Arsenic in Edible and Medicinal Mushrooms from Southwest China

Ji Zhang,[a] Hong-Gao Liu,[b] Shi-Jun Li,[b] Jie-Qing Li,[b] Yuan-Zhong Wang,[a,*] & Tao Li[c,*]

[a]Institute of Medicinal Plants, Yunnan Academy of Agricultural Sciences, 650200 Kunming, China; [b]College of Food Science and Technology, Yunnan Agricultural University, 650201 Kunming, China; [c]College of Resources and Environment, Yuxi Normal University, 653100 Yuxi, China

*Address all correspondence to: Yuan-Zhong Wang, Institute of Medicinal Plants, Yunnan Academy of Agricultural Sciences, 650200 Kunming, China; Tel.: +86 0871-65222338; boletus@126.com, ltyx_1976@126.com

ABSTRACT: Many species of wild-grown mushrooms are appreciated as food and also found use in traditional medicine. As arsenic is one of the most hazardous elements due to the carcinogenic risk, the contents of total arsenic in 48 species of wild-grown edible and medicinal mushrooms in China were determined by atomic fluorescence spectrometry. The results showed that the highest content was found in *Scleroderma citrinum* (1.70 mg kg^{-1} dry weight, dw), whereas the lowest content was found in *Termitomyces eurrhius* (0.17 mg kg^{-1} dw).

KEY WORDS: edible and medicinal mushrooms, heavy metal, total arsenic

ABBREVIATION: dw: dry weight

I. INTRODUCTION

Many species of edible wild-grown mushrooms are appreciated as food and also find use in traditional medicine.[1] They are important functional food with medicinal values, including antitumor, immunomodulating, antioxidant, antiviral, detoxification, hepatoprotective, antidiabetic, and other effects.[2–6]

Arsenic is one of the most hazardous elements due to the carcinogenic risk.[7] The usual content of arsenic in fruiting bodies of wild-grown mushrooms from unpolluted areas were 0.5–5 mg kg^{-1} dry weight (dw).[8] To our knowledge, the extreme arsenic content of 2115 mg kg^{-1} dw was found in *Sarcosphaera coronaria*.[9] High accumulation of arsenic with mean contents of about 100 mg kg^{-1} dw was reported in genus *Laccaria*,[10] and in *L. amethystea* collected from a heavily polluted site in Denmark its amount was even 1420 mg kg^{-1} dw.[11]

In China, few data on arsenic contents of edible and medicinal mushrooms are available. High values of arsenic in wild-grown mushrooms were found in *Thelephora vialis* (44 mg kg^{-1} dw) and *Tricholoma matsutake* (22 mg kg^{-1} dw);[12] however, very low content of arsenic (0.72 mg kg^{-1} dw) was found in *Laccaria amethystea* from Southwest China.[13] The aim of this study was to investigate the contents of total arsenic in 48 species of wild-grown mushrooms from Southwest China.

II. MATERIALS AND METHODS

A. Mushroom Material

Matured specimens of 48 species of edible and medicinal mushrooms were collected during summer and autumn in 2011 and 2012 from different spatially distant sites of Yunnan and Sichuan Provinces of China. The study areas are distant from industrial pollution. Each mushroom was carefully washed with deionized water in the lab and dried at 40°C until a constant mass was achieved. Identification of the specimens was performed by the taxonomic keys of Mao,[14] Dai et al.,[15–17] and Index Fungorum (www.indexfungorum.org). For each species, one pooled sample was analyzed.

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B. Methods

The contents of total arsenic were determined on an atomic fluorescence spectrometer (AFS-3100, Beijing Kechuanghaiguang Inc., China) after dry digestion. The methods for sample digestion and total arsenic detection were performed according to the Chinese standard GB/T5009.11-2003.[18] The content of total arsenic in the certified reference materials GBW10016 (tea) declared by the producer is 0.09 ± 0.01 mg kg^{-1}, while our measurements showed 0.088 ± 0.006 mg kg^{-1} (n =3). In addition, with every set of 10 samples examined, one blank sample was included.

III. RESULTS AND DISCUSSION

The contents of total arsenic of the samples are presented in Table 1. The result showed that the arsenic contents in all samples were not exceeding 1.70 mg kg^{-1} dw. The highest content of arsenic was 1.70 mg kg^{-1} dw in *Scleroderma citrinum*, followed by 1.69 mg kg^{-1} dw in *Russula violacea*, 1.60 mg kg^{-1} dw in *Termitomyces globulus*, and 1.46 mg kg^{-1} dw in *Tricholoma bakamatsutake*.

