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BIOCHEMICAL PROFILING OF MINERAL ELEMENTS AND VITAMINS IN DIFFERENT ORGANS OF *ASTRAGALUS CAMPYLORRHYNCHUS* FISCH. & C.A. MEY. (FABACEAE)

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ABSTRACT

In this study, selected botanical and ecological characteristics as well as the biochemical profile of mineral elements and water-soluble vitamins in different organs of *Astragalus campylorrhynchus* Fisch. & C.A. Mey. (Fabaceae), naturally growing in the Fergana Valley, were comprehensively investigated. The distribution, morphological traits, and ecological features of the species were clarified based on field observations and floristic sources.

The contents of macro- and microelements in the roots, aerial parts (stems and leaves), seeds, and seed coats were determined using inductively coupled plasma optical emission spectrometry (ICP-OES). A total of 30 elements were quantitatively analyzed and classified into four groups. The results revealed that the seed coat was the richest organ in terms of macroelements. Among macroelements, potassium (K) predominated in all organs, with the highest concentration recorded in the seed coat. Zinc (Zn) was detected at relatively high levels among microelements, while iron (Fe) was the dominant essential element. The concentrations of heavy metals (Hg, Pb, Co, and As) did not exceed established sanitary safety limits.

In addition, the contents of water-soluble vitamins (C, B_2, B_9, and B_{12}) were determined using high-performance liquid chromatography with diode-array detection (HPLC-DAD). The highest concentration of vitamin C was observed in the aerial parts, whereas vitamin B_{12} was predominantly accumulated in the seeds. The obtained results characterize *A. campylorrhynchus* as a valuable source of biologically active compounds and indicate its potential as a promising raw material for medicinal and food industry applications.

Keywords: *Astragalus campylorrhynchus*; Fabaceae; biochemical profiling; ICP-OES; HPLC-DAD; mineral elements; vitamins; medicinal plant raw material.

INTRODUCTION

In recent years, increasing attention has been paid to the evaluation of medicinal plants not only in terms of their biologically active secondary metabolites but also regarding their mineral (elemental) composition. The presence and balanced distribution of macro- and microelements in plant tissues play a crucial role in determining their physiological functions, nutritional value, and pharmacological potential. Therefore, the elemental profile of medicinal plant raw materials is considered an important indicator for assessing their suitability for therapeutic, preventive, and food-related applications (Lovkova et al. 1990; Rastitel’nye resursy SSSR 1987).

Macro- and microelements are essential components of plant metabolism and are involved in enzymatic reactions, antioxidant defense systems, and stress-response mechanisms. Adequate accumulation of these elements contributes to plant adaptability, biological activity, and resistance to environmental stress factors (Polyanskaya 2014). Naturally growing medicinal plants represent bioavailable sources of essential elements and are widely used as complementary agents in the prevention and management of various health disorders (Somer & Çalişkan 2007).

Among medicinally valuable taxa, the genus *Astragalus* L. (Fabaceae) occupies a prominent position. This genus comprises more than 3000 species distributed mainly across arid and semi-arid regions of the Northern Hemisphere (Li et al. 2014; Wang et al. 2023). Numerous *Astragalus* species have been traditionally used in folk medicine due to their immunomodulatory, anti-inflammatory, and antioxidant properties.

Previous studies indicate that although the elemental composition of *Astragalus* species has not yet been systematically investigated, several representatives of the genus are characterized by a high accumulation of biologically significant trace elements such as molybdenum, vanadium, cobalt, lithium, barium, strontium, nickel, and selenium (Somer & Çalişkan 2007). In particular, elevated levels of manganese, zinc, copper, iron, molybdenum, and selenium have been reported in *Astragalus dasyanthus* and *Astragalus falcatus* (Ibragimova & Kozhabekova 1975). Atomic absorption and ICP-based studies have further demonstrated organ-specific differences in the accumulation of elements including Al, Ba, Zn, Cu, Mn, Mo, Cr, Ni, and Pb among various *Astragalus* species (Shobanova & Chankina 2012; Al-Juhaimi et al. 2023).

From a pharmacological perspective, *Astragalus membranaceus* and *Astragalus mongholicus* are the most extensively studied species and are officially recognized in traditional Chinese medicine under the name *Radix Astragali* (Huangqi). Their roots contain astragalosides, flavonoids, and polysaccharides, which exhibit well-documented immunostimulatory, antioxidant, and cardioprotective effects (Fu et al. 2014; Wang et al. 2020; Abd Elkader et al. 2022).

