RPE | Radiation Physics & Engineering
An International Peer-Reviewed Journal
Published by K.N. Toosi University of Technology

http://rpe.kntu.ac.ir

Research Article

Radiation Physics and Engineering 2022; ?(?):?–?
https://doi.org/

Radiological assessment of different varieties of pistachios produced in Iran

Reza Pourimani*, Monireh Mohebian, Mobina Abdi
Department of Physics, Faculty of Science, Arak University, Arak, Iran

HIGHLIGHTS

- Measurement of natural radionuclides in some popular variety of pistachios.
- Calculation of radiometric parameters for these varieties.
- Comparison of them contains with other reported work from other countries.
- Provided discussion about of radiological indices.
- Comparing of radionuclides absorption in point of varieties

ABSTRACT

Nuclear radiations are harmful to the human body. The main sources of nuclear radiation are the decay chains of U-238, U-235, and Th-232 and also some radionuclides as K-40, which are present in small amounts in the materials of the earth's crust, including plants, rocks, soil and water. Radioactive substances are transferred to the human body in a variety of ways, including plant and animal products. Therefore, it is very important to determine the amount of radioactive substances in food products. In this research, seven samples of pistachios with different types were collected from Tehran markets in Iran. In this project, ultra-pure germanium spectroscopy system model GCD30195 was used. The specific activities of Ra-226, Th-232 and K-40 varied from < 1.96 to 9.86, from 1.21 to 1.95, and from 317.22 to 382.80 Bq.kg^{-1}. The artificial radionuclide of Cs-137 in all samples was lower than minimum detectable value (MDA). Calculations of the radiological impact showed that consumption of pistachios would endanger human health. The results of this study also showed that the amount of natural radionuclides in pistachio cores is higher than pistachio shells.

KEYWORDS
Pistachio
HPGe
Ra-226
Th-232
Radiation
Radionuclide

HISTORY
Received: ?
Revised: ?
Accepted: ?
Published: ?

1 Introduction

Radioactive materials are naturally present in the earth's crust. The main sources of nuclear radiation are the decay chains of U-238, Th-232 and U-235 and some individual radionuclides such K-40. This radiation is harmful to living tissue and can cause cancer or genetic abnormalities (Abojassim and Hashem, 2019). In recent years many research were done in foods stuff containing radionuclides (Pourimani and Anoosheh, 2015; Pourimani and Asadpour, 2016; Pourimani and Mortazavi Shahroudi, 2018; Pourimani and Mohebian, 2021). Many researchers have measured the radiation levels of nuts in other countries such as Iraq, Ukraine, and Italy (Abojassim and Hashem, 2019; Abda et al., 2020; Ezzulddin et al., 2017). pistachios are one of the oilseeds your body needs, rich in nutrients such as potassium, phosphorus, vitamins B6 and B1, and full of antioxidants. Antioxidants play a vital role in the health of the body. These substances reduce the risk of cancer and other diseases by preventing damage to the body's cells. Pistachios are essential for eye health due to their antioxidants lutein and zagrantin. Pistachios contain fiber and are good for digestive health. On the other hand, 21% of the total weight of pistachios is protein and it is important for people who have a vegetarian diet. Pistachio shell is also used to produce activated carbon and tar extraction in industry (Raw, 2012). Considering the importance of pistachios in the diet and its shell in industry, it is important to know the specific amount of different radioactive nuclei in it, pistachio and sunflower seeds have been done in different parts of the world, including Iran (Ezzulddin et al., 2017).

