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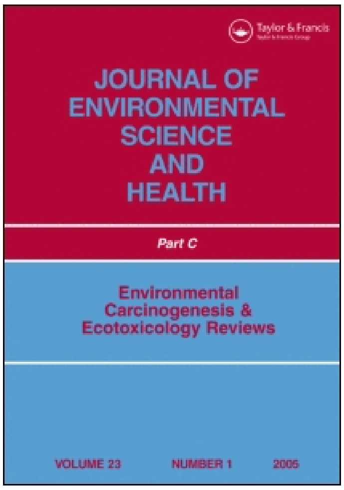

Journal of Environmental Science and Health, Part C
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597270

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Online Publication Date: 01 July 2008

To cite this Article Falandysz, Jerzy(2008)'Selenium in Edible Mushrooms',Journal of Environmental Science and Health, Part C,26:3,256 — 299

To link to this Article: DOI: 10.1080/10590500802350086

URL: http://dx.doi.org/10.1080/10590500802350086

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Journal of Environmental Science and Health Part C, 26:256–299, 2008
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ISSN: 1059-0501 (Print); 1532-4095 (Online)
DOI: 10.1080/10590500802350086

Selenium in Edible Mushrooms

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Selenium is vital to human health. This article is a compendium of virtually all the published data on total selenium concentrations, its distribution in fruitbody, bioconcentration factors, and chemical forms in wild-grown, cultivated, and selenium-enriched mushrooms worldwide. Of the 190 species reviewed (belonging to 21 families and 56 genera), most are considered edible, and a few selected data relate to inedible mushrooms. Most of edible mushroom species examined until now are selenium-poor (< 1 μg Se/g dry weight). The fruitbody of some species of wild-grown edible mushrooms is naturally rich in selenium; their occurrence data are reviewed, along with information on their suitability as a dietary source of selenium for humans, the impact of cooking and possible leaching out, the significance of traditional mushroom dishes, and the element's absorption rates and co-occurrence with some potentially problematic elements. The Goat's Foot (*Albatrellus pes-caprae*) with ~ 200 μg Se/g dw on average (maximum up to 370 μg/g dw) is the richest one in this element among the species surveyed. Several other representatives of the genus *Albatrellus* are also abundant in selenium. Of the most popular edible wild-grown mushrooms, the King Bolete (*Boletus edulis*) is considered abundant in selenium as well; on average, it contains ~ 20 μg Se/g dw (maximum up to 70 μg/g dw). Some species of the genus *Boletus,* such as *B. pinicola, B. aereus*, *B. aestivalis*, *B. erythropus*, and *B. appendiculus,* can also accumulate considerable amounts of selenium. Some other relatively rich sources of selenium include the European Pine Cone Lepidella (*Amanita strobiliformis*), which contains, on average, ~ 20 μg Se/g dw (up to 37 μg/g dw); the *Macrolepiota* spp., with an average range of ~ 5 to < 10 μg/g dw (an exception is *M. rhacodes* with < 10 μg/g dw); and the *Lycoperdon* spp., with an average of ~ 5 μg Se/g dw. For several wild-grown species of the genus *Agaricus,* the selenium content (~ 5 μg/g dw) is much greater than that from cultivated Champignon Mushroom; these include *A. bisporus*, *A. bitorquis*, *A. campestris*, *A. cesarea*, *A. edulis*, *A. macrosporus*, and *A. silvaticus*. A particularly rich source of selenium could be obtained from selenium-enriched mushrooms that are cultivated on a substrate fortified with selenium (as inorganic salt or selenized-yeast). The Se-enriched Champignon Mushroom could contain up to 30 or 110 μg Se/g dw, while the Varnished Polypore (*Ganoderma lucidum*) could contain up to 72 μg Se/g dw. An increasingly growing database on chemical forms of selenium of mushrooms

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Received April 5 2008; accepted July 2 2008.
Inspiration by Margaret Rayman (UK) is acknowledged. This study has been supported by the Ministry of Science and Higher Education under grant no. DS-8250-4-0092-8.

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indicates that the seleno-compounds identified in carpophore include selenocysteine, selenomethionine, Se-methylselenocysteine, selenite, and several unidentified seleno-compounds; their proportions vary widely. Some aspects of environmental selenium occurrence and human body pharmacokinetics and nutritional needs will also be briefly discussed in this review.

Key Words: Food; fungi; health; human; metalloids; mushroom; nutrition; selenium

1. INTRODUCTION

Knowledge of the amounts and chemical forms of selenium compounds in food sources, foodstuffs or dietary supplements (nutraceuticals), their intake and absorption rates, as well as further human body biotransformation pathways resulting in accumulation, activity, and release of selenium is vital to understanding the complexity of maintaining human health. This is because selenium is fundamentally essential to man. Selenium is required in biosynthesis of important selenoenzymes. Examples of these important, known selenoenzymes and selenoproteins include glutathione peroxidases, iodothyronine 5′-deiodases, thioredoxin reductases, selenoprotein P, and selenoprotein W. Some are active as catalysts for reduction of extracellular oxidants (such as hydrogen peroxide and lipid hydroperoxides), thereby protecting cells from potential damage by these hazardous compounds. They can also play a role in some pathways of energy metabolism and gene expression. Selenoprotein P and selenoprotein W, two important extracellular glycoproteins, are particularly rich in selenocysteine residues. These and some other aspects of selenium and food and human health of selenium have been comprehensively reviewed in a number of recent articles (1–6).

Selenium usually accompanies sulfur ores of certain metallic elements of the volcanic origin as well as some deposits of coal. Natural ores of this element do not occur. Selenates (SeO_4^{2-}) are more water soluble than selenites (SeO_3^{2-}). Therefore, selenates can more easily infiltrate from soil into soil solution as well as be transported with ground and surface water and be absorbed by plants (7).

Soil, sediment, and water are the primary sources of selenium to fungi and vascular plants and, further, to animals that are natural in the human food chain worldwide. Abundance of selenium in food sources and foodstuffs of plant and animal origin is the function of its content in soil, bioavailability, biotransformation, food web transfer, and accumulation/homeostasis potential of selenium ions and organoseleno compounds. Therefore, the selenium content of locally available food sources and foodstuffs varies spatially worldwide. This phenomenon seems more marked for terrestrially available food than seafood. For example, the selenium content of terrestrial plants depends on the amount of the element available in soils, with > 2, 0.11 and 0.005 μg Se/g dw found in whole-wheat grain from soils of high (United

States), low (New Zealand), and ultra-low (China) selenium status, respectively (1).

The selenium content of surface soil horizon worldwide is usually below 0.5 mg/kg, while most soils contain from 0.1 to 2 mg Se/kg dry weight (1, 8). In some regions of the world where soil selenium content is < 0.125 mg/kg dw, severe endemic Se deficiency in humans causes juvenile cardiomyopathy (Keshan disease) and chondrodystrophy (Kaschin-Beck disease). Surface soil horizon can contain 5 mg Se/kg dw or more (areas with moor soils, alkaline soils) (8, 9). Soil that contains nearly 8 mg/kg may lead to highly elevated amounts of this element in regionally produced food, resulting in excessive daily intake of 3200–6690 μg Se per person (i.e., 100 times over nutritional needs) and chronic selenosis. At the seleniferous sites, soil contains up to 90 mg Se/kg dw (1). Selenium-accumulator plants (genus *Astragalus*, *Xylorrhiza*, *Oonopsis,* and *Stanleya*) caused selenium poisoning of livestock (10). The values of bioconcentration factor (BCF; a quotient of concentration in plant and substrate calculated from dry weight data) of selenium in plants of the families of *Compositae*, *Fabaceae (Leguminosae), Cruciferae,* and the genus *Allium* when grown at soils abundant in this element can reach as much as 1000 (7).

Soil management may result in the increase of selenium content of soil that is poor in this element and may support the growth of selenium up-regulated vegetable food. Cultivation of some species of plants and mushrooms or the culturing of yeast with substrate fortified in inorganic salts of selenium (e.g., sodium selenate; Na_2SeO_4) enables production of food that is enriched in this element (e.g., selenium-enriched garlic, which contains even up to > 1000 μg Se/g dw) (11, 12).

Livestock usually contains between 0.3 and 0.4 μg Se/g fresh weight in muscle meat and about 4-fold and 10- to 16-fold more in liver and kidneys, respectively, while the selenium level of feed is the only and highly regulating agent (1). The mineral feed mixtures that are fortified with selenium (sodium selenate; sodium selenite, Na_2SeO_3) or sodium hydrogen selenite ($NaHSeO_3$) when fed to farm animals result in enhanced selenium content of the slaughtered animal meats (kidney, liver) from 4.0 ± 0.9 to 8.8 ± 2.3 μg/g dw (13).

The main focus of this article is to summarize data on total selenium content and its chemical forms in edible wild-grown and cultivated mushrooms in the context of body fate of this element and human nutritional needs. Selected data on selenium in a few species of inedible mushrooms are also included.

2. BODY FATE OF SELENIUM

Absorption

Selenium occurs mostly at –2, +4, and +6 oxidation states and forms covalently bounded compounds with C-Se and Se-S bonds. The human fate of dietary seleno-compounds can differ from other mammals. Under normal circumstances, their fate and activity depend on their original chemical forms at the time of ingestion (14). Some chemical-form-dependent variations in efficiency of dietary selenium absorption have been observed. In this context, it is important to note that the type of foodstuffs may also play a role in determining its significance as a source of selenium and other essential elements. Selenium largely occurs in natural food as selenium-containing amino acids and in foods of plant origin, mainly as selenomethionine and that of animal origin as selenocysteine. The chemical forms of selenium that are ingested are important factors that determine not only the element's bioavailability but also its metabolic fate, distribution, nutritional importance (accessibility for functional selenoproteins), accumulation, and toxicity (14, 15). Selenocysteine-containing animal proteins previously mentioned are the most readily available source of this element to man (5).

Selenium as selenomethionine in solution is actively transported (mechanism shared with methionine) with a yield of above 95%, and passively as inorganic selenate or selenite, with yields of above 90% and about 60%, respectively (14). Some dietary factors can influence the absorption rate of selenium (e.g., vitamin C hampers selenite absorption). Selenium in wheat, wheat bread, fish, or meat could be retained similarly in humans, as indicated by the enhancement of glutathione peroxidase activity, even though the absorption rate may fluctuate somewhat (14).

Distribution

Inorganic selenium compounds are absorbed and excreted quickly. However, when selenium is ingested in the form of selenomethionine, its clearance rate is substantially slower. Selenomethionine can be readily incorporated into body tissues in a nonspecific and unregulated manner. Selenomethionine, when absorbed by humans or animals, is not distinguishable from methionine and can be incorporated into general body proteins (14).

