WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 8.074
Volume 8, Issue 3, 47-62. Review Article ISSN 2277– 7105

TRACE ELEMENTS CONCENTRATIONS IN TURKEY SPECIES OF WILD GROWING EDIBLE MUSHROOMS: A REVIEW

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Article Received on 25 Dec. 2018,
Revised on 16 Jan. 2019,
Accepted on 07 Feb. 2019
DOI: 10.20959/wjpr20193-14260

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ABSTRACT

Turkey has great mushroom-producing potential due to environmental conditions. It is a popular natural food in Turkey. This article review presents scientific information on trace element (Cu, Cd, Zn, Pb, Mn, Fe, Cr, Ni). The studies included 17 species which collected from several regions in Turkey. The lowest Cu levels obtained was in *Rhizopogon roseolus* (2.19 ug/g) and, the highest level of Cu was in *Melanoleuca stridula* as 75.40 mg/kg dw). The lowest Cd contents was 0.024 µg/g in *Morchella costata*, and the highest concentration of Cd in reviews was found in *Hydnum repandum* (7.45-0.124 mg/ kg). The zinc content was found vary from 9.74 mg/kg in *Craterellus cornucopioides* to 354.0 mg/kg in *Helvella leucopus*. Minimum and maximum levels of Pb were measured as 0.9 mg/kg and 9.2 mg/kg dry matter in *Morchella esculenta* and Lactarius deliciosus. The highest concentration of Mn in the studied mushrooms was found in 197 mg/kg *Melanoleuca stridula*, whereas the lowest manganese content was 0.83 µg/g in *Morchella costata*. The highest and the lowest levels of Iron were found in *Rhizopogon roseolus* and Cantharellus cibarius. The highest chromium content (22.7 mg/g d.w.) was found in Armillaria mellea, whereas the lowest chromium content (0.074 mg/g d.w.) was found in *Rhizopogon roseolus. Armillaria mellea* and *Rhizopogon roseolus* had the minimum and maximum Ni concentrations at 0.04 ug/g and 17.44 mg/ kg respectively. The different results due to soil properties, species of mushroom, mushroom structure and morphological type, geographical origins, environmental conditions, method analysis used,

mushroom structure and morphological type. The purpose of reviews is to evaluate the level of toxic elements (Cd, Pb, Cr, Ni) and essential elements (Cu, Zn, Mn, Fe) in some species of mushrooms from Turkey. These scientific data are useful in the fields mushroom science, food science and health science.

KEYWORDS: Trace elements; Wild Mushrooms: Turkey.

INTRODUCTION

Mushrooms along with other fungi are something special in the living world, being neither plant nor animal (Cheung, 2008). But had for long been classified as plants. It was only in 1969 that Whittaker reclassified these organisms into a separate kingdom, the Fungi (Whittaker, 1969). The number of mushrooms on Earth is estimated at 140,000, yet maybe only 10% (approximately 14,000 named species) (Wasser, 2002). Not far from 14,000 mushroom species, described according to the rules of mycological nomenclature, represent about 10% of the estimated number of species existing on Earth. More than 2000 species are safe for consumption, and almost 700 species are known to possess significant pharmacological properties (Kalač, 2016). Mushroom, also known as mantar in Turkey. Turkey is rich in mushrooms diversity, as well as medicinal plant. Turkish public have a tradition of using a number of mushrooms for food, instead of the treatment of infectious diseases and various ailments (Akyuz, Onganer, ERECEVIT, & Kirbag, 2010).

Heavy metal concentrations in mushroom are considerable higher than those in agricultural crop plants, vegetables and fruits (Manzı et al., 2001). As a result of their effective take-up mechanism. Several reviews of trace element contents in mushrooms were published (Stijve & Roshnik, 1974;:KalacΪ & Svoboda,1998; Seeger, 1982; Vetter, 1994).

