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Original Research Article

ICP-AES analysis of inorganic elements in *Carthami Flos* from various geographic locations

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ABSTRACT

Using microwave digestion and inductively coupled plasma atomic emission spectroscopy (ICP-AES), 28 inorganic elements were analyzed in 40 batches of safflower (Carthamus tinctorius Linn.) samples, which are the dried tubular flowers, from Anhui, Gansu, Jiangsu, Xinjiang, and Yunnan. The results revealed the following: Among the heavy metals, copper (Cu) had the highest concentration across all 40 batches of safflower samples, with mercury (Hg) and lead (Pb) also being relatively high. Safflower samples from Yunnan had significantly higher Hg levels compared to those from other provinces. The levels of Pb and Cu among samples from different provinces were generally not significantly different, while arsenic (As) and cadmium (Cd) levels were either low or undetectable. Among the major elements, potassium (K) had the highest concentration, phosphorus (P) and magnesium (Mg) were lower, and sodium (Na) had the lowest concentration. Safflower samples from Gansu had significantly higher Na and Mg concentrations, and samples from Yunnan and Xinjiang had higher P levels compared to those from other provinces. Safflower samples from Yunnan had significantly lower K levels compared to samples from other provinces, and there were no significant differences in K levels among samples from the other provinces. In the case of essential trace elements, iron (Fe) and boron (B) were relatively high, while nickel (Ni) was the lowest. Safflower samples from Xinjiang and Gansu had higher chromium (Cr) levels, and samples from Gansu had the highest levels of manganese (Mn), Fe, Ni, and strontium (Sr), while samples from Anhui had the highest levels of Zn and B. Conversely, samples from Jiangsu had the lowest levels of Cr, Mn, Fe, and Ni; Gansu samples had the lowest Zn levels; and Yunnan samples had the lowest Sr and B levels. Principal component analysis and cluster analysis showed that safflower samples from the same province tended to cluster together. Specifically, samples from Anhui and Jiangsu clustered closely, samples from Gansu and Xinjiang were relatively close, and samples from Yunnan were more distanced from those of other provinces. This study established a rapid and accurate method for determining the inorganic element content in safflower, and the results indicated notable differences in inorganic element content among safflower samples from different origins.

Keywords: *Carthami Flos*; inductively coupled plasma-atomic emission spectrometer (ICP-AES) method

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Carthami Flos (CF) refers to the dried tubular flowers of Carthamus tinctorius Linn., which belongs to the Compositae family[1]. Safflower was introduced into the Central Plains of China in the Han Dynasty, initially only as a dye, and then mainly as a traditional Chinese medicine[2]. As a dye, safflower is mainly used to dye silk and paper, or to make cosmetics such as rouge and lipstick[3]. Safflower has the effects of activating blood circulation and dredging menstruation, dispersing blood stasis and relieving pain. It is mainly used to treat amenorrhea in clinic. Dysmenorrhea. Symptomatic mass and drug safety. Research shows that the composition of inorganic elements in soil has a certain correlation with the content of inorganic elements in plants, and the soil in different regions will also affect the safety of safflower as a medicinal material[4,5]. At present, the domestic research on the composition and content of inorganic elements in safflower is mostly concentrated in Xinjiang, while the research on safflower from other places is insufficient. In addition, there is a lack of comparative research on the content of heavy metals and other inorganic elements in safflower from different places. Recent research results show that safflower is a commonly used traditional Chinese medicine for activating blood circulation and removing blood stasis[6] for its damage to[7,8] and falling attack during its growth. At present, there is a certain rule in the absorption of elements in soil, so the pharmacological research shows that safflower has anticoagulation. Antithrombotic. Dilate blood vessels. Improve microcirculation and regulate immunity[9] 7-11. At present, quinone chalcone glycosides have been isolated and reported from safflower. Flavonoids. Spermidine. Alkaloids. More than 200 compounds such as organic acids and steroids[9] 21.

Safflower is not only widely used. With high economic value and strong adaptability to the environment, it is cultivated all over the world[10,11], Xinjiang, China. Henan. Zhejiang. Yunnan. It is planted in Sichuan, Gansu and other places[2]. At present, the commercial planting of Safflower in China is mainly concentrated in Xinjiang. Yunnan and Gansu, among which, the planting area in Xinjiang accounts for more than 50% of China’s safflower planting area, and its safflower output accounts for more than 80% of China’s safflower output[12]. As a bulk Chinese medicinal material, it is still unclear whether safflower has the problem of excessive content of heavy metals and harmful elements, while the Chinese Pharmacopoeia[1] only limits the content of its effective components, and lacks the detection standards of heavy metals and harmful elements in safflower. The safety of Carthamus tinctorius affects the efficacy and safety of its constituent compounds and injections[13,14]. Therefore, it is urgent to strengthen the exploration of the composition law of its inorganic elements and improve the distribution law of the content of inorganic elements in Carthamus tinctorius from the same origin, which has a certain practical significance.

At present, inductively coupled plasma mass spectrometry is mostly used to analyze the content of inorganic elements in medicinal materials. Inductively coupled plasma atomic emission spectrometry (ICP-AES) measures the optical spectrum (165–800 nm), which can not only detect multiple spectral lines in the atomic spectrum at the same time, but also detect a variety of atoms and ions at the same time. In addition, ICP-AES has low detection limit, good reproducibility and fast instrumental analysis speed[15], and the time required for each sample is 2–6 min. In view of this, this study uses microwave digestion and ICP-AES to analyze the inorganic elements in safflower samples from different provinces (autonomous regions), in order to reveal the law of the content of inorganic elements in safflower from different provinces (autonomous regions), and then provide reference for rational fertilization and quality control of medicinal materials in the process of safflower cultivation.

1. Materials and methods

1.1. Materials

The 40 batches of safflower samples tested were all dried tubular flowers of safflower of Compositae plants, which were collected when the flowers turned from yellow to red. See **Table 1** for the origin information. The collected safflower samples were dried in the shade at the place of origin, crushed, sieved through 50 meshes, and dried and preserved. The voucher specimen is stored in Jiangsu Collaborative Innovation Center for the industrialization of traditional Chinese medicine resources of Nanjing University of traditional Chinese medicine. All safflower samples were identified by Yan Hui, associate professor of School of medicine, Nanjing University of traditional Chinese medicine.

Table 1. Location information of 40 batches of *Carthami Flos* samples tested.

