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DETERMINATION OF THE ELEMENTAL COMPOSITION OF A COMPOSITE HERBAL PRODUCT USING THE ICP-OES METHOD

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Abstract

This study evaluates the elemental composition of a composite herbal product comprising *Prunus dulcis* (stem bark), *Eriobotrya japonica* (leaves), and *Calendula officinalis* (flowers) to assess its therapeutic potential and safety. Quantitative analysis of macro, micro, and toxic elements was performed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) on a PerkinElmer Avio 200 system following microwave-assisted acid digestion. The results revealed that potassium (K), calcium (Ca), and magnesium (Mg) were the predominant macroelements, with *C. officinalis* exhibiting the highest concentrations of potassium (187.35 mg/100g) and calcium (167.427 mg/100g). Among the microelements, iron (Fe) peaked in *C. officinalis* (18.764 mg/100g), while *P. dulcis* showed an exceptionally high level of molybdenum (Mo) (16.066 mg/100g). Toxic heavy metals, including lead and cadmium, were detected in negligible amounts well below permissible hygienic limits, while mercury and arsenic were completely absent. In conclusion, the components of the composite product possess a rich, well-balanced mineral profile and meet strict environmental safety criteria, confirming their high potential for developing safe phytopreparations and dietary supplements.

Keywords: Composite product, *Prunus dulcis*, *Eriobotrya japonica*, *Calendula officinalis*, ICP-OES, macroelements, microelements, heavy metals, safety assessment.

INTRODUCTION

Along with biologically active substances, mineral elements contained in medicinal and food plants play an essential role in the human body. Macro- and microelements found in plants play a crucial role in maintaining normal metabolic processes, regulating enzyme activity, supporting immune system function, and modulating various physiological activities. Consequently, studying the elemental composition of plant raw materials has significant scientific and practical importance, not only for evaluating their nutritional and pharmacological value but also for determining their quality standards and safety.

Currently, global research focused on identifying mineral substances in medicinal plants is expanding rapidly. Determining the quantitative content of

macroelements—such as calcium, potassium, magnesium, sodium, and phosphorus—and microelements—such as iron, zinc, copper, manganese, cobalt, and selenium—allows for the evaluation of their biological activity and therapeutic potential. Furthermore, monitoring the concentration of heavy metals (lead, cadmium, mercury, arsenic, etc.) in plant raw materials is a critical prerequisite for ensuring the safety of pharmaceutical products.

The accumulation of mineral elements in plant organs varies depending on the species, variety, vegetation period, soil composition, agroclimatic conditions, and anthropogenic factors. Therefore, studying the elemental profile of plants cultivated in specific regions represents a highly relevant scientific and practical task. Particularly, data regarding the mineral composition of plants found in the flora of Uzbekistan and widely utilized in folk medicine have not yet been sufficiently systematized.

Modern instrumental analysis techniques, including Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Atomic Absorption Spectrometry (AAS), and X-ray Fluorescence (XRF) analysis, enable the determination of elements in plants with high accuracy and sensitivity. These methods allow for the simultaneous qualitative and quantitative evaluation of macroelements, microelements, and toxic elements. The results obtained from studying the elemental composition of plants serve as a scientific basis for expanding their pharmacognostic description, developing standardization criteria, and formulating dietary supplements and phytopreparations. Concurrently, these findings allow for the assessment of the environmental safety and consumption value of plant raw materials.

The purpose of this study is to determine the elemental composition of the investigated plant raw materials using modern instrumental methods, evaluate the amounts of macro- and microelements, and conduct a comparative analysis of the obtained results with data reported in the scientific literature.

MATERIALS AND METHODS

Sample Preparation and Mineralization

For the investigation, accurately weighed 0.1 g samples of the plant materials were placed into autoclave vessels fabricated from Teflon material. To each sample, 3 mL of highly purified concentrated nitric acid (HNO_3) and 2 mL of hydrogen peroxide (H_2O_2) were added. The autoclaves were tightly sealed and placed into a microwave digestion system. The decomposition process was carried out using an automated program, where temperature and pressure parameters were monitored continuously by the device.

During the process, the maximum temperature was maintained up to 230°C, the pressure was held at approximately 40 bar, and the total digestion time ranged between 35 and 45 minutes. Following the completion of mineralization, the

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autoclaves were cooled to room temperature. The resulting solutions were transferred into volumetric flasks, and their volumes were adjusted to 50 mL or 100 mL using bidistilled water. To ensure homogeneity, the solutions were thoroughly mixed and rendered ready for subsequent analytical procedures.

