



RESEARCH ARTICLE

Phytochemicals analysis and antioxidant potential of hydroalcoholic extracts of fresh fruits of *Pistacia atlantica* and *Pistacia khinjuk*

Hamid Dalvand¹, Seyed Mohammad Mahdi Hamdi^{1*}, Fatemeh Nori kotanaee¹ & Hassan Ahmadvand²

¹Department of Biology, Islamic Azad University, Tehran, Iran

²Department of Biology, Research Center for Molecular Medicine, Institute of Mental Health and Addiction, Hamadan University of Medical Sciences, Hamadan, Iran

*Email: m.hamdi@iauctb.ac.ir



ARTICLE HISTORY

Received: 09 August 2023
Accepted: 15 October 2023

Available online
Version 1.0 : 31 December 2023



Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

Copyright: © The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited (<https://creativecommons.org/licenses/by/4.0/>)

CITE THIS ARTICLE

Dalvand H, Hamdi S M M, Kotanaee F N, Ahmadvand H. Phytochemicals analysis and antioxidant potential of hydroalcoholic extracts of fresh fruits of *Pistacia atlantica* and *Pistacia khinjuk*. Plant Science Today (Early Access). <https://doi.org/10.14719/pst.2853>

Abstract

Medicinal plants are known for containing potent antioxidants, primarily due to the presence of phytochemical components with diverse biological properties. In this study, we assessed the chemical constituents and antioxidant potential of *Pistacia atlantica* and *P. khinjuk*. The essential oils from *P. atlantica* and *P. khinjuk* oleoresin were obtained through hydrodistillation, and their chemical constituents were identified using gas chromatography-mass spectrometry (GC-MS). Additionally, we evaluated the total phenolic and flavonoid contents, total antioxidant activity, and free radical quenching potentials of hydroalcoholic extracts from *P. atlantica* and *P. khinjuk*. These assessments were performed using the Folin-Ciocalteu method, aluminum chloride method, phosphomolybdate test, and 2,2-diphenyl-1-picrylhydrazyl (DPPH) inhibition assay (Half-maximal inhibitory concentration (IC₅₀ value)), respectively. The results revealed that the major phytochemical components in *P. atlantica* essential oil were α -pinene, camphene, β -pinene, D-limonene, cyclohexene, and careen. Additionally, *P. khinjuk* essential oil contained α -pinene, β -Pinene, trans-verbenol, bicyclo (3.1.1)heptan, verbenene, camphene, D-limonene, and α -campholenal. Furthermore, the total phenols and flavonoids content of *P. atlantica* were higher than those of *P. khinjuk*. However, the total antioxidant capacity was significantly greater in *P. khinjuk* than in *P. atlantica*. The IC₅₀ value (DPPH assay) was also significantly higher in *P. khinjuk* compared to *P. atlantica*. Although the essential oils of both plants exhibited antioxidant effects, *P. atlantica* essential oils demonstrated superior antioxidant effects compared to *P. khinjuk*. In conclusion, the presence of abundant phytochemical components, such as monoterpenes, was observed in both the plants. These findings suggest that *P. atlantica* and *P. khinjuk* generally possess considerable antioxidant activity.

Keywords

Antioxidant activity; chemical composition; GC-MS analysis; *Pistacia atlantica*; *P. khinjuk*

Introduction

In recent years, herbal medicines have gained popularity due to their therapeutic properties (1). Throughout the history of medicine, medicinal plants have consistently played a crucial role in treating various diseases, includ-

ing cardiovascular, gastrointestinal inflammatory, and neurodegenerative diseases (2). According to the World Health Organization (WHO), up to 80% of people worldwide now rely on traditional medicine for their primary health needs (3). The growing interest in scientific research has heightened the importance of medicinal plants and their phytochemical constituents for therapeutic and pharmaceutical purposes. Over the past few decades, numerous studies have aimed to explore various biological aspects of medicinal plants (4, 5). Over the years, considerable research attention has focused on exploring the antioxidant actions of medicinal herbs. A substantial body of evidence supports the notion that the antioxidant capacity of medicinal plants can counteract mechanisms associated with various diseases, particularly oxidative stress (6). The available data underscores the significance of oxidative stress in the pathophysiology of several pathological conditions. Oxidative stress occurs when the generation of free radicals, especially reactive oxygen species (ROS), surpasses the intrinsic antioxidant defense mechanism (7). Substances that quench ROS are recognized as antioxidative agents (3). Medicinal plants have been identified as potential source of potent antioxidant compounds (3). Numerous studies have proposed that phytochemical constituents, such as flavonoids, polyphenols, saponins, tannins, and alkaloids, may play a potential role as antioxidant substances (3, 8).

