Occurrence of 8 trace elements in *Rhizoma Cibotii* from China and exposure assessment

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Abstract

The contamination of trace elements in Chinese edible herbs has attracted a worldwide concern. In this study, the occurrence and quantitative analysis of 8 trace elements in *Rhizoma Cibotii* were investigated. Results demonstrated that the trace elements of Cr, Ni, Cu, Zn and Pb were detected in all analyzed samples, the occurrence frequencies of As, Se and Cd were 98.3%, 96.6% and 98.3%, respectively. The highest mean levels was found in Zn (17.32 mg/kg), followed by Pb (8.50 mg/kg) and Cu (3.51 mg/kg). Based on their contamination levels, the mean exposure of individual elements was estimated. The calculated HQ values were less than 1, indicating that the contamination of trace elements in *Rhizoma Cibotii* did not pose significant health risks to human. This study provides baseline information on trace elements in *Rhizoma Cibotii*, and it is necessary to monitor its trend in future for human health.

1. Introduction

Trace elements are essential for the normal development, growth, and physiology of an organism (Zhang 2017). Humans are exposed to trace elements in their daily lives from a variety of sources, such as water, air, food and medicines (Gaonkar et al. 2020; Pan and Wang 2012; Sadeghi et al. 2019; Zhou et al. 2014). At present, a variety of trace elements have been studied and detected in different fields, especially the investigation of trace elements in food has attracted more and more attention (Gupta et al. 2019; Latifi and Jalali 2018; Nordberg and Nordberg 2016). Among these trace elements, chromium (Cr), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), selenium (Se), cadmium (Cd) and lead (Pb), are all widely investigated in various foods (Batista et al. 2010; Iwegbue et al., 2010; Jiang et al. 2016; Jiao et al. 2018; Sadeghi et al. 2019). It is known that the exposure to As, Cd and Pb is very dangerous and may cause adverse effects in animals and humans (Bilandžić et al. 2010). On the other hand, Cr, Cu, Ni, Zn and Se are all essential elements for human body, which play important roles for maintenance of numerous physiological processes. However, they can also generate toxic effects at high concentrations (Bilandžić et al. 2010; Iwegbue et al. 2010). Thus, many organizations and countries have regulated maximum levels (MLs) of trace elements in foods with the aim to preserve consumer confidence and human health (Akbari et al. 2012; Li et al. 2018; Potorti et al. 2020).

Chinese edible herbs are closely associated with a rich history, civilization, and cuisine (Dong et al. 2016; Yang et al. 2018). They are broadly used for alleviating and treating various human diseases owing to their benefits to human health worldwide (Dong et al. 2016). However, the Chinese edible herbs may suffer from a few safety problems, such as the contamination of trace elements (Li et al. 2018; Yang et al. 2018). The pollution of soil with trace elements is the mainly source for the contamination of these herbs, which is caused by polluted irrigation, atmospheric dusts, industrial activity, pesticides and fertilizers residue (Tokaloğlu 2012). Therefore, Chinese edible herbs may possess high concentrations of various trace elements, which have a negative impact on human physiological health. Especially, the quantitative analysis of trace element concentrations play an important role in understanding the effectiveness of Chinese edible herbs in treating different diseases and exploring their pharmacological

action. So it is necessary to investigate the contamination concentrations of multiple trace elements in Chinese edible herbs and then to estimate the risk assessment of the consumers.

Inductively coupled plasma mass spectrometry (ICP-MS), emerging as an element-specific detector, shows the excellent advantages of wide linear range, high sensitivity and multiple elements detection ability. It has the ability to identify both major and trace elements in a sample at a single injection (Batista et al. 2010). Therefore, ICP-MS has been employed in simultaneous detection of multi-component trace elements in various foods (Milani et al. 2019; Potorti et al. 2020).

Rhizoma Cibotii, known as one of the Chinese edible herbs, is getting broad interest all over the world. It is the dried rhizome of *Cibotium barometz* (Linn.) J. Sm., which has a variety of therapeutic effects for human health. However, there is a lack of the information about trace elements in *Rhizoma Cibotii*. Therefore, the aim of the present study was firstly to determine the occurrence and contamination levels of 8 trace elements namely Cr, Ni, Cu, Zn, As, Se, Cd and Pb in *Rhizoma Cibotii* by ICP-MS. Then the estimated daily intake and potential health risks were performed by a combination of the contamination levels with the consumption data of *Rhizoma Cibotii* products.