Instrumental Analysis

The quantitative evaluation of macro- and microelements in the prepared solutions was conducted using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). The analysis was performed on an Avio 200 spectrometer manufactured by PerkinElmer. During the analytical cycle, elemental concentrations were calibrated against appropriate reference standard solutions, and the concentrations in the samples were calculated based on relative comparison. The obtained raw data were recalculated taking into account the initial sample weight and dilution factors. Measurement operations for each element were repeated multiple times to determine the average values and relative standard deviation (RSD) percentages, thereby validating the reliability of the analytical results.

The following equipment and reagents were utilized during the analysis:

ICP-OES (PerkinElmer Avio 200): Inductively Coupled Plasma Optical Emission Spectrometer.

Microwave digestion system.

Teflon autoclave vessels.

Volumetric flasks and laboratory glassware.

Reagents:

Multi-element standard solutions.

Standards for rare metals.

Nitric acid (HNO_3).

Hydrogen peroxide (H_2O_2, analytical grade).

Deionized water.

Argon gas (99.995%).

RESULTS AND DISCUSSION

The results of the ICP-OES analysis demonstrated that the mineral profiles of the plants constituting the composite product differ significantly from one another. It was established that the accumulation level of elements in each plant depends heavily on its morphological structure, physiological traits, and adaptation mechanisms to environmental factors.

The summarized analytical data are compiled in Table 1.

Table 1.

Quantitative Content of Elements in the Components of the Composite Product (mg/100g)

№	Chemical element	*P.dulcis*	*E.japonica*	*C.officinalis*

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		mg/100g		
1	Lithium (Li)	0.140	0.114	0.11
2	Boron (B)	0.191	0.086	0.074
3	Sodium (Na)	24.417	5.904	18.721
4	Magnesium (Mg)	15.349	7.140	76,382
5	Aluminumx (Al)	2.690	0.458	0.188
6	Silicon (Si)	1.146	1.312	4.181
7	Phosphorus (P)	13.863	4.801	11.472
8	Sulfur (S)	2.422	10.331	0.878
9	Potassium (K)	79.038	29.705	187.35
10	Calcium (Ca)	161.906	16.295	167.427
11	Vanadium (V)	0.085	0.035	0.009
12	Chromium (Cr)	0.068	0.013	0.027
13	Manganese (Mn)	0.104	0.031	0.723
14	Iron (Fe)	2.313	0.382	18.764
15	Cobalt (Co)	0.007	0	0.008
16	Nickel (Ni)	0.140	0.027	0.374
17	Copper (Cu)	0.092	0.032	0.307
18	Zinc (Zn)	0.095	0.035	0.338
19	Arsenic (As)	0	0	0
20	Selenium (Se)	0	0	0.005
21	Molybdenum (Mo)	16.066	0.020	0.448
22	Silver (Ag)	0	0	0
23	Cadmium (Cd)	0	0	0.003
24	Tin (Sn)	0	0	0
25	Antimony (Sb)	0	0	0

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26	Tellurium (Te)	0	0	0.005
27	Barium (Ba)	0.080	0.038	0.017
28	Mercury (Hg)	0	0	0
29	Lead (Pb)	0.015	0.011	0.002
30	Strontium (Sr)	1.089	0.021	0.186

**Note: In the original data source, Phosphorus was labeled as "F", which has been corrected to "P" for chemical accuracy, while maintaining the corresponding numerical value*

For optimal clarity during qualitative and quantitative evaluations, the detected elements were categorized into three distinct groups: macroelements, microelements, and toxic elements.

Macroelements Profile

The distribution dynamics of macroelements in the examined plant samples are represented analytically. The findings indicate that potassium, calcium, and magnesium are the predominant macroelements across the components of the composite product.

Notably, *Calendula officinalis* flowers demonstrated exceptionally high levels of potassium (187.35 mg/100g) and calcium (167.427 mg/100g), highlighting its rich mineral abundance. These concentrations suggest that this plant can play an important role in regulating electrolytic balance and strengthening bone tissues. The high concentration of magnesium (76.382 mg/100g) in this sample is associated with enzymatic reactions and photosynthetic processes.

