



A RESEARCH ARTICLE

Therapeutic Potential and Safety Profiles of Libyan *Thymus capitatus* and *Rosmarinus officinalis*: Quantitative Elemental Analysis Linked to Human Health Guidelines



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Abstract

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The mineral compositions for two herbals plants grown in Libyan wilderness, namely *Thymus Capitatus* and *Rosmarinus Officinalis* have been detected using four different digestion methods. plant samples were measured for calcium, magnesium, potassium, sodium, phosphorus, iron, manganese, zinc, copper, cobalt, chromium, nickel, lead and cadmium by flame atomic absorption spectrometry (AAS) technique. The macrominerals calcium, magnesium potassium and sodium were found to dominate species in the selected plants ranging from calcium which has the highest level to sodium with the lowest concentration. Iron, zinc, manganese and nickel concentrations were detected in minor levels while copper, lithium and lead were found in trace levels. Calcium, magnesium, potassium and sodium were detected in water extraction of these plants at significant amount while other minerals were not detected in water extraction. Besides, chromium, cobalt and cadmium were not detected by any digestion methods. The findings from the study revealed that the water extract contains respectively the amount of Ca, Mg, K and Na that is equivalent to the Recommended Daily Allowance (RDA) of these macronutrients which are important for human health. However, the water extract of Fe, Zn, Mn, Ni, Cu and Li is not enough to supply the RDA of these metals. Consuming enough amount to ground particles of these herbals may supply the RDA of these micronutrients. The very low level of Pb make these plants safe for disease treatment. The statistical analysis exhibited significant variance in yield between the water extraction method and other extraction procedures. The discrepancy that can be explained by the limited solubility of the corresponding water-soluble salts. On the other hand, there is a slight variance between ashing procedure and other two procedures ($\text{HNO}_3/\text{H}_2\text{O}_2$ and $\text{HNO}_3/\text{HClO}_4$). In general, the concentration ranges obtained using ($\text{HNO}_3/\text{HClO}_4$) acid mixture is a bit higher compared to ($\text{HNO}_3/\text{H}_2\text{O}_2$) and dry ashing procedures

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1. Introduction

Industrialization of last decades has led to newly discovers in medical sciences and a better understanding infectious diseases as well as metabolic disorders. Modern drugs which manufactured by pharmaceutical companies are still unable to meet all needs of majority of the people in poor countries [1, 2]. Recent study by the World Health Organization (WHO) has proven that about 80% of the people in the world still relies on the traditional treatment for many diseases [3]. Through it, Medicinal plants play an important role in traditional treatment for many diseases and are utilized as home remedies. Thus, it can be used a traditional therapy includes the utilize of plant extracts [4-6].

More than 40 elements have been considered to be essential for life systems in both mammals and plants. An element is considered essential when it satisfies the body requirements. Supplementation with the element is therefore necessary to treat deficiencies associated with its low concentration in body fluids [7-10].

Minerals (inorganic elements) necessary for normal body functions can be classified into two categories relaying on the quantity required for the body or the amount found in the plants:

macrominerals and microminerals. Macrominerals such as calcium, potassium and magnesium found to be relatively in a high level while microminerals such as copper, nickel and manganese found to be in relatively low level [11,12]. Although minerals are often essential for many living organisms, they become toxic if found at high levels. In addition some elements are consider to toxic even present at trace concentrations [13,14].

The significance of the selected elements in this study will be briefly discussed: calcium is the fifth most abundant element in the earth [7]. Adult male body contains approximately 1200 g of calcium. About 99% of these amount present in the skeleton [15]. Calcium helps functions such as muscle growth and impulses in the brain [16]. The deficiency of calcium could result in osteoporosis and rickets. In addition, the excess of calcium could deposit in gall bladder and kidney [15]. Magnesium represents the tenth abundant metals in the earth [7]. Magnesium is an important in the regulation of cellular sodium, potassium and calcium [17]. The deficiency of magnesium in human body could cause convulsions and behavioural disturbances [18]. The relative high level of magnesium could cause symptoms such as depressed deep tendon reflexes and respiration [19]. Sodium is an important element for blood plasm, maintenance of the osmotic pressure of the body fluid and nervous system [20]. The deficiency of sodium leads to dehydration, weakness, and mental confusion [21]. Sodium toxicity could lead to hypertension [22]. Potassium is essential cation of the intracellular fluid and extracellular fluid and also influences muscle activity [23]. Potassium deficiency could produce kidney [24]. Potassium toxicity could lead to renal failure, advanced dehydration and Addison's disease [25].

Iron is required for metalloenzymes such as nitrogenase, various oxidase, reductases, dehydrogenase and haemoglobin [26]. Iron deficiency could lead to anaemia [27]. Excess levels of iron in the tissues could cause hemosiderosis [28]. Zinc is essential for many enzymes for their activity. It is important for RNA and DNA. It is also required for healthy immune system [29]. Zinc deficiency results in under- performing immune system, loss of smell, skin problems, falling hair, etc. [30]. The high levels of zinc could result in toxicity symptoms such as drowsiness, diarrhoea and hallucinations [31]. Manganese is required for immune system, involved in production of energy, regulates blood sugar levels and cell reproduction [32]. Some research indicates the manganese deficiency could lead to impairs glucose metabolism and reduce insulin production [33]. High levels of manganese in air may lead to mental and emotional disturbances [34]. Copper is required for several proteins and metalloenzymes including B-hydroxylase, dopamine and cytochrome oxidase [35]. Copper deficiency could lead to thyroid gland, heart disease and nervous system problem [36]. The excess levels of copper will cause gastric pain, coma, learning disabilities and liver damage [37]. Chromium (III) is an essential nutrient that helps the body to utilize sugar and may also may involve in protein and fat metabolisms [38]. Chromium deficiency could lead to decrease insulin effectiveness [39]. Ingesting and breathing large amounts of excess of chromium (VI) may cause runny nose, nosebleeds and ulcers [40]. Cobalt is necessary for normal red blood cell formation [41]. The effect of cobalt deficiency is degeneration of nervous system [42]. Co (II) compound could lead to DNA strand breaks, sister-chromatid exchanges and aneuploidy [43]. Lithium is used to reduce the developing dementia risk and increase bone density [44]. Lithium deficiency could be one of the factor that cause Alzheimer's disease [45]. The toxicity side of lithium could cause commonly affect renal function [46]. Many scientists though that nickel maybe necessary for human body [47]. Lower levels of nickel were observed in blood of anaemic children compared to healthy children [48]. High levels of nickel could cause altered hormone and enzyme activities and can impact glucose tolerance, blood pressure and immune function [49]. Lead and cadmium are considered to be toxic even excess in trace levels [50]. The ingestion of these metals in food or in drink could cause several symptoms such as nausea, vomiting abdominal cramp and headache within minutes of ingestion [51].