*Corresponding author: r-pourimani@araku.ac.ir

2 Materials and Methods

In this project, seven samples of pistachios with different types of Ahmad Aghaei, Akbari, Fandoughi and Koleghoochi Rafsanjan and Damghan were collected from Tehran markets in Iran. Sampling was done randomly. For each type of pistachio, pistachio shell was homogeneous and homogeneous powder after separation from the kernel by mill (Mohebian and Pourimani, 2020; IAEA, 2004). 300 g of each pistachio sample was transferred to small cylindrical containers and then each container was coded according to the type of sample. Coding was done according to the type of sample. Type Ahmad Aghaei Rafsanjan with AMR code, Ahmad Aghaei Damghan with AMD code, Akbari Rafsanjan with AKR code, Akbari Damghan with AKD code, Rafsanjan fandoghi with FDR code, Damghan fandoghi with FDD code, Rafsanjan Kalle Ghoochi with KGR code. Containers of pistachio samples were sealed with aquarium glue. The reason for sealing is to prevent the leakage of radon gas from the container, which is necessary to maintain the equilibrium of radionuclide activity in the chain (Gilmore and Hemingway, 2008). Detector energy calibration and efficiency were determined by the standard RGU and Cs-137 source with specified activity. The energy-channel relationship is presented in Eq. (1) (Linear Energy Calibration Equation):

$$\text{Energy} = 7.52 + (0.33 \times \text{Channel}) \tag{1}$$

In this project, ultra-pure germanium spectroscopy system model GCD30195 was used. The detector has a voltage of 1.95 keV with a voltage of v3000 and an efficiency of 30%.

2.1 The efficiency of detector

Using the efficiency calibration curve, the efficiency of gamma lines was determined to be 295.22, 351.93, 609.31 related to decay products Ra-226, 338.32, 583.19, 911.25 related to decay products Th-232 and 1460.83 related to K-40 radionuclide (Firestone et al., 1997):

$$\varepsilon(\%) = \frac{NetArea}{A \times BR(\%) \times T} \times 100 \tag{2}$$

where $NetArea$ is the net count below the peak of all energy corresponding to E_i energy, A is the specific radionuclide activity, $BR(\%)$ is the probability of emitting photons with E_i energy, and T is the count time. The gamma ray spectrum of each sample was recorded for 86400 seconds. Spectra were recorded using Lsrmbsi software and spectra analysis was performed using Gammavision 32 software (Mohebian and Pourimani, 2020). Background radiation measured under the same conditions for a container filled with double-distilled water and subtracted from the spectra of the samples (Pourimani and Mohebian, 2021).

2.2 The specific activity of radioactive nuclei

Using the net level below the full energy peak, the efficiency of the detector-sample system, the mass of the sample and the probability of gamma emission, the specific activity of Ra-226, Th-232, K-40 and Cs-137 in the samples can be calculated (UNSCEAR, 1988):

$$A = \frac{NetArea}{\varepsilon(\%) \times BR(\%) \times T \times M} \times 100 \tag{3}$$

where A is the specific radionuclide activity in the sample in terms of Bq.kg^{-1}, ε is the detector efficiency, and M is the mass of the sample in kg. $NetArea$, T, and $BR(\%)$ are defined according to Eq. (1).

If the activity of a radioactive nucleus in a sample is less than the minimum measurable activity (MDA) of that nucleus by the detector, then the activity of that specific nucleus is less than MDA (Mohebian and Pourimani, 2020).

3 Measurements of the radiological parameters

3.1 Radium Activity equivalent (Ra_{eq})

The total radioactivity of natural radionuclides, including Ra-226, Th-232, and K-40 in the samples can be defined as the equivalent of Ra-226 radioactivity, which is calculated using Eq. (4) (UNSCEAR, 1988):

$$Ra_{(eq)} = A_{Ra} + 1.43\ A_{Th} + 0.077\ A_K \tag{4}$$

3.2 Absorbed dose rate (ADR)

The dose of gamma radiation absorbed (D) in the air at an altitude of 1 m above the ground (average height of the gonads) for natural radionuclides is obtained from Eq. (5)) (UNSCEAR, 1988):

$$D\ (\text{nGy.h}^{-1}) = 0.427\ A_{Ra} + 0.662\ A_{Th} + 0.0432\ A_K \tag{5}$$

The Scientific Committee on the Effects of Atomic Radiation Sources reports the global average of the absorption dose rate in air from ground materials at nGy.h^{-1} (59.29) (UNSCEAR, 1988).

