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Determination of the Nutritional Properties and Biological Activity of Medicinal Herbs and Spices Grown in Syria

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The present study provides an integrated evaluation of the nutritional composition, antioxidant capacity, and mineral profile of six medicinal herbs and spices cultivated or sourced from Syria: (*Ocimum basilicum* L.), mint (*Mentha* spp.), nutmeg (*Myristica fragrans* Houtt.), rosemary (*Rosmarinus officinalis* Spenn.), clove (*Syzygium aromaticum* (L.) Merr. & Perry), and thyme (*Thymus vulgaris* L.). Significant interspecific variations ($p < 0.001$) were observed across most measured parameters, indicating both genetic and environmental influences. Basil and mint exhibited the highest protein contents (14.79% and 14.44%, respectively) and elevated ash values (9.38% and 8.63%). Basil showed the highest concentrations of calcium (23,711 mg·kg^{-1}), potassium (31,000 mg·kg^{-1}), and zinc (63.25 mg·kg^{-1}), while mint contained the highest magnesium (514.7 mg·kg^{-1}) and iron (451.7 mg·kg^{-1}) levels. In contrast, nutmeg recorded the highest fat content (20.67%) but the lowest ash (2.41%) and mineral concentrations overall. Regarding antioxidant properties, rosemary demonstrated the highest antioxidant activity (98.77 mg TEAC·g^{-1}), followed by clove (91.37 mg TEAC·g^{-1}). Clove exhibited the highest total polyphenol content (60.71 mg GAE·g^{-1}), whereas mint showed the highest flavonoid (24.46 mg QE·g^{-1}) and phenolic acid contents (11.693 mg CAE·g^{-1}). Nutmeg presented the lowest flavonoid concentration (1.75 mg QE·g^{-1}). Overall, leafy herbs (basil and mint) were characterized by higher protein and mineral accumulation, whereas seed spices such as nutmeg were richer in lipophilic compounds but lower in mineral density. The marked variability in phytochemical and elemental profiles highlights the species-specific metabolic characteristics and the influence of environmental factors, supporting the potential of Syrian herbs and spices as valuable natural sources of bioactive compounds and essential nutrients.

Keywords: medicinal herbs, nutritional properties, antioxidant properties, mineral profile

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Introduction

Medicinal herbs and spices are considered an important part of human nutrition and health (Khatib et al., 2021) as they are considered a rich source of biologically active compounds with therapeutic potential (Opara and Chohan, 2014). In addition, they have applications in the field of cooking, as they contribute to the prevention of diseases and the promotion of health through their antioxidant, antimicrobial and anti-inflammatory properties (Jungbauer and Medjakovic, 2012; Parham et al., 2020). In Syria, herbs have been traditionally employed not only as culinary flavorings but also as integral components of folk medicine. Local populations have long used these medicinal plants to treat a variety of ailments, leveraging their natural bioactive compounds as therapeutic agents. This ethnomedical practice highlights a rich heritage of traditional healing, influenced by Syria's unique environmental conditions, and underscores the importance of further research into the pharmacological efficacy and safety of these herbal remedies (Khatib et al., 2021b; Hani et al., 2022). Previous studies that focused on its nutritional composition and biological activity when grown in a specific location in Syria have shown that climatic conditions and their dynamic may affect agricultural cultivation, except for Syria (Khatib et al., 2021; Mesmar et al., 2022). Among these, rosemary (*Rosmarinus officinalis* Spenn.), mint (*Mentha* spp.), clove (*Syzygium aromaticum* (L.) Merr. & Perry), thyme (*Thymus vulgaris* L.), basil (*Ocimum basilicum* L.), and nutmeg (*Myristica fragrans* Houtt.) are widely recognized for their health benefits. These plants are rich in essential oils, phenolic compounds, and flavonoids, which have been associated with various biological activities, including antioxidant and antimicrobial effects (Kurian, 2012; Parham et al., 2020). Despite the global recognition of these herbs, there is a paucity of comprehensive studies focusing on their nutritional composition and biological activities when cultivated in specific regions such as Syria. The unique climatic and soil conditions in Syria may influence the phytochemical profiles and, consequently, the health-promoting properties of these plants (Khatib et al., 2021a, 2021b).

Rosmarinus officinalis is known for its high antioxidant activity, primarily due to compounds like carnosic acid and rosmarinic acid. Recent studies have highlighted its potential to reduce oxidative stress and improving cognitive function (Bakırel et al., 2007; Hussain et al., 2022). Previous studies have shown that it is an anti-inflammatory and has therapeutic importance and an effect on the nervous system due to its active compounds (Rahbardar and Hosseinzadeh, 2020). Although it is cultivated along the Mediterranean, information about the species cultivated in Syria remains limited.

