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Metal Determination in Iranian Saffron

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Abstract

The present investigation reports a quantitative analysis of metals in the saffron samples collected from seven different saffron production areas in the Khorasan Razavi province, Iran. Khorasan Razavi is the leading producer of saffron in Iran, and more than 95% of the global production of this expensive spice is attributed to Iran. Since environmental pollution is increasing, saffron is contaminated with various organic and inorganic contaminants such as heavy metals. Twenty-one saffron samples were collected in the flowering season of 2018 and analyzed for metal content. The concentration of microelements and heavy metals including Zn, Fe, Ca, Mn, Mg, Na, K, Pb, Cd, Cu, and Cr was determined in the samples collected from three farms in each production area with graphite furnace and flame atomic absorption spectroscopy. The results revealed that the collected saffron stigmas contain a wide range of minerals and heavy metals with different concentrations. Potassium is the most abundant element, and Cd had the least concentration in the saffron. It can be concluded that ecological management plans such as reducing chemical fertilizers and improving organic fertilizers can decline the extent of heavy metals in the saffron.

Keywords

Saffron; Heavy Metal; Atomic Absorption Spectroscopy; Khorasan Razavi.

1. INTRODUCTION

Saffron is a three-branch and dried stigma of saffron flower (*Crocus sativus* L.). Saffron grows in low rain areas of Iran with cold winter and hot summer [1]. The edible part of the saffron, stigma, is the most expensive spice worldwide [2]. Crocin, picrocrocin, and safranal are the principal secondary metabolites of the saffron [3], and the Iranian saffron has the highest content of these metabolites [4]. Iran is the primary producer of saffron, and more than 95% of the global production of this expensive product is attributed to Iran [5]. The Khorasan Razavi province is considered the main producer of saffron in Iran [6].

In addition to being used as a spice, saffron has medicinal properties also, and its antispasmodic and sedative activities are known from ancient times [2]. During the last decade, researches have focused on the tumoricidal and anti-carcinogenic properties of the saffron [7,8]. More recently, free radical scavenging and detoxifying capacities of the saffron were studied [9-11]. Plants need some essential nutrients to grow, and its deficiency is usually compensated by different fertilizers. Although, the use of chemical fertilizers increases the plant's growth and improves their performance, but reduces the stability and health of agricultural productions. Environmental contamination also occurs as a result of the use of chemical fertilizers [12].

Although some chemical elements are present in small amounts, they play a vital role in the metabolic processes and are required for human's health [13]. Micro-elements are present in the enzyme's structure and affect the biochemical activities of the cells [14]. Elements such as sodium, potassium, magnesium, and manganese are present at the levels of mg/g whereas chromium, iron, copper, zinc, and cadmium are present at levels lower than µg/g. Besides, some rare elements have been reported at the levels of ng/g and lower [15]. The presence of essential elements is affected by the geochemical properties of the soil and plant ability to absorb these elements. The solubility of these compounds is very high in the water due to their ionic structure so, they are rapidly absorbed through the plant roots, as the primary organ to absorb these compounds. The leaf blades are the other sources for the absorption of these elements, influenced by rainfall, atmospheric dust, plant protection agents, and fertilizers [14].

Heavy metals are one of the most well-known environmental pollutants which cause various health problems. They are toxic in specific

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concentrations for living organisms, including humans [16]. These elements have low mobility in the soil and do not transfer to the underlying layers [17]. Unlike organic contaminants, heavy metals are irreplaceable, non-degradable, and stable in the soil. These elements are naturally present in the soil, but extra amounts are also introduced to the environment due to human activities [18].
In the present study, a total of 21 samples were collected from 7 major saffron producing regions of the Khorasan Razavi province in Iran. The collected samples pre-concentrated and subjected to atomic absorption spectrometer to quantify the 7 minerals (K, Mg, Na, Ca, Fe, Zn and Mn) and 4 heavy metals (Cr, Cu, Pb and Cd) of saffron stigmas samples. The aim was to assess the saffron quality for human consumption and investigate the amount of heavy metals due to the permitted range of Iranian national standard (Pb≤10 mg/kg based on INSO, 259-1).

