ICP-MS Analysis of Inorganic Elements in *Astragalus membranaceus* from Gansu Province

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Abstract [**Objectives**] To investigate the content and distribution of inorganic elements in *Astragalus membranaceus* sourced from various regions in Gansu Province. [**Methods**] 28 batches of *A. membranaceus* samples were collected and subsequently digested using the Multiwave 7000 super microwave digestion system. The contents of aluminum (Al), barium (Ba), beryllium (Be), cobalt (Co), chromium (Cr), iron (Fe), gallium (Ga), magnesium (Mg), manganese (Mn), nickel (Ni), antimony (Sb), tin (Sn), strontium (Sr), titanium (Ti), thallium (Tl), vanadium (V), and zinc (Zn) were quantified utilizing a PerkinElmer 2000 inductively coupled plasma mass spectrometer. Principal component analysis was performed utilizing SPSS 25.0 to identify the distinctive characteristic elements of *A. membranaceus*. Additionally, systematic cluster analysis was conducted using these characteristic elements as variables to investigate the relationship between the primary inorganic elements and the geographical origin of *A. membranaceus*. [**Results**] 17 inorganic elements were identified in *A. membranaceus* specimens collected from Gansu Province, with characteristic elements including Ba, Co, Fe, Ga, Mn, Zn, and Sn. The contents of inorganic elements in various sources of *A. membranaceus* exhibited significant variability and demonstrated distinct clustering characteristics. [**Conclusions**] *A. membranaceus*, originating from Gansu Province, exhibits a high content of inorganic elements. However, variations in ecological environments can lead to differences in the specific inorganic elements that are enriched. This study aims to provide a reference for the further development and application of *A. membranaceus*.

Key words ICP-MS, *Astragalus membranaceus*, Geographical origin, Inorganic elements, Principal component analysis, Cluster analysis

1 Introduction

Gansu Province is recognized as the primary production area for the geo-authentic crude drug *Astragalus membranaceus*, as well as a significant source of contemporary commodity medicinal materials. The *Bencaojing Jizhu* (*Collective Notes to the Canon of Materia Medica*) documents that the authentic production regions for *A. membranaceus* in Gansu Province include Longxi and Dangchang, *etc.* Currently, *A. membranaceus*, sourced from Longxi, Weiyuan, and Minxian in southern Gansu, constitutes nearly 50% of China's total production of *A. membranaceus*[1]. The roots of *A. membranaceus* are utilized for medicinal purposes, and its primary active components include polysaccharides, saponins, flavonoids, as well as amino acids and various mineral elements. This plant exhibits a range of effects, including anti-inflammatory, antiseptic, antioxidant, and immunomodulatory properties[2-4]. In livestock and poultry farming, *A. membranaceus* and its active components serve as feed additives that can enhance the growth performance of farmed animals and bolster their immune responses, *etc.*[5-11]. These additives are now extensively utilized in animal husbandry practices. Currently, the market supply of *A. membranaceus* is predominantly comprised of cultivated products. Research has indicated that variations in the ecological and geographical environments, as well as differences in cultivation and processing techniques, can significantly affect the quality of *A. membranaceus*[12].

Mineral elements constitute essential nutrients for the growth of animals, and the minerals present in *A. membranaceus* significantly influence its quality and efficacy. Prior research has indicated that there are geographical variations in the content of inorganic elements found in *A. membranaceus* herbs[13]. This study collected samples of *A. membranaceus* from various geographical origins and different cultivation batches in Gansu, and established ICP-MS methods to quantify the content of 17 inorganic elements, namely aluminum (Al), barium (Ba), beryllium (Be), cobalt (Co), chromium (Cr), iron (Fe), gallium (Ga), magnesium (Mg), manganese (Mn), nickel (Ni), antimony (Sb), tin (Sn), strontium (Sr), titanium (Ti), thallium (Tl), vanadium (V), and zinc (Zn). The composition and distribution patterns of these inorganic elements were analyzed using principal component analysis and cluster analysis, with the aim of providing a reference for the further development and application of *A. membranaceus*.