Metabolism

Inorganic selenium compounds such as selenite or selenate are absorbed by mammal body and are further reduced to hydrogen selenide (H—Se—H), which, as the presumed key selenium intermediate, is used for the synthesis of selenoamino acid (e.g., selenocysteine) and selenoproteins (2, 3). Selenium in selenocysteine is almost fully ionized; this is what enables it to be an efficient catalyst for cells. A proposed metabolic pathway for selenomethionine includes *trans*-selenation to selenocysteine and the β-lyase reduction to hydrogen selenide, while methylselenocysteine includes the β-lyase reduction to monomethylselenol (CH_3-Se-H), which may be further methylated or demethylated back to selenide (1, 15).

Ingested selenium can bind with toxic elements such as mercury and cadmium to prevent their toxic action and to act antagonistically with other elements (e.g., As, Ba, Cu, Zn). Absorbed inorganic mercury ion and selenium could form an equimolar complex that specifically binds to plasma protein but less to some other proteins (16). Selenoprotein P that contains histidine and up to 10 selenocysteine moieties per molecule seems to bind certain metallic elements (6).

Excretion

Selenite and other forms of selenium (except selenomethionine) that are used in the biosynthesis of functional selenoproteins appear to be under homeostatic regulation. Selenite and selenocysteine are readily excreted in the urine when in excess (14). In mammals, hydrogen selenide not used for selenoprotein synthesis is believed to be disposed after biotransformation to selenosugar and/or stepwise methylation to monomethylselenol, dimethylselenide, and trimethylselenonium ions (15). Trimethylselenonium ion is a good urinary marker of intake of toxic doses of selenium. Selenomethionine, selenite, selenate, selenoaminoacids, and selenocholine are also urinary excreted selenocompounds, and daily urinary excretion of selenium could be as much as half of its daily intake (14).

3. SELENIUM: HUMAN NUTRITIONAL NEEDS AND TOXICITY

The intake of selenium from food should be sufficient to support the optimal expression of the selenocysteine-enzymes. Selenium that is incorporated as selenocysteine residues in various selenoproteins of animal meats is the most desirable form of selenium in food for humans. Under normal circumstances, dietary intake of selenium rarely exceeds the needs for selenocysteine-enzymes expression. In contrast, deficient intake of selenium (less than 40 μg Se per person per day) is more widespread (1, 3). Dietary allowance for selenium is 0.87 μg/kg body weight (60.9 μg/person; 70 kg body weight). The recommended daily allowance is 55 μg Se/person for healthy adults. The maximum safe, daily dietary dosage of selenium assessed is 400 μg/person. Adverse health effects may occur at daily dosage of 900–1600 μg/person, and selenosis occurs at 3200–5000 μg/person (1, 3, 10).

The plasma and erythrocyte selenium concentrations of man of deficient, adequate, and excessive selenium intake correlate positively with selenium-intake status. In contrast, the level of glutathione peroxidase activity is not as sensitive to selenium status. Selenocysteine in proteins such as glutathione peroxidase and selenoprotein P occurs in stoichiometric amounts, while that of selenomethionine in hemoglobin and albumin occurs on a random basis (14).

Seleno-compounds exert effects on cells, which are strictly compositional and concentration-dependent. An inverse relationship between selenium intake and the incidence of certain cancers has been documented in epidemiological studies (3). Selenium (selenoproteins) at supranutritional doses may have anticancer properties. The mechanisms of impact of Se on cancer reduction remain to be explored. Selenium at greater doses can be either cytotoxic or possibly carcinogenic (10). As mentioned before, the successive methylation of hydrogen selenide (H-Se-H) to monomethylselenol (CH_3-Se-H), dimethylselenide (CH_3-Se-CH_3 ↑; breath), and trimethylselenonium ion ($(CH_3)_3Se^+$; urine) can detoxify excess selenium; on the other hand, oxidation of excess hydrogen selenide may lead to production of toxic superoxide and other reactive oxygen species (H_2O_2, O_2) (1, 10).

4. TOTAL SELENIUM AND ITS CHEMICAL FORMS IN GENERAL AND IN SELENIUM-ENRICHED FOOD

Foods of plant origin containing from 0.017 ± 0.012 to 0.12 ± 0.06 μg Se/g dw in the vegetables and from 0.0062 ± 0.0016 to 0.089 ± 0.11 μg Se/g dw in fruits rich in starch or sugar are poor in selenium. An exception is protein-abundant *leguminosae* or *cruciferes* rich in glucosinolate (mustard, caraway, cabbages) as well as young asparagus and oat flakes that are relatively abundant in selenium (13). Egg yolk and the offal meats (liver, kidney) of livestock usually did contain selenium at concentrations of magnitude greater than muscle meats. In addition, fishes and seafood are considered as foodstuffs that are relatively abundant in selenium with 0.56 ± 0.2 to 2.0 ± 0.5 μg/g dw in some products and species (1, 13, 17).

As mentioned earlier, at nonseleniferous regions such as Central and Eastern Europe, livestock fed with feed with added selenium (usually as sodium selenate) will contain selenium at greater concentrations in muscle and organ meats when compared with the animals fed with local feeds (13). Selenium of cattle or pork meats probably constitutes selenoproteins and selenoenzymes as major forms, which are considered highly bioavailable.

5. SELENIUM IN WILD-GROWN MUSHROOMS

Wild-grown edible mushrooms are natural foods that are frequently abundant in mineral elements (18). Some species of mushroom are particularly rich in certain elements, including arsenic, iron, mercury, selenium, silver, and vanadium (19–29).

Tubes and gills are usually the morphological parts of the carpophore (fruitbody, sporocarp) that are most abundant in selenium, and the cap (pileus) contains this element in greater concentrations than the stem (stipe, stalk). However, data regarding selenium distribution in the mushrooms' fruitbody is relatively small (Table 1).

Table 1: Selenium in morphological parts of mushrooms (μg/g dw; adapted)

Species	n	Tubes/gills	Flesh part of cap	Cap	Stipe	Ref.
Boletus edulis	1	16	7.7		6.4	30
	1	47	29		29	33
	1			18	5.5	34
	1	34		20		31
	16			23 ± 13 (6.0–56)	11 ± 7 (4.0–32)	32
Suillus luteus	1	1.3	0.46		0.33	30
				0.66	0.54	34
Coprinus comatus	1			0.96	0.71	34
Xerocomus badius	1–2	5.4		3.4	5.8	31
Leccinum rufescens	1			0.99	0.96	34
Leccinum scabrum	15			0.52 ± 0.33 (0.18–1.4)	0.13 ± 0.10 (0.011–0.32)	23
Amanita muscaria	1	4.0	4.0		1.2	30
	1			3.2	1.1	35
	1			4.2	1.5	35
Amanita phalloides	1			0.33	0.19	35
Macrolepiota procera	4			3.9 ± 0.7 (3.1–4.7)	2.5 ± 0.3 (2.1–2.9)	28
	2			3.7 (3.6–3.9)	2.6 (2.1–2.9)	28
	3			3.8 ± 1.8 (1.8–5.2)	3.0 ± 1.4 (1.4–4.0)	28
	12			3.7 ± 1.0 (2.0–5.8)	2.6 ± 0.8 (1.5–4.2)	28

Table 2: Selenium contents of edible fungi worldwide (μg/g dw; adapted)

Order, family, genus and species	Country/site	n	Year	Mean/median	Range	Reference
	Pezizales, Morchellaceae; Morchella					
Morchella conica Thimble Cap	Switzerland	1	*ca.* 1974	0.11		49
	Switzerland	3	*ca.* 1977	0.10	0.10–0.11	30
	Switzerland	3	1975–82	0.13	0.07–0.20	43
Morchella elata Black Morel	Switzerland	2	1975–82	0.085	0.07–0.10	43
Morchella esculenta Common Morel	Switzerland	1	*ca.* 1977	0.065		30
	France	1	1989–90	46(?)		39
	Mexico	1	1993–99	1.8		68
	Italy	10	*ca.* 2004	1.3	0.67–2.0^{ci}	69
	Czech/Slovakia	1	*ca.* 2007	< 0.50		22
Morchella vulgaris	Switzerland	2	1975–82	0.12	0.08–0.16	43
Morchella spp.	Finland	1	1976–99	0.04		70
	Mitrophora					
Mitrophora hybrida	France	1	1989–90	44(?)		39
	Italy	16	*ca.* 2004	1.5	0.99–1.9^{ci}	69
	Ptychoverpa					
Ptychoverpa bohemica	Italy	19	*ca.* 2004	2.2	1.6–2.9^{ci}	69
	Gyromitra					
Gyromitra esculenta False Morel ⊗	Switzerland	1	*ca.* 1974	0.035		49
	Poland	3	1975–81	6.1(?)	5.9–6.3	38
	Finland	2	1976	0.07	0.06–0.07	71
	Switzerland	3	*ca.* 1977	0.035	0.028–0.042	30
	Finland	6	1976–99	0.39		70
	Switzerland	2	1975–82	0.035	0.03–0.04	43
	Czech/Slovakia	1	*ca.* 2007	0.42		22
Gyromitra gigas	Switzerland	1	1975–82	0.06		43
	Helvella					
Helvella auriculo-judae	Italy	11	*ca.* 2004	1.6	0.80–2.4^{ci}	69
Helvella crispa	Switzerland	2	1975–82	0.075	0.07–0.08	43

(Continued on next page)

Table 2: Selenium contents of edible fungi worldwide (μg/g dw; adapted) (*Continued*)

Order, family, genus and species	Country/site	n	Year	Mean/median	Range	Reference
Switzerland	1	*ca.* 1977	0.18		30	
	Italy	16	*ca.* 2004	1.7	1.2–2.2^{ci}	69
Helvella lacunosa Black Elfin Saddle	Switzerland	1	*ca.* 1977	0.036		30
	Mexico	1	1993–99	0.78		68
Tuberales; Tuberaceae; Tuber						
Tuber aestivum	Switzerland	1	1977	0.03		30
Aphyllophorales; Thelephoraceae; Sarcodon						
Sarcodon imbricatum	Poland	2	1975–81	0.63	0.57–0.69	38
	Switzerland	6	1975–82	1.9	0.61–3.3	43
	Slovenia	1	1976	1.7		35
	Switzerland	1	*ca.* 1977	1.7		30
Hydnaceae; Hydnum						
Hydnum repandum Common Hedgehog Fungus	Norway	1	*ca.* 1978	0.10		34
	Slovenia	2	*ca.* 1979	0.10	0.07–0.14	33
	Switzerland	8	1975–82	0.10	0.01–0.59	43
	Italy	18	*ca.* 2004	1.3	0.97–1.7^{ci}	69
	Denmark	1	1980	BDL		20
	Czech/Slovakia	2	*ca.* 2007	0.15	0.15–< 0.20	22
Hydnum rufescens	Finland	13	1976–99	0.09		70
Boletopsis						
Boletopsis grisea	Switzerland	—	1982	0.26		42
	Sweden	—	1988	1.9		42
Boletopsis leucomelaena	Sweden	—	1948	0.77		42
	Switzerland	—	1985	0.61		42
	Sweden	—	1993	0.60		42
Boletopsis subsqamosa	United States	—	1996	2.8		42
Ramariaceae; Ramaria						