2. EXPERIMENTAL

Saffron samples (as fresh flowers) were collected from the leading producer centers of Khorasan Razavi province, including Zaveh, Torbat-e Heydariyeh, Torbat-e Jam, Roshtkhar, Taybad, Kashmar, and Neyshaboor, in November 2018. The samples were randomly collected from three different farms of each region, and transferred to the central laboratory of the Research Institute of Food Science and Technology, Mashhad, Iran. The stigmas were separated and dried in the oven at 70 ˚C for 120 min. Dried stigmas were grounded and sieved. The particle sizes after sieving were below 0.25 mm. Geographical coordinates and the map of the study region are shown in Table 1 and Fig. 1, respectively.

2.2. Instrumentation

A SensAA GBC atomic absorption spectrometer (Dandenong, Australia) controlled by Avanta Version 2.0.2 software equipped with a flame and a graphite furnace atomizer with deuterium background correction was employed for the measurement of metal contents of saffron. Pb and Cd determination was done by graphite furnace technique (GFAAS). The working device parameters (gasses, optics, and electronics) were adjusted for maximum absorption for each element recommended by the manufacturer. Analysis of other metals content was done with, air–acetylene and N_2O–acetylene flame atomic absorption spectrometry (FASS). The purity of acetylene, argon, and N_2O were 99.99%. The standard calibration curves were plotted with absorption against concentration with optimized parameters. Good linearity was observed with a definite range for each metal. The mean values (mg/kg in dry matter) were reported on triplicate analyses of all samples.

Table 1. Geographical coordinates of the study region.

City	Latitude Degree Minute	Longitude Degree Minute	Altitude (m)	Annual rainfall (mm)
Zaveh	35° 16'	59° 27'	1350	219.0
Torbat-e Heydariyeh	35° 16'	59° 13'	1365	267.2
Torbat-e Jam	35° 14'	60° 37'	909	174.7
Roshtkhar	34° 58'	59° 37'	1146	174.5
Taybad	34° 44'	60° 46'	812	178.8
Kashmar	35° 14'	58° 27'	1051	203.0
Neyshaboor	36° 12'	58° 47'	1198	232.5

Fig. 1. The map of the study region.

2.3. Chemicals

Hydrochloric acid, nitric acid, hydrogen peroxide, and other chemicals were purchased from Merck (Darmstadt, Germany) and Sigma-Aldrich (Missouri, USA). All other chemicals were of analytical reagent grade and used without any purification. Homemade deionized water (DI) was used for standard and sample preparation. The standard solutions were prepared with dissolving an appropriate amount of the single stock standards of each element and kept at 4 ˚C until analysis. Working standard solutions were prepared daily by diluting stock solutions in deionized water or 0.1 M nitric acid solution. All glassware was cleaned by soaking in a 1.4 mol L^{-1} HNO_3 solution for at least 24 h and rinsed with deionized water before use. Statistical analysis was conducted using excel 2013and all experiments were done in triplicate.

2.4. Digestion procedures

About 0.2 g of dried samples were weighed and digested with 5 mL HNO_3 and $HClO_4$ (20:1, v/v) mixture. After complete digestion and removal of the acid, the residue was filtered through the filter paper and adjusted to 20 mL with deionized water for determination.

3. RESULT AND DISCUSSION

In this study, eleven elements were determined in dried stigmas of saffron flowers using atomic absorption spectrometer (AAS). The obtained results show that saffron stigmas contain a high concentration of major metal (Ca, Fe, Mg, Mn, Zn, Na, and K), which are essential for human biological activities. Cu, Pb, Cd, and Cr were also found relatively in all of the samples. Concentrations of the metal in the saffron stigmas are presented in Table 2.

3.1. Mineral content

3.1.1. Potassium

The mineral content analysis of saffron revealed that the, Torbat-e Jam and Kashmar had the highest (169861.8 mg/kg) and lowest (108618.3 mg/kg) mean concentration values of the potassium, respectively (Table 2). Meaningful differences were observed in the K content of samples from different regions. Among determined elements, potassium was found to have the highest concentration varied between 226801.8 and 91835.80 mg/kg. In the sandy and light soils, or in the plants that require a higher amount of potassium during their growth, such as saffron, we have to add some potassium to the soil.

Table 2. Content of 11 elements in saffron from study region.

