sciendo

DOI: 10.2478/fv-2019-0019

FOLIA VETERINARIA, 63, 2: 55—59, 2019

EDIBLE SPRUCE (*MORCHELLA ESCULENTA*), ACCUMULATOR OF TOXIC ELEMENTS IN THE ENVIRONMENT

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ABSTRACT

In this study we examined the dried fruiting bodies of *Morchella esculenta*, collected in the area of the coal and biomass based thermal power plant in Vojany from the nearby Bahoň marsh, in the Slovak Republic. The area is characterized by a high environmental burden, especially because of air pollutant emissions from the power plant operation. Twenty-three (23) chemical elements were found in the dried fruiting bodies after microwave-assisted sample preparation using an Inductively Coupled Plasma Mass Spectrophotometer ICP-MS AGILENT 7500c system. The mercury content was determined employing a special AMA 254 apparatus intended for the determination of Hg directly in dry powdered fruiting bodies without microwave digestion. The content of toxic elements expressed in mg.kg^{-1} DW (dry weight) were as follows: Hg 0.048—0.052 (RSD—Relative Standard Deviation = 4.80 %); Cd 4.543—6.169 (RSD = 3.35 %); Pb 0.261—0.291 (RSD = 2.67 %); As 0.455—0.469 (RSD = 5.79 %); Cr 1.585—1.616 (RSD = 2.33 %); and Ni 8.166—9.276 (RSD = 3.03 %). The contents of cadmium, nickel and mercury exceeded the hygiene limits, while the contents of arsenic and lead approached the hygiene limits. Due to the high levels of toxic elements, the fruiting bodies collected in the location are not suitable for culinary purposes. The mushroom *Morchella esculenta* acts as an accumulator of toxic elements from the environment in which it grows and can be considered as an indicator of environmental pollution.

Key words: AMA 254; chemical elements; edible spruce; ICP-MS; *Morchella esculenta*

INTRODUCTION

Spruce fungi are important and valuable wild growing edible mushrooms. Spruce mushrooms are available freshly harvested, dried or otherwise prepared. Their biggest exporters include Pakistan [15] and Turkey [3]. In India they are used by the pharmaceutical industry [13] and find also extensive application as a delicacy in food preparation. The edible spruce (*Morchella esculenta*) grows on all continents.

This fungi is considered gold, growing in mountainous regions from March to June, under the trees and shrubs, up to 2500—3500 m above sea level [1]. Spruce mushrooms contain a number of biologically active compounds beneficial to human health, such as polysaccharides, β-glucans, with immunomodulatory and anticancer properties [20, 21]. They have high nutritional value, rich and unique scent due to the presence: of alcohols, such as oct-1-ene-3-ol, octadecan-1-ol, cyclooctyldecanol, 2-metylaminoethanol, ethanol, trans-undec-2-en-1-ol [18], phenolics, esters, ketones or organic acids, delicious taste and meaty texture. Some extracts from mushrooms appear to have a positive effect in cancer therapy, cardiovascular diseases or diabetes mellitus therapy [9]. The fungi also contain: β-carotenes, lycopene, tocopherols, ascorbic acid [19], phenolic compounds and flavonoids, which possess antioxidant properties [6]. Spruce mushrooms are also valued for their content of biologically active substances with the properties of enzymes, inhibitors of proteases and lectins [20]. Spruce mushrooms are a rich source of essential elements but, on the other hand, may also contain some toxic chemical elements [4, 5, 10, 11, 12].

Coal-fired power plant has been considered as a very important source of regional air pollution and ecosystem acidification due to its huge emissions of acidic pollutants. The major air pollutants released by coal based power plants include SO_2, NO_x particulate matter (PM) and heavy metals [14]. There are different types of particulate matter, depending on the chemical composition and size. The dominant form of particulate matter from coal-fired plants is coal fly ash. The minor constituents of fly ash depend upon the specific coal bed composition but all of the heavy metals (Ni, Cd, Sb, As, Cr., Pb, etc.) generally found in fly ash are toxic in nature. In the past, fly ash was generally released into the atmosphere, but air pollution control standards now require that it be captured prior to release by fitting pollution control equipment. In developed countries like Germany, 80 % of the fly ash generated is being utilized, whereas in India only 3 % is used [17]. The outlet PM concentrations vary according to the ash content of the coal, type and the removal efficiency of the dust collectors. Unfortunately, there are different standards specified for power plants built in different periods [14].

One should also consider that the coal-fired power plants are huge sources of emissions of acidic pollutants. The soil pH is an important parameter determining the mobility and plant availability of most nutrients. Some heavy metals (Cd, Zn, Pb, Cu) are mobile pollutants and may be easily leached from acidified soil and potentially reach the ground water [7].

The aim of this study was to examine the fruiting bodies of edible spruce collected in environmentally polluted area for their contents of essential and toxic chemical elements and thus their ability to act as an indicator of environmental pol̓lution.

MATERIALS AND METHODS

As the experimental material we used the homogenous powder from dried spruce fungi (*Morchella esculenta*). Spruce mushrooms (3 kg fresh matter) were collected in mid-April, 2018, at the Bahoň marsh in the village of Beša, near the thermal power plant in Vojany in the Slovak Republic. After drying in a hot air dryer (BINDER, Germany) at 60 °C to a constant weight and milling to a fine powder (mixer STRAUME, Ukraine), the fungal material was used for analysis.

The content of 23 chemical elements was determined in triplicate after microwave-assisted sample preparation (speedwave, Berghof Products Instruments GmbH, Germany) using an Inductively Coupled Plasma Mass Spectrophotometer ICP-MS AGILENT 7500c system (Agilent, USA). The analyses were carried out at the State Veterinary and Food Institute in Košice, using accredited methods.