2 Materials and methods

2.1 Instruments The instruments utilized in this study comprised a PerkinElmer 2000 inductively coupled plasma mass spectrometer (PerkinElmer, USA), a Multiwave 7000 super microwave digestion system (Anton Paar, Austria), and a ME24-102 electronic balance (Mettler-Toledo, Switzerland).

2.2 Main drugs and reagents The samples of *A. membranaceus* utilized for the analysis were collected from various locations, including Longxi County, Dangchang County, Weiyuan County, Minxian County, Jingyuan County, Minyue County, Wudu District, and Chengxian County in Gansu Province, resulting in a total of 28

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batches of samples. The origin information for the *A. membranaceus* samples is presented in Table 1.

Table 1 Origin information of *Astragalus membranaceus* samples

No.	Geographical origin	No.	Geographical origin
S1	Jingyuan County	S15	Minxian County
S2	Minyue County	S16	Minxian County
S3	Minxian County	S17	Minxian County
S4	Minxian County	S18	Minxian County
S5	Minxian County	S19	Wudu District
S6	Minxian County	S20	Chengxian County
S7	Minxian County	S21	Longxi County
S8	Minxian County	S22	Weiyuan County
S9	Minxian County	S23	Weiyuan County
S10	Minxian County	S24	Weiyuan County
S11	Minxian County	S25	Dangchang County
S12	Minxian County	S26	Dangchang County
S13	Minxian County	S27	Dangchang County
S14	Minxian County	S28	Dangchang County

A mixed standard solution containing Al, Ba, Be, Cr, Co, Fe, Ga, Mg, Mn, Ni, Sb, Sn, Sr, Ti, Tl, V, Zn (Lot No.: R2-MEB694161, specification: 10 μg/mL) was procured from PE Company, USA. Additionally, a Ti internal standard solution (Lot No.: CL3-188MKBY1, specification: 1 000 μg/mL) and a standard tuning solution containing Co, Mn, and Be (Lot No.: 36-47GSX1, specification: 0.1 μg/mL) were also obtained from the same supplier. The 65% nitric acid solution exhibited excellent purity, and the water utilized was ultrapure.

2.3 Preparation of test solution Approximately 0.3 g of crude powder were accurately weighed and transferred into a quartz digestion tank. Subsequently, 2 mL of nitric acid and 1 mL of ultrapure water were added and thoroughly mixed. The digestion process was conducted following a specific protocol (0 – 5 min, 0 – 800 W; 5 – 15 min, 800 W; 15 – 30 min, 800 – 1 200 W; 30 – 50 min, 1 200 W; and the cooling temperature was 80 ℃). Following the complete dissolution of the samples, they were removed, allowed to cool, and subsequently transferred to a 25 mL volumetric flask. The digestion tank was rinsed with a small volume of water, and the washings were combined in the volumetric flask. The solution was then adjusted to a fixed volume using a 3% nitric acid solution, ensuring thorough mixing to obtain the test solution. A blank sample solution was prepared using the same procedure.

2.4 Preparation of standard solution A precise volume of a mixed standard solution containing 17 elements was transferred into a 100 mL volumetric flask. Subsequently, a 3% nitric acid solution was added, and the mixture was diluted to the calibration mark. The solution was then shaken thoroughly to obtain a mixed standard stock solution with a concentration of 1 000 ng/mL.

2.5 Preparation of internal standard solution 0.002 mL of the Ti internal standard solution was transferred into a 100 mL volumetric flask. Subsequently, a 3% nitric acid solution was added, and the mixture was diluted to the calibration mark. The solution was then shaken thoroughly to obtain a mixed internal standard solution with a concentration of 20 ng/mL.

2.6 Operational conditions of instrument The operational conditions of the instrument were as follows: plasma power, 1 200 W; flow rate, 18 L/min; atomizing gas pressure, 100 psi; temperature, 2 ℃; collision gas (helium) pressure, 0.1 MPa; pulse voltage, 900 V; analog voltage, – 1 675 V; auxiliary gas flow rate, 0.8 L/min; carrier gas flow rate, 0.86 L/min; cooling circulating water temperature, 15 ℃. The measurement mode employed was the collision reaction mode, and each sample was analyzed three times to obtain an average value. Ti was chosen as the internal standard solution to correct and compensate for the matrix effect and signal drift associated with the samples. The internal standard solution was introduced online via a peristaltic pump, with a dilution factor of approximately 1 : 10 between the internal standard and the samples.