Ramaria aurea	Switzerland	2	*ca.* 1977	5.1	3.7–6.6	30
	Switzerland	8	1975–82	5.1	0.73–11	43
	Austria	1	1987	1.3		31
	France	1	1989–90	39(?)		39
Ramaria botrytis	Switzerland	2	1975–82	1.0	0.65–1.4	43
	Clavulina					
Clavulina cristata	Croatia	1	1990	0.06		72
	Clavariaceae; Clavariadelphus					
Clavariadelphus pistillaris	Switzerland	2	1975–82	0.35	0.14–0.56	43
	Switzerland	2	*ca.* 1977	0.55	0.36–0.65	30
	Cantharellaceae; Cantharellus					
Cantharellus cibarius Common Chanterelle	Poland	6	1975–80	6.3 ± 0.5 (?)	5.3 – 6.7	38
	Sweden	1	*ca.* 1974	0.14		49
	Switzerland	4	1975–82	0.05	0.05–0.06	43
	Slovenia	1	1976	0.04		33, 35
	Finland	5	1976	0.04	0.03–0.04	71
	Finland	18	1976+99	0.18		70
	Switzerland	2	*ca.* 1977	0.17	0.14–0.20	30
	Norway	1	*ca.* 1978	0.090		34
	Finland	3	1979–82	0.07	0.05–0.08	65
	Poland	10	*ca.* 1985	0.23 ± 0.06		73
	Austria	1	1987	< 2		31
	Yugoslavia	3	*ca.* 1991	0.10 ± 0.02		71
	Mexico	1	1993–99	0.38		68
	Slovakia	2	*ca.* 1997	0.17	0.13–0.20	17
	Bohemia	—	*ca.* 2004	0.25 ± 0.05		45
	Italy	27	*ca.* 2004	1.3	0.96–1.6^{ci}	69
Cantharellus lutescens Golden Chanterelle	Finland	1	1976–99	0.03		70
	Bohemia	—	*ca.* 2004	0.18 ± 0.06		45
	Italy	—	*ca.* 2004	1.2	0.88–1.6^{ci}	69
Cantharellus pallens	Bohemia	—	*ca.* 2004	0.24 ± 0.04		45
Cantharellus tubaeformis Yellow Foot	Finland	18	1976–99	0.13		70
	Denmark	1	1980	BDL		20
	Finland	2	1982	0.11	0.11–0.11	65
	Czech/Slovakia	1	*ca.* 2007	0.14		22

(Continued on next page)

Table 2: Selenium contents of edible fungi worldwide (μg/g dw; adapted) (*Continued*)

Order, family, genus and species	Country/site	n	Year	Mean/median	Range	Reference
Craterellus						
Craterellus cornucopioides Horn of Plenty	Finland	8	1976–99	0.14		70
	Switzerland	2	*ca.* 1977	0.26	0.22–0.30	30
	Denmark	3	1980–81	0.4	BDL–1.0	20
	Finland	1	1982	0.09		65
	Switzerland	3	1975–82	0.12	0.06–0.17	43
	France	1	1989–90	34(?)		39
Leatiporus						
Leatiporus sulphureus	Hungary	1	1987	0.76		75
Polyporaceae; Polyporus						
Polyporus badius	Hungary	1	*ca.* 1993	1.7		76
Drendropolyporus umbellatus	France	1	1989–90	25(?)		39
Grifola						
Grifola biennis	Switzerland	—	1996	< 0.01		42
Grifola frondosa	United States	—	1992	< 0.02		42
Grifola umbellata	Switzerland	—	1995	< 0.01		42
Albatrellus						
Albatrellus cristatus	France	1	1991	3.1		42
Albatrellus confluens	Sweden	1	1953	1.1–1.3		42
	Sweden	1	1972	1.6		42
	Switzerland	1	—	1.4–2.0		42
	Corsica	1	—	10–12		42
	Switzerland	1	1973	4.4		42
Albatrellus ellisii	United States	1	1995	96		42
	United States	1	1996	43–50		42
	United States	1	1996	47–48		42
Albatrellus flettii	United States	1	1996	23–24		42

Albatrellus hirtus	United States	1	1995	<0.01		42
	United States	1	1996	0.089		42
Albatrellus ovinus	Norway	1	*ca.* 1978	0.37		34
	Finland	13	1976–99	0.33		70
	Finland	3	1979–82	0.47	0.16–0.67	65
	Switzerland	5	1975–82	0.35	0.03–1.3	43
	Czech/Slovakia	1	*ca.* 2007	0.27		22
Albatrellus pes-caprae Goats' Foot	Slovenia	1	1912	110		42
	Switzerland	1	1979	74		42
	Switzerland	2	1982	57	41–74	42
	Switzerland	2	1983	64	52–76	42
	France	1	1984	150		42
	Slovenia	1	1995	370		42
	France	1	1991	155		42
	Switzerland	1	1992	110		42
	Germany	1	1995	49		42
	Switzerland	1	1996	105		42
	Boletales; Boletaceae; Gyrodon					
Gyrodon lividus	Switzerland	2	1975–82	0.28	0.24–0.31	43
	Boletinus					
Boletinus cavipes	Switzerland	4	1975–82	0.26	0.12–0.56	43
	Suillus					
Suillus bovinus European Cow Bolete	Poland	6	1975–81	2.5±0.6	1.7–3.3	38
	Słowenia	1	1976	0.49		33. 35
	Finland	1	1982	0.05		65
	Poland	5	*ca.* 1985	0.62±0.33		73
	France	1	1989–90	35(?)		39
	Czech/Slovakia	1	*ca.* 2007	1.1		22
Suillus collinitus	Italy	14	*ca.* 2004	3.0	$2.2–3.7^{ci}$	69
	Czech/Slovakia	1	*ca.* 2007	1.4		22
Suillus granulatus Dotted-Stalk Bolete	Switzerland	2	*ca.* 1977	0.82	0.46–1.2	30
	Switzerland	6	1975–82	1.4	0.83–2.1	43
	Sweden	2	*ca.* 1995	1.0*	0.85–1.2	77
	Italy	17	*ca.* 2004	3.4	$2.4–4.5^{ci}$	69
	Czech/Slovakia	1	*ca.* 2007	2.7		22
Suillus grevillei Larch Bolete	Switzerland	1	*ca.* 1977	0.19		30

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Table 2: Selenium contents of edible fungi worldwide (μg/g dw; adapted) (*Continued*)

Order, family, genus and species	Country/site	n	Year	Mean/median	Range	Reference
	Switzerland	8	1975–82	0.45	0.27–0.71	43
	France	1	1989–90	42(?)		39
	Sweden	2	*ca.* 1995	0.37*	0.28–0.46	77
	Czech/Slovakia	2	*ca.* 2007	1.1	1.1–1.2	22
Suillus luteus Slipoery Jack	Switzerland	3	*ca.* 1977	0.70	0.38–1.3	30
	Norway	1	*ca.* 1978	0.66		34
	Poland	3	1975–81	4.3(?)	4.2 – 4.5	38
	Switzerland	1	1975–82	0.45		43
	Finland	1	1982	0.50		65
	Poland	5	*ca.* 1985	1.5±0.2		73
	Austria	1	1987	1.1		35
	France	1	1989–90	27(?)		39
	Sweden	3	*ca.* 1995	0.71*	0.58–0.92	77
	Italy		*ca.* 2004	3.3	2.2–4.3	69
	Czech/Slovakia	1	*ca.* 2007	1.9		22
Suillus variegatus Variegated Bolete	Finland	10	1976–99	1.0		70
	Poland	4	1980–81	3.4 ± 0.6 (?)	2.7 – 4.1	38
	Finland	2	1982	0.48	0.45–0.52	65
	France	1	1989–90	130(?)		39
	Sweden	1	*ca.* 1995	0.36*		77
	Czech/Slovakia	3	*ca.* 2007	0.85 ± 0.26	0.59–1.1	22
		Xerocomus				
Xerocomus badius Bay Bolete	Switzerland	1	*ca.* 1977	0.09		30
	Switzerland	8	1975–82	0.24	0.08–0.77	43
	Poland	8	1979–81	12 ± 2 (?)	10 – –17	38
	Poland	10	*ca.* 1985	0.21±0.05		73
	Austria	1	1987	3.4^{cap}		31
	France	—	1989–90	26(?)		39
	Bohemia	—	*ca.* 2004	< 0.16		45
	Bohemia	—	*ca.* 2004	0.22 ± 0.04		45

Xerocomus chrysonteron	Switzerland	1	*ca.* 1977	0.16		30
Red-cracking Bolete	Switzerland	21	1975–82	0.12	0.04–0.47	43
	Italy	10	*ca.* 2004	1.6	1.1–2.2^{ci}	69
	Czech/Slovakia	3	*ca.* 2007	0.16±0.08	< 0.14–0.22	22
Xerocomus dryophilus	Italy	12	*ca.* 2004	1.9	1.5–2.2^{ci}	69
Xerocomus ferrugineus	Italy	14	*ca.* 2004	1.8	1.3–2.3^{ci}	69
Xerocomus rubellus	Italy	45	*ca.* 2004	1.8	1.5–2.0^{ci}	69
Xerocomus subtomentosus	Switzerland	1	*ca.* 1977	0.068		30
Yellow-cracking Bolete	Switzerland	6	1975–82	0.10	0.03–0.18	43
	Finland	2	1982	0.08	0.06–0.09	65
	France	—	1989–90	51(?)		39
	Sweden	1	*ca.* 1995	0.04*		77
	Czech/Slovakia	1	*ca.* 2007	0.31		22
Xerocomus versicolor	Switzerland	2	1975–82	0.085	0.08–0.09	43
		Chalciporus				
Chalciporus piperatus	Sweden	1	*ca.* 1975	1.7*		77
	Czech/Slovakia	1	*ca.* 2007	4.8		22
		Boletus				
Boletus aereus	Italy	19	*ca.* 2004	25	16–32^{ci}	69
Boletus aestivalis Summer Bolete	Switzerland	7	1975–82	11	1.6–15	43
	France	1	1989–90	50(?)		39
	Bohemia	—	*ca.* 2004	17±0		45
	Italy	24	*ca.* 2004	21	17–25^{ci}	69
	Czech/Slovakia	3	*ca.* 2007	15±2	14–17	22
Boletus appendiculatus	France	1	1989–90	53(?)		39
	Italy	12	*ca.* 2004	7.3	5.5–9.1^{ci}	69
	Czech/Slovakia	1	*ca.* 2007	2.5		22
Boletus cavipes	Czech/Slovakia	2	*ca.* 2007	1.4	1.3–1.5	22
Boletus edulis King Bolete	Serbia	1	1971–72	22		33, 35
	Slovenia	1	1971–72	20		33, 35
	Slovenia	1	1971–72	19		33, 35
	Yugoslavia	6	*ca.* 1974	14	12–19	49
	Switzerland	1	*ca.* 1974	9.2		49
	Poland	8	1975–81	16 ± 3	13–20	38