Mercury was determined directly in the dried powdered material without microwave digestion using a mercury analyser AMA 254 (ALTEC s. r. o., Czech Republic) according to the manufacturer's instructions.

All chemicals used for analyses were super-pure and of analysis (p.a.) quality.

RESULTS AND DISCUSSION

The spruce (*Morchella esculenta*) grows from March to June in various places, mainly under the bushes of sloe or juniper, under pine trees, cedars and other woody plants in abundance. It grows on all continents. Spruce (*Morchella esculenta*) is an economically important mushroom [3]. It has found practical application as a culinary delicacy as well as medicinal fungus due to its content of

Table 1. The content of toxic elements in dried fruiting bodies of edible spruce (*Morchella esculenta*)

Chemical element	$X^{at.\ num.}$	Content of element mg.kg^{-1} DW	RSD [%]	Hygiene limit mg.kg^{-1} DW
Mercury	Hg^{80}	0.048—0.052	4.8	0.05
Cadmium	Cd^{48}	4.573—6.169	3.35	0.2
Lead	Pb^{82}	0.261—0.291	2.67	0.3
Arsenic	As^{33}	0.455—0.469	5.79	0.5
Chromium	Cr^{24}	1.585—1.616	2.33	4
Nickel	Ni^{28}	8.166—9.276	3.03	2

DW—dry weight; RSD—relative standard deviation; $X^{at.\ num.}$—element symbol and atomic number

Table 2. The content of essential elements in dried fruiting bodies of edible spruce (Morchella esculenta)

Chemical element	$X^{at.\ num.}$	Content of element mg.kg^{-1} DW	RSD [%]
Boron	B^{5}	1.548	1.90
Sodium	Na^{11}	1.267	4.17
Magnesium	Mg^{12}	178.7	3.76
Aluminium	Al^{13}	174.3	2.28
Potassium	K^{19}	658.8	1.59
Calcium	Ca^{20}	49.18	1.06
Scandium	Sc^{21}	159.8	nd
Manganese	Mn^{25}	47.69	2.04
Iron	Fe^{26}	156.7	2.56
Cobalt	Co^{27}	0.158	3.75
Copper	Cu^{29}	39.71	3.52
Zinc	Zn^{30}	176.7	10.44
Selenium	Se^{34}	0.179	33.21
Silver	Ag^{47}	0.059	4.81
Indium	In^{49}	8.166	nd
Antimony	Sb^{51}	8.029	8.01
Bismuth	Bi^{83}	159.8	nd
Uranium	U^{92}	0.052	4.5

DW—dry weight; RSD—relative standard deviation; nd—not detected
$X^{at.\ num.}$—element symbol and atomic number

biologically active substances, such as polysaccharides, which are supposed to have an immunostimulatory effect; also phenolic compounds that contribute to antibacterial, antimicrobial and antitumour activities [2, 8]. Fungi are able to accumulate important chemical elements, e. g. potassium, phosphorus, selenium, iron, zinc, manganese or copper [4], but on the other hand, they also absorb toxic elements, such as mercury, cadmium, lead, arsenic, chromium and nickel from the soil on which they grow. These toxic elements pose a danger to human health [5, 10, 11, 12].

Table 1 shows the content of toxic elements determined in our study in the samples of fruiting bodies of edible spruce mushrooms collected in the location suspected of environmental pollution. The content of chemical elements fluctuated in some range. The hygiene limit was exceeded for the content of cadmium, nickel and mercury [16]. The levels of arsenic and lead approached the limits.

Mohammad et al. [15] determined lower toxic elements in *Morchella esculenta* fruiting bodies in Pakistan and they also compared the content of the elements with levels found in France, where lead reached the concentration of 44.2 mg.kg^{-1}, cadmium 3.6 mg.kg^{-1}, chromium 5.98 mg.kg^{-1}, copper 46.4 mg.kg^{-1}, and nickel 15.4 mg.kg^{-1}. These concentrations are high and refer to the environmental burden in the region where *Morchella esculenta* was collected.

In our study, the hygiene limits were exceeded the most for nickel and cadmium. Senapati [17] presented information about diseases due to the presence of heavy metals in fly ash, such as lung cancer (nickel), anaemia, hepatic disorders (cadmium, cancer (chromium), and anaemia (lead). However, the information of greatest concern is the fly ash that reaches the pulmonary region of the lungs and remains there for long periods of time or the submicron particles deposited on the alveolar walls where the metals could be transferred into the blood plasma across the cell membrane.

Table 2 shows the content of essential and other chemical elements that reflect the content of pollutants which passed to the soil from power plant emissions and waste water. The content of the chemical elements are evidently related to the chemical composition of the substrate on which the fungi are grown.

The knowledge about low concentration of sodium (1.26 mg.kg^{-1}) and higher concentration of potassium (658.8 mg.kg^{-1}) in spruce fruiting bodies appears useful when formulating low-salt diets for some patients, however we refer only to those that grew on unpolluted soil.

CONCLUSIONS

The fruiting bodies of spruce (*Morchella esculenta*) have excellent organoleptic properties. Spruce fungi has acquired an application in the preparation of culinary delicacies. They have been used in natural medicine since ancient times. The immunostimulatory properties of edible spruce are mainly due to the presence of polysaccharides and various phytochemicals, such as phenolic compounds, flavonoids, tocopherols, ascorbic acid or vitamin D. These compounds are responsible for antioxidant, anti-inflammatory, anticancer, antiallergic, antimicrobial and immunostimulatory effects. However, spruce grown on polluted soil can contain also relatively high levels of heavy metals. Their ability to accumulate chemical elements from the environment allows the spruce (*Morchella esculenta*) to act as an indicator of environmental pollution.

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Received March 8, 2019
Accepted June 14, 2019