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Original Article

Effects of Geographical Origin and Extraction Methods on the Phenolic Content of *Salvia officinalis*

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Abstract

Introduction: *Salvia officinalis L.*, also known as sage, is a widely used medicinal plant known for its rich phenolic content and associated health benefits. It is known that the phenolic profile of sage varies depending on the geographical origin and extraction method. This study aimed to evaluate the phenolic acid composition of S. officinalis samples collected from two geographical locations, Jordan and Isparta-Türkiye, using three extraction techniques.

Methods: Dried plant materials were extracted using infusion, decoction, and organic solvent extraction (methanol/acetonitrile) and the phenolic content was analyzed analyzed using high-performance liquid chromatography with photodiode array detection (HPLC-PDA). Here, 15 phenolic compounds were screened and evaluated.

Results: In this study, rosmarinic acid appeared as the predominant compound in decoction extracts from both locations (19,442 mg/g in Jordan and 17,485 mg/g in Türkiye, respectively), while epicatechin was the major component in infusion extracts. Organic solvent extracts showed moderate levels of phenolics, with rosmarinic acid being the most abundant.

Conclusions: Both geographical origin and extraction technique affected the phenolic content of *S. officinalis*. The decoction method was found to be the most effective extraction method for phenolic compounds, indicating superior efficacy in maximizing the health-promoting properties of the plant.

Keywords: Extraction, Salvia officinalis, HPLC, phenolic compounds

1. Introduction

The genus Salvia L., encompassing over 900 species, is considered the largest genus in the family Lamiaceae. It is distributed worldwide in both subtropical and temperate regions. In Türkiye, Salvia is represented by 86 different species, some of which are perennial and exhibit shrubby or semi-shrub growth forms(1).

Salvia officinalis (*S. officinalis*) holds a significant place in traditional medicine for its health-promoting properties and its therapeutic applications in the treatment of various ailments. Historically, sage has been recommended in the treatment of coughs, as a diuretic, as an emmenagogue, as a wound healer, for managing ulcers, and for maintaining oral health (2). Today, *S. officinalis* continues to be widely used across the world, maintaining its esteemed status in traditional medicine. Recent scientific studies have confirmed that *S. officinalis* possesses antidiabetic (3), antioxidant, gastroprotective (4), anti-inflammatory

(5), antiviral (6), anti-obesity (5), antispasmodic (7), fungicidal and bactericidal (8), and anticarcinogenic (9) activities. Moreover, *S. officinalis* finds wide application in the preparation and preservation of food products (10) as well as serving as a flavoring agent in the perfume and cosmetic industries (8).

It is known that the leaves of *S. officinalis* contain tannic acid, oleic acid, ursonic acid, ursolic acid, carnosol, carnosic acid, fumaric acid, chlorogenic acid, caffeic acid, nicotinamide, flavones, flavonoid glycosides, and estrogenic substances (11). Additionally, the flowers, leaves, and stems of *S. officinalis* contain alkaloids, carbohydrates, fatty acids, glycosidic derivatives, phenolic compounds (such as coumarins, flavonoids, and tannins), polyacetylenes, steroids, terpenes/terpenoids, and waxes (12-14). It is particularly rich in flavonoids, especially rosmarinic acid and luteolin-7-glucoside (15). This phenolic-rich profile underlies sage's potent antioxidant properties and medicinal uses.

The phenolic composition of sage can vary significantly depending on the environmental conditions and the plant's geographical origin. As with other medicinal plants, the phytochemical profile of *S. officinalis* is influenced by factors such as climate, soil characteristics, and altitude (16). In addition to this, the yield and profile of phenolic compounds obtained from *S. officinalis* vary significantly depending on the method of extraction (infusion, decoction, or the use of organic solvents). In general, organic solvent extracts were found to provide higher total phenolic content and antioxidant activity compared to aqueous infusions (17).

This study aimed to determine the phenolic acid content of *S. officinalis* plants from different geographical origins using different extraction methods.