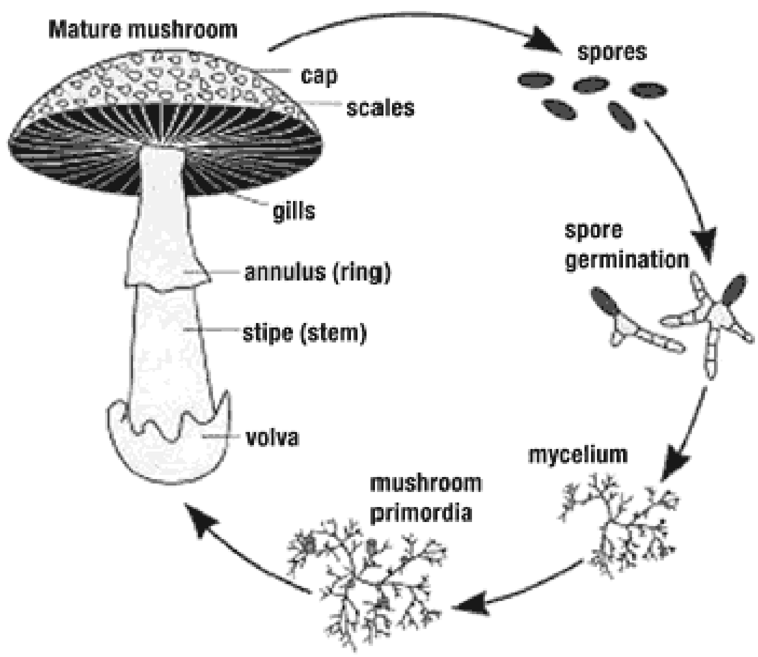
The fruiting bodies of mushrooms are characterized by a high level of well assimilated mineral elements. Major mineral constituents in mushrooms are K, P, Na, Ca, Mg and elements like Cu, Zn, Fe, Mo, Cd form minor constituents (Bano and Rajarathanum, 1982; Bano et al., 1981). Mushrooms have been found to accumulate heavy metals like cadmium, lead, arsenic, copper, nickel, silver, chromium and mercury (Wondratschek and Roder, 1993;Svoboda et al., 2001; Issilogglu et al., 2001; Malinowska, 2004). The mineral proportions vary according to the species, Heavy metals are individual metals and metal compounds that can impact human health. Heavy metal concentrations in mushroom are considerably higher than those in agricultural crop plants, vegetables and fruit (kalyoncu et al. 2010).

Furthermore, The principal factors influencing the accumulation of heavy metals in macrofungi has been noted to be affected by environmental and fungal factors. Environmental factors, such as organic matter contents, PH, metal concentrations in soil or substrate and fungal factors, such as species of mushroom, fungal structure, development of mycelium and fruit bodies, age of mycelium and biochemical composition are known to affect metal accumulation in macrofungi (Kalac and Svoboda 2000; Isiloglu et al. 2001).

The purpose of reviews is to evaluate the level of toxic elements (Cd, Pb,Cr, Ni) and essential elements (Cu,Zn,Mn,Fe) in some species of mushrooms from Turkey. These scientific data are important in the fields, mushroom science, food science and health science.

1. Mycological terms

A mushroom is the fleshy, spore-bearing fruiting body of a fungus. The fruiting body (carpophore, mycocarp) in higher fungi is found mostly above ground. A fruiting body grows from spacious underground mycelia (hyphae) by the process of fructifying. The lifetime of the bulk of fruiting bodies have a short lifetime only about 10-14 days (Kalač,2009). This figure illustrates the life cycle of mushroom.



Life cycle of mushroom (www.mushroomgrow.com)

2. The content of major mineral elements

The comparison of the results given in table below,the concentration levels of (Cd, Pb,Cr ,Ni Cu,Zn,Mn,Fe) in 17 species which collected from several regions in Turkey. These scientific data are important in the fields mushroom science, food science and health science. Analytical methods used by inductively coupled plasma mass spectrometry (ICP-MS) or Atomic absorption spectrometry (AAS).

