 2008).

Radionuclides can enter the human body through air, water, and food, and can remain in the body for extended periods; thus, humans are exposed to radionuclides present in the foods they consume daily. The diet consumed generally by the population is mixed with different nutrients, among which carbohydrates take an important part and are mainly furnished from cereal crops. They are the dominant source of carbohydrates, providing the major source of energy and contributing significantly to protein intake (Lafiandra, 2014). Cereal crops can accumulate radionuclides primarily through seeds, roots, and leaves, whereas humans are exposed to these radionuclides through consumption (Zakariya et al., 2021). The concentrations of radionuclides in cereal crops vary widely due to differences in background levels, climate, agricultural practices, and physicochemical processes (Tettey-Larbi et al., 2013). The radionuclides ^{137}Cs and ^{40}K exhibit relatively high soil-to-plant transfer factors due to their chemical similarity as monovalent cations, whereby plant potassium uptake mechanisms do not effectively discriminate between Cs^{+} and K^{+} (IAEA, 2010). Moreover, potassium is furnished through long-term use of chemical fertilizers (Cengiz et al., 2021).

In this study, the main objective was to assess the Excess Lifetime Cancer Risk (ELCR) associated with the consumption of selected cereal crops in Albania. To achieve this, the activity concentrations of natural radionuclides were measured using HPGe gamma-ray spectrometry, and the corresponding annual effective doses were calculated. The results were then compared with several international reference values, all of which provide guidelines for radioactivity levels and annual effective dose limits in foodstuffs.

Materials and methods

Sample collection and preparation

Fifteen cereal crop samples, which are consumed mostly frequently in Albania were collected from local markets of Tirana city. These samples were air dried on trays, and then oven dried in laboratory at a temperature of about 80ºC for 14 hours or until constant weight (Cengiz et al., 2022). They are homogenized, since some cereal crops were in the form of grains, while others were in the form of flour. Each sample was put in a 250 ml Marinelli beaker, and the mass is accurately weighed and recorded. The containers were then sealed using gas tightness insulation tape to avoid radon gas escape and stored for about 30 days to allow restoring the radioactive equilibrium for ^{226}Ra.

Measurements and calculations of the activity concentration

The method of gamma-ray spectrometry with High Purity Germanium (HPGe) detector was used for the measurements of activity concentrations of

radionuclides present in cereal crops samples. The detector has an energy resolution (FWHM) of 1.8 keV for 1.33 MeV γ-energy of ^{60}Co and 40% relative efficiency. The energy calibration was performed in the range from 50 keV to 2000 keV by a mathematical model using LabSOCS™ Calibration Sofware. The absolute efficiency uncertainties were calculated at each peak and varies from 10% at low energies (below 1000 keV) to 4% at high energies (Shyti, 2019).
The activity concentration A (in Bq kg^{-1}) were calculated by the following formula (1):

$$A(Bq\ kg^{-1}) = \frac{N}{\varepsilon(E_\gamma) \cdot P_\gamma \cdot t \cdot m} \quad (1)$$

where N is the net peak area of peak after background subtracted, $\varepsilon(E_\gamma)$ is the absolute efficiency in the peak, at energy $E\gamma$, P_γ is the gamma-ray yield, t is the counting live time and m is sample mass in kilogram (Dovlete et al., 2004). The results were corrected for self-absorption due to differences in sample composition and coincidence summing due to the decay cascade of different radionuclides. The activity concentration of radionuclides ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs were calculated, respectively. The activity concentration of ^{226}Ra was calculated indirectly, by the averages of activities of daughters ^{214}Pb and ^{214}Bi, in energy peaks 295.2 and 351.9 keV for ^{214}Pb, while for ^{214}Bi energy peaks are taken 609.3 keV and 1120.29 keV. In the case of ^{232}Th, the activity concentration was calculated by the activity of ^{228}Ac in energy peaks 338.4 and 911.2 keV. The activity concentration of ^{40}K was calculated using the gamma energy of 1460.8 keV, whereas for ^{137}Cs gamma energy of 661.7 keV was used. All gamma emission yields, and gamma lines energy were taken from the Nuclide-LARA library (Bé et al., 2008). The time interval of measurement for each sample was 24 hours. An empty Marinelli beaker was counted under the same conditions to determine the background. Minimum detectable activity (MDA) was performed by using the Currie method and respectively 4.66 Bq kg^{-1} for ^{226}Ra, 0.03 Bq kg^{-1} for ^{232}Th, 0.11 Bq kg^{-1} for ^{40}K and 0.01 Bq kg^{-1} for ^{137}C (Currie, 2004).