2. Methods

2.1 Plant Materials

The *S. officinalis* L. samples used in this study were freshly collected from different geographical regions. One sample was obtained from an area in Jordan, while the other was gathered from Isparta province, Türkiye. Both samples were harvested during the flowering stage of the plant, in the early morning hours, to minimize exposure to direct sunlight and preserve the integrity of the plant tissue. The fresh collected plant materials (leaves and stems) were subjected to a drying process under controlled conditions to maintain sample integrity and ensure the stability of the phenolic compounds.

2.2 Preparation of Extraction

The dried *S. officinalis* leaves were extracted using three different techniques: infusion, decoction, and organic solvent extraction. For each extraction, 200 mg of plant material was weighed and transferred to separate tubes and then 4 mL of the relevant solvent was added. For organic solvent extraction, methanol/acetonitrile was used in a 1:1 ratio. It was subjected to an overnight shaking process utilizing an orbital shaker. During the decoction method, 4 mL of distilled water was added to each plant material, and then it was heated in a boiling water bath for 15 minutes. In the infusion method, 4 mL of boiling water was added to the plants and the contents were left to infuse at room temperature for 15 min.

2.3 Analysis of phenolic compounds

Quantitative analysis was performed using a Shimadzu Nexera-i LC-2040C 3D Plus HPLC system. A diode array detector (DAD) was employed, with detection carried out at 254 nm. During chromatographic separation, a reversed-phase Phenyl-Hexyl column (4.6 × 150 mm, 3 µm; GL Sciences Intersustain, Japan) was used. The mobile phase consisted of 0.1% formic acid in deionized water (Solvent A) and acetonitrile (Solvent B), both of HPLC grade (Merck), applied according to the gradient program presented in Table 1. The mobile phase flow rate was set at 1.0 mL/min throughout the analysis. Both samples and standards were injected at a volume of 10 µL and the column temperature was maintained at 30 °C.

Individual phenolic compound contents of each extract used in the study were screened for 15 standard phenolic compounds. The analysis of these 15 standards, which were detected quantitatively in the extracts were performed separately. These standard compounds were: Vanillic acid, caffeic acid, epicatechin, p-coumaric acid, salicylic acid, cinnamic acid, rosmarinic acid, quercetin, chlorogenic acid, apigenin-7-O-glucoside, rutin, naringenin, 4-hydroxybenzoic acid, gallic acid and ferulic acid.

Table 1. Gradient pump program of mobile phase

Step	Flow Rate (mL/min)	Time (min)	Solvent B %	Solvent A %
1	1.00	0.01	5	95
2	1.00	7.00	9.5	90.5
3	1.00	20.00	17	83
4	1.00	35.00	40	60
5	1.00	40.00	100	0
6	1.00	40.01	Stop	—

3. Results

Using the method described in Table 1, fifteen phenolic compounds were analyzed. The maximum absorbance wavelength for each phenolic compound was determined, and all compounds were scanned at their respective maximum wavelengths (Figure 1).

