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Determination of Heavy Metal and Radioactivity in *Agaricus campestris* Mushroom Collected from Kahramanmaraş and Erzurum Proviences

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A B S T R A C T

In this study, radioactivity and heavy metals accumulations in *Agaricus campestris* mushroom collected from Kahramanmaraş and Erzurum provinces was determined. HPGe gamma detector was used for the determination of radioactivity concentrations. Heavy metal content was measured using a ICP-MS. As radioactive element; natural (^{238}U, ^{232}Th ^{40}K) and artificial radionuclide (^{137}Cs) concentrations were determined. The values of the committed effective dose were calculated. Same measurements were made in soils. Absorbed dose and excess lifetime cancer risk were calculated. Amount of Mg, Al, Ca, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Cd, Pb^{206}, Pb^{207} and Pb^{208} as heavy metals of mushrooms were determined. ^{238}U, ^{232}Th, ^{40}K activity concentrations of mushroom collected from Erzurum was determined as 12.1 ± 0.8, 11.7 ± 0.9, 497.7 ± 17.8 Bq/kg, respectively and ^{137}Cs was not detected by system. ^{232}Th and ^{40}K activity concentrations of mushroom collected from Kahramanmaraş was determined as 13.4 ± 0.5, 134.9 ± 6.3 Bq/kg, respectively, ^{238}U and ^{137}Cs was not detected by system similarly. The value of the committed effective dose collected from Erzurum and Kahramanmaraş were calculated as 75 and 29 µSv respectively and these values were found lower than 290 µSv accepted as world average. Absorbed dose and risk of lifetime cancer for Erzurum was determined as 37.39 nGy/h, 16.5 x 10^{-5}; absorbed dose and excess lifetime cancer risk for Kahramanmaraş was determined as 30.92 nGy/h, 13.3 x 10^{-5} respectively. Amount of daily intake for each heavy metal was calculated. Radionuclide activity concentrations and accumulations of heavy metal were not founded threaten level to healthy, except from arsenic As (0.025 and 0.039 mg/kg) in mushroom collected from both provinces. They were found a bit higher than upper limit (0.015 mg/kg) in report which is prepared World Health Organization (WHO) and Food and Agriculture Organization of the United Nations (FAO) jointly.

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Kahramanmaraş ve Erzurum'dan toplanan *Agaricus campestris* mantarlarının radyoaktivite tayini ve ağır metal miktarlarının belirlenmesi

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Ö Z E T

Bu çalışmada, Kahramanmaraş ve Erzurum ilinden toplanan *Agaricus campestris* mantarlarındaki radyoaktivite ve ağır metal birikimleri belirlenmiştir. Radyoaktivite konsantrasyonları için HPGe gama dedektörü, ağır metal miktarlarının belirlenmesi için ise ICP-MS kullanılmıştır. Radyoaktif element olarak doğal (^{238}U, ^{232}Th ^{40}K) ve yapay (^{137}Cs) radyonüklit konsantrasyonları belirlenmiş ve mantarlardan dolayı alınan efektif doz değerleri hesaplanmıştır. Yetişme yerleri olan topraklarda da aynı ölçümler yapılmış, soğrulan dozlar ve yaşam boyu kanser riski hesaplanmıştır. Ağır metal olarak Mg, Al, Ca, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Cd, Pb^{206}, Pb^{207} ve Pb^{208} miktarları belirlenmiştir. Erzurum'dan toplanan mantarlardaki ^{238}U, ^{232}Th, ^{40}K aktivite konsantrasyonları sırasıyla 12,1 ± 0,8, 11,7 ± 0,9, 497,7 ± 17,8 Bq/kg olarak hesaplanmış ve ^{137}Cs sistem tarafından ölçülememiştir. Kahramanmaraş'tan toplanan mantarlarda, ^{232}Th ve ^{40}K aktivite konsantrasyonları sırasıyla 13,4 ± 0,5, 134,9 ± 6,3 Bq/kg olarak hesaplanmış, ^{238}U ve ^{137}Cs aynı şekilde sistem tarafından ölçülememiştir. Mantarlardan dolayı alınan efektif doz Erzurum ve Kahramanmaraş için sırasıyla 75 ve 29 µSv hesaplanmış olup dünya ortalaması kabul edilen 290 µSv'den küçük bulunmuştur. Erzurum için soğrulan doz 37,39 nGy/saat, yaşam boyu kanser riski 16,5 x 10^{-5}, Kahramanmaraş için soğrulan doz 30,92 nGy/saat, yaşam boyu kanser riski 13,3 x 10^{-5} olarak hesaplanmıştır. Her ağır metal için günlük alım miktarları belirlenmiştir. Radyoknüklit aktivite konsantrasyonları ve ağır metal birikim miktarları sağlığı tehdit edecek seviyede bulunmamış olup, yalnızca arsenik (As) miktarları (0,025 ve 0,039 mg/kg) her iki ilden toplanan mantarlarda da Dünya Sağlık Örgütü (WHO) ve Birleşmiş Milletler Gıda ve Tarım Örgütü'nün (FAO) gıda katkısı uzmanları topluluğunca hazırlanan ortak raporunda izin verilen üst limitten (0,015 mg/kg) bir miktar fazla bulunmuştur.