Therefore, the present work aims to investigate the mineral composition of *Thymus capitatus* and *Rosmarinus officinalis* through the quantitative determination of fourteen elemental concentrations namely calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), iron (Fe), zinc (Zn), manganese (Mn), nickel (Ni), copper (Cu), lithium (Li), chrome (Cr), cobalt (Co), lead (Pb) and cadmium (Cd). In addition to estimate the Recommended Daily Amounts (RDA) of these minerals which are necessary for human health. Moreover, to make sure these plants are safe in aspect of toxic metals levels.

Several statistical methods were employed to evaluate significant differences in mineral composition among the herbal plants, as well as to assess variations arising from the sample preparation methods [52-54].

2. Materials And Methods

2.1. Chemicals

Deionized water was produced through distillation and ion exchange resins process and was supplied by West Tripoli Power Station. The chemicals that were utilized in this research were analytical grade and supplied by Ventron GmbH, Farmitalia Carlo Erba S.P.A., Fluka Chemika, and Merck (Darmstadt, Germany).

2.2. Sample preparation

Medicinal plants were harvested in the spring season and washed with deionized water. The plants were air dried for around three weeks, then the herb species were finely chopped and placed in an oven at 90°C for about 24 hours. After that, the plant samples were grounded in a ceramic mortar and stored in dry glass jar. In this study, three digestion methods and water extraction were applied to extract the minerals from plant matrix.

2.3. Wet digestion Procedure 1

Twenty grams of each herbal sample were transferred into 80 ml beakers then, 20 ml of con. HNO₃ were added to each beaker and covered with watch glasses after NO₂ bubble was released. In the next step, the samples mixtures were refluxed gently until their volume became less, then the contents were allowed to cool for approximately 5 minutes at room temperature. 5 ml of HClO₄ were added and boiled to almost dryness then the contents were allowed to cool to room temperature. The content of the beaker was dissolved in 0.1N HNO₃, boiled, then cold to room temperature then filtered by a glass filter into 50-ml volumetric flasks and diluted with 0.1N HNO₃ to marks.

2.4. Wet digestion Procedure 2

The wet digestion procedure 2 followed the same procedure as the pervious method except of that, H₂O₂ was supplied instead of HClO₄ for the treatment of the herbal mixture.

2.5. Dry ashing Procedure

Two grams of each individual plant sample were introduced into crucibles and then transferred into a muffle furnace, where they were heated at 500°C for 8 hrs. The crucibles were transferred from the furnace and allowed to cool at room temperature. The ash was dissolved in 10 ml of nitric acid (1:1) and filtered through a glass filter. The filtrate was transferred into 50-mL volumetric flasks and diluted to the marks with 0.1N HNO₃.

2.6. Water infusion procedure

Two grams of each herbal sample were transferred into 80-mL beakers and covered with watch glasses. A sufficient water was added to each beaker and refluxed for 1 hour, then filtered and transferred into 50-mL volumetric flasks and diluted with 0.1N HNO₃ to the marks. This procedure is similar to traditional procedure to extract some of pharmacologically active organic compounds and elements.

2.7. Instruments

Herbal samples were measured for, Ca, Mg, K, Na, P, Fe, Mn, Zn, Cu, Co, Cr, Ni, Pb and Cd by flame atomic absorption spectrometry (AAS) using a Philips atomic spectrometer Model PU9400X England. The elements: potassium, sodium, and lithium were measured by using flame photometer. All peaks were background subtracted to remove interferences from the media such as deionized water and oxidizing agents.

3. Results And Discussion

Comparison of the concentrations of the studied minerals within each individual medicinal plant

The first part of the discussion investigates the profiles of the mineral's concentration for the selected plants. The mean concentration of each element in the selected plants presented in Table 1, and Figure 1.

Table1. The mean concentration ($\mu\text{g/g}$) of macrominerals and microminerals in *T. capitates* and *R. officinalis* with different digestion methods. Recommended daily amounts (RDA) *.

element	plant	digestion with $\text{HNO}_3 / \text{HClO}_4$	digestion with $\text{HNO}_3 / \text{H}_2\text{O}_2$	ashing	water infusion	RDA
Ca	<i>T. capitates</i>	26274	22279	17303	2044	1.0g/day
	<i>R. officinalis</i>	15292	12458	10159	1196	
Mg	<i>T. capitates</i>	9046	9210	7080	2524	340 mg
	<i>R. officinalis</i>	10587	10612	8633	2751	
Na	<i>T. capitates</i>	2409	2481	1958	1226	1.5 g/day
	<i>R. officinalis</i>	5120	4811	4708	2134	
K	<i>T. capitates</i>	14699	14490	1958	1226	4 mg/day
	<i>R. officinalis</i>	13173	15117	13606	8387	
Fe	<i>T. capitates</i>	575	605	390	ND	18 mg/day
	<i>R. officinalis</i>	786	758	572	ND	
Zn	<i>T. capitates</i>	40.10	45.79	25.75	ND	8 mg/day
	<i>R. officinalis</i>	37.32	36.21	26.22	ND	
Mn	<i>T. capitates</i>	40.47	34.84	23.15	ND	5 mg/day
	<i>R. officinalis</i>	30.11	32.13	22.22	ND	
Ni	<i>T. capitates</i>	91.14	90.23	8.75	ND	160 $\mu\text{g/day}$
	<i>R. officinalis</i>	45.67	43.23	7.28	ND	
Cu	<i>T. capitates</i>	16.46	12.25	23.52	ND	1.7 mg/day
	<i>R. officinalis</i>	9.85	12.50	25.56	ND	
Li	<i>T. capitates</i>	7.30	5.2	ND	ND	1mg/day
	<i>R. officinalis</i>	7.95	8.2	ND	ND	
Pb	<i>T. capitates</i>	9.14	9.23	ND	ND	-
	<i>R. officinalis</i>	7.20	6.02	ND	ND	

*Average of triplicate determinations, %R.S.D.= 0.03-0.10; *ND = not detected * Cr, Co and Cd not detected *RDA = The recommended daily amounts [55-60].