2.7 Examination of linear relationships A suitable volume of the mixed standard reserve solution was taken, to which a 3% nitric acid solution was added in order to create a series of concentrations of the standard solution. The concentration of each elemental solution was plotted on the x-axis, while the corresponding response values were plotted on the y-axis. Subsequently, linear regression analysis was performed.

2.8 Repeatability, precision and recovery tests Six samples of *A. membranaceus* were collected, and the test solution was prepared in accordance with the method in Section **2.4**. The content of inorganic elements was quantified following the conditions in Section **2.6**. Subsequently, the relative standard deviation (*RSD*) of the measured values for each inorganic element was calculated. Known contents of *A. membranaceus* samples were utilized for the spike and recovery test, with each concentration level being assessed in quintuplicate according to the established testing protocol. The recovery rates for each element, along with the *RSD* of the measured values, were then computed[14].

2.9 Determination of inorganic elements in samples The sample solution of *A. membranaceus* was analyzed to quantify the content of inorganic elements in accordance with the method in Section **2.6**.

2.10 Data analysis Principal component analysis and systematic cluster analysis were conducted utilizing SPSS 25.0 software.

3 Results and analysis

3.1 Investigation of linear relationships As illustrated in Table 2, the correlation coefficients of the working curves for each element ranged from 0.994 1 to 1.000 0, indicating a strong linear relationship.

3.2 Repeatability test The *RSD* of the determined values for each element ranged from 1.3% to 3.4%, indicating a high level of reproducibility for the method.

3.3 Precision and recovery tests As presented in Table 3, the spiked recoveries for each element varied between 88.2% and 104.5%, with the *RSD* ranging from 0.6% to 4.2%. These results indicate that the method demonstrates both good accuracy and precision.

Table 2 Investigation results of linear relationship

Element	Linear equation	r	Element	Linear equation	r
Al	$y = 10.153\,69x - 81.642\,41$	0.999 5	Ni	$y = 0.136\,738\,2x - 0.736\,154$	1.000 0
Ba	$y = 2.465\,371x - 6.841\,538$	0.999 7	Sb	$y = 2.715\,733x - 0.183\,5$	0.995 4
Be	$y = 86.754\,73x + 0.006\,152\,9$	0.994 1	Sn	$y = 2.547\,346x - 0.516\,62$	0.998 6
Cr	$y = 0.056\,126\,3x - 0.024\,768$	0.999 7	Sr	$y = 1.627\,416x - 2.378\,260$	1.000 0
Co	$y = 0.248\,647\,1x - 3.327\,37$	0.999 9	Ti	$y = 7.743\,718x - 2.631\,728$	0.999 8
Fe	$y = 0.273\,157\,4x - 17.277\,38$	0.999 6	Tl	$y = 0.835\,726\,4x - 0.024\,18$	0.999 9
Ga	$y = 0.168\,414\,8x - 5.285\,573$	0.999 9	V	$y = 0.235\,845\,7x - 0.217\,436$	1.000 0
Mg	$y = 4.354\,793x - 48.471\,49$	0.999 4	Zn	$y = 0.732\,881\,4x - 6.517\,8$	1.000 0
Mn	$y = 0.314\,973\,4x - 2.673\,528$	1.000 0			

Table 3 Precision and recovery test results ($n = 5$, %)