City	Zn (mg/kg)	Fe (mg/kg)	Ca (mg/kg)	Cu (mg/kg)	Mg (mg/kg)	Na (mg/kg)	K (mg/kg)	Mn (mg/kg)	Cr (mg/kg)	Pb (ng/g)	Cd (ng/g)
RO	63.50 ± 0.49	356.2±1.2	695.50±2.5	25.8±1.3	8394.50±1.9	5552.80±1.2	226801.8±3.6	114.9±0.6	95.8±2.6	28832.3±5.3	746.80±5.7
RO	45.80 ± 0.50	147.4±1.8	373.30±3.5	12.7±1.8	7211.90±2.8	2050.80±1.3	143217.9±2.0	35.10±0.3	12.3±6.1	7987.20±5.6	293.60±2.1
RO	57.50 ± 0.25	123.2±1.8	699.40±3.8	12.7±1.3	6058.20±2.7	2872.10±2.1	107457.6±4.1	26.30±0.9	33.0±7.1	8750.80±4.6	1866.4±2.8
TJ	65.50 ± 0.54	426.6±2.9	961.30±3.5	22.4±1.5	9796.40±3.2	3753.70±4.7	209587.6±1.8	132.7±1.1	60.1±4.7	9924.50±4.7	595.10±3.5
TJ	54.50 ± 0.27	212.8±6.01	531.60±2.9	14.0±1.3	10250.6±3.6	3370.20±0.5	146408.8±1.8	60.60±0.4	44.0±2.6	49048.5±6.5	1741.8±4.7
TJ	33.40 ± 0.57	136.5±3.3	444.60±4.7	14.9±1.6	8431.20±2.8	2625.40±1.2	153589.0±7.1	45.30±0.6	10.5±7.6	38718.6±4.9	297.70±7.5
NE	54.10 ± 0.53	227.8±4.8	808.60±4.6	16.5±1.4	9364.90±1.9	9340.80±2.7	157609.9±6.2	39.10±0.3	65.1±6.4	6310.30±4.7	562.70±6.8
NE	55.30 ± 0.15	274.9±5.1	295.20±3.5	15.0±1.7	11191.1±2.1	14889.2±2.2	146252.2±4.4	56.70±0.3	27.4±4.1	3558.80±5.1	253.00±4.8
NE	40.80 ± 0.71	177.1±3.8	552.60±3.8	15.2±1.1	10881.2±4.7	3164.80±0.6	165200.2±3.6	33.50±0.3	10.2±4.8	3073.60±1.5	225.80±6.7
TH	33.60 ± 0.15	203.3±2.5	660.10±2.5	13.7±1.8	7267.70±1.6	4524.40±0.7	122143.3±4.7	43.60±0.4	29.6±8.1	4631.50±5.7	220.50±7.2
TH	48.80 ± 0.67	236.5±2.4	1085.2±4.8	11.1±1.6	8520.00±5.4	12005.5±2.1	139001.4±0.9	43.40±0.8	61.9±5.9	18142.3±1.8	506.40±9.1
TH	54.90 ± 0.79	342.6±1.5	1290.4±2.8	19.2±1.8	9176.80±1.7	3339.50±1.5	157891.3±2.3	52.40±0.8	10.6±3.4	5072.70±9	163.60±4.5
KA	157.3 ± 0.83	356.3±2.5	1654.1±4.5	16.1±1.2	9366.80±0.9	6128.20±3.1	130271.0±1.9	61.80±0.5	ND	7794.10±6	414.70±3.6
KA	163.3 ± 0.13	167.2±2.4	725.00±5.5	12.3±0.9	8031.70±4.2	10017.6±1.5	91835.80±4.8	48.10±0.5	ND	10348.6±2.8	595.70±5.8
KA	136.9 ± 0.39	402.3±1.6	969.50±6.4	26.1±1.3	8961.90±4.9	22947.8±0.8	103748.2±9.1	41.70±0.2	31.8±3.1	9341.40±3.5	642.20±3.4
ZA	48.40 ± 0.46	173.3±1.7	488.90±3.4	13.7±1.5	7274.20±3.8	3220.30±0.9	124805.9±6.4	31.30±0.2	23.9±5.7	10686.5±6.7	531.30±2.7
ZA	26.30 ± 0.68	147.2±5.1	706.10±3.4	13.3±1.7	8890.50±3.8	5524.90±1.5	126002.8±5.8	35.30±0.1	11.6±2.1	3933.10±4.8	234.70±7.4
ZA	118.5 ± 0.32	326.4±4.3	514.70±2.6	13.3±1.4	8997.10±1.2	3472.10±1.4	161586.9±4.7	45.90±0.7	24.7±0.3	9456.20±6.9	784.60±7.4
TA	57.10 ± 0.56	521.5±6.1	529.20±4.8	18.0±1.3	9286.50±4.7	8973.60±2.2	172733.3±6.7	94.40±0.1	71.0±5.9	7096.50±7.1	395.20±5.6
TA	58.20 ± 0.89	153.9±2.5	688.40±3.9	12.2±1.2	7058.70±4.5	9933.00±3.1	133465.3±5.2	34.20±0.3	3.60±4.6	7722.90±7.2	403.70±6.8
TA	34.20 ± 0.76	106.3±4.1	592.80±3.7	10.0±0.8	6854.00±8.5	5294.20±0.9	125443.8±4.6	35.00±0.4	4.60±4.4	7856.60±3.8	583.50±4.8