3.3 Calculation of alpha, gamma indexes and internal risk index (H_{in}) and external risk index (H_{ex})

External gamma and gamma radiation indices are used to evaluate the excess gamma radiation of pistachio samples. In addition to radon gas decay in samples, alpha radiation measurements are performed using internal and alpha risk indices. Equations (6) to (9) show the alpha, gamma index, internal and external risk index, respectively (EC, 1999; Inuyomi et al., 2019). To ensure the safety of pistachio samples the value of the mentioned equations must be less than one.

$$I_\alpha = \frac{A_{Ra}}{200} \tag{6}$$

$$I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \tag{7}$$

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \tag{8}$$

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \tag{9}$$

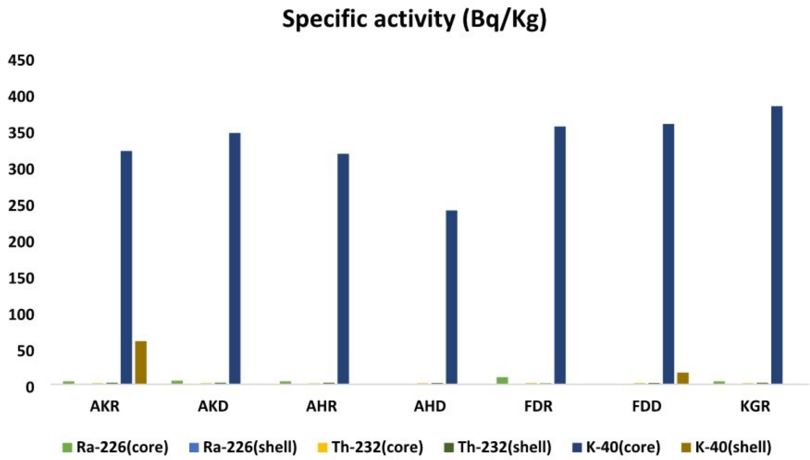

Figure 1: Specific activity ($Bq.kg^{-1}$) for the sample.

3.4 Calculating annual gonads equivalent dose

The dose absorbed by some important organs of the body such as the thyroid gland, lungs, gonads can be calculated using Eq. (10) by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (UNSCEAR, 2008).

$$AGDE\ (\mu \text{Sv.y}^{-1}) = 3.09\ A_{Ra} + 4.18\ A_{Th} + 0.314\ A_K \tag{10}$$

3.5 calculating the effective annual dose

The effective annual dose for each individual resulting from the intake of natural radionuclides and Cs-137 is obtained using Eq. (11) (UNSCEAR, 2008):

$$D_w = \sum A_i \times DCF_i \times Cr \tag{11}$$

where A_i is the specific activity of the radionuclides of Ra-226, Th-232, K-40, and Cs-137 in $Bq.kg^{-1}$. DCF_i is the conversion factor in terms of Sivert per Becquerel, which is equal to 2.8×10^{-7}, 6.9×10^{-7}, 6.2×10^{-9}, and 1.3×10^{-8}, respectively (Pawel et al., 2007).

Cr is the annual consumption of pistachios which is 600 g in Iran (MAJ, 2019). The conversion factor depends on two factors, the main type of radioisotope being in the pistachio sample.

3.6 Excessive risk of lifelong cancer (ELCR)

The calculation of the additional cancer risk due to environmental gamma radiation is calculated using Eq. (12) (UNSCEAR, 2008).

$$ELCR = AED \times AL \times RF \tag{12}$$

where AED, AL, and RF are effective annual dose, Average lifespan, and risk factor, respectively. The International Committee for Radiation Protection set the risk conversion factor at $0.05\ Sv^{-1}$ (Pawel et al., 2007). According to the World Health Organization for Iranians, the AL was 71.15 years (DOC, 2017). The global average of $ELCR$ is 0.29×10^{-3} and the maximum allowable limit is 10^{-3} (Abojassim and Hashem, 2019; IAEA, 2011).