Mentha spp., according to recent studies, various components, such as volatile oils, flavonoids, and tannins, which have been shown to confer medicinal importance (Eftekhari et al., 2021). Peppermint extract and essential oils are promising agents in traditional medicine. Their wide-ranging effects have been demonstrated. Peppermint contains aromatic compounds such as menthol and carvone, which are biologically active components, in addition to their antimicrobial properties (Anjum et al., 2024; Sonawane and Sonawane, 2025). These compounds are distinguished by their high antioxidant value and neuroprotective effects due to their phenolic properties by reducing oxidative stress (Sonawane and Sonawane, 2025).

Syzygium aromaticum contains many phytochemicals, such as sesquiterpenes, monoterpenes, hydrocarbons, and phenolic compounds. Eugenol, a compound with strong antioxidant and antimicrobial activities. The concentration of eugenol can vary based on cultivation conditions, underscoring the need for region-specific analyses (Maggini et al., 2024). It has been used traditionally for dental pain relief and as a food preservative. Studies have shown that eugenol has an important antimicrobial activity in essential oil (Batiha et al., 2020; Haro-González et al., 2021).

Thymus vulgaris is considered one of the most important plants widely cultivated in Syria. The significance of this plant lies in its therapeutic and medicinal properties, as it is rich in two compounds: thymol and carvacrol. These compounds are known for their antibacterial properties, in addition to their antioxidant capacity. Previous studies have indicated that thymol plays a significant role as an anti-inflammatory agent (Alkufeidy et al., 2021; Vassiliou et al., 2023).

Ocimum basilicum is distinguished by its important modern properties, in addition to its benefits in preventing some diseases and affording protection against several chronic diseases due to their anti-inflammatory and antioxidant activities containing essential oils like linalool and eugenol, contributing to its anti-inflammatory and antimicrobial effects (Gajula et al., 2009; Filip, 2017). While widely studied globally, there is a lack of data on nutritional and phytochemical profiles. However, research indicates that *O. basilicum* demonstrates various pharmacological activities, including wound-healing, antibacterial, antifungal, antioxidant, and anti-inflammatory properties (Zhakipbekov et al., 2024).

Myristica fragrans, due to its nutritional and therapeutic potential, has been the subject of many experiments on rodent models, but so far, clinical data are limited. Cloves, like other herbs studied in this research, are considered to have important antibacterial, anticancer, antioxidant, antifungal, anti-inflammatory, and hepatoprotective properties. This is attributed to myristicin, one of the most effective compounds (Kumari et al., 2021; Sultan et al., 2023).

Despite the widespread culinary and medicinal use of these herbs and spices, comprehensive comparative data regarding their nutritional composition, antioxidant capacity, and mineral profiles – particularly for specimens cultivated or sourced from Syria – remain limited. Environmental conditions, soil composition, and regional agricultural practices may significantly influence phytochemical and elemental accumulation, leading to variability in their nutritional and biological properties. Therefore, systematic evaluation is necessary to identify species with superior nutritional and antioxidant potential and to better understand how regional factors affect their bioactive profiles.

Accordingly, this study aims not only to characterize the proximate composition, antioxidant properties, and macro- and micro-element contents of six commonly used medicinal herbs and spices grown in Syria, but also to determine their relative nutritional and functional value. The findings are intended to contribute to the scientific understanding of region-specific medicinal plants, support the development of functional foods and dietary supplements, and provide baseline data for future research on soil–plant interactions and phytochemical optimization.

Material and Methodology

Materials

Basil, mint, rosemary, and thyme were cultivated on the Syrian coast (Latakia region, Syria) under typical Mediterranean climatic conditions (average temperature 18–25 °C; relative humidity 60–75%). The plants were grown in open-field conditions in well-drained loamy soil without the application of synthetic fertilizers during the growth period. Leaves were harvested at full vegetative stage (prior to flowering) to ensure optimal phytochemical content. Nutmeg and clove, which are not locally cultivated species, were obtained from certified herbal stores in Latakia, Syria. All purchased samples were from the same commercial batch to ensure homogeneity and were verified based on morphological characteristics.