Element	Low concentration		Medium concentration		High concentration	
	Recovery	*RSD*	Recovery	*RSD*	Recovery	*RSD*
Al	98.2	1.2	96.8	1.6	100.5	0.7
Ba	90.9	0.6	92.5	0.8	97.6	1.1
Be	99.6	1.4	97.4	0.9	102.4	1.8
Cr	103.4	2.2	99.2	1.4	90.5	3.2
Co	100.2	3.5	94.7	0.7	98.5	2.0
Fe	90.8	0.8	95.1	2.8	92.4	0.9
Ga	93.1	1.7	100.3	3.1	99.8	1.5
Mg	100.4	3.1	95.8	2.1	97.2	2.3
Mn	104.5	2.7	101.4	1.8	96.4	3.4
Ni	98.0	4.2	98.5	2.4	104.1	1.6
Sb	91.2	2.5	94.7	0.8	99.8	1.2
Sn	95.4	3.2	92.7	1.4	94.3	2.8
Sr	98.6	4.0	94.7	2.8	97.5	2.3
Ti	102.6	1.9	98.4	0.7	100.7	2.5
Tl	96.8	2.8	102.8	3.1	97.2	1.4
V	88.2	0.9	93.7	2.4	96.7	3.1
Zn	94.8	3.4	98.9	1.6	95.2	2.6

3.4 Determination of inorganic elements in samples It is evident from Table 4 that the content of the same inorganic elements in *A. membranaceus* varied across different geographical origins and batches. The contents of each element were as follows: Al (158.81 – 2 162.37 mg/kg), Ba (2.28 – 20.93 mg/kg), Be (0.01 – 0.07 mg/kg), Cr (0.90 – 56.47 mg/kg), Co (0.05 – 0.51 mg/kg), Fe (127.04 – 1 045.33 mg/kg), Ga (0.58 – 5.60 mg/kg), Mg (816.22 – 2 623.56 mg/kg), Mn (7.54 – 38.07 mg/kg), Ni (1.06 – 6.93 mg/kg), Sb (0.01 – 0.02 mg/kg), Sn (0.01 – 0.47 mg/kg), Sr (5.21 – 25.15 mg/kg), Ti (4.92 – 26.24 mg/kg), Tl (0.01 – 0.03 mg/kg), V (0.24 – 3.80 mg/kg), and Zn (11.75 – 55.91 mg/kg).

The order of magnitude of the content of each element, when expressed as a median, was as follows: Mg, Al, Fe, Zn, Mn, Ti, Sr, Ba, Ni, Ga, V, Co, Sn, Be, Cr, Tl, and Sb.

3.5 Principal components of inorganic elements in *A. membranaceus* of different geographical origins As illustrated in Table 5, three principal components were extracted based on the criterion of an eigenvalue exceeding 1. The first principal component accounted for 68.324% of the variance, the second principal

Table 4 Determination results of inorganic element contents in *Astragalus membranaceus* samples mg/kg

No.	Al	Ba	Be	Cr	Co	Fe	Ga	Mg	Mn	Ni	Sb	Sn	Sr	Ti	Tl	V	Zn
S1	365.91	5.41	0.02	1.11	0.11	242.78	1.72	1 239.99	15.66	3.23	0.01	0.47	11.27	9.18	0.02	0.59	31.37
S2	158.81	2.28	0.01	1.92	0.05	127.04	0.58	1 152.98	7.54	1.06	0.01	0.01	13.10	4.92	0.01	0.24	12.62
S3	913.68	8.79	0.03	9.40	0.25	541.25	2.91	1 844.76	24.89	3.79	0.02	0.03	11.31	16.05	0.03	1.54	22.36
S4	444.22	5.17	0.02	2.75	0.18	276.71	1.67	991.99	15.84	2.21	0.01	0.02	7.76	9.35	0.01	0.70	18.10
S5	317.18	3.61	0.01	0.90	0.10	204.49	1.07	913.68	11.66	1.53	0.01	0.01	7.67	7.92	0.01	0.46	16.79
S6	328.05	3.15	0.02	1.71	0.08	192.74	0.94	840.58	10.27	1.17	0.01	0.01	5.21	6.79	0.01	0.50	12.75
S7	875.39	5.91	0.01	4.04	0.18	365.47	1.95	854.07	11.36	1.92	0.02	0.05	7.34	12.49	0.01	1.38	11.75
S8	588.67	3.64	0.03	1.36	0.14	254.09	1.13	1 118.17	13.88	2.22	0.01	0.01	7.07	8.54	0.01	0.89	24.97
S9	652.63	5.76	0.02	3.29	0.18	353.29	1.84	1 126.87	16.49	2.21	0.01	0.02	10.79	12.97	0.01	1.06	12.49
S10	280.19	2.85	0.01	0.94	0.09	198.83	0.83	816.22	9.18	1.38	0.01	0.03	6.27	7.21	0.01	0.45	12.57
S11	904.98	7.04	0.04	7.61	0.23	569.53	2.21	961.54	17.53	2.72	0.02	0.02	7.19	18.93	0.01	1.29	23.45
S12	419.42	4.25	0.01	2.02	0.12	282.37	1.31	1 039.85	12.92	1.94	0.01	0.05	7.25	10.09	0.01	0.66	23.32
S13	381.57	4.08	0.01	2.52	0.11	253.65	1.28	828.40	12.44	1.51	0.01	0.01	6.57	9.57	0.01	0.63	20.71
S14	409.42	5.01	0.02	2.11	0.17	284.98	1.61	1 139.92	13.92	2.45	0.01	0.02	10.18	10.96	0.01	0.70	29.59
S15	373.30	4.38	0.01	1.25	0.11	239.30	1.37	1 083.36	13.05	1.86	0.01	0.02	8.24	8.78	0.01	0.62	25.71
S16	258.88	3.96	0.01	1.47	0.07	182.30	1.16	1 100.77	10.44	1.17	0.01	0.01	10.70	7.28	0.02	0.40	17.97
S17	513.84	7.26	0.04	1.75	0.13	296.29	2.45	1 057.26	14.40	1.49	0.01	0.02	8.88	10.70	0.01	0.81	15.53
S18	455.53	5.50	0.02	1.61	0.14	283.24	1.74	1 366.17	14.40	1.59	0.01	0.02	12.62	10.83	0.02	0.78	17.71
S19	687.43	10.88	0.02	6.49	0.20	456.84	3.61	1 679.43	22.93	4.64	0.02	0.02	10.96	13.66	0.02	1.14	27.98

