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A Survey of Heavy Metal and Organochlorine Pesticide Contaminations in Commercial Lingzhi Products

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ABSTRACT

One of the major problems in the use Chinese herbal medicinal (CM) products is product safety. Alarm has been heightened internationally in recent years on the contamination of CM products by heavy metals or toxic contaminants such as pesticide residues. In this study, the levels of several representative toxic elements including lead (Pb), arsenic (As), mercury (Hg) and cadmium (Cd), and the contents of several common organochlorine pesticides in Lingzhi (*Ganoderma lucidum*) samples purchased commercially in China and Southeast Asia were determined. Of the 36 samples analyzed, the As in about one third, and Cd in more than one half of the samples were found to contain metal concentrations exceeding their respective allowable limits in China and the U.S. Pesticides are less of a problem. Among 7 of the 36 samples randomly selected, none of them was contaminated with pesticides exceeding the allowable limit. The metal results suggest that the quality and safety of CM products have to be critically assessed before the products can be put in clinical trials or placed on the market. Both GAP and GMP guidelines are strongly recommended to ensure the production of quality and contamination-free CM products.

Key words: Lingzhi, heavy metal, pesticide residue, good agriculture practice (GAP), good manufacturing practice (GMP)

INTRODUCTION

Recently, there is a burst of enthusiasm for the study of Chinese herbal medicine (CM) because of their therapeutic effects, which are often complementary to those of western drugs. One of the major problems in marketing CM product is the contamination of CM herbal products by toxic metals and pesticide residues. The presence of these contaminants in some commercial samples has severely damaged the overall image of CM products[1-3]. In China, the issue is being treated as a top priority item in the modernization of CM industries. Similar situation exists in Europe and the U.S. In 1994, the U.S. Congress passed the Dietary Supplement Health and Education Act (DSHEA) that amended the U.S. Federal Food, Drug, and Cosmetic ACT (FFDCA). Based on DSHEA, a dietary supplement is considered unsafe if it presents a significant or unreasonable risk of illness or injury under conditions of use recommended or suggested in labeling. Since then, there has been an accelerated growth of the dietary supplements and functional foods market in the US and other countries.

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The two basic elements of CM quality are therapeutic efficacy and health safety. Health safety includes quality control and assurance of the herbal plants, scientifically quantified pharmacological effects, the minimization of external contaminations, and the elimination of possible adverse effects, such as the induction of herb-drug interactions[4]. To ensure the safety of herbal products, the first line of defense is to adopt good agriculture practice (GAP) guidelines in order to produce high quality and contamination-free raw herbal plants[5]. For the quality assurance of herbal dietary supplements, the original herbs containing excessive levels of pesticides should not be allowed to prepare downstream herbal products[4].

According to the "Shen Nong's Herbal Classic", a more than 2000-year old Chinese medicinal book, Língzhi (*Ganoderma lucidum*) belongs to a superior class of herbal medicines. The meaning of *Lingzhi* in Chinese is "herb of spiritual potency". It is widely used by people in the Orient because of its reported effects of strengthening the immune system, promoting blood circulation, reducing fatigue, and preventing pre-mature aging. Lingzhi contains polysaccharide G009, which has demonstrated antioxidant behavior against HL-60 cells *in vitro* and dose-dependent inhibition of lipid peroxidation in rat brain cells *in vitro*[6,7]. The studies of polysaccharides, terpenes, and other bioactive compounds in Lingzhi extract reported that Lingzhi exhibits purported anti-tumor and immunomodulating activities[6,8-12].

In this paper, results obtained from a survey program conducted in 2000 are presented. The commercial samples were purchased from the open market in China and Hong Kong. The objective of this paper is to discuss analytical method development, and to give the readers a general overview of the quality of commercial lingzhi products in China and Hong Kong. The source and identities of the samples are not listed to avoid regulatory implications.

Table 1. The precision, limit of detection and analytical recovery of the ICP-MS method

Element	RSD%[a]	Limit of detection[b] (ng/mL)	Recovery (%)[c]
As	2	0.09	94.7
Cd	8	0.07	105
Pb	7	0.1	90.6
Hg	3	10	97.9

[a]2% HNO_3 blank solution measured 11 times.
[b]Limit of detections was calculated based on 3 times of standard deviation of the blank solution measurement.
[c]Recovery based on reference material Apple Leaves, NIST SRM 1515.