4 Results

The specific activity values of radioactive nuclei of Ra-226, Th-232, K-40, and Cs-137 in seven samples of pistachio core and seven samples of pistachio shell are given in Table 1. Data on radium equivalent activity (Ra_{eq}), annual effective dose (AED) and excess lifetime cancer risk (ELCR) calculated in Tables 2 and 4 for pistachio core and their shell samples, respectively. Also data on air dose rate (D), internal and external risk indices (H_{in} and H_{ex}), alpha-gamma index (I_α and I_γ) and effective annual gonadal dose (AGDE) in Tables 3 and 5. It is given for pistachio and their shell samples, respectively.

5 Discussion and conclusion

Based on the data in Table 1 and Fig. 1 the highest specific activity of radium nucleus in the FDR sample (9.86 ± 1.176) and the lowest activity in the FDD, AHD samples was obtained. The highest and lowest specific activity of thorium nucleus are in FDR and AHR samples (1.95 ± 0.30, 1.21 ± 0.37), respectively. The highest specific activity of potassium radioactive nucleus was obtained in KGR sample (382.80 ± 11.85) and the lowest amount of activity was obtained in AHR sample (317.22 ± 10.32). The specific activity level of cesium radioactive nuclei in pistachio cores and pistachio shells and the specific activity level of radium radioactive nuclei in the shell of all samples is less than the level of MDA. The highest specific activity of thorium and potassium radioactive nuclei is in AHR and AKR sample shell (2.27 ± 0.30, 59.39 ± 3.34), respectively. The amount of activity due to the specific nuclei of radium, thorium and potassium is less than the allowable average (35, 40, and 400 $Bq.kg^{-1}$). Based on the data in Tables 2 and 4, the average activity of radium equivalent for pistachios and pistachio shells was 31.54 and 3.57

Table 1: Specific activities of Ra-226, Th-232, and K-40 radionuclides in pistachio core samples.

	Sample	Activity ($Bq.kg^{-1}$)				
		Ra-226	Th-232	CS-137	MDA	K-40
Pistachio core	AKD	5.05 ± 0.83	1.37 ± 0.30	<MDA	0.71	345.94 ± 10.76
	FDD	<1.96	1.84 ± 0.30	<MDA	0.59	358.05 ± 10.51
	AKR	3.93 ± 0.96	1.38 ± 0.26	<MDA	0.48	321.07 ± 10.32
	FDR	9.86 ± 1.176	1.95 ± 0.30	<MDA	0.48	354.70 ± 11.3
	KGR	4.06 ± 1.02	1.48 ± 0.28	<MDA	0.67	382.80 ± 11.85
	AHD	<2.38	1.52 ± 0.42	<MDA	0.80	239.10 ± 7.90
	AHR	4.01 ± 0.89	1.21 ± 0.37	<MDA	0.80	317.22 ± 10.32
	Average	3.84	1.53	<MDA	0.62	331.26
Pistachio shell	AKD	<2.95	2.06 ± 0.28	<MDA	1.01	<13.88
	FDD	<2.98	1.69 ± 0.28	<MDA	0.97	16.06 ± 3.61
	AKR	<2.76	2.17 ± 0.32	<MDA	0.94	59.39 ± 3.34
	FDR	<2.93	1.28 ± 0.30	<MDA	0.96	<14.61
	KGR	<2.92	2.09 ± 0.29	<MDA	0.97	<14.59
	AHD	<2.93	1.88 ± 0.30	<MDA	0.97	<14.71
	AHR	<2.94	2.27 ± 0.30	<MDA	1.02	<9.13
	Average	<2.91	1.92	<MDA	0.97	10.77

Table 2: Radium equivalent activity, effective annual dose and cancer risk in pistachio samples.

