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Wild growing mushrooms for the Edible City? Cadmium and lead content in edible mushrooms harvested within the urban agglomeration of Berlin, Germany

Martin Thomas Schlecht, Ina Säumel*

Department of Ecology, Technische Universität Berlin, Ernst Reuter Platz 1 (BH 9-1), D-10587 Berlin, Germany

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ABSTRACT

Health effects by consuming urban garden products are discussed controversially due to high urban pollution loads. We sampled wild edible mushrooms of different habitats and commercial mushroom cultivars exposed to high traffic areas within Berlin, Germany. We determined the content of cadmium and lead in the fruiting bodies and analysed how the local setting shaped the concentration patterns. EU standards for cultivated mushrooms were exceeded by 86% of the wild mushroom samples for lead and by 54% for cadmium but not by mushroom cultures. We revealed significant differences in trace metal content depending on species, trophic status, habitat and local traffic burden. Higher overall traffic burden increased trace metal content in the biomass of wild mushrooms, whereas cultivated mushrooms exposed to inner city high traffic areas had significantly lower trace metal contents. Based on these we discuss the consequences for the consumption of mushrooms originating from urban areas.

1. Introduction

Accelerated urbanisation and related environmental degradation reduce arable land availability worldwide, especially nearby cities (Chen, 2007; FAOSTAT, 2014). Fertile soils and regional food production get lost and food miles increase (Satterthwaite et al., 2010). Consequently, future food production as an integrated urban activity is postulated to enhance urban resilience (Barthel and Isendahl, 2013). The vision of the 'Edible City' promises a strategic step towards the development of sustainable and productive urban landscapes that will considerably reduce the ecological footprint of cities (Bohn and Vilijoen, 2011).

Beyond urban agriculture and horticulture, the collection of wild growing edibles can contribute to local food security (e.g. Toledo and Burlingame, 2006; Uprety et al., 2012). Wild edible and medicinal mushrooms have been acknowledged for subsistence uses (Boa, 2004). The consumption of wild edible mushrooms is high, notably in East Asia and Europe (Mleczek et al., 2013). Furthermore, about 35 mushroom species have been cultivated commercially, 10-20 species of those on an industrial scale (Sanchez, 2004; Aida et al., 2009).

In general, mushrooms are seen as healthy food sources being low in calories and with nutritional contents comparable to most legumes and meats (Kalač, 2009). Mushrooms become increasingly attractive as functional foods for nutritional and medicinal effects (Barros et al., 2008; Roupas et al., 2012; Reis et al., 2012; Wang et al., 2014). The food industry is especially interested to develop a new generation of foods based on both cultivated and wild growing edible mushrooms (Barros et al., 2008). The production of mushrooms increased by 90% within the last decade (FAOSTAT, 2014). However, mushrooms are also known to accumulate trace metals (Kalač and Svoboda, 2000; Kalač, 2010; Falandysz and Borovička, 2013). Trace metal concentrations in mushrooms are significantly higher than those in agricultural crop plants, vegetables, fruits or even animal tissue (Mleczek et al., 2013). Especially, cadmium, lead, silver, mercury and arsenic are considered as hazardous metals or metalloids in mushrooms (Falandysz and Borovička, 2013). Various studies from rural sites highlighted negative health effects from the ingestion of mushrooms (e.g. Kalač and Svoboda, 2000; Cocchi et al., 2006; Svoboda et al., 2006; Falandysz and Borovička, 2013).

The health effects from the consumption of food products grown in cities are questioned due to high urban pollution (Alloway, 2004; Hough et al., 2004; Leake et al., 2009) and resulting levels of pollutants in urban vegetables (e.g. Säumel et al., 2012). Similar health risks might be also associated with the consumption

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* Corresponding author.
E-mail address: ina.saeumel@tu-berlin.de (I. Säumel).

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of urban edible mushrooms, but studies from urban areas are scarce compared to studies at rural sites (but see Kuusi et al., 1981; Svoboda and Kalač, 2003; Falandysz and Bielawski, 2007; Ji et al., 2009). Effects of urbanisation on fungal communities are mostly unknown (Newbound et al., 2010).

In this study, we harvested 184 samples of 18 different wild growing edible mushroom species within different urban habitats in Berlin, Germany. Additionally, we exposed commercial mushroom cultures to high traffic areas within the inner city of Berlin. We determined the content of Pb and Cd in fruiting bodies depending on species (i.e. genus, trophic status) and sampling site characteristics (i.e. habitat type, local traffic burden, presence or absence of barriers between sampling site and roads) to assess the health impact for consumers and to discuss consequences for the integration of edible mushrooms into 'Edible City' approaches.

2. Material and methods

We collected in total 518 wild common edible mushrooms in the typical harvest period from May to November 2013 within the city of Berlin, Germany. The sampling sites represented different urban habitats (i.e. cemeteries, parks, gardens, forests or along roads; habitat classification according to Berlin Department for Urban Development, 2009; see Fig. 1) and were characterized by the following parameters: distance to nearest road (d) in meters, traffic burden on the nearest road (tb) according to the number of vehicles per day ($1 \leq 5000$; $2 = 5001–10{,}000$; $3 = 10{,}001–15.000$; $4 = 15{,}001–20000$; $5 = 20{,}001–30000$; $6 = 30{,}001–40000$; $7 \geq 40{,}001$; Berlin Department for Urban Development, 2009), presence or absence of barrier between sampling sites and nearest roads (b). Furthermore, we classified the overall traffic burden (otb) within a radius of 250 m around the planting sites (for details see von Hoffen and Säumel, 2014).

