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QUANTITATIVE ANALYSIS OF MACRO AND MICROELEMENT CONTENT IN BLACK AND YELLOW CUMIN SEEDS

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Annotation.
This article presents the results of determining the content of macro and microelements in seeds of yellow cumin (Carum carvi) and black cumin (Bunium persicum) using the inductively coupled plasma optical emission spectrometry (ICP-OES) method. The results showed that a total of 69 chemical elements were identified in the samples. Among the macroelements, potassium, calcium, magnesium, phosphorus, and sodium were found in higher amounts, while among the microelements, iron, aluminum, zinc, manganese, and boron were observed to be present in relatively higher concentrations compared to other elements.

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Introduction. The consumption of medicinal plants and spices is increasing worldwide year by year. In particular, cumin varieties stand out for their medicinal properties and nutritional value. In recent years, special attention has been paid in Uzbekistan and abroad to the development of biologically active products based on natural raw materials.

Cumin species belong to the Apiaceae and Ranunculaceae families and contain approximately 15–20% protein and up to 30–40% fatty acids [1, 2]. Cumin seeds are rich in minerals such as potassium, calcium, magnesium, and iron. Mineral substances play an important role in regulating plasma concentration in the human body and activating enzymatic processes. Currently, the richness of mineral elements in cumin species plays a significant role in the development of medicinal products based on natural raw materials in the pharmaceutical industry.

Materials and Methods. The content of chemical elements in black cumin (*Bunium persicum*) and yellow cumin (*Carum carvi*) seeds was determined using inductively coupled plasma optical emission spectrometry (ICP-OES).

Preparation of the working sample solution. A 1 g portion of a pre-dried and ground sample was weighed using an analytical balance with an accuracy of 0.001 g (Navigator™, OHAUS®). The sample was ashed by the dry ashing method in a muffle furnace (Nabertherm, Germany) through stepwise heating. The temperature was increased from 95 °C to 550 °C and maintained for 5 hours. To the obtained ash, 6 ml of

70% acid and 2 ml of 60% acid of ICP-MS grade were added, followed by heating. The solution volume was adjusted to 100 ml with ultrapure water and filtered through a 0.45 μm filter.

Preparation of standard solutions. In this study, standard solutions from High Purity Standards (USA) containing 68 elements in 2% nitric acid (10 mg/L), as well as a mercury standard (1000 mg/L) from Sigma-Aldrich (Germany) in a 2 mol/L HNO_3 medium, were used. In addition, primary working solutions were prepared in a 2% HNO_3 medium based on an Aristar (USA) standard solution containing 25 elements (10 mg/L). Additional calibration solutions with three different concentrations were obtained by serial dilution. A 2% HNO_3 solution was used as a blank sample. After ensuring that the coefficient of determination (R^2) of the calibration curves for all 69 chemical elements exceeded 0.995, spectrometric analyses were carried out.

Analysis procedure. The determination of elemental composition was carried out using an iCAP PRO X Duo ICP-OES inductively coupled plasma optical emission spectrometer provided by Thermo Fisher Scientific (USA). The development of the research methodology and processing of the obtained analytical data were performed using the specialized Qtegra ISDS software environment.

Analysis method parameters. The experiment was carried out under inductively coupled plasma (ICP) spectrometry conditions using the following parameters to ensure high accuracy and reproducibility of measurements. In the sample introduction system, Tygon® tubing was used: yellow/white for sample delivery and white/white for drainage. The pump speed was set at 45 rpm, ensuring a stable solution flow. A glass cyclonic spray chamber was used for aerosol generation, enabling efficient particle separation and formation of a stable aerosol. A glass concentric nebulizer was selected to produce fine and uniform droplets.

Gas flows were set as follows: nebulizer gas flow — 0.6 L/min, cooling (plasma) gas flow — 12.5 L/min, and auxiliary gas flow — 0.5 L/min. These parameters ensured stable plasma operation and optimal analytical conditions. The central tube diameter was 2 mm, allowing efficient sample introduction into the plasma.

The radio frequency (RF) power was set to 1150 W, ensuring sufficient plasma energy and complete ionization of elements. Each measurement was performed in triplicate to improve result reliability. The analysis time for both axial and radial modes was set to 15 seconds, considered optimal for sufficient signal acquisition and accuracy.