Freshly harvested leafy samples (basil, mint, rosemary, thyme) were washed with distilled water to remove surface impurities and air-dried at room temperature (25 ±2 °C) in a shaded, well-ventilated area for 7–10 days until constant weight was achieved. Drying was performed away from direct sunlight to minimize degradation of heat- and light-sensitive bioactive compounds. Nutmeg and clove samples were used in their dried commercial form and were visually inspected to ensure absence of fungal contamination or physical damage. All dried samples were ground using a Tefal Electric Grinder (GT110838, Germany) and sieved through a 0.5 mm mesh to obtain a uniform fine powder. The powdered samples were stored in airtight, light-resistant polyethylene containers at 4 °C until analysis to prevent oxidation and degradation of phenolic compounds. All analyses were conducted within two weeks of sample preparation.

Methods

Physicochemical and nutritional evaluation

Dry matter, ash, and protein content

AACC method 08-01 will be used to determine the dry matter, ash, and crude protein content (AACC, 1996). The semi-micro Kjeldahl method was used to determine nitrogen content. The usual factor of 5.7 was used to convert nitrogen to protein. According to manufacturer guidelines, the Ancom XT15 Fat Extractor (USA) will be used to measure the sample's fat content.

Mineral compounds analysis

Mineral elements (Ca, Na, K, Mg, Al, Ba, Cu, Fe, Li, Mn, Sr, and Zn) were determined using inductively coupled plasma optical emission spectroscopy (ICP-OES; Thermo iCAP Dual 6500, USA). Approximately 0.2 g of ground sample was subjected to microwave-assisted digestion (Ethos One, Milestone, Italy) in Teflon vessels containing 8 mL of 65% HNO_3. The digestion protocol lasted 1 hour with a temperature ramp not exceeding 200 °C. Each digested sample was diluted to 50 mL with ultrapure water, and a blank (acid only) was run in parallel. Calibration was conducted using certified standard solutions (Merck): 10,000 ppm (Ca, Fe, K, Mg, P) and 1,000 ppm (Na, Al, Ba, Cu, Li, Mn, Sr, Zn). A three-point calibration curve was generated for each element. Internal standard correction (yttrium and ytterbium ions at 2–5 $mg \cdot L^{-1}$) was applied to minimize instrumental drift.

Antioxidant characteristics

DPPH – Free Radical Scavenging Activity

The free radical scavenging activity was measured according to Yen and Chen (1995) with slight modifications. A solution of 0.012 g DPPH in 100 mL ethanol was prepared, and 4 mL of this solution was added to 1 mL of the ethanolic seed extract. After incubation, absorbance was read at 515 nm using a Jenway 6405 UV–Vis, UK. Results are reported as a mg of Trolox equivalent antioxidant capacity (TEAC) per gram of dry matter.

Total polyphenol content

Total polyphenols were estimated using a modified Folin-Ciocalteu method (Singleton et al., 1965). Briefly, 0.1 mL of extract was mixed with 0.1 mL of Folin-Ciocalteu reagent and 1 mL of 20% sodium carbonate. After incubation, absorbance was measured at 700 nm (Jenway 6405 UV–Vis, UK. Results are expressed in mg of gallic acid equivalent (GAE) per gram of dry matter.

Total flavonoid content

Flavonoid content was determined following the method of Willett (2002) with minor modifications. A 0.5 mL aliquot of the extract was combined with 0.1 mL of 10% (w/v) Aluminum chloride in ethanol, 0.1 mL of 1 M potassium acetate, and 4.3 mL of distilled water. After 30 min in the dark, absorbance was measured at 415 nm (Jenway 6405 UV–Vis, UK). Results are reported as mg quercetin equivalents (QE) per gram of dry matter.

Total phenolic acid content

Total phenolic acids were measured according to Jain et al. (2017). A 0.5 mL aliquot of extract was mixed with 0.5 mL of 0.5 M HCl, 0.5 mL of Arnova reagent (10% $NaNO_2$ + 10% Na_2MoO_4), 0.5 mL of 1 M NaOH, and 0.5 mL of water. After mixing, the absorbance was read at 490 nm (Jenway 6405 UV–Vis, UK). Results are expressed as mg of caffeic acid equivalents (CAE) per gram of dry matter.

Statistical analysis

The data were analyzed with GenStat software (12th edition). A one-way analysis of variance (ANOVA) was performed to assess differences among samples at the 0.05 significance level ($p < 0.05$). Tukey‘s Honest Significant Difference (HSD) test was applied for pairwise comparisons to identify which groups differ.

Results and Discussion

Nutritional properties

The analysis of nutritional properties (Table 1) of six selected herbs reveals statistically significant differences ($p < 0.001$) among the samples for all measured components. Nutmeg showed the highest fat content, whereas basil and mint showed relatively high protein levels. In contrast, clove and thyme demonstrated comparatively lower values in certain nutritional aspects. The results reveal a significant variation in the nutritional properties of the herbs studied, which may be attributed to their botanical characteristics and biochemical composition.