Introduction

The consumption of wild edible mushrooms is increasing, even in the developed world, because of a good content of proteins as well as a higher content of trace minerals (Agrahar-Murugkar and Subbulakshmi, 2005) and wide variety of free radical scavenging molecules which have antioxidant activity (Rajalıngam et al., 2013) Also, mushrooms have a mechanism to accumulate heavy metals from environment (Sesli and Tüzen, 1999). It is known that wild-growing mushrooms can accumulate important content of toxic metallic elements and metalloids and natural and artifical radionuclides (Gadd, 1994; Kalač, 2001; Svoboda et al., 2000; Vetter, 2004). Therefore, mushrooms can be used as bioindicators for environmental pollution. On the other hand, many studies carried out to evaluate the possible danger to human health from the consumption of mushrooms containing heavy metals (Gast el al., 1988; Ouzoni et al., 2007). So determining radioactivity and heavy metals in environment and food staf is very important for to know radiation and risk level which affect people direct or indirect (Rühm et al., 1997; Rosa et al., 2011). The content of the highly toxic elements in many wild edible mushroom species collected from unpolluted sites is frequently much higher than that in other plant food items (Vetter, 1993). Also heavy metal accumulation mechanism of mushrooms is species-specific. Higher contents of heavy metal have been observed in the fruiting bodies of mushrooms collected from the areas close to heavy metal smelters (Isiloglu et al., 2001; Kalač et al., 1991; Kalač et al., 1996). Thus, determining content of heavy metal and radioactivity in wild edible mushroom is more important than plant and other food items. Turkey has a great potential for edible mushroom-growing due to climatic conditions (Pekak et al., 2011). Therefore, Turkey is becoming an important exporter for wild edible mushrooms (Yamaç et al., 2007). Wild edible mushrooms of Turkey are exported to European countries such as France, Switzerland, Germany, England, Belgium, Holland, Luxemburg, Austria, Spain, Sweden, Norway and the United States of America, Japan, central Asia and central eastern European countries. To export the wild edible mushrooms, radiation certificate should be submitted (Pekşen and Akdeniz, 2012).

The main objectives of this study were: (i) to determine ^{232}Th, ^{238}U, ^{40}K and artificial radionuclide ^{137}Cs activity concentrations and heavy metals content in *Agaricus campestris* mushrooms collected from Kahramanmaraş and Erzurum provinces in Turkey (ii) to calculate effective dose for each mushroom (iii) to investigate difference between mushroom's radionuclides concentrations and heavy metals (iv) to determine radionuclides content's in soil of mushroom and to calculate absorbed dose and excess lifetime cancer risk.

