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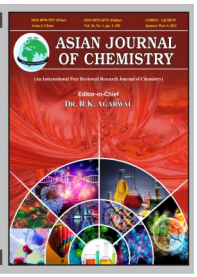

Radioactivity Levels in Some Mushroom Species and Consequent Doses

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The radioactivity concentrations of natural radionuclides ^{232}Th, ^{40}K, ^{238}U, have been determined for various mushroom samples collected from black sea region in Ordu and Kastomonu provinces of Turkey. NaI (Tl) γ-scintillation counter is used for radioisotope concentration measurements. The radionuclide activity concentrations of ^{232}Th, ^{40}K, ^{238}U in the mushroom species were found to be ranging from 0.354 to 5.43, 4.37 to 90.9, 1.03 to 8.45 Bq/kg, respectively. Annual effective doses for ingestion of edible mushrooms were calculated and it is shown that exposure is mainly due to ^{232}Th natural radionuclides. The mean annual effective dose due to the intake of mushrooms was found to be 1.13×10^{-04} mSv.

Keywords: Mushroom, Radioactivity, Activity concentration, Consequent dose.

INTRODUCTION

Wild-growing macro fungi have been a popular delicacy in many countries, mainly in Central and Eastern Europe. Wild-growing mushrooms are also essential foods for many, low in calories, high in vegetable proteins, iron, zinc, vitamins and minerals. Mushrooms also have a long history of use in traditional chinese medicine. In most countries, some people collect wild-mushrooms to contribute to the nutrient intake[1-3]. Therefore, it is essential to know the levels of activity concentrations in edible mushrooms. In Middle and East Black sea region the climate is mild particularly in spring and autumn and rainy thus it is ideal for fungal growth especially in upper northern part of Turkey.

Foods such as mushrooms, berries and game meat collected from the wild may continue to be a radiological problem for a long time. Radioactive isotopes of elements (radionuclides) are naturally present in the environment, including our bodies and our food and water. Background levels of radionuclides in foods vary and are dependent upon several factors, including the type of food and the geographic region where the food has been grown up. The common radionuclides in food are potassium-40 (^{40}K), radium-226 (^{226}Ra) and uranium-238 (^{238}U) and their progeny. The review of edible mushroom radioactivity was done by Kalac[4]. The investigations made in the literature related to radionuclide in mushrooms from past to the present are usually concerned with ^{137}Cs[5-11]. However, there is less research on activity measurements of natural radionuclides. The aim of this study is to determine ^{232}Th, ^{40}K; ^{238}U radionuclide concentrations and annual effective doses for consumption of edible mushrooms in the samples collected from black sea region of Turkey and compare our results with similar measurements from literature.

EXPERIMENTAL

Mushroom samples for this study were taken from around Ordu and Kastamonu provinces in the Black sea region, Turkey between dates from July to October of 2011. Samples of mushrooms were collected as follows; *Cantharellus cibarius, Cantharellus lutescens, Hygrophoropsis aurantiaca, Hypholom afasciculare* and *Russula delica* from Fatsa region forestries, *Pycnoporus cinnabarinus, Hypholoma* spp., *Paxillus involutus*, *Clitocybe sinopica*, *Pycnoporus* spp. The species, family, edibility and the location of investigated mushrooms are given in Table-1.

Sample collection sites were located approximately 500 m apart and sites were chosen where conditions were ideal for the collection of mushrooms. At each chosen site, samples of edible and wild mushrooms were collected within an approximate 30 m radius. All mushrooms were collected individually (10-200 g fresh mass). Stalks and caps of individual mushrooms were sampled and analyzed together, since mushrooms are usually consumed as a whole. All the samples were cleaned from mud and then the collected samples were separately put