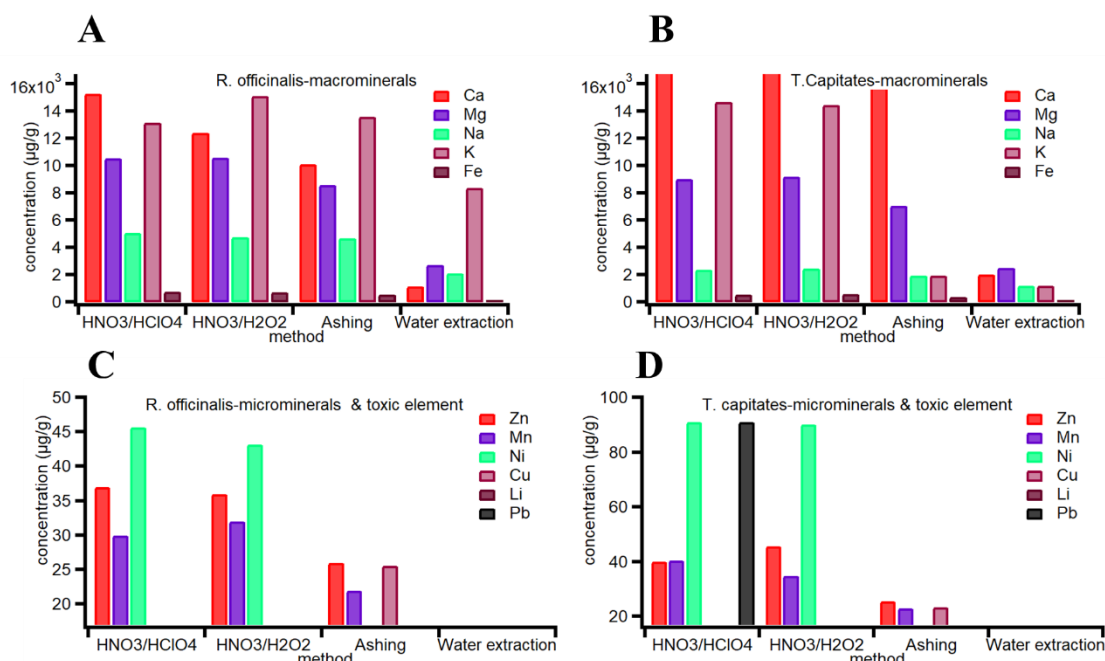


Figure 1. The concentration of microminerals, microminerals and toxic elements in the selected Libyan medicinal plants with four different procedures; A (macrominerals in *R. officinalis*), B (macrominerals in *T. capitates*), C (microminerals and toxic element in *R. officinalis*), D (microminerals and toxic element in *T. capitates*).

3.1. The macronutrients elements

The dependence of macrominerals concentrations on digestion methods with ($\text{HNO}_3/\text{HClO}_4$), ($\text{HNO}_3/\text{H}_2\text{O}_2$), dry ashing and water infusion procedures for chosen plants are shown in Table1 and Figure 1(A&B). The data revealed that the macrominerals: calcium, potassium, magnesium, sodium and iron are existed in highly predominate species in the samples of these herbal plants regardless of the method digestion. Among these, calcium exhibited the highest concentration, whereas iron was present at the lowest level in these samples. The concentration superiority of calcium over that of magnesium and potassium of sodium is very noticeable using sample preparation method. These observations are strongly supported by the previously published literature data [61]. However, the important of iron usually less abundant and found in a significant amount in these herbals which could be a good source for iron deficiency in human body. Iron concentration in these plants was found in a good agreement in some previous studies in some other countries [62-64]. Dry ashing procedure to digest the samples resulted in concentrations with considered to be inferior compared to the concentrations obtained using $\text{HNO}_3/\text{HClO}_4$ and $\text{HNO}_3/\text{H}_2\text{O}_2$ procedures. The order of relative concentrations of the detected macrominerals based on digestion procedures is:

$$\text{Ca} > \text{K} > \text{Mg} > \text{Na} > \text{Fe}$$

It is noteworthy that the mean concentration of calcium, magnesium, Potassium, and sodium in water extract is significantly lower than the concentration in the solution of the acid digested samples, this most likely attributed to the lower solubility of organic and the inorganic compounds of these elements in water. With simple calculation we can conclude that about 976 mL, 420 mL, 2058 mL and 1220 mL of water extract obtained using 20 g sample of this medicinal plant are expected to contain respectively the amounts of calcium, magnesium, Potassium and sodium that are equivalent to the Recommended Daily Allowance (RDA) of the these mineral elements proposed by different institutions and authors, we can realize that this plant can be an important source of certain mineral elements namely calcium, magnesium, potassium and sodium as macronutrients. The content of iron in studied plant samples was not detected by refluxing 2.0g of plant tissues. However, since iron is indeed proven to exist in the acid mixture extract and in dry ashed samples, thus the disappearance of iron in water extract could be due to the lower solubility of its compounds in pure water. This problem could to certain extent be solved by increasing the sample size of this plant for water extract or by consuming as ground particles in capsules to benefit from the iron,

3.2. The microminerals and toxic elements

The concentration of microminerals and toxic elements with different digesting methods are presented in Table 1 and Figure 1(C&D). The results indicated that nickel had the highest concentration in both plants followed by zinc and manganese which found in the same level in both plants. In addition, copper was presented at moderate levels, whereas lithium was detected at the lowest concentration among the micronutrients in both plant samples. It is also noteworthy that, the concentration of nickel in *T. capitatus* was approximately twice that observed in *R. officinalis*. This may reflect a higher selectivity of *T. capitatus* for this element.

The microminerals Ni, Zn, Mn and Cu have been recognized as essential for plant and human. These elements have enormous impact on human health. Insufficient dietary intakes of these minerals impair several functions of the reproductive system, central nervous system, energy metabolism and enzyme activities and thus could cause serious illnesses [65]. The presence of the trace metals zinc, manganese, copper and nickel not detected in the water extract under our experimental conditions. Thus, the consume of water extraction of 2.0 grams of plant samples are not equivalent to the Recommended Daily Allowance (RDA) of these elements. The consuming sufficient amount of ground particles of these plants could supply the RDA of these minerals.

The toxic element lead found in lower levels compared to other macrominerals. Furthermore, the microminerals chrome, cobalt and toxic elements, Cd, were not detected. The lowest level of Pb and

non-detected data of Cr, Co and Cd make these plants safe, for consuming these plants to supply the Recommended Daily Allowance (RDA) of these elements, in the point of view of toxic levels.

The concentrations pattern of microminerals and toxic elements were found for the analyzed samples as follow:

$$\text{Ni} > \text{Zn} \geq \text{Mn} > \text{Cu} > \text{Li} > \text{Pb}$$

The mean concentration of these microminerals and toxic elements, Pb, were found to be with the range of many studies around the world [6, 9, 66-69].

3.3. Statistical analysis

The Principal Component Analysis (PCA), Partial Least Squares Discriminant Analysis (PLS-DA), Hierarchical Cluster Analysis (HCA) and boxplot were utilized to assess the significant differences between herbal plants toward their mineral composition, as well as to estimate variations arising from the methods that used to prepare the samples. PCA results exhibits variation between the selected plants. The first two principal components explaining 84% of the total variance, as seen in Figure 4. Moreover, PCA data reveal that there is significant variation between water extracting method and other methods (wet and dry methods). This could be related to the mineral composition which extracted by water infusion only represent the soluble salts minerals only. In addition, there is slight variance between ashing method and wet methods ($\text{HNO}_3/\text{H}_2\text{O}_2$ and $\text{HNO}_3/\text{HClO}_4$ methods), as seen in Figure 4.