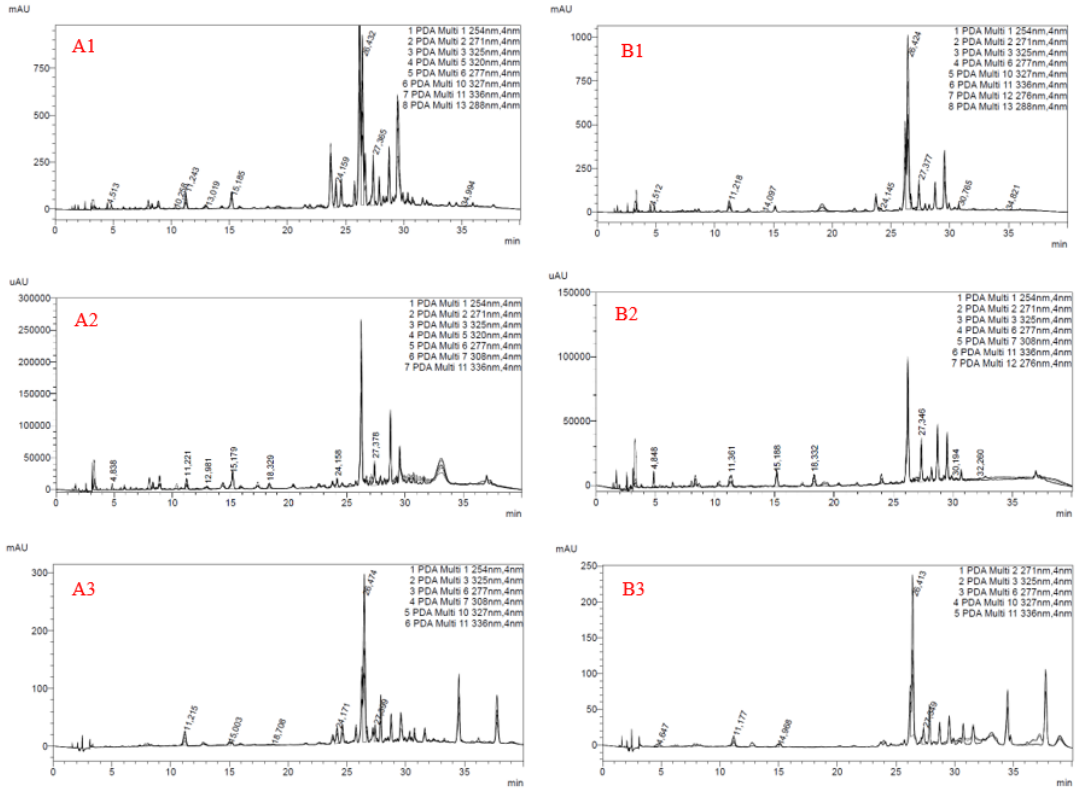

Figure 1. HPLC chromatogram of different extracts of *S. officinalis; **A:** Isparta **B:** Jordan* (1: Decoction, 2: Infusion, 3: Methanol/Acetonitrile).

Table 2. The amounts of phenolic compounds determined in different extracts of *S. officinalis* leaves (mg/g dry plant)

	Compounds	Retention Time (min)	Decoction		Infusion		Methanol/Acetonitrile	
			Isparta	**Jordan**	**Isparta**	**Jordan**	**Isparta**	**Jordan**
1	Gallic acid	4.352	0.115±0,007	0.139±0,002	0.042±0,003	0.051±0,003	-	0.032±0,004
2	4-Hydroxybenzoic acid	10.217	-	-	-	-	-	-
3	Chlorogenic acid	12.073	**0.631**±0,007	**0.587**±0,009	0.119±0,004	0.095±0,006	0.243±0,009	0.129±0,005
4	Vanillic acid	12.437	-	-	-	-	-	-
5	Caffeic acid	12.850	0.129±0,003	-	0.038±0,004	-	-	-
6	Epicatechin	14.150	**2.423**±0,257	0.026±0,002	**0.779**±0,023	**0.293**±0,008	0.214±0,012	0.123±0,006
7	p-Coumaric acid	18.486	-	-	0.031±0,001	0.031±0,005	0.006±0,001	-
8	Ferulic acid	20.971	-	-	-	-	-	-
9	Salicylic acid	21.929	-	-	-	-	-	-
10	Rutin	23.494	1.249±0,009	0.169±0,003	0.134±0,004	-	0.305±0,009	-
11	Rosmarinic acid	26.857	**17.485**±0,793	**19.442**±0,549	-	-	**5.611**±0,074	**4.392**±0,390
12	Apigenin-7-glucoside	27.574	1.142± 0,030	0.709± 0,010	0.153±0,002	0.126±0,006	0.111±0,010	0.094±0,006
13	Cinnamic acid	30.234	-	0.038± 0,005	-	0.001±0,0002	-	-
14	Quercetin	32.008	-	-	-	0.004±0,0003	-	-
15	Naringenin	34.939	0.013± 0,001	0.004±0,0003	-	-	-	-

Qualitative and quantitative analysis of 15 phenolic compounds obtained from different extracts of *S. officinalis* grown in various geographical locations was performed by HPLC-DAD (Table 2). The quantity of each compound was ascertained in milligrams (mg) per gram (g) of dry plant material. According to our HPLC data, rosmarinic acid was found to have the highest concentration in the decoction extracts of the plants grown in both Isparta and Jordan (17.485 mg/g and 19.442 mg/g, respectively). In addition, although rosmarinic acid was the highest phenolic compound in organic solvent extracts (5.611 mg/g and 4.392 mg/g, respectively), it could not be detected in infusion extracts. Epicatechin was found to be the highest phenolic compound in the infusion extracts. In all extracts, p-coumaric acid, cinnamic acid, quercetin, and naringenin were minor components.