2.1.Copper

Copper is an essential trace element that is a great source to the health, it is essential for proper functioning of organs and metabolic processes. Copper plays a critical role in a variety of biochemical processes (Yaman and Akdeniz 2004). but may be toxic to both humans and animals when its concentration exceeds the safe limits (Gast et al. 1988). In general, the copper content in mushrooms is higher than vegetables. The results given in table (1) showed that the concentration of copper in mushrooms is usually 100–300 mg/kg, which is not considered a health risk (Soylak et al. 2005). The copper content of the data presented ranged from 2.19 µg/g to 75.40 mg/kg dw, The lowest concentration of copper observed was *Rhizopogon roseolus*, whereas *Melanoleuca stridula* had the highest.

Table (1): Element concentrations of the mushroom species:

Species	Cu	Cd	Pb	Zn	Mn	Fe	Cr	Ni	Unit	Region	Reference
Armillaria mellea	45.6	0.5	2.1	70.3	28.2	312	22.7	15.9	µg/g	Middle black sea region	Isildak et al., 2004
Armillaria mellea	15.6		1.4	43.5	49.1	510			mg/kg	Black sea	Sesli et al., 2008
Boletus badius	26.8	0.5	2.1	51.6	19.8	287	1.9	ND	mg/kg	Kastamonu	Isildak et al., 2004
Boletus badius	8.4	0.14	8.9	64.4	24.8	377	1.2	9.5	mg/kg	Kastamonu	Mendil et al., 2004
Hydnum repandum	55.1-5.15	7.450.124	1.38-0.453						mg/kg	YesËilyurt forestry	Demirbaş, 2000
Hydnum repandum	11.2	N.D	N.D	36.2	20.8	199	2.74	0.58	µg/g	East Black Sea	Ayaz, 2011
Hydnum repandum	23.80	0.26	2.34	48.80	56.80	502	5.24	5.68	mg/kg	Anatolia	Yamaç et al., 2007
Amanita ovoidea	5.00	0.26		29.78	9.23		4.59		mg/kg	Bigadiç (Balıkesir)	ŞEN, Alli, ÇÖL, Celikkollu, & Balci, 2012
Amanita ovoidea	19.0	0.91	4.6	83.0	33.0	710	**11.8**	14.8	mg/kg	Mugla	Sarikurkcu, Tepe, Solak, & Cetinkaya, 2012
Craterellus cornucopioides	3.58		0.44	9.74	7.23	300			µg/g	Istanbul	Gezer et al., 2015
Craterellus cornucopioides	73.8		1.8	167	145	502			mg/kg	Black sea	Sesli et al., 2008
Cantharellus cibarius	37.30	0.22	n.d	71.5	25.2	130	2.09	1.10	µg/g	East Black Sea	Ayaz, 2011
Cantharellus cibarius	15.5		1.3	72.5	131	1741				Black sea	Sesli et al., 2008
Cantharellus cibarius		0.036	0.04				0.69	0.17	µg/g	Western black sea	Konuk et al., 2007
Cantharellus tubaeformis	63.4		2.2	106	87.4	205			mg/kg	Black sea	Sesli et al., 2008
Cantharellus tubaeformis	44.6	0.14	n.d	57.5	48.4	166	1.57	0.77	µg/g	East Black Sea	Ayaz, 2011
Morchella vulgaris		0.036	0.06				0.08	0.04	µg/g	Western black sea	Konuk et al., 2007
Morchella vulgaris	32.6	0.3	2.1	42.3	15.2	174	4.2	2.8	µg/g	Middle black sea	Isildak et al., 2004
Morchella esculenta	ND	1.1	3.5	41.4	20.4	243	8.2	2.5	µg/g	Mddle black sea	Isildak et al., 2004
Morchella esculenta	16.4	0.79	0.9	84.0	27.9	148	21.00	7.3	mg/kg	Osmaniye	Sarikurkcu et al., 2012