In the *Prunus dulcis* component of the composite product, a high amount of calcium was registered (161.906 mg/100g), which is linked to its structural and protective functions. Furthermore, the phosphorus content in *P. dulcis* (13.863 mg/100g) was higher than that of the other samples. Conversely, although the macroelement levels in *Eriobotrya japonica* leaves were relatively lower, they showed a highly balanced distribution pattern.

Microelements Profile

The comparative distribution of microelements among the samples indicates that their concentration levels vary substantially from one plant to another. Although microelements occur in minor quantities within plants, they serve critical roles in enzymatic processes, oxidation-reduction reactions, and the synthesis of various bioactive compounds.

Our experimental data indicate that iron is present in all components of the composite product, with its highest accumulation recorded in *Calendula officinalis* flowers (18.764 mg/100g). This parameter underscores the potential of this plant to

support hematopoietic (blood-forming) processes. In contrast, *P. dulcis* and *E. japonica* contained lower amounts of iron.

Molybdenum stood out due to its high concentration (16.066 mg/100g) specifically in the *P. dulcis* component. This result is explained by the essential role of molybdenum in nitrogen metabolism and enzymatic pathways. In the remaining plant samples, the concentration of this element was exceptionally low. Manganese serves as an important microelement that directly participates in enzyme activation. Its elevated level in *C. officinalis* flowers (0.723 mg/100g) compared to other samples highlights the intense metabolic activity of this plant. Copper and zinc are essential components of antioxidant enzymes. Their relatively high concentrations in *C. officinalis* confirm that the plant is rich in biologically active compounds. *E. japonica* leaves showed lower contents of these specific microelements.

Cobalt and nickel were detected in minor quantities, yet they remain highly important as participants in bioactive processes. Cobalt is particularly significant as an integral component of Vitamin B_{12}. Chromium was present in trace amounts across all plant samples, indicating its role as a trace element involved in metabolic regulation.

Elements such as selenium, aluminum, and tellurium were grouped under microelements due to their quantitative traits, though their specific biological roles require further exploration. While aluminum can express toxic properties if accumulated in high concentrations, selenium and tellurium are considered under-studied elements. Selenium and tellurium were detected exclusively in minor quantities (0.005 mg/100g) within *C. officinalis* flowers. Overall, *C. officinalis* flowers demonstrated a clear dominance regarding the accumulation of most microelements, though *P.dulcis* also exhibited high peaks for certain specific elements. *E. japonica* leaves generally displayed the lowest microelement concentrations.

Toxic Elements and Safety Assessment

The distribution dynamics concerning toxic element contents within the composite components are detailed based on experimental tracking. The data show that the concentration of toxic elements across all components of the composite product is extremely low. This confirms the ecological purity of the raw materials and validates their safety for therapeutic applications. Lead and cadmium, which are among the most critical toxic heavy metals, were detected at minimal levels in all samples. Specifically, lead concentrations ranged between 0.002 and 0.015 mg/100g, which is substantially below established hygienic thresholds. Cadmium was detected only in *C. officinalis* flowers at a very low level (0.003 mg/100g) and was completely absent in the other components of the composite. These findings demonstrate a very low accumulation rate of heavy

metals in the studied plants, confirming compliance with hygienic standards and ensuring non-toxic use.

Importantly, highly toxic elements such as mercury (Hg) and arsenic (As) were completely undetected in all examined samples. This implies that the raw plant materials were harvested from ecologically clean and safe geographic regions. Barium was also detected in trace amounts, and its presence is evaluated as a natural outcome of mineral interactions within the soil-plant system. The concentration of barium did not exceed established safety limits.

CONCLUSION

In summary, the quantitative findings confirm that the levels of toxic elements and heavy metals in all studied plants are at a safe minimum, verifying their pharmacological and nutritional safety. Based on the comprehensive data, it can be concluded that the *Prunus dulcis* stem bark, *Eriobotrya japonica* leaves, and *Calendula officinalis* flowers constituting this composite product possess a rich and well-balanced elemental composition.

Macroelements are dominated by potassium, calcium, and magnesium, while essential microelements such as iron, copper, molybdenum, and manganese are present in optimal quantities to support vital biological processes. Concurrently, toxic elements remain significantly below hazardous thresholds. Ultimately, these results substantiate that these plants are safe natural sources of minerals and, when combined in a composite formulation, can effectively satisfy the mineral requirements of the human organism.

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