The therapeutic benefits of medicinal plants has gained increasing importance in recent times, supported by data from numerous studies highlighting the medicinal and nutritional value of plant species belonging to the genus *Pistacia* (9, 10). *Pistacia atlantica* is among the well-known medicinal plants of this genus with various traditional uses attributed to it, including therapeutic actions on the gastrointestinal, nervous, cardiovascular, respiratory, and renal systems (10). Previous research has documented a range of beneficial effects of *P. atlantica*, including antioxidant, antimicrobial, anti-inflammatory, anticancer, antidiabetic and wound healing effects (9, 10). Several valuable compounds, such as phenolic compounds, flavonoids, and tannins, have been identified in various parts of *P. atlantica* (9). Another important species within genus *Pistacia* is *P. khinjuk* (11). Research has shown that *P. khinjuk* has therapeutic applications in cardiovascular diseases, toothache, indigestion, and cancers, as per traditional medicine (11). While a considerable body of research has focused on the therapeutic effects of plant species belonging to the genus *Pistacia*, less attention has been given to the connection between these therapeutic impacts and the presence of phyto-constituents. Several studies have demonstrated the antioxidant (12), antibacterial, wound healing (13), and antihyperlipidemic (14) effects of *P. khinjuk*. Detailed phytochemical analysis of *P. khinjuk* revealed an abundance of phenols, tannins, and glycosides (15). Hence, this study was undertaken to examine the phytochemical constituents and antioxidant potential of *P. atlantica* and *P. khinjuk*.

Materials and Methods

The present study employed an *in vitro* approach to investigate the phytochemical constituents and antioxidant potential of *Pistacia atlantica* and *P. khinjuk*.

Chemicals and Reagents

All required chemicals including ethanol, sodium sulfate, sodium carbonate, Folin-Ciocalteu reagent, aluminium chloride, Tris, 2,2-Diphenyl-1-picrylhydrazyl (DPPH) and methanol, were purchased from Merck (Germany) and Sigma (USA) companies.

Plant Material Collection

For the purpose of this study, oleoresin and fruits of *P. atlantica* and *P. khinjuk* were collected in May 2020 from the Khargūshān Mountains, located at the end of the Khorramabad-Andimeshk freeway, and the Bisim Mountains in Khorramabad County, Lorestan Province, Iran. Subsequently, the identification of the herbal samples was conducted by botanists from the Lorestan Agriculture and Natural Resources Research Center, Khorramabad, Iran.

Essential Oil Preparation

After herbal identification, oleoresin samples were used for the preparation of essential oil. The essential oil was prepared according to the method of Bagheri *et al.* (16). Subsequently, the excess moisture in the essential oil was removed by placing it in a dark vial in a freezer at 18°C using anhydrous sodium sulfate.

Preparation of Extracts

To prepare hydroalcoholic extracts of *P. khinjuk* and *P. atlantica*, fresh fruits were air-dried under shaded conditions at room temperature. The dried fruits were subsequently ground into a powder. The resulting powders were dissolved in a hydro-alcohol mixture comprising 50% distilled water and 50% ethanol, with a ratio of 1:1, at a temperature of 70°C. The maceration method was employed to extract hydroalcoholic solutions from *P. atlantica* and *P. khinjuk*. The suspension was allowed to macerate at 30°C for a duration of 72 hr. After maceration, the suspension was filtered, and the solvent was separated using a rotary evaporator (IKA-RV10, Germany) (17).

Phytochemical Analysis by Gas Chromatography/Mass Spectroscopy (GC-MS)

A GC-17A gas chromatograph (Shimadzu, Japan) coupled to a gas chromatography/mass spectroscopy (GC/MS)-QP5050 mass spectrometer (Shimadzu, Japan) was used to identify the phytochemical components. A 30 m, 0.22 mm ID fused silica capillary column was utilized to separate the chemical compounds. In addition, a 0.25 µm film of BP-5 (Shimadzu, Japan) was applied to the column. The carrier gas used was helium at 0.8 mL/min. The split injection was carried out with a split ratio of 1:50. The detector temperature was 260°C and the injection port temperature was 280°C. The GC column temperature was increased to 280°C and then held for 5 min. The essential oil constituents were characterized by calculating the retention indices under temperature-programmed conditions for n-alkanes (C8-C20). The oil was also analyzed on a PB-5 column under the same chromatographic conditions (16).