MATERIALS AND METHODS

A total of 36 Lingzhi commercial samples, either in capsule or tablet form, were purchased in open market in China and Hong Kong. Individual capsules or tablets of each sample were combined, homogenized and stored at room temperature in the dark before analysis. The contents in capsule samples were individually emptied into a container and the combined powder samples re-homogenized by a mechanical shaker. The tablet samples were mixed, ground in a mortar and then homogenized. Original powder samples packaged in bags or boxes were also combined and re-homogenized. Each homogenized sample was re-assigned by a sequential numerical code.

I. *Metal Determination by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)*

Four elements: arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg) were determined in each sample by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS, Model Elan 6100, Perkin Elmer), after microwave acid digestion and acid dissolution. The arsenic, cadmium, mercury, and lead standard solution were supplied by BDH spectrosol.

For analysis of As, Pb, and Cd elements, 0.2 to 0.5 g of each Lingzhi sample was digested with 0.5 mL conc. H_2SO_4 and 5 mL HNO_3 by microwave oven digester (MDS-2000, CEM) for 2 hr. The digest was cooled down and diluted to 50 mL in a volumetric flask. The final solution was analyzed by ICP-MS. For analysis of Hg, 10-30 mg of dry sample was weighted into a specific sample cell. At 800°C, the sample was pyrolyzed and the content of Hg in the sample was swept into a Hg analyzer and determined by atomic absorption.

ICP-MS, Elan 6100 spectrometer (Perkin Elmer) was used for As, Cd and Pb determination, with the conditions: forward power, 1.0 kW; vacuum pressure, 1.8×10^{-6}; nebulizer flow rate, 0.99 L/min; lens voltage, 5.5 V; analog voltage, -2374.22 V; pulse stage voltage, 1350 V; dual detector, sweep/reading, 3, reading/replicate, 1, dwell time, 100 ms, and integration time, 100 ms. A Mercury Analyzer (LumexRA-915+) was used for Hg determination under a pyrolysis temperatureof 800°C, with air flow rate of 2 L/min and using an absorption cell length of 10 m.

The recovery experiment was carried out using the Reference material of Apple leaves (NIST SRM 1515). The certified values were: As, 380 ng/g; Cd, 14 ng/g; Pb, 470 ng/g, and Hg, 44 ng/g, respectively. Standard addition method was used in the experiment.

The precision was established by duplicate runs involving different operators and different ICP/MS instruments for the same batch of samples. The Limit of Detection (LOD) was determined based on 3 times of standard deviation running a matrix blank, a CM sample containing none of the studied metals.

II. *Organochlorine Pescides by GC-ECD*

The presence of organochlorine pesticides (OCPs) in Lingzhi samples was analyzed by a procedure involving sample extraction, organochlorine pesticide fraction isolation, and finally GC-ECD analysis on a HP6890 GC system. Briefly, 1 g of selected Lingzhi sample was extracted by a solvent mixture of 20% acetone in petroleum ether (v/v) in an Accelerated Solvent Extractor, ASE200 (Dionex). The extract was concentrated to 1 mL and applied to florisil SPE column for cleanup. The OCPs were eluted with 12 mL 5% ethyl ether in petroleum ether (v/v), and the eluant was concentrated to 1 mL by a stream of nitrogen and injected into GC.

The recovery and LOD of the method for each organochlorine pesticide are summarized in Table 2. Two procedures are compared in recovery experiments: one involved the use of reagent blanks spiked with known organochlorine pesticide standards, and the other involved the use of standards spiked in real Lingzhi samples. The second procedure involved five different runs, each with a different Lingzhi sample. Overall reasonably satisfactory recovery results (70-130%) were observed for the pesticides studied.

Table 2. Percentage of recovery, limit of detection and precision of organochlorine pesticides determined by GC-ECD method

Organochlorine pesticides	%Recovery using standard spiked reagent blank	%Recovery using standard spiked in real Lingzhi samples; range of five runs	Limit of detection (ng/g)	RSD, % (n = 6 or 7*)
1. Gamma-BHC	78	64-115	0.6	17.6
2. Heptachlor	103	90-132	0.8	12.2
3. Aldrin	68	55-84	0.2	14.5
4. Heptachlor Epoxide Isomer B(IS)	68	59-74	--	13.4
5. 4,4'-DDE	70	53-73	0.2	6.5
6. Dieldrin	70	61-81	0.2	11.9
7. o,p-DDD	70	65-73	0.1	6.3
8. Endrin	115	103-131	1.3	16.1
9. P,p'-DDD	86	61-107	0.2	14.9
10. 4,4'-DDT	99	76-160	1.7	16.8
11. Methoxychlor	104	102-196	0.9	11.9
Mean	85	74-104	----	