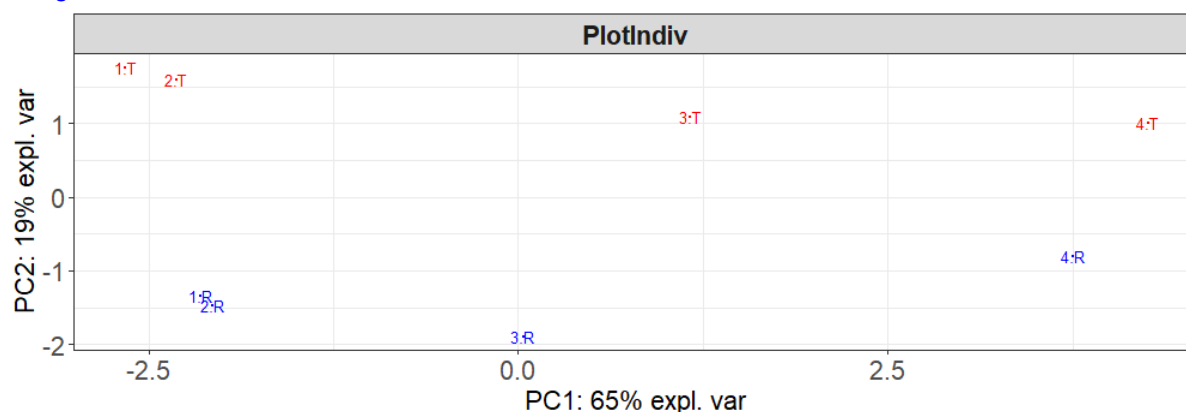


Figure 4. PCA analysis of elemental composition of *R. officinalis* and *T. capitates*; 1.S ($\text{HNO}_3/\text{HClO}_4$ for *R. officinalis*), 2.S ($\text{HNO}_3/\text{H}_2\text{O}_2$ for *R. officinalis*), 3.S (dry ashing for *S. Officinalis*), 4.S (water extraction for *R. officinalis*), 1.T ($\text{HNO}_3/\text{HClO}_4$ for *T. capitates*), 2.T ($\text{HNO}_3/\text{H}_2\text{O}_2$ for *T. capitates*), 3.T (dry ashing for *T. capitates*), 4.T (water extraction for *T. capitates*).

PLS-DA result indicates that a clear variation between *T. capitates* and *R. officinalis* in terms of digestion methods. The result also exhibits distinct clustering for certain groups, water infusion method and other digestion methods. In addition, there are slight differences between ashing method and wet methods ($\text{HNO}_3/\text{H}_2\text{O}_2$ and $\text{HNO}_3/\text{HClO}_4$ methods), as seen in Figure 5.

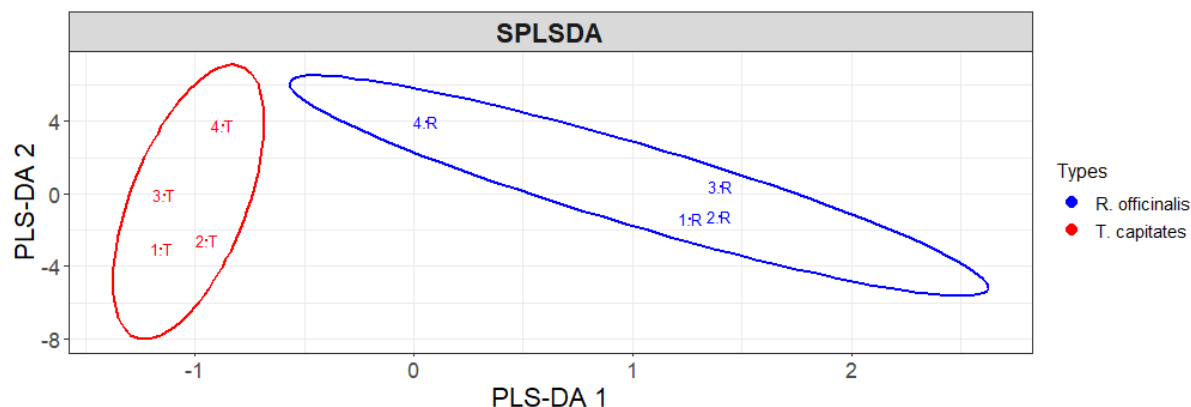


Figure 5. PLS-DA analysis of elemental composition of *R. officinalis* and *T. capitates*; 1.S ($\text{HNO}_3/\text{HClO}_4$ for *R. officinalis*), 2.S ($\text{HNO}_3/\text{H}_2\text{O}_2$ for *R. officinalis*), 3.S (dry ashing for *S. officinalis*), 4.S (water extraction for *R. officinalis*), 1.T ($\text{HNO}_3/\text{HClO}_4$ for *T. capitates*), 2.T ($\text{HNO}_3/\text{H}_2\text{O}_2$ for *T. capitates*), 3.T (dry ashing for *T. capitates*), 4.T (water extraction for *T. capitates*).

($\text{HNO}_3/\text{HClO}_4$ for *T. capitates*), 2.T ($\text{HNO}_3/\text{H}_2\text{O}_2$ for *T. capitates*), 3.T (dry ashing for *T. capitates*), 4.T (water extraction for *T. capitates*).

The cluster dendrogram plot exhibit clear variation between water extraction procedure and other digestion procedures. Similar groups clustered together indicate that these methods have similar ability to extract these minerals from the sample, as seen in Figure 6.

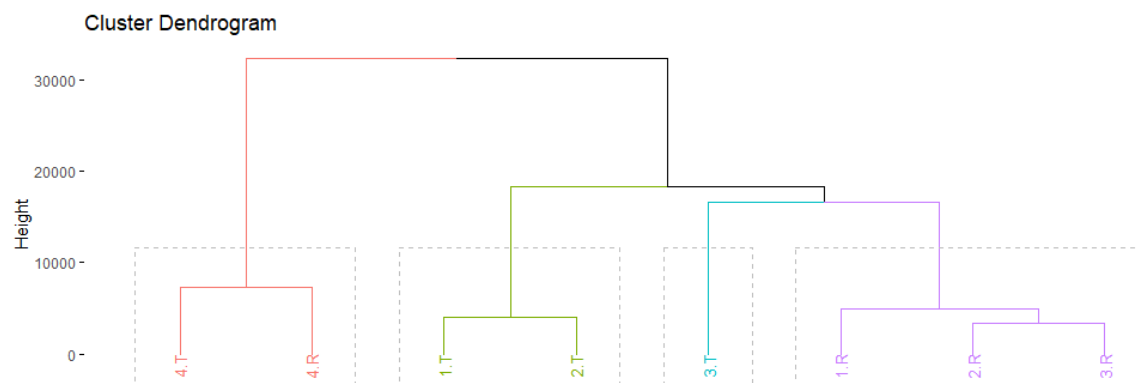


Figure 6. Dendrogram Plots showing separation of digestion methods which used to extract elements from *R. officinalis* and *T. capitates*; 1.S ($\text{HNO}_3/\text{HClO}_4$ for *R. officinalis*), 2.S ($\text{HNO}_3/\text{H}_2\text{O}_2$ for *R. officinalis*), 3.S (dry ashing for *S. officinalis*), 4.S (water extraction for *R. officinalis*), 1.T ($\text{HNO}_3/\text{HClO}_4$ for *T. capitates*), 2.T ($\text{HNO}_3/\text{H}_2\text{O}_2$ for *T. capitates*), 3.T (dry ashing for *T. capitates*), 4.T (water extraction for *T. capitates*).