No.	Location	Longitude	Latitude	Altitude
S1	Dangshan County in Anhui Province	E117°16′55″	N31°51′58″	50
S2	Dangshan County in Anhui Province	E117°16′55″	N31°51′58″	50
S3	Dangshan County in Anhui Province	E117°16′55″	N31°51′58″	50
S4	Guazhou City in Gansu Province	E95°45′00″	N40°24′53″	1171
S5	Guazhou City in Gansu Province	E95°47′36″	N38°06′10″	1178
S6	Guazhou City in Gansu Province	E95°47′36″	N38°06′10″	1178
S7	Yumen City in Gansu Province	E97°44′34″	N40°30′57″	1254
S8	Yumen City in Gansu Province	E97°44′34″	N40°17′30″	1254
S9	Yumen City in Gansu Province	E97°44′34″	N40°17′30″	1254
S10	Yumen City in Gansu Province	E97°45′58″	N40°17′29″	1247
S11	Yumen City in Gansu Province	E97°45′58″	N40°17′30″	1247
S12	Yumen City in Gansu Province	E97°46′16″	N40°17′15″	1247
S13	Yumen City in Gansu Province	E97°46′16″	N40°17′15″	1247
S14	Yumen City in Gansu Province	E97°45′07″	N40°17′00″	1254
S15	Yumen City in Gansu Province	E97°45′07″	N40°17′00″	1254
S16	Qixia District in Jiangsu Province	E118°56′13″	N32°06′16″	8
S17	Qixia District in Jiangsu Province	E118°56′13″	N32°06′16″	8
S18	Qixia District in Jiangsu Province	E118°56′13″	N32°06′16″	8
S19	Qixia District in Jiangsu Province	E118°57′00″	N32°06′18″	8
S20	Qixia District in Jiangsu Province	E118°57′00″	N32°06′18″	8
S21	Qixia District in Jiangsu Province	E118°57′00″	N32°06′18″	8
S22	Qixia District in Jiangsu Province	E118°56′12″	N32°06′19″	9
S23	Qixia District in Jiangsu Province	E118°56′12″	N32°06′19″	9
S24	Qixia District in Jiangsu Province	E118°56′12″	N32°06′19″	9
S25	Yumin County in Xinjiang Uygur autonomousregion	E82°48′50″	N46°00′14″	1180
S26	Jimsar County in Xinjiang Uygur autonomousregion	E89°03′10″	N44°21′07″	726
S27	Jimsar County in Xinjiang Uygur autonomousregion	E89°03′10″	N44°21′07″	726
S28	Jimsar County in Xinjiang Uygur autonomousregion	E89°03′10″	N44°21′07″	726
S29	Qapqal Xibe Autonomous County in Xinjiang Uygur autonomousregion	E85°36′50″	N42°07′37″	602
S30	Huocheng County in Xinjiang Uygur autonomousregion	E80°51′14″	N44°14′31″	715

S31	Huocheng County in Xinjiang Uygur autonomousregion	E80°51′43″	N44°14′41″	715
S32	Huocheng County in Xinjiang Uygur autonomousregion	E80°46′51″	N44°18′32″	715
S33	Emin County in Xinjiang Uygur autonomousregion	E84°12′32″	N46°35′24″	520
S34	Urumqi County in Xinjiang Uygur autonomousregion	E87°37′30″	N43°48′39″	800
S35	Urumqi County in Xinjiang Uygur autonomousregion	E87°33′50″	N43°50′24″	800
S36	Yining County in Xinjiang Uygur autonomousregion	E81°45′21″	N44°00′28″	1000
S37	Yutian County in Xinjiang Uygur autonomousregion	E85°36′50″	N42°07′37″	1431
S38	Yongsheng County in Yunnan Province	E101°35′31″	N24°51′50″	1424
S39	Yongsheng County in Yunnan Province	E100°42′14″	N26°29′27″	1424
S40	Yongsheng County in Yunnan Province	E100°42′14″	N26°29′27″	1424

Contains Hg, Pb, Cu, As, Cd, Na, Mg, P, K, Cr, Mnfe, Ni, Zn, Sr, B, Li, Be, Tl, Bi, Sc, Ti, V, Co, Ga, Y, Multi element standard solution of Ba and Al (concentration 100 μg·mL^{-1}) (batch number GSB 04-1767-2004) and internal standard solution ^{73}Ge (batch number GSB 04-1728-2004). ^{115}In (batch No. GSB 04-1731-2004) and ^{209}Bi (batch No. GSB 04-1719-2004) of single element standard solution (the concentration is 1000 μg·mL^{-1}) purchased from the national non ferrous metals and electronic materials analysis and testing center; nitric acid (superior pure, batch No. 180725) and hydrogen peroxide (superior pure, batch No. 180819) were purchased from Shanghai Sinopharm chemical reagent company; watsons distilled water.

1.2. Method

1.2.1. Sample collection

Five point sampling method is adopted, which is respectively in the field (10 m × 5 m) sampling at the intersection of two diagonals and the middle point from the intersection to the four corners. About 2 kg tubular flowers are picked from each field and mixed as a batch of samples. Three fields for each batch of samples.

1.2.2. Preparation method of standard solution

Precisely pipette 200 μL of 100 μg·mL^{-1} multi-element standard solution, dilute to 10 mL with distilled water, and prepare the solution containing Hg, Pb, Cu, As, Cd, Na, Mg, P, K, Cr, Mn, Fe, Ni, Zn, Sr, B, Li, Be, Tl, Bi, Sc, Ti, V, Co, Ga, Y, Ba and Al mixed standard mother solution, the mass concentration is 2 μg·mL^{-1}, serially diluted to prepare a series of mass concentration of standard solution.

1.2.3. Sample solution preparation method

Accurately weigh 0.2 g of safflower sample powder, put it into a polytetrafluoroethylene digestion tank, add 7 mL of nitric acid and 3mL of hydrogen peroxide, and let it stand for 10 min. After the reaction is not violent, cover and seal it, and put it into a milestone ethos D-type microwave digestion instrument (Milestone company, Italy). The digestion procedure is: heat up from room temperature to 180 °C after 10 minutes; after 5 minutes, it was heated from 180 °C to 220 °C, and digested at 220 °C for 20 min; cool to room temperature. Take out the digestion tank, volatilize the acid in the fume hood, and fix the volume to 50 mLwith distilled water as the sample solution. Mix 7 mL nitric acid and 3 mL hydrogen peroxide as blank.

1.2.4. Sample determination method

The sample solution is injected into optima^{TM} 2100 DV inductively coupled plasma emission spectrometer (Perkin Elmer company of the United States) for determination. The determination conditions are: plasma RF power 1.3 kW; the cooling air flow rate is 15 L·min^{-1}, the carrier gas flow rate is 0.8L·min^{-1}, and the auxiliary air flow rate is 0.2 L·min^{-1}; observation direction axial; the observation height is 15 nm; one reading time: 5 S; injection delay 30 s; pump speed 15 r·min^{-1}. Repeat the determination for 3 times for each sample, and take the average value of the results.

1.2.5. Methodological review

1) Precision test. Take mass concentration 2μg·mL^{-1} mix the standard mother liquor and repeat the determination for 6 times according to the above method.
2) Repeatability test. Prepare 6 sample solutions in parallel and determine them according to the above method.
3) Stability test. Sample solution, respectively, 0 after preparation. 1. 2. 4. 6. At 8 and 12 h, the determination shall be carried out according to the above method.
4) Sampling recovery test. Accurately weigh an appropriate amount of the same sample and add 80% of each element in the known sample. 100% and 120% of the standard solution shall be determined according to the above method.