III. *Determination of Polysaccharides in Lingzhi Samples*

Total polysaccharides were determined by the published procedures with slight modification[13]. Briefly, 1 to 2 g of each Lingzhi sample was extracted in 2 × 10 mL water at 60°C in a shaker bath for 1 hr. The extract was centrifuged at 9000 rpm for 10 min and residue is discarded. One milliliter of the supernatant was washed with 20, 10, 10 mL of 95% ethanol sequentially and centrifuged at 3000 rpm for 20 min. The ethanol fraction was discarded and the residue was dried by a stream of nitrogen gas. One milliliter of 6M HCl was added to the residue and boiled for 30 min. The acidic solution was then adjusted to neutral pH by NaOH and diluted to appropriate volume with deionized water. One milliliter of the solution was boiled with 1 mL 3,5-dinitro-salicylic acid for 5 min. The mixture was cooled down quickly and appropriate dilution was made to fit calibration curve for UV absorbance measurement (UV/Vis Spectrophotometer, U-2001, Hitachi). For a control sample, the above procedures were repeated except that 1 mL 6 M HCl used above was replaced by 1 mL deionized water.

IV. *Analysis of Lingzhi Capsule Samples*

The capsules were cleaned with de-ionized water and naturally dried. For each of the cleaned capsule samples, 0.2 g of the individual sample was weighted and transferred into a 50-mL glass volumetric flask and dissolved with 5% HNO_3 in the flask with continuous shaking. After the sample was completely dissolved the sample was diluted with deionized water to the final volume for analysis. The contents of heavy metals contained in the capsules were determined with ICP-MS (HP 4500, series 300). The instrument operating conditions were as follows: forward power, 1.2 kW; reflected power, < 3 W; coolant gas flow rate, 15 L/min; auxiliary gas flow rate, 1.0 L/min; carrier gas flow rate, 1.13 L/min; sample depth/mm, 7.3 mm; integration time, 0.9 sec; solution uptake rate, 0.5 mL/min; and spray chamber temperature, 2°C.

The limit of detections was determined by 3 times of standard deviation of blank runs, and the concentration based LODs were then converted to dry solid sample based ones. The results were: As, 23 ng/g; Cd, 3 ng/g; Hg, 18 ng/g; and Pb, 28 ng/g.

The capsule material was identified as agar material based on FTIR analysis. In the procedure, 0.1g of dry sample was dissolved with distilled water in a glass plate. Then the sample was dried with IR light. Some dry sample powder was taken to make a sample disc with KBr. IR spectral analysis was conducted with Nicolet FIR spectrometer. The sample was scanned in the wavelength range of 400-4000cm^{-1}. Two characteristic peaks of 1654.3 and 1654.16 were identified as amide compounds. The band of 1082.01 cm^{-1} was characterized as the vibration band of C-O bending and the band at 3400.49 cm^{-1} was identified as NH(-NH-, NH_2) vibration band, indicative of agar material.

RESULTS AND DISCUSSION

I. *Levels of Toxic Heavy Metalts in Lingzhi Products*

The contents of the four toxic heavy metals: arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg) in the 36 Lingzhi commercial products are listed Table 3.

The permitted levels of heavy metals in Chinese herbal medicines set in different countries are different. As shown in Table 4, the permitted levels set by Hong

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Table 3. Concentrations of As, Cd, Pb and Hg in Lingzhi products (ng/g)