(To be continued)

(Continued)

No.	Al	Ba	Be	Cr	Co	Fe	Ga	Mg	Mn	Ni	Sb	Sn	Sr	Ti	Tl	V	Zn
S20	772.28	7.74	0.04	3.66	0.21	447.27	2.52	1 000.70	14.18	2.47	0.02	0.03	8.30	16.27	0.02	1.21	15.49
S21	446.83	5.57	0.02	11.88	0.14	340.67	1.74	1 183.43	14.58	2.04	0.01	0.05	17.40	11.36	0.01	0.79	17.06
S22	662.20	5.82	0.01	4.05	0.15	315.44	1.87	1 057.26	13.84	1.88	0.01	0.05	7.88	12.01	0.01	0.85	20.58
S23	1 026.80	9.92	0.04	2.69	0.30	608.25	3.29	1 474.94	28.19	4.11	0.02	0.07	11.57	23.84	0.03	1.66	37.94
S24	2 162.37	20.93	0.07	56.47	0.51	1 045.33	5.60	2 623.56	38.07	5.27	0.02	0.01	14.79	26.24	0.03	3.80	24.23
S25	345.02	3.95	0.01	1.84	0.12	248.43	1.21	1 087.71	11.31	1.61	0.01	0.05	10.66	9.22	0.01	0.59	20.41
S26	636.09	12.23	0.01	2.52	0.21	425.95	3.96	2 245.04	31.02	4.53	0.01	0.02	16.75	14.66	0.03	0.99	55.91
S27	874.52	14.36	0.04	7.31	0.32	497.74	4.42	2 284.20	36.63	6.93	0.02	0.02	20.32	15.23	0.03	1.31	29.06
S28	417.25	7.37	0.01	3.11	0.13	285.42	2.42	1 892.62	16.14	2.22	0.01	0.04	25.15	10.01	0.01	0.73	25.54

component contributed 12.292%, and the third principal component contributed 6.099%. Consequently, the cumulative variance explained by these components was 86.716%. The findings indicated that the majority of the inorganic element information pertaining to *A. membranaceus* could be reflected by the three principal components. This suggests that these three principal components are the primary factors contributing to the variability observed among different batches of *A. membranaceus* sourced from various geographical origins.

As illustrated in Table 6, Ba, Co, Fe, Ga, and Mn exhibited higher loading values in principal component 1. In contrast, Zn demonstrated elevated loading values in principal component 2, while Sn was characterized by higher loading values in principal component 3.

