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Pharmacognostic, Phytochemical Characterization, and Antioxidant Potential of *Coriandrum sativum* L. Fruits from Western Iran

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ABSTRACT

Coriandrum sativum L. (coriander) is a medicinal and culinary herb known for its pharmacological properties, mainly due to flavonoids, phenolic acids, and essential oil. However, detailed pharmacognostic and antioxidant studies on its fruit are limited. This experimental study was carried out at the Faculty of Pharmacy, Hamadan University of Medical Sciences during 2024–2025. Fruits of *C. sativum* were collected from Nahavand, Iran, and identified through standard macroscopic and microscopic analyses. Physicochemical parameters such as total ash, water-soluble ash, acid-insoluble ash, and moisture content were measured. The yields of the methanolic extract and essential oil were measured. Phytochemical profiling was performed using HPLC (rutin, quercetin, gallic acid) and GC-MS (volatile compounds). Antioxidant activity was evaluated using the DPPH assay on extracts, essential oil, and pure compounds. Average fruit dimensions were (1.52 ± 0.51 mm) × (0.27 ± 0.16 mm). Total ash, water-soluble ash, acid-insoluble ash, and moisture content were 6.54 ± 0.25%, 1.70 ± 0.07%, 0.825 ± 0.03%, and 3.4%, respectively. Methanolic extract and essential oil yields were 11% and 0.3%. HPLC analysis revealed rutin (57.48 ± 0.80 mg/50 g plant), quercetin (13.09 ± 0.17 mg/50 g plant), and gallic acid (10.15 ± 0.17 mg/50 g plant) as major phenolic compounds. GC-MS detected 48 volatile compounds, mainly linalool (57.85%), α-pinene (6.78%), and γ-terpinene (5.48%). The methanolic extract showed strong antioxidant activity (55.09 ± 1.75% inhibition at 1 mg/mL), outperforming the essential oil (21.29 ± 6.86% at 15 mg/mL). Among pure compounds, quercetin (75.69%) and gallic acid (74.32%) exhibited the highest DPPH scavenging activities at 100 µg/mL, while linalool showed moderate activity (44.18 ± 6.29% at 100,000 µg/mL). The fruits of C. sativum are rich in bioactive polyphenols and essential oil constituents. The strong antioxidant activity of the methanolic extract is mainly due to rutin, quercetin, and gallic acid. These results highlight coriander's potential as a natural antioxidant in pharmaceutical and nutraceutical applications and support further research.

Keywords: Antioxidant activity, DPPH, Essential oil, GC-MS, HPLC

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INTRODUCTION

In recent decades, the global pursuit of safer and more effective therapeutic agents has reignited interest in medicinal plants, many of which have long histories of traditional use. These botanicals are increasingly recognized as valuable sources of bioactive compounds, particularly antioxidants, that significantly contribute to the prevention of oxidative stress–induced conditions such as cancer, cardiovascular diseases, and neurodegenerative disorders. Among the vast array of medicinal plants, *Coriandrum sativum* L., commonly known as coriander, is an aromatic herb belonging to the Apiaceae family that stands out due to its widespread culinary and medicinal applications.

Several studies have highlighted the pharmacognostic and pharmacological properties of *Coriandrum sativum* L. According to the Iranian Herbal Pharmacopoeia (Ghasemi Dehkordi et al., 2003), compiled in Iran, its essential oil mainly contains linalool and coriandrol, with defined physicochemical characteristics and standardized quality control parameters [1]. In a review conducted in India, Singh Daksha et al. examined the microscopic traits, ash values, chemical constituents, therapeutic

uses, dosage, and side effects of various parts of the plant, emphasizing its antioxidant, sedative, antifungal, and antibacterial activities [2]. A more recent investigation by Hajiloui et al., performed in Tunisia, assessed the antioxidant, antimicrobial, anticholinesterase, and antidiabetic effects of essential oil and extract of *C. sativum*, along with pharmacokinetic profiling of linalool [3]. Additionally, a study conducted in Mexico by Muñiz-Márquez et al. investigated the phenolic content and antioxidant activity of *C. sativum* using HPLC and DPPH assays, identifying compounds such as quercetin and gallic acid, and confirming its significant free radical scavenging potential [4].