4. Discussion

It is known that *S. officinalis* cultivated in different regions or under varying environmental conditions may exhibit distinct phenolic profiles. Genetic differences—such as different cultivars or closely related species—also contribute to this chemotypic diversity. This has been demonstrated in a study comparing various Salvia taxa: although rosmarinic acid was the dominant phenolic compound in all cases, *Salvia africana*, a species native to South Africa, was rich in unique caffeic acid dimers that accounted for approximately 40% of the total phenolics. In contrast, the cultivated variety *S. officinalis "Icterina"* was particularly abundant in flavone glycosides, including glycosides of apigenin, luteolin, and scutellarein (18). It has also been emphasized that the time of harvest significantly affects the levels of phenolic compounds, even in infusion preparations (19).

In this study, we have found notable differences in the phenolic compound content of *S. officinalis* grown under different climatic conditions. Rosmarinic acid was the dominant compound across all samples, with the highest concentrations found in decoctions (Isparta: 17.485 ± 0.793 mg/g DW; Jordan: 19.442 ± 0.549 mg/g DW), consistent with previous findings (20,21). Due to its high polarity and water solubility, it is expected to be efficiently extracted by water-based techniques (22). The investigation revealed that the second major compound was epicatechin. Epicatechin content showed one of the starkest geographic contrasts: Isparta decoction samples yielded 2.423 ± 0.257 mg/g DW, while Jordan samples contained only 0.026 ± 0.002 mg/g DW. This dramatic difference may reflect environmental influences such as altitude, UV exposure, or temperature, which can significantly impact the biosynthesis of flavonoids (23).

It is acknowledged that the yield of phenolic compounds is influenced by the employed extraction methods. For example, to recover chlorogenic acid efficiently traditional extraction methods such as fresh tissue homogenization and leaf decoction have been used (24). Additionally, the use of deep eutectic solvents (DESs) has been explored for extracting phenolic compounds, including chlorogenic acid, from *S. officinalis* (25).

In the current study, chlorogenic acid was efficiently extracted via decoction (0.631 ± 0.007 mg/g DW in Isparta), consistent with its thermal stability and high solubility in hot water. Likewise, apigenin-7-glucoside and rutin were better extracted by decoction and methanol/acetonitrile, likely due to their mid-polarity and affinity for both water and organic solvents. Rutin levels, for example, reached 1.249 ± 0.009 mg/g DW in the Isparta decoction samples compared to only 0.169 ± 0.003 mg/g DW in the Jordan sample. These findings are consistent with the high solubility of these compounds in mid-polar solvents and extended heat exposure, which enhances flavonoid release from cellular matrixes (26). Some phenolics, including 4-hydroxybenzoic acid, ferulic acid, and salicylic acid, were not detected in any of the extracts. These compounds may exist in trace amounts or in conjugated forms not readily released without hydrolysis, as previously suggested in phytochemical surveys of Salvia species (22).

In summary, this study demonstrates that both geographic origin and extraction technique significantly influence the phenolic profile of *S.*

officinalis. The decoction method was found to be the most effective extraction approach in terms of both yield and diversity of phenolic compounds. These findings affirm that solvent polarity, extraction temperature, and duration play critical roles in the efficiency of polyphenol extraction from medicinal plants.

5. Conclusion

It is acknowledged that the chemical composition of plants cultivated in disparate geographical regions is influenced by factors such as climate and soil composition. This study, which utilized sage collected from two different geographical locations, revealed that the presence of phenolic compounds was more prevalent than in other extracts. However, minor variations were observed in the decoction extracts. Sage is a plant that is utilized by the public. In the present study it was demonstrated that sage is more efficacious in terms of phenolic compound content when boiled before consumption.

Conflict of interest: The authors declare no conflict of interest.

Ethics approval: Not applicable

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