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Pattern and concentrations of trace metals in mushrooms harvested from trace metal-polluted soils in Pretoria, South Africa

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ABSTRACT

Consumption of mushrooms is believed to assist in supplying basic nutrients that are required for human growth and well-being maintenance. It has been noted that vegetables and other agricultural crops may uptake trace metals from polluted soils. The present study investigated the pattern and concentrations of trace metals in mushrooms cultivated on polluted soils collected around three mining areas in Brits, South Africa. Spawns of mushroom *Agaricus bisporus* (white button and crimini varieties) mixed with chicken composted manures sponsored by a certified supplier in Pretoria were spread on polluted soil and allowed to grow to maturity under a controlled environment for mushrooms before harvesting. Harvested mushrooms were separated into caps and stalks and analysed for trace metal contents using inductively coupled plasma mass spectrometry (ICP–MS). The results showed that the concentrations obtained for trace metals in the stalks were more than those recorded for caps, with the exception of copper and zinc. The concentrations of trace metals in the mushrooms were in the ranges of 0.63 ± 0.07 μg/g–370.4 ± 4.71 μg/g Cr, 6.84 ± 0.32 μg/g–492 ± 1.79 μg/g Mn, 0.08 ± 0.03 μg/g–16.37 ± 6.43 μg/g Co, 1.19 ± 0.17 μg/g–54.12 ± 2.70 μg/g Ni, 16.75 ± 0.34 μg/g–51.30 ± 2.91 μg/g Cu, 39.71 ± 0.41 μg/g–257.95 ± 2.38 μg/g Zn and 0.24 ± 0.02 μg/g–4.26 ± 0.09 μg/g Pb. The transfer factor (TF) showed that Cr, Mn, Co and Zn were bio-accumulated from the soil by the mushrooms. Generally, the values obtained for Cr, Zn and Co exceeded the recommended limit for human consumptions. The results proved that mushrooms can bio-accumulate trace metals from the soil hence care should be taken not to cultivate them on polluted soils.

1. Introduction

The consumptions of edible mushrooms as a component of healthy human diet are increasing worldwide. Edible mushrooms contain basic nutrients, high proteins, vitamins as well as minerals required for human growth and development (Agrahar-Muruggkar and Subbulakshmi, 2005). Edible mushrooms have also been reported to have medicinal properties. *Agaricus blazei* Murill, for example, has immunomodulatory, anti-carcinogenic and anti-mutagenic properties and is still in use as a healthy food for the prevention of cancer (Delmanto et al., 2001). *Trametes versicolor* and *Coriolus versicolor* were reported to have anti-tumour property against different types of cancers (Hsieh and Wu, 2001). Despite their potential ability to prevent cancer other studies have indicated the ability of mushrooms to accumulate trace metals in their tissues (Demirbas, 2001) and as such may pose serious health risk to humans (Ghast et al., 1988). Trace metals are often non-biodegradable and the increase in various developmental projects especially within the urban city centres may increase the level of trace metals in the soil (Olowoyo and Lion, 2013).

Soils become contaminated by the accumulation of trace metals through emissions from the rapidly expanding industrial areas, mine tailings, leaded gasoline, wastewater irrigation, and atmospheric deposition especially in the urban areas (Khan et al., 2008). Mushrooms could be cultivated in a controlled environment and could be harvested directly from the field. Agrahar-Muruggkar and Subbulakshmi (2005) observed that in Europe, the consumption of wild growing mushrooms is gaining preference over those cultivated indoor or in the greenhouse. In Africa, it is a common practice to see individuals visiting the veld in order to harvest mushrooms directly from the field. Gadd (2007) indicated that mushrooms play a key role in element recycling in the biogeochemical processes of soil, rock and mineral surfaces, and the plant root–soil interface.

Fulfilling this role may involve the mobility or accumulation of trace metals in mushroom tissues. *Agaricus macrosporus*, for example, was reported to have a high affinity for Cadmium (Cd), while *Coprinus comatus* had a high bio-accumulative potential for lead (Pb) (Garcia et al., 1998; Melgar et al., 1998). Many fungi including mushrooms have developed a variety of mechanisms which allows them to survive, grow and flourish on substrates with high metal levels (Branco, 2010). As stated by

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Lepsova and Mejstrik (1998) trace metal concentration in mushrooms is often higher than those in other agricultural crop plants such as vegetables and fruits because of a very effective mechanism that enables them to take up some trace elements from their substrate. The accumulations of trace metals in fungi can be variable depending on the mushroom species, the part involved, the stage at harvest, the fruiting body and environmental factors such as soil organic matter, soil pH, and the concentration of trace metals in the soil (Garcia et al., 1998; Demirbas, 2001; Tuzen, 2003).

