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X-RAY FLUORESCENCE- BASED COMPARATIVE ASSESSMENT OF MINERAL ELEMENT COMPOSITION IN *AVENA SATIVA*, *ERUCA SATIVA*, *SALVIA OFFICINALIS*, AND *TRIGONELLA FOENUM-GRAECUM* L.

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ABSTRACT

In order to identify natural remedies for mineral deficiency, this study compared the nutritional value of four plants: *Avena sativa*, *Eruca sativa*, *Salvia officinalis*, and *Trigonella foenum-graecum* L. using X-ray fluorescence (XRF) analysis. The plants were obtained from Baghdad, Iraq, and were washed and dried before use. The XRF analysis was conducted to evaluate the contents of the mineral nutrients that are present in these plants, which were 10 mineral oxides classified as major oxides: CaO, K_2O, SiO_2, P_2O_5, MgO, and SO_3, and minor oxides: MnO, Al_2O_3, Fe_2O_3, and I. These concentrations were expressed as %. The results demonstrated that *Salvia officinalis* contains the highest concentrations of these minerals, followed by *Eruca sativa, Trigonella foenum, and* then *Avena sativa.* These variations in the mineral accumulation may be attributed to the plant parts, genotypes, and the environmental conditions. In conclusion, the results indicate that XRF is consider a quick method for measuring the mineral concentrations of therapeutic plants.

Keywords: *Avena Sativa, Eruca Sativa, Salvia officinalis, Trigonella Foenum-Graecum* L, XRF.

1 INTRODUCTION

People have utilized plants as food and medicine for a long time. They are recognized as important natural sources of bioactive compounds and minerals. Due to their involvement in several physiological and biochemical processes inside the human body, mineral elements are especially important among their dietary components. Maintaining appropriate cellular function, enzyme activity, bone formation, oxygen transport, and electrolyte balance requires essential minerals such potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P), iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu). Numerous factors, such as plant species, plant parts, geographic origin, soil composition, and agricultural and meteorological conditions, affect the concentration of minerals in plant components [1, 2]. Arugula or rocket are other names for *Eruca sativa* Mill., a green vegetable belonging to the Brassicaceae family. It is commonly consumed as a raw vegetable due to its unique flavor and healthy attributes. Numerous bioactive compounds, vitamins, minerals, and nutritional elements are known to be provided by the plant. Its mineral makeup includes important minerals including potassium, calcium, magnesium, phosphorus, iron, zinc, manganese, and copper. Growth conditions and nutrient availability have been connected to variations in *E. sativa's* mineral buildup, underscoring the necessity of examining its elemental composition to assess its nutritional quality [3]. The Lamiaceae family includes the fragrant perennial herb known as sage, or *Salvia officinalis* L. It is used as a culinary spice and medicinal herb and is grown extensively. In addition to minerals that enhance their nutritional value, the leaves also have bioactive substances and essential oils. Previous elemental tests have indicated that *S. officinalis* contains calcium, potassium, magnesium, sodium, iron, manganese, copper, zinc, and other elements. The relatively high concentration of several essential elements, particularly potassium and magnesium, supports this plant's nutritional relevance [4].

One important grain crop in the Poaceae family is oats, or Avena sativa L. Oat grains are often eaten due to their advantageous nutritional composition, which contains proteins, lipids, dietary fiber, β-glucan, vitamins, and minerals. Among the nutritionally important mineral elements present in oats are calcium, iron, magnesium, phosphorus, potassium, sodium, zinc, copper, and manganese. Because the mineral composition of oat grains can vary based on cultivar, geographic origin, and growing conditions, elemental characterization is useful for evaluating the nutritional quality of oat grains [5].

The annual herb fenugreek, also known as *Trigonella foenum-graecum* L., belongs to the Fabaceae family. It is commonly grown and used as an ancient medicinal herb, spice, food ingredient, and pasture crop. The nutritious leaves and seeds contain a variety of bioactive compounds, proteins, dietary fiber, vitamins, and minerals.

Fenugreek has been shown to contain trace elements including iron, manganese, zinc, and copper in addition to important elements like potassium, calcium, magnesium, phosphorus, and sodium. There have also been reports of significant differences in mineral contents between several fenugreek genotypes and growing locales [6].

