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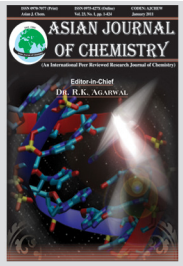

Multivariate Analysis of Trace Element Contents in *Angelica sinensis* and Soil

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The contents of Hg, Mn, As, Pb, Cu, Mg, Cd, Ni, Fe, Zn and Cr in *Angelica sinensis* (Oliv.) Deils of Yunnan and soil from 14 locations in Yunnan province of China were determined by inductively coupled plasma atomic emission spectroscopy (ICP-AES). The results showed high contents of Zn, Cu, Pb, Fe and Mg in soil and Mg, Fe, Mn, Zn and Cu in *A. sinensis* compared with other trace elements. Among the determined 11 trace elements, *A. sinensis* had relatively strong enrichment to Mn, Cr and Mg. In *A. sinensis*, As-Mg and Ni-Fe were significantly positive correlated; while As-Ni, Cu-Cd, Pb-Fe were significantly negative correlated. Meanwhile, As(plant)-As(soil), Cd(plant)-Hg(soil), Cu(plant)-Mn(soil) and Ni(plant)-Pb(soil) showed strong positive correlation, whereas Mn(plant)-Cu(soil), Pb(plant)-Cd(soil) and Cr(plant)-Pb(soil) showed negative correlation. This paper presented the trace elements properties of *A. sinensis* and expected to be useful for quality evaluation of this medicinal plant.

Key Words: *Angelica sinensis*, Trace element, Medicinal plant, ICP-AES.

INTRODUCTION

Angelica sinensis (Oliv.) Diels is a perennial herb belonging to the family Apiaceae[1]. Its dried root is widely used in Chinese traditional medicine to treat gynecological ailments, fatigue, mild anemia and hypertensive[2]. Its main pharmacological effects include antioxidative and immunomodulatory activities[3]. In China, *A. sinensis* is grown in the provinces of Gansu, Yunnan, Sichuan, Shaanxi and Hubei. It is considered that the best roots sold in the markets of Southeast Asia, called "Yungui", were from Yunnan[4]. According to the investigation, the cultivation history of *A. sinensis* in Yunnan province has been more than 90 years. Northwest Yunnan is one of the main cultivation areas of *A. sinensis* which has been formed in 1974. After that, the other cultivation area, northeast Yunnan, was also developed. At present, the cultivation area of *A. sinensis* in Yunnan has reached 9 700 hm^2.

Northwest Yunnan is located in the east Himalaya. It is a hot spot of ethnic diversity. Tibetan, Naxi, Bai, Lisu and other peoples live in this area. Most of local people in the Northwest Yunnan still live in poverty and have a strong dependence on the medicinal plants such as *A. sinensis*[5]. Because people in this area still use traditional medicine as a main treatment for most of the diseases. On the other hand, with the development of social economy, medicinal plants also are seemed as special economic plants to increase family income.

As reported, trace elements played an important role in the reactions which would lead to the formation of these active constituents in medicinal plants[6]. Meanwhile, trace elements involved directly in a variety of physiological activities of organisms[7-11]. Plant is an important carrier of transferring trace elements from natural environment to human body[12]. Therefore, the research of trace element contents in medicinal plant is very important[13]. It is one of the interesting fields in medicinal plant research[14] and there are many reports in literature on the trace element content in medicinal plant[6-18]. However, little is known about *A. sinensis*.

In this study, we determined the contents of 11 elements in *A. sinensis* and soil from 14 locations in Yunnan Province and analyzed the correlation of trace elements within *A. sinensis* and also between *A. sinensis* and soil.

EXPERIMENTAL

The root of *A. sinensis* and soil were collected from two main *A. sinensis* cultivation areas, northwest and northeast Yunnan, in November, 2009 (Table-1).

Sample preparation: Roots were carefully washed *in situ* and again in the laboratory with deionized water to remove soil and dried at 60 ºC until a constant weight was obtained. 1.0 g powdered dry samples were weighed into 100 mL glass beakers. 10 mL HNO_3 and 2 mL H_2O_2 were added to the samples. The mixture was digested on a hot plate at low

TABLE-1
DETAILS OF SAMPLE LOCATION OF *Angelica sinensis*

No.	Location	Longitude (E)	Latitude (N)	Altitude (m)
1	Shemile, Xuanwei	104°12'	26°01'	2010
2	Jichang, Xuanwei	104°13'	25°55'	2055
3	Nuge, Zhanyi	104°12'	25°52'	2060
4	Zhongchahe, Fuyuan	104°09'	25°44'	2025
5	Huaping, Fuyuan	104°10'	25°44'	1975
6	Hanjia, Zhanyi	103°40'	25°38'	2010
7	Xujiaqing, Zhanyi	103°42'	25°38'	1920
8	Machang Heqing	100°03'	26°28'	3100
9	Machang, Heqing	100°03'	26°28'	3110
10	Xiaomachang, Heqing	100°03'	26°30'	3010
11	Gemerong, Deqin	99°18'	27°48'	2500
12	Luohuaba, Weixi	99°17'	27°08'	2520
13	Lameirong, Yulong	99°29'	27°09'	2840
14	Lameirong, Yulong	99°28'	27°09'	2880

temperature for 2 h. Then 15 mL deionized water was added. Solutions were precisely transferred to 100 mL volumetric flasks and made to volume with deionized water.