Total Phenols Content

The content of total phenolic compounds in the extracts was determined using the Folin-Ciocalteu method. Each tube was filled with 750 μ L of the Folin-Ciocalteu reagent. Subsequently, 100 μ L of the extracts were added to each tube, followed by vortexing, and the mixture was maintained at 25°C for 5 min. Next, 750 μ L of sodium carbonate were added to the tubes, and the solutions were kept at 25°C for 40 min. The absorbance was measured at 725 nm, and a standard curve was plotted. The results were expressed as milligrams of gallic acid equivalent per 100 grams (mg GAE /100 g) of dry extract.

Total Flavonoids Content

The total flavonoid content was determined through aluminum chloride colorimetric analysis. Initially, a 2% solution of aluminum chloride in ethanol was prepared. Subsequently, 500 μ L of the aluminum chloride solution and 0.5 mL of each extract at various concentrations were added to individual tubes. After vortexing, the samples were left at 25°C for 1 hr. Absorbance measurements were taken at a wavelength of 420 nm, and standard curves for flavonoids were generated using quercetin. The results were expressed as milligrams of quercetin equivalent per 100 grams (mg QE/100 g) of dry extract.

Total Antioxidant Capacity

The total antioxidant capacity was determined using the phosphomolybdate method. Each tube was filled with 1 mL of phosphomolybdate reagent and 0.1 mL of the extract. The resulting solutions were vortexed and placed in boiling water for 90 min. Absorbance measurements were taken at a wavelength of 695 nm, and an antioxidant standard curve was constructed using ascorbic acid. The results were expressed as the equivalent of ascorbic acid per gram (AAE/g) of dry extract.

DPPH Assay

To evaluate the antioxidant effect of the extracts, the inhibition of free radical generation was measured using the DPPH method. Each tube was filled with 0.8 mL of buffer, 0.2 mL of extracts, and 1 mL of DPPH solution in methanol, followed by vortexing. The solutions were then incubated at 25°C in the dark for 45 min. After the designated time, the absorbance of the samples was measured at a wavelength of 517 nm. The absorbance values of both the blank and the samples were calculated using the following equation:

$$I\% = [(A_{\text{blank}} - A_{\text{sample}}) / A_{\text{blank}}] \times 100 \dots \dots \dots (\text{Eqn. 1})$$

I% = the percentage of DPPH scavenging effect

A_{blank} = absorbance in negative control

A_{sample} = absorbance of samples.

The results were reported as IC_{50} values to compare the scavenging effect of the extracts. The IC_{50} value represents the concentration of the specimens required to quench the free radicals of DPPH by 50% (18).

Statistical Analysis

Data analysis was conducted using SPSS version 22.0 and Microsoft Office Excel 2019. Tests were repeated three times for each sample, and means were computed. Analysis of Variance (ANOVA), followed by Duncan's post hoc test, was employed to evaluate differences between experimental groups (extracts). Statistical significance was considered for all P values < 0.05.

Results

Chemical Constituents of Essential Oils

The chemical constituents of *Pistacia atlantica* and *P. khinjuk* were determined using GC-MS. The hydrodistillation of *P. atlantica* and *P. khinjuk* oleoresins yielded 26% and 23% of gum weight, respectively. As illustrated in Table. 1 and Fig. 1, the essential oil of *P. atlantica* was found to contain six chemical constituents including α -pinene (93.2%), β -Pinene (2.55%), camphene (2.18%), cyclohexene (0.88%), D-limonene (0.82%), and careen (0.54%). The GC-MS analysis of the essential oil of *P. khinjuk* revealed eight phytochemical constituents, with α -pinene (78.71%), β -Pinene (11.73%), trans-verbol (3.18%), bicyclo(3.1.1.) heptan (1.86%), verbenene (1.22%), camphene (1.2%), D-limonene (1.14%), and α -campholenal (1.06%) were found in *P. khinjuk* essential oil (Table 2 and Fig. 2).

Total Phenol Contents

Table 3 and Fig. 3 illustrates the total phenolic values of the hydroalcoholic extracts of *P. atlantica* and *P. khinjuk*. According to the results obtained, the total phenol content was 723.3750 \pm 102.49957 mg GAE/100 g dry extract for the hydroalcoholic extract of *P. atlantica* and 689.6250 \pm 87.73104 mg GAE/100 g dry extract for the hydroalcoholic extract of *P. khinjuk*, respectively. There was no significant difference observed in the total phenolic content between *P. atlantica* and *P. khinjuk* (P = 0.6935).

Total Flavonoid Content

As depicted in Table 3 and Fig. 4, the total flavonoid content was 5.0485 \pm 0.60374 mg QE/100 g dry extract for the hydroalcoholic extract of *P. atlantica* and 4.2379 \pm 0.14854 mg QE/100 g dry extract for the hydroalcoholic extract of *P. khinjuk*, respectively. A significant difference in total flavonoid content was observed between *P. atlantica* and *P. khinjuk* (P = 0.0396).