Boxplot graph indicates there is significant variation in these plants in terms of mineral concentration. For instance, these plants have a significant variation in concentration of calcium, potassium, sodium, magnesium, nickel. While there are small significant differences between these herbals according to zinc and lead, as seen this example, Figure 7.

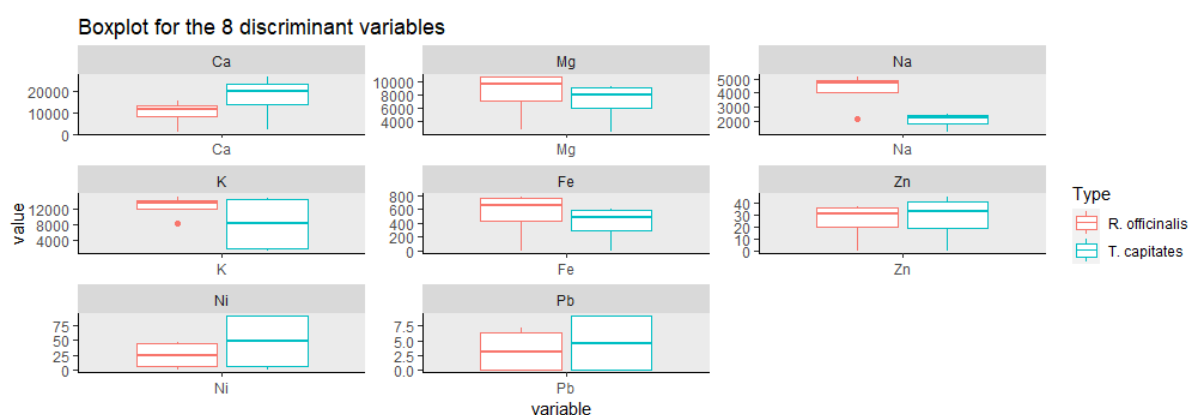


Figure 7. Grouped Boxplots showing the possible minerals that considered as marker to differentiate between *R. officinalis* and *T. capitates*.

4. Conclusion

The concentration of macrominerals, microminerals and some of toxic elements were determined in *R. officinalis* and *T. capitates*. From the data, the concentration levels of these minerals in the selected plants were found to be in this order: $\text{Ca} > \text{K} > \text{Mg} > \text{Na} > \text{Fe} > \text{Ni} > \text{Zn} \geq \text{Mn} > \text{Cu} > \text{Li} > \text{Pb}$. The macrominerals calcium and sodium were found to present in major levels. It is noticeable that, the concentration of Ca in *T. capitates* higher than in *R. officinalis* (two folded), while the concentration of Mg and Na found to be higher in *R. officinalis* compared to the level of these minerals in *T. capitates*. The concentration of Fe, Zn, Mn and Ni were found in minor levels while Cu, Li and Pb were detected in trace levels. The concentration of Ca, Mg, K and Na were detected in water extraction at significant amount, while other minerals not detected in water extraction. This could be related to the solubility of these elements' salts in water. Cr, Co and Cd not detected by any digestion methods.

The statistical analysis revealed that clear superiority of ($\text{HNO}_3/\text{HClO}_4$) as wet digestion method followed by ($\text{HNO}_3/\text{H}_2\text{O}_2$) method to prepare the samples for measurements. While the water extract represents the lowest procedure to extract the minerals. The statistical analysis also demonstrated that there are significant differences in the selected medical plants in term of mineral concentrations. For instance, the herbals have a significant difference in concentration of Cu, Na and Ni. This may relate to the different ability of the plants to absorb these metals. While there is no significant variance between these herbals according to the concentration of Mg and Zn.

Conflict of Interest

The authors confirm that there are no financial or personal conflicts of interest that could affect the work reported in this paper.

References

1. Taylor, D. (2001). Poor world health and rich world wealth: Commercial companies alone can't solve the health problems of developing countries. *BMJ*, 322(7287), 629-630. <https://doi.org/10.1136/bmj.322.7287.629>
2. Okatch, H., Ngwenya, B., Raletamo, K. M., & Andrae-Marobela, K. (2012). Determination of potentially toxic heavy metals in traditionally used medicinal plants for HIV/AIDS opportunistic infections in Ngamiland District in Northern Botswana. *Analytica chimica acta*, 730, 42-48. <https://doi.org/10.1016/j.aca.2011.11.067>
3. World Health Organization. (2002). The WHO strategy for traditional medicine: Review of the global situation and strategy implementation in the Eastern Mediterranean Region.
4. Anal, J. M. H., & Chase, P. (2016). Trace elements analysis in some medicinal plants using graphite furnace-atomic absorption spectroscopy. *Environmental Engineering Research*, 21(3), 247–255. <https://doi.org/10.4491/eer.2016.007>
5. Farnsworth, N., Akerele, O., & Bingel, A. (1987). Medicinal plants in therapy. *Journal of Ethnopharmacology*, 19(3), 336. [https://doi.org/10.1016/0378-8741\(87\)90016-x](https://doi.org/10.1016/0378-8741(87)90016-x)
6. Ajasa, A. M. O., Bello, M. O., Ibrahim, A. O., Ogunwande, I. A., & Olawore, N. O. (2004). Heavy trace metals and macronutrients status in herbal plants of Nigeria. *Food Chemistry*, 85(1), 67–71. <https://doi.org/10.1016/j.foodchem.2003.06.004>
7. Cox, P. J. (1994). Handbook on metals in clinical and analytical chemistry H.G. Seiler, A. Sigel and H. Sigel (editors), Dekker, New York, 1993. Pages: xx + 753. \$195.00. ISBN 0-8247-9094-4. *Talanta*, 41(12), 2201–2202. [https://doi.org/10.1016/0039-9140\(94\)80002-2](https://doi.org/10.1016/0039-9140(94)80002-2)
8. TOLONEN, M. (1996). Vitamins. *Vitamins and Minerals in Health and Nutrition*, 99–147. <https://doi.org/10.1533/9781845698461.99>
9. Serfor-Armah, Y., Nyarko, B. J. B., Akaho, E. H. K., Kyere, A. W. K., Osae, S., Oppong-Boachie, K., & Osae, E. K. (2001). Activation analysis of some essential elements in five medicinal plants used in Ghana. *Journal of Radioanalytical and Nuclear Chemistry*, 250(1), 173–176. <https://doi.org/10.1023/A:1013211819951>
10. Muhammad, Z., Mir, A. K., Mushtaq, A., Gul, J., Shazia, S., Kifayat, U., Sarfaraz, K. M., Farooq, A., Asma, J., Abdul, N., Arshad, M. A., Zia, u. R., & Zahid, U. (2010). Elemental analysis of some medicinal plants used in traditional medicine by atomic absorption spectrophotometer (AAS). *Journal of Medicinal Plants Research*, 4(19), 1987–1990. <https://doi.org/10.5897/jmpr10.081>
11. Arifin, Z. (2008). Some microminerals which are essential for biological system and its analysis methods.
12. Hadinoto, S., Fasa, L. R., & Smith, H. (2021). Macro and Micro Minerals Composition of Indian Scad (*Decapterus russelli*) From Mollucas Waters. *Journal of Physics: Conference Series*, 1940(1), 12037. <https://doi.org/10.1088/1742-6596/1940/1/012037>
13. Elekes, C. C., Dumitriu, I., Busuioc, G., & Iliescu, N. S. (2010). The appreciation of mineral element accumulation level in some herbaceous plant species by ICP–AES method. *Environmental Science and Pollution Research*, 17(6), 1230–1236. <https://doi.org/10.1007/s11356-010-0299-x>