0.5 g powdered dry soil samples were weighed into 100 mL glass beakers. 8 mL HNO_3 and 5 mL HF were added. After the mixture was dry, 2 mL of $HClO_4$ was added, then 0.5 mol L^{-1} HCl was added to make to volume until it was dried.

Instrumentation and analytical procedures: ICP-AES: ICPQ-1000 (Shimadzu, Japan); R_f power: 1.2 kW; carrier gas: 1.0 L min^{-1}, auxiliary gas: 1.5 L min^{-1}, coolant gas: 10.5 L min^{-1}; viewing height: 15 mm; measure time: 20 s; grating line: 19201 mm^{-1} (1:lines).

The detection wavelength, detection limit, recovery and relative standard deviation of the elements are shown in Table-2.

RESULTS AND DISCUSSION

The contents of 11 trace elements in *A. sinensis* and soil are presented in Table-3. The results showed that high content of trace elements in soil as Zn (40 692.08 mg kg^{-1}), Cu (8 449.44 mg kg^{-1}), Pb (7 141.63 mg kg^{-1}), Fe (4 367.50 mg kg^{-1}) and Mg (3 520.83 mg kg^{-1}) and Hg, Mn, As, Cd, Ni and Cr were relatively low. High contents of trace elements in *A. sinensis* as Mg (259.71 mg kg^{-1}), Fe (122.36 mg kg^{-1}), Mn (38.27 mg kg^{-1}), Zn (20.37 mg kg^{-1}) and Cu (12.48 mg kg^{-1}) and Hg, As, Pb, Cd, Ni and Cr contents are relatively low. Mg, Fe, Mn, Zn and Cu are all essential elements to human body[19].

TABLE-2
DETECTION WAVE LENGTH AND LIMITS, RECOVERY AND PRECISION OF THE METHOD

Element	Detection wave length (nm)	Detection limits (μg mL^{-1})	Recovery (%)	RSD (%)
Hg	253.6	0.034	100.1	1.32
Mn	279.5	0.070	107.4	0.99
As	193.7	0.011	103.3	0.47
Pb	283.3	0.046	98.5	1.01
Cu	324.8	0.055	99.9	0.99
Mg	285.2	0.066	100.3	0.09
Cd	228.8	0.071	103.4	0.59
Ni	231.6	0.056	98.2	0.95
Fe	248.3	0.049	99.9	1.32
Zn	213.9	0.084	98.5	0.47
Cr	285.5	0.084	98.4	0.49

Mg is a key element in cell metabolism, involved in a variety of enzyme-catalyzed reaction *in vivo*; iron has an important impact on the transport of oxygen *in vivo*; Mn participates in the formation of hemoglobin and the regulation blood sugar balance; Zn is an integral part of many metal enzymes; Cu plays an important role in the central nerve function[14,19,20].

The enrichment coefficients of trace elements in *A. sinensis* are displayed in Table-3. Among the enrichment coefficient of the 11 trace elements in *A. sinensis*, the order of average was Mn > Cr > Mg > Ni > Fe > Cd > As > Hg > Cu > Zn > Pb. The result improved that *A. sinensis* had strong enrichment ability on Mn, Cr and Mg than other trace elements.

The correlation analysis of the trace element in *A. sinensis* is given in Table-4. The result showed that As-Mg, Ni-Fe had significantly positive correlation ($p < 0.05$), that meant these elements in the *A. sinensis* had a good synergy. Whereas, As-Ni, Cu-Cd had significantly negative correlation ($p < 0.01$), Pb-Fe were significantly negative correlation ($p < 0.05$). It indicated that these elements had antagonism.

The correlation analysis of trace elements in *A. sinensis* and soil is demonstrated in Table-5. The results showed that Mn in plant and Cu in soil was negatively correlated ($p < 0.05$), As in plant and in soil was significant correlated ($p < 0.05$), Pb in plant and Cd in soil was significantly negatively correlated ($p < 0.05$) , Cu in plant and Mn in soil was significantly correlated ($p < 0.05$), Cd in plant and Hg in soil was significant negative correlated ($p < 0.01$), Ni in plant and Pb in soil was significantly correlated ($p < 0.05$), Cr in plant and Pb in soil had a significant negative correlation ($p < 0.05$).