Coriandrum sativum has been traditionally used across various cultures for its carminative, digestive, antidiabetic, anti-inflammatory, and antimicrobial properties. Recent phytochemical investigations have attributed these biological activities to its wide variety of secondary metabolites, such as flavonoids, phenolic acids, and terpenoids. Of particular interest are compounds such as quercetin, rutin, gallic acid, and linalool, which exhibit notable antioxidant activities through mechanisms that include free radical scavenging and metal ion chelation [2, 5].

Despite its known therapeutic potential, comprehensive pharmacognostic studies on *C. sativum* fruits—integrating morphological, chemical, and biological characterization—remain limited. Such evaluations are crucial for ensuring the identity, safety, and efficacy of herbal raw materials, particularly in pharmaceutical and nutraceutical applications. Standardized pharmacognostic analysis, including macroscopic and microscopic examination, determination of ash and moisture content, extractive yield assessment, and advanced chemical profiling using techniques such as HPLC and GC-MS, forms the foundation for quality control and bioactivity validation.

The present study aims to systematically evaluate the pharmacognostic properties and antioxidant potential of *C. sativum* fruits collected from Nahavand, Iran. Validated HPLC and GC-MS techniques were applied to quantify major polyphenolic and volatile constituents, and the antioxidant capacity was evaluated using the DPPH radical scavenging assay. By integrating pharmacognostic data with phytochemical and bioactivity findings, this study provides valuable insights into the therapeutic value of *C. sativum* and supports its future applications in herbal medicine.

MATERIALS AND METHODS

Plant Material and Sample Preparation

The present experimental work was carried out at the Faculty of Pharmacy, Hamedan University of Medical Sciences (2024–2025). Fruits of *Coriandrum sativum* L. (Apiaceae) were collected from cultivated farmlands in Nahavand (Hamedan Province, Iran) in September 2024. The plant was authenticated, and a voucher specimen (No. 558) was deposited in the Faculty Herbarium (Hamedan, Iran). The fruits were dried and stored at 25 °C until analysis.

Macroscopic and Microscopic Characterization

Fruit dimensions were measured using a digital caliper (MEIJI, Japan). Microscopic features were examined using a dissecting microscope and a light microscope (Labomed LX400, USA).

For microscopic analysis, 3 g of coriander fruit powder was gently crushed and boiled with a 20% potassium hydroxide solution. After cooling, the supernatant was discarded, and the residue was treated with H2O2, rinsed four times with distilled water, sectioned, and examined under a light microscope. Some sections were stained with methylene blue. Transverse sections of the endosperm were also examined [6, 7].

Determination of Ash and Moisture Content

Total, Water-Soluble, and Acid-Insoluble Ash

For ash determinations, 2 g of powdered fruit was weighed into a pre-weighed silica crucible and incinerated in a muffle furnace (Nabertherm, Germany) at 800 °C for 15 min to obtain total ash. The residue was then processed for water-soluble and acid-insoluble ash following pharmacopeial protocols [1].

Total Ash (%) = (Weight of Ash / Initial Sample Weight) × 100; Water-Soluble Ash (%) = (Weight Difference after Water Extraction / Initial Sample Weight) × 100; Acid-Insoluble Ash (%) = (Residue Weight after HCl Extraction / Initial Sample Weight) × 100

Moisture Content (Dean–Stark Method)

Moisture content was determined by the Dean–Stark distillation method. A total of 50 g of fruits was placed in a flask with 300 mL of xylene and heated for 2 hours. The volume of the separated water was recorded and used to calculate the moisture percentage using the following formula:

Moisture (%) = (Volume of Water (mL) × Density (g/mL)) / Initial Weight (g) × 100

Preparation of Extract and Essential Oil

Methanolic Extract (Maceration)

Fifty grams of powdered fruit was macerated with 5 L of methanol, at room temperature for 72 hours, and all treatments were repeated three times. The combined extracts were concentrated at 50 °C under vacuum using a rotary evaporator (Heidolph Laborota 4000, Germany) and then stored in a refrigerator at 8 °C until further use. Yield was calculated based on initial dry weight. Four serial 1:2 dilutions were prepared from the 10 mg/mL extract stock solution for chemical and DPPH analyses (1, 0.5, 0.25, 0.125 mg/ml). For HPLC analysis, 20 mg of extract was entirely dissolved in 2 mL HPLC-grade methanol, passed through a PTFE syringe filter (0.44 µm), and transferred to HPLC vials. They were kept at 8 °C until analysis.