Lactarius deliciosus,	13.4	0.10	9.2	47.1	15.4	180	1.2	9.2	mg/kg	Kastamonu	Mendil et al., 2004
Lactarius deliciosus,	10.60	0.47	0.42	69.80	16.80	146	4.24	2.46	mg/kg	Anatolia	Yamaç et al., 2007
Lactarius deliciosus,		0.030	0.02				0.36	0.18	µg/g	Western black sea	Konuk et al., 2007
Rhizopogon roseolus	2.19	0.029	0.37	11.02	8.49	39.97	0.074	0.206	µg/g	Denizli	Gezer et al., 2015
Rhizopogon roseolus	33.80	0.47	0.54	62.40	18.20	824	9.44	17.44	mg/kg	Anatolia	Yamaç et al., 2007
Russula delica,		0.034	0.03				0.16	0.08	µg/g	W Western black sea	Konuk et al., 2007
Russula delica,	37	1.04	2.5	52	66	470	0.10	5.4	mg/kg	Isparta	Sarikurkcu et al., 2012
Melanoleuca stridula	75.40	1.30	9.04	90.60	197.40	524	3.30	4.54	mg/kg	Anatolia	Yamaç et al., 2007
Melanoleuca stridula	37.97	0.60		35.73	17.51		3.92		mg/kg	Bigadiç	ŞEN, Alli, ÇÖL, Celikkollu, & Balci, 2012
Morchella costata		0.43	0.47	10.72	0.83		0.082	0.361	µg/g	Denizli	Gezer et al., 2015
Morchella costata		0.024	0.02				1.68	0.40	µg/g	Western black sea	Konuk et al., 2007
Lepista nuda	68.8	2.9	3.5	47.6	49.3	321	10.4	4.2	µg/g	Middle black sea region	Isildak et al., 2004)
Lepista nuda	20	1.1	1.4	45	16	568			mg/kg	Western black sea	Turkekul, Elmastas, & Tüzen, 2004)
Helvella leucopus		6.06	1.0	354.0			2.30	3.0	mg/kg	Isparta	Sarikurkcu et al., 2012
Helvella leucopus		0.03	0.007				0.80	0.30	µg/g	Western black sea	Konuk et al., 2007

The copper content of *Rhizopogon roseolus* from Denizli region had the lowest copper concentration whereas Anatolia region had the highest (2.19 µg/g. 33.80 mg/kg) respectively, whereas *Melanoleuca stridula* from Anatolia region had the highest copper concentration compared in Bigadiç region (75.40 mg/kg, 37.97 mg/kg), respectively. The WHO permissible limit for copper in all foods is 40 mg/kg (Zhu, 2011: Bahemuka, 1999). Copper concentrations of mushroom samples in the literature have been reported to be in the ranges: 4.71– 51.0 mg/kg (Tüzen et al. 1998), 11.4-15.8 mg/kg (Li, 2011), 10.3–145 mg/kg (Sesli and Tüzen 1999), and 15–73 mg/kg (Sesli et al. 2008), respectively.

2.2.Cadmium (cd)

Cadmium has been considered the second risky mushroom trace element after mercury. It is a very toxic metal. Cadmium (Cd) has no known useful role in higher organisms (Hogan 2010). Cadmium levels in blood serum increased following mushroom consumption, it is accumulate in kidneys, spleen, and liver (Kalač, 2000). The results in table (1) show that the amounts of cadmium recorded for species of mushrooms varied between 0.024 µg/g in *Morchella costata* (WESTERN BLACK SEA REGION) and 7.45 mg/kg in *Hydnum repandum* (YesËilyurt forestry).

These results of cadmium levels are agreement with that reported by (Svoboda et al. 2001) 0.81–7.50 mg/kg.

On the other hand, The Cadmium content was 0.433 µg/g in *Morchella costata* from Denizli region, while 0.62,0.124, 3.12,3.42,5.43,0.26 mg/kg, dry-weight in *Hydnum repandum* (YesËilyurt forestry region).

Not all results were compatible with the WHO mentions maximum permissible levels in raw plant materials for cadmium which amount to 0.30 mg/kg.

Mushrooms may contain large amounts of Cd. It can enter the environment (air, water, soil and Human activities).