Protein

The results indicate that basil and mint exhibited the highest protein contents among the six herbs studied, with values of 14.79 and 14.44% respectively. Protein deficiency is one of the most common types of malnutrition (Bravo et al., 2021). In addition, plant protein is considered functional food (Hertzler et al., 2020). Plant proteins are preferred, given their nutritional value, compared to animal-derived proteins (Rahman and Lamsal, 2021). A 2021 study on basil

Table 1 Nutritional properties of analyzed samples

Sample	Nutritional properties		
	ash %	fat %	protein %
Basil	9.38 ±0.4587^{e}	5.99 ±0.2069^{c}	14.79 ±0.1238^{e}
Mint	8.63 ±0.0040^{e}	2.69 ±1.5942^{ab}	14.44 ±0.1238^{e}
Nutmeg	2.41 ±0.2168^{a}	20.67 ±0.5475^{d}	7.88 ±0.0141^{b}
Rosemary	6.02 ±0.2182^{c}	6.11 ±0.0663^{c}	10.51±0.1238^{d}
Clove	3.86 ±0.1390^{b}	5.35 ±0.6400^{bc}	6.30 ±0.1238^{a}
Thyme	6.97 ±0.1182^{d}	1.89 ±0.5952^{a}	9.72 ±0.1238^{c}
p-value	<.001	<.001	<.001

Notes: Values are means ± standard deviation (n = 2). Means within the same column with different superscripts are significantly different ($p < 0.05$)

seeds reported that they contain protein content up to 22.5%. It was noted that follow-up monitoring was conducted on Paper (Bravo et al., 2021). However, a previous study on shade-dried leaves, reported a crude protein content was 7.74% (Shittu et al., 2021). In contrast, clove had the lowest protein content (6.3%), which is comparable to previous studies (Xue et al., 2022). Classification as a spice is primarily valued for its volatile oil composition rather than macronutrient density (Cortés-Rojas et al., 2014).

Fat content

The results showed that nutmeg has the highest percentage of fat content compared to other types at 20.67%. Nutmeg seeds contain a substantial proportion of fixed oil, typically 24–40% by weight, with most sources citing 25 and 40% of fat in the kernel. This high percentage is due to its high fatty acid content. Sources indicate that the highest fat content is in the nucleus, where it reaches 50% (Bello et al., 2014). These fixed oils are mainly composed of fatty acids such as myristic, palmitic, oleic, and linoleic acids (Obranović et al., 2020). The discrepancy in the result compared to previous studies is due to several factors, the most important of which are the difference in species, environment, and genetic factors as well (Abourashed and El-Alfy, 2016; Obranović et al., 2020; Ashokkumar et al., 2022; Elfia and Susilo, 2023; Khamnuan et al., 2023; Vikram & Raj, 2025). Thyme recorded the lowest fat content, followed by thyme at 1.89%, and then mint. This result is almost consistent with previous findings, as herbs in the Lamiaceae family, to which thyme, mint, and basil belong, have low values, ranging from 1–2%. Their primary bioactive constituents are volatile essential oils, not lipids (Quílez et al., 2020; Vlaicu et al., 2022).

Ash content

The highest percentages were found in basil 9.38% and mint, 8.63%. As ash content reflects mineral content, previous studies on basil, a 2023 study, which was slightly lower compared to other results, indicate that dietary ash content plays an important role in regulating sugar. Minerals are inorganic substances essential for human nutrition (Ezegbe et al., 2023; Imo et al., 2018). Nutmeg showed an ash content of 2.41%, the lowest of any of the herbs and spices tested. Nutmeg has a high fat content and a low ash content, as previously found in studies. The ratios ranged between 1.9 and 3.87%, making the sample studied relatively similar. Although the ash content indicates the presence of some trace elements, nutmeg is not primarily a mineral-rich spice. The lower ash content in nutmeg compared to basil or mint reflects its biological role (Bamigboye et al., 2020; Okiki et al., 2023)

Antioxidant activity

The analysis of the antioxidant properties (Table 2) shows a remarkable variation, indicating species-specific differences. This aligns with previous studies indicating that antioxidants differ among herbal species due to variations in phenolic and environmental factors (Rayess et al., 2023; Intharuksa et al., 2024). In this study, the antioxidant activity of the herbs ranged from 90.18 to 98.77 mg GAE·g^{-1}, with rosemary 98.77 mg GAE·g^{-1} and clove 91.37 mg GAE·g^{-1} recording the highest values. This is consistent with previous reports highlighting rosemary and clove as exceptionally rich in antioxidant compounds. A previous study conducted in 2018 reported that the high percentage is due to the *major* phenolic diterpenes responsible for rosemary's antioxidant properties, including carnosic acid, carnosol, rosmanol, and epirosmanol. The antioxidant