Material and Methods

Mushrooms

The species, habitat, province, district, village and location mushrooms are given in Table 1. Mushroom specimens were collected in Kahramanmaraş province, in December of 2014 and in Erzurum province, in October of 2014. The morphological and ecological characteristics were noted, and specimens were photographed in their natural habitat. Mushrooms was dried for future use, then identified by mycolog Ertuğrul Sesli according to morphological characteristic.

Table 1 Species, habitat, province, district, village and location of mushrooms

	Species of mushrooms	
Location	*A. campestris* L.: Fr.	*A. campestris* L.: Fr.
Habitat	On soil	On soil
Province, district and village	Kahramanmaraş, Göksun, Yağmurlu	Erzurum, Tekman, Dalsöğüt
Coordinate	38°05'23.6"N 36°36'07.7"E	39°34'17.4"N 41°13'36.4"E

Soil Samples

Soil samples were taken from 2-3 cm depth from ground where mushrooms grew up. Then soil samples were eliminated for analysis.

Samples preparation

All the mushroom samples and soils were sliced and dried at a drying mechanism at 10°C for radioactivity (Gwynn et al., 2013) and for heavy metal analysis (Semreen et al., 2011) until they were completely dehydrated. Mushroom and soil samples were crushed for passing a 40 mm mesh sieve. They were then transferred to an uncontaminated empty plastic cylindrical container of uniform size (50 mm in height, 60 mm in diameter) and sealed for a period of 4 weeks in order to allow for radon and its short-lived progenies to reach secular radioactive equilibrium prior to gamma spectroscopy (Turhan et al., 2007).

Radioactivity Measurements

Radioactivity measurements were performed by using a HPGe computer controlled detector having the resolution of 1.9 keV for the 1332 keV energy line of ^{60}Co with conventional electronics and 15% relative efficiency (Canberra, GC1519 model) and Genie 2000 as the software. The detector was shielded with a 10 cm thick lead layer to reduce the background due to the cosmic rays and the radiation nearby the system.

The gamma-ray lines of 295.2 keV from ^{214}Pb, 352.0 keV from ^{214}Pb and 609.4 keV from ^{214}Bi were used to evaluate the ^{238}U activity concentration, while 583.1 keV gamma-rays from ^{208}TI, 238.6 keV from ^{212}Pb and 911. keV from ^{228}Ac were used to determine to the ^{232}Th activity concentration. The activity concentrations of ^{40}K and ^{137}Cs were determined by using their 1460 keV and 661 keV gamma-ray lines, respectively.

The specific activity of each sample was then calculated utilizing the following formula:

$A = Cnet / (\varepsilon \times I_\gamma \times t \times m)$ (Changizi et al., 2012) where; C net is the net area of the total absorption line, A is the activity of the isotope in Bq /kg, I_γ is the absolute intensity of the transition, t is the sample measurement time, ε is the full energy peak efficiency, and m is the mass of the sample.

Effective dose: A possible risk of radioactivity for human being that consume these mushrooms is expressed by the effective dose (E) given in mSv/y (Faweya et al., 2015). The contribution to the annual effective dose to an adult that consume these species of mushrooms is calculated as follows;

E = Y x Z x dk where; Y is the specific activity (Bq/kg dw) of each of the radionuclides that the mushroom contains. dk is the effective dose conversion factor by ingestion of radionuclide (Sv/Bq). The values of this conversion factor for adults are: 0.28, 0.23, 1.3 x 10^{-2} and 6.2×10^{-3} μSv / Bq, for ^{238}U, ^{232}Th, ^{137}Cs and ^{40}K, respectively. Z is the annual intake of fresh mushrooms (kg, fw). The average annual consumption of mushrooms by adult Turkish people is about 0.5 kg fw (The Union of Turkish Agricultural Chambers, 2015)

Absorbed dose rate in air (D): The greatest part of the gamma radiation comes from terrestrial radionuclides. There is a direct connection between terrestrial gamma radiation and radionuclide concentrations. If a radionuclide activity is known then its exposure dose rate in air at 1 m above the ground can be calculated using the formula UNSCEAR (2000):

D(nGy/h) = 0.462 A_U + 0.604 A_{Th} +0.0417 A_k + 0.030A_{Cs} where; D is the dose rate at 1m above the ground, A_U, A_{Th}, A_K and A_{Cs} are the activity concentrations of ^{238}U, ^{232}Th, ^{40}K, ^{137}Cs respectively, in the samples. The conversion factors of ^{238}U, ^{232}Th and ^{40}K are 0.462, 0.604, 0.0417 and 0.030 nGy/h per Bq/kg, respectively (Kurnaz et al., 2007).