Essential Oil (Hydrodistillation)

Essential oil was extracted from 100 g of dried fruits by hydrodistillation using a Clevenger-type apparatus for 3 hours. The oil was dried over anhydrous sodium sulfate and stored at 8 °C. Essential oil stock solution (30 mg/mL methanol) was serially diluted for chemical and DPPH analyses.

Preparation of Test Samples

Stock solutions of rutin, quercetin, gallic acid (Sigma-Aldrich), and linalool (Merck) were prepared in methanol and diluted serially (1:2) for DPPH analyses. Specific dilutions ranged from 0.78 µg/mL to 100 µg/mL for pure compounds. Two separated concentrations of linalool were prepared: 0.78 µg/mL to 100 µg/mL and 781.25 µg/mL to 100000 µg/mL.

HPLC Analysis of Extract Components

Method Validation

Standard solutions of quercetin, rutin, and gallic acid as phenolic compounds were obtained from Sigma-Aldrich Corporation (St. Louis, MO, USA) and dissolved in HPLC-grade methanol prior to use. Concentration ranges were as follows: rutin and gallic

acid (0.005, 0.010, 0.5, 1, 5, 10, 20, 100 ppm) and quercetin (0.05, 0.5, 1, 5, 10, 20, 40, 50, 80, 100 ppm). All solutions were passed through PTFE hydrophilic syringe filters and injected into the HPLC system and analyzed. Calibration curves were plotted by peak areas against different concentrations of standards. Peak identity and purity were assessed using a photodiode array detector (200–400 nm) [8, 9].

HPLC Analysis of Extract Components

HPLC analysis was performed on a Shimadzu RP-HPLC system, which was equipped with a photodiode array detector (SPD-M20A), a dual pump (LC-20AD), and an auto-sampler (SIL-20AC). Separation was achieved on a reversed-phase C18 column (25 cm × 4.6 mm × 3 µm) maintained at 25 °C. The mobile phase consisted of HPLC-grade water (solvent A) and methanol (solvent B; Merck, Germany), and spectral data were collected for all peaks between 200 – 400 nm. The flow rate was set at 0.5 mL/min, with injection volumes of 20 µL for both standards and sample extracts. Gradient elution was applied as follows: 0–10 min, 10 % B; 10–30 min, 10-50 % B; 30–50 min, 50-100% B; 50–70 min, 100% B, followed by a 10 min re-equilibration. Total run time per sample was 70 minutes [10].

GC-MS Analysis of Essential Oil

The chemical profile of the essential oil was determined using a gas chromatography–mass spectrometry (GC–MS) system (Agilent 7890A, USA) equipped with an HP-5 capillary column (30 m × 0.25 mm i.d., 0.25 µm film thickness). Injector, ion source, and detector temperatures were set to 250 °C, 200 °C, and 280 °C, respectively, while helium served as the carrier gas at a constant flow of 1.1 mL/min.

The oven temperature program began at 60 °C, increased at 5 °C/min to 250 °C, and was held for 2 min. A 1 µL aliquot of the essential oil was injected for analysis. Identification of compounds was performed by calculating Kováts retention indices (KIs) using a series of n-alkane standards and by comparing the mass spectra with the WILEY, NIST, and Adams libraries. Relative abundances were estimated by normalizing peak areas [11, 12].

DPPH Radical Scavenging Assay

The antioxidant activity was assessed using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method, with slight modifications to the protocol reported by Kamkar *et al.* [13]. A 0.3 mM DPPH solution in methanol was freshly prepared and kept in the dark. Various concentrations of the methanolic extract, essential oil of *C. sativum*, and standard compounds including ascorbic acid, rutin, quercetin, gallic acid, and linalool were prepared in methanol. A volume of 150 µL of each dilution was transferred into a 96-well microplate, followed by 60 µL of DPPH solution. The mixtures were incubated in the dark at room temperature for 30 min. Absorbance was recorded at 517 nm using a UV–Vis spectrophotometer. Each experiment was conducted in triplicate.