Sample	Ra_{eq} ($Bq.kg^{-1}$)	AED ($\mu Sv.y^{-1}$)			Total AED	Cr	ELCR
		Ra-226	Th-232	K-40	($mSv.y^{-1}$)	($kg.y^{-1}$)	($\times 10^{-3}$)
AKR	30.62	2.2	0.77	179.8	0.18	0.016	0.53
AKD	33.64	2.82	0.76	193.7	0.20	0.014	0.57
AHR	30.16	2.24	0.67	177.6	0.18	0.016	0.52
AHD	20.58	0	0.85	133.9	0.13	0.021	0.39
FDR	39.96	5.52	1.09	198.6	0.21	0.014	0.59
FDD	30.2	0	1.03	200.5	0.20	0.014	0.58
KGR	35.65	2.27	0.82	214.4	0.22	0.013	0.63
min	20.58	0	0.67	133.9	0.13	0.013	0.39
max	39.96	5.52	1.09	214.4	0.22	0.021	0.63
mean	31.54	2.15	0.86	185.50	0.19	0.015	0.54

Table 3: The Radiological hazard indicators of pistachio core samples.

Sample	ADR ($nGy.hr^{-1}$)	H_{in}	H_{ex}	Gamma and Alpha indices		AGDE ($\mu Sv.y^{-1}$)
				I_α	I_γ	
AKR	16.04	0.09	0.08	0.01	0.25	118.72
AKD	17.59	0.1	0.09	0.02	0.27	129.95
AHR	15.82	0.09	0.08	0.02	0.25	117.05
AHD	10.89	0.05	0.05	0	0.17	81.43
FDR	20.53	0.13	0.1	0.04	0.32	149.99
FDD	16.05	0.08	0.08	0	0.25	120.11
KGR	18.73	0.1	0.09	0.02	0.29	138.93
min	10.89	0.05	0.05	0	0.17	81.43
max	20.53	0.13	0.1	0.04	0.32	149.99
mean	16.52	0.09	0.08	0.02	0.26	122.31

Table 4: Radium equivalent activity, effective annual dose and cancer risk in pistachio shell samples.

Sample	Ra_{eq} ($Bq.kg^{-1}$)	AED ($\mu Sv.y^{-1}$)			Total AED ($\mu Sv.y^{-1}$)	ELCR ($\times 10^{-6}$)
		Ra-226	Th-232	K-40		
AKR	7.67	0	0.99	0.73	1.72	5.01
AKD	2.94	0	0.94	0	0.94	2.74
AHR	3.24	0	1.04	0	1.04	3.03
AHD	2.68	0	0.86	0	0.86	2.51
FDR	1.82	0	0.58	0	0.58	1.69
FDD	3.65	0	0.77	0.19	0.96	2.8
KGR	2.98	0	0.96	0	0.96	2.8
min	1.82	0.00	0.58	0.00	0.58	1.69
max	7.67	0.00	1.04	0.73	1.72	5.01
mean	3.57	0.00	0.88	0.13	1.01	2.94

Table 5: Radiological hazard indices of pistachio shell samples.

Sample	Ra_{eq} (Bq.kg^{-1})	AED (μSv.y^{-1})			Total AED (μSv.y^{-1})	AGDE ($\times 10^{-6}$)
		Ra-226	Th-232	K-40		
AKR	3.78	0.02	0.02	0.00	0.06	27.71
AKD	1.24	0.01	0.01	0.00	0.02	8.61
AHR	1.37	0.01	0.01	0.00	0.02	9.48
AHD	1.13	0.01	0.01	0.00	0.02	7.85
FDR	0.77	0.00	0.00	0.00	0.01	5.32
FDD	1.69	0.01	0.01	0.00	0.03	12.10
KGR	1.26	0.01	0.01	0.00	0.02	8.73
min	0.77	0.00	0.00	0.00	0.01	5.32
max	3.78	0.02	0.02	0.00	0.06	27.71
mean	1.61	0.01	0.01	0.00	0.03	11.40