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Table 2: Selenium contents of edible fungi worldwide (μg/g dw; adapted) (*Continued*)

Order, family, genus and species	Country/site	n	Year	Mean/median	Range	Reference
	Switzerland	17	1975–82	14	4.5–19	43, 78
	Finland	2	1976	9.9	5.5–14	71
	Finland	21	1976–99	14		70
	Switzerland	9	*ca.* 1977	13	4.1–20	30
	Norway	1	*ca.* 1978	18		34
	Finland	20	1979–82	17	5.9–37	65
	Poland	5	*ca.* 1985	15 ± 3		73
	Finland	—	1985	13		66
	Austria	1	1987	20		31
	Hungary	2	1984–87	21	11–30	75
	France	2	1989–90	23	16–31^{c}	39
	Macedonia	5	*ca.* 1991	10 ± 0		74
	Serbia	3	*ca.* 1991	16 ± 0		74
	Slovenia	8	*ca.* 1991	18 ± 2		74
	Yugoslavia	4	*ca.* 1991	27 ± 2		74
	Mexico	1	1993–99	1.3		68
	Sweden	7	*ca.* 1995	10*	5.6–15	77
	Poland	7	1998	29 ± 10	16–44^{cap}	32,79
	Poland	11	2000	8.7 ± 89	1.1–27^{cap}	32
	Poland	10	2000	32 ± 20	18–70^{cap}	32
	Poland	16	2000	23 ± 11	6.0–56^{cap}	32
	Finland	—	2001	19	5.2–63	44
	Finland	—	2001	7.5	5.4–9.5	44
	Bohemia	—	*ca.* 2004	33±1		45
	Bohemia	—	*ca.* 2004	18±1		45
	Italy	41	*ca.* 2004	31	24–38^{ci}	69
	United States	—	*ca.* 2004	16		59
	United States	—	*ca.* 2004	19		60

Boletus erythropus	Switzerland	1	*ca.* 1977	6.6		30
	Switzerland	2	1975–82	2.7	2.6–3.1	43
	France	1	1989–90	35(?)		39
	Italy	10	*ca.* 2004	7.3	5.0–9.6^{ci}	69
	Czech/Slovakia	2	*ca.* 2007	6.4	4.9–7.8	22
Boletus pinicola Pinewood King Bolete	Finland	1	1976	27		70
	Switzerland	2	1975–82	43	42–44	43
	Czech/Slovakia	2	*ca.* 2007	50	44–55	22
Boletus radicans	Switzerland	3	1975–82	2.4	2.1–2.8	43
	Czech/Slovakia	1	*ca.* 2007		4.5	22
Boletus regius	Switzerland	1	1975–82	14		43
	Leccinum					
Leccinum carpini (L. *griseum*)	Switzerland	8	1975–82	0.91	0.16–1.8	43
	France	1	1990	42(?)		39
	Bohemia	—	*ca.* 2004	1.6±0.1		45
	Czech/Slovakia	2	*ca.* 2007	1.3	1.2–1.5	22
Leccinum rufum Red Aspen Bolete	Poland	2	1975–81	7.0 (?)	7.0 – 7.0	38
	Finland	5	1976–99	1.7		71
	Norway	1	*ca.* 1978	0.99		34
	Switzerland	3	1975–82	1.3	1.0–1.7	43
	France	—	1990	43(?)		39
	Sweden	2	*ca.* 1995	0.44*	0.34–0.54	77
	Czech/Slovakia	1	*ca.*. 2007	2.0		22
Leccinum scabrum Brown Birch Scaber Stalk	Poland	4	1975–80	4.7 ± 0.6(?)	3.9 – 5.1	38
	Switzerland	2	*ca.* 1977	0.23	0.16–0.31	30
	Norway	1	*ca.* 1978	0.12		34
	Slovenia	1	*ca.* 1979	0.31		33
	Finland	9	1979–82	0.69	0.28–2.2	65
	Poland	10	*ca.* 1985	0.82 ± 0.30		73
	Poland	15	2000	0.52 ± 0.33	0.18–1.4^{cap}	23,79
	Poland	15	2000	0.50 ± 0.30	0.22–1.2^{cap}	23
	Poland	15	2000	1.5 ± 1.3	0.13–5.4^{cap}	23
	Sweden	1	*ca.* 1995	0.32*		77

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Table 2: Selenium contents of edible fungi worldwide (μg/g dw; adapted) (*Continued*)

Order, family, genus and species	Country/site	n	Year	Mean/median	Range	Reference
	Czech/Slovakia	1	*ca.* 2007	0.49		22
Leccinum versipelle Orange Birch Bolete	Finland	27	1976–99	1.3		70
	Finland	5	1982	0.61^{c}	0.28–1.3	65
	Gomphidiaceae; Gomphidius					
Gomphidius glutinosus	Switzerland	1	*ca.* 1977	0.05		30
	Norway	1	*ca.* 1978	0.39		34
	Switzerland	2	1975–82	0.12	0.06–0.18	43
	Chroogomphus					
Chroogomphus rutilus	Switzerland	1	1975–82	0.10		43
	Czech/Slovakia	2	*ca.* 2007	0.2	0.22–< 0.30	22
	Agaricales; Pleurotaceae; Pleurotus					
Pleurotus ostreatus Common Oyster Mushroom	Denmark	4	1980–81	1.1	BDL–3.4	20
	Hungary	—	1985	1.0±0.5		75, 80
	France	1	1989–90	37(?)		39
	Spain	2	*ca.* 1994	0.28	0.27–0.30	81
	Switzerland	7	1994	0.67	0.35–1.1	82
	Finland	$1,5^{kg}$	*ca.* 2001	0.15		83
	Lentinus					
Lentinula edodes	Switzerland	5	1994	0.60	0.54–0.93	82
	Finland	1.5^{kg}	*ca.* 2001	0.039		83
	Hygrophoraceae; Hydrophorus					
Hygrophorus lucorum	Czech/Slovakia	1	*ca.* 2007	0.70		22
Hygrophorus marzuolus	Switzerland	10	1975–82	1.3	0.63–2.1	43
Hygrophorus miniatus	Switzerland	1	*ca.* 2004	0.12		30
Hygrophorus penarius	Italy	15	*ca.* 2004	1.5	$0.95–2.1^{ci}$	69
Hygrophorus pratensis	Switzerland	1	*ca.* 1977	0.13		30

Hygrophorus russula	Switzerland	4	1975–82	1.0	0.57–1.4	43
	Italy	11	*ca.* 2004	2.0	1.6–2.4^{ci}	69
	Czech/Slovakia	1	*ca.* 2007	1.6		22
	Hygrocybe					
Hygrocybe punicea	Slovenia	1	1976	0.62		35
	Tricholomotaceae; Laccaria					
Laccaria affinis	Italy	17	*ca.* 2004	2.3	1.6–2.9^{ci}	69
Laccaria amethystina Amethyst Deceiver	Slovenia	1	*ca.* 1979	0.20		33
	Switzerland	2	1975–82	0.29	0.075–0.50	43
	Denmark	6	1980–81	0.7	0.4–1.1	20
	Belgium	1	1984	0.19		84
Laccaria laccata	Czech/Slovakia	1	*ca.* 2007	0.23		22
	Clitocybe					
Clitocybe geotropa	Switzerland	2	*ca.* 1977	1.0	0.88–1.2	30
	Switzerland	3	1975–82	2.2	1.6–2.6	43
	Italy	19	*ca.* 2004	3.8	2.8–4.8^{ci}	69
Clitocybe gibba	Switzerland	3	1975–82	1.2	0.87–1.5	43
	Italy	12	*ca.* 2004	2.8	2.1–3.5^{ci}	69
Clitocybe nebularis	Switzerland	15	1975–82	3.0	0.95–7.2	43
	Switzerland	2	*ca.* 1977	0.20	0.11–0.30	30
	Italy	28	*ca.* 2004	5.4	4.3–6.5^{ci}	69
	Czech/Slovakia	1	*ca.* 2007	5.0		22
Clitocybe odora	Czech/Slovakia	1	*ca.* 2007	0.46		22
	Tricholoma					
Tricholoma acerbum	Switzerland	3	1975–82	1.6	1.0–2.2	43
Tricholoma flavovirens	Poland	4	1975–81	2.8±0.3	2.5–3.2	38
Tricholoma georgii	Switzerland	18	1977–78	8.6	2.9–18	85
	Switzerland	7	1977–79	4.1	3.4–5.8	86
	Switzerland	9	1977–79	15	11–18	86
Tricholoma terreum	Switzerland	1	*ca.* 1977	0.076		30
	Switzerland	7	1975–82	0.14	0.02–0.33	43
	France	1	1989–90	32(?)		39
	Croatia	1	1990	0.24		72

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Table 2: Selenium contents of edible fungi worldwide (μg/g dw; adapted) (*Continued*)

Order, family, genus and species	Country/site	n	Year	Mean/median	Range	Reference
		Melanoleuca				
Melanoleuca evenosa	Slovenia	1	1976	1,6		33, 35
		Calocybe				
Calocybe gambosa	Switzerland	28	1975–82	7.8	0.03–18	43
	France	1	1989–90	25(?)		39
	Italy	18	*ca.* 2004	6.5	5.4–7.6^{ci}	69
		Armilariella				
Armillaria mellea Honey Mushroom	Poland	3	1975–81	5.8(?)	5.4 – 5.9	38
	Finland	1	1975–82	0.84		65
	Switzerland	2	1975–82	0.32	0.25–0.38	43
	France	1	1989–90	29(?)		39
	Italy	14	*ca.* 2004	0.79	0.35–1.2^{ci}	69
		Lyophyllum				
Lyophyllum connatum	Czech/Slovakia	1	*ca.* 2007	2.1		22
Lyophyllum decastes	Italy	22	*ca.* 2004	3.2	2.0–4.4^{ci}	69
Lyophyllum fomosum	Czech/Slovakia	2	*ca.* 2007	5.9	2.7–9.1	22
		Collybia				
Collybia butracea	Luxemburg	1	1984	1.5		84
Collybia dryophila	Slovenia	1	1976	0.37		35
		Lepista				
Lepista luscina	Spain	—	*ca.* 2005	2.5		61
Lepista nebularis	Switzerland	15	1975–80	3.0	0.95–7.2	87
Lepista nuda	Switzerland	13	1975–82	1.1	0.09–2.7	43
	Belgium	1	1983	2.2		84
	Switzerland	18	*ca.* 1987	1.3	0.5–2.6	88
	Croatia	1	1990	0.40		72
	Hungary	1	*ca.* 1993	1.0		76