Antioxidant activity (AA%) was calculated according to the following equation:

$$AA\% = [(Abs\ Control - Abs\ Sample) / Abs\ Control] \times 100$$

In this equation, Abs Control refers to the absorbance of the control mixture (all reagents without the test compound), and Abs Sample corresponds to the absorbance of the tested compound. Ascorbic acid (2.5 mg/mL) was used as a positive control. The inhibition percentages at various concentrations were plotted for each compound.

Statistical Analysis

All experiments were performed in triplicate, and the results were expressed as mean ± standard deviation (SD). For the HPLC and GC-MS analyses, the values represent the mean of triplicate injections. Data processing and statistical calculations were carried out using GraphPad Prism version 8.

RESULTS

Macroscopic and Microscopic Characteristics

The fruits of *Coriandrum sativum* were ovoid in shape, with an average size of (1.52 ± 0.51) × (0.27 ± 0.16) mm, as determined using a digital caliper. Stereomicroscopic and light microscopic examinations revealed characteristic anatomical structures, including endosperm, epicarp, calcium oxalate crystals, stomata, and sclereids in the mesocarp, etc. These structures confirm the typical diagnostic traits of the species. Figure 1, 2 shows representative microscopic features.

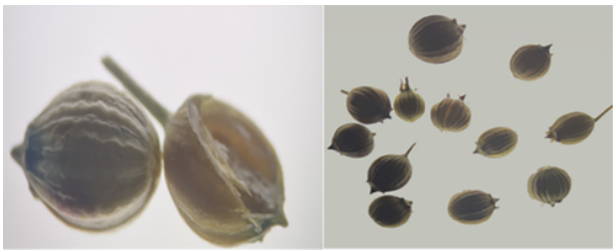


Fig. 1 Stereomicroscopic analysis of coriander fruits (*Coriandrum sativum* L.) at 20× magnification

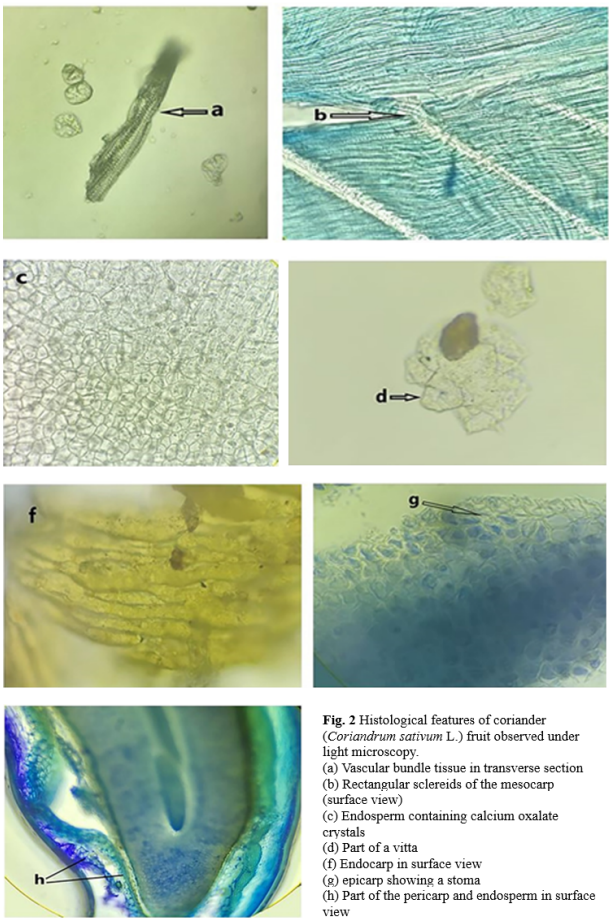


Fig. 2 Histological features of coriander (*Coriandrum sativum* L.) fruit observed under light microscopy.
(a) Vascular bundle tissue in transverse section
(b) Rectangular sclereids of the mesocarp (surface view)
(c) Endosperm containing calcium oxalate crystals
(d) Part of a vitta
(f) Endocarp in surface view
(g) epicarp showing a stoma
(h) Part of the pericarp and endosperm in surface view

Ash and Moisture Content

The total ash content was relatively high (6.54 ± 0.25%), while both water-soluble ash (1.70 ± 0.07%) and acid-insoluble ash (0.825 ± 0.03%) remained within pharmacopoeial limits. The moisture content was low (3.4%), indicating appropriate post-harvest drying and favorable conditions for storage stability.