Results and discussion

Activity concentration in the cereal crop samples

The activity concentration of natural radionuclides ^{226}Ra, ^{232}Th, ^{40}K and artificial ^{137}Cs were measured in the cereal crop samples. The activity concentration and the uncertainty (±1σ) for ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs radionuclides were presented in Table 1 (Spahiu et al., 2023). The range of activity were found to be 0.91 to 10.34 Bq kg^{-1} for ^{226}Ra, from <MDA to 2.2 Bq kg^{-1} for ^{232}Th and 28.35 to 446.36 Bq kg^{-1} for ^{40}K. The activity for ^{137}Cs was below MDA for most of samples, where 0.65 Bq kg^{-1} highest value was found for Kidney white beans.

The radionuclide of ^{40}K had the highest value of the activity concentration for all samples. Radionuclide of ^{137}Cs, was detected in low level only in four samples as shown in Table 1. The activity concentration of ^{137}Cs may be related to the contaminated soil by the Chernobyl or nuclear tests fallout, also transfer factors of radionuclides and the metabolic system of these plants.

Table 1. Activity concentration of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs for 15 cereal crops

	Activity concentration ±1σ (Bq kg^{-1})				
No.	Sample ID	^{226}Ra	^{232}Th	^{40}K	^{137}Cs
1	Green pea	4.99 ± 0.23	1.48 ± 0.16	359.03 ± 15.49	<MDA
2	Barley grain	0.91 ± 0.11	1.43 ± 0.15	115.29 ± 5.51	<MDA
3	Beige beans	4.24 ± 0.18	2.09 ± 0.22	303.08 ± 12.96	<MDA
4	Kidney white beans	2.54 ± 0.21	<MDA	363.16 ± 15.66	0.65 ± 0.22
5	Bulgur wheat	7.03 ± 0.56	<MDA	81.22 ± 4.01	<MDA
6	Wheat grain	0.93 ± 0.18	1.62 ± 0.18	117.30 ± 2.46	0.35 ± 0.04
7	Wheat flour	7.89 ± 0.50	1.21 ± 0.14	31.36 ± 5.41	<MDA
8	Bean sprouts	8.66 ± 0.64	1.32 ± 0.16	446.36 ± 19.04	<MDA
9	Corn grain	6.92 ± 0.57	1.36 ± 0.16	70.33 ± 3.54	<MDA
10	Corn flour	9.36 ± 0.78	2.20 ± 0.24	35.88 ± 2.60	<MDA
11	Rice	2.56 ± 0.16	<MDA	28.35 ± 2.08	0.58 ± 0.21
12	Oat grain	10.34 ± 1.17	2.10 ± 0.18	105.23 ± 5.59	<MDA
13	Rye grain	2.11 ± 0.15	1.42 ± 0.16	112.63 ± 5.28	0.46 ± 0.06
14	Lentil Greece	6.84 ± 0.56	1.19 ± 0.13	255.60 ± 10.63	<MDA
15	Lentil Canada	4.92 ± 0.44	0.52 ± 0.08	247.70 ± 10.72	<MDA

The relatively high concentration of ^{40}K can be explained by the physicochemical properties of the soil in which they are grown, the transfer factors of radionuclides from the soil to cereal crops and the metabolic features of these plants. Moreover, organic fertilizers and chemical fertilizers can be used, which can lead to increase soil fertility and plant production.

Excess Lifetime Cancer Risk

The excess lifetime cancer risk (ELCR) by gamma radiation was calculated from equation 2 (ICRP, 1990),

$$ELCR = AED \cdot LT \cdot RF \qquad (2)$$

Where AED is the annual effective dose expressed in Sv^{-1}, LT is the average lifetime taken 70 years, RF is a risk factor expressed in Sv^{-1}, which for stochastic effects is taken 0.05 for the public [ICRP, Pub. 103].