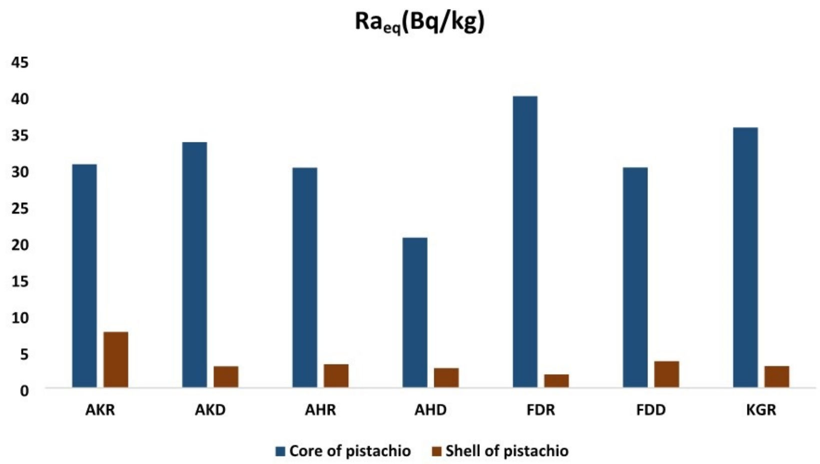

Figure 2: Comparison of radium equivalent activity between pistachio core samples and pistachio shell.

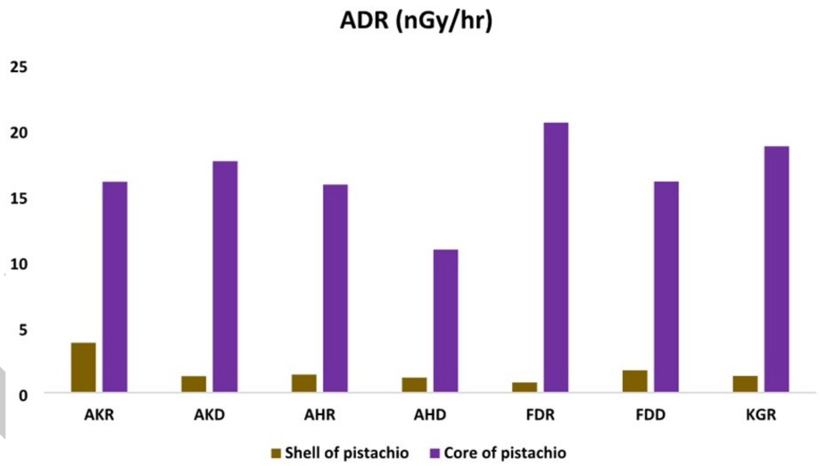

Figure 3: The absorbed dose rate of gamma radiation for samples.

Bq.kg^{-1}, respectively. Table 2 shows a higher absorption dose rate in the FDR pistachio core sample. Also, Figs. 2 and 3 show that the radium activity equivalent and the absorbed dose of pistachio samples are higher than pistachio shells samples, which indicates high radioactivity of pistachio cores compared to pistachio shells. In all samples, the total concentration of measured radionuclides did not exceed the IAEA limit of 1000 Bq.kg^{-1} for food gamma emitters. Consequently, the pistachios analyzed in this article are considered safe for human consumption (IAEA, 2016). The absorption dose rate due to gamma radiation specific of natural radioactive nuclei is lower than the average amount in all samples (59.29 nGy.h^{-1}). In Fig. 4, the absorbed dose rate in the air at a height of one meter above the ground surface of the studied pistachio shell is compared with other countries. This figure shows well that the Iranian pistachio shell is healthier in terms of quality The results show that the average dose of in-

Table 6: Comparison of activity, radium equivalent activity, absorbed dose rate, gamma index and internal risk index of this study with other parts of the world.

sample	Activity ($Bq.kg^{-1}$)			Ra_{eq} ($Bq.kg^{-1}$)	ADR ($nGy.hr^{-1}$)	I_γ	H_{in}	Reference
	Ra-226	Th-232	K-40					
Almonds (Iraq)	4.90	2.43	256.50	28.13	14.42	0.23	0.09	(Abojassim and Hashem, 2019)
Pistachio (Erbil)	0.05	0.35	268.93	21.26	11.45	0.18	0.06	(Ezzulddin et al., 2017)
Hazelnut(Erbil)	0.05	0.28	258.84	20.39	10.98	0.18	0.05	(Ezzulddin et al., 2017)
Core Walnut (Ukraine)	5.11	16.05	124.30	37.63	17.23	0.28	0.11	(Abda et al., 2020)
Core Walnut (Romania)	2.81	ND	135.70	13.26	1.85	0.11	0.04	(Abda et al., 2020)
AKR	3.93	1.38	321.07	30.63	16.04	0.25	0.09	This work
AHR	4.01	1.21	317.22	30.17	15.82	0.25	0.09	This work
FDR	9.86	1.95	354.70	39.96	20.53	0.32	0.13	This work