Radium equivalent activity (Ra_{eq}) and external Hazard index (H_{ex}): The results were evaluated in terms of the radiation hazard by means of the Ra-equivalent activity (Ra_{eq}) and external hazard index (H_{ex}). Radium equivalent activity is a widely used hazard index and it is calculated through the relation given by Beretka and Mathew (1985). It is assumed that 370 Bq/kg of $^{226}Ra(^{238}U)$, 259 Bq/kg of ^{232}Th and 4810 Bq/ kg of ^{40}K produce the same gamma-ray dose rate

$Ra_{eq} = A_{Ra} + 1.43\ A_{Th} + 0.077\ A_K$ where; A_{Ra}, A_{Th} and A_K are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively.

The external hazard index H_{ex} was calculated for the investigated samples using the model proposed by Krieger (1981) assuming thick walls without windows and doors, where the external hazard index is given by

$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \leq 1$ where; A_{Ra}, A_{Th} and A_K are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively (Kurnaz et al., 2007).

Annual gonadal dose equivalent (AGDE): The activity bone marrow and the bone surface cells are considered as the organs of interest by UNSCEAR (1988). Therefore, the AGDE due to the specific activities of ^{226}Ra, ^{232}Th and ^{40}K was calculated using the following formula (Mamont-Ciesla et al., 1982):

AGDE (μSv/year) = 3.09 A_{Ra} + 4.18 A_{Th} + 0.314 A_K (Kurnaz et al., 2007).

Annual effective dose equivalent (AEDE): In order to estimate the annual effective doses, one has to take into account to conversion coefficient from absorbed dose in air to effective and the outdoor occupancy factor. In the UNSCEAR (2000) reports, a value of 0.7 Sv/Gy was used for the conversion coefficient from absorbed dose in air to effective dose received by adults, and 0.2 for the outdoor occupancy factor. The annual effective dose equivalent was calculated from following equation:

AEDE (μSv/year) = D(nGy/h) × 8760(h/year) × 0.2 × 0.7(Sv/Gy) ×10^{-3} (Kurnaz et al., 2007).

Excess lifetime cancer risk: Excess lifetime cancer risk (ELCR) was calculated by using equation:

ELCR= AEDE x DL xRF where DL is duration of life (70 year) and RF is risk factor (Sv^{-1}), fatal cancer risk per Sievert. For stochastic effects, ICRP 60 uses values of 0.05 for the public (ICRP, 1990).

Heavy Metal Content

Apparatus and Reagents: A Bruker 820-MS Inductively Coupled Plasma Mass Spectrometer (ICP-MS) and a Cem Mars 5 Closed Vessel Microwave Digestion System were used in the studies. All reagents (Merck) were ultra-pure, and deionise water was used to prepare the solutions. All glassware was soaked in nitric acid for 30 min and rinsed with deionized water before use.

Sample treatment: Mushroom samples (0.5 g) were digested in a mixture of 5 mL of HNO_3 (65%), 2 mL of HCl (37%) in a microwave digestion system for 31 min and diluted to 50 mL volume with deionised water. After digested samples were quantitatively transferred into 100 mL polypropylene volumetric flasks and diluted to volume with ultrapure water. These samples were analysed by inductively coupled plasma mass spectrometry (ICP-MS).

Estimated daily intake (EDI) of heavy metals: The estimated daily intake (EDI) of heavy metals depends on both the metal concentration level and the amount of consumption of mushrooms. The EDI of metals for adults was determined using the following equation (Zhuang et al., 2008):

EDI= (C_{metal} x W) / m

where C_{metal} is the concentration of heavy metals in mushroom; W represents the daily average consumption of mushroom; m is the body weight. Calculations were made assuming body weight of 70 kg for adults and a 17 g average daily consumption.