1.3. Data processing

Take the mass concentration of the standard solution as the abscissa (x). The peak area of each standard is the ordinate (y) to calculate the regression equation of each inorganic element. Correlation coefficient. Linear range. Limit of detection and limit of quantitation. Cluster analysis and principal component analysis were carried out on the experimental data by using SIMCA-P 14.1 software, and the scatter diagram of principal component analysis was drawn.

2. Results and analysis

2.1. Investigation of linear relationship

Regression equation of standard curve of 28 inorganic elements. Correlation coefficient. Linear range. See **Table 2** for detection limit and quantitation limit. It can be seen from **Table 2**: The linear relationship of the standard curves of 28 inorganic elements is good, and the detection limit and quantitative limit are low.

Table 2. Regression equation, correlation coefficient (r), linear range, limit of detection (LOD), and limit of quantification (LOQ) of standard curves of 28 inorganic elements.

No.	Inorganicelement	Regressionequation	r	Lineararrange/(ng·mL^{-1})	LOD/(ng·mL^{-1})	LOQ/(ng·mL^{-1})
1	Hg	$y = 35.170x - 82.926$	1.0000	0.040–5.000	0.010	0.040
2	Pb	$y = 8969.400x + 3830.600$	0.9999	1.000–200.000	0.550	1.660
3	Cu	$y = 872.330x + 1284.500$	0.9998	1.000–200.000	0.100	0.100
4	As	$y = 35.825x + 23.811$	0.9998	1.000–200.000	0.310	0.310
5	Cd	$y = 132.710x + 113.510$	0.9998	1.000–200.000	0.210	0.800
6	Na	$y = 82.341x + 3565.600$	0.9575	1.000–200.000	0.520	1.560
7	Mg	$y = 26.389x + 95.478$	0.9988	1.000–200.000	0.420	1.270
8	P	$y = 0.511x + 6.586$	0.9800	1.000–200.000	0.510	1.550
9	K	$y = 22.818x - 38.233$	0.9930	1.000–200.000	0.650	1.950
10	Cr	$y = 501.800x + 1591.700$	0.9999	1.000–200.000	0.640	1.910
11	Mn	$y = 179.140x + 164.710$	0.9999	1.000–200.000	0.630	1.900
12	Fe	$y = 10.421x + 58.664$	0.9984	1.000–200.000	0.340	1.020
13	Ni	$y = 345.210x + 415.300$	0.9999	1.000–200.000	0.850	2.560
14	Zn	$y = 51.543x - 0.913$	0.9995	1.000–200.000	0.190	0.570
15	Sr	$y = 197.090x + 217.110$	0.9997	1.000–200.000	0.330	0.980

16	B	$y = 1632.900x - 36.252$	0.9999	1.000–200.000	0.480	1.450
17	Li	$y = 8946.900x + 622.090$	1.0000	1.000–200.000	0.420	1.270
18	Be	$y = 1754.200x + 3.861$	0.9999	1.000–200.000	0.100	0.290
19	Tl	$y = 12100x + 6139.500$	0.9998	1.000–200.000	0.580	1.750
20	Bi	$y = 53735.000x - 1.000 \times 10^6$	0.9842	2.000–400.000	0.770	2.310
21	Sc	$y = 100.610x + 18.588$	1.0000	1.000–200.000	0.320	0.740
22	Ti	$y = 7.809x + 10.830$	0.9996	1.000–200.000	0.110	0.320
23	V	$y = 377.990x + 336.710$	0.9998	1.000–200.000	0.030	0.100
24	Co	$y = 1147.900x + 854.170$	0.9999	1.000–200.000	0.110	0.400
25	Ga	$y = 103.580x + 108.220$	0.9998	1.000–200.000	0.140	0.420
26	Y	$y = 651.560x + 635.200$	0.9996	1.000–200.000	0.080	0.250
27	Ba	$y = 875.930x + 1072.000$	0.9997	1.000–200.000	0.700	2.110
28	Al	$y = 7.332x + 22.260$	0.9994	1.000–200.000	0.280	0.830

2.2. Methodological review

The RSD value of each inorganic element content in the precision test is 0.49%–4.80%, indicating that the precision of the instrument is good. The RSD value of each inorganic element content in the repeatability test is 1.06%–4.50%, indicating that the method has good repeatability. The RSD value of each inorganic element content in the stability test is less than 4.98%, indicating that the sample solution is stable within 12 h. In the test of sample adding recovery rate, the sample adding recovery rate is 96.80%–105.70%, and the RSD value is less than 4.00%, indicating that this method is accurate and reliable.

2.3. Analysis of inorganic elements in 40 Batches of safflower samples

Heavy metals in 40 batches of safflower samples. A large number of elements. The contents of essential trace elements and other 12 inorganic elements are shown in **Table 3** respectively, **Tables 4**, **5** and **6**.

It can be seen from **Table 3** that the content of Cu in 40 batches of safflower samples is the highest; the contents of Hg and Pb are also high; as is in S_4 and S_5 samples from Guazhou City, Gansu Province, and S_7 samples from Yumen City, Gansu Province. S_8. $S_1$0. $S_1$1. $S_1$2. $S_1$3 and $S_1$4 samples, $S_2$5 samples from Yumin County, Xinjiang and $s_3$8 samples from Yongsheng County, Yunnan were detected; CD was only detected in $S_4$0 samples from Yongsheng County, Yunnan Province.

It can be seen from **Table 4** that in the 40 batches of safflower samples tested, K content (19.961–62.413 mg·g^{-1}) is the highest, P content (2.479–4.898 mg·g^{-1}) and Mg content (1.283–3.074 mg·g^{-1}) are low, and Na content (0.155–1.212 mg·g^{-1}) is the lowest.

It can be seen from **Table 5** that the Fe content in the essential trace elements of 40 batches of safflower samples tested (196.443–1407.164 μg·g^{-1}) and B content (55.552–136.285 μg·g^{-1}) is high, and the Ni content is (0.181–2.635 μg·g^{-1}) minimum.

Table 3. Contents of heavy metal elements in 40 Batches of *Carthami Flos* samples tested.

No.[1)]	**Content/μg·g^{-1}**[2)]				**No.**[1)]	**Content/μg·g^{-1}**[2)]			
	Na	**Mg**	**P**	**K**		**Na**	**Mg**	**P**	**K**
S1	0.221	1.821	3.021	56.394	S21	0.266	1.797	2.849	58.958
S2	0.246	1.695	2.479	52.240	S22	0.285	1.811	3.249	59.657
S3	0.279	2.141	2.748	61.739	S23	0.279	1.697	3.269	58.864