14. Sarma, H., Deka, S., Deka, H., & Saikia, R. R. (2011). Accumulation of Heavy Metals in Selected Medicinal Plants. *Reviews of Environmental Contamination and Toxicology*, 63–86. https://doi.org/10.1007/978-1-4614-0668-6_4
15. Harper, H. A., Mayes, P. A., & Rodwell, V. W. (1973). Review of physiological chemistry (Vol. 46, pp. 1-477). Los Altos, CA: Lange medical publications. <https://doi.org/10.1002/bjs.1800510229>
16. Pravina, P., Sayaji, D., & Avinash, M. (2013). Calcium and its role in human body. *International Journal of Research in Pharmaceutical and Biomedical Sciences*, 4(2), 659-668.
17. Romani, A., & Scarpa, A. (1992). Regulation of cell magnesium. *Archives of Biochemistry and Biophysics*, 298(1), 1–12. [https://doi.org/10.1016/0003-9861\(92\)90411-Y](https://doi.org/10.1016/0003-9861(92)90411-Y).
18. Kirkland, A. E., Sarlo, G. L., & Holton, K. F. (2018). The role of magnesium in neurological disorders. *Nutrients*, 10(6), 730. <https://doi.org/10.3390/nu10060730>
- a. 19 O'Gara, P. (2006). Pathophysiology, Clinical Evaluation, and Medical Management. *Vascular Medicine*, 503–515. <https://doi.org/10.1016/b978-0-7216-0284-4.50040-3>
19. Kodintsev, V. V., Lenda, I. V., Ponomarev, A. V., Naumov, N. A., & Salatov Ya, S. (2022). Sodium as one of the basic elements in human life. *European Journal of Natural History*, 5, 4-7.
20. Reynolds, R. M., Padfield, P. L., & Seckl, J. R. (2006). Disorders of sodium balance. *BMJ*, 332(7543), 702–705. <https://doi.org/10.1136/bmj.332.7543.702>
21. Liebman, B. F., & Langford, H. G. (1985). Hypertension and sodium salts. *Science*, 228(4697), 351–353. <https://doi.org/10.1126/science.3983635>
22. McDonough, A. A., Thompson, C. B., & Youn, J. H. (2002). Skeletal muscle regulates extracellular potassium. *American Journal of Physiology–Renal Physiology*, 282(6), F967–F974. <https://doi.org/10.1152/ajprenal.00007.2002>
23. Tarail, R., & Elkinton, J. R. (1949). Potassium deficiency and the role of the kidney in its production. *The Journal of Clinical Investigation*, 28(1), 99–113. <https://doi.org/10.1172/JCI102046>
24. Tchounwou, P., & Udensi, U. (2017). Potassium homeostasis, oxidative stress, and human disease. *International Journal of Clinical and Experimental Physiology*, 4(3), 111. https://doi.org/10.4103/ijcep.ijcep_43_17
25. (Ed.). (2001). The Importance of Iron for Biological Systems. *Inorganic Biochemistry of Iron Metabolism*, 17–48. Portico. .ch2. <https://doi.org/10.1002/0470845791>
26. Lopez, A., Cacoub, P., Macdougall, I. C., & Peyrin-Biroulet, L. (2016). Iron deficiency anaemia. *The Lancet*, 387(10021), 907–916. [https://doi.org/10.1016/S0140-6736\(15\)60865-0](https://doi.org/10.1016/S0140-6736(15)60865-0)
27. MacDonald, R. A. (1963). Hemochromatosis and Hemosiderosis. *Kanzo*, 5(1), 34–36. <https://doi.org/10.2957/kanzo.5.34>
28. Skrajnowska, D., & Bobrowska-Korczak, B. (2019). Role of zinc in immune system and anti-cancer defense mechanisms. *Nutrients*, 11(10), 2273. <https://doi.org/10.3390/nu11102273>
29. Askary, V. R., Jahan, N. A., Sabbagh, A., Jahani, F. S., Dourandish, N., & Kamachali, A. R. K. (2011). A potential medicinal importance of zinc in human health and chronic diseases. *Clinical Biochemistry*, 44(13), S323–S324. <https://doi.org/10.1016/j.clinbiochem.2011.08.795>
30. Nriagu, J. (2019). Zinc Toxicity in Humans. *Encyclopedia of Environmental Health*, 500–508. <https://doi.org/10.1016/b978-0-12-409548-9.11836-6>
31. Studer, J. M., Schweer, W. P., Gabler, N. K., & Ross, J. W. (2022). Functions of manganese in reproduction. *Animal Reproduction Science*, 238, 106924. <https://doi.org/10.1016/j.anireprosci.2022.106924>
32. Baly, D. L., Curry, D. L., Keen, C. L., & Hurley, L. S. (1984). Effect of manganese deficiency on insulin secretion and carbohydrate homeostasis in rats. *The Journal of Nutrition*, 114(8), 1438–1446. <https://doi.org/10.1093/jn/114.8.1438>
33. Santos-Burgoa, C., Rios, C., Mercado, L. A., Arechiga-Serrano, R., Cano-Valle, F., Eden-Wynter, R. A., Texcalac-Sangrador, J. L., Villa-Barragan, J. P., Rodriguez-Agudelo, Y., & Montes, S. (2001). Exposure to manganese: Health effects on the general population, a pilot study in central Mexico. *Environmental Research*, 85(2), 90–104. <https://doi.org/10.1006/enrs.2000.4104>
34. Pinto, J. T., Hsieh, T.-C., Brown, S., Madrid, J., & Wu, J. M. (2017). 10. Advances of effects of copper on cardiovascular health. *Handbook of Nutrition in Heart Health*, 213–228. https://doi.org/10.3920/978-90-8686-853-7_10