2.3. Lead (pb)

Lead has been considered the third risky mushroom trace element after cadmium and mercury.

lead is toxic and non-essential metals as they are toxic even in traces (Unak et al. 2007). García, (2009) reported that some factors could affect lead concentrations of the edible mushrooms: species, ecology, morphological part and soil characters, such as metal levels, pH and organic matter. The preceding table shows the minimum and maximum levels of Pb were measured as 0.9 mg/kg and 9.2 mg/kg dry matter in *Morchella esculenta* (Osmaniye regine) and *Lactarius deliciosus*(Kastamonu regine), respectively. Most of results less than 4.5 mg/kg except *Morchella esculenta* (9.0), *Melanoleuca stridula* (9.04) and *Boletus badius* (8.9). Levels in raw plant materials for lead which amount to 10.0 mg/kg (WHO, 1998).The lead results of all mushroom species were in agreement with WHO and literature.

Lead concentrations of mushroom samples in the literature have been reported to be in the ranges*:* 0.67 to 12.9 mg/kg (Zhu, 2011), 0.75– 7.77 mg/kg (Tüzen et al. 1998), 0.40–2.80 mg/kg (Svoboda et al. 2000), 1.43–4.17 mg/kg (Tüzen 2003), 0.800–2.700 mg/kg (Türkekul et al. 2004), 0.82–1.99 mg/kg (Soylak et al. 2005), and 0.9– 2.6 mg/kg (Sesli et al. 2008), respectively.

2.4.Zinc (Zn)

Zinc is very important mineral needed by our body systems. It is also very important in protein, nucleic acid, and energy metabolism. It supports a healthy immune system. Zinc is also used in medicines that treat rashes, acne, dandruff and athlete’s foot (Okwulehie and Ogoke 2013).

In addition it is very important in protein, nucleic acid, and energy metabolism. A review results show that the zinc content of the mushrooms studied was found to vary from 9.74 mg/kg in *Craterellus cornucopioides* to 354.0 mg/kg in *Helvella leucopus* (Table). More than two-thirds of the samples were under the permissible limit of 60 mg/kg recommended values in foods (WHO 1982).

Zinc concentrations of edible mushroom samples in the literature have been reported to be: 30.0 – 150.0 mg/kg (Kalac and Svaboda, 2000), 29.0 – 146.0 mg/kg (Sarikurkcu et al. 2011), 29.3 – 158.0 mg/kg (Isiloglu et al., 2001), 26.7 – 186.0 mg/kg (Genccelep et al. 2009) and 21.0 – 100.0 mg/kg (Cayir et al., 2010). The Zn results of most mushroom species were in agreement with those found in the literature.

2.5 Manganese(Mn)

Manganese, one of the least toxic metals. Mn is essential in normal reproductive functions and normal functioning of the central nervous system. Its deficiency causes myocardial infection and other cardiovascular diseases and also disorder of bony cartilaginous growth in children and rheumatic arthritis in adults (Khan et al., 2008). It plays a vital role in the activation of a large number of enzymes including in the tricarboxylic acid cycle (Chandra, 1990). The (FAO/WHO., 1984) limit for medicinal plants has not yet been established for Mn. The range of Mn concentration in selective medicinal plants of Egypt was between 44.6 ppm to 339 ppm Sheded et al. (2006). Toxicity limits of manganese for plants are high (400–1,000 mg/kg) (Zhu, 2011). In the present work, the highest concentration of Mn in the mushrooms studied was found in 197 mg/kg *Melanoleuca stridula* (Anatolia region), whereas the lowest manganese content was 0.83 µg/g *in Morchella costata* (Denizli region). The reported manganese concentrations in previous studies for wild-growing mushrooms were : 7.6–56.2 µg g-1 (Demirbas 2001b), 14.5–63.6 µg g-1 (Isıloglu et al., 2001), 5.0–60.0 µg g-1 (Kalaˇc and Svoboda 2001), 21.7–74.3 µg g-1 (Mendil et al., 2004), 18.1–103 µg g-1 (Mendil et al., 2005), 14.2–69.7 µg g-1 (Soylak et al., 2005), 13.5–113 µg g-1 (Zhu et al., 2011) respectively. Most of The manganese values in this study are in agreement with results in the literature.