For the elemental characterization of plant materials, X-ray fluorescence (XRF) spectroscopy is a useful analytical technique. Many components can be determined simultaneously, and it can provide rapid analysis with relatively minimal sample preparation. Recent applications have used XRF to identify major and trace elements in plant tissues, including potassium, calcium, manganese, iron, copper, zinc, and others [7-9]. Thus, XRF provides a practical way to compare different plant species' mineral composition.

The aim of the current study is to compare the nutritional value of the mentioned plants and to find natural alternatives to mineral deficiencies through analysis using X-ray fluorescence (XRF).

2 MATERIALS AND METHODS

2.1 Collection and preparation of plants material

Four medicinal plants were chosen for XRF mineral contents analysis: *Avena sativa*, *Eruca sativa*, *Salvia officinalis*, and *Trigonella foenum-graecum* L. The plant parts employed were the leaves of *Eruca sativa* and *Salvia officinalis*, as well as the seeds of *Avena sativa* and *Trigonella foenum-graecum* L. These components were dried and finely processed to create powdered materials after being cleaned of any dust particles using tap and distilled water. Before being used, these samples were kept in a dark, clean container [10].

2.2 XRF analysis

The analysis of mineral contents of the mentioned plants were conducted in the laboratory of the department of geology, college of science, University of Baghdad. This technique was determined ten mineral oxides (CaO, K2O, Sio2, P2O5, MgO, So3, MnO, Al2O3, Fe2O3, and I) present in different concentration (%) in all tested plants,

2.3 Statistical analysis

This experiment was carried out in three triplicates (n = 3), and the findings were expressed using the mean ± SD. The statistical analysis was done using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). The four plants were compared using one-way analysis of variance (ANOVA) to identify any significant differences. The significance level for differences was set at $p < 0.05$ [11].

3 RESULTS

Table 1 demonstrated the mineral composition in (%) of the plant species *Avena sativa*, *Eruca sativa*, *Salvia officinalis*, *Trigonella foenum-graecum* L analyzed by XRF.

Table 1: Mineral oxides composition (%) of the four plant species *Avena sativa*, *Eruca sativa*, *Salvia officinalis*, *Trigonella foenum-graecum* L analyzed by XRF.

Mineral oxides symbol	*Salvia officinalis*	*Eruca sativa*	*Trigonella foenum-graecum L*	*Avena sativa*	p-value
CaO	7.6887 ± 0.0035[a]	7.6037± 0.0021[b]	5.9420 ± 0.0010[c]	4.5533±0.0015[d]	< 0.001
K2O	4.6563± 0.0015[a]	2.2950±0.0010[b]	1.8640±0.0010[c]	1.6800±0.0010[d]	< 0.001
SiO2	13.1267±0.0153[a]	3.7623±0.0015[b]	1.7040±0.0026[c]	1.6240±0.0020[d]	< 0.001
P2O5	1.02967±0.0042[a]	0.8655±0.0003[b]	0.6691±0.0001[c]	0.3724±0.0002[d]	< 0.001
Mgo	2.8730±0.0020[a]	1.7730±0.0010[b]	1.0053±0.0015[c]	0.3782±0.0002[d]	< 0.001
So3	3.6303±0.0015[a]	3.5120±0.0010[b] b	0.7542±0.0002c c	0.4724±0.0001[d]	< 0.001
Mno	0.04714±0.00002[a]	0.02216±0.00001[b]	0.01438±0.00001[c]	0.01396±0.00001[d]	< 0.001
Al2o3	2.1947±0.0015[a]	0.5223±0.0002[b]	0.4216±0.0002c c	0.1553±0.0002[d]	< 0.001
Fe2O3	2.0980±0.0010[a]	0.8983±0.0002[b]	0.1642±0.0002[c]	0.0830±0.00002[d]	< 0.001
I	0.0006±0.00002[d]	0.03267±0.00001[a]	0.0075±0.0002[b]	0.0061±0.0002[c]	< 0.001

*Values are expressed as mean ± SD, (n=3), (p < 0.001).