Element	As		Cd		Pb		Hg*	
Sample code	Mean of duplicate runs	Relative error (%)	Mean	Relative error (%)	Mean	Relative error (%)	Mean	Relative error (%)
1	1262	5.4	20.60	71.9	396	22.4	< LOD	
2	1119	80.2	223.3[a]	67.2	2146	4.3	373.2	16.9
3	1339	2.8	73.29	12.8	832.6	28.9	52.17	43.5
4	< LOD		106.4[a]	3.4	956.9	1.3	28.29	55.9
5	3737[a]	32.5	115.8[a]	4.8	< LOD		118.8	59.3
6	3250[a]	4	70.07	13.4	368.1	38.6	< LOD	
7	< LOD		25.14	17.5	103.3	37.9	< LOD	
8	701	48.8	< LOD		< LOD		< LOD	
9	1862[a]	11	80.22	1.9	2216	4.2	152.2	16.7
10	668	48.8	118.4[a]	7.4	4382	13.3	< LOD	
11	< LOD		< LOD		111.7	88.9	< LOD	
12	< LOD		469.6[a]	0.1	1509	14.2	< LOD	
13	2.63e5 [a]	7.7	74.86	28.1	2350	4.4	2897	
14	447.9	31.7	54.10	35.4	339.9	12.2	310.9	80.5
15	547.8	19.3	142.2[a]	8.9	1407	0.1	< LOD	
16	1437	44.5	43.23	19.9	388.6	35.6	183.9	1.6
17	3497[a]	13.6	110.5[a]	1.4	422.8	19.9	24.34	10.2
18	129.2	11.7	11.11	11.7	364.1	8.1	< LOD	
19	2287[a]	1.4	506.6[a]	1.2	796.5	11.4	18.16	59.9
20	263.7	4.4	293.3[a]	8.6	439.5	19.8	< LOD	
21	< LOD		121.1[a]	20.8	33.98	4.0	< LOD	
22	< LOD		< LOD		117.1	15.2	120.6	25.4
23	524.3	6.4	141.4[a]	47.2	618.8	39.0	< LOD	
24	250.5	19.5	143.4[a]	18.5	370.8	60.5	< LOD	
25	549.7	17.5	162.7[a]	7.5	848.1	19.1	< LOD	
26	828.8	8.9	18.10	78	44.75	97	< LOD	
27	2725[a]	55.2	< LOD		816.9	4.9	120.0	18
28	1308	5.9	< LOD		1467	14.3	< LOD	
29	2430[a]	7.1	< LOD		185.1	50.7	< LOD	
30	2671[a]	2.1	164.0[a]	21.6	956.1	0.8	< LOD	
31	549.0	12.3	191.7[a]	7.4	463.9	6.5	< LOD	
32	1662[a]	2.8	224.9[a]	1.4	1626	0.5	17.00	15.2
33	1290	3.9	223.3[a]	24.9	432.1	3.9	40.19	7.2
34	369.1	16.1	247.1[a]	18.8	352.9	61	< LOD	
35	1302	4.3	88.26	11.0	2339	39.7	57.29	29.4
36	338.5	1.4	152.7[a]	23.1	486.4	69.2	13.18	14.0
37	1792[a]	2.0	295.0[a]	4.3	2663	17.7	27.19	20.6
38		17.2		19.3		24.8		27.9
39		19.5		20.7		25.3		23.0

[a]Represent the toxic element concentration exceeds the allowed limit in China or USA (see Table 7).
[b]Mean error % = 24.22 ± 7.64 for the four elements tested.

Kong and China are more restricted than United States and WHO, and the permitted levels set by Singapore requests are the highest.

As shown by Table 3, of the four trace elements analyzed, As and Cd are the two having more problems. Among the 36 samples analyzed, the As level in about one third of the sample exceeds the limit listed in Table 4, and the Cd level in more than one half of the samples exceeds the limits, sometimes by large margin. Both Hg and Pb, however, are having concentration levels within the allowable limits.

II. *Organochlorine Pescides in Selected Samples*

Seven of the Lingzhi samples were analyzed for organochlorine pescides and the results are presented in

Table 4. Permitted levels of heavy metals in Chinese herbal medicines set in different countries

Substance	Hong Kong[18]	China[19]	USA[20]	WHO[21]	BP[22]	Singapore (Pharmacopeia)
As	2.0	2.0	5.0		5.0	5.0
Cd	0.3	0.3	0.3	0.3		5.0
Pb	5.0	5.0	10.0	10.0	5.0	20.0
Hg	0.2	0.2	0.2			0.5

Units: ppm. As: Arsenic; Cd: Cadmium; Pb: Lead; Hg: Mercury; BP: British Pharmacopoeia; CP: Chinese Pharmacopoeia.

Table 5. Organochlorine pesticides found in Lingzhi samples (ng/g)

OCPs	1	8	12	14	21	29	35
Gamma-BHC	ND	ND	2.28	7.09	ND	ND	ND
Heptachlor	ND	ND	ND	ND	ND	ND	ND
Aldrin	ND	ND	ND	ND	ND	ND	ND
4.4'-DDE	ND	ND	ND	ND	ND	36.46	ND
Dieldrin	ND	ND	ND	ND	ND	ND	ND
o,p-DDD	ND	ND	ND	ND	ND	4.54	ND
Endrin	ND	ND	ND	ND	ND	12.06	ND
p.p'-DDD	ND	ND	ND	ND	ND	8.96	ND
4.4'-DDT	ND	ND	ND	3.79	ND	ND	ND
Methoxychlor	ND	ND	ND	ND	ND	ND	ND

ND: not detected.