2.6. Iron(Fe)

Iron is highly required physiologically formation and to enhance oxygen carrying capacity of red blood cells. Fe is necessary for the formation of haemoglobin and also plays an important role in oxygen and electron transfer in human body. Its deficiency causes gastrointestinal infection, anaemia, nose bleeding and myocardial infection (Ullah et al., 2012).

The results show that, all species of mushrooms except one species, The iron concentrations ranged in Rhizopogon roseolus were 39.97 µg/g) Denizli region (and 824 mg/kg (Anatolia region), While Cantharellus cibarius) Black sea region (recorded that the highest level 1750mg/kg. The iron concentrations in selective medicinal plants the WHO (FAO/WHO., 1984) limit has not yet been established for iron. Kalac and Svoboda (2000) reported iron content was found to vary between 30.0 and 150.0 mg/kg.

The range of iron in selective medicinal herbs of Egypt in the study carried out was between 261 ppm to 1239 ppm (Jabeen et al., 2010).

Previous studies indicate that iron concentrations was as follows : 31.3–1190 mg/kg (Sesli, 1999), 30–150 mg/kg (Kalač, 2000), 56.1–7162 mg/kg (Mendil, 20040. The results thus obtained are compatible with reported value in the literature.

2.7. Chromium

Chromium can be considered even a trace element, but in excessive dose is a toxic for health. Chromium (VI) compounds are toxins and known human carcinogens, whereas Chromium (III) is an essential nutrient.

But the chromium contents were higher than those reported earlier and the copper levels were lower than literature values. The trace metal contents in the mushrooms are mainly affected by acidic and organic matter content of their ecosystem and soil (Gast et al. 1988). Mushrooms have significantly higher chromium content than other food (Barancsi, 2002).

To illustrate the results,The highest chromium content (22.7 µg/g d.w.) was found in *Armillaria mellea* (middle black sea region), whereas the lowest chromium content (.0.074 µg/g d.w.) was found in *Rhizopogon roseolus*(Denizli region). The Cr contents of mushrooms seem to differ with respect to sampling areas.

These values were well below the FDA recommended daily intake of chromium for foods and feeds, which is 120 mg/kg (Haider et al. 2004).

Chromium values in mushroom samples have been reported to be in the ranges: 7.0–11.0 mg/kg (Sivrikaya et al. 2002) and 1.95–73.8 mg/kg (Yamaç et al. 2007). The Chromium values in the present study are in good agreement with the reported values in the literature.

2.8. Nickel (Ni)

Nickel is useful as an activator of some enzyme systems (Zhu, 2011), but harmful if its found at high levels. There is evidence that nickel helps with disease tolerance in plants, although it is still unclear how this happens. Nickel (Ni) plays important roles in the biology of microorganisms and plants (Sigel et al. 2008).

Nickel has various biological functions in the body. It plays important roles as a catalytic centre in redox and non-redox enzymes, where it has important ramifications in terms of human health (e.g. urease), energy science (e.g. hydrogenase) and the environment (e.g. carbon monoxide dehydrogenases) (Martin el, 2013). According to the results in this study, maximum nickel level was 0.04 µg/g in *Morchella vulgaris* (WESTERN BLACK SEA REGION) and 17.44 mg/kg in *Rhizopogon roseolus* (Anatolia). The WHO recommended daily intake of nickel was between 100 and 300 mg/kg WHO.(1994). Nickel values have been reported in the ranges 8.2 – 21.6 mg/kg (D.Mendil, 2004) and 1.22 – 58.60 mg / Kg (Yamac, 2007), respectively. The results obtained, in the current study, indicated that nickel content of the investigated mushroom samples were found to be comparable with those reported in the literature.

CONCLUSION

According to the results in this study that microelements or trace elements generally are essential for humans. That is include iron, zinc, copper, manganese, nickel and chromium, Other trace metals like, lead and cadmium are toxic to humans.

The levels of metal concentrations in the samples were also compared with those reported in the literature. The results of this review are generally in agreement with the reported results.

It should also be noted that some variance is possible due to the different analytical techniques used.

In addition metal concentrations vary over a wide range within the mushrooms species, by cause of the accumulation rate.

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