Therefore, the amount of added fertilizer to the soil by the farmer maybe one reason for the difference in the amount of potassium in the soil and thus the plant [19]. Potassium as one of the most important and high consumption elements in the human food chain has a significant physiological function in the plants. It also has a vital role to improve the quality and quantity of agricultural products.

3.1.2. Magnesium

The obtained results (Table. 2) indicated that the concentration of Mg is significantly different among the samples, and Neyshaboor and Taybad saffron's had the highest (10479.1 mg/kg), and lowest (7733.10 mg/kg) mean concentration values, respectively. This element is absorbed through the soil and is one factor affecting saffron performance [20]. Some other researches show that improving the soil structure and increasing the cation exchange capacity of the soil by reducing the washing of potassium, calcium, and magnesium had a positive effect on the saffron performance [21]. Also, It has been reported magnesium plays a role in keeping the electric potential of nerves and activating certain enzyme systems in the human body [22].

3.1.3. Sodium

The results showed that the amount of Na is significantly different in the samples from different regions. Kashmar and Torbat-e Jam saffron's had the highest (13031.2 mg/kg), and lowest (3249.80 mg/kg) mean concentration values of sodium, respectively (Table 2). Sodium is essential for the plant's nutrition and is one of the most abundant elements in the saffron. Sodium increase the resistance of the plants to dehydration, and the importance of this element in saffron is highlighted by the fact that the most saffron planting areas are low water and rainfall.

3.1.4. Calcium

Roshtkhar and Neishaboor had the highest (1720.5 mg/kg), and lowest (552.10 mg/kg) mean concentration values of calcium, respectively (Table 2). The results showed that the amount of calcium was significantly different in the saffron from different planting areas. Calcium is essential in the detoxifying of heavy metals and plant tolerance to environmental stresses [23]. It is an abundant nutrient in arid soils but is nearly non-mobile, and its transfer inside the plant is very low [24]. Feeding the plant with calcium fertilizers can improve the activity of antioxidant enzymes and is suitable for saffron growth [25].

3.1.5. Iron

The cultivating region has an important effect on the concentration of iron in the saffron, which in our study change from 106.3 to 521.5 mg/kg. The samples from Kashmar and Zaveh had the highest (308.6 mg/kg), and lowest (215.6 mg/kg) mean iron contents, respectively (Table 2). The use of fertilizers, to keep the soil fertility, increase the iron content. The mobility and accessibility of low consumption elements such as iron decreased due to the formation of stable complexes with insoluble organic compounds [26]. Zhou and Wang [27] found that the addition of soluble organic compounds reduced the iron absorption capacity in the soil colloids and increased its solubility, especially in the calcareous soils. The use of cow manure can increase the concentration of iron [28].

3.1.6. Zinc

The concentrations of the zinc in the saffron samples are significantly affected by the planting area and changes from 26.30 to 163.2 mg/kg. The maximum mean amount (152.5 mg/kg) of zinc was determined in Kashmar saffron, and Torbat-e Heydariyeh saffron had the lowest mean amount (45.81 mg/kg). The concentrations of this element were relatively higher in the farms of younger age and decreased within creasing of the annual saffron harvest and the farm age. Zinc is essential for plants to form and active growth hormones. Only a small amount of zinc can be absorbed by the plant, and the residue is in an inaccessible form. The main reason for stabilization of the most elements in the soils, including zinc, is the relatively high acidity and calcareousness (Limestone) of soils [29].

3.1.7. Manganese

Meaningful differences were observed in the concentration of manganese in the saffron samples that changes from 26.30 to 132.7 mg/kg. The saffron samples collected from Torbat-e Jam and Zaveh had the highest (79.60 mg/kg), and lowest (37.50 mg/kg) mean concentration values of manganese, respectively. It is essential to control the concentration of low consumption elements such as manganese and iron because of their important role in stimulating the heavy metals colloid's mobility in the soil [30].