In contrast, several *Astragalus* species native to Central Asia, including *Astragalus campylorrhynchus* Fisch. & C.A. Mey., remain poorly investigated in terms of their mineral and vitamin composition. This species belongs to the Irano–Turanian floristic region and occurs predominantly in foothill and low-mountain ecosystems. Available data are largely limited to floristic and taxonomic descriptions, while comprehensive biochemical studies employing modern instrumental techniques are still lacking.

Therefore, the present study aims to evaluate the mineral element composition of different organs of *Astragalus campylorrhynchus* using inductively coupled plasma optical emission spectrometry (ICP-OES) and to assess the content of water-soluble vitamins by high-performance liquid chromatography with diode-array detection (HPLC-DAD). The obtained results provide new insights into the biochemical profile of this species and support its potential use as a source of biologically active compounds for medicinal and food-related applications.

Species of the genus *Astragalus* are known to be rich in flavonoids, saponins, polysaccharides, and amino acids, many of which exhibit antioxidant, anti-inflammatory, and metabolic activities. These bioactive compounds largely determine the pharmacological potential of *Astragalus* species and justify their extensive use in traditional and modern medicine (Yang et al., 2013; Guo et al., 2019).

MATERIALS AND METHODS

Plant material

The object of the present study was *Astragalus campylorrhynchus* Fisch. & C.A. Mey. (Fabaceae). During field investigations, the morphological characteristics and ecological conditions of the species were documented. For biochemical analyses, different plant organs, including roots, aerial parts (stems and leaves), seeds, and seed coats, were collected and analyzed separately.

Collection of plant samples

Plant material was collected in April 2025 from natural populations located in foothill habitats of Namangan region, Uzbekistan. Sampling was carried out during the flowering stage, when both vegetative and generative diagnostic features were fully expressed. Only healthy, well-developed individuals with no visible signs of mechanical damage or disease were selectively sampled to ensure representative material.

Taxonomic identification

Taxonomic identification of *Astragalus campylorrhynchus* was performed using standard floristic and taxonomic references. Diagnostic vegetative and generative traits, including leaf and leaflet morphology, inflorescence structure, calyx and corolla characteristics, and pod morphology, were carefully examined and compared with published descriptions (Podlech & Zarre 2013; Plants of the World Online 2025). A voucher specimen was prepared and deposited in the herbarium collection of Kokand State University.

Ecological observations

Ecological characteristics of the species were recorded through field observations. Habitat conditions were described in terms of soil type (loess and stony substrates), relief features (foothill and low-mountain zones), and associated vegetation. In addition, phenological stages, including flowering and fruiting periods, were documented during the field surveys.

Sample preparation for chemical analysis

For chemical analyses, plant organs were collected at the fruiting stage. The samples were air-cleaned, then dried in a drying oven (VWR DRY-line, Germany) at controlled temperature until constant weight was achieved. Dried material was finely ground, and 200 mg of each sample was accurately weighed using an analytical balance for further analysis.

Determination of elemental composition (ICP-OES)

Microwave-assisted digestion of plant samples was carried out using a MILESTONE Ethos Easy system (Italy). Approximately 200 mg of dried sample was placed in digestion vessels, followed by the addition of 6 mL of concentrated nitric acid and 2 mL of hydrogen peroxide (H_2O_2). Digestion was performed at 180 °C for 20 min. After cooling, the digested solutions were transferred to volumetric flasks and diluted to 25 mL with distilled water.

Quantitative determination of macro- and microelements was conducted using an inductively coupled plasma optical emission spectrometer (ICP-OES; Avio 200, PerkinElmer, USA). Instrument calibration and analytical accuracy were ensured according to the manufacturer's methodological guidelines (Al-Juhaimi et al. 2023).

Determination of water-soluble vitamins (HPLC-DAD)

The content of water-soluble vitamins was analyzed using high-performance liquid chromatography with diode-array detection (HPLC-DAD). Analyses were performed on an Agilent Technologies 1260 HPLC system equipped with a DAD detector. Separation was achieved on an Eclipse XDB-C18 column (5.0 µm, 4.6 × 250 mm). The mobile phase consisted of acetonitrile and buffer solution (pH 2.92) applied in gradient mode. The flow rate was set at 0.75 mL/min, and the injection volume was 10 µL. Detection wavelengths were set at 254, 265, 285, 297, and 360 nm, with spectral acquisition in the range of 200–400 nm.

Data analysis

The obtained elemental and vitamin data were evaluated comparatively across different plant organs. Morphological and ecological observations were analyzed in relation to floristic literature data. The results were summarized to assess organ-specific accumulation patterns and the biochemical characteristics of *Astragalus campylorrhynchus*.