TABLE 1
SPECIES, FAMILY, EDIBILITY AND THE COLLECTION PROVINCES OF THE ANALYZED MUSHROOMS

No	Mushroom species	Edibility	Family	Region of collection
1	*Pleurotus ostreatus* (Jacq.) P.Kumm.	Edible	Pleurotaceae	Kastamonu
2	*Cantharellus cibarius* Fr.	Edible	Cantharellaceae	Fatsa
3	*Amanita rubescens* (Pers.)	Edible	Amanitaceae	Kastamonu
4	*Cantharellus lutescens* (Pers.) Fr.	Edible	Cantharellaceae	Fatsa
5	*Pycnoporus cinnabarinus* (Jacq.) P. Karst.	Inedible	Polyporaceae	Kastamonu
6	*Hypholoma* spp. (Fr.) P.Kumm.	-	Strophariaceae	Kastamonu
7	*Paxillus involutus* (Batsch) Fr.	Not recommend	Paxillaceae	Kastamonu
8	*Hygrophoropsis aurantiaca* (Wulfen) Maire	Not recommend	Hygrophoropsidaceae	Fatsa
9	*Hypholoma fasciculare* (Huds.) P.Kumm.	Poisonous	Strophariaceae	Fatsa
10	*Clitocybe sinopica* (Fr.) P.Kumm.	Poisonous/suspect	Tricholomataceae	Kastamonu
11	*Pycnoporus* spp. (P. Karst.)	-	Polyporaceae	Kastamonu
12	*Russula delica* (Fr.)	Edible	Russulaceae	Fatsa

into plastic bags and bags were covered with aluminium foil to protect from external effects before taking to laboratory. The mushroom samples were rinsed with distilled water before processing. The collected samples were dried at 105 °C for 24 h in a temperature-controlled furnace. Dried samples were homogenized using a mixer and stored in cylindrical polyethylene bottles prior to analysis. All polyethylene bottles were cleaned by soaking overnight in 10 % nitric acid solution and then rinsed with water before the samples were placed in the bottles. The dried samples were ground and then grinded before passed through a 90 sieve. Then, samples put into airtight containers and allowed to stand for a period of one month to reach secular equilibrium before measurements.

A 7.62 cm × 7.62 cm NaI(TI) detector was employed for the γ-ray spectrometry measurements. The data acquisition of the energy spectra were performed by using an integrated spectroscopy system from ORTEC Inc. The system utilized MAESTRO-32 (version 6.06) software package of the same company. The detector was surrounded by a 5 cm thick lead to shield the γ-radiation from background. The detector has an energy resolution of about 7.6 % at 662 keV of ^{137}Cs peak. Each sample was counted for a period of 30000s. The background measurements were performed for the same period of time. The photopeak at 1.460 MeV was used for the measurement of ^{40}K while those at 1.760 MeV peak from ^{214}Bi and 2.614 MeV from ^{208}TI were used for the measurement of ^{226}Ra(^{238}U) and ^{232}Th activities, respectively. The energy calibration was performed using ^{60}Co(1 μCi) and ^{226}Ra (10 μCi) standart sources. Activities concentration were calculated by using the eqn. 1:

$$A_V(Bqkg^{-1}) = \frac{C}{\varepsilon P_\gamma M_S} \quad (1)$$

where C is count rate of γ-radiation (count/sec), ε is detector efficiency of γ-radiation (24 %), P_γ is transition probability of γ-radiation and M_S is mass of samples in kg[12,13].

RESULTS AND DISCUSSION

The results of activity concentrations are given in Table-2 for the natural radionuclides of ^{232}Th, ^{40}K and ^{238}U in the mushroom samples. ^{232}Th, ^{40}K, ^{238}U radionuclide concentrations in the mushroom species were found to be ranging from 0.354 to 90.9 Bq/kg. According to Fig. 1 and Table-2, the radionuclide concentrations of ^{40}K in the samples are generally higher than those of other radionuclides measured. Our results were compared with the measured concentrations of radionuclides in vegetation, fruits and mushrooms species from different countries as follows. Minimum-maximum radionuclide concentrations of ^{232}Th were reported 2.37-7.20 Bq/kg in vegetation/plant samples collected from Bahawalpur division and Islamabad federal capital territory-Pakistan[14]. Minimum-maximum activity concentrations of ^{40}K were reported 189.9-410.2 Bq/kg in that samples. However our results were between 0.354-5.43 Bq/kg for ^{232}Th and 4.37-90.9 Bq/kg for ^{40}K. Another study reported that activity concentration of ^{40}K ranged from 116 to 130 Bq/kg in wheat grains from mahabaleshwar field[15]. ^{40}K activity concentration in fruiting bodies of different fungal species collected in poland was reported between 150 and 3600 Bq/kg[16]. The results of ^{232}Th activity concentration in the present study showed a good agreement with ^{232}Th in vegetation/plant