Table 2 Antioxidant properties of analyzed samples

Sample	Antioxidant properties			
	antioxidant activity (mg TEAC·g^{-1})	polyphenols (mg GAE·g^{-1})	flavonoids (mg QE·g^{-1})	phenolic acid (mg CAE·g^{-1})
Basil	91.20 ±10.535^{a}	8.44 ±0.7071^{a}	5.95 ±0.3179^{b}	3.096 ±0.2119^{a}
Mint	90.10 ±8.976^{a}	46.13 ±1.6971^{d}	24.46 ±1.1650^{e}	11.693 ±1.8008^{c}
Nutmeg	90.54 ±10.364^{a}	18.97 ±1.1549^{b}	1.75 ±0.2249^{a}	7.756 ±0.3106^{b}
Rosemary	98.77 ±3.331^{a}	41.46 ±0.0314^{c}	16.36 ±0.0714^{d}	7.871 ±0.0172^{b}
Clove	91.37 ±11.138^{a}	60.71 ±0.0236^{e}	12.01 ±0.3704^{c}	11.119 ±0.1198^{c}
Thyme	90.53 ±10.297^{a}	20.64 ±1.6106^{b}	11.61 ±0.0189^{c}	9.339 ±0.7171^{bc}
p-value	0.929	<.001	<.001	<.001

Notes: Values are means ± standard deviation (n = 2); means withing the same column with different superscripts are significantly different (p <0.05); TEAC – trolox equivalent antioxidant capacity; GAE – gallic acid equivalent; QE – quercetin equivalent; CAE – caffeic acid equivalent activity of carnosic acid is attributed to its ability to increase or maintain the activity of the enzymes superoxide dismutase and glutathione peroxidase, both of which are important in treating diseases and preserving food (Nieto et al., 2018). Carnosic acid and carnosol are considered to inhibit lipid peroxidation by up to 100 and 88%, respectively (Wijeratne and Cuppett, 2007). Clove buds also possess antioxidant properties, as they can react to oxidative stress in our bodies by free-radicalizing compounds found in cloves, such as eugenol and eugenyl acetate (Rani and Jena, 2021). Similarly, in another study on clove oil, it was found that the chemical constituent of 65.3% eugenol exhibited strong antioxidant properties and inhibited lipid peroxidation (Das et al., 2020).

Total polyphenols

Polyphenols are secondary metabolites that play a protective role in plants against ultraviolet radiation, oxidative stress, and pathogenic attack. In human nutrition, dietary polyphenols are associated with reduced risk of cancer and cardiovascular diseases due to their antioxidant and anti-inflammatory properties (Ivanišová et al., 2023). The major phenolic compounds commonly identified in herbs and spices include phenolic acids (e.g., gallic acid), flavonol glucosides, phenolic volatile compounds such as eugenol and acetyl eugenol, and tannins (Cortés-Rojas et al., 2014; Indiarto et al., 2024). In the present study, significant variation ($p < 0.001$) was observed in total polyphenol content among the analyzed samples. Clove exhibited the highest value (60.71 mg GAE·g^{-1}), whereas basil showed the lowest (8.44 mg GAE·g^{-1}). The elevated polyphenol content in clove is consistent with its well-documented richness in eugenol and related phenolic derivatives, which contribute substantially to its antioxidant capacity (Cortés-Rojas et al., 2014). Variability in total polyphenol content among species may be attributed to several factors, including extraction conditions (solvent type, polarity, and concentration), plant part analyzed, and environmental factors such as soil composition and climate (Ahmed et al., 2022; Indiarto et al., 2024). Furthermore, maturity stage plays a crucial role in determining phenolic composition, particularly in clove buds, where more mature cloves tend to accumulate higher levels of eugenol and related phenolics (Tursiloadi et al., 2015; Indiarto et al., 2024). Therefore, differences between the present findings and previously reported values may reflect variations in harvest stage, post-harvest handling, and extraction methodology.