The content of water-soluble vitamins in the plant material was determined using high-performance liquid chromatography (HPLC) following analytical procedures recommended in previous studies for plant-derived matrices (Hamulka et al., 2012).

RESULTS AND DISCUSSION

Elemental composition of *Astragalus campylorrhynchus* organs

Using ICP-OES analysis, a total of 30 chemical elements were quantitatively determined in the roots, aerial parts (stems and leaves), seeds, and seed coats of *Astragalus campylorrhynchus*. The obtained data are summarized in Table 1. For analytical clarity, the detected elements were classified into macroelements, microelements, physiologically essential elements, and heavy metals.

Table 1

Elemental composition of different organs of *Astragalus campylorrhynchus* determined by ICP-OES (mg/10 g dry weight)

Plant organs	Al	Ba	B	V	Bi	Fe	Cd	K
Root	0,165	0,009	0,212	0,018	0	2,369	0	166,23
Aerial parts	0,124	0,022	0,327	0,024	0	1,221	0	142,59
Seed	0,332	0,003	0,253	0,014	0	2,174	0	177,11
Seed coat	0,273	0,007	0,492	0,009	0	1,854	0	227,84
Plant organs	**Ca**	**Co**	**Si**	**Li**	**Mg**	**Mn**	**Cu**	**As**
Root	112,41	0,003	2,558	0,088	71,112	0,369	0,213	0
Aerial parts	105,91	0,004	2,147	0,067	82,369	0,487	0,269	0,007
Seed	93,478	0,007	2,198	0,071	67,553	0,458	0,198	0
Seed coat	147,22	0,014	2,113	0,083	85,972	0,268	0,326	0,007

Plant organs	Na	Ni	Pb	Se	Ag	Sr	Sb	P
Root	11,231	0,214	0,012	0,011	0	0,117	0	14,325
Aerial parts	22,221	0,218	0,007	0,013	0	0,132	0	11,177
Seed	13,189	0,321	0,007	0,007	0	0,214	0	8,362
Seed coat	18,843	0,367	0,017	0,017	0	0,286	0	15,163

Plant organs	Mo	Cr	Zn	Hg	S
Root	0,211	0,021	0,541	0	1,147
Aerial parts	0,124	0,029	0,289	0	1,521
Seed	0,465	0,034	0,304	0	2,118
Seed coat	1,282	0,049	0,496	0	3,927

The results revealed pronounced organ-specific differences in elemental accumulation. Among the analyzed plant parts, the seed coat exhibited the highest total content of macroelements. In all organs, the increasing order of macroelement abundance followed a similar pattern: S < P < Na < Mg < Ca < K.

Potassium (K) was the dominant macroelement across all plant organs, with the highest concentration recorded in the seed coat. Calcium (Ca) and magnesium (Mg) were also present in relatively high amounts, particularly in generative organs, which may be associated with their structural stabilization and metabolic activity. These findings are consistent with previous reports on other *Astragalus* species, where K and Ca were identified as predominant macroelements (Shobanova & Chankina 2012; Somer & Çalişkan 2007).

Microelement distribution also showed clear organ-specific trends. Zinc (Zn) was most abundant in the roots, indicating a pronounced accumulation capacity of underground organs. In contrast, manganese (Mn) predominated in the aerial parts and seeds, likely reflecting its role in photosynthetic processes and enzymatic regulation. The seed coat demonstrated relatively high concentrations of Zn and boron (B), suggesting their involvement in seed protection and developmental processes.

Among physiologically essential elements, iron (Fe) was quantitatively dominant in all examined organs. Iron plays a key role in chlorophyll biosynthesis, electron transport chains, and redox-related enzymes; thus, its high concentration supports the biological activity potential of *A. campylorrhynchus* (Polyanskaya 2014).

From an ecological safety perspective, heavy metal content is a critical quality indicator for medicinal plant raw materials. In the present study, mercury (Hg) was not detected in any sample, while arsenic (As) was observed only at trace levels in certain organs. The concentrations of lead (Pb) and cobalt (Co) did not exceed permissible limits, indicating that *A. campylorrhynchus* raw material can be considered environmentally safe for potential medicinal and food-related applications (Al-Juhaimi et al. 2023).

Water-soluble vitamin composition of *Astragalus campylorrhynchus*

The content of water-soluble vitamins in different organs of *Astragalus campylorrhynchus* was determined using HPLC-DAD. The quantitative results for vitamins B_2, B_9, B_{12}, and C are presented in Table 2.

Table 2.