In South Africa, mushrooms are regarded as healthy foods and used as vegetables for soups. Mushrooms are also used for medicinal purposes due to their chemical composition, and have been used in preventing life threatening diseases such as hypertension and cancer (Manzi et al., 2001). Mushrooms, unlike plants can accumulate large concentrations of trace metals such as lead, cadmium, iron, copper, manganese, zinc, chromium, nickel, aluminium, and mercury in their fruiting bodies (Kalac et al., 2004).

The present study reported on the pattern and concentration of trace metals in mushroom *Agaricus bisporus* (white button and crimini varieties) harvested from a trace metal polluted soil with a view to determining the possible health risk that may be associated with its consumption when harvested from mining-contaminated soil.

2. Methodology

2.1. Sample collection and analysis

Soil samples from three different mining areas producing platinum (site A), chromium (site B) and iron and chromium (site C) were collected into 45 pots of 22 cm diameter. The pot plants were organised into two groups based on the two different varieties of mushroom spawns *A. bisporus* (white button and crimini varieties) obtained from a certified supplier with each group having three replicates. The soil from Sefako Makgatho Health Science University different from the polluted soils from the mining areas was used as control soil (site D) with three replicates as well. Mushroom spawns and chicken composted manure substrates were obtained from a local supplier around, Pretoria, South Africa.

2.2. Mushroom growth

The mushrooms were grown under a controlled environment described for the growth of mushrooms (Chang et al., 2004). Mushroom spawn of *A. bisporus* (white button and crimini varieties) mixed with chicken composted manures was spread on contaminated soils as casing layer. The room temperature and the temperature of the compost were regulated during the experiments which were the vegetative and the reproductive phases until the first break when the mushrooms started to appear using a heater and thermometer to check the compost temperature. The heater was switched on to increase the room temperature and as the room temperature was increased the compost temperature was also increased in the pot plants and when the compost temperature reached its required peak, the heater was switched off so that the room temperature could drop to its required peak. The room temperature was kept at 22.5 ± 0.5 °C and the compost temperature was kept in the range of 24 °C–27 °C.

The room was kept humid by sprinkling water inside it twice every day until the reproductive phase. When the mycelia started to appear the watering of the pots was discontinued but the floor where the pots were placed continued to be splashed twice a day every day (early in the morning and in the evening) with a watering container until harvest. At maturity after four weeks for white button and five weeks for crimini mushrooms, they were harvested and separated into caps and stalks and were oven-dried at 60 °C for 48 h. The dried samples were then ground and sieved through a 2.0 mm diameter sieve. The pulverized mushroom samples were then analysed for trace metal content.

2.3. Trace metal determination

Mushrooms and soil samples for trace metal determination were wet digested using the microwave digestion system as described by Mustafa et al. (2005). Five grammes (5 g) of each sample were digested with 6 ml of nitric acid, HNO_3 (Suprapure, Merck), 2 ml of perchloric acid $HClO_4$ (Suprapure, Merck), 3 ml of hydrochloric acid (HCl Merck) and 2 ml of hydrofluoric acid (HF Merck) in a microwave digestion system. The resulting solution was then made up to volume by adding deionized water to the digested sample and

Table 1
Mean dry weight trace metal concentrations in the caps and stalks of mushroom *Agaricus bisporus* (white button) grown on mine soils.