2. Materials And Methods

2.1 Reagents and chemicals

A multi-element standard solution, with concentrations of 20.00 µg/mL Cr, Ni and Cu, 50.00 µg/mL for Zn, 10.00 µg/mL for As and Pb, and 5.00 µg/mL for Se and Cd, was purchased from Inorganic Ventures (Virginia, USA). Mixed internal standard solution (Sc, Rh, In, Bi) with the individual concentration of 1000 µg/mL was provided by the National Center for analysis and testing of non-ferrous metals and electronic materials (Beijing, China). In this study, the reagents used in this method are of superior purity unless otherwise specified. Nitric acid was obtained from Merck (Darmstadt, Germany). Ultrapure water (18.2 MΩ/cm) was produced by a Milli-Q purification water apparatus (Millipore Co., USA). ICP-MS tuning solution was purchased from Thermo Fisher Scientific (Bremen, Germany).

2.2 Sample preparation and analysis

In this study, 58 samples were collected from 11 sites (Provinces of Fujian, Guangxi, Jiangxi, Sichuan, Yunnan, Chongqing, Hunan, Hubei, Guangdong, Guizhou and Anhui) from June to October 2018. The quantitative analysis of trace elements was performed based on the previously reported method (Jiao et al. 2018). Briefly, the samples were digested using nitric acid in Teflon bombs. The obtained test solutions were determined by ICP-MS (Thermo iCAPQ, Bremen, Germany).

The working standard solutions, with concentrations range from 50 to 4000 ng/mL for Pb and Zn, from 0 to 400 ng/mL for Cr, Cd, Ni and Cu, from 0 to 50 ng/mL for As and Se, were prepared from suitable dilutions of the stock solutions, which were analysed in triplicate and the average was used.

2.3 Method validation

The data acquisition and analysis were processed with the Otegra™ Intelligent Scientific Data Solution™ software. The internal standard method was used for quantification. The method was validated by linearity, the limit of detection (LOD, S/N > 3) and quantification (LOQ, S/N > 10), accuracy and precision. Accuracy and precision were evaluated by recovery experiments at two different spiking levels (100 and 1000 ng/mL for Pb and Zn). The inter-day precision was accomplished by repeating experiments consecutively for three working days.

2.4 Risk assessment for human health

The dietary exposure assessment to trace elements from *Rhizoma Cibotii* consumption was investigated by the estimated daily intake (EDI), which was calculated using the following Equation

$$EDI = (C \times IR) / BW \quad (1)$$

Where C represents the mean element concentration in the *Rhizoma Cibotii* samples (mg/kg); IR is the daily ingestion amount of *Rhizoma Cibotii* for adults. BW is the mean human body weight (60 kg for adults) (Jiao et al. 2018).

The human risk assessment associated with *Rhizoma Cibotii* consumption was characterized by the hazard quotient (HQ), which was calculated according to the equation:

$$HQ = EDI / RfD \quad (2)$$

Where RfD is the reference dose (mg/kg/day) set by the United States Environmental Protection Agency. The RfD values for Cr, Ni, Cu, Zn, As, Se, Cd and Pb elements were 0.003, 0.020, 0.040, 0.300, 0.0003, 0.005, 0.001, 0.004 mg/kg bw/day respectively. The hazard risk can be divided into five levels according to the HQ value: not significant (HQ≤1), low (1<HQ<9.9), moderate (10<HQ<19.9), high (20<HQ<99), and serious (≥100) (Jiao et al. 2018).

2.5 Statistical analysis

The data were statistically analyzed by Excel and SPSS 16.0. One-way ANOVA was used for comparing the detection results, and P < 0.05 was considered a significant difference.

3. Results And Discussion

3.1 Method validation

The validation parameter of the ICP-MS method has been listed in Table 1. Good linearity was obtained for each trace element with the correlation coefficients (r^2) higher than 0.999. The values of LODs and

LOQs were 0.003-0.006mg/kg and 0.010-0.020mg/kg respectively. Accuracy was expressed as the recoveries, which ranged from 88.7% to 103%. The intra- and inter-day precision were expressed as the relative standard deviations (RSDs), which were ranged from 2.75% to 6.21%, and ranged from 3.29% to 7.95%, respectively. Obviously, the obtained results demonstrated that the proposed method was suitable for the determination of trace elements in *Rhizoma Cobotii* products.