Table 6. Permitted levels of pesticides in Chinese herbal medicines set in different countries

Substance	Hong Kong[18]	China[19]	USA[20]	European Union[21]	Japan[22]	Korea[23]
Hexachlorocyclohexane (αβδ)	0.30	0.20	0.01	0.30	0.20	0.01
Alachlor				0.02		
Aldrin	0.05		0.01	0.05		0.01
Dieldrin	0.05		0.01	0.05		0.01
DDT (sum of p,p'-DDT, o,p'-DDT, p,p'-DDE and p,p'-TDE)	1.00			1.00	0.02	0.01
Heptachlor (sum of heptachlor and heptachlor epoxide)	0.05			0.05		
Hexachlorobenzene	0.10		0.01	0.10		
Lindane (γ-Hexachlorocyclohexane)	0.60		0.01	0.60		
Malathion				1.00	1.00	
Methidathion				0.20	0.02	

Units: ppm. CP: Chinese Pharmacopoeia; EP: European Pharmacopoeia; JP: Japanese Pharmacopoeia.

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Table 7. Total polysaccharide in Lingzhi (weight %)

Sample no	Wt % polysaccharide (run 1)	Wt % polysaccharide (run 2)	Mean (wt %)	((1)-(2) / mean) × 100%
1	8.78	9.93	9.36	12.28
2	6.45	5.96	6.20	7.9
3	3.28	3.85	3.57	15.97
4	0.26	0.23	0.25	12.0
5	2.30	2.64	2.47	13.77
6	2.21	2.64	2.43	17.69
7	3.19	3.57	3.38	11.24
8	2.05	1.86	1.95	9.74
9	5.72	7.02	6.37	20.41
10	10.10	9.55	9.82	5.60
11	10.39	10.76	10.58	3.50
12	10.20	8.11	9.15	22.84
13	9.52	10.98	10.25	14.24
14	3.54	3.70	3.62	4.42
15	10.01	11.02	10.52	9.60
16	3.63	3.39	3.51	6.84
17	25.98	26.98	26.48	3.78
18	0.06	0.07	0.06	16.67
19	9.41	8.81	9.11	6.59
20	27.97	31.35	29.66	11.39
21	4.74	4.10	4.42	14.48
22	1.78	2.23	2.00	22.50
23	5.44	5.55	5.49	2.00
24	4.46	4.66	4.56	4.39
25	22.52	19.60	21.06	13.87
26	10.35	11.35	10.85	9.22
27	2.64	1.95	2.30	30.00
28	1.49	1.37	1.43	8.39
29	6.57	5.78	6.17	12.80
30(s)	5.65	5.65	5.65	0
31(s)	6.25	5.25	5.75	17.39
32(s)	0.58	0.41	0.49	34.69
33(s)	0.05	0.07	0.06	33.3
34(s)	0.15	-------- *	0.15	0
35(s)	1.72	2.21	1.96	25.0
36(s)	0.14	0.16	0.15	13.33
				13.15
				8.64

*Due to insufficient sample, only one determination was obtained.

Table 5. Three of the samples were found to contain low levels of Gamma-BHC, 4.4'-DDE, o,p-DDD, p.p'-DDD and 4.4'-DDT, as shown in the Table. The other organochlorine pesticides were not detected in these three samples; and none of the 10 organochlorine pesticides were found in any of the other samples. These negative findings are all labelled as ND (not detected) in the table. Of the seven samples, only one of them showed significant contamination problems (sample 29). Among the pesticides tested, the DDT series and Gamma-BHC are the ones most frequently observed. This pattern is consistent with the findings commonly reported for pesticides in soil. The concentrations of pesticides found in the survey samples are in general below the allowable limits set by different countries (Table 6).

III. *Quality Evaluation Based on Polysaccharides Content*

Lingzhi contains a complex mixture of chemicals including polysaccharides, triterpenoids, and a variety of proteins, peptides, amino acids, etc. Furthermore, commercial Lingzhi products are derived from different Lingzhi plant species, and thus precise assessment of the purity of Lingzhi would be impossible without the availability of detailed information regarding the source and manufacturing process of the products, which is lacking in our study. In this survey, the content of polysaccharides in the samples are compared since the component is listed in Chinese Pharmacopoeia as the indicator active ingredient in Lingzhi, and many manufacturers claim the efficacy of their products by labeling the polysaccharides content. The results are summarized in Table 7. As the results show, the polysaccharide contents of these samples vary over a wide range from less than 0.1% to about 30%. Such variation in product properties reflect the serious problem of lacking of standardization in product quality. In recent years, herbal quality evaluation based on the quantitative determination of marker species or compositional fingerprinting is beginning to attract increasing attention, as exemplified in a recent article on Lingzhi(14).