As a result, this set of parameters ensured stable, accurate, and reproducible experimental results. The obtained results are presented in Figure 1.

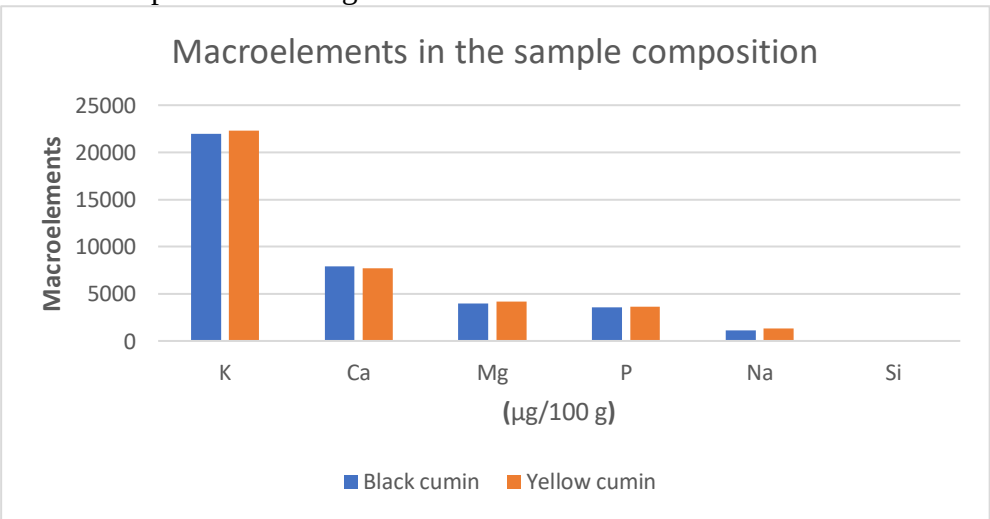


Fig. 1. Macroelements in the sample composition (μg/100 g)

Histogram based on inductively coupled spectrometry results show a clear hierarchy of macroelement accumulation in black cumin (*Bunium persicum*) and yellow cumin (*Carum carvi*) samples in the following order: K > Ca > Mg > P > Na > Si.

Among macroelements, potassium (K) was found in the highest concentration. According to the results, potassium content in yellow cumin was 378.4 mg/100 g higher than in black cumin. Potassium and sodium play an important role in maintaining cell membrane potential, transmitting nerve impulses, and regulating water–electrolyte balance.

Calcium (Ca) content was 192.43 mg/100 g higher in black cumin. Calcium is the main component of bones and teeth and plays a crucial role in muscle contraction, nerve impulse transmission, and blood coagulation processes.

Magnesium (Mg) content was 214.8 mg/100 g higher in yellow cumin. Magnesium plays an important role in numerous enzymatic reactions, energy metabolism, and the functioning of the neuromuscular system.

Phosphorus (P) content was higher in yellow cumin by 76.84 mg/100 g. Phosphorus, together with calcium, is involved in bone formation and energy metabolism (as part of ATP) [3].

Sodium (Na) content was 232.59 mg/100 g higher in yellow cumin. Sodium is important for maintaining water–salt balance and transmitting nerve impulses.

Silicon (Si) content was 70.88 mg/100 g in black cumin and 70.90 mg/100 g in yellow cumin, with a very small difference of 0.02 mg/100 g. Silicon plays an important role in connective tissue formation, skin health, and collagen synthesis [4].

Overall, the results show that both black and yellow cumin seeds are rich in macroelements. Some elements (Ca) are higher in black cumin, while others (K, Mg, P and Na) are more abundant in yellow cumin. This indicates that both species represent important sources of minerals from both nutritional and pharmacological perspectives.