In previous literature, as we mentioned above, an extreme arsenic content was found in a species of the genus *Scleroderma*, but the content in *S. cepa* was 0.653 mg kg^{-1} dw.[19] Some studies on species of the genus *Russula* from China showed that the average contents of arsenic were 0.44–1.3 mg kg^{-1} dw.[12,19,20] But low contents of arsenic (≤0.02 mg kg^{-1} dw) in *Russula* species from Turkey and Greece have been reported.[21,22] For *Termitomyces* species, compared to this study, similar content (1.6 mg kg^{-1} dw) in *Termitomyces* species was found in Xichuan Province, China.[19] However, low contents were found in *T. eurrhius* (0.17 mg kg^{-1} dw) and *T. robustus* (0.92 mg kg^{-1} dw) in Nigeria.[23] Arsenic contents of *Tricholoma* species were <0.3 mg kg^{-1} dw in Turkey and <0.05 mg kg^{-1} dw in Hungary.[21,24]

The lowest content of arsenic was 0.019 mg kg^{-1} dw in *Lentinus edodes*, followed by 0.058 mg kg^{-1} dw in *Ganoderma philippii*, 0.071 mg kg^{-1} dw in *Osteina obducta*, and 0.090 mg kg^{-1} dw in *Boletus auripes*.

To our knowledge, no report has been published on arsenic in genera *Lentinus* or *Osteina*. There are few reports on arsenic in genus *Ganoderma*, but lack of information on the sample origin made us doubt whether these samples were wild type. Arsenic contents of genus *Boletus* in the literature were <0.02 mg kg^{-1} dw in Greece,[22] ~0.1 mg kg^{-1} dw in Finland and Italy,[25,26] and <1.0 mg kg^{-1} dw in China.[12,19,27] But a higher content was found in Turkey (3.72 mg kg^{-1} dw).[28] In our study, most *Boletus* species contained low contents of arsenic (<0.80 mg kg^{-1} dw), except *B. impolitus*, in which the content was 1.28 mg kg^{-1} dw.

Arsenic occurs in organic and inorganic forms in food. The most toxic inorganic forms are As (III) and As (V), whereas the methylated organic forms are considered nontoxic.[29] Llorente-Mirandes et al.[30] reported that inorganic arsenic was the major arsenic compound in *L. edodes* samples, accounting for 84% of the total arsenic. What is more, mushrooms collected from urban and industrial areas polluted with toxic compounds, such as arsenic, usually show highly elevated content of such constituents.[7,31] In Poland, high levels of As (III) and As (V) (up to 27.1 and 40.5 mg kg^{-1} dw, respectively) were found in *Xerocomus badius* mushrooms collected from areas subjected to high anthropopressure, whereas the contents that were below 0.5 mg kg^{-1} dw for each arsenic form were found for the samples collected from unpolluted areas.[32] Therefore, for further study in China, it needs to be considered about the forms of arsenic in wild-grown mushrooms and the background content of arsenic.

IV. CONCLUSION

The contents of total arsenic in 48 species of wild-grown mushrooms in Southwest China were determined in this study. The results showed that the arsenic contents in all samples were not exceeding 1.70 mg kg^{-1} dw.

TABLE 1: Arsenic Contents of Wild-Grown Mushrooms Collected from Southwest China (mg kg^{-1}, dry weight)

Species	Site	Sample size*	Arsenic content
Albatrellus cristatus (Schaeff.) Kotl. & Pouzar	Yimen, Yunnan	20	0.27
Amanita caesarea (Scop.) Pers.	Shangri-La, Yunnan	2	0.17
Amauroderma guangxiense J.D. Zhao & X.Q. Zhang	Pu'er, Yunnan	2	0.41
Auricularia auricula-judae (Bull.) Quél.	Xichang, Sichuan	98	0.36
Boletus aereus Bull.	Yimen, Yunnan	14	0.34
Boletus auripes Peck	Yimen, Yunnan	112	0.090
Boletus brunneissimus W.F. Chiu	Anning, Yunnan	4	0.58
Boletus edulis Bull.	Anning, Yunnan	49	0.14
Boletus ferrugineus Schaeff.	Yimen, Yunnan	20	0.32
Boletus impolitus Fr.	Yimen, Yunnan	13	1.28
Boletus magnificus W.F. Chiu	Yimen, Yunnan	33	0.23
Boletus pallidus Frost	Anning, Yunnan	31	0.65
Boletus satanas Lenz	Dechang, Sichuan	54	0.20
Boletus speciosus Frost	Dechang, Sichuan	12	0.25
Boletus tomentipes Earle	Eshan, Yunnan	13	0.40
Boletus umbriniporus Hongo	Yimen, Yunnan	2	0.34
Catathelasma ventricosum (Peck) Singer	Yimen, Yunnan	10	0.36
Ganoderma capense (Lloyd) Teng	Pingbian, Yunnan	1	0.34
Ganoderma tsugae Murrill	Lanping, Yunnan	9	0.74
Ganoderma philippii (Bres. & Henn. ex Sacc.) Bres	Pu'er, Yunnan	20	0.058
Lactarius chichuensis W.F. Chiu	Yuxi, Yunnan	29	0.17
Lactarius volemus (Fr.) Fr.	Yimen, Yunnan	119	1.03
Leccinum rugosiceps (Peck) Singer	Anning, Yunnan	115	0.31
Lentinus edodes (Berk.) Singer	Xichang, Sichuan	61	0.019
Lepista nuda (Bull.) Cooke	Shangri-La, Yunnan	23	0.88
Macrocybe gigantea (Massee) Pegler & Lodge	Pu'er, Yunnan	2	1.06
Osteina obducta (Berk.) Donk	Yimen, Yunnan	102	0.071
Pleurotus ostreatus (Jacq.) P. Kumm.	Yimen, Yunnan	60	0.11
Ramaria formosa (Pers.) Quél.	Yuxi, Yunnan	55	1.07
Ramaria rufescens (Schaeff.) Corner	Shangri-La, Yunnan	4	1.27
Retiboletus griseus (Frost) Manfr. Binder & Bresinsky	Yimen, Yunnan	4	0.75
Russula pseudodelica J.E. Lange	Yimen, Yunnan	2	1.20