3.2 Concentrations of trace elements in *Rhizoma Cobotii*

The concentrations of 8 trace elements in the 58 *Rhizoma Cobotii* samples were shown in Table 2. Briefly, Cr, Ni, Cu, Zn and Pb were detected in all analyzed samples, the occurrence frequencies of As, Se and Cd were 98.3%, 96.6% and 98.3%, respectively. The mean concentration of Cr, Ni, Cu, Zn, As, Se, Cd, and Pb elements were 1.92, 1.75, 3.51, 17.32, 0.06, 0.18, 0.09, 8.50 mg/kg, respectively, which were decreasing in the order of Zn, Pb, Cu, Cr, Ni, Se, Cd and As. This order of trace elements level, except for Pb, was a little similar with the levels in the other Chinese medicine Cortex Moutan reported by Li et al. (2018), which in the order of Zn, Cu, Pb, Cr and Cd. Among 58 test samples, there were 43 sand-scorch *Rhizoma Cobotii* and 15 raw *Rhizoma Cobotii* samples. The sand-scorch *Rhizoma Cobotii* is a processed product of *Rhizoma Cobotii* according to the sand-scorch method. The contamination levels of the target trace elements between the sand-scorch *Rhizoma Cobotii* and the raw *Rhizoma Cobotii* were compared in Table 3, which shown no significant differences among the various *Rhizoma Cobotii* products ($p>0.05$).

The data showed that Zn was the most abundant trace element in the *Rhizoma Cobotii* analyzed. The concentrations ranged from 5.59 to 350.82 mg/kg with a mean level of 17.32 mg/kg. The results were compared with those in published studies. The concentrations of Zn in the medicinal herb samples widely consumed in Kayseri (Turkey) have been measured, which ranged from 3.75 to 88.0 mg/kg with a mean level of 32.5 mg/kg (Tokalioğlu 2012). Zn is an important essential element, which can act on protein synthesis and gene expression (Batista et al. 2010). However, if the concentration higher than 10 mg/kg, Zn acts as a toxic metal element (Kohzadi et al. 2019). The permissible limit in edible plants set by the Food and Agriculture Organization of the United Nations and World Health Organization (FAO/WHO) is 27.4 mg/kg (Kohzadi et al. 2019), and 3 samples out of the total 58 *Rhizoma Cobotii* samples exceeded the limit.

Pb was the second abundant trace element. The concentrations ranged from 2.22 to 27.70 mg/kg and the mean level was 8.50 mg/kg. Pb is a toxic heavy metal element that occurs naturally in the environment. Pb has adverse health effects including neurotoxicity, nephrotoxicity, and cardiovascular toxicity (Jiao et al. 2018). Various countries and organizations have set the maximum limits of Pb for herbal medicine. In China, the United States, and the European Union, the ML value of Pb in herbal medicine is 5 mg/kg. The International Organization for Standardization (ISO) and WHO set a ML of 10 mg/kg (Li et al. 2018). Compared with these ML values, 48 *Rhizoma Cobotii* samples out of the total 58 samples (82.8%) exceeded the ML of 5 mg/kg and 14 samples exceeded the ML of 10 mg/kg, which indicated that the Pb contamination in *Rhizoma Cobotii* products is a serious problem and should be given more attention.

The concentrations of Cu were in the range of 2.59-5.16 mg/kg with the mean level of 3.51 mg/kg. The data was compared with other published studies. In 35 *Epimedium* samples collected from 30 provinces, autonomous regions, and municipalities of China, the highest Cu level was found in a sample from Hunan province (661.04 mg/kg) and the lowest was found from Yunnan province (8.59 mg/kg) (Yang et al. 2018). The results were much higher than those in present study. Cu is an essential element in trace amounts, but it is toxic in an excessive amount. Excess Cu can accelerate lipid peroxidation and exhaust the glutathione, leading to the organism more vulnerable (Jiao et al. 2018). The Ministry of Foreign Trade and Economic Cooperation of China (MFTEC) have set the Cu-allowable concentration at 20 mg/kg for herbal medicine (Li et al. 2018). It was obvious that all concentrations in 58 *Rhizoma Cibotii* samples were below the regulated value.

The Cr concentrations ranged from 0.44 to 4.90 mg/kg and the mean level was 1.92 mg/kg. Cr is an essential element for human physiological functions. Cr deficiency would increase the risk of cardiovascular disease, but its accumulation would lead to the blood glucose reduced, digestion system and cardiovascular system disorders (Kohzadi et al. 2019). For comparison, the mean concentration of Cr in 30 medicinal herb samples from Turkey was 2.59 mg/kg, which was similar to the value in the present study (Tokalioğlu 2012). Moreover, the Pharmacopoeia of China has set the permissible limit of 2.0 mg/kg for Cr in herbal medicine. Therefore, the concentrations in 23 *Rhizoma Cibotii* products (39.7%) exceeded the limit, indicating more attention should be given to control the contamination of Cr.