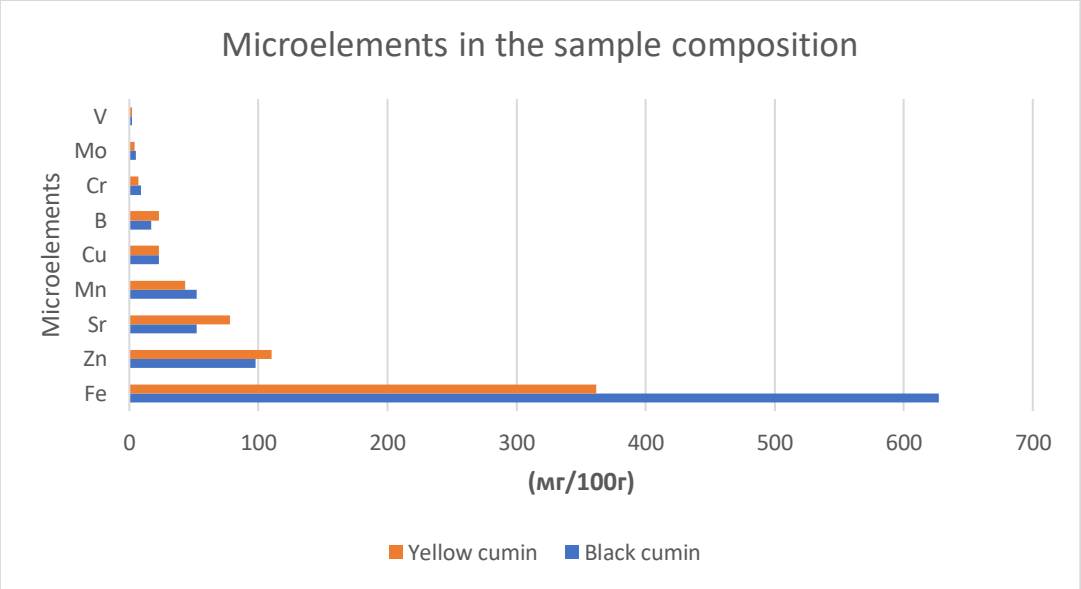


Fig. 2. Microelements in the sample composition (mg/100 g)

The analysis of microelements showed that iron (Fe) content in black cumin (627.4 µg/100 g) is significantly high. Iron plays an important role in blood formation and oxygen transport. In contrast, zinc (110.3 µg/100 g) was found in higher amounts in yellow cumin and contributes to skin regeneration and immune system activity [5].

According to the study results, a number of biologically important microelements were identified in the seeds of black cumin (Bunium persicum) and yellow cumin (Carum carvi). Among them, iron, zinc,

manganese, and copper were found in relatively high concentrations, indicating their important role in determining the biological and nutritional value of these plants.

The largest quantitative difference among microelements was observed for iron (Fe). In black cumin seeds, its content reached 627.42 mg/100 g, which is 265.77 mg/100 g higher than in yellow cumin seeds (361.655 mg/100 g). Iron is a component of many enzymes involved in redox reactions and plays a key role in cellular respiration and metabolism [6]. Therefore, the high iron content in black cumin enhances its importance as a biologically active raw material.

Zinc (Zn), on the contrary, was found in higher amounts in yellow cumin, exceeding black cumin by 11.99 mg/100 g. Zinc is involved in the active centers of many enzyme systems and plays a crucial role in protein synthesis, immune processes, and antioxidant defense mechanisms [7].

Manganese (Mn) was also higher in black cumin, exceeding yellow cumin by 8.93 mg/100 g. Manganese acts as a cofactor for many enzymes and participates in carbohydrate and lipid metabolism [8], as well as in antioxidant enzyme systems.

Copper (Cu) content was nearly identical in both plant seeds, with only a 0.6 mg/100 g difference. Copper is involved in redox processes, energy metabolism, and hematopoiesis [9].

In addition, boron (B) and strontium (Sr) were found in higher amounts in yellow cumin, exceeding black cumin by 6.02 mg/100 g and 25.44 mg/100 g, respectively. Boron plays an important role in plant growth and development, while strontium is associated with mineral metabolism processes [10].

Overall, comparative analysis showed that although the mineral composition of black cumin and yellow cumin seeds is generally similar, there are significant differences in the levels of certain elements. In particular, the large variations in iron and strontium content are important indicators in evaluating their biological and nutritional value. These findings scientifically support the use of both types of cumin seeds as biologically active raw materials in food, pharmaceutical, and traditional medicine applications.



Fig. 3. iCAP Pro X Duo inductively coupled plasma optical emission spectrometer (Thermo Scientific, USA)

Ultramicroelements are elements present in very small amounts in the body, but they play an important role in enzymatic, antioxidant, and immune processes. According to ICP-OES analysis results, a number of biologically active ultramicroelements were identified in cumin seeds.