	Italy	13	*ca.* 2004	3.6	2.5–4.7^{ci}	69
Lepista personata	Switzerland	9	1975–82	3.2	2.3–4.5	43
	Croatia	1	1990	1.5		72
	Marasmius					
Marasmius oreades Fairy Ring Mushroom	Switzerland	3	*ca.* 1977	0.68	0.23–1.5	30
	Finland	6	1975–82	1.6	1.1–3.6	65
	Switzerland	24	1975–82	0.92	0.02–2.4	43, 89
	Denmark	1	1980	5.0		20
	France	1	1989–90	40(?)		39
	Italy	—	*ca.* 2004	2.7	2.5–3.0^{ci}	69
	Entolomataceae; Clitopilus					
Clitopilus prunulus	Norway	1	*ca.* 1978	4.0		34
	Hungary	—	1987	4.9±0.1		76
	France	1	1989–90	39(?)		39
	Italy	14	*ca.* 2004	6.7	5.6–7.9^{ci}	69
	Croatis	1	1990	0.39		72
Entoloma saundersii	Italy	23	*ca.* 2004	1.8	1.1–2.4^{ci}	69
	Amaniteceae; Amanita					
Amanita cesarea Cesars's Mushroom	Mexico	1	1993–99	1.8		68
Amanita ovoidea	Switzerland	1	1975–82	0.35		43
	Italy	12	*ca.* 2004	1.8	1.1–2.6^{d}	69
Amanita rubescens European Blusher	Switzerland	1	*ca.* 1977	0.65		30
	Slovenia	1	*ca.* 1979	0.18		33
	Switzerland	28	1975–82	0.50	0.17–1.3	43
	Austria	1	1987	< 0.4		31
	Belgium	1	1984	0.42		84
	Poland	3	*ca.* 1985	0.37±0.12		73
	France	1	1990	34(?)		39
	Croatia	1	1990	0.45		72
	Mexico	1	1993–99	1.7		68
	Hungary	7	1994–00	1.5 ± 0.2		90
	Bohemia	—	*ca.* 2004	1.9 ± 0.1		45
	Bohemia	5	*ca.* 2004	0.83 ± 0.06		45

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Table 2: Selenium contents of edible fungi worldwide (μg/g dw; adapted) (*Continued*)

Order, family, genus and species	Country/site	n	Year	Mean/median	Range	Reference
	Italy	23	*ca.* 2004	0.20	0.20–0.20^{d}	69
Amanita solitaria European Solitary Lepidella	Bohemia	1	1961	4.7		47
	Switzerland	2	1975–82	9.3	8.2–10	43
	France	1	1989–90	33(?)		39
	England	1	1990	0.68		47
	Bohemia	8	2003–05	3.0±4.5	0.82–14	47
Amanita spissa	Switzerland	3	1975–82	2.0	0.39–3.7	43
	Czech/Slovakia	1	*ca.* 2007	0.53		22
	Croatia	1	1990	0.34		72
Amanita strobiliformis European Pine Cone Lepidella	Switzerland	2	1975–82	13	9.8–15	43
	Slovakia	1	1984	15		47
	Hungary	5	1993–95	14 ± 5		90
	Bohemia	25	2004–05	21 ± 8	6.5–37	22
	Unknown	1	2005	17		22
Amanita vaginata Grisette	Switzerland	1	*ca.* 1977	0.12		30
	Switzerland	11	1975–82	0.74^{c}	0.10–2.8	43
	France	1	1989–90	33(?)		39
	Croatia	1	1990	1.2		72
	Italy	15	*ca.* 2004	2.0	2.0–2.0^{d}	69
Amanita vittadinii Vittadini's Lepidella	Bohemia	2	1980	3.5	2.9–4.0	47
Agaricaceae; Macrolepiota						
Macrolepiota procera Parasol Mushroom	Slovenia	3	1976	2.4±0.6	2.4–2.9^{cap}	35
	Slovenia	2	*ca.* 1979	2.1	1.8–2.4	33
	Switzerland	2	*ca.* 1977	0.70	0.4–1.0	30
	Finland	3	1979–82	4.8	2.8–6.2	65
	Switzerland	6	1975–82	2.5	0.3–5.6	43
	Poland	1	*ca.* 1985	0.83		73

	Hungary	1	1987	5.8^{cap}		75
	Yugoslavia	3	*ca.* 1991	1.9 ± 0.0		74
	Yugoslavia	3	*ca.* 1991	2.7 ± 0.1		74
	Sweden	2	*ca.* 1995	1.3^{*}	0.54–2.1	77
	Hungary	1	1996	5.7^{cap}		91
	Poland	12	1999	3.7±1.0	$2.0–5.8^{cap}$	28
	Poland	3	2000	3.8±1.8	$1.8–5.2^{cap}$	28
	Poland	4	2000	3.9±0.7	$3.1–4.7^{cap}$	28
	Poland	2	2000	3.7	$3.6–3.9^{cap}$	28
	Bohemia	—	*ca.* 2004	8.3±0.6		45
	Italy	15	*ca.* 2004	3.5	$2.6–4.3^{ci}$	69
	Spain	—	*ca.* 2005	1.3		61
Macrolepiota rhacodes Shaggy Parasol	Finland	1	1979–82	5.6^{cap}		65
	Switzerland	4	1975–82	5.2	3.6–7.1	43
	Denmark	1	1980	30		20
	Hungary	1	1987	7.6		75
	Bohemia	—	*ca.* 2004	10±0		45
	Italy	10	*ca.* 2004	8.5	$6.1–11^{ci}$	69
	Agaricus					
Agaricus aegerita	Italy	—	*ca.* 2004	1.4	$1.1–1.8^{ci}$	69
Agaricus aestivalis	Switzerland	1	1975–82	9.4		43
Agaricus arvensis Horse Mushroom	Switzerland	1	*ca.* 1974	7.8		49
	Switzerland	1	*ca.* 1976	1.9		30, 92
	Slovenia	1	*ca.* 1979	2.0		33
	Denmark	10	1980–81	5.5	0.9–9.8	20
	Austria	1	1981	$< 0.8^{cap}$		31
	Austria	1	1981	2.2^{lam}		31
	Switzerland	1	1979	1.6		86
	Switzerland	2	1975–82	1.5	1.4–1.5	43
	Hungary	—	1985	4.6±0.9		80, 93
	Sweden	2	*ca.* 1995	0.33^{*}	0.04–0.62	77
	Italy	23	*ca.* 2004	3.8	$3.1–4.4^{ci}$	69
	Bohemia	—	*ca.* 2004	3.0±0.2		45
	Bohemia	—	*ca.* 2004	1.1±0.1		45
	Bohemia	—	*ca.* 2004	2.3±0.2		45

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Table 2: Selenium contents of edible fungi worldwide (μg/g dw; adapted) (*Continued*)

Order, family, genus and species	**Country/site**	**n**	**Year**	**Mean/median**	**Range**	**Reference**
Order, family, genus and species	Country/site	n	Year	Mean/median	Range	Reference
Agaricus augustus The Prince	Switzerland	2	*ca.* 1976	1.3	0.8–1.8	30, 92
	Denmark	1	1980	2.2		20
	Austria	1	1987	2.1^{cap}		31
Agaricus benesii Red Staining Agaricus	Switzerland	1	*ca.* 1976	1.4		30, 92
Agaricus bisporus Champignon	Switzerland	1	*ca.* 1974	0.08		49
	Taiwan	1	*ca.* 1974	0.34		49
- *var. albidus* (white; cultivated)	Taiwan	2	*ca.* 1976	1.9	0.8–2.9	30, 92
- *var. avallaneus*	France	2	*ca.* 1976	1.6	1.0–2.2	30, 92
	Poland	2	1980	9.2(?)	9.0 – 9.4	38
	Switzerland	4	1975–82	0.75	0.63–0.85	43
	Finland	1	1976	0.30		71
- *Canned*	Finland	4	1976	0.20	0.10–0.40	71
	Finland	8	1979–82	0.85	0.45–1.2	65
	Hungary		1984–86	0.71±0.42		80,93
	Austria	—	1987	1.7		31
	Germany	6	1988–2000	0.60		13
	United States		*ca.* 1993	3.0		94
	Spain	2	*ca.* 1994	0.30	0.25–0.34	81
	Switzerland	29	1994	2.4	1.3–5.7	82
	Scotland		*ca.* 1995	0.89		95
	Slovakia	3	*ca.* 1997	0.67	0.51–0.95	17
	United States	—	*ca.* 1999	1.0		53
	Hungary	—	*ca.* 2000	134(?)		40
	Hungary	—	*ca.* 2000	130(?)	81–150 (?)*	41
- *var. albidus* (white; cultivated)	Finland	$1,5^{kg}$	*ca.* 2001	1.4		83
- *var. brown* (cultivated)	Finland	$1,5^{kg}$	*ca.* 2001	3.2		83
	Hungary	1^{kg}	*ca.* 2003	1.9 ± 0.1		96
	Hungary	1^{kg}	*ca.* 2003	3.8 ± 0.9		96