Flavonoid acid content

The highest percentage of flavonoids was for mint at 24.24 mg QE·g^{-1}, followed by rosemary at 16.36 mg QE·g^{-1}. The lowest percentage was for nutmeg at 1.75 mg QE·g^{-1}. This is consistent with previous studies showing that all studied mint species possess large amounts of phenolic compounds responsible for antioxidant activity, particularly tyrosinase inhibition. In addition, phenolics are sufficient compounds, along with terpenoids, to characterize *Mentha* sp. (Zeljković et al., 2021). The composition of the phenolic compounds within each species. The most important phenolic compounds are flavonoids. They are characterized by the presence of lipophilic flavonoids. Phenolic compounds have been found to have a specific connection with a broad pharmacological effect (Mimica-Dukic and Bozin, 2008). Flavonoids are known to act as free radical scavengers neutralizing reactive oxygen species. Flavonoids affect cardiovascular disease by improving endothelial function and reducing inflammation (Zahra et al., 2024). In addition, the flavonoid content of nutmeg is the lowest, 1.75 mg QE·g^{-1}, among the herbs studied. This content differs from previous studies, possibly due to differences in extraction methods, genetic factors, or cultivation location (Sabandar et al., 2023; Erizal et al., 2024).

Phenolic acid

Mint showed higher concentrations than other samples, at 11.693 mg CAE·g^{-1}. This is consistent with previous studies, which have shown that it contains, caffeic acid derivatives and rosmarinic acid, known for their anti-inflammatory and antioxidant properties. Rich concentrations of luteolin have been found in many mint varieties, known for their antioxidant, antitumor, and cardioprotective properties (Zamljen et al., 2024). These differences can be explained by by diffrences in climate, and maybe by the use of different solvents for the extraction of phenolic compounds (Sadowska et al., 2024). Mint and thyme are members of the Lamiaceae family, and the Lamiaceae family contains the simplest phenolic compounds, which are derivatives of benzoic and cinnamic acids, which are related to the group of phenolic acids including gallic, coumaric, caffeic, ferulic acids (Sytar et al., 2022). Clove's elevated phenolic acid content is supported by its eugenol derivatives and gallic acid-related compounds (Cortés-Rojas et al., 2014). The result show that basil had the lowest phenolic acid content, 3.09 mg CAE·g^{-1}, compared to mint and thyme. While basil extracts are mainly composed of phenolic acids (Azizah et al., 2023). Previous studies reported that basil leaves are rich in phenolic acids, especially rosmarinic, caffeic, and ferulic acids, with concentrations ranging from about 5.8 to 8.8 mg·g^{-1} extract, depending on cultivar and extraction method (Romano et al., 2022).

Macro and micro elements

The analysis in this research shows in (Table 3), showed basil is the highest potassium 31,000 mg·kg^{-1} and calcium 23,711 mg·kg^{-1}, aligning with previous analyses showing basil as the richest source of Ca, K, Mg, and P among culinary (Zaguła et al., 2016), while nutmeg had the lowest mineral density across most elements. Clove exhibited remarkably high manganese content 599.4 mg·kg^{-1}, making it a standout among the tested spices, aligning with literature highlighting Clove aromaticum as one of the richest dietary sources of Mn (Dhaheri et al., 2023).

Calcium (Ca), Potassium (K), Magnesium (Mg)

Basil showed the highest level of calcium 23,711 mg·kg^{-1}, which is consistent with previous studies indicating that leafy herbs often show high levels of calcium (Kiczorowska et al., 2015). While the highest content of potassium was also found in basil 31,000 mg·kg^{-1}, previous research proved that (ICP-OES analysis of culinary herbs and spices contains the highest percentage of potassium, followed by calcium (Pavlović et al., 2020). Whereas mint and basil (mint 514.7 mg·kg^{-1}, basil 398 mg·kg^{-1}) showed high levels of magnesium, consistent with previous analyses of dried herbs reporting substantial Mg as crucial for chlorophyll and enzyme function (Pavlović et al., 2020).

Iron (Fe)

Mint and rosemary (mint 451.7 mg·kg^{-1}, rosemary 253.1 mg·kg^{-1}) had the highest Fe concentrations among the studied herbs. Iron is an essential micronutrient for plants. Iron acts as a cofactor in enzymes involved in photosynthesis, which plays a significant role in chlorophyll biosynthesis. Leafy herbs, such as mint and rosemary, have a high photosynthetic rate, which means they accumulate large amounts of iron in their tissues (Marschner and Marschner, 2012). Previous studies have reported that herbs in the Lamiaceae