Table 1. Ultramicroelements in the sample composition (µg/100 g)

№	Element	Black cumin	Yellow cumin	Biological role
1	Li	16.72	12.191	Supports the functioning of the neuro-immune system
2	Rb	9.949	14.767	Cell signaling and metabolic processes
3	Ti	6.114	3.258	Cofactor of oxidase enzymes, energy metabolism
4	Te	4.866	5.429	Activity of antioxidant enzymes
5	Pt	3.811	2.244	Metabolic processes and energy metabolism

Ultramicroelements in black and yellow cumin seeds play an important role in supporting cellular metabolism, enzymatic activity, and antioxidant systems.

Lithium (Li) is present in higher amounts in black cumin compared to yellow cumin (difference of 4.529 µg/100 g) and supports the functioning of the nervous and immune systems.

Rubidium (Rb) is more abundant in yellow cumin and contributes to cell signaling and metabolic processes.

Ultramicroelements such as Nd, Ir, Sm, Os, Sc, La, Zr, Tb, Tm, Be, Au, Ga, and Rh are present in both black cumin and yellow cumin seeds in very small amounts (<1 µg/100 g). They also contribute to metabolic processes, enzymatic activity, and cell signaling [11], but were not included in the main analysis table due to their low concentrations.

Cumin seeds are widely used in the food, pharmaceutical, and traditional medicine industries, and their chemical composition is important for human health. In addition to macro- and microelements, small amounts of heavy and toxic metals are also detected in cumin seeds. The presence and concentration of these elements are important for assessing toxic load in the body and ensuring food safety [12].

Table 2. Content of toxic and heavy elements in the sample (µg/kg)

№	Elements	Black cumin	Yellow cumin	Maximum permissible level according to hygienic standards
1	Hg (Mercury)	0.087 ± 0.01	0.07 ± 0.01	0,3
2	As (Arsenic)	0.176 ± 0.28	<LOD	1,0
3	Pb (Lead)	1.333 ± 0.08	0.653 ± 0.03	1,0
4	Cd (Cadmium)	0.273 ± 0.01	0.24 ± 0.01	0,2

Note: <LOD – below the limit of detection, the amount is very low or not detected.

According to the table data, the content of toxic elements in black and yellow cumin seeds was evaluated by comparison with hygienic standards. The results showed that the levels of mercury (Hg) and arsenic (As) in both samples are significantly lower than the maximum permissible limits established by the Ministry of Health of the Republic of Uzbekistan [13].

However, for lead (Pb) and cadmium (Cd), some values were observed to be close to or exceeding the established regulatory limits.

Conclusion. The results of the study showed that black cumin (*Bunium persicum*) and yellow cumin (*Carum carvi*) seeds are rich in mineral elements, with potassium (22329.9 µg/100 g) being the most abundant among the macroelements. Calcium content was found to be higher in black cumin (7922.9 µg/100 g), confirming its importance for the bone and tissue system.

Microelement analysis revealed that iron is present in higher amounts in black cumin (627.4 µg/100 g), playing a key role in hematopoiesis and oxygen transport, while zinc is relatively higher in yellow cumin, supporting the immune system and antioxidant defense. Manganese also predominates in black cumin and is involved in enzymatic processes.

Additionally, ultra-trace elements (Li, Rb, Ti, Te, Pt), although present in small quantities, play an important role in supporting metabolic and antioxidant processes in the body. Analysis of toxic elements showed that mercury and arsenic levels are below permissible limits; however, in some cases, lead and cadmium levels were observed to be close to or slightly exceeding regulatory thresholds.

Overall, the obtained results indicate that black and yellow cumin seeds have high potential as biologically active raw materials for use in the food industry, pharmaceuticals, and traditional medicine. At the same time, strengthening sanitary and hygienic control is advisable to ensure their safe application.

The consumption of medicinal plants and spices is increasing worldwide each year. In particular, cumin species stand out due to their medicinal properties and nutritional value. In recent years, special

attention has been paid in Uzbekistan and abroad to the development of biologically active products based on natural raw materials.

Cumin species belong to the Apiaceae and Ranunculaceae families and contain approximately 15–20% protein and up to 30–40% fatty acids [1, 2]. Cumin seeds are rich in minerals such as potassium, calcium, magnesium, and iron. Mineral substances play an important role in regulating plasma concentration in the human body and activating enzymatic processes. Currently, the richness of cumin species in mineral elements holds an important place in the pharmaceutical industry for the development of therapeutic products based on natural raw materials.

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