S4	0.536	2.782	2.608	62.363	S24	0.287	1.786	3.107	59.419
S5	1.212	2.829	2.658	55.187	S25	0.219	2.359	3.872	49.352
S6	0.589	2.161	4.127	60.139	S26	0.475	2.616	4.033	57.894
S7	0.651	3.074	2.604	55.751	S27	0.194	1.657	4.373	51.548
S8	0.761	2.907	2.561	55.408	S28	0.178	1.588	4.303	57.446
S9	0.696	2.951	2.747	57.111	S29	0.201	1.505	3.644	58.378
S10	0.662	3.013	2.735	56.995	S30	0.186	1.460	3.686	57.744
S11	0.674	2.943	2.636	56.532	S31	0.297	2.170	2.780	56.845
S12	0.661	2.973	2.593	56.951	S32	0.301	2.198	2.591	58.405
S13	0.704	3.004	2.634	56.689	S33	0.179	1.651	3.961	52.722
S14	0.521	2.636	4.111	54.771	S34	0.170	1.660	3.681	47.979
S15	0.456	2.497	2.723	56.488	S35	0.169	2.196	4.163	62.413
S16	0.254	1.812	2.944	60.379	S36	0.155	1.462	3.835	47.608
S17	0.263	1.804	2.998	61.902	S37	0.333	2.099	2.883	57.817
S18	0.261	1.764	2.937	60.741	S38	0.161	1.311	4.063	38.971
S19	0.294	1.813	3.111	58.745	S39	0.231	1.556	3.950	28.991
S20	0.263	1.799	3.018	62.339	S40	0.166	1.283	4.898	19.961

1) S1, S2, S3: Dangshan County in Anhui Province; S4, S5, S6: Guazhou City in Gansu Province; S7, S8, S9, S10, S11, S12, S13, S14, S15: Yumen City in Gansu Province; S16, S17, S18, S19, S20, S21, S22, S23, S24: Qixia District in Jiangsu Province; S25: Yumin County in Xinjiang Uygur Autonomous Region; S26, S27, S28: Jimsar County in Xinjiang Uygur Autonomous Region; S29: Qapqal Xibe Autonomous County in Xinjiang Uygur Autonomous Region; S30, S31, S32: Huocheng County in Xinjiang Uygur Autonomous Region; S33: Emin County in Xinjiang Uygur Autonomous Region; S34, S35: Urumqi County in Xinjiang Uygur Autonomous Region; S36: Yining County in Xinjiang Uygur Autonomous Region; S37: Yutian County in Xinjiang Uygur Autonomous Region; S38, S39, S40: Yongsheng County in Yunnan Province.
2) undetected is not detected.

It can be seen from **Table 6** that in the 40 batches of safflower samples tested, the Al content (149.168-1235.769 $\mu g \cdot g^{-1}$) was relatively high, and the safflower samples from Jiangsu and Anhui did not detect Sc, Co and Sc. Y, Sc, Co and Y were also not detected in some safflower samples from Xinjiang and Yunnan.

Table 4. Contents of large elements in 40 batches of safflower samples tested.

No.[1)]	**Content/($mg \cdot g^{-1}$)**				**No.**[1)]	**Content/($mg \cdot g^{-1}$)**			
	Na	**Mg**	**P**	**K**		**Na**	**Mg**	**P**	**K**
S1	0.221	1.821	3.021	56.394	S21	0.266	1.797	2.849	58.958
S2	0.246	1.695	2.479	52.240	S22	0.285	1.811	3.249	59.657
S3	0.279	2.141	2.748	61.739	S23	0.279	1.697	3.269	58.864
S4	0.536	2.782	2.608	62.363	S24	0.287	1.786	3.107	59.419
S5	1.212	2.829	2.658	55.187	S25	0.219	2.359	3.872	49.352
S6	0.589	2.161	4.127	60.139	S26	0.475	2.616	4.033	57.894
S7	0.651	3.074	2.604	55.751	S27	0.194	1.657	4.373	51.548
S8	0.761	2.907	2.561	55.408	S28	0.178	1.588	4.303	57.446
S9	0.696	2.951	2.747	57.111	S29	0.201	1.505	3.644	58.378
S10	0.662	3.013	2.735	56.995	S30	0.186	1.460	3.686	57.744
S11	0.674	2.943	2.636	56.532	S31	0.297	2.170	2.780	56.845
S12	0.661	2.973	2.593	56.951	S32	0.301	2.198	2.591	58.405
S13	0.704	3.004	2.634	56.689	S33	0.179	1.651	3.961	52.722

S14	0.521	2.636	4.111	54.771	S34	0.170	1.660	3.681	47.979
S15	0.456	2.497	2.723	56.488	S35	0.169	2.196	4.163	62.413
S16	0.254	1.812	2.944	60.379	S36	0.155	1.462	3.835	47.608
S17	0.263	1.804	2.998	61.902	S37	0.333	2.099	2.883	57.817
S18	0.261	1.764	2.937	60.741	S38	0.161	1.311	4.063	38.971
S19	0.294	1.813	3.111	58.745	S39	0.231	1.556	3.950	28.991
S20	0.263	1.799	3.018	62.339	S40	0.166	1.283	4.898	19.961

1) S1, S2, S3: Dangshan County in Anhui Province; S4, S5, S6: Guazhou City in Gansu Province; S7, S8, S9, S10, S11, S12, S13, S14, S15: Yumen City in Gansu Province; S16, S17, S18, S19, S20, S21, S22, S23, S24: Qixia District in Jiangsu Province; S25: Yumin County in Xinjiang Uygur Autonomous Region; S26, S27, S28: Jimsar County in Xinjiang Uygur Autonomous Region; S29: Qapqal Xibe Autonomous County in Xinjiang Uygur Autonomous Region; S30, S31, S32: Huocheng County in Xinjiang Uygur Autonomous Region; S33: Emin County in Xinjiang Uygur Autonomous Region; S34, S35: Urumqi County in Xinjiang Uygur Autonomous Region; S36: Yining County in Xinjiang Uygur Autonomous Region; S37: Yutian County in Xinjiang Uygur Autonomous Region; S38, S39, S40: Yongsheng County in Yunnan Province.
2) undetected is not detected.

Table 5. Contents of essential trace elements in 40 batches of *Carthami Flos* samples tested.

No.[1)]	**Content/($\mu g \cdot g^{-1}$)**						
	Cr	**Mn**	**Fe**	**Ni**	**Zn**	**Sr**	**B**
S1	6.561	28.307	465.618	1.064	44.046	22.593	136.285
S2	9.439	24.729	450.980	0.435	28.777	20.639	92.998
S3	9.107	26.779	549.118	0.581	46.910	27.493	120.436
S4	11.780	50.500	878.487	1.597	33.135	37.474	130.056
S5	28.721	50.929	1407.164	2.059	30.060	60.276	99.962
S6	12.742	47.858	820.687	1.621	29.994	90.289	110.116
S7	9.476	48.935	1188.009	1.536	29.962	73.125	103.783
S8	24.023	43.496	1144.767	2.635	28.726	65.727	95.274
S9	24.442	45.393	1182.203	1.692	28.890	67.506	98.822
S10	17.468	45.672	1136.503	1.537	29.196	69.492	101.830
S11	12.354	46.887	1192.277	1.319	28.542	67.667	98.570
S12	22.591	46.447	1219.845	1.581	29.304	69.311	97.993
S13	20.322	46.850	1214.124	1.452	28.366	66.366	97.178
S14	14.942	36.292	930.714	1.284	29.976	47.436	93.662
S15	10.373	36.391	741.051	0.835	28.182	63.534	94.028
S16	8.599	21.946	252.155	0.329	35.392	22.279	117.527
S17	7.191	20.713	196.443	0.181	35.846	21.965	114.934
S18	7.043	20.467	196.647	0.185	34.496	21.716	108.926
S19	8.076	24.036	311.165	0.353	34.709	21.444	117.401
S20	8.548	22.631	274.622	0.343	33.469	22.229	113.221
S21	8.306	24.265	368.746	0.347	33.034	22.723	112.384
S22	7.393	23.281	284.393	0.426	35.044	21.313	121.599
S23	5.111	21.080	221.074	0.651	39.053	19.535	117.629
S24	7.951	21.692	268.714	0.284	38.171	21.362	114.661
S25	7.640	35.109	737.599	1.137	29.029	37.314	94.459
S26	19.277	38.693	757.346	1.155	28.884	77.700	94.060