Extraction and Essential Oil Yield

Extraction of 50 g of dried *C. sativum* fruits yielded 5.5 g of concentrated methanolic extract (11%). In addition, hydrodistillation of 100 g of dried fruit produced 0.3 mL of essential oil, corresponding to a yield of 0.3%, which falls within the typical range reported for this species (Table 1).

Table 1 Yield of methanolic extract and essential oil from *C. sativum* fruits

Sample	Initial weight (g)	Yield (g or mL)	Yield (%)
Methanolic Extract	50	5.5 g	11
Essential Oil	100	0.3 mL	0.3

HPLC Analysis of Extract Components

Calibration curves for rutin, quercetin, and gallic acid exhibited excellent linearity, with correlation coefficients (R^2) greater than 0.98. The limits of detection (LOD), limits of quantification (LOQ), retention times, and other analytical parameters are summarized in Table 2. Among the quantified compounds, rutin was present at the highest concentration (57.48 ± 0.80 mg per 50 g of extract), followed by quercetin (13.09 ± 0.17 mg) and gallic acid (10.15 ± 0.17 mg). Representative chromatograms of standard compounds are shown in Figures 3A–C.

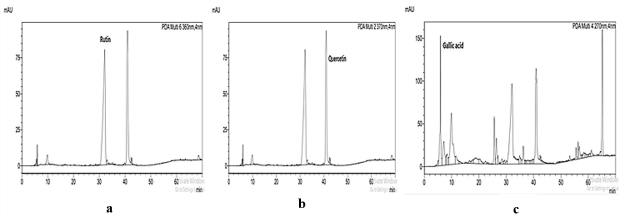


Fig. 3 Representative HPLC chromatograms of coriander fruit methanolic extract: (a) rutin at 360 nm, (b) quercetin at 370 nm, and (c) gallic acid at 270 nm.

Table 2 Determination of rutin, quercetin, and gallic acid in 50 g methanolic extract: retention times, quantification, and maximum absorption wavelengths

Compound	RT (min)	λmax (nm)	LOD (ng/mL)	LOQ (ng/mL)	RSD (%)	Number of compounds in the extract (mg/50 g of the plant)
Rutin	31	360	20	50	1.4	57.48 ± 0.80
Quercetin	41	370	20	50	1.3	13.09 ± 0.17
Gallic Acid	6	270	500	1000	1.7	10.15 ± 0.17

GC-MS Analysis of Essential Oil

Analysis of *C. sativum* essential oil by GC-MS revealed 48 volatile compounds, representing 95.5 % of the total oil composition. (Table S1). Linalool was the major constituent (57.85%), followed by α-pinene (6.78%) and γ-terpinene (5.48%). Most of the identified compounds were oxygenated monoterpenes. A representative chromatogram is presented in Figure 4. The complete composition of the essential oil is shown in the Supplementary Material (Table S1).

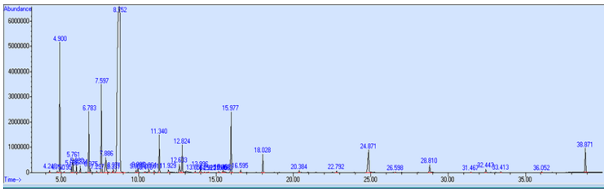


Fig. 4 GC-MS chromatogram of *Coriandrum sativum* fruit essential oil

Radical scavenging Activity (DPPH Assay)

Plant Extract and Essential Oil

The antioxidant potential of *Coriandrum sativum* L. methanolic extract and essential oil was determined using the DPPH radical scavenging method. Antioxidants, in this test, change the purple DPPH radical into a yellow-colored substance, serving as evidence of free radical neutralization. The methanolic extract exhibited significantly higher radical scavenging activity compared to the essential oil at all tested concentrations.

At 1 mg/mL, the extract showed 55.09 ± 1.75% inhibition, whereas the essential oil at 15 mg/mL showed only 21.29 ± 6.86% inhibition (Table 3). The dose-response relationships of DPPH radical scavenging activity for both the methanolic extract and essential oil are illustrated separately in Figure 5. These graphs clearly demonstrate the concentration-dependent inhibition for each sample. The standard antioxidant, ascorbic acid (2.5 mg/mL), exhibited 63.42 ± 1.75% inhibition.