Table 3 Macro- and microelements profile of analyzed samples

Elements	Macro- and microelements (mg·kg^{-1})					
	basil	mint	nutmeg	rosemary	clove	thyme
Ag	0.04 ±0.01^{a}	0.04 ±0.01^{a}	0.01 ±0.03^{a}	0.03 ±0.02^{a}	0.02 ±0.01^{a}	0.06 ±0.07^{a}
Al	194.8 ±1.54^{d}	576.3 ±13.41^{f}	4.0 ±1.36^{a}	270.8 ±6.48^{e}	50.2 ±1.96^{b}	176.7 ±3.93^{c}
As	0.10 ±2.05^{b}	1.29 ±0.61^{b}	nd	0.23 ±0.19^{b}	0.74 ±1.54^{b}	2.13 ±1.65^{b}
Ba	17.60 ±0.04^{c}	27.71 ±0.03^{e}	1.67 ±0.01^{a}	11.74 ±0.04^{b}	28.23 ±0.10^{f}	18.39 ±0.09^{d}
Ca	23,711 ±50.70^{f}	16,903 ±38.03^{d}	1,988 ±1.01^{a}	11,600 ±50.58^{c}	6,666 ±17.71^{b}	19,051 ±41.00^{e}
Cd	nd	nd	nd	nd	nd	nd
Co	0.23 ±0.09^{c}	0.19 ±0.09^{c}	nd	nd	nd	nd
Cr	1.22 ±0.04^{d}	1.73 ±0.02^{e}	nd	1.93 ±0.03^{f}	nd	0.46 ±0.08^{c}
Cu	14.51 ±0.08^{e}	11.53 ±0.05^{c}	13.46 ±0.05^{d}	14.51 ±0.02^{e}	4.79 ±0.02^{a}	7.93 ±0.05^{b}
Fe	204.7 ±0.29^{d}	451.7 ±0.82^{f}	22.8 ±0.27^{a}	253.1 ±1.18^{e}	42.2 ±0.27^{b}	148.4 ±0.49^{c}
K	31,000 ±76.75^{f}	21,181 ±43.08^{e}	5,270 ±15.66^{a}	14,761 ±51.88^{c}	11,756 ±33.15^{b}	15,442 ±42.55^{d}
Li	0.18 ±0.00^{b}	0.87 ±0.01^{e}	0.00 ±0.00^{a}	0.25 ±0.00^{c}	0.18 ±0.00^{b}	0.39 ±0.06^{a}
Mg	398.0 ±0.83^{e}	514.7 ±0.58^{f}	211.8 ±0.45^{b}	246.9 ±0.80^{c}	267.2 ±0.81^{d}	192.2 ±0.37^{a}
Mn	52.6 ±0.11^{c}	70.5 ±0.19^{d}	34.5 ±0.06^{b}	24.9 ±0.18^{a}	599.4 ±2.13^{e}	34.5 ±0.07^{b}
Na	689 ±1.72^{b}	1343 ±2.19^{d}	258 ±0.54^{a}	2,495 ±10.73^{f}	2,142 ±7.04^{e}	754 ±2.37^{c}
Ni	nd	0.449 ±0.19^{c}	nd	nd	nd	18.17 ±0.36^{d}
Pb	1.23 ±0.50^{b}	1.07 ±0.83^{b}	nd	1.08 ±0.40^{b}	0.80 ±0.52^{b}	0.68 ±0.015^{b}
Sb	1.36 ±0.72^{ab}	1.97 ±0.78^{ab}	0.04 ±0.70^{a}	1.00 ±1.03^{ab}	1.37 ±0.33^{ab}	2.65 ±1.11^{b}
Se	1.92 ±1.68^{a}	1.01 ±0.57^{a}	nd	0.17 ±0.88^{a}	0.94 ±1.26^{a}	1.48 ±0.48^{a}
Sr	97.78 ±0.35^{f}	81.78 ±0.09^{e}	7.41 ±0.02^{a}	41.33 ±0.14^{b}	65.02 ±0.16^{c}	76.44 ±0.30^{d}
Zn	63.25 ±0.64^{f}	22.06 ±0.28^{c}	13.47 ±0.17^{b}	41.02 ±0.68^{e}	5.99 ±0.53^{a}	50.61 ±1.31^{e}

Notes: Values are means ± standard deviation (n = 2); means along the same row with different superscripts are significantly different ($p < 0.05$); nd – not detected family have iron concentrations like those of culinary herbs such as basil, thyme, and rosemary (García-Galdeano et al., 2020; Sajkowska et al., 2025). Clove has the highest Mn concentration, 599 mg·kg^{-1}, and this is greater than the other levels that were detected in leafy herbs.

Manganese (Mn)

Clove has the highest Mn concentration, 599 mg·kg^{-1}, and this is greater than the other levels that were detected in leafy herbs. Manganese is a direct cofactor in the biosynthesis of phenolic compounds and antioxidants. The manganese in clove buds is therefore very rich in secondary metabolites (eugenol, tannins, and flavonoids), which contribute to its metabolic profile (Alejandro et al., 2020; Xue et al., 2022).