S27	27.747	35.329	722.374	0.683	34.311	20.620	85.888
S28	19.728	31.563	440.034	0.538	33.570	35.260	94.705
S29	18.472	35.857	868.146	1.114	29.746	50.404	81.347
S30	15.756	34.262	757.279	0.938	29.743	50.744	84.021
S31	8.898	32.004	610.517	0.757	37.067	30.920	120.307
S32	6.429	28.931	564.346	0.613	33.944	30.194	127.300
S33	24.968	42.145	1040.878	1.194	31.512	34.687	93.938
S34	22.080	34.077	710.398	0.715	32.623	15.980	79.946
S35	14.387	23.933	580.190	1.173	28.569	29.200	98.594
S36	18.258	33.537	591.150	0.709	33.251	8.719	81.556
S37	9.445	35.663	688.988	0.749	36.652	30.518	103.804
S38	8.566	25.676	276.754	1.892	34.783	8.926	69.620
S39	9.622	32.544	600.662	1.044	38.541	5.972	88.675
S40	7.452	18.277	225.076	1.123	36.624	8.146	55.552

1) S1, S2, S3: Dangshan County in Anhui Province; S4, S5, S6: Guazhou City in Gansu Province; S7, S8, S9, S10, S11, S12, S13, S14, S15: Yumen City in Gansu Province; S16, S17, S18, S19, S20, S21, S22, S23, S24: Qixia District in Jiangsu Province; S25: Yumin County in Xinjiang Uygur Autonomous Region; S26, S27, S28: Jimsar County in Xinjiang Uygur Autonomous Region; S29: Qapqal Xibe Autonomous County in Xinjiang Uygur Autonomous Region; S30, S31, S32: Huocheng County in Xinjiang Uygur Autonomous Region; S33: Emin County in Xinjiang Uygur Autonomous Region; S34, S35: Urumqi County in Xinjiang Uygur Autonomous Region; S36: Yining County in Xinjiang Uygur Autonomous Region; S37: Yutian County in Xinjiang Uygur Autonomous Region; S38, S39, S40: Yongsheng County in Yunnan Province.
2) undetected is not detected.

Table 6. Contents of other 12 inorganic elements in 40 batches of *Carthami Flos* samples tested.

No.[1)]	**Content/($\mu g \cdot g^{-1}$)**[2)]											
	Li	**Be**	**Tl**	**Bi**	**Sc**	**Ti**	**V**	**Co**	**Ga**	**Y**	**Ba**	**Al**
S1	1.374	0.086	4.223	5.615	-	18.592	0.701	-	1.355	-	7.381	474.941
S2	1.142	0.076	4.038	5.366	-	14.404	0.578	-	1.071	-	5.833	401.690
S3	1.202	0.086	4.309	5.727	-	20.786	0.790	-	1.591	-	8.755	512.179
S4	2.045	0.121	4.325	5.746	0.085	38.717	1.755	0.088	3.505	0.164	18.396	1087.487
S5	2.001	0.120	4.075	5.419	0.187	42.782	2.407	0.266	3.497	0.270	16.937	1235.769
S6	1.779	0.098	4.076	5.417	0.027	30.784	1.236	0.079	10.298	0.024	50.473	702.486
S7	2.533	0.115	4.294	5.707	0.135	39.179	2.071	0.229	3.307	0.242	15.530	1091.684
S8	2.062	0.115	4.203	5.584	0.314	45.144	2.253	0.196	3.553	0.257	15.936	1170.390
S9	1.833	0.113	4.278	5.686	0.108	37.141	1.995	0.180	3.065	0.160	14.509	1012.156
S10	2.492	0.107	4.280	5.689	0.081	35.366	1.845	0.240	2.702	0.164	13.689	927.681
S11	1.855	0.116	4.266	5.670	0.132	37.423	2.057	0.141	3.743	0.188	17.557	1089.188
S12	2.022	0.113	3.982	5.291	0.181	40.344	2.265	0.226	3.447	0.244	16.025	1153.269
S13	2.021	0.119	4.260	5.661	0.119	40.659	2.092	0.181	3.053	0.173	14.712	1062.792
S14	1.880	0.112	4.251	5.650	0.079	33.500	1.789	0.085	2.386	0.104	12.054	1003.737
S15	1.851	0.104	4.269	5.675	0.029	30.414	1.367	-	3.449	0.057	17.808	796.101
S16	0.622	0.065	4.085	5.429	-	8.231	0.142	-	0.566	-	3.807	183.211
S17	0.540	0.061	4.002	5.318	-	6.508	0.088	-	0.435	-	3.349	149.168
S18	0.539	0.065	4.177	5.551	-	7.295	0.109	-	0.528	-	3.530	180.763
S19	0.792	0.069	4.047	5.378	-	11.017	0.317	-	0.790	-	4.953	278.001

S20	0.737	0.067	4.151	5.517	-	9.588	0.244	-	0.629	-	4.142	238.371
S21	0.758	0.073	3.928	5.221	-	13.584	0.451	-	0.919	-	5.559	347.069
S22	0.940	0.077	4.261	5.663	-	10.084	0.235	-	0.699	-	4.563	238.921
S23	0.718	0.064	4.024	5.350	-	7.450	0.161	-	0.801	-	4.794	213.024
S24	0.647	0.069	4.224	5.613	-	9.663	0.284	-	0.950	-	5.417	265.468
S25	1.628	0.098	4.050	5.387	0.027	27.137	1.256	0.011	2.062	0.051	10.028	780.637
S26	1.229	0.092	3.963	5.268	0.021	26.464	1.159	0.020	4.143	0.014	20.275	634.296
S27	0.851	0.087	4.102	5.453	0.035	35.760	1.136	-	1.847	0.061	9.171	583.037
S28	0.656	0.076	4.259	5.663	-	18.096	0.586	-	1.940	-	9.741	350.773
S29	1.183	0.096	4.083	5.426	0.086	55.735	1.749	0.027	1.469	0.165	7.145	815.174
S30	1.081	0.088	3.998	5.313	0.056	45.207	1.533	-	1.339	0.109	6.695	719.113
S31	1.275	0.089	4.250	5.650	-	22.385	0.900	-	2.204	-	11.585	564.650
S32	1.313	0.088	4.007	5.329	-	21.831	0.893	-	1.376	-	7.411	548.774
S33	1.302	0.101	4.200	5.581	0.105	52.061	2.097	0.081	2.712	0.183	13.348	888.985
S34	0.856	0.084	4.003	5.322	-	36.766	1.326	-	1.568	0.114	7.978	552.818
S35	0.862	0.072	3.806	5.059	-	27.782	1.049	-	1.355	-	6.925	530.949
S36	0.714	0.084	4.024	5.348	-	32.850	0.980	-	1.844	0.033	9.648	535.566
S37	1.354	0.100	4.173	5.547	0.005	32.789	1.269	-	2.362	0.070	12.319	734.502
S38	0.593	0.071	4.281	5.691	-	5.334	0.276	-	1.123	-	6.218	315.261
S39	0.871	0.097	4.282	5.695	0.009	18.129	1.050	-	0.847	0.059	4.461	684.884
S40	0.371	0.068	4.228	5.621	-	4.733	0.174	-	0.384	-	2.669	216.880