Table 3 DPPH radical scavenging activity (%) of the methanolic extract and the essential oil

Sample (mg/mL) – Extract	Inhibition (%)	Sample (mg/mL) – EO	Inhibition (%)
1.0	55.09 ± 1.75	15	21.29 ± 6.86
0.5	50.69 ± 1.39	7.5	17.13 ± 2.44
0.25	46.99 ± 2.63	3.75	14.35 ± 1.06
0.125	41.66 ± 3.67	1.875	9.26 ± 1.45

Since the dose-response curves for the extract, essential oil, and pure compounds did not follow a linear pattern within the tested ranges, we did not calculate IC_{50} values. Instead, the radical scavenging activity is reported as percentage inhibition at the specific concentrations tested.

Table 4 DPPH inhibition (%) of rutin, quercetin, and gallic acid at different concentrations

Sample (μg/mL)	Rutin	Quercetin	Gallic Acid
0.78	16.10 ± 3.38	55.82 ± 2.42	67.47 ± 7.26
1.56	47.26 ± 7.75	72.60 ± 0.97	70.54 ± 2.91
3.125	65.76 ± 0.97	74.66 ± 0.97	72.26 ± 1.46
6.25	71.58 ± 0.49	74.66 ± 0.00	72.60 ± 0.00
12.5	71.92 ± 0.97	75.00 ± 0.48	73.29 ± 0.97
25	72.26 ± 1.46	75.34 ± 0.00	73.63 ± 0.48
50	72.61 ± 0.97	75.69 ± 0.48	74.32 ± 0.49
100	73.29 ± 0.97	75.69 ± 1.45	74.32 ± 0.49

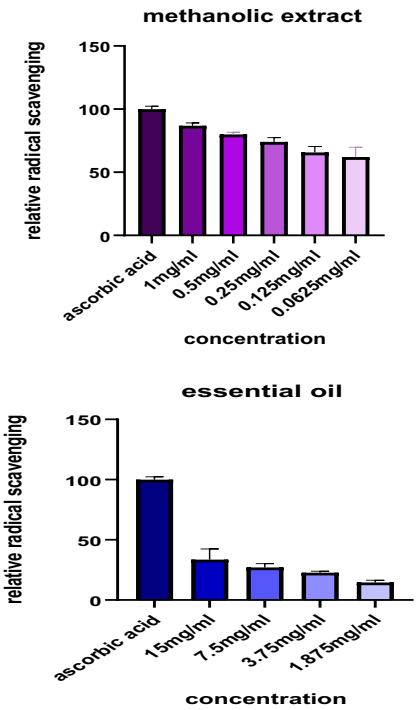


Fig. 5 Relative (%) DPPH radical scavenging activity of methanolic extract and essential oil of *Coriandrum sativum* at different concentrations

Table 5 DPPH inhibition (%) of linalool across two concentration ranges

Sample (µg/mL) – Linalool 1	% Inhibition	Sample (µg/mL) – Linalool 2	% Inhibition
0.78	-4.45 ± 1.46	781.25	36.99 ± 0.00
1.56	-4.44 ± 0.49	1562.5	37.33 ± 0.48
3.125	-4.10 ± 0.97	3125	37.67 ± 0.00
6.25	-3.08 ± 0.49	6250	38.36 ± 0.00
12.5	-1.03 ± 1.45	12500	38.70 ± 4.36
25	-1.02 ± 0.48	25000	40.42 ± 0.97
50	2.05 ± 0.00	50000	42.47 ± 0.97
100	2.39 ± 2.42	100000	44.18 ± 6.29

Individual Polyphenols and Linalool

Among the tested polyphenols, quercetin and gallic acid exhibited the highest DPPH radical scavenging activity, even at lower concentrations, whereas linalool, the main component of the essential oil, demonstrated weak activity, even at much higher concentrations (Tables 4 and 5, Fig. 6).