- Canned (sliced)	Far East	—	*ca.* 2003	< 0.05		96
- Canned (whole)	Far East	—	*ca.* 2003	< 0.05		96
	Italy	20	*ca.* 2004	3.4	2.6–4.2^{a}	69
	Spain	—	*ca.* 2006	1.6		63
- *Se-enriched*	United States	—	*ca.* 1999	53		52
- *Se-enriched*	Hungary	—	*ca.* 2006	51		63
Agaricus bitorquis Spring Agaricus	Spain	1	1976	1.9		92
	Switzerland	8	1976	5.0	2.1–7.8	92
	Switzerland	1	*ca.* 1977	1.9		30
	Switzerland	9	1977–78	8.9	3.7–11	97
	Switzerland	22	1975–82	5.8	1.0–11	43
	Denmark	7	1980–81	5.1	0.8–11	20
	Italy	20	*ca.* 2004	13	9.4–17^{a}	69
Agaricus caesarea	Italy	—	*ca.* 2004	3.3	2.6–4.1^{a}	69
Agaricus campestris Meadow Mushroom	Slovenia	3	1974–79	1.8±2.1	0.33–4.2	33, 35
	The Nederlands	—	1976	1.8		92
	Switzerland	3	1976	4.2	1.8–7.7	30, 92
	Switzerland	36	1975–82	5.7	0.99–22	43
	Switzerland	18	*ca.* 1980	6.1	1.0–13	98
	Denmark	2	1980–81	5.3	5.6–7.0	20
	France	2	1989–90	24(?)	20 – 28^{c}	39
	Mexico		1993–99	8.4		68
	Sweden	1	*ca.* 1995	0.66*		77
	Italy	30	*ca.* 2004	4.3	3.3–5.3^{a}	69
	Czech/Slovakia	10	*ca.* 2007	4.7±1.2	3.4–7.5	22
Agaricus edulis	Switzerland	8	*ca.* 1977	5.0	2.1–7.8	30
Agaricus essettei	Italy	16	*ca.* 2004	2.9	2.4–3.5^{a}	69
Agaricus excellens	Czech/Slovakia	1	*ca.* 2007	13		22
Agaricus haemorrhoidarius Bleeding Agaricus	Switzerland	3	1975–82	4.2	2.9–5.4	69
	Denmark	1	1980	6.8		20
Agaricus langei	Switzerland	1	*ca.* 1976	6.3		30, 92

(Continued on page 281)

Table 2 lists published data on the total selenium content of edible wild-grown and cultivated mushrooms worldwide. These data are presented in order based on higher mushrooms' systematic classification (36, 37). Of the 188 mushroom species reviewed (belonging to 21 families and 56 genera), a few are inedible (Table 2). These few selected inedible species are included only for the purpose of comparison with the edible ones. The question of whether some species of wild-grown mushroom should be edible or inedible really depends on local tradition and the procedures of preparation and cooking.

A figure of 180 species of wild-grown and more or less edible mushroom species for which selenium data exist is not that high, especially, when compared with the number of published data for elements more frequently determined (zinc, copper, cadmium, etc.) than selenium. In addition, in many of the species reviewed in Table 2, frequently, only a single carpophore or stand was examined. In the present estimation, the number of edible species worldwide should be much greater than 200.

Another problem is analytical quality of data that are available for selenium in mushrooms, as can be drawn from Table 2. The absolute concentration values of selenium provided at least by certain investigators are evidently biased (38–41). In some cases, the data reported by these authors may be as much as three orders of magnitude greater than those reported for the same mushroom species by other authors using validated procedure. Obviously, all these excessive data (shown in Table 2 and marked with a question mark in parentheses) are highly doubtful or simply wrong. For the reason mentioned, two other published sets of data on selenium in mushrooms in Latin America and in some of the European stands are not included in the present review.

The mushroom most frequently studied regarding its selenium content is King Bolete (*Boletus edulis*), which is relatively abundant in this element (Table 2). Among the mushroom species examined until now, the Goat's Foot (*Albatrellus pes-caprae*) with ∼ 200 μg, Se/g dw on average (up to 370 μg Se/g dw), is the richest one in this element (Table 2). In an interesting survey by Stijve et al. (42), selenium data is known also for several other representatives of the genus *Albatrellus*. Species such as *A. ellisii* seem to be rich in selenium (∼ 100 μg/g dw), but lower levels were found in *A. flettii* (∼ 25 μg/g dw), *A. confluens* (∼ 5 μg/g dw and up to 12 μg/g dw), *A. cristatus* (∼ 3 μg/g), and other *Albatrellus* spp. (Table 2).

King Bolete, as mentioned, is considered to be abundant in selenium, and on the average contains ∼ 20 μg Se/g dw (maximum up to 70 μg/g dw) (Table 2). Pinewood King Bolete (*B. pinicola*) is also considerably rich in selenium and contains on average ∼ 40 μg/g dw, but the number of specimens examined from three stands is only five (Table 2). Some other species of the genus *Boletus* could be also considered as relatively abundant in selenium: *B. aereus* and *B. aestivalis* (∼ 20 μg/g dw), *B. erythropus* (∼ 10 μg/g dw), and *B. appendiculus* (∼ 5 μg/g dw) (Table 2).

Table 2: Selenium contents of edible fungi worldwide (μ g/g dw; adapted) *(Continued)*

Order, family, genus and species	Country/site	n	Year	Mean/median	Range	Reference
Agaricus lanipes	Denmark	1	1980	39		20
Agaricul litoralis	Denmark	1	1980	8.1		20
Agaricus macrocarpus	Denmark	2	1908–81	11	2.7–19	20
	The Netherlands	1	*ca.* 1976	4.6		92
	Switzerland	1	*ca.* 1977	4.6		30
	Slovenia	1	*ca.* 1979	1.9		33
	Denmark	1	1980	3.6		20
	Italy	16	*ca.* 2004	3.9	3.2–4.8^{d}	69
Agaricus moelleri	Czech/Slovakia	1	*ca.* 2007	5.6		22
Agaricus nivescens	Italy	17	*ca.* 2004	3.0	3.0–3.0^{d}	69
Agaricus silvicola Wood Mushroom	Switzerland	1	*ca.* 1976	3.9		30, 88
	Slovenia	2	*ca.* 1979	1.5	0.96–2.0	33
	Switzerland	16	1975–78	1.1	0.60–1.5^{c}	99
	Switzerland	24	1975–82	1.2	0.27–3.6	43
	The Netherlands	1	*ca.* 1977	7.0		30
	Denmark	2	1980–81	6.3	5.6–7.0	20
	Denmark	2	1980–81	6.4	5.1–7.7	20
	Croatia	—	1990	0.62^{c}		72
	France	1	1990	23(?)		39
	Italy	10	*ca.* 2004	2.9	2.4–3.5^{d}	69
Agaricus silvaticus Red-staining Mushroom	Switzerland	1	1976	4.3		30, 92
	Switzerland	2	1979–80	1.0	1.0–1.1	86
	Switzerland	5	1975–82	6.2	3.5–8.1	43
	Denmark	1	1980	29		20
	France	1	1990	31		39
	Czech/Slovakia	2	*ca.* 2007	16	8.1–25	22
Agaricus squamullfer	Czech/Slovakia	1	*ca.* 2007	8.3		22

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Table 2: Selenium contents of edible fungi worldwide (μg/g dw; adapted) *(Continued)*

Order, family, genus and species	**Country/site**	**n**	**Year**	**Mean/median**	**Range**	**Reference**
	Coprinaceae; Coprinus					
Coprinus atramentarius Alcohol Ink Cap	Finland	4	1979–82	0.59	0.02–2.1	65
	Switzerland	10	1975–82	1.0	0.17–3.2	43
	France	1	1989–90	32(?)		39
Coprinus comatus Shaggy Mane	Slovenia	1	1976	0.34		33
	Switzerland	1	*ca.* 1977	010		30
	Norway	1	*ca.* 1978	0.96		34
	Slovenia	1	*ca.* 1979	0.34		33
	Finland	6	1979–82	0.60	0.40–1.1	65
	Switzerland	18	1975–82	0.65	0.06–2.7	43
	Switzerland	18	1975–84	0.79	0.13–2.7	100
	Denmark	8	1980–81	0.8	BDL–2.2	20
	France	1	1989–90	36(?)		39
	Croatia	1	1990	0.29		72
	Italy	11	*ca.* 2004	2.1	1.1–2.9^{ci}	69
	Czech/Slovakia	1	*ca.* 2007	2.2		22
Coprinus micaceus Glistening Ink Cap	Switzerland	6	1975–82	0.20	0.06–0.29	43
	Austria	1	1987	< 0.3		31

	Psathyrella					
Psathyrella candolleana Suburban Psathyrella	Belgium	1	1985	0.17		84
	Strophariaceae; Stropharia					
Stropharia aeruginosa	Switzerland	3	1975–82	0.43	0.29–0.72	43
Stropharia coronilla	Switzerland	2	1975–82	0.05	0.014–0.09	43
Stropharia rugosoannulata	Poland	3	1975–81	7.1(?)	7.0 – 7.4	38
	Hypholoma					
Hypholoma capnoides	Hungary	—	*ca.* 1993	2.1		76
Hypholoma fasciculare Sulfur Tuft	Slovenia	1	1976	0.30		33, 35
	Switzerland	2	*ca.* 1977	0.20	0.16–0.25	30
	Belgium	1	1984	0.10		84
	France	1	1989–90	52(?)		39
	Kuehneromyces					
Kuehneromyces mutabilis	Croatia	1	1990	0.18		72
	Cortinariaceae; Cortinarius					
Cortinarius praestans	Slovenia	1	1976	1.0		35
	Switzerland	1	*ca.* 1977	1.0		30
	Switzerland	8	1975–82	1.4	0.72–2.3	43
	Italy	12	*ca.* 2004	4.0	1.1–6.9^{ci}	69
Cortinarius saturatus	Slovenia	1	1976	0.63		33, 35

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Table 2: Selenium contents of edible fungi worldwide (μg/g dw; adapted) *(Continued)*

Order, family, genus and species	Country/site	n	Year	Mean/median	Range	Reference
		Rozites				
Rozites caperata Gypsy	Finland	1	1979–82	0.61		65
	Switzerland	7	1975–82	0.40	0.14–0.67	43
	Bohemia^{Pa}	—	*ca.* 2004	0.80±0.07		45
	Italy	16	*ca.* 2004	1.9	1.6–2.2^{ci}	69
		Russulales; Russulaceae; Russula				
Russula adusta	Finland	1	1979–82	0.06^{c}		65
Russula aeruginea Tacky Green Russula	Switzerland	1	*ca.* 1977	0.65		30
	Finland	3	1979–82	0.16	0.09–0.26	65
	Poland	4	*ca.* 1985	0.21±0.14		73
Russula aurea	Czech/Slovakia	1	*ca.* 2007	0.24		22
Russula badia	Finland	1	1979	0.07		65
Russula cyanoxantha Variable Russula	Slovenia	2	1976	0.66	0.43–0.88	33
	Croatia	1	1990	0.79		72
Russula flava Graying Yellow Russula	Finland	2	1979–82	0.09	0.07–0.10	65
Russula fragilis	Finland	1	1979	0.15		65
	Czech/Slovakia	2	*ca.* 2007	< 0.15	< 0.12–< 0.15	22
Russula integra	Czech/Slovakia	1	*ca.* 2007	0.21		22
	Croatia	1	1990	0.14		72
Russula olivacea	Poland	5	*ca.* 1985	0.12±0.02		73
	Italy	12	*ca.* 2004	1.4	0.84–2.0^{ci}	69
	Czech/Slovakia	2	*ca.* 2007	< 0.20	< 0.09–< 0.20	22
Russula paludosa Tall Brittle Gills	Finland	2	1976–99	0.07		70
	Switzerland	1	*ca.* 1977	0.11		30
	Finland	1	1979–82	0.15		65
	Czech/Slovakia	2	*ca.* 2007	0.20	0.11–0.30	22
Russula vesca	Slovenia	1	*ca.* 1979	0.21		33
	Italy	25	*ca.* 2004	1.7	1.4–2.1^{ci}	69
	Czech/Slovakia	2	*ca.* 2007	0.36	0.33–0.40	22
Russula vinosa	Czech/Slovakia	1	*ca.* 2007	< 0.09		22
Russula virescens	Switzerland	5	1975–82	1.2	0.52–2.1	43
	Bohemia^{B}	—	*ca.* 2004	1.0±0.1		45