1) S1, S2, S3: Dangshan County in Anhui Province; S4, S5, S6: Guazhou City in Gansu Province; S7, S8, S9, S10, S11, S12, S13, S14, S15: Yumen City in Gansu Province; S16, S17, S18, S19, S20, S21, S22, S23, S24: Qixia District in Jiangsu Province; S25: Yumin County in Xinjiang Uygur Autonomous Region; S26, S27, S28: Jimsar County in Xinjiang Uygur Autonomous Region; S29: Qapqal Xibe Autonomous County in Xinjiang Uygur Autonomous Region; S30, S31, S32: Huocheng County in Xinjiang Uygur Autonomous Region; S33: Emin County in Xinjiang Uygur Autonomous Region; S34, S35: Urumqi County in Xinjiang Uygur Autonomous Region; S36: Yining County in Xinjiang Uygur Autonomous Region; S37: Yutian County in Xinjiang Uygur Autonomous Region; S38, S39, S40: Yongsheng County in Yunnan Province.
2) undetected is not detected.

2.4. Analysis of inorganic elements in safflower samples from different provinces (autonomous regions)

Heavy metals in safflower samples from different provinces (autonomous regions). The contents of major elements and essential trace elements are shown in **Table 7** Respectively, **Tables 8** and **9**.

It can be seen from **Table 7** that the Hg content of safflower samples from Yunnan is the highest, which is significantly higher than that of safflower samples from other provinces (autonomous regions), while the Hg content of safflower samples from Jiangsu is the lowest; the Pb content of safflower samples from Yunnan and Gansu is higher, which is significantly higher than that of safflower samples from Jiangsu; there was no significant difference in Cu content in safflower samples from different provinces (autonomous regions); the contents of as and Cd in safflower samples from different provinces (autonomous regions) are low or not detected.

It can be seen from **Table 8** that the contents of Na and Mg in safflower samples from Gansu are significantly higher than those in safflower samples from other provinces (autonomous regions); the content of P in safflower samples from Yunnan and Xinjiang was significantly higher than that of safflower samples from other provinces (autonomous regions); the content of K in safflower samples from Jiangsu is the highest, and the content of K in safflower samples from Yunnan is significantly lower than that in safflower samples from other provinces (autonomous regions).

It can be seen from **Table 9** that the content of Cr in safflower samples from Xinjiang and Gansu is higher, which is significantly higher than that of safflower samples from Jiangsu; mn in safflower samples from Gansu. Fe. The contents of Ni and SR are the highest, which are significantly higher than those of safflower samples from other provinces (autonomous regions); the contents of Zn and B in safflower samples from Anhui are the highest; cr in safflower samples from Jiangsu. Mn. The contents of Fe and Ni, Zn in safflower samples from Gansu and Sr and B in safflower samples from Yunnan are the lowest, which are significantly lower than those in safflower samples from other provinces (autonomous regions).

Table 7. Contents of heavy metal elements in *Carthami Flos* samples from different provinces (autonomous regions) ($\bar{X} \pm SD$).

Province (Autonomous region)	Content/(μg·g^{-1})[1)]				
	Hg	**Pb**	**Cu**	**As**	**Cd**
Anhui	0.365 ± 0.092b	3.711 ± 0.176ab	16.368 ± 4.330a	-	-
Gansu	0.449 ± 0.061b	3.935 ± 0.115a	14.804 ± 1.572a	0.131 ± 0.121	-
Jiangsu	0.350 ± 0.075b	3.547 ± 0.107b	14.177 ± 0.591a	-	-
Xinjiang	0.511 ± 0.129b	3.755 ± 0.324ab	14.103 ± 1.582a	0.002 ± 0.000	-
Yunnan	1.478 ± 0.866a	4.058 ± 0.503a	13.589 ± 2.453a	0.006 ± 0.000	0.125 ± 0.000

[1)] Different lowercase letters in the same column indicate the significant ($P < 0.05$) difference Undetected.

Table 8. Contents of major elements in *Carthami Flos* samples from different provinces (autonomous regions) ($\bar{X} \pm SD$).

Province (Autonomous region)	Content/(mg·g^{-1})[1)]			
	Na	**Mg**	**P**	**K**
Anhui	0.249 ± 0.029b	1.886 ± 0.230b	2.749 ± 0.271b	56.791 ± 4.762ab
Gansu	0.677 ± 0.190a	2.814 ± 0.265a	2.895 ± 0.575b	57.032 ± 2.165ab
Jiangsu	0.272 ± 0.014b	1.787 ± 0.037b	3.053 ± 0.143b	60.112 ± 1.327a
Xinjiang	0.235 ± 0.092b	1.894 ± 0.390b	3.677 ± 0.577a	55.089 ± 4.691b
Yunnan	0.186 ± 0.039b	1.383 ± 0.150b	4.304 ± 0.518a	29.307 ± 9.508c

[1)] Different lowercase letters in the same column indicate the significant ($P < 0.05$) difference.

Table 9. Contents of essential trace elements in *Carthami Flos* samples from different provinces (autonomous regions) (X ± SD).

Province (Autonomous region)	Content/(μg·g^{-1})[1)]						
	Cr	**Mn**	**Fe**	**Ni**	**Zn**	**Sr**	**B**
Anhui	8.369 ± 1.575ab	26.605 ± 1.796bc	488.572 ± 52.943bc	0.693 ± 0.329bc	39.911 ± 9.748a	23.575 ± 3.531bc	116.573 ± 21.900a
Gansu	17.436 ± 6.425a	45.471 ± 4.751a	1087.986 ± 197.931a	1.596 ± 0.435a	29.528 ± 1.323bc	64.850 ± 12.970a	101.773 ± 9.997a
Jiangsu	7.580 ± 1.087b	22.235 ± 1.404c	263.773 ± 55.711c	0.344 ± 0.140c	35.468 ± 1.998ab	21.618 ± 0.914bc	115.364 ± 3.682a
Xinjiang	16.391 ± 6.750a	33.931 ± 4.423b	697.634 ± 150.915b	0.883 ± 0.242b	32.223 ± 2.900b	34.789 ± 17.479b	95.379 ± 14.640a
Yunnan	8.547 ± 1.085ab	25.499 ± 7.135c	367.497 ± 203.573c	1.353 ± 0.469a	36.649 ± 1.879ab	7.681 ± 1.531c	71.282 ± 16.624b

[1)] Different lowercase letters in the same column indicate the significant ($P < 0.05$) difference.