3.2. Heavy metal content

3.2.1. Chromium

As seen in the results, the chromium concentration of saffron in different cities was significantly affected by the planting area (3.60-95.8 mg/kg). Roshtkhar and Zaveh samples had the highest (41.8 mg/kg), and lowest (20.1 mg/kg) mean concentration values of chromium, respectively (Table 2). In general, chromium is not present naturally in the water, and its presence is only through industrial contamination [31, 32]. Accumulation of the heavy metals in the soil is related to the long-term and excessive use of chemical and organic fertilizers and the use of industrial wastewater. An ecological strategy, like using organic materials such as rotted manure can be adapted to prevent the accumulation of heavy elements in the food chain.

3.2.2. Copper

The results in Table 2 revealed significant differences from 10.0 to 26.1 mg/kg in the copper content of different saffron samples and, Kashmar saffron had the highest mean concentration value (18.1 mg/kg). In comparison, Taybad samples had the lowest mean concentration value (13.4 mg/kg) of copper. Heavy metals, especially copper, in specific concentrations, can affect the amounts of crocin. According to the study of Rostami et al., copper nitrate at the level of 0.5 g/kg can increase the crocin in the saffron [33]. However, the long-term presence of this metal in the soil or an increase in its concentration around the plant's root can affect the saffron growth directly or indirectly [34].

3.2.3. Lead

According to the obtained results, as shown in Table 2, the amounts of Pb is significantly different (3073.60-49048.5 ng/g) in the samples from different regions, and Torbat-e Jam and Taybad saffron had the highest (32563.9 ng/g) and lowest (7558.80 ng/g) mean concentration values, respectively. The concentration of the lead is within the permissible limits of Iranian national standard (10 mg/kg based on INSO, 259-1) in all of the samples [35]. The lead contents of the plants are mainly controlled by human activities [36]. It is proved that the development of industrial activities increases the lead concentration in the soil and farmland system [37]. Lead contamination can cause some problems in the plant functions such as aperture function, photosynthesis, and breathing, which increase peroxidation of the lipids, change the activity of antioxidant enzymes, and decrease the plant's performance. In the infected areas with lead, application of zinc fertilizer reduced the caused damages and can be used to keep the plants growth [38, 39].

3.2.4. Cadmium

Cadmium is considered as one of the most toxic heavy metals and a significant threat to human and plant life. The analysis of saffron stigmas revealed the presence of Cd in all of the tested samples, and the highest mean amount (878.20 ng/g) of cadmium was determined in Torbat-e Jam, and the lowest mean (296.80 ng/g) was from Torbat-e Heydaryeh samples. Long-term use of phosphate fertilizers can affect the cadmium concentration in the agricultural lands [40]. Cadmium is added to the soil approximately 1g per hectare annually, due to the application of the phosphate fertilizers [41, 42]. Excessive use of phosphorus fertilizers caused the accumulation of phosphorus in the soil, reducing its efficiency, and increase the heavy metals content in particular [43, 44].

3.2.5. Figures of Merit

Eleven calibration curve with working standard solutions was constructed for determining the concentration of analytes. Squared correlation coefficients (r^2) were between 0.984 to 0.999. The analytical characteristics of the atomic absorption spectrometer (AAS) instrument, including linearity, limits of detection (LODs), limits of quantification (LOQs) and relative standard deviations (RSD) are shown in Table 3. A standard mix solution of analytes, was used for RSD% measurements (n = 5).

3.2.6. Discussion

The present study aimed at the quantification of minerals and heavy metals contents of Iranian saffron samples. Wide ranges of varieties were seen in the amount of mineral elements of saffron stigmas in our analysis, and the results showed that the levels of metal concentration mainly depend on the environmental conditions such as the soil conditions and the use of fertilizer. There is no a meaningful relationship between the longitude, latitude, and altitude of the study region and the abundance of the measured metals in the saffron sample. Perhaps, only it can be said that, in areas with higher annual rainfall, heavy metals have a lower concentration in the samples. Similar work has been done by Divirikli et al. (2006) in Turkey by measuring eight trace metals including Cu, Fe, Ni, Cd, Mn, Pb, Cr, and Zn on eleven different spices. They found that, among the measured elements, cadmium had the lowest level while the levels of iron in the samples were generally highest, which is in agreement with our results. Other similar quantitative research has been done by Jia et al. (2011) on 19 metal including Ca, Fe, Mg, P, Sr, Al, Mn, Zn, V, Cr, Se, Co, Ni, Mo, As, Cu, Cd, Hg and Pb on the saffron samples of Tibet and Henan cities of China [45]. In this study P (phosphorus) had the highest concentration in the samples of both cities, while Cd in Tibet and Se in Henan samples had the lowest concentration. Another study was conducted in 2010 by Melnyk et al., to determine the eight elements, including Ca, Mg, Fe, Mn, Zn, Cu, Cd, and Pb, on the saffron's stigma [46].