Results and Discussion

Radioactivity Measurements

Mushrooms: Agaricus campestris collected from Kahramanmaraş and Erzurum are called *Agaricus campestris* (K) and *Agaricus campestris* (E), respectively.

Activities for ^{238}U, ^{232}Th, ^{137}Cs and ^{40}K in mushroom samples (dry weight) are presented in Table 2.

It is known that most of the radioactivity that humans are exposed arises mainly from natural radionuclides. The three main components of natural radiation are ^{232}Th and ^{238}U series and ^{40}K (UNSCEAR 2000, Belivermiş et al., 2008).

In this study, ^{238}U activity concentration in A. campestris (E) was found 12.1±0.8 Bq/kg and in A. campestris (K) was not detected by system. Our values were found lower than *Pleurotus squarrosulus* and *Pleurotus tuber-regium* from Nigeria (21.64 ± 7.23: 17.64 ± 5.98 Bq/kg, respectively: Faweya et al., 2015).

^{232}Th activity concentration in *A. campestris* (E) and *A. campestris* (K) was found 11.7±0.9 and 13.4±0.5 Bq/kg, respectively. These activity concentrations were found higher than *Psathyrella atroumbonata* (9.13 ± 4.02 Bq/kg) and lower than *Termitomyces robustus* (14.31 ± 6.01 Bq/kg) from Nigeria (Faweya et al., 2015).

^{40}K activity concentration in *A. campestris* (E) and *A. campestris* (K) was found 497.7 ±17.8 and 134.9±6.3 Bq/kg, respectively. This values were found lower than content in *Agaricus blazei*, *Pleurotus ostreatu*s and *Pleurotus ostreatoroseus* from Sao Paulo, Brazil (860 ±4, 849 ±4 and 1535± 10, respectively: Castro et al., 2012), *Heterobasidion annosum*, *Lycoperdon umbrinum* from Poland (150± 114, 810±142 Bq/kg, respectively: Mietelski et al., 2010).

Natural radionuclide activity concentrations can be until 600 Bq/kg in agricultural products and natural radioactivity level is 2000 Bq/kg according to WHO (1989). So, there is no healty risk from natural radionuclides for *A. campestris* (E) and (K).

In addition, artificial radionuclide ^{137}Cs activity concentration in both mushrooms was not detected by system. ^{137}Cs activity concentration was found lower than *Lentinula edodes*, *Pleurotus ostreatus* from Brazil (2.2 ± 0.1, 4.9 ± 0.3 Bq/kg, respectively: Castro et al., 2007).

Soil samples: Activities for ^{238}U, ^{232}Th, ^{137}Cs and ^{40}K in soil samples (dry weight) are presented in Table 3.

Avareges of ^{238}U, ^{232}Th, ^{40}K activity concentration were found 24.3 ± 1.2, 21.4 ± 0.7 and 212.8 ± 2.7 Bq/kg, respectively. All of these values were found lower than world avarege values (45, 45, 400 Bq/kg respectively, UNSCEAR, 2000). ^{137}Cs activity concentration in soil were comparable soil values of Fırtına Valley, Turkey (19–232 Bq/kg, Kurnaz et al., 2007) and higher than İstanbul and Çanakkale, Turkey soils values (2–81, 2–25 Bq/kg, respectively: Karahan and Bayulken, 2000: Karakelle et al. 2002).

Effective dose: Effective dose (E), absorbed dose rate in air (D), Radium equivalent activity (Ra_{eq}) and external hazard index (H_{ex}) Annual gonadal dose equivalent (AGDE) Annual effective dose equivalent (AEDE) Risk of lifetime cancer are presented in Table 4.

The annual effective dose values of A. campestris (K) and (E) were found 29 and 75 µSv/y, respectively. There values were found higher than lingonberries and blueberries for Nordic populations (16.0, 6.0 µSv/y, respectively: Turtiainen et al., 2014) However, effective doses were found below the world average value (290 µSv/y). The low level of contamination reveals that the consumption of wild mushroom species will not cause any health problems.