Russula viridosa	Switzerland	1	*ca.* 1977	0.52		30
Russula xerampelina Crab-scented Brittle Gills	Finland	2	1979–82	0.08	0.05–0.10	65
	Poland	9	*ca.* 1985	0.33±0.25		71
	Czech/Slovakia	1	*ca.* 2007	0.16		22
	Lactarius					
Lactarius deliciosus Saffron Milk Cap	Slovenia	4	1976	0.77±0.46	0.18–1.3	35
	Slovenia	1	*ca.* 1979	0.46		33
	Finland	5	1976–99	1.1		70
	Switzerland	2	*ca.* 1977	0.59	0.39–0.79	30
	Finland	1	1979–82	0.89		65
	Switzerland	11	1975–82	1.1	0.52–1.8	43
	Croatia	1	1990	1.0		72
Lactarius camphoratus Fragrant Milk Cap	Belgium	1	1985	0.19		84
Lactarius deterrimus	Finland	2	1976–99	0.83		70
	Austria	—	1986	1.7		31
Lactarius necator Mutagen Milk Cap	Finland	8	1979–82	0.09	0.05–0.16	65
Lactarius piperatus Peppery Milk Cap	Switzerland	20	1975–82	0.94	0.28–2.1	43, 46
	Switzerland	2	*ca.* 1977	1.0	0.95–1.2	30
	Slovenia	1	1976	0.50		33, 35
	Czech/Slovakia	1	*ca.* 2007	0.49		22

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Table 2: Selenium contents of edible fungi worldwide (μg/g dw; adapted) *(Continued)*

Order, family, genus and species	Country/site	n	Year	Mean/median	Range	Reference
Lactarius rufus Red-hot Milk Cap	Finland	5	1976	0.04	0.003–0.05	71
	Finland	2	1979–82	0.14	0.11–0.17	65
	Finland	5	1976–99	0.09		70
	Czech/Slovakia	4	*ca.* 2007	0.35±0.15	0.18–0.54	22
Lactarius torminosus Woolly Milk Cap	Finland	5	1976	0.60	0.20–1.1	71
	Slovenia	1	1976	1.3		35
	Switzerland	1	*ca.* 1977	0.37		33
	Finland	8	1979–82	1.9	1.3–2.8	65
	Finland	4	1976–99	1.9		70
	Czech/Slovakia	1	*ca.* 2007	2.0		22
Lactarius trivialis Trivial Milk Cap	Finland	6	1976	0.20	0.10–0.30	43
	Finland	4	1979–82	0.17	0.12–0.26	65
	Finland	2^z	1979–82	0.17	0.12–0.22	65
	Finland	7	1976–99	0.36		70
	Finland	—	2001	< 0.5		44
Lactarius vellereus	Croatia	1	1990	0.07		72
Lactarius volemus Fishy Milk Cap	Slovenia	1	1976	0.69		35
	Austria	1	1987	0.64		31

	Lycoperdales; Lycoperdaceae; Lycoperdon					
Calvatia excipuliformis	Switzerland	1	*ca.* 1977	2.5		30
	Finland	1	1979–82	1.9		65
	France	1	1989–90	38(?)		39
	Czech/Slovakia	2	*ca.* 2007	8.5	4.9–12	22
Calvatia gigantea Giant Puffball	Switzerland	2	*ca.* 1977	1.4	0.96–1.8	30
Calvatia utriformis	Slovenia	1	1976	1.8		33
	Switzerland	4	1975–82	1.4	1.2–1.7	43
	Poland	4	*ca.* 1985	2.9±0.4		73
	Italy	24	*ca.* 2004	5.0	4.2–5.7[ci]	69
Lycoperdon perlatum Common Puffbal	Slovenia	1	1976	3.6		35
	Switzerland	3	*ca.* 1977	0.77	0.39–1.2	30
	Norway	1	*ca.* 1978	2.4		34
	Switzerland	23	1975–82	3.2	0.95–11	43
	Switzerland	18	1979–85	2.0	0.8–6.6	101
	Poland	5	*ca.* 1985	4.4±1.2		73
	Bohemia	—	*ca.* 2004	4.2±0.1		45
	Bohemia	—	*ca.* 2004	3.5±0.2		45
	Italy	13	*ca.* 2004	3.4	2.6–4.3[ci]	69

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Table 2: Selenium contents of edible fungi worldwide (μg/g dw; adapted) (*Continued*)

Order, family, genus and species	Country/site	n	Year	Mean/median	Range	Reference
Lycoperdon pyriforme	Switzerland	1	1977	0.06		30
	Switzerland	4	1975–82	1.0	0.24–1.6	43
	Czech/Slovakia	1	*ca.* 2007	5.2		22
Lycoperdon saccatum	Croatia	1	1990	2.5		72
Lycoperdon umbrinum	Switzerland	1	*ca.* 1977	0.25		30
		Bovista				
Bovista plumbea	Switzerland	9	1975–82	1.5	1.2–2.3	43
	Czech/Slovakia	3	*ca.* 2007	2.0±0.4	1.6–2.3	22
		Vascellium				
Vascellium pratense	Czech/Slovakia	2	*ca.* 2007	4.9	3.5–6.3	22
		Langermannia				
Langermannia gigantea	Bohemia	—	*ca.* 2004	4.1±0.2		45
		Auriculariales; Auriculariaceae; Hirneola				
Hirneola auricula judae	Switzerland	1	*ca.* 1977	0.055		30
	France	1	1989–90	39(?)		39
Hirneola polytricha	Switzerland	1	*ca.* 1977	0.02		30

∗Calculated from fresh weight data: assuming water content 90 %; [d] 95 % confidence interval; [z]Canned; [⊗]inedible or poisonous; BDL, below detection limit; [lam]Lamellae.

Other relatively rich species of selenium are the European Pine Cone Lepidella (*Amanita strobiliformis*), which contains on average ∼ 20 μg Se/g dw (up to 37 μg/g dw), and some other edible representatives of the genus *Amanita,* which contains ∼1 μg/g dw (Table 1). The cultivated Champignon Mushroom (*A. bisporus*) is poor in selenium, with ∼ 0.5 μg/g dw on average. For several wild-grown species of the genus *Agaricus* selenium, content is much greater than for cultivated Champignon (∼ 5 μg/g dw) and includes species such as *A. bitorquis*, *A. cesarea*, *A. campestris*, *A. edulis*, *A. macrosporus*, and *A. silvaticus*, and is ∼ 2 μg/g dw for *A. aestivalis* (Table 2).

Mushrooms of the genus *Lycoperdon,* with ∼ 5 μg Se/g dw, show somewhat elevated selenium content. The selenium content of *Tricholoma georgii* is also elevated (∼ 10 μg Se/g dw) but not in other species of this genus, with ∼ 3 μg/g dw down to ∼ 0.2 μg Se/g dw (Table 2). Other somewhat richer sources of selenium can be found in mushrooms such as *Calocybe gambosa* (∼ 8 μg Se/g dw), *Romaria* spp. and *Clitophilus prunulus* (∼ 5 μg Se/g dw), *Lycophyllum* spp. (∼4 μg/g dw), and *Clitocybe* spp. (∼ 3 μg/g dw) (Table 2). The representatives of many other genera investigated are less abundant in selenium or, in other words, are poor in this element. The examples are: *Lepiota* spp. and *Sarcodon imbricatus,* for which on average is ∼ 2 μg/g dw; *Hydrophorum* spp. and *Cortinarius* spp., with ∼ 1 μg/g dw; *Coprinus* spp. and *Rozites* spp., with ∼ 0.5 μg/g dw; and < 0.5 μg/g dw for *Russula* spp., *Cantharellus* spp., *Cratellus* spp., *Hydnum* spp., *Boletopsis* spp., *Morchella* spp., *Gyromitra* spp., *Helvella* spp., *Laccaria* spp., or *Armillariella* spp. (Table 2).

Certainly, several representatives of the genera of *Albatrellus* and *Boletus* characterized appear to have the specific ability to take up and accumulate selenium in the fruitbody. In most studies on selenium in mushrooms reviewed (Table 2), the data on soil (substrate) selenium content does not exist. Selenium content of soil bedrock probably can influence to some degree the selenium content of wild-grown mushroom, but this phenomenon was not studied in detail (23, 24, 27, 28, 32, 43–45).

The values of BCF of total selenium in King Bolete (*B. edulis*) at an area that was contaminated because of over 200 years of operation of a lead smelter varied between 8.8 and 9.2 for the caps and between 4.7 and 9.8 for the stems. The total selenium content of soil at that site was 5.9±4.2 μg/g dw (top 1–6 cm soil layer), while selenium was non detectable in 6–23 cm and deeper layers. The carpophores of Bay Bolete (*Xerocomus badius*) and Red-cracking Bolete (*X. chrysenteron*) when compared with that of King Bolete excluded (BCF < 1) selenium both in the caps and in stems (48). The value of bioconcentration factor of selenium noted for wild-grown *Agaricus bitorquis* is 43, 11–26 for *A. campestris*, 3 for *A. silvicola*, 8 for *A. arvensis*, and 12–59 for *Calocybe gambosa* (43–40).

Mushrooms with relatively high selenium content can also contain elevated concentrations of silver, but no significant correlation between these elements occurred for European Pine Cone Lepidella (*A.strobiliformis*) (47). For example, King Bolete (*B. edulis*) or Parasol Mushroom (*M. procera*) are both relatively rich in selenium and mercury (49, 50).