TABLE-3
CONTENTS OF TRACE ELEMENTS IN SOIL AND *A. sinensis* AND THE ENRICHMENT COEFFICIENTS

Element	Soil (mg kg^{-1})	Plant (mg kg^{-1})	Enrichment coefficient*
Hg	7.22 ± 1.99	0.036 ± 0.011	0.0052
Mn	94.97 ± 19.71	38.27 ± 5.67	0.4174
As	8.20 ± 0.82	0.186 ± 0.054	0.0225
Pb	7 141.63 ± 1 652.99	2.21 ± 0.60	0.0003
Cu	8 449.44 ± 1 280.39	12.48 ± 0.87	0.0015
Mg	3 520.83 ± 1 704.61	259.71 ± 25.96	0.0952
Cd	10.71 ± 2.21	0.241 ± 0.062	0.0236
Ni	31.70 ± 4.32	2.46 ± 0.40	0.0790
Fe	4 367.50 ± 1 000.12	122.36 ± 10.80	0.0295
Zn	40 692.08 ± 13 375.85	20.37 ± 1.54	0.0006
Cr	19.15 ± 3.71	4.01 ± 0.34	0.2160

*Enrichment coefficient = content of trace element in plant/content of trace element in soil.

TABLE-4
CORRELATION COEFFICIENT BETWEEN TRACE ELEMENTS IN *A. sinensis*

	Hg	Mn	As	Pb	Cu	Mg	Cd	Ni	Fe	Zn
Mn	0.271	–	–	–	–	–	–	–	–	–
As	-0.311	0.211	–	–	–	–	–	–	–	–
Pb	-0.421	-0.297	0.372	–	–	–	–	–	–	–
Cu	-0.091	0.268	0.367	-0.020	–	–	–	–	–	–
Mg	-0.020	0.208	0.578*	0.063	0.307	–	–		–	–
Cd	-0.030	-0.449	0.146	0.285	-0.683**	0.104	–	–	–	–
Ni	0.181	0.242	-0.673**	-0.328	-0.076	-0.366	-0.418	–	–	–
Fe	-0.062	0.394	-0.288	-0.644*	0.193	-0.032	-0.455	0.577*	–	–
Zn	0.500	0.412	0.243	-0.212	0.415	0.336	-0.165	-0.028	0.137	–
Cr	0.117	-0.104	-0.187	0.186	-0.028	0.266	0.256	0.128	0.115	-0.037

*Correlation is significant at the 0.05 level. **Correlation is significant at the 0.01 level. The same below.

TABLE-5
CORRELATION COEFFICIENT BETWEEN TRACE ELEMENTS IN SOIL AND *A. sinensis*

Plant	Soil										
	Hg	Mn	As	Pb	Cu	Mg	Cd	Ni	Fe	Zn	Cr
Hg	0.416	-0.093	-0.121	0.191	0.249	-0.275	0.333	0.025	0.241	0.293	-0.122
Mn	0.327	-0.093	0.407	0.252	-0.644*	-0.219	0.010	-0.016	-0.489	0.249	0.312
As	-0.381	-0.222	0.550*	-0.353	-0.299	0.094	-0.480	-0.126	-0.346	-0.467	0.341
Pb	-0.267	-0.323	0.269	-0.332	0.118	0.019	-0.554*	0.334	-0.255	-0.402	0.018
Cu	0.449	0.612*	0.310	-0.080	-0.224	0.490	-0.207	-0.165	-0.405	-0.099	-0.264
Mg	-0.117	-0.171	0.479	-0.156	-0.126	0.201	-0.424	-0.107	-0.230	0.028	0.444
Cd	-0.775**	-0.492	-0.207	-0.483	0.512	-0.288	-0.181	-0.051	0.342	-0.344	0.132
Ni	0.495	0.275	-0.168	0.536*	-0.064	0.181	0.038	-0.178	-0.055	0.525	-0.255
Fe	0.311	0.543*	-0.294	0.308	-0.399	0.015	0.152	-0.406	-0.174	0.477	-0.056
Zn	0.249	0.272	-0.095	0.158	0.186	-0.007	-0.015	0.090	-0.436	0.198	-0.363
Cr	0.078	0.127	-0.199	-0.549*	0.249	-0.160	-0.351	-0.312	0.085	-0.071	0.017

Conclusion

Determination of 11 elements in *A. sinensis* and soil by ICP-AES was performed. The soil contained Zn, Cu, Pb, Fe and Mg in larger contents than other elements and *A. sinensis* contained Mg, Fe, Mn, Zn and Cu in larger contents than other elements. For the enrichment coefficient of the 11 trace elements in *A. sinensis*, the *A. sinensis* had stronger enrichment ability on Mn, Cr and Mg. In the *A. sinensis*, As-Mg, Ni-Fe showed strong positive correlation while As-Ni, Cu-Cd, Pb-Fe showed negative correlation. Meanwhile, As(plant)-As(soil), Cd(plant)-Hg(soil), Cu(plant)-Mn(soil) and Ni(plant)-Pb(soil) show strong positive correlation, while Mn(plant)-Cu(soil), Pb(plant)-Cd(soil) and Cr(plant)-Pb(soil) show negative correlation. This study provided a theoretical basis for the quality evaluation of *A. sinensis*.

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