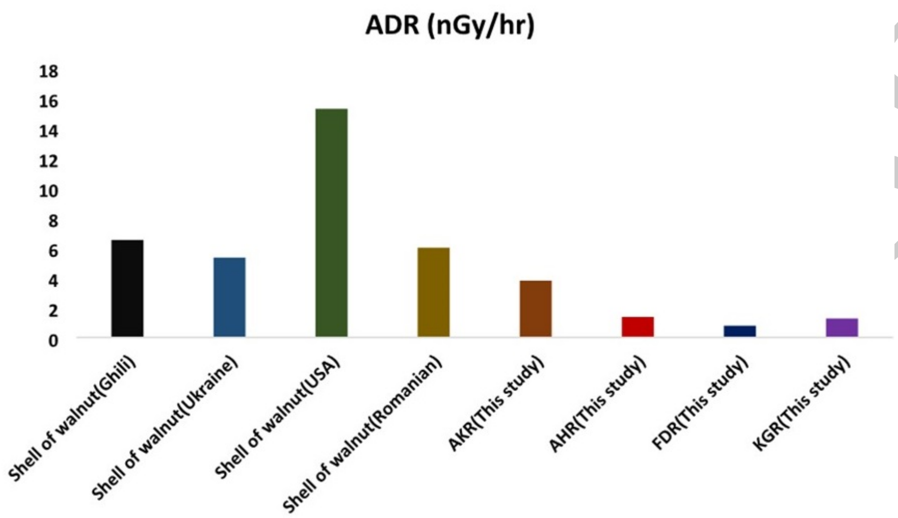

Figure 4: The absorbed dose rate (ADR) of gamma radiation for different samples between countries.

gestion due to pistachio core consumption is lower than the Global average annual effective dose (0.30 $mSv.y^{-1}$) (Higley, 2006).

Internal and external risk indices in pistachio core samples vary from 0.05 to 0.013 and 0.05 to 0.10, respectively. Internal and external risk indices in pistachio shell samples vary from 0 to 0.02. Alpha and gamma index for pistachio core samples ranged from 0 to 0.04 and 0.17 to 0.32. Alpha and gamma index for pistachio shell samples was calculated from 0 to 0.02. The average internal risk index and gamma index of pistachio samples were calculated with 0.09 and 0.26, respectively, which is higher than the sample of pistachio shell. Comparison of radioactivity of pistachio core samples with other parts of the world shows that the measured thorium is lower than Ukrainian walnut and Iraqi almond core. According to the data in Table 6. The amount of radium and potassium activity in the FDR sample is higher than the data. Radium equivalent activity and absorption dose in FDR sample show higher value than Erbil pistachio.

6 Conclusions

The results of this study show that the amount of radiation from the radioactive nuclei of radium, thorium, potassium and cesium in samples of pistachio cores is higher than pistachio shells and also the radiation of the studied samples is higher than the radiation of some other countries. Using the results and comparing them, it can be seen that the use of pistachios in the diet and pistachio skin in the process of producing activated carbon is safe.

References

Abda, J. M., Abullah, K. O., Hussein, A. M., et al. (2020). Measurement of natural radioactivity concentrations in walnut collected from different markets in Sulaimanya city-Kurdistan region-Iraq. In *IOP Conference Series: Materials Science and Engineering*, volume 871, page 012075. IOP Publishing.

Abojassim, A. A. and Hashem, R. H. (2019). Measurement of natural radioactivity in certain types of nut samples in Iraq. *Iranian Journal of Medical Physics*, 16(2):120–125.