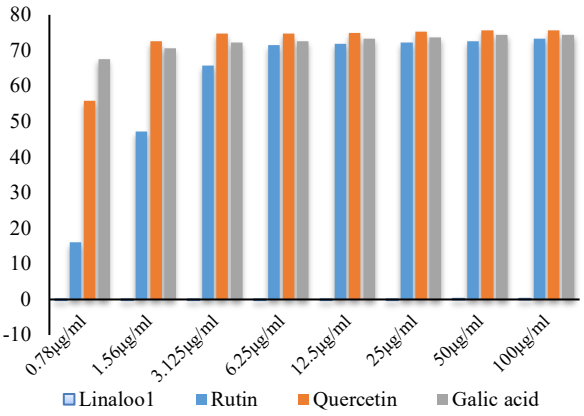


Fig. 6 DPPH scavenging activity (%) of rutin, quercetin, gallic acid, and linalool

These results highlight the potent antioxidant activities of quercetin and gallic acid, confirming their significant contribution to the radical scavenging potential of *Coriandrum sativum* extracts. In contrast, linalool exhibited notably weak antioxidant activity, even at high concentrations, suggesting that the essential oil's antioxidant effects are primarily due to other minor constituents rather than its major component.

DISCUSSION

Medicinal plants are recognized as valuable reservoirs of bioactive compounds and continue to serve as a foundation for modern drug discovery. The growing concerns over antimicrobial resistance and side effects of synthetic drugs have reignited interest in natural products and pharmacognostic research [14]. Among these, *Coriandrum sativum* L. (Apiaceae) is notable for its diverse biological potentials, which involve antioxidant, antimicrobial, anti-inflammatory, and antidiabetic effects [15], largely attributed to its phytochemical constituents such as flavonoids, phenolics, and terpenoids. Therefore, a comprehensive pharmacognostic evaluation is essential to understand its therapeutic potential better.

Macroscopic and microscopic evaluations are fundamental for verifying the quality and detecting adulteration in medicinal plants, in accordance with established pharmacopoeial standards. The Iranian Pharmacopoeia describes coriander (*Coriandrum sativum* L.) fruits as ovate, measuring 2–2.5 × 2–6 mm, greenish-yellow, and hard [1]. In the present study, coriander fruits cultivated in Nahavand exhibited ovate morphology with average dimensions of 1.52 ± 0.51 × 0.27 ± 0.16 mm, and a greenish-yellow, rigid texture. While fruit size was slightly smaller than pharmacopoeial specifications, other macroscopic features were consistent. These differences may be attributed to environmental factors and geographic origin.

Anatomical examination revealed mesocarp sclereids, endosperm containing calcium oxalate microcrystals, epidermis with stomata, pericarp, and endosperm [1, 6]. These observations corroborate previously reported microscopic features. Microscopic analysis revealed diagnostic features such as epicarp, sclereids, calcium oxalate crystals, and endosperm structures, which are crucial for quality control and detection of adulteration in herbal formulations.

Physicochemical parameters provide essential criteria for verifying the purity and authenticity of herbal drugs. Total ash consists of physiological ash derived from the plant tissue and non-physiological ash originating from environmental contaminants. Acid-insoluble ash is used as an additional quality indicator [16].

Previous reports have documented for coriander fruit powder a maximum moisture content of 10%, total ash of 6–7%, acid-insoluble ash of 1.5%, alcohol-soluble extractives ≥10%, and volatile oil content ranging from 0.05% to 0.3% depending on origin [1, 5, 17].

In the present study, Nahavand-grown coriander fruits showed a moisture content of 3.4% (w/w), total ash of 6.54 ± 0.25%, water-soluble ash 1.7 ± 0.07%, acid-insoluble ash 0.825 ± 0.03%, methanolic extract yield of 11%, and a volatile oil yield of 0.3%. These findings fall within pharmacopoeial limits and confirm the purity and quality consistency of the plant material.

Flavonoids such as rutin, coumarins, and phenolic acids represent important classes of secondary metabolites in coriander fruit

extracts. Rajeshwari et al. reported that rutin was the predominant flavonoid in *Coriandrum sativum* extracts, with methanolic extraction yielding higher amounts than ethanolic extraction [18]. In the present study, HPLC analysis of the methanolic extract of coriander fruits quantified three major phenolic compounds: rutin (57.48 ± 0.80 mg/50 g dry fruit powder), quercetin (13.09 ± 0.17 mg/50 g dry fruit powder), and gallic acid (10.15 ± 0.17 mg/50 g dry fruit powder). Consistent with previous reports, rutin was the most abundant constituent, followed by quercetin and gallic acid.