So, we need to calculate the annual effective dose (AED) for each sample by intake of radionuclides was estimated using the following equation (3), defined from the UNSCEAR (2008) report,

$$(AED)_n = \sum_i I_n \times A_{in} \times C_i \qquad (3)$$

where $(AED)_n$ is expressed in μSv y^{-1} and n refers to the corresponding sample number n, A expresses the activity concentration. I_n is the annual consumption rate of cereal crops in kg/year and Ci is the dose conversion factor in unit of μSv Bq^{-1}. The consumption rate was taken at 25 kg/year for Wheat, 10 kg/year for Rice and 5 kg/year for all the others as part of the human diet (UNSCEAR, 2008). The dose conversion factors for ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs are taken, 0.0062 μSv Bq^{-1}, 0.28 μSv Bq^{-1}, 0.23 μSv Bq^{-1} and 0.013 μSv Bq^{-1} (ICRP, 2012). The range of annual dose was found from 6.49 μSv y^{-1} for the Barley grain to 67.01 μSv y^{-1} for the Wheat flour. The international reference values for the annual dose from basic foods are in the range 200-1000 μSv y^{-1} by the report UNSCEAR (2008), 200–500 μSv y^{-1} by WHO (2021) and the allowable limits of 1000 μSv y^{-1} by the report ICRP (2007) for all age groups.

The values of ELCR for each sample were presented in Table 2. The range of the ELCR was found to be from $2.3 \cdot 10^{-5}$ to $23.5 \cdot 10^{-5}$ and the average value is $8.2 \cdot 10^{-5}$. The lifetime probability of developing cancer risk arising from these cereal crops taken with the daily diet shown to have the highest value for three types of Wheat. This is directly related to the amount of consumption but also to the concentration of radionuclides activity. These cereal crops exhibiting higher ELCR values are likely influenced by enhanced uptake of radium and thorium from soil, as well as higher annual consumption rates. Barley grain exhibits the lowest ELCR value, primarily due to the low concentration of ^{226}Ra in this type of grain.

Table 2. The Excess Lifetime Cancer Risk (ELCR) for cereal crop samples

No.	Sample ID	ELCR ($\times 10^{-5}$)
1	Green pea	6.9
2	Barley grain	2.3
3	Beige beans	6.2
4	Kidney white beans	5.2
5	Bulgur wheat	21.6
6	Wheat grain	11.9
7	Wheat flour	23.5
8	Bean sprouts	9.6
9	Corn grain	4.7
10	Corn flour	5.9
11	Rice	3.2
12	Oat grain	7.1
13	Rye grain	2.8
14	Lentil Greece	6.6
15	Lentil Canada	5.3

In Table 3 the range of ELCR are given for similar studies and for present study. The results show consistency with some studies; however, a wider range has been reported in others. These variations are attributable to differences in the measured activity concentrations, the consumption rates used in the calculations, and, in certain instances, the lifetime considered. Variations in food types and the number of samples analyzed further contribute to the observed discrepancies. Although a few cereal crops exhibit approaching or slightly ELCR values, these levels remain comparable with those reported worldwide and do not indicate an immediate radiological concern.

Table 3. The Excess Lifetime Cancer Risk (ELCR) for similar studies

No.	Study	ELCR ($\times 10^{-5}$)
1	**Present study**	**2.3 – 23.5**
2	G.B. Cengiz et al,	11.8 – 54.5
3	S. S. Baz et al,	2 – 12.9
4	R. Keser et al,	5 - 24
5	J. Mellawati et al,	1.2 – 3.2
6	W, S. Pereira et al,	0.1 - 10
7	Sh. A. Jasim et al,	6.8 - 165
8	A. Abbasi et al,	1.6 - 42

The average value of ELCR due to the presence of radionuclides in the cereal crops was found $8.2 \cdot 10^{-5}$, which is lower than the world average value of $29 \cdot 10^{-5}$ [UNCSEAR, 2000]. The radiological risk of radioactivity, the annual effective dose and excess lifetime cancer risk have been evaluated for 15 samples. The average values of radiological hazard for all cereal crop samples were lower than the world average value. Therefore, all cereal crop samples are safe for consumption in accordance with recommended diets.

Conclusions

In this paper, the excess lifetime cancer risk (ELCR) was assessed, due to the consumption of some cereal crop samples. The range of annual dose was found from 6.49 μSv y^{-1} to 67.01 μSv y^{-1}. All values for the annual dose are lower than the international values by the reports of UNSCEAR (2008), WHO (2021) and ICRP (2007) for all age groups.

The range of the ELCR was found to be from $2.3 \cdot 10^{-5}$ to $23.5 \cdot 10^{-5}$ and the average value is $8.2 \cdot 10^{-5}$. The average value of ELCR due to the presence of radionuclides in the cereal crops was found $8.2 \cdot 10^{-5}$, which is lower than the world average value of $29 \cdot 10^{-5}$.

Therefore, results indicated radiological risk rising from consumption of cereal crops in Albania is acceptable and no harmful health effects are expected. All cereal crop samples are safe for consumption in accordance with recommended diets.

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