Ni is considered as an essential trace element. However, at higher concentrations, it can propose as a carcinogen affecting the lung and nasal cavities (Alhusban et al. 2019; Kohzadi et al. 2019). In this study, the concentrations of Ni were in the range of 0.37-3.92 mg/kg and the mean level was 1.75 mg/kg. Potorti et al. (2020) reported that the concentrations of Ni in different types of spices and herbs collected from Italy and Tunisia were varied from 0.165 mg/kg (detected in Laurel) to 0.834 mg/kg (detected in Thyme), which was lower than the results here.

The concentrations of Se were in the range of <0.02-4.25 mg/kg with the mean level of 0.18 mg/kg. Except that the concentrations in two products were 4.12 and 4.25 mg/kg, the results in the other 56 products were in the range of <0.02-0.08 mg/kg. These values were largely in agreement with the Se results in the medicinal and aromatic plants studied by Ozkutlu et al. (2011), which ranged between 0.01 and 1.13 mg/kg in the analyzed plants. Sheded et al. (2006) found the Se concentrations ranged from 0.058 to 0.600 mg/kg in seven medicinal plants in Egypt. Se is an essential trace element. However, excessive intake of Se can also cause poisoning, which indicated that Se is essential only in a narrow concentration range (Ozkutlu et al. 2011).

The range of Cd concentrations in 58 *Rhizoma Cibotii* products was <0.01-2.65 mg/kg and the mean concentration was 0.09 mg/kg. Cd has been classified as a human carcinogen by the International Agency for Research on Cancer (IARC) (Jiao et al. 2018). More pieces of evidence have indicated that Cd poisoning would lead to many diseases including osteopenia, anemia, kidney failure (a disease called Itai-itai) (Kohzadi et al. 2019). The permissible limit for Cd in medicinal herb set by China, the WHO, and

the USA National Sanitation Foundation International (NSFI) were 0.3 mg/kg (Li et al. 2018). Here, two samples exceeded the permissible limit, which should arouse more attention to the health of people.

The range of As levels among the total 58 *Rhizoma Cibotii* products was <0.01-0.19 mg/kg and the mean concentration was 0.06 mg/kg. Compared with the concentrations of As in *Epimedium* sample (ranged from 0.16 to 2.34 mg/kg), the data in this work was much lower (Yang et al. 2017). Besides, the results were also lower than those in Mediterranean edible herbs (ranged from 1.35-3.25 mg/kg) (Volpe et al. 2015). As was a toxicity element, which has been classified as carcinogenic to humans by IARC (Alhusban et al. 2019). According to the permissible limit of 5 mg/kg for As set by WHO, the concentrations in all analyzed samples were below the limit (Alhusban et al. 2019).

3.3 Variations of trace elements from different origin sites

To provide more information about the trace elements contamination of *Rhizoma Cibotii* in the Chinese market, 58 *Rhizoma Cibotii* products were classified by 11 different origin sites consisting of Fujian, Guangxi, Jiangxi, Sichuan, Yunnan, Chongqing, Hunan, Hubei, Guangdong, Guizhou and Anhui province in China. The concentrations of target trace elements in the products originated from various sites were summarized in Table 4, which shown that the mean concentrations ranged from 0.84 mg/kg (Chongqing) to 2.65 mg/kg (Anhui) for Cr, 0.59 mg/kg (Guangdong) to 2.02 mg/kg (Jiangxi) for Ni, 2.78 mg/kg (Guangdong) to 3.68 mg/kg (Hunan) for Cu, 9.22 mg/kg (Guangdong) to 83.39 mg/kg (Sichuan) for Zn, 0.033 mg/kg (Chongqing) to 0.190 mg/kg (Hubei) for As, 0.021 mg/kg (Chongqing) to 0.32 mg/kg (Guangxi) for Se, 0.02 mg/kg (Jiangxi) to 0.59 mg/kg (Sichuan) for Cd and 5.11 mg/kg (Anhui) to 24.02 mg/kg (Chongqing) for Pb, respectively. Notably, there is a large variety of concentrations of the trace elements among *Rhizoma Cibotii* products originated from different sites. For instance, the mean concentration of Cd among the samples from Sichuan was 29.5 times higher than that from Jiangxi. And the mean concentration of Zn from Sichuan was 9.0 times higher than that from Guangdong. The variation was possibly attributed to the different *Rhizoma Cibotii* species and the different growing environments in different origin sites.