Zinc (Zn)

Basil and thyme (basil 63.25 mg·kg^{-1}, thyme 50.61 mg·kg^{-1}) contained the highest Zn concentrations among the tested herbs, whereas clove showed the lowest, 5.99 mg·kg^{-1}. Previous studies have shown that culinary herbs such as basil and thyme often contain high concentrations of zinc, which supports this result (García-Galdeano et al., 2020; Sajkowska et al., 2025). Zinc is an important element for plants because it acts as a cofactor for enzymes such as superoxide dismutase (Zn-SOD), alcohol dehydrogenase, and RNA polymerase. Due to their active metabolism and the high density of glandular forms that store zinc-binding proteins and receptors, more zinc is accumulated in leafy herbs such as basil and thyme (Broadley et al., 2007; Marschner and Marschner, 2012).

Aluminum (Al)

Mint showed the highest levels of Al, followed by rosemary and basil (576.3 mg·kg^{-1}, 270.8 mg·kg^{-1}, and 194.8 mg·kg^{-1}, respectively). Nutmeg had the lowest concentration of aluminum, 4.0 mg·kg^{-1}. Aluminum is not an essential nutrient for plants, but it is one of the most abundant elements in soil. It accumulates in plant tissues depending on soil pH and type. Because the large leaf area of mint and rosemary tends to absorb a greater amount of aluminum and root-soil interactions in slightly acidic soil (Feng, 2007; Bojórquez-Quintal et al., 2017). High Al levels in mint and rosemary may therefore reflect soil conditions of their cultivation sites rather than their genetic traits (Adamczyk-Szabela et al., 2015). In contrast, seeds such as nutmeg accumulate very little Al, which explains their low content compared to leafy herbs (Agency for Toxic Substances and Disease Registry (US), n.d.).

Lead (Pb) and Nickel (Ni)

Trace levels of lead were observed in basil, mint, rosemary, and thyme, respectively (1.23 mg·kg^{-1}, 1.07 mg·kg^{-1}, 1.08 mg·kg^{-1}, and 0.68 mg·kg^{-1}). Previous studies have shown that herbs and spices may contain variable levels of lead, reflecting various contamination pathways such as soil and atmospheric deposition (Angelon-Gaetz et al., 2022; Alawadhi et al., 2024). Nickel was detected only in mint and thyme (0.449 and 8.17 mg·kg^{-1}, respectively), but not in other samples. Nickel is a cofactor for urease and is therefore an essential micronutrient for plants. However, its presence in some herbs depends on soil levels and the uptake of specific species (Brown et al., 1987; Yusuf et al., 2010).

Strontium (Sr)

The highest concentrations of strontium were found in basil and mint (97.78 and 81.78 mg·kg^{-1}), nutmeg contained the lowest, 7.41 mg·kg^{-1}. While Strontium (Sr) is not an essential nutrient for plants, it is chemically similar to Ca^{2+}, which allows plant roots to absorb it through the same transport pathways. Therefore, plants with high Ca accumulation, such as basil and mint, also tend to accumulate higher Sr levels. The lower Sr content in nutmeg can be explained by its nature as a seed spice, which generally accumulates lipophilic compounds (fixed oils and essential oils) rather than minerals. Seeds typically have lower Ca and consequently Sr compared to leafy herbs (Kabata-Pendias, 2010; Burger and Lichtscheidl, 2018).

Conclusion

This study provides an integrated evaluation of the nutritional composition, antioxidant capacity, and macro- and micro-element profiles of selected medicinal herbs and spices from Syria, generating baseline data for regional phytochemical characterization. Significant interspecific variability was observed, indicating that species identity and environmental conditions strongly influence nutritional and bioactive composition. The results allow differentiation of species by functional potential. *Ocimum basilicum* and *Mentha* spp. showed relatively high protein and mineral contents, suggesting their value as nutrient-rich ingredients in functional foods. *Myristica fragrans* was characterized by higher lipid content, indicating potential as a source of bioactive fixed oils. *Syzygium aromaticum* and *Rosmarinus officinalis* exhibited the strongest antioxidant activity, supporting their use as natural antioxidant agents in food and nutraceutical applications. Overall, Syrian herbs and spices represent promising natural resources for the development of functional products and region-specific nutritional strategies. Future studies incorporating seasonal variation, soil-plant interactions, and molecular analyses will help further clarify factors affecting bioactive compound accumulation and support optimization of cultivation and processing practices.

Conflicts of interest

The authors have no competing interests to declare.

Ethical Statement

This article does not include any studies that would require an ethical statement.

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