2.5. Cluster analysis of 40 batches of safflower samples

The cluster analysis pedigree of 40 batches of safflower samples is shown in **Figure 1**.

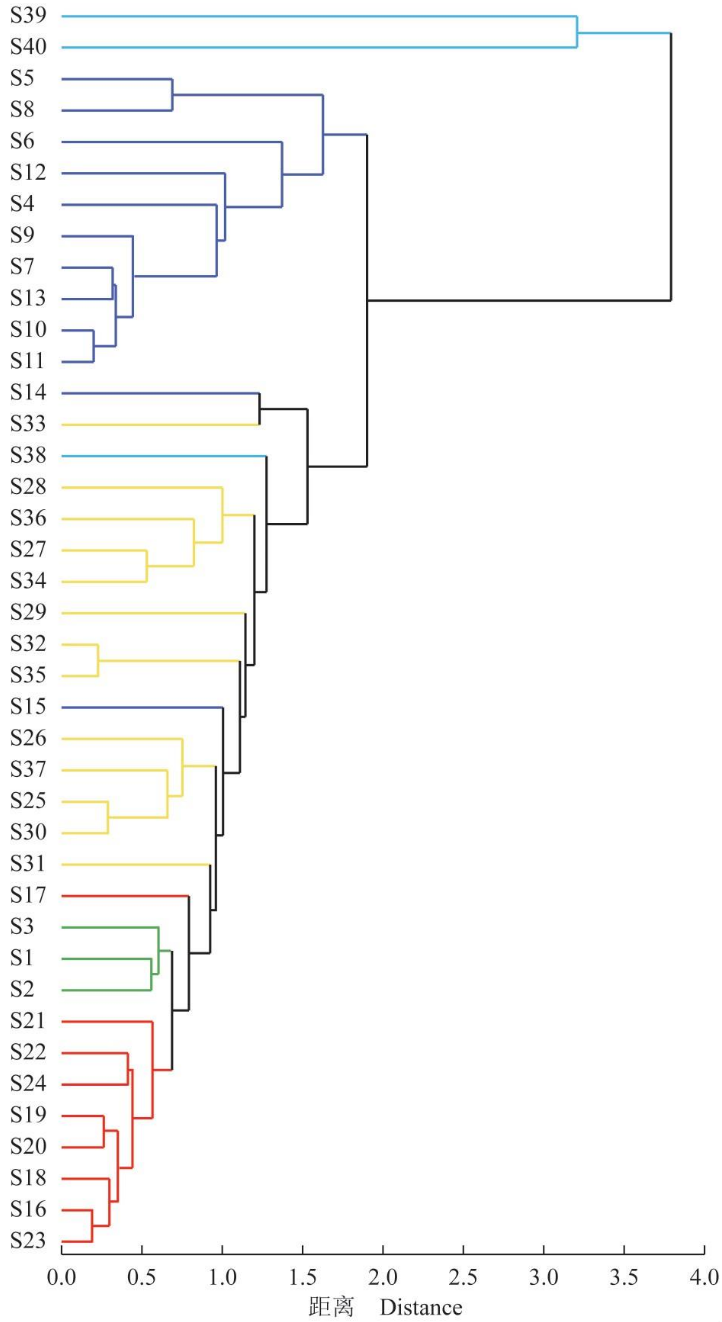

Figure 1. Dendrogram of 40 batches of *Carthami Flos* samples tested by cluster analysis.

: Anhui Province; : Gansu Province; : Jiangsu Province; : Xinjiang Uygur autonomousregion; : Yunnan Province.

S1, S2, S3: Dangshan County in Anhui Province; S4, S5, S6: Guazhou City in Gansu Province; S7, S8, S9, S10, S11, S12, S13, S14, S15: Yumen City in Gansu Province; S16, S17, S18, S19, S20, S21, S22, S23, S24: Qixia District in Jiangsu Province; S25: Yumin County in Xinjiang Uygur Autonomous Region; S26, S27, S28: Jimsar County in Xinjiang Uygur Autonomous Region; S29: Qapqal Xibe Autonomous County in Xinjiang Uygur Autonomous Region; S30, S31, S32: Huocheng County in Xinjiang Uygur Autonomous Region; S33: Emin County in Xinjiang Uygur Autonomous Region; S34, S35: Urumqi County in Xinjiang Uygur Autonomous Region; S36: Yining County in Xinjiang Uygur Autonomous Region; S37: Yutian County in Xinjiang Uygur Autonomous Region; S38, S39, S40: Yongsheng County in Yunnan Province.

It can be seen from **Figure 1** that on the whole, safflower samples from the same province (autonomous region) can be better grouped into one group. Among them, safflower samples from Anhui and Jiangsu gather first, safflower samples from Gansu and Xinjiang are closer, and safflower samples from Yunnan are far away from safflower samples from other provinces (autonomous regions).

2.6. Principal component analysis of 40 Batches of safflower samples

The results of principal component analysis show that the cumulative variance contribution rate of the first four principal components reaches 81.4%. Therefore, the first four principal components are extracted to draw the scatter diagram of principal component analysis. The results are shown in **Figure 2**. It can be seen from **Figure 2** that on the whole, safflower samples from the same province (autonomous region) can gather well, which is consistent with the clustering analysis results, except that the distribution of safflower samples from Yunnan is relatively scattered.