TABLE-2
RADIONUCLIDE CONCENTRATIONS OF ^{232}Th, ^{40}K, ^{238}U Bq/Kq IN SOME MUSHROOM SPECIES

No	Mushroom species	Radionuclide concentrations (Bq/kg)		
		^{232}Th	^{40}K	^{238}U
1	*Pleurotus ostreatus*	0.919 ± 0.303	89.355 ± 5.688	8.454 ± 0.790
2	*Cantharellus cibarius*	0.551 ± 0.178	86.247 ± 4.137	6.280 ± 0.358
3	*Amanita rubescens*	3.434 ± 0.204	26.896 ± 4.178	7.246 ± 0.457
4	*Cantharellus lutescens*	5.433 ± 0.200	9.990 ± 3.741	1.035 ± 0.433
5	*Pycnoporus cinnabarinus*	0.472 ± 0.197	42.458 ± 3.563	5.694 ± 0.424
6	*Hypholoma* spp.	1.102 ± 0.234	75.758 ± 4.364	3.019 ± 0.487
7	*Paxillus involutus*	2.170 ± 0.170	6.556 ± 3.301	3.850 ± 0.379
8	*Hygrophoropsis aurantiaca*	3.142 ± 0.264	90.909 ± 4.845	7.246 ± 0.564
9	*Hypholoma fasciculare*	0.354 ± 0.189	32.468 ± 3.784	5.694 ± 0.440
10	*Clitocybe sinopica*	2.480 ± 0.175	17.483 ± 3.159	4.755 ± 0.378
11	*Pycnoporus* spp.	1.137 ± 0.173	4.371 ± 3.147	2.944 ± 0.377
12	*Russula delica*	1.299 ± 0.190	29.970 ± 3.650	2.330 ± 0.413

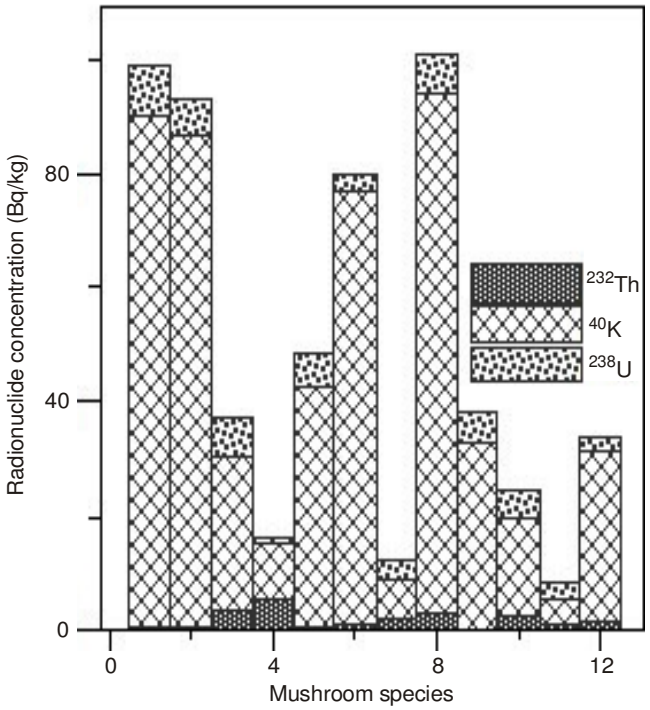

Fig. 1. Change of ^{232}Th ^{40}K, ^{238}U, concentrations in mushroom species horizontal axes how sample number given in Table-1