Table 3. Analytical characteristics of the AAS instrument.

Characteristics Performance	Zn	Fe	Ca	Cu	Mg	Na	K	Mn	Cr	Pb	Cd
LOD	0.08	0.51	40.02	0.25	1.15	21.25	32.56	0.25	0.52	1.32	0.13
LOQ	0.38	2.10	186.25	1.20	5.50	103.89	129.42	0.95	2.15	5.80	0.55
Linear Range	0.4-1.6	2-9	180-800	1-5	5-20	100-400	120-600	1-4	2-15	5-20	0.2-2
Squared correlation coefficients (r^2)	0.995	0.984	0.999	0.991	0.998	0.998	0.999	0.954	0.992	0.999	0.998
RSD (%, n=5)	3.71	3.23	4.09	3.98	4.19	4.49	2.46	4.02	2.88	6.29	4.89

4. CONCLUSION

This study showed that the stigma contained a high amount of Fe, Zn, Mn, Cu, Ca, and Mg, but harmful elements, Cd and Pb, were not detected. In our study, in all samples, potassium and cadmium showed the highest and lowest concentrations, respectively. Potassium, magnesium, and sodium are the most abundant elements in all of the samples. Saffron samples of Torbat-e Jam had the highest concentration of K, and Kashmar had the lowest. The concentration of all measured heavy metals was low, and all was in the permitted range of Iranian national standard. Pb, in the saffron samples of Taybad, had the best condition and Torbat-e Jam was the worst. Cd, in the samples of Torbat-e Jam and Torbat-e Heydariyeh, had the highest and lowest content, respectively. Cu, in Kashmar samples, had the highest content, and Taybad was the lowest. this study showed that the amount of heavy metals found in Iranian saffron is negative or much lower than the permissible range, and there is not worrying report on the heavy metals in Iranian saffron.

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اندازه گیری فلزات در زعفران ایران

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چکیده

تحقیق حاضر اندازه گیری فلزات موجود در نمونه های زعفران جمع آوری شده از هفت نقطه در سطح استان خراسان رضوی را گزارش می کند. استان خراسان رضوی بزرگترین تولید کننده زعفران در ایران است و بیشتر از ۹۵٪ تولید جهانی این ادویه ، در ایران تولید می شود. با افزایش آلودگی‌های محیطی، زعفران به انواع آلاینده های آلی و غیرآلی مانند فلزات سنگین آلوده می شود. به منظور برآورد مقدار فلزات زعفران، ۲۱ نمونه زعفران در فصل گلدهی سال۱۳۹۷، جمع آوری و مقدار فلزات آنها اندازه گیری شد. غلظت عناصر میکرو شامل روی، آهن، کلسیم، منیزیم، سدیم، پتاسیم، و منگنز و فلزات سنگین شامل مس، سرب، کادمیم و کروم در نمونه های زعفران در سه مزرعه از هر شهرستان با دستگاه جذب اتمی مجهز به شعله و کوره تعیین و مورد تجزیه و تحلیل قرارگرفت. این تحقیق نشان داد کلاله‌های جمع شده زعفران حاوی طیف وسیعی از مواد معدنی و فلزات سنگین با رنج غلظتی مختلف هستند. طبق نتایج به دست آمده پتاسیم فراوان ترین عنصر و کادمیم کمترین عنصر موجود در زعفران است. این نتایج، استفاده از کودهای آلی به عنوان جایگزین کودهای شیمیایی برای کاهش غلظت فلزات سنگین به عنوان یک مدیریت زیست محیطی بسیارمطلوب را پیشنهاد می دهد.

واژه‌های کلیدی

زعفران، فلزات سنگین، اسپکتروسکوپی جذب اتمی، خراسان رضوی.