Absorbed dose rate in air (D): Absorbed dose rate in air of Erzurum and Kahramanmaraş was calculated 37.39 and 30.92 nGy/h. These values were found lower than values of Eastern Desert of Egypt (488 nGy/h, Arafa, 2004) and İstanbul, Turkey (49 nGy/h, Karahan and Bayulken, 2000). Our result was found lower than international recommended value (55 nGy/h) (UNSCEAR, 1988).

Table 2 ^{238}U, ^{232}Th, ^{137}Cs and ^{40}K activity concentrations of mushroom samples (dry wright)

Radionuclides	Mushroom	
	Agaricus campestris (E)	*Agaricus campestris* (K)
^{238}U (Bq/kg)	12.1±0.8	ND*
^{232}Th (Bq/kg)	11.7±0.9	13.4±0.5
^{137}Cs (Bq/kg)	ND*	ND*
^{40}K (Bq/kg)	497.7 ±17.8	134.9±6.3

ND* = Not detected.

Table 3 ^{238}U, ^{232}Th, ^{137}Cs and ^{40}K activity concentrations of soil samples (dry wright)

Radionuclides	Location of soil sample	
	Erzurum	Kahramanmaraş
^{238}U (Bq/kg)	32.6 ± 1.7	15.9 ± 0.7
^{232}Th (Bq/kg)	22.2 ± 0.9	20.5 ± 0.4
^{137}Cs (Bq/kg)	58.8 ± 3.2	59.2 ± 0.5
^{40}K (Bq/kg)	170.6 ± 6.8	255.0 ± 8.5

Table 4 E, D, Ra_{eq}, H_{ex}, AGDE, AEDE, Risk of lifetime cancer values of mushroom and soil

Parameters	*A.campestris (K) value*	*A.campestris (E) value*	WAV[1]
E (µSv/y)	29	75	290
D (nGy/h)	37.39	30.92	55
Ra_{eq} (Bq/kg)	77.47	64.88	370
H_{ex}	0.19	0.16	-
AGDE (µSv/year)	246.4	214.9	2398
AEDE (mSv/year)	45.85	37.92	70
RLC[2]	16.5×10^{-5}	13.3×10^{-5}	0.29×10^{-3}

[1]WAV: The World average value; [2]RLC: Risk of lifetime cancer

Radium equivalent activity (Ra_{eq}) and external hazard index (H_{ex}): Radium equivalent activity (Ra_{eq}) in Erzurum and Kahramanmaraş was calculated 77.47, 64.88 Bq/kg respectively. Our results were found lower than Fırtına Valley, Turkey(166.3 Bq/kg, Kurnaz et al., 2007) and Eastern Desert of Egypt (493.8 Bq/kg, Arafa, 2004). Also, our result was found lower than international recommended value (370 Bq/kg, UNSCEAR, 2000).

External hazard index (H_{ex}) in Erzurum and Kahramanmaraş was calculated 0.19, 0.16. These values were found lower other countries result such as China (Xiazhuang Granite Area) (0.84, Yang et al., 2005) and Egypt (Eastern Desert) (2.03, Arafa, 2004).

Annual gonadal dose equivalent (AGDE): Annual gonadal dose equivalent (AGDE) in Erzurum and Kahramanmaraş was calculated 246.4, 214.9 µSv/year, respectively. The average value of AGDE was found to be 2398 mSv/year for Eastern Desert of Egypt (Arafa, 2004) and 550.5 mSv/year for Fırtına Valley, Turkey (Kurnaz et al., 2007). This value of AGDE is higher than our result.

Annual effective dose equivalent (AEDE): The annual effective dose rate (AEDE) values in Erzurum and Kahramanmaraş were calculated 45.85 and 37.92 mSv/year, respectively. The world average annual effective dose equivalent (AEDE) from outdoor terrestrial gammaradiation is 70 mSv/year (UNSCEAR, 1988). So, our values are lower than the world average value and Istanbul value (69.8 mSv/year, Karahan and Bayulken, 2000).