(continued)

TABLE 1: Arsenic Contents of Wild-Grown Mushrooms Collected from Southwest China (mg kg^{-1}, dry weight) (continued)

Species	Site	Sample size*	Arsenic content
Russula vinosa Lindblad	Yimen, Yunnan	4	0.43
Russula violacea Quél.	Yuxi, Yunnan	25	1.69
Russula virescens (Schaeff.) Fr.	Yuxi, Yunnan	50	0.53
Rigidoporus ulmarius (Sowerby) Imazeki	Lanping, Yunnan	1	0.66
Sarcodon scabrosus (Fr.) P. Karst.	Shangri-La, Yunnan	4	0.92
Scleroderma citrinum Pers.	Yuxi, Yunnan	42	1.70
Shiraia bambusicola Henn.	Lanping, Yunnan	96	0.11
Sparassis crispa (Wulfen) Fr.	Lanping, Yunnan	1	0.84
Suillus pictus (Peck) A.H. Sm. & Thiers	Huize, Yunnan	48	0.27
Termitomyces globulus R. Heim & Gooss.-Font.	Yuxi, Yunnan	33	1.60
Thelephora ganbajun M. Zang	Weixi, Yunnan	15	0.15
Tricholoma bakamatsutake Hongo	Shangri-La, Yunnan	8	1.46
Tricholoma pessundatum (Fr.) Quél.	Shangri-La, Yunnan	19	0.16
Wolfiporia extensa (Peck) Ginns	Weixi, Yunnan	2	0.11
Xerocomellus rubellus (Krombh.) Šutara	Yuxi, Yunnan	24	0.33

*Number of individuals in a pooled sample

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REFERENCES

1. Wang XM, Zhang J, Wu LH, Zhao YL, Li T, Li JQ, Wang YZ, Liu HG. A mini-review of chemical composition and nutritional value of edible wild-grown mushroom from China. Food Chem. 2014;151:279–85.
2. Wasser SP. Medicinal mushrooms science: history, current status, future trends, and unsolved problems. Int J Med Mushrooms. 2010;12(1):1–16.
3. Chang ST, Wasser SP. The role of culinary-medicinal mushrooms on human welfare with pyramid model for human health. Int J Med Mushrooms. 2012;14(2):95–134.
4. De Silva DD, Rapior S, Hyde KD, Bahkali AH. Medicinal mushrooms in prevention and control of diabetes mellitus. Fungal Divers. 2012;56(1):1–29.
5. Khan MA. Tania M. Nutritional and medicinal importance of Pleurotus mushrooms: an overview. Food Rev Int. 2012;28(3):313–29.
6. Mortimer PE, Karunarathna SC, Li Q, Gui H, Yang X, Yang X, He J, Ye L, Guo J, Li H, Sysouphanthong P, Zhou D, Xu J, Hyde KD. Prized edible Asian mushrooms: ecology, conservation and sustainability. Fungal Divers. 2012;56(1):31–47.
7. Falandysz J, Borovička J. Macro and trace mineral constituents and radionuclides in mushrooms: health benefits and risks. Appl Microbiol Biotechnol. 2013;97(2):477–501.
8. Kalač P. A review of chemical composition and nutritional value of wild-growing and cultivated mushrooms. J Sci Food Agr. 2012;93(2):209–18.
9. Byrne AR, Šlejkovec Z, Stijve T, Fay L, Goessler W, Gailer J, Lrgolic KJ. Arsenobetaine and other arsenic species in mushrooms. Appl Organomet Chem. 1995;9(4):305–13.
10. Kalač P, Svoboda L. A review of trace element concentrations in edible mushrooms. Food Chem. 2000;69(3):273–