Essential oils are volatile, lipophilic, and strongly aromatic plant metabolites, typically obtained via hydrodistillation. Coriander fruit essential oil is primarily composed of linalool, accompanied by α-pinene, γ-terpinene, camphene, and limonene, with relative proportions influenced by cultivation conditions [1]. Talebi et al., using GC-MS, reported linalool as the dominant component in Iranian and Iraqi *Coriandrum sativum* samples, with oxygenated monoterpenes representing the largest chemical class [19]. Similar findings were observed by Anwar et al. in coriander essential oil from Pakistan [20, 21].

GC-MS analysis identified 48 compounds (95.5% of the oil), with linalool (57.85%) as the major constituent, followed by α-pinene, γ-terpinene, and camphene. Oxygenated monoterpenes predominated (67.76%), in agreement with previous studies, although the relative abundance showed regional variations, reflecting the influence of environmental factors on coriander essential oil composition.

Antioxidants function as protective agents by eliminating reactive oxygen species (ROS) and limiting the onset of oxidative stress–induced diseases. Among various *in vitro* methods, the DPPH assay is widely used to evaluate the radical-scavenging activity of plant extracts and essential oils, based on their ability to reduce the violet DPPH radical at 517 nm [22-24].

In the DPPH radical scavenging assay, the coriander extract and essential oil were evaluated alongside pure compounds, including quercetin, rutin, gallic acid, linalool, and ascorbic acid. The methanolic extract exhibited a markedly stronger inhibitory effect against DPPH compared to the essential oil, whereas in some previous studies, the antioxidant activity of the essential oil was reported to be considerably high. For instance, Jafari et al. reported that the antioxidant activity of the essential oil was higher than that of ascorbic acid, which is in contrast with the present findings [25]. However, Jabir et al. observed results consistent with our study, indicating that linalool lacked sufficient capacity to inhibit DPPH [26].

Given these discrepancies between our results and previous reports, the antioxidant potential of the main constituents of the extract and essential oil was further investigated. The results of pure compounds showed that quercetin and gallic acid had the strongest antioxidant effects. Linalool, at concentrations equivalent to those found in the extract, similarly to the findings of Jabir et al., failed to inhibit DPPH, and only at much higher concentrations displayed minimal antioxidant activity [26]. Therefore, considering the higher radical scavenging activity of extract components compared to linalool—the major constituent of the essential oil—the stronger antioxidant effect of the extract observed in this study seems reasonable. Nonetheless, due to differences in plant material, environmental conditions, and experimental variations, direct comparisons with other studies should be interpreted with caution. Additionally, potential synergistic or antagonistic effects among the constituents of extracts and essential oils, as well as their in vivo activity, should not be overlooked.

The comparative analysis of pure compounds revealed that gallic acid and quercetin exhibited superior radical scavenging activity compared to rutin and linalool. Specifically, gallic acid demonstrated potent inhibition even at low concentrations (μg/mL range), consistent with its known high antioxidant capacity [27, 28]. The activity of quercetin was also found to be concentration-dependent, surpassing other standards at higher concentrations (Fig. 6). These findings confirm that the significant antioxidant activity observed in the crude methanolic extract is likely attributable to the presence of these potent phenolic compounds, particularly rutin, quercetin, and gallic acid, rather than the terpenoid components found in the essential oil [29].

CONCLUSION

The fruits of *Coriandrum sativum* cultivated in Nahavand were shown to contain valuable bioactive compounds, with strong antioxidant activity mainly due to quercetin and gallic acid. The pharmacognostic profile aligns with standard references, supporting its inclusion in herbal pharmacopeias and potential use in pharmaceutical and nutraceutical formulations. Given its clinical relevance and notable economic and export value in Iran, further studies are needed to standardize its composition and support its industrial applications.

Consent for Publication

Not Applicable.

Data Availability

The data supporting the findings of this study are available within the article and its Supplementary Material. Additional data are available from the corresponding author upon reasonable request.

Conflict of Interests

The authors declare that they have no conflict of interests.

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Authors' contributions

Armita Ramezani performed the experiments, analyzed and interpreted the data, and drafted the manuscript. Dara Dastan contributed to the experimental work, data interpretation, and critical revision of the manuscript. Shirin Moradkhani conceived and supervised the study, secured the research funding, provided scientific guidance, critically revised the manuscript, and approved the final version of the manuscript.

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