DOC (2017). Life Expectancy for Countries. https://www.infoplease.com/world/health-andsocial-statistics/life-expectancy-countries.

EC, E. (1999). Radiation Protection 112: Radiological protection principles concerning the natural radioactivity of building materials. *Nuclear Safety and Civil Protection.*

Ezzulddin, S. K., Ahmed, A. H., Samad, A. I., et al. (2017). Radioactivity measurement of nuts and seeds available in erbil city markets. In *AIP Conference Proceedings*, volume 1888, page 020022. AIP Publishing LLC.

Firestone, R. B., Shirley, V. S., Baglin, C. M., et al. (1997). The 8^{th} edition of the Table of Isotopes. In *Proceedings of the 9^{th} International Symposium on Capture gamma-ray spectroscopy and related topics. V. 2.*

Gilmore, G. and Hemingway, J. (2008). Practical gammaray spectrometry, John Willey and Sons. *Inc, Chichester, West Sussex, UK.*

Higley, K. A. (2006). Effects of radioactivity on plants and animals. In *Radionuclide Concentrations in Food and the Environment*, pages 209–224. CRC Press.

IAEA (2004). Compliance Monitoring for remediated site, IAEA-TECDOC-1415, IAEA, VIENNA. *International Atomic Energy Agency.*

IAEA (2011). Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. IAEA Safety standards series no GSR Part 3 (Interim), TI/PUB/1531: 190219. *International Atomic Energy Agency.*

IAEA (2016). Criteria for Radionuclide Activity Concentrations for Food and Drinking Water. IAEA-TECDOC-1788. *International Atomic Energy Agency.*

Inuyomi, S. O., Ore, O. T., and Abiodun, O. P. (2019). Evaluation of the natural radioactivity levels and radiological assessment of nuts commonly consumed in Ile-Ife, South West, Nigeria. *Journal of Radiation Science and Technology*, 5(2):15–19.

MAJ (2019). Ministry of Agriculture-Jahad. https://www.maj.ir.

Mohebian, M. and Pourimani, R. (2020). Specific activity and radiation hazard of radionuclides in wheat and bean produced near Shazand, Iran. *Iranian Journal of Medical Physics*, 17(6):394–400.

Pawel, D., Leggett, R., Eckerman, K., et al. (2007). Uncertainties in cancer risk coefficients for environmental exposure to radionuclides. *ORNL/TM-2006/583, Oak Ridge National Laboratory, Oak Ridge, TN.*

Pourimani, R. and Anoosheh, F. (2015). A study on transfer factors of environmental radionuclides: radionuclide transfer from soil to different varieties of rice in Gorgan, Iran. *Iranian Journal of Medical Physics*, 12(3):189–199.

Pourimani, R. and Asadpour, F. (2016). Determination of Specific Activities of Radionuclides in Soil and Their Transfer Factor from Soil to Bean and Calculation of Cancer Risk for Bean Consumption in Iran. *Arak Medical University Journal (AMUJ)*, 19(107):9–18.

Pourimani, R. and Mohebian, M. (2021). Study of Background Correction of Gamma-Ray Spectrometry Using Reference Materials. *Iranian Journal of Science and Technology, Transactions A: Science*, 45(2):733–736.

Pourimani, R. and Mortazavi Shahroudi, S. M. (2018). Radiological assessment of the artificial and natural radionuclide concentrations of wheat and barley samples in Karbala, Iraq. *Iranian Journal of Medical Physics*, 15(2):126–131.

Raw, P. (2012). Composition of foods raw, processed, prepared usda national nutrient database for standard reference, release 25. *United States Department of Agriculture (USDA).*

UNSCEAR, S. (1988). Effects and risks of ionizing radiation. *United Nations, New York*, pages 565–571.

UNSCEAR, U. (2008). Report of the United Nations scientific committee on the effects of atomic radiation, sources, effects, and risks of ionizing radiation. *United Nations sales publication, New York. United Nations.*