81.
11. Larsen EH, Hansen M, Gössler W. Speciation and health risk consideration of arsenic in the edible mushroom Laccaria amethystina collected from contaminated and uncontaminated locations. Appl Organomet Chem. 1998;12(4):285–91.
12. Yin LL, Shi GQ, Tian Q, Shen T, Ji YQ, Zeng G. Determination of the metals by ICP-MS in wild mushrooms from Yunnan, China. J Food Sci. 2012;77(8):T151–55.
13. Liu YT, Sun J, Luo ZY, Rao SQ, Su YJ, Xu RR, Yang YJ. Chemical composition of five wild edible mushrooms collected from Southwest China and their antihyperglycemic and antioxidant activity. Food Chem Toxicol. 2012;50(5):1238–44.
14. Mao XL. The macrofungi of China. Zhengzhou: Henan Science and Technology Press; 2000.
15. Dai YC, Yang ZL. A revised checklist of medicinal fungi in China. Mycosystema. 2008;27(6):801–24.
16. Dai YC, Yang ZL, Cui BK, Yu CJ, Zhou LW. Species diversity and utilization of medicinal mushrooms and fungi in China (Review). Int J Med Mushrooms. 2009;11(3):287–302.
17. Dai YC, Zhou LW, Yang ZL, Wen HA, Bau T, Li TH. A revised checklist of edible fungi in China. Mycosystema. 2010;29(1):1–21.
18. GB/T5009.11-2003. Determination of total arsenic and abio-arsenic in foods. Beijing: Chinese Ministry of Health, 2003.
19. Zhang D, Gao T, Ma P, Luo Y, Su P. Bioaccumulation of heavy metal in wild growing mushrooms from Liangshan Yi nationality autonomous prefecture, China. Wuhan Univ J Nat Sci. 2008;13(3):267–72.
20. Chen XH, Zhou HB, Qiu GZ. Analysis of several heavy metals in wild edible mushrooms from regions of China. Environ Contam Toxicol. 2009;83(2):280–85.
21. Konuk M, Afyon A, Yagiz D. Minor element and heavy metal contents of wild growing and edible mushrooms from western Black sea region of Turkey. Fresen Environ Bull. 2007;16(11A):1359–62.
22. Ouzouni PK, Petridis D, Koller WD, Riganakos KA. Nutritional value and metal content of wild edible mushrooms collected from West Macedonia and Epirus, Greece. Food Chem. 2009;115(4):1575–80.
23. Falade OS, Adepoju OO, Owoyomi O, Adewusi SR. Chemical composition and toxic trace element composition of some Nigerian edible wild mushrooms. Int J Food Sci Technol. 2008;43(1):24–29.
24. Vetter J. Arsenic content of some edible mushroom species. Eur Food Res Technol. 2004;219(1):71–74.
25. Nikkarinen M, Mertanen E. Impact of geological origin on trace element composition of edible mushrooms. J Food Compos Anal. 2004;17(3):301–10.
26. Giannaccini G, Betti L, Palego L, Mascia G, Schmid L, Lanza M, Mela A, Fabbrini L, Biondi L, Lucacchini A. The trace element content of top-soil and wild edible mushroom samples collected in Tuscany, Italy. Environ Monit Assess. 2012;184(12):7579–95.
27. Li T, Wang Y, Zhang J, Zhao Y, Liu H. Trace element content of Boletus tomentipes mushroom collected from Yunnan, China. Food Chem. 2011;127(4):1828–30.
28. Turhan Ş, Zararsız A, Karabacak H. Determination of element levels in selected wild mushroom species in Turkey using non-destructive analytical techniques. Int J Food Prop. 2010;13(4):723–31.
29. Prasad MNV. Trace elements as contaminants and nutrients: consequences in ecosystems and human health. Hoboken, NJ: Wiley; 2008.
30. Llorente-Mirandes T, Barbero M, Rubio R, López-Sánchez JF. Occurrence of inorganic arsenic in edible Shiitake (Lentinula edodes) products. Food Chem. 2014;158:207–15.
31. Kalač P. Trace element contents in European species of wild growing edible mushrooms: a review for the period 2000-2009. Food Chem. 2010;122(1):2–15.
32. Niedzielski P, Mleczek M, Magdziak Z, Siwulski M, Kozak L. Selected arsenic species: As(III), As(V) and dimethylarsenic acid (DMAA) in Xerocomus badius fruiting bodies. Food Chem. 2013;141(4):3571–77.