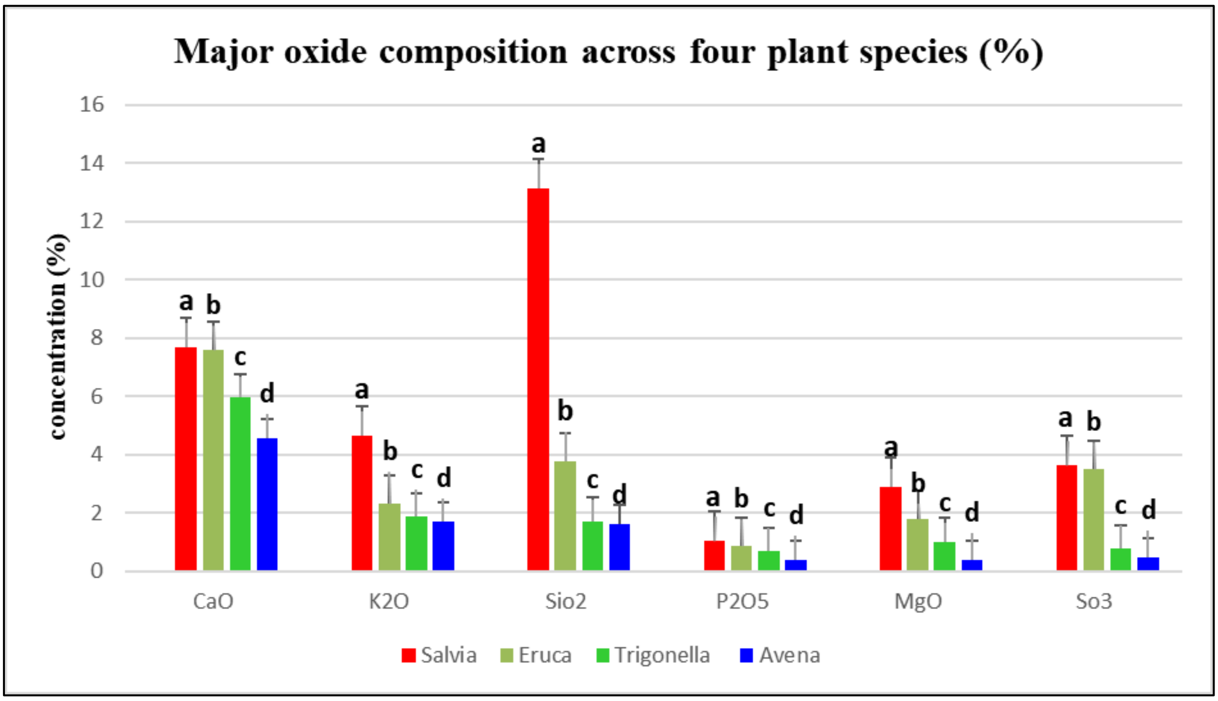

Figure 1-a Major oxide composition (%) across plant species, CaO, K2O, Sio2, P2O5, MgO, and So3