Stratified per habitat type and species we analysed Pb and Cd content in randomly chosen subsamples of the wild edible mushrooms ($n = 184$). The subsample consisted of a total of 18 different species of 11 genera (Table 1). We sampled four species of *Agaricus* (*Agaricus arvensis, Agaricus bitorquis, Agaricus campestris Agaricus suberonatus*), three of *Boletus* (*Boletus luridus, Boletus recticulatus, Boletus badius*), two of *Macrolepiota* (Macroleptiota *mastoidea,* Macroleptiota *procera*), two of *Russula* (*Russula exalbicans, Russula vesca*) and each one species of *Xerocomus* (*Xerocomus chrysenteron*), *Armillaria* (*Armillaria solidipes*), *Coprinus* (*Coprinus comatus*), *Calvatia* (*Calvatia gigantea*), *Leccinum* (*Leccinum scabrum*), *Sparassis* (*Sparassis crispa*) and *Tuber* spp.

In order to explore potential health risks of commercial mushrooms cultivars cultivated in urban areas, we exposed 16 cultivars of *Agaricus bisporus* to high traffic areas within the inner city of Berlin, Germany. *A. bisporus* is the most cultivated mushroom worldwide (Aida et al., 2009) and can be cultivated in a simple and cheap way (Reis et al., 2012). Mature fruiting bodies of *A. bisporus* were harvested after the common growing period of 15 days.

Directly after the harvest, the mushrooms were identified using mushroom guides books (Breitenbach and Kranzlin, 1984, 1986, 1991; Moser, 1983; Pegler, 1990; Winkler, 1996; Gminder, 2008) and when necessary, with additional expertise from the German Mycological Society. The mushrooms were carefully cleaned of all surface contamination by a stainless steel knife as usual for mushrooms prior to prepare dishes and afterwards frozen. The fruiting bodies of the mushrooms were oven dried at a temperature of 65 °C for 72 h in vessels to include most parts of the leaking juice per sample. After drying, the samples were ground (<100 μm) and stored in a desiccator. Contents of Cd and Pb in the samples were analysed after digestion for subsequent determination of aqua regia soluble portion of elements (for details see EN13657:2002) and by inductively coupled plasma mass spectrometry (ICP-MS; for details see ENISO17294–2:2004). Certified reference material (SRM 3128 (Pb) and SRM 3108 (Cd); ICP Multielement Standard VIII, Merck KGaA, Germany) was used to assess quality of the measurements (see UBA, 2011). The recovery rate ranged from 95 to 100% for both elements. The applied methods have been previously used in determination of metals in mushroom (e.g. Yin et al., 2012).

We used analysis of variance (ANOVA) for data analysis. Cd or Pb content in the dried biomass were the response variables and species, genera, trophic status, and the parameters characterising local settings at sampling site (urban habitat type, overall traffic burden, distance to the nearest road and number of vehicles of the nearest road, presence and absence of a barrier) were taken as explanatory variables. Homogeneity of data (Brown–Forsythe's test) and normal distribution of data (Shapiro–Wilk test) were tested before applying the ANOVA. Log transformations were applied to comply with the assumptions of the residual normality and variance homogeneity needed for the analysis. We used the Bonferoni test for the comparison of means. Effects were considered significant at $p < 0.05$ level. The statistical analysis was done by using R version 2.15.2 (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

Pb and Cd content in the wild edible mushrooms differed significantly among species and genera. Few samples had concentrations below the detection limit (see Table 2). Comparing the trace metal content within a genus, high differences were detected for *Boletus* and *Macrolepiota* species (i.e. *B. luridus* and *B. reticulatus* differed on average Cd content but not on Pd content, *B. boletus* had low Pb and Cd contents and *M. mastoidea* had significantly lower Pb contents than *M. procera*, while Cd contents were similar; Fig. 2). In contrast, no differences were detected for *Russula* and *Agaricus ssp.* (Fig. 2). Certain species tended to gather less Pb, but accumulated high amounts of Cd (*X. chyrsenteron*), and others showed relatively low levels of both the tested elements (i.e. *S. crispa, B. luridus,* Table 2).

Eighty two percent of all wild mushroom samples exceeded EU standard of 0.3 mg/kg wet weight for Pb and two third of our samples exceeded EU standard of 0.2 mg/kg wet weight for Cd for cultivated mushrooms (EC, 2006). A third of all samples exceeded these limits for both elements, only six percent did not exceed the limits for both elements. For eleven out of eighteen species over 90 percent of the samples analysed in this study exceeded the EU standards for Pb in cultivated mushrooms, whereas in all species at least one sample did not exceed the limits for Cd. A third of our samples were characterized by Cd contents higher than the EU limits set for mushroom species other than typically cultivated species such as *Agaricus bisporus*, *Pleurotus ostreatus* and *Lentinus edodes* (EC, 2008). In contrast to wild growing mushrooms, samples from sixteen commercial *A. bisporus* cultures had significantly lower trace metal content in the fruiting bodies ($F_{Cd} = 4.8$, $p_{Cd}<0.001$; $F_{Pb} = 20.5$, $p_{Pb}<0.001$); no sample exceeded the EU standard for Pb and Cd (EC, 2006, Table 2).

Pb content of wild growing urban mushrooms was in average seven times higher than the respective EU standard (Table 2). *A. bitorquis, A. subperonatus*, *A. campestris, A. arvensis*, *M. procera*, *R. exalbicans*, *Russula versca,* and *C. gigantea* all accumulated higher amounts of Pb, compared to the other species; in average ten times higher than EU standard for Pb. Low average Pb contents were detected in *B. badius*, *A. solidipes*, *S. crispa,* and *L. scabrum*. Only few samples of these species exceeded EU standard for Pb.

Pb content of wild growing mushrooms depended on trophic