			Trace metals (μg/g)						
Sites	Pot	Mushroom parts	Cr	Mn	Co	Ni	Cu	Zn	Pb
A	a	Caps	0.89 ± 0.19	6.84 ± 0.32	0.10 ± 0.01	3.47 ± 0.19	23.59 ± 0.19	48.39 ± 0.53	ND
		Stalks	13.76 ± 1.20	173.65 ± 15.6	3.77 ± 2.49	12.79 ± 4.46	18.15 ± 0.24	39.71 ± 0.41	0.44 ± 0.02
	b	Caps	1.01 ± 0.11	8.79 ± 0.11	0.23 ± 0.40	1.19 ± 0.17	29.91 ± 0.46	74.88 ± 0.79	ND
		Stalks	51.88 ± 3.49	424 ± 1.49	10.08 ± 2.30	36.16 ± 6.34	22.53 ± 1.39	52.73 ± 3.80	1.58 ± 0.19
	c	Caps	2.16 ± 0.13	12.33 ± 0.32	0.31 ± 0.00	5.79 ± 5.49	30.15 ± 2.59	67.55 ± 6.59	ND
		Stalks	69.38 ± 7.23	459.2 ± 135.76	12.33 ± 1.51	44.61 ± 1.29	22.69 ± 1.97	78.06 ± 4.78	2.08 ± 0.16
B	d	Caps	2.53 ± 0.84	8.18 ± 0.04	0.13 ± 0.03	7.2 ± 0.51	39.6 ± 0.09	62.14 ± 0.56	ND
		Stalks	13.54 ± 0.22	19.91 ± 2.58	0.66 ± 0.00	4.68 ± 0.14	28.3 ± 1.02	60.44 ± 2.98	ND
	e	Caps	2.27 ± 0.20	8.35 ± 0.94	0.16 ± 0.06	2.79 ± 0.63	30.19 ± 1.24	79.67 ± 3.56	ND
		Stalks	68.65 ± 8.89	57.7 ± 8.20	2.61 ± 0.26	23.62 ± 3.18	20.19 ± 0.39	63.43 ± 0.02	0.31 ± 0.01
	f	Caps	3.19 ± 0.06	9.37 ± 0.25	0.16 ± 0.00	2.59 ± 1.28	26.43 ± 0.18	68.18 ± 2.16	ND
		Stalks	49.14 ± 0.08	50.99 ± 2.51	2.07 ± 0.01	15.51 ± 0.60	18.96 ± 0.06	61.75 ± 1.80	0.36 ± 0.00
C	g	Caps	4.51 ± 0.35	9.34 ± 0.26	0.08 ± 0.03	6.69 ± 4.55	43.67 ± 0.44	65.69 ± 1.11	ND
		Stalks	38.08 ± 5.62	37.89 ± 9.51	0.64 ± 0.05	11.69 ± 1.28	51.30 ± 2.91	134.4 ± 7.35	0.79 ± 0.05
	h	Caps	9.24 ± 1.76	19.17 ± 0.91	0.22 ± 0.04	3.71 ± 2.26	38.12 ± 0.99	72.8 ± 1.82	0.24 ± 0.02
		Stalks	129.6 ± 10.18	130.3 ± 1.27	1.53 ± 0.03	11.47 ± 2.89	33.03 ± 5.35	86.77 ± 1.85	1.48 ± 0.09
	i	Caps	28.34 ± 13.56	21.49 ± 6.92	0.28 ± 0.03	6.67 ± 4.26	30.01 ± 1.29	73.37 ± 1.37	0.38 ± 0.07
		Stalks	370.4 ± 4.71	236.4 ± 54.59	3.35 ± 0.48	20.90 ± 6.44	17.45 ± 0.93	84.12 ± 1.39	4.26 ± 0.09
D	j	Caps	1.65 ± 0.20	12.38 ± 0.86	0.37 ± 0.07	6.6 ± 1.09	28.88 ± 0.37	74.74 ± 3.03	ND
		Stalks	5.82 ± 0.04	232.25 ± 9.83	14.41 ± 0.26	28.89 ± 10.89	29.72 ± 2.49	61.81 ± 10.21	2.16 ± 0.64
	k	Caps	0.63 ± 0.07	13.39 ± 0.91	0.13 ± 0.09	3.13 ± 0.73	28.9 ± 0.51	54.86 ± 0.09	0.35 ± 0.07
		Stalks	4.37 ± 0.93	193.5 ± 56.00	10.97 ± 3.29	16.49 ± 2.66	28.47 ± 3.05	80.52 ± 16.60	1.64 ± 0.29
	l	Caps	1.93 ± 0.12	24.32 ± 2.98	1.02 ± 0.32	3.08 ± 0.43	27.96 ± 0.89	51.46 ± 1.86	0.33 ± 0.09
		Stalks	4.71 ± 2.13	329.5 ± 79.05	18.29 ± 3.19	25.24 ± 7.55	29.54 ± 2.38	257.95 ± 2.38	2.99 ± 1.09

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