samples. However, the results of present ^{40}K activity levels were found to be relatively lower than that of the mentioned vegetation/plant samples, wheat grains samples and different fungal species collected in Poland. According to a previous study, average ^{238}U concentrations of watermelon green parts with roots and zucchini green parts with roots were measured as 0.65 and 0.72 Bq/kg, respectively[17]. Activity concentration of ^{238}U in wheat grains from Mahabaleshwar field was found to be 0.03-0.04 Bq/kg in by Pulhali *et al.*[15]. ^{238}U activity concentration was found to be higher in present study which varies between 1.03 and 8.45Bq/kg when compared to earlier reports by Pulhali *et al.*[15] and Al-Kharouf *et al.*[17]. By inspecting the obtained results, we could conclude that: the soils in the studied area have high natural levels of radioactive materials and different mushroom species collected from same area have different accumulation capacity.

Effective dose: Radiation exposure through ingestion of edible mushrooms is stem from radionuclides of uranium and thorium decay series and artificial nuclides collected in mushrooms. Annual effective dose can be determined from activity concentration of the radionuclides present in samples as follows. Activity concentration can be related to (D_e) an effective dose per year (Sv/year) using a dose coefficient (Sv/Bq) and average annual consumption of edible mushrooms. Data for age related dose coefficients for ingestion of radionuclides have been published by ICRP[18] (1996). Dose conversion factors for ingestion of radionuclides by adult person are taken from[8] and calculated from the following equation:

$$D = A_c A_i F R \quad (2)$$

where D shows effective dose in Sv/year, A_c is activity in Bq/kg, F is a dose conversion factor (Sv/Bq) and A_i is average annual consumption of mushrooms (kg dm/kg fm) and R is average ratio between the dry mass (dm) and fresh mass (fm) of mushrooms which has a mean value of 0.08 (kg dm/kg fm)[3]. The average mushroom consumption for adults is taken typical value of 4 kg fm[19]. The activity concentrations are averaged for five different edible mushrooms and annual effective doses are calculated. The average activities of edible mushrooms for ^{232}Th, ^{40}K, ^{238}U are 2.32, 48.5, 5.07 Bq/kg, respectively and dose conversion factors for same nuclides are 2.30×10^{-7}, 6.02×10^{-9} and 4.50×10^{-8}, respectively. Annual effective doses are found to be 1.71×10^{-4} mSv, 9.34 × 10-5 mSv and 7.30×10^{-5} mSv for ^{232}Th, ^{40}K and ^{238}U, respectively and average dose being 1.13×10^{-4} mSv. Although activity concentration of ^{40}K is the highest in the samples, it is seen from results that greater part of ingested annual dose is due to ^{232}Th present in mushroom species. Ban-nai *et al.*[19] reported that dose due to intake of mushrooms to be 4×10^{-5} mSv for ^{137}Cs for the same amount of annual consumption. Their results for ^{137}Cs were lower than our averaged result for ^{232}Th, ^{40}K and ^{238}U.

Conclusion

Radioactivity concentrations were determined for various mushroom species. ^{232}Th, ^{40}K and ^{238}U activity concentrations in the mushroom species were found to be ranging from 0.354 to 5.43, 4.37-90.9 and 1.03-8.45 Bq/kg respectively. The obtained results were compared with earlier researches reported in the literature. Annual effective doses were calculated for ingestion of edible mushrooms and it is shown that exposure is mainly due to natural ^{232}Th radionuclide present in mushrooms. The mean annual effective dose due to the intake of mushrooms is 1.13×10^{-4} mSv. ^{232}Th is the γ emitting nuclide that contributed highest to the daily effective dose and hence to the mean annual effective dose. It is concluded that the soils in the studied area could have high natural levels of radioactive materials and different mushroom species collected from same area could be capable of different accumulation power.

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