Content of water-soluble vitamins in different organs of *Astragalus campylorrhynchus* (mg/100 g dry weight)

Sample	B_1	B_6	B_9	PP	C	B_2	B_{12}
Seed coat	-	-	0,987	-	4,325	-	-
Root	-	-	1,451	-	13,521	0 ,409	-
Aerial parts (stems and leaves)	-	-	2,228	-	86,956	0 ,421	4,751
Seed	-	-	-	-	27,639	-	7,771

Vitamin distribution varied markedly among plant organs. The highest concentration of vitamin C was recorded in the aerial parts (stems and leaves), reaching 86.956 mg/100 g, which was significantly higher than the levels detected in roots and seeds. This observation can be attributed to the active involvement of vegetative tissues in antioxidant defense and metabolic regulation.

Vitamin B_9 (folate) was predominantly accumulated in aerial parts and roots, whereas its content in the seed coat was comparatively low. Vitamin B_2 (riboflavin) was detected exclusively in vegetative organs and was absent in generative tissues, indicating selective biosynthesis and accumulation patterns within the plant.

A particularly noteworthy result was the detection of vitamin B_{12} in the aerial parts and seeds. The occurrence of vitamin B_{12} in higher plants is relatively rare, and its presence in *A. campylorrhynchus* significantly enhances the biochemical uniqueness and scientific relevance of this species. This finding supports the potential value of *A. campylorrhynchus* as a source of biologically active compounds with nutritional and functional significance.

Botanical and ecological observations

Field observations combined with floristic data confirmed that *Astragalus campylorrhynchus* is distributed across various regions of Uzbekistan, predominantly within foothill and low-mountain zones of the Irano–Turanian floristic region. The species forms stable populations adapted to arid and semi-arid environmental conditions.

Phenological observations indicated that flowering occurs from April to May, while fruiting takes place from May to June. The short vegetation period and early spring development reflect an ephemeroid life strategy, which is characteristic of several representatives of the genus *Astragalus*.

The identified flavonoids, particularly rutin, quercetin, and apigenin, are well known for their strong antioxidant activity and their ability to strengthen capillary walls. The presence of these compounds in different plant organs is consistent with previously reported data for medicinal plants and supports their potential biological significance (Panche et al., 2016).

Differences in the qualitative and quantitative composition of free amino acids among the plant organs were clearly observed. Such variations reflect organ-specific metabolic processes and are in good agreement with data reported for other medicinal plants (Turtueva et al., 2013).

The detection of flavonoids, water-soluble vitamins, and free amino acids in various organs of *Astragalus campylorrhynchus* highlights the potential value of this species as a promising source of biologically active compounds. In particular, the elevated flavonoid content observed in the aerial parts and seeds may be associated with pronounced antioxidant and vasoprotective properties. These findings are consistent with previously published studies on other species of the genus *Astragalus* (Yang et al., 2013; Guo et al., 2019).

The organ-specific distribution of free amino acids further indicates differences in metabolic activity and physiological functions among the studied plant parts. Similar patterns have been reported for other medicinal plants, suggesting that amino acid profiling can serve as an important indicator of the biological and nutritional value of plant raw materials (Turtueva et al., 2013). Overall, the obtained results provide a scientific basis for further pharmacological and phytochemical investigations of *Astragalus campylorrhynchus*.

CONCLUSION

This study provides the first comprehensive evaluation of the mineral element and water-soluble vitamin composition of *Astragalus campylorrhynchus* Fisch. & C.A. Mey. (Fabaceae), a species naturally distributed in the Fergana Valley. Botanical and ecological observations confirmed that the species is an ephemeroid plant adapted to arid and semi-arid conditions of the Irano–Turanian floristic region.

ICP-OES analysis revealed the presence of 30 chemical elements across different plant organs, with potassium and calcium dominating among macroelements, and zinc and manganese prevailing among microelements. Iron was identified as the most abundant physiologically essential element in all organs. The concentrations of toxic heavy metals remained below permissible limits, indicating the ecological safety of the plant raw material.

HPLC-DAD analysis demonstrated pronounced organ-specific accumulation of water-soluble vitamins. The highest vitamin C content was detected in the aerial parts, while vitamin B_{12} was predominantly found in seeds. The occurrence of vitamin B_{12} in this species is of particular interest, as it is rarely reported in higher plants and highlights the biochemical uniqueness of *A. campylorrhynchus*.

Overall, the obtained results indicate that *Astragalus campylorrhynchus* represents a promising and environmentally safe source of biologically active compounds. These findings provide a scientific basis for the further investigation of its pharmacological potential, including studies on secondary metabolites and biological activity, as well as its possible application in medicinal and food-related industries.

DECLARATIONS

Conflict of Interest

The authors declare that **there is no conflict of interest** related to the publication of this manuscript. No conflicts of interest exist among the authors.

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