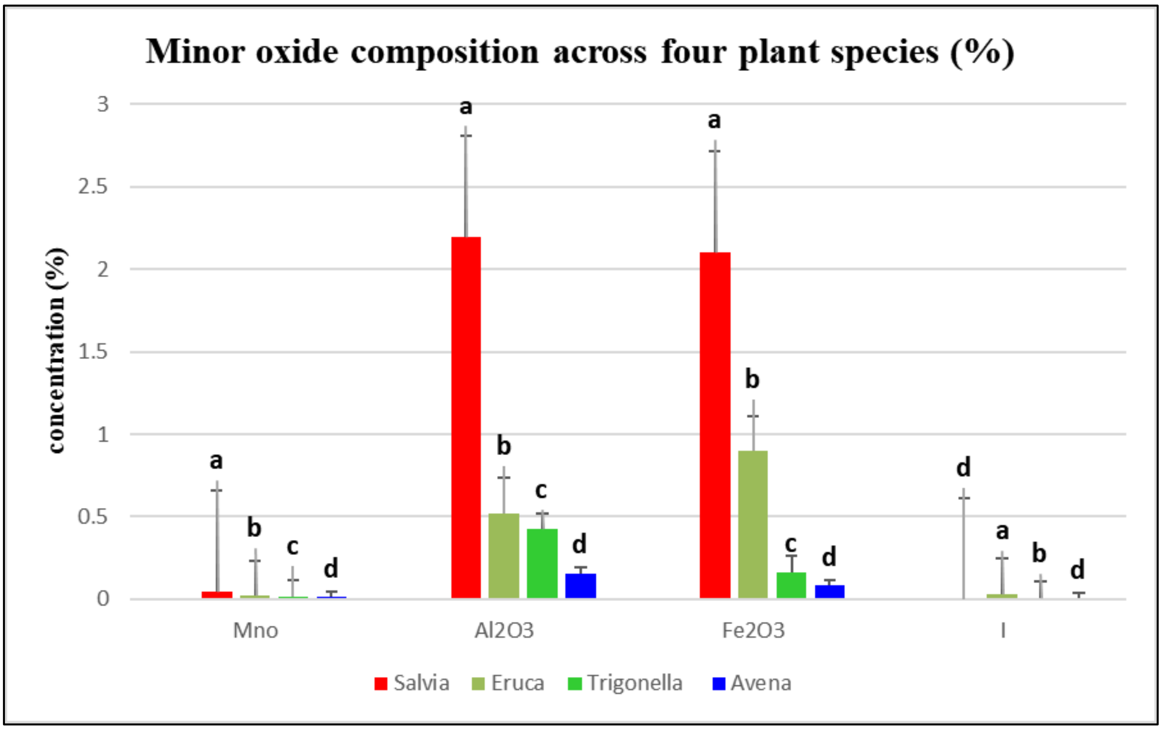

Figure 1-b Minor and trace oxide composition (%) across four plant species, MnO, Al2O3, Fe2O3, and I

4 DISCUSSION

The above results showed a significant difference ($p < 0.001$) in the mineral concentration between these plants, especially the leaves of *S. officinalis,* which contain higher concentrations of all ten minerals except for iodine (I), followed by the leaves of *E. sativa,* then by the seeds of *T. foenum-graecum* L., while the seeds of *Avena sativa* have the lowest contents of these minerals

Figure (1-a) demonstrate the major oxide composition (%) for these plant species, the higher contents of CaO, K2O, Sio2, P2O5, MgO, and So3 were present in the leaves of *S. officinalis which was* 7.6887 ± 0.0035^{a}, 4.6563 ± 0.0015^{a}, 13.1267 ± 0.0153^{a}, 1.02967 ± 0.0042^{a}, 2.8730 ± 0.0020^{a}, and 3.6303 ± 0.0015^{a}, respectively. While the lowest content of these mineral oxide was *Avena sativa, which contain* 4.5533 ± 0.0015^{d}, 1.6800 ± 0.0010^{d}, 1.6240 ± 0.0020^{d}, 0.3724 ± 0.0002^{d}, 0.3782 ± 0.0002^{d}, and 0.4724 ± 0.0001^{d}, respectively, $p < 0.001$.

On the other hand, table (1-b) showed the minor or trace oxide composition (%) of these plant species.

The higher contents of MnO, Al2O3, and Fe2O3 were present in the leaves of *S. officinalis which was* 0.04714 ± 0.00002^{a}, 2.1947 ± 0.0015^{a}, and 2.0980 ± 0.0010^{a}, respectively. While the lowest contents of these oxides were present in *Avena sativa which was* 0.01396 ± 0.00001^{d}, 0.1553 ± 0.0002^{d}, and 0.0830 ± 0.00002^{d}, respectively, $p < 0.001$.

As for concentration of iodine, *E. sativa contain the highest concentration of it which was* 0.03267 ± 0.00001^{a}, while the lowest concentration was present in *S. officinalis* which was 0.0006 ± 0.00002^{d}.

Living things cannot manufacture minerals, which are inorganic elements with vital metabolic activities. Although they make up less than 1% of the minerals in our bodies, trace minerals are vital to life. In the human body, calcium plays a crucial role. It controls oocyte activation, muscular contraction, and the development of strong teeth and bones[12] .

Ralf Mueller's research demonstrated the necessity of sulfur in clinical settings, including the management of skin conditions [13].

[14] demonstrated that *S. officinalis* contain Mg, Fe, K, Mn, Ca, and P but these mineral compositions were decreased when the plant is exposed to any environmental stresses as water deficiency.

On the other hand, [15] found that the S. officinalis contain concentrations of the macronutrients were ranging from Ca which owns the highest concentration to Fe with the lowest concentration, while the highest micronutrients was for Mn and the lowest for Zn.