35. Rajeswari, S., & Swaminathan, S. (2014). Role of copper in health and diseases. *Int. J. Cur. Sci*, 10, 94-107.
36. Rafati Rahimzadeh, M., Rafati Rahimzadeh, M., Kazemi, S., & Moghadamnia, A. A. (2024). Copper poisoning with emphasis on its clinical manifestations and treatment of intoxication. *Advances in Public Health*, 2024(1), Article 6001014. <https://doi.org/10.1155/2024/6001014>.
37. Lewicki, S., Zdanowski, R., Krzyżowska, M., Lewicka, A., Dębski, B., Niemcewicz, M., & Goniewicz, M. (2014). The role of Chromium III in the organism and its possible use in diabetes and obesity treatment. *Annals of Agricultural and Environmental Medicine*, 21(2), 331–335. <https://doi.org/10.5604/1232-1966.1108599>
38. Anderson, R. A. (1998). Chromium, glucose intolerance and diabetes. *Journal of the American College of Nutrition*, 17(6), 548–555. <https://doi.org/10.1080/07315724.1998.10718802>
39. Chowdhury, S. A., & MacFarlane, D. (2015). Chromium Tanning and Its Toxicity. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.2709101>
40. Moravcová, M., Siatka, T., Krčmová, L. K., Matoušová, K., & Mladěnka, P. (2025). Biological properties of vitamin B12. *Nutrition Research Reviews*, 38(1), 338–370. <https://doi.org/10.1017/S095442242400020X>
41. Catalani, S., Rizzetti, M. C., Padovani, A., & Apostoli, P. (2012). Neurotoxicity of cobalt. *Human & Experimental Toxicology*, 31(5), 421–437. <https://doi.org/10.1177/0960327111431080>.
42. Beyersmann, D., & Hartwig, A. (1992). The genetic toxicology of cobalt. *Toxicology and Applied Pharmacology*, 115(1), 137–145. [https://doi.org/10.1016/0041-008X\(92\)90274-M](https://doi.org/10.1016/0041-008X(92)90274-M)
43. Pérez-Granados, A. M., & Vaquero, M. P. (2002). Silicon, aluminium, arsenic and lithium: essentiality and human health implications. *Journal of Nutrition Health and Aging*, 6(2), 154-162.
44. Aron, L., Ngian, Z. K., Qiu, C., Choi, J., Liang, M., Drake, D. M., Hamplova, S. E., Lacey, E. K., Roche, P., & Yuan, M. (2025). Lithium deficiency and the onset of Alzheimer's disease. *Nature*, 645(8081), 712–721. <https://doi.org/10.1038/s41586-025-09112-1>
45. TIMMER, R. T., & SANDS, J. M. (1999). Lithium Intoxication. *Journal of the American Society of Nephrology*, 10(3), 666–674. <https://doi.org/10.1681/asn.v103666>
46. Zambelli, B., & Ciurli, S. (2013). Nickel and Human Health. *Interrelations between Essential Metal Ions and Human Diseases*, 321–357. https://doi.org/10.1007/978-94-007-7500-8_10
47. Angelova, M. G., Petkova-Marinova, T. V., Pogorielov, M. V., Loboda, A. N., Nedkova-Kolarova, V. N., & Bozhinova, A. N. (2014). Trace Element Status (Iron, Zinc, Copper, Chromium, Cobalt, and Nickel) in Iron-Deficiency Anaemia of Children under 3 Years. *Anemia*, 2014, 1–8. <https://doi.org/10.1155/2014/718089>
48. Yang, J., & Ma, Z. (2021). Research progress on the effects of nickel on hormone secretion in the endocrine axis and on target organs. *Ecotoxicology and Environmental Safety*, 213, 112034. <https://doi.org/10.1016/j.ecoenv.2021.112034>
49. Abarikwu, S. O. (2013). Lead, Arsenic, Cadmium, Mercury: Occurrence, Toxicity and Diseases. *Pollutant Diseases, Remediation and Recycling*, 351–386. https://doi.org/10.1007/978-3-319-02387-8_7
50. Landrigan, P. J. (1982). Occupational and community exposures to toxic metals: lead, cadmium, mercury and arsenic. *Western Journal of Medicine*, 137(6), 531.
51. Ouheda, S. A., Takteek, T. M., & Gharghar, F. (2025). Elemental Analysis of Some Libyan Medicinal Plants Using Inductively Coupled Plasma Atomic Emission Spectroscopy. *African Journal of Advanced Pure and Applied Sciences*, 778-787.
52. Saleh A. Ouheda, Toraia M. Takteek, & Sanaa M. Abushhewa. (2025). Determination of elements in *Salvia officinalis* and *Polygonum equisetiforme*. 725–716, (38)10, *مجلة العلوم الشاملة*. <https://doi.org/10.65405/act9m296>
53. Saleh A. Ouheda, Toraia M. Takteek, Sanaa M. Abushhewa, & Fawzeya Gharghar. (2025). The statistical evaluation of digestion methods for *Myrtus Communis* and *Peganum Harmala*. *مجلة العلوم* 1882–1873, (36)9, *الشاملة*. <https://doi.org/10.65405/19jdt32>
54. Azadbakht, L., & Esmailzadeh, A. (2012). Macro and micro-nutrients intake, food groups consumption and dietary habits among female students in Isfahan University of Medical Sciences. *Iranian Red Crescent Medical Journal*, 14(4), 204.