Excess lifetime cancer risk: Excess lifetime cancer risk in Erzurum and Kahramanmaraş was calculated 16.5 x 10^{-5} and 13.3 x 10^{-5}. World avarege Excess lifetime cancer risk is 0.29 x 10^{-3} (Taskin et al., 2009). So our values is lower than average risk of lifetime of world.

Heavy Metal content

Heavy metal content (mg/kg, dw) of *A. campestris* (E) and (K) are presented in table 5.

Table 5 Heavy metal contents (mg/kg, dw) in *A. campestris* mushroom

Heavy metal	Mushroom	
	A.campestris (K)	*A.campestris* (E)
Mg	187.4	182.7
Al	17.83	89.73
Ca	735.0	1165.3
Cr	0.041	0.043
Mn	30.1	27.9
Fe	96.9	73.7
Co	0.63	0.64
Ni	28.3	24.7
Cu	88.16	38.90
Zn	102.2	97.37
As	0.024	0.039
Se	3.55	4.55
Cd	0.76	0.66
Pb206	1.29	0.60
Pb207	1.17	0.57
Pb208	1.21	0.57

Mg content of *A. campestris* (K) and (E) were determined 187.4, 182.7 mg/kg, respectively. Mg content of some mushrooms has been reported 55.3- 71.0 mg/kg (Wang and Hou, 2011) and 350 mg/kg (Gaso et al., 2000)

Rudawska and Leski (2005) reported that Al contents of mushrooms samples were ranged from 8.5 to 365 mg/kg. In this study, the Al content of the samples was 17.83 (K) and 89,73 (E).

Ca is known to accumulate in the humic horizon, particularly in its upper layer, where mycelium of mushroom grows. In a previous study, Ca content of *A.campestris* from Russia has been reported 850 mg/kg (Gorbunova et al., 2009). Value of *A.campestris* (K) (735.0 mg/kg) is lower and *A.campestris* (E) (1165.3 mg/kg) higher than data of previous study. It can be concluded that difference of humic horizon.

In the literature; the Cr values have been reported to be 0.60 - 24.3 mg/kg (Michelot et al., 1998, Demirbaş, 2002, Isildak et al., 2004). Our Cr values are 0.041 and 0.043 mg/kg for *A. campestris* (K) and (E), respectively and lower than data of previous studies.

Manganese, one of the least toxic metals, if inhaled as MnO_2 dust is more hazardous than ingested manganese. Toxicity limits of manganese for plants are high (400–1000μg/g). Our values of A. campestris (K) and (E) are 30.1, 27.9 mg/kg, respectively and under toxicity limits.

The Fe content of the samples were found as 96.9 (K) and 73.7 (E) mg/kg. Iron values in mushrooms samples have been reported in the range of 31.3–1190 mg/kg (Sesli and Tuzen, 1999). Fe content of A. campestris has been reported 50-150 mg/kg other previous study (Borovicka and Randa, 2007). Our iron values are in agreement with literature values.

The average Co content of samples is 0.64 mg/kg. All published papers concur that cobalt contents are commonly below or around 0.5 mg/ kg, only a limited proportion exceeds 1.0 mg kg (Kalač, 2010). Our data slightly exceeds the literature.

Some researchers reported that the amount of Ni in mushrooms ranged from 11 to 145 mg/kg (Barcan et al., 1998, Yilmaz et al., 2003). Average of Ni content of *A. campestris* (K) and (E) is 26.5 mg/kg and comparable previous studies values.

Cu is accumulated by the genera *Agaricus* (147–260 mg/kg: Vetter, 1993) The Cu value has been reported to be 10–70 mg/kg in mushrooms (Kalač and Svoboda, 2000). Our Cu values were 88.16 (K) and 38.90 (E) mg/kg and exceeded the literature data especially in the mushroom sample collected from Kahramanmaraş province.