In the study of [3]which found that the *E. sativa* contain higher concentration of K, which was 11.474 ± 0.047, followed by Mg which was 2.588 ± 0.263, while the lowest concentration was for Cu, 0.008 ± 0.001. also contain Na, Ca, Fe, P, Zn, and Mn in different concentrations.

[16] found that *Avena sativa was contain iron, copper, zinc, magnesium, calcium and potassium were* 2.5–3.0, 0.2–0.4, 1.6–2.0, 62.4–89.1, 44.0–102.7, and 241.7–258.3 mg/100 g DW, respectively, which was 258.3 *± 0.*54 for potassium, while 0.4 ± 0.01 for copper.

According to the study of [17] which found that *T. foenum-graecum* L contain higher concentration of zinc which was 28.77 ppm, while the lowest content of mineral was for copper.

The current findings were in line with [6] which found that the highest content of macro-elements was for calcium which was 7942.89 ± 8.32, while the lowest macro-element was for phosphorous which was 744.58 ± 1.15, while iron was the highest micro-element concentration which was 398.75 ± 2.55 μg/g DW.

Also contain other elements such as zinc, copper, manganese, molybdenum, aluminum, nickel, chromium, selenium, cobalt, cadmium, and lead but in different values.

T. foenum-graecum seeds from Sudan were found to contain 1306, 1550, 415, 331, 158, 49, 22, and 10 mg/100 g of potassium, manganese, phosphorus, copper, calcium, sodium, iron, and zinc, respectively [18]. The seeds of thirteen cultivars of *T. foenum-graecum* from Turkey were found to be high in calcium (2341 μg/g) and magnesium (1372 μg/g) in another study [19]. Additionally, it has been noted that the quantities of nickel, copper, cobalt, chromium, cadmium, aluminum, and lead vary across the cultivars under study. According to Pandey and Awasthi [20], the Indian *T. foenum-graecum* seeds have phosphorus, calcium, iron, and zinc concentrations of 544.5, 70.5, 11.6, and 5.7 mg/100 g, respectively. There have also been reports of variations in the amounts of several elements in the seeds of 10 Turkish fenugreek species, including calcium, chromium, manganese, zinc, copper, magnesium, selenium, aluminum, and lead [21]. The maximum concentrations of iron, calcium, manganese, copper, and zinc among the twenty-five *T. foenum-graecum* genotypes from India were 781.2, 25.65, 5.82, and 26.28 μg/g DW, respectively [22].

The observed variations in elemental concentrations among the plants under study could be explained by variations in plant organs, growth conditions, soil nutrient availability, and species-specific variations in nutrient uptake and translocation.

According to [23], which discovered that genotype and environmental factors affected variations in mineral concentrations.

Plant genetics, the growing environment, and management techniques all affect the mineral content of plants. Mineral nutrient absorption is influenced by both plant and environmental factors, including genetics, variety, root architecture, development stage, and temperature, seasonality, and CO2 levels. The availability and absorption of mineral nutrients are also significantly influenced by agronomy, which includes plant densities, irrigation, fertilizer inputs, and other practices [24].

In the study of [25] the results indicated that the accumulation and the distribution of minerals depends on the plant parts were accumulated in the roots then in the stems then in the leaves. The highest concentrations of K and pb were present in stems and leaves of plants.

The findings of [26] offer strong evidence that, in certain environmental conditions, such as in the context of resource-altered global change, assessing the coupling of a typical range of mineral nutrients in plant tissues may represent a highly novel and potent indicator of nutritional mismatches between supply and demand.

As a result, XRF analysis offers a helpful method for comparing the elemental makeup of edible and medicinal plants and may assist in locating plant sources with potentially beneficial nutritional mineral profiles.

5 CONCLUSION

The mineral content of the plants under study varied significantly, according to the XRF analysis ($p < 0.001$). Of all the mineral oxides examined, *Salvia officinalis* had the greatest quantities, followed by *Eruca sativa*, *Trigonella foenum-graecum*, and *Avena sativa*. These results validate the value of XRF as a quick analytical method for comparative mineral evaluation of plant materials and show significant diversity in elemental accumulation among plant species and plant sections.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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