55. Rana, S., Agrawal, N., & Singh, A. (2020). Study of dietary intake of micro and macronutrients and comparison with the Recommended Daily Allowance (RDA). *IP Journal of Nutrition, Metabolism and Health Science*, 3(1), 10–12. CLOCKSS. <https://doi.org/10.18231/j.ijnmhs.2020.003>
56. Greger, J. L. (1998). Dietary Standards for Manganese: Overlap between Nutritional and Toxicological Studies. *The Journal of Nutrition*, 128(2), 368S–371S. <https://doi.org/10.1093/jn/128.2.368s>
57. Flyvholm, M.-A., Nielsen, G. D., & Andersen, A. (1984). Nickelgehalt in Lebensmitteln und Bestimmung der Nickelaufnahme. *Zeitschrift FOR Lebensmittel-Untersuchung Und -Forschung*, 179(6), 427–431. <https://doi.org/10.1007/bf01043419>
58. Enderle, J., Klink, U., di Giuseppe, R., Koch, M., Seidel, U., Weber, K., Birringer, M., Ratjen, I., Rimbach, G., & Lieb, W. (2020). Plasma Lithium Levels in the General Population: A Cross-Sectional Analysis of Metabolic and Dietary Correlates. *Nutrients*, 12(8), 2489. <https://doi.org/10.3390/nu12082489>
59. Turck, D., Castenmiller, J., de Henauw, S., Hirsch-Ernst, K.-I., Kearney, J., Knutsen, H. K., Maciuk, A., Mangelsdorf, I., McArdle, H. J., Pelaez, C., Pentieva, K., Siani, A., Thies, F., Tsabouri, S., Vinceti, M., Aggett, P., Fairweather-Tait, S., Martin, A., et al. (2019). Dietary reference values for sodium. *EFSA Journal*, 17(9). <https://doi.org/10.2903/j.efsa.2019.5778>
60. Ajasa, A. M. O., Bello, M. O., Ibrahim, A. O., Ogunwande, I. A., & Olawore, N. O. (2004). Heavy trace metals and macronutrients status in herbal plants of Nigeria. *Food Chemistry*, 85(1), 67–71. <https://doi.org/10.1016/j.foodchem.2003.06.004>
61. RAZIC, S., ONJIA, A., DOGO, S., SLAVKOVIC, L., & POPOVIC, A. (2005). Determination of metal content in some herbal drugs—Empirical and chemometric approach. *Talanta*, 67(1), 233–239. <https://doi.org/10.1016/j.talanta.2005.03.023>
62. Majolagbe, A. O., Kuteyi, V., Onwordi, C. T., & Yusuf, K. A. (2013). Concentration and bioavailability of iron in some selected blood-building medicinal plants in southwest Nigeria. *Journal of Environment*, 2(1), 19-24.
63. Subramanian, R., Gayathri, S., Rathnavel, C., & Raj, V. (2012). Analysis of mineral and heavy metals in some medicinal plants collected from local market. *Asian Pacific Journal of Tropical Biomedicine*, 2(1), S74–S78. [https://doi.org/10.1016/s2221-1691\(12\)60133-6](https://doi.org/10.1016/s2221-1691(12)60133-6)
64. Nieder, R., Benbi, D. K., & Reichl, F. X. (2018). Macro- and Secondary Elements and Their Role in Human Health. *Soil Components and Human Health*, 257–315. https://doi.org/10.1007/978-94-024-1222-2_6
65. Gomez, M. R., Cerutti, S., Olsina, R. A., Silva, M. F., & Martínez, L. D. (2004). Metal content monitoring in *Hypericum perforatum* pharmaceutical derivatives by atomic absorption and emission spectrometry. *Journal of Pharmaceutical and Biomedical Analysis*, 34(3), 569–576. [https://doi.org/10.1016/s0731-7085\(03\)00643-5](https://doi.org/10.1016/s0731-7085(03)00643-5)
66. Ražić, S., Onjia, A., & Potkonjak, B. (2003). Trace elements analysis of *Echinacea purpurea*—herbal medicinal. *Journal of Pharmaceutical and Biomedical Analysis*, 33(4), 845–850. [https://doi.org/10.1016/s0731-7085\(03\)00338-8](https://doi.org/10.1016/s0731-7085(03)00338-8)
67. Sahito, S. R., MEMON, A., KAZI, T., KAZI, G., PIRZADO, Z., & SHAR, G. (2011). Comparison of Wet Ashing Methods for Medicinal Plants, *Celosia argentea* and *Cubeba officinalis* by Atomic Absorption Spectrophotometer. *Journal of The Chemical Society of Pakistan*, 26(4), 135.
68. Ferreira, L. D. S., Lopes, R. P., Ulbrich, M. N. C., Guaratini, T., Colepicolo, P., Lopes, N. P., Garla, R. C., Oliveira Filho, E. C., Pohlit, A. M., & Zucchi, O. L. A. D. (2012). Concentration of Inorganic Elements Content in Benthic Seaweeds of Fernando de Noronha Archipelago by Synchrotron Radiation Total Reflection X-Ray Fluorescence Analysis (SRTXRF). *International Journal of Analytical Chemistry*, 2012, 1–8. <https://doi.org/10.1155/2012/407274>

الإمكانات العلاجية وتقييم السلامة لنباتي الزعتر الليبي وإكليل الجبل: دراسة كمية للعناصر المعدنية وربطها بالإرشادات الصحية للإنسان

الملخص

تم تحديد التركيب المعدني لنباتين عشبيين ينموان في البرية الليبية، وهما *Thymus capitatus* (الزعتر البري) و *Rosmarinus officinalis* (إكليل الجبل/الروزماري)، باستخدام أربع طرق مختلفة للهضم الكيميائي. وقد تم قياس تراكيز عناصر الكالسيوم، والمغنيسيوم، والبوتاسيوم، والصوديوم، والفوسفور، والحديد، والمنغنيز، والزنك، والنحاس، والكوبالت، والكروم، والنيكل، والرصاص، والكادميوم باستخدام تقنية مطيافية الامتصاص الذري (AAS).

أظهرت النتائج أن العناصر الكبرى (Macrominerals)، وهي الكالسيوم والمغنيسيوم والبوتاسيوم والصوديوم، كانت العناصر السائدة في النباتات المدروسة، حيث تراوحت تراكيزها من الكالسيوم الذي سجل أعلى مستوى إلى الصوديوم الذي سجل أقل تركيز. كما تم الكشف عن الحديد والزنك والمنغنيز والنيكل بتراكيز منخفضة نسبياً، في حين وُجد النحاس والليثيوم والرصاص بكميات ضئيلة جداً. وتم الكشف عن الكالسيوم والمغنيسيوم والبوتاسيوم والصوديوم في المستخلص المائي لهذه النباتات بكميات ملحوظة، بينما لم يتم الكشف عن العناصر الأخرى في المستخلص المائي. إضافة إلى ذلك، لم يتم الكشف عن الكروم والكوبالت والكادميوم باستخدام أي من طرق الهضم المستخدمة.

أوضحت نتائج الدراسة أن المستخلص المائي يحتوي على كميات من الكالسيوم والمغنيسيوم والبوتاسيوم والصوديوم تعادل أو تساهم بشكل ملحوظ في تلبية الاحتياج اليومي الموصى به (RDA) لهذه العناصر الكبرى، والتي تُعد ضرورية لصحة الإنسان. ومع ذلك، فإن كميات الحديد والزنك والمنغنيز والنيكل والنحاس والليثيوم الموجودة في المستخلص المائي غير كافية لتلبية الاحتياج اليومي الموصى به من هذه العناصر الضئيلة. ومن ناحية أخرى، فإن استهلاك كميات مناسبة من المسحوق النباتي الكامل لهذين النباتين العشبيين قد يساهم في توفير الاحتياج اليومي الموصى به من هذه العناصر الضئيلة. كما أن الانخفاض الشديد في مستوى الرصاص يدل على أن هذه النباتات آمنة للاستخدام في الأغراض العلاجية.

أظهر التحليل الإحصائي وجود فروق واضحة في كفاءة الاستخلاص بين طريقة الاستخلاص بالماء وطرق الاستخلاص الأخرى. ويمكن تفسير هذا الاختلاف بمحدودية ذوبانية الأملاح القابلة للذوبان في الماء. في المقابل، لوحظت فروق طفيفة فقط بين طريقة الرماد الجاف (Dry Ashing) والطريقتين الأخرين المعتمدتين على الهضم الحمضي باستخدام خليط حمض النيتريك/فوق أكسيد الهيدروجين ($\text{HNO}_3/\text{H}_2\text{O}_2$) وخليط حمض النيتريك/حمض اليبركلوريك ($\text{HNO}_3/\text{HClO}_4$) وبشكل عام، كانت تراكيز العناصر المقاسة باستخدام خليط $\text{HNO}_3/\text{HClO}_4$ أعلى قليلاً مقارنةً بتلك الناتجة عن طريقتي $\text{HNO}_3/\text{H}_2\text{O}_2$ والرماد الجاف.

الكلمات المفتاحية: البرية الليبية، الذوبانية في الماء، مطيافية الامتصاص الذري (AAS)، التحليل الإحصائي