The hierarchical cluster analysis was carried out based on the standardized by Z-score, between-groups linkage, and Euclidean distance, which was illustrated in a dendrogram (Fig 1). The results indicated that these 58 products from 11 different origin sites were divided into 3 classes when the average Euclidean distance is 5. Yunnan, Hubei, Guangxi, Fujian, Jiangxi, and Anhui province belong to the first class, Guangdong, Chongqing, and Guizhou province belong to the second class, Sichuan and Hunan province belong to the third class.

3.4 Risk assessment of trace elements for human health

This study estimated the intake of trace elements through the ingestion of *Rhizoma Cibotii*. Use the maximum consumption value of *Rhizoma Cibotii* based on The Chinese Pharmacopoeia to provide the “worst-case” (12 g/day) to estimate daily intake (Liu et al. 2018). As shown in Table 5, the highest estimated daily heavy metal intake was Zn (3.46 µg/kg bw/day), followed by Pb (1.70 µg/kg bw/day), Cu

(0.70 µg/kg bw/day), Cr (0.38 µg/kg bw/day), Ni (0.35 µg/kg bw/day), Se (0.036 µg/kg bw/day), Cd (0.018 µg/kg bw/day) and As (0.012 µg/kg bw/day). HQs of all trace elements were below 1, indicating that in this study, *Rhizoma Cobotii* may not pose a health risk to the human body due to consumption. The results were similar to those of previous study (Shen et al. 2017), which reported that EDI of Cu, Zn, Pb, and Cd was within the tolerable range during *Cortex Moutan* (Chinese edible herbs) consumption. Nan et al. (2020) reported that the mean daily intake level and target hazard quotient calculated by the total concentration of Pb in *Paeoniae Radix Rubra* and *Astragali Radix* was over safety standards, suggesting taking these Chinese edible herbs may pose potential health risks.

4. Conclusions

In conclusion, the occurrence and quantitative analysis of 8 trace elements was investigated in 58 *Rhizoma Cobotii* samples. The exposure assessment of these trace elements was assessed. The results showed that the contamination of trace elements in *Rhizoma Cobotii* caused low health risks, but additional and/or interactive effects might occur due to exposure to multiple contaminants. Therefore, it is necessary to monitor its trend in future for human health.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Zhijie Chu: Experiment, Data analysis, Writing - Original Draft. **Hongxia Xu:** Collected samples, Experiment, Writing - Original Draft. **Lijun Shao:** Collected samples, Validation. **Jin Li:** Collected samples, Data analysis. **Xiaolin Wang:** Experiment, Data analysis. **Yanni Jiao:** Software, Writing - Original Draft. **Dafeng Jiang:** Funding acquisition, Methodology, Writing-Reviewing, and Editing. **Peimin Yang:** Methodology, Writing- Reviewing, and Editing.

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Tables

Table 1. Validation parameters of ICP-MS method for the detection of multi-elements

Element	r^2	LOD (mg/kg)	LOQ (mg/kg)	Level 1 ^a			Level 2 ^b		
				Recovery (%)	Intra- RSD (%)	Inter- RSD (%)	Recovery (%)	Intra- RSD (%)	Inter- RSD (%)
Cr	0.9996	0.005	0.015	102	4.22	5.37	98.3	3.73	6.09
Ni	0.9997	0.003	0.010	96.7	5.38	5.72	99.3	4.47	5.28
Cu	0.9998	0.005	0.015	95.8	4.33	4.98	102	3.67	3.29
Zn	0.9991	0.006	0.020	88.7	5.48	4.96	90.9	5.34	4.67
As	0.9996	0.003	0.010	95.7	3.19	4.36	98.4	2.95	4.04
Se	0.9992	0.006	0.020	89.2	2.75	3.59	96.1	5.18	6.87
Cd	0.9994	0.003	0.010	99.4	5.48	5.14	103	3.62	4.83
Pb	0.9993	0.003	0.010	96.6	4.89	5.23	99.3	6.21	7.95

Level 1^a: 100 ng/mL for Pb and Zn; 10 ng/mL for Cr, Cd, Ni and Cu; 1 ng/mL for As and Se;

Level 2^a: 1000 ng/mL for Pb and Zn; 100 ng/mL for Cr, Cd, Ni and Cu; 10 ng/mL for As and Se.