In this study, mean of Zn content of mushrooms is 99.8 mg/kg. Zn content of *A. campestris* has been reported 75-200 mg/kg (Alonso et al., 2003, Borovicka and Randa, 2007) so our values are comparable previous studies.

Arsenic in a real environment (nature) is the most hazardous inorganic element due to the carcinogenic risk, and there are no safe levels of arsenic (Falandysz and Borovicka, 2013). As content of *A. campestris* has been reported 2.60 mg/kg (Svoboda and Chrastny, 2008). Content of (K) and (E) was 0.025 and 0.039 mg/kg respectively and was found a bit higher than upper limit (0.015 mg/kg) in report which is prepared World Health Organization (WHO) and Food and Agriculture Organization of the United Nations (FAO) (Prasad, 2008) jointly.

Se content of *A. campestris* has been reported 2-10 mg/kg (Borovicka and Randa 2007, Szynkowska et al. 2008) and our average of Se content was 4.05 mg/kg.

The genus *Agaricus* can accumulate Cd (Melgar et al. 1998). In previous studies; Cd content of *A. campestris* has been reported between 2 and 50 mg/kg (Andersen et al., 1982; Kalač et al., 1989; Zurera-Cosano et al., 1987). Normal range of Cd in mushrooms according to WHO (1999) is 0.012-60 mg/kg. Our mean values of Cd content is 0.71 mg/kg and within safety range.

^{206}Pb is the final step in the decay chain of ^{238}U, the radium series or uranium series. ^{207}Pb is the end of the Actinium series from ^{235}U. ^{208}Pb is the end of the Thorium series from ^{232}Th. Lead content of *A. campestris* has been reported 2-5 mg/kg (García et al. 2009) in the literature.

In this study the mean value of lead respectively when compared with the permissible concentration of 0.012-6 mg/kg (Peter et al., 1985), were within the normal range and could be considered safe for consumption.

Metals can be accumulated in mushrooms and this accumulation is dependent, in general, the metabolism is strongly affected species and the chemical composition of the substrate on which fungi obtain nutrients (Georgescu and Busuioc, 2011).

Estimated Daily Intake

Daily consumption of mushroom was taken 17g (500g/30day) and calculated estimated daily intake. Estimated dailiy intake of mushrooms presented in Table 6.

Table 6 Estimated daily intake of mushrooms (µg/kg/day)

Heavy metal	Mushroom	
	A.campestris (K)	*A.campestris* (E)
Mg	45.5	44.4
Al	4.3	21.8
Ca	178.5	282.9
Cr	0.009	0.01
Mn	7.3	17.9
Fe	23.5	17.9
Co	0.15	0.15
Ni	6.8	5.9
Cu	21.9	9.4
Zn	24.8	23.6
As	0.005	0.009
Se	0.86	1.1
Cd	0.18	0.16
Pb206	0.3	0.1
Pb207	0.2	0.1
Pb208	0.2	0.1

The permissible aluminium dose for an adult is quite high (60 mg per day, WHO, 1989). For an average adult (60 kg bodyweight), the provisional tolerable daily intake (PTDI) for lead, iron, copper and zinc are 214 µg, 48 mg, 3 mg and 60 mg, respectively (WHO, 1999). The maximum permissible doses for an adult are 3 mg Pb and 0.5 mg Cd perweek, but the recommended doses are only one-fifth of those quantities (CEC, 2002). According to the CEC report and WHO permissible limits, there is no risk of *A. campestris* (K) and (E) for healt.

Conclusion

In this study, radioactivity and heavy metal accumulations of *Agaricus campestris* mushroom collected from Kahramanmaraş and Erzurum provinces was determined. The investigated parameters reveal that the low level of contamination of wild edibe mushroom (*A. campestris*) will not cause any health problems.

Mushrooms can accumulate radionuclides in the same way as they do heavy metals. The uptake of metal ions in mushrooms is in many respects different from plants. The contents of trace metals or radionuclides are related to species of mushroom, collecting area of the sample, age of fruiting bodies and mycelium, and distance from any source of pollution (Kalač et al., 1991). Thus, this study can be extended considering parameters above-mentoined.

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