6. SELENIUM CONTENT OF SELENIUM-ENRICHED MUSHROOMS

The Champignon Mushroom (*A. bisporus*) cultivated on substrates that are fortified with selenium salts effectively picks up this element and accumulates in fruitbody (51–55). For example, selenium as sodium selenite (Na_2SeO_3) that is added to a substrate was accumulated by Champignon Mushroom at concentrations of up to 3 μg Se/g fresh weight; i.e., up to 30 μg Se/g dw (assuming 90% water content) (51). These authors fortified the substrate with selenium at 2, 5, 10, 30, and 60 mg dose per cultivation box (size 40 × 60 cm; about 13 kg of substrate per box in a layer of $\sim$ 18 cm thick).

In other experiments with Champignon Mushroom, when the selenium added was as selenite at 10 μg/g compost, the mushrooms accumulated 110 μg Se/g dw of fruitbody; when added as selenized-yeast (10 μg Se/g compost) they accumulated 160 μg Se/g dw (54, 56). In addition, the Varnished Polypore (*Ganoderma lucidum*), which is cultivated on a substrate fortified at 100–250 μg Se/g (added as sodium selenite), also effectively accumulated (at $\sim$ 20-30%) this element in the fruiting bodies up to 72 μg Se/g dw (57).

7. CHEMICAL FORMS OF SELENIUM IN WILD-GROWN AND CULTIVATED MUSHROOMS AND IN SELENIUM ENRICHED-MUSHROOMS

Wild-grown Mushrooms

In an early study of King Bolete and Champignon Mushroom, selenium was found to be mainly located in low molecular weight fraction or as inorganic compounds. In lipids it is located $\sim$ 10%, with a similar amount in nucleic acids, while in proteins, chitin and polysaccharides fraction is $\sim$ 20% (51). In a study by Slejkovec et al. (58), King Bolete and Goat's Foot (*A. pes-caprae*) contained mostly low-molecular weight (6 kDa) seleno-compounds. A small fraction of the extractable selenium (after proteolysis) in Goat's Foot is selenite (3.0–9.2%), while selenocysteine is minor in this species, and selenocysteine in King Bolete is at 7.5% and selenomethionine is at 1.0%. A bulk portion of seleno-compounds in these species still needs to be elucidated (58).

In King Bolete (*Boletus edulis*), after extraction with sodium hydroxide solution (0.05 mol/dm^3), hydrochloric acid solution (0.05 mol/dm^3), or hot water (at 60°C), and further fractionation of the extract using size exclusion liquid chromatography, selenium found was associated primarily with low but also high molecular weight fractions (alkaline extraction) (59). Further, hot water extraction and enzymatic protein hydrolysis proved selenocysteine, selenomethionine, selenomethylselenocysteine, and two unidentified compounds as major organoseleno constituents of *B. edulis* (60).

Hot water extracts of the fruiting bodies of wild-grown Parasol Mushroom (*Macrolepiota procera*), Lurid Bolete (*Boletus luridus*), and *Lepista luscina* contained, respectively, 47, 49, and 91% of selenium found in crude mushrooms. Hot water-soluble seleno-compounds occurred in the low molecular weight fraction, and selenomethionine at varying amounts was the major unbound (not protein bound) constituent of the extracts for these three species. In addition, several others of unknown structure seleno-compounds detected were in these mushrooms (61).

Selenium-enriched Mushrooms

The selenized vegetable, such as broccoli, tomato leaves, and cucumbers accumulate selenium as selenate, while selenized wheat grain, corn, rice, soybeans, and yeast accumulate selenium as selenomethionine (12). Selenized garlic, onions, Brussels sprouts, and leek accumulate selenium as Se-methylselenocysteine and γ-glutamyl-*Se*-methylselenocysteine (12, 62).

The fruiting bodies of commercially cultivated Champignon Mushroom (*A.bisporus*) do not contain significant amounts of selenium (selenomethionine) firmly bound to proteins, but fruiting bodies of this species that have grown up (selenium-enriched) on substrates fortified with selenium could contain protein-bound selenomethionine as well as a number of unidentified seleno-compounds. Selenomethionine that is unbound with proteins in cultivated ordinary Champignon Mushroom was hot water (at 85°C) labile, while that bound to proteins of selenium-enriched specimens was hot water stable (63). Champignon Mushroom grown up in radioselenium-fortified substrate (^{75}Se as irradiated SeO_2) was accumulated in the fruiting bodies selenium as biotransformed seleno-compounds. They occurred in the majority of low molecular weight compounds and were of inorganic nature and to some degree also as higher molecular weight seleno-compounds (51). A three-step extraction process using water, pepsin, and trypsin yielded up to 75% of selenium found in selenium-enriched Champignon Mushroom, and selenium (IV) and selenocysteine were the major seleno-compounds found (54).

After proteolysis using proteolitic and cell wall digestion enzymes, Lysing enzyme and Driselase for the caps of Champignon Mushroom grown up on selenized-yeast added compost; selenomethionine, which is the major seleno-compound found in selenized yeast, was also the dominant Se-compound in mushroom, while selenocysteine and Se(IV) were also detected (56).

Selenocysteine, selenomethionine, methylselenocysteine, and inorganic selenium were in *Lentinula edodes* and *Agaricus bisporus* (54). In another survey, selenized mushroom Shiitake (*Lentinula edodes*) accumulated selenium as selenomethionine, and this compound might be bound to high molecular mass (> 40,000 kDa) protein. Nevertheless, apart from selenomethionine, some other but minor (by amount) seleno-compounds seem to be possible in selenized Shitake (12).

The selenium chemical forms found in Varnished Polypore (*Ganoderma lucidum*) were seleno-proteins (56–61%), seleno-polysaccharides (11–18%), the nucleic acid fraction (0.067–0.22%), and other seleno-components (13.8–20.0%) (57). Up to 88% of selenium biotransformed by these Varnished Polypore to organoseleno compounds occurred as water-soluble and alkaline-soluble proteins (probably with selenocysteine as the major seleno-compounds).

To sum up, the mushrooms' fruitbody identified until now are seleno-compounds such as selenocysteine, selenomethionine, Se-methylselenocysteine, or selenite and the presence of several unidentified seleno-compounds were confirmed or indicated, while their proportions varied.

8. IMPACT OF COOKING ON SELENIUM CONTENT OF MUSHROOMS

In some surveys, the authors found water-soluble seleno-compounds in mushrooms (57, 59–61, 63). Even breakage of the major seleno-compound to several constituents after hot water extraction of cultivated Champignon Mushroom (at 85 °C) occurs (63). Probably depending on the local gourmet tradition worldwide, there are various dishes or cooking receipts that require initial mushroom boiling. Mushrooms frequently have to be blanched (boiling water treated usually for up to 5 min.) before further use as a meal ingredient. Nevertheless, blanching is not necessary for Champignon Mushroom, the caps of Parasol Mushroom (*M. procera*), or Saffron Milk Cap (*Lactarius deliciosus*) dishes because they are cooked (roasted) directly while eating raw, unprocessed (fresh) mushrooms must be avoided. Dried, whole or crushed, the fruiting bodies of some mushroom species (e.g., of the genus *Boletus*, *Xerocomus* or *Leccinum*) could be added to a dish directly or together with water macerate (e.g., when cooking traditional dish named "bigos" in Poland). Mushrooms dried and further powdered are also used as ingredients to make sauces.

There are only two studies reporting on the impact of boiling selenium content of mushrooms. Complete mushroom caps (probably of the Champignon Mushroom) after being boiled for 20 min. with distilled water leaked 44% of originally present selenium (total Se content between and after experiment was 1.3–1.5 and 0.76–0.79 μg Se/g dw, respectively) (64). In Finland, *Lactarius* mushrooms are eaten in considerable amounts, after boiling. During the boiling, the mean selenium content of *Lactarius torminosus* decreased by 32% (53).

9. SELENIUM BIOAVAILABILITY FROM THE MUSHROOM MEAL

It is well known that chemical forms of an element as the major factor but also other dietary factors have an impact on the element's bioavailability from food as well as their biological role.

In two earlier studies, selenium compounds contained in mushrooms were poorly bioavailable to man and rat (66, 67). Female university students aged 20 to 35 years were supplemented daily with 150 μg selenium per person given as mushroom (a roll with 5.95 g of dried King Bolete taken with a meal) during 28 days. They had slightly (13%) enhanced the plasma selenium concentration and significantly (26%) enhanced erythrocyte selenium concentration. By the criteria of plasma selenium concentration, the bioavailability of selenium from King Bolete was considered weak (66).

Selenium-enriched Champignon Mushroom (53 μg Se/g dw) fed to rats significantly increased both liver and mammary glutathione *S*-transferase activity and significantly reduced the occurrence of 7,12-dimethylbenz(*a*)anthracene (DMBA) induced mammary epithelial cell DNA adducts (anti-3,4-dihydrodiol-1,2-epoxide-DMBA-deoxyguanosine adducts). The authors suggested that Se-enriched mushrooms may be used as an effective method to retard chemically induced tumors (53).

10. CONCLUSIONS

Most of nearly 190 species of wild-grown or cultivated edible mushrooms collected worldwide and examined until now for selenium are poor in Se; most of them contain less than 1 μg Se/g dw in caps or whole fruiting bodies. The Goat's Foot (*Albatrellus pes-caprae*), which contains $\sim$ 200 μg Se/g dw on average (up to 370 μg/g dw), could be considered to be an especially rich source of Se; however, it is one of the many unpopular species of very limited or negligible culinary use or significance. The same criterion largely applies to several other mushroom species of the genus *Albatrellus*.

Boletus edulis (King Bolete) and closely related species such as *B. pinicola, B. aereus*, *B. aestivalis*, *B. erythropus*, and *B. appendiculus* are some of the more popular and abundant species that are relatively rich in selenium and may represent the most important source of this element to humans from wild mushrooms. A few other wild-grown mushroom species of the genus *Agaricus*, *Amanita*, *Macrolepiota,* or *Lycoperdon* can also contain selenium at elevated concentrations ($\sim$5-$\sim$20 μg Se/g dw), but they are much less valued when compared with *Boletus spp*. because of their limited and local significance as gourmet.

Of the cultivated mushrooms, species such as Champignon Mushroom or Varnished Polypore can be enriched in selenium when grown on selenium fortified (as inorganic salt or selenized-yeast) substrate, but their commercial and nutritional/medical significance is unknown.

The seleno-compounds identified until now in edible, wild-grown and selenium-enriched cultivated mushrooms are selenocysteine, selenomethionine, Se-methylselenocysteine, or selenite, and several unidentified seleno-compounds; their proportions vary widely. There is a scarcity of knowledge on the impact of mushroom cooking and traditional preserving (drying, salting, pickling) on selenium behavior as well as its availability and significance as a source of this element from mushroom meals to humans.

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