Based on the contribution of the principal components to the total variance, along with the factor loadings, the characteristic inorganic elements of *A. membranaceus* can be identified as Ba, Co, Fe, Ga, Mn, Zn, and Sn.

Table 5 Principal component analysis eigenvalues and variance contribution of inorganic elements in *Astragalus membranaceus*

Component	Initial eigenvalue			Sum of squared loadings		
	Total	Variance percentage	Accumulation %	Total	Variance percentage	Accumulation %
1	11.615	68.324	68.324	11.615	68.324	68.324
2	2.090	12.292	80.617	2.090	12.292	80.617
3	1.037	6.099	86.716	1.037	6.099	86.716
4	0.803	4.722	91.438			
5	0.540	3.178	94.616			
6	0.272	1.597	96.213			
7	0.250	1.468	97.681			
8	0.147	0.862	98.543			
9	0.079	0.462	99.006			
10	0.076	0.447	99.453			
11	0.037	0.220	99.673			
12	0.025	0.149	99.822			
13	0.015	0.088	99.910			
14	0.010	0.056	99.967			
15	0.004	0.021	99.987			
16	0.002	0.009	99.996			
17	0.001	0.004	100.000			

Table 6 Principal component analysis loading matrix of inorganic elements in *Astragalus membranaceus*

Component	1	2	3
Al	0.916	−0.359	0.069
Ba	0.977	0.053	−0.074
Be	0.787	−0.352	0.197
Cr	0.767	−0.431	−0.096
Co	0.970	−0.184	0.043
Fe	0.929	−0.322	0.031
Ga	0.965	0.138	−0.057
Mg	0.849	0.370	−0.248
Mn	0.946	0.242	−0.028
Ni	0.874	0.355	0.074
Sb	0.778	0.137	0.000
Sn	−0.093	0.369	0.815
Sr	0.454	0.572	−0.420
Ti	0.901	−0.176	0.155
Tl	0.899	0.236	0.105
V	0.915	−0.364	0.043
Zn	0.471	0.684	0.164

3.6 Cluster analysis of inorganic elements in *A. membranaceus* of different geographical origins The data were imported into SPSS 25.0, and the samples were analyzed using systematic clustering with intergroup linkage and Pearson correlation. The results are presented in Fig. 1.

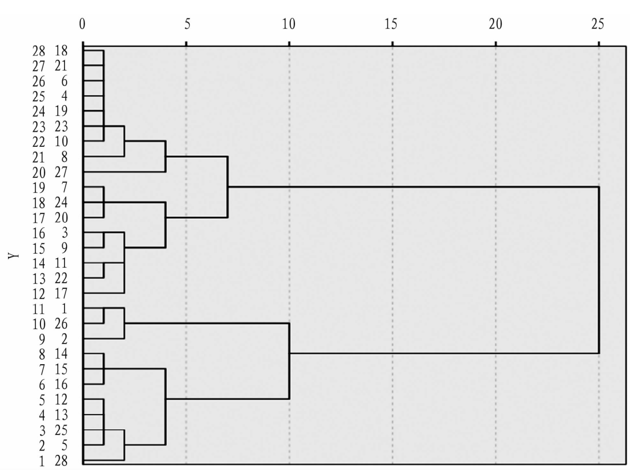

Fig. 1 Cluster analysis of inorganic elements in *Astragalus membranaceus* from different origins

As illustrated in Fig. 1, when the class spacing was set to 15, the 28 batches of samples were categorized into two distinct groups. The first group, comprising samples S1-S2, S5, S12-S16, S25-S26, and S28, primarily originated from Jingyuan County, Minyue County, Minxian County, and Dangchang County. This suggests that the 17 elements enriched in *A. membranaceus* herbs from these regions exhibit similarities. The second group included samples S3-S4, S6-S11, S17-S24, and S27, which were clustered together and originated from Weiyuan County.