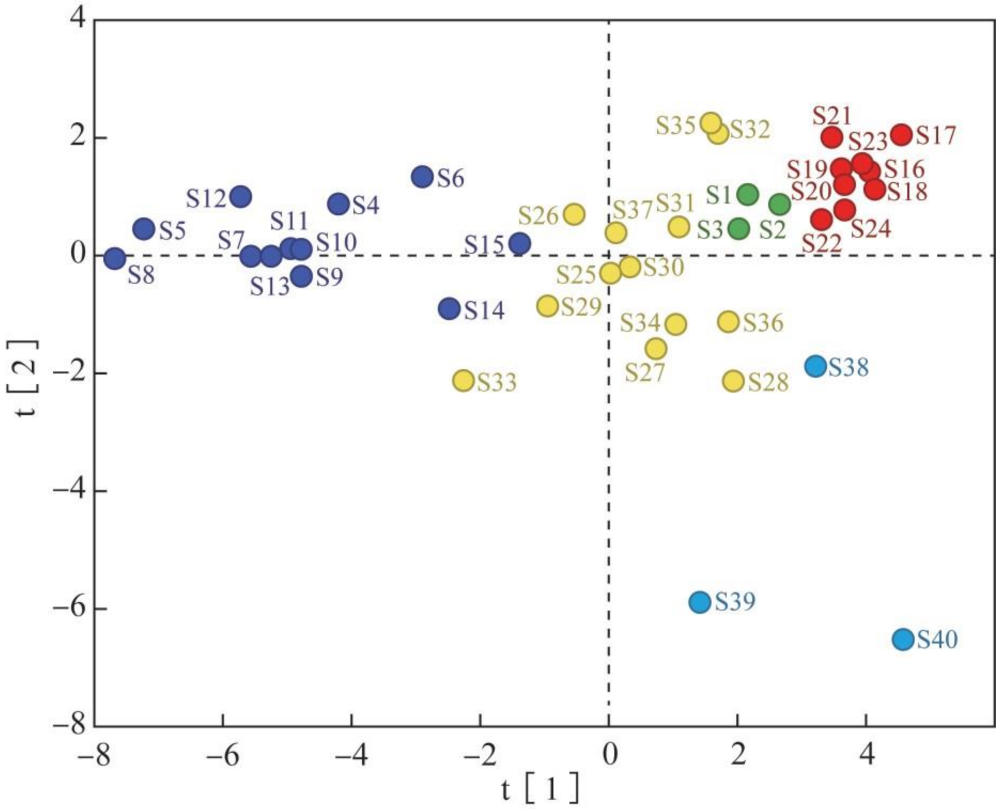

Figure 2. Scatter plot of 40 batches of *Carthami Flos* samples tested by principal component analysis.
●: Anhui Province; ●: Gansu Province;●: Jiangsu Province; ●: Xinjiang Uygur autonomousregion;●: Yunnan Province.
S1, S2, S3: Dangshan County in Anhui Province; S4, S5, S6: Guazhou City in Gansu Province; S7, S8, S9, S10, S11, S12, S13, S14, S15: Yumen City in Gansu Province; S16, S17, S18, S19, S20, S21, S22, S23, S24: Qixia District in Jiangsu Province; S25: Yumin County in Xinjiang Uygur Autonomous Region; S26, S27, S28: Jimsar County in Xinjiang Uygur Autonomous Region; S29: Qapqal Xibe Autonomous County in Xinjiang Uygur Autonomous Region; S30, S31, S32: Huocheng County in Xinjiang Uygur Autonomous Region; S33: Emin County in Xinjiang Uygur Autonomous Region; S34, S35: Urumqi County in Xinjiang Uygur Autonomous Region; S36: Yining County in Xinjiang Uygur Autonomous Region; S37: Yutian County in Xinjiang Uygur Autonomous Region; S38, S39, S40: Yongsheng County in Yunnan Province.

3. Discussion and conclusion

There are two ways for human body to absorb and utilize inorganic elements, one is to absorb them with direct dietary intake, and the other is to add them after solvent extraction[16]. As a dual-purpose plant for medicine and food, safflower contains inorganic elements that are closely related to its nutritional value and safety. At present, safflower has been included in the list of traditional Chinese medicine that can be used as health food by the National Health Commission, and has broad development prospects. According to WM 2-2001 green industry standard for the import and export of medicinal plants and preparations, the total content of heavy metals in green medicinal plants should be less than or equal to 20.0 $mg \cdot kg^{-1}$, Cu content less than or equal to 20.0 $mg \cdot kg^{-1}$, Hg content less than or equal to 0.2 $mg \cdot kg^{-1}$, Pb content less than or equal to 5.0 $mg \cdot kg^{-1}$, Cd content less than or equal to 0.3 $mg \cdot kg^{-1}$, as content less than or equal to 2.0 $mg \cdot kg^{-1}$. The Hg content in 40 batches of safflower samples exceeded the standard, Pb. The content of as and CD did not exceed the standard, and the content of Cu in S_1 sample from Dangshan County, Anhui Province exceeded the standard. Shu et al.[17] found that without any measures to eliminate the Hg memory effect, 0.5$\mu g \cdot L^{-1}$ Hg can produce obvious memory effect, and with the increase of Hg concentration, the memory effect continues to strengthen. In this study, the content of Hg in heavy metals in 40 batches of safflower samples exceeded the standard, which is speculated to be mainly due to the failure to take measures to eliminate Hg memory effect during the experiment. Among the safflower samples from different provinces (autonomous regions), the Pb content in the safflower samples from Yunnan and Gansu is higher. Except that it is significantly higher than the safflower samples from Jiangsu, the Pb content in the safflower samples from all provinces (autonomous regions) is not significantly different on the whole, which may be because the absorption of Pb by safflower is independent of the Pb concentration in the environment[18]. The content of Cu in the tested safflower samples is the highest, which is consistent with the research results of Tian et al.[19], possibly because the plant needs to absorb Cu ions from the soil during the growth process to ensure normal photosynthesis and growth[20,21].

Among the large elements contained in the tested safflower sample, the content of K is the highest, and the content of P and Mg is in the middle, which may be related to the selective absorption of these three large elements by safflower. Jia et al.[22] believe that safflower is a kind of medium P demand. Plants that need more K, and in the process of growth, the absorption of K is larger in the seedling stage and bud stage, especially the flower has the largest demand for K[7,23], which may be the reason that the content of K and P in safflower samples is higher than that of other large elements.

In the cluster analysis diagram, the composition of inorganic elements in the samples clustered into a class is similar. The results of cluster analysis and principal component analysis show that safflower samples from Gansu can be better gathered together. It is speculated that most of the safflower samples from Gansu come from the base, and the planting varieties are relatively single. Safflower samples from Xinjiang are relatively scattered, which may be related to the large number of safflower varieties (more than 300 varieties)[12]. In addition, Xinjiang’s vast territory and diverse planting methods are also potential reasons for the dispersion of samples. Xinjiang belongs to the temperate continental climate with low precipitation, and the high-quality safflower planting areas are mainly concentrated at an altitude of 1000–1250 m[12], while Yunnan belongs to the tropical monsoon climate. The average altitude of the main safflower planting areas (such as Yongsheng County) is about 1300 m, with a good climate and stable precipitation[24]. Different climatic and ecological conditions lead to great differences in the composition of inorganic elements in the safflower samples in Yunnan and other regions.

In this study, microwave digestion and ICP-AES were used to analyze 28 inorganic elements in 40 batches of safflower samples from different habitats, and a rapid method was established. A method for accurate analysis of inorganic elements in safflower. The results of this study show that safflower is rich in a variety of beneficial elements K. P and Na and trace element Fe. B and Zn. However, the beneficial elements Ca and Se were not detected in this study, and they need to be detected in later experiments. In addition, it is also necessary to strengthen the monitoring of the content of heavy metals in safflower and control the heavy metal pollution in soil. There are certain differences in the content of inorganic elements in safflower samples from different places of origin. Therefore, it is necessary to use different types of fertilizers in the growth process of safflower according to different places of origin, so as to reduce the differences between places of origin and improve the overall quality of safflower medicinal materials on the market. In addition, the relationship between the content of inorganic elements in soil and that in safflower also needs to be further explored.

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Conflict of interest

The authors declare no conflict of interest.

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