Total Antioxidant Capacity

As Table. 3 and Fig. 5 show, the total antioxidant capacity was 0.2427 \pm 0.06296 μ mol AAE/100 g dry extract for the hydroalcoholic extract of *P. atlantica* and 0.7943 \pm 0.13071 μ mol AAE/100 g dry extract for the hydroalcoholic extract of *P. khinjuk*, respectively. A significant difference in total flavonoid content was found between *P. atlantica* and *P. khinjuk* (P < 0.0001).

DPPH Assay

The data in Table 3 indicates that the IC_{50} of the DPPH assay was 872.94 μ g/mL for *P. atlantica* and 1094.14 μ g/mL for *P. khinjuk*, respectively.

Table 1. Phytochemical constituents of *P. atlantica* essential oil.

Compounds	Peak number	Area (%)
α -pinene (terpene)	1	93.2
β -Pinene (monoterpene)	2	2.55
Camphene (monoterpene)	3	2.18
cyclohexene	4	0.88
D- limonene (monoterpene)	5	0.82
careen	6	0.54

Table 2. Phytochemical constituents of *P. khinjuk* essential oil.

Compounds	Peak number	Area (%)
α -pinene (terpene)	1	78.71
β -Pinene (monoterpene)	2	11.73
trans-verbol (monoterpene)	3	3.18
Bicyclo(3.1.1.)heptan (sesquiterpenes)	4	1.86
Verbenene (terpene)	5	1.22
Camphene (monoterpene)	6	1.2
D- limonene (monoterpene)	7	1.14
α -campholenal (monoterpene)	8	1.06

Discussion

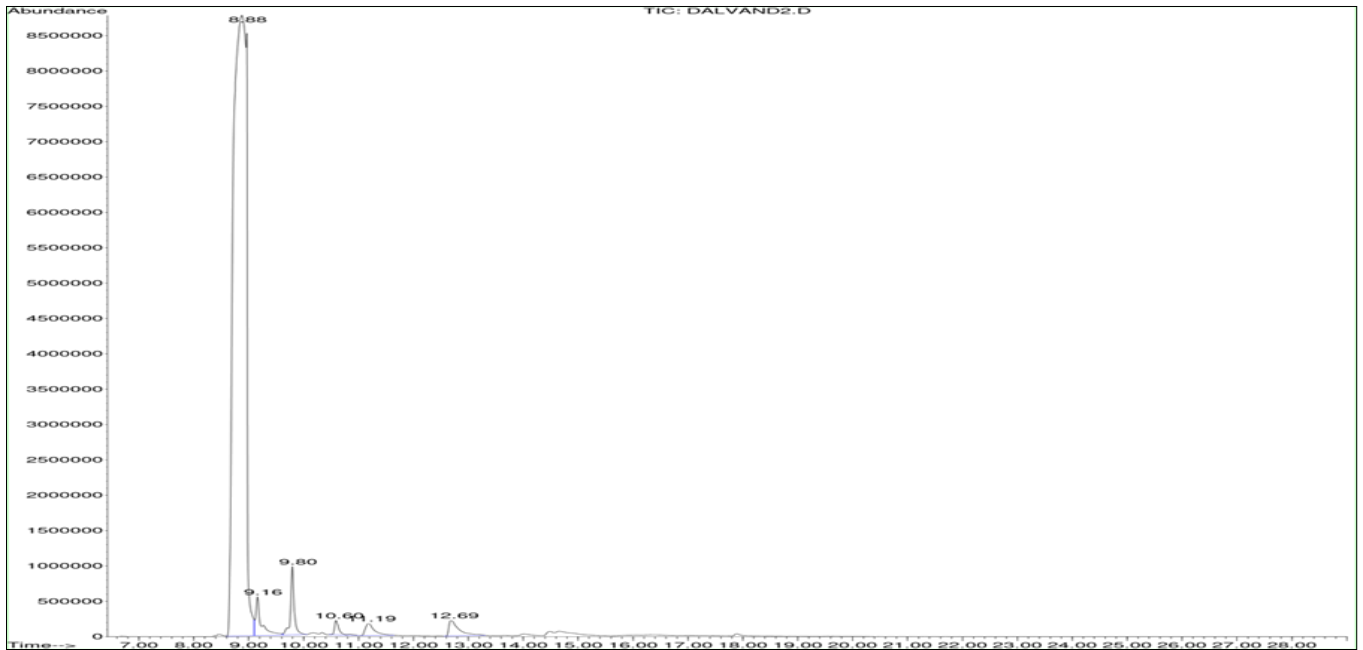