Table 2. Contamination levels of trace elements in *Rhizoma Cibotii* products

Element	Occurrence/Total (%)	Contamination levels (mg/kg)		
		Maximum	Minimum	Mean
Cr	58/58 (100%)	4.90	0.44	1.92
Ni	58/58 (100%)	3.92	0.37	1.75
Cu	58/58 (100%)	5.16	2.59	3.51
Zn	58/58 (100%)	350.82	5.59	17.32
As	57/58 (98.3%)	0.19	< 0.01	0.06
Se	56/58 (96.6%)	4.25	< 0.02	0.18
Cd	57/58 (98.3%)	2.65	< 0.01	0.09
Pb	58/58 (100%)	27.70	2.22	8.50

Table 3. Mean concentrations of trace elements in different kinds of *Rhizoma Cibotii* products

Mean concentrations (mg/kg)	Elements							
	Cr	Ni	Cu	Zn	As	Se	Cd	Pb
1-scorch <i>Rhizoma Cibotii</i> (n=43)	2.03	1.85	3.55	18.85	0.06	0.13	0.10	8.33
raw <i>Rhizoma Cibotii</i> (n=15)	1.62	1.46	3.40	12.95	0.04	0.33	0.07	8.99
P-value	1.92	1.75	3.51	17.32	0.05	0.18	0.09	8.50

Table 4. Concentrations of trace elements among *Rhizoma Cibotii* products from various origin sites

Origin Sites (numbers)	Values (mg/kg)	Elements							
		Cr	Ni	Cu	Zn	As	Se	Cd	Pb
Fujian (9)	Max	4.08	3.92	4.21	12.35	0.09	0.04	0.10	11.06
	Min	0.96	0.65	2.59	6.66	0.02	0.02	< 0.01	3.22
Guangxi (30)	Mean	2.18	1.74	3.45	9.44	0.05	0.03	0.04	5.78
	Max	4.90	3.91	5.16	12.82	0.12	4.25	0.13	27.70
	Min	0.67	0.37	2.70	5.63	0.02	< 0.02	0.01	2.22
	Mean	2.13	1.76	3.59	9.89	0.06	0.32	0.03	8.70
Jiangxi (3)	Max	2.21	2.79	3.76	11.32	0.04	0.03	0.02	7.23
	Min	0.87	0.93	3.06	5.59	0.02	0.02	0.01	6.13
	Mean	1.68	2.02	3.51	9.39	0.04	0.03	0.02	6.51
Sichuan (5)	Max	1.59	2.51	4.32	350.82	0.12	0.03	2.65	18.31
	Min	0.44	0.70	2.94	7.70	< 0.01	0.02	0.01	3.80
	Mean	1.21	1.84	3.57	83.39	0.08	0.03	0.59	9.40
Yunnan (4)	Max	2.76	2.57	3.59	12.80	0.06	0.04	0.04	9.39
	Min	0.65	0.59	2.92	9.15	0.02	< 0.02	0.02	6.08
	Mean	1.58	1.70	3.38	10.85	0.04	0.04	0.03	8.33
Chongqing(1)	/	0.84	1.96	3.20	25.25	0.033	0.021	0.151	24.02
Hunan (1)	/	1.57	1.62	3.68	59.98	0.059	0.043	0.469	10.92
Hubei (1)	/	0.97	1.60	2.83	9.50	0.190	0.033	0.090	7.07
Guangdong(1)	/	1.08	0.59	2.78	9.22	0.042	0.048	0.023	13.86
Guizhou (1)	/	0.95	1.15	3.63	10.63	0.034	0.037	0.043	14.39
Anhui (2)	Max	3.11	2.15	3.74	12.00	0.069	0.036	0.035	6.48
	Min	2.19	1.87	3.39	8.07	0.043	0.025	0.021	3.75
	Mean	2.65	2.01	3.57	10.03	0.06	0.03	0.03	5.11

Table 5. Exposure assessment of heavy metals in *Rhizoma Cibotii* products

Values	Elements							
	Cr	Ni	Cu	Zn	As	Se	Cd	Pb
(ug/kg/d)	0.38	0.35	0.70	3.46	0.012	0.036	0.018	1.70
HQ	0.13	0.018	0.018	0.012	0.040	0.0072	0.018	0.43

Figures

Figure 1

The dendrogram for the variations of trace elements in *Rhizoma Cibotii* from different origin sites

Supplementary Files

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- [SupplementaryMaterialSampleanddata.xlsx](#)