IV. *Harmful Substances in Selected Capsule Samples*

The capsule samples were randomly selected from the Lingzhi samples. After emptying the content, the capsules were rinsed with cold water. Extensive rinsing was avoided because it would dissolve the capsule material. Two capsule samples were found to be made of primarily agar material. One of the samples, for instance, is positively identified as corn protein by IR spectral matching.

The heavy metals in capsule samples were analyzed by ICP-MS after sample dissolution with dilute HNO_3 acid. Results from the analysis are tabulated below in Table 8. Substantial amounts of As were found in two of the samples 13 and 36, while Pb was found in sample 13. Comparing with the Linzhi samples shown in Table 3, those samples with high As and Pb contents in the capsule material are also high in Lingzhi samples themselves. Thus, possibility exists that the two metals found in capsule were actually metals in residue Lingzhi powders attached to the capsule wall which were not washed away completely during water rinsing. For practical purposes, it can be concluded that both the capsule and Linzhi material in these samples are high in As and Pb contents.

Chan and Lo[15] analyzed the heavy metals As, Cd, Hg, and Pb in Lingzhi plant materials by ICP-AES and ICP-MS after microwave digestion. They demonstrated that the lowest limits of detection for major and trace elements are in the range of hundreds of ppt to sub-ppt levels, comparable to ours. Our study surveyed only 10 of the common pesticides while provides no information on other possible pesticide types. For instance, Leung *et al.*[16] recently found that all the ten batches of Radix notoginseng samples contained quintozene (pentachloronitrobenzene), an organochlorine pesticide. In the same year (2005), the U.S. issued a warning to people who may have used imported ginseng products under the Federal Food, Drug, and Cosmetic Act because these products contained the pesticides procymidone and quintozene. The U.S. FDA had not established maximum amount of residues allowed (tolerance) for these pesticides in ginseng. The FDA sets that “A raw agricultural commodity or processed food or feed is deemed to be unsafe and adulterated if a pesticide chemical residue for which no tolerance has been set at present”[17]. As such, it is important the growers should not use any pesticides that the allowance has not been established for the herbs.

The data discussed in this paper are taken from a survey carried out in 2000. It is worthwhile to compare them with more recent Lingzhi data as shown in Table 9. These samples were purchased commercially in China in 2005. The metal data for these samples fall in general in the low end of the distributions as observed in the 2000 survey.

One point should be made about the problem of metal contamination in CM herbs. Metal exists in CM drugs in different chemical forms, which often differ drastically in biological interaction and toxicity. For instance, of the various forms of arsenic, inorganic AsIII and AsV are considered the most toxic. The methylated forms of organic As such as mono- and di-methyl as are less toxic, whereas the metabolite arsenobetaine is innocuous. Thus, the speciation of metals in CMM is just as important as the determination of total quantities, and the banning of products based solely on total metal contents without considering their specific chemical forms is scientifically unfounded and misleading. The speciation of metals is an important area of interest in the CM community, and many reviews on the subject can be found in recent reports[5].

Table 8. Toxic elements contents in Linzhi capsule samples determined by ICP-MS(ng/g)

Sample no.	As	Cd	Hg	Pb
6	<LOD	<LOD	<LOD	<LOD
13	169.9	<LOD	<LOD	65.0
27	<LOD	<LOD	<LOD	<LOD
36	459.6	<LOD	<LOD	<LOD

Table 9. The contents of toxic elements in Lingzhi (*Ganoderma lucidum*) *powder and Lingzhi* sporule samples ($ng \cdot g^{-1}$) — survey data in 2005[16]

	Pb	Cd	Hg	As	Polysaccharides
1	479	259	29	518	0.53
2	170	304	41	433	0.50
3	192	375	38	149	1.14
4	505	373	44	274	1.09
5	392	377	43	252	1.45

CONCLUSIONS

The study showed that the contamination of commercial Lingzhi samples by trace toxic elements and pesticide residues is a problem requiring continuing attention. Both GAP and GMP guidelines are strongly recommended to ensure the production of quality and contamination-free CM products. An organized effort with international participation on the subject should be actively pursued to ensure the safety of commercial herbal plants and their derived products such as herbal dietary supplements.

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