4 Discussion

Minerals constitute fundamental nutrients necessary for the growth of animals. Essential minerals are categorized into macronutrients and micronutrients based on the specific requirements of the animal. The primary macronutrients include Ca, P, K, Mg, Na, S, and Cl, and the essential trace elements consist of Cr, Co, Cu, I, Fe, Mn, Mo, Se, and Zn[15]. The findings of this study indicate that the inorganic elements present in *A. membranaceus* from Gansu are abundant, thereby establishing a foundation for the subsequent application of *A. membranaceus* in livestock and poultry breeding. Furthermore, the findings indicate significant variations in the contents of Ba, Co, Fe, Ga, Mn, Zn, and Sn in *A. membranaceus* sourced from various locations in Gansu. This information offers valuable insights for the procurement of *A. membranaceus*. In addition to the essential trace elements required for growth and development, certain harmful trace elements may be present in the animal body. These elements, which are not necessary for physiological processes, can enter the diet through environmental pollution, feed additives, and other sources. Common harmful trace elements include Pb, Cd, Hg, As, Cu, Tl, Sb, and Te. These substances not only accumulate in the animal body, leading to detrimental health effects, but they may also be excreted in urine and feces, thereby posing a potential threat to the ecological environment. All 28 batches of *A. membranaceus* herbs included in this study were analyzed for the presence of Pb, Cd, As, Hg, and Cu in accordance with the standard requirements outlined in the 2020 edition of the *Chinese Veterinary Pharmacopoeia* prior to testing. The results were found to be compliant with regulatory standards. Additionally, the assay results indicated that the contents of Tl and Sb in *A. membranaceus* were low, measuring between 0.01 – 0.03 mg/kg for Tl and 0.01 – 0.02 mg/kg for Sb. These findings suggest that the levels of harmful trace elements in *A. membranaceus* from Gansu are minimal, thereby indicating a high safety profile for this herb. The content of Al in *A. membranaceus* has been found to be generally elevated. Given that excessive Al intake can result in adverse effects such as loss of appetite and indigestion, as well as impair the intestinal absorption of essential minerals including P, Sr, Fe, and Ca[16], the Al content in *A. membranaceus* from Gansu may pose a potential safety risk and warrants further investigation.

5 Conclusions

The method developed in this study demonstrates high accuracy and commendable precision, enabling the analysis of 17 inorganic elements in *A. membranaceus* sourced from Gansu. This particular variety of *A. membranaceus* is characterized by a rich composition of inorganic elements and a low content of harmful trace elements, indicating its superior quality and safety. Consequently, when considering the purchase of *A. membranaceus*, it is advisable to prioritize products originating from Gansu. The variations in the content of inorganic elements present in *A. membranaceus* from various production regions in Gansu Province offer valuable insights for the future selection of optimal production areas for this species. As concerns regarding the quality and safety of livestock and poultry products continue to rise, the utilization of *A. membranaceus* and other natural herbs in livestock and poultry farming is increasingly regarded as a promising avenue. Future research should focus on the content and distribution of inorganic elements in *A. membranaceus* sourced from various regions of China. Such investigations aim to provide valuable insights for the further development and application of *A. membranaceus* in livestock and poultry farming.

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tion indexes of extraction process.

4.2 Pre-experimental investigation There are many Chinese herbal medicines in compound preparations of traditional Chinese medicine, which also leads to many impurities, and the separation of impurities in the process of liquid chromatography identification or thin layer identification is particularly important[15]. In the pre-experiment, the content determination of methanol-water, acetonitrile-water, acetonitrile-0.1% phosphoric acid and methanol-0.15% glacial acetic acid in the fluidity system was investigated. It was found that during the content determination methods of psoralen and astilbin, it was difficult to separate impurities when using the same mobile phase and determination method. In order to save time and mobile phase, separate determination methods were established. Psoralen had good resolution, good peak shape and strong specificity under acetonitrile-0.1% phosphoric acid system; astilbin had good resolution and peak shape in methanol-0.15% glacial acetic acid. In the preliminary experiment, the thin-layer chromatographic identification of *F. simplicissima* Lour. and *S. glabra* Roxb. in the extract was preliminarily studied, and the suitable developing agent was selected, and the effective ingredients and impurities were effectively separated, and there was no interference from negative samples, which provided reference for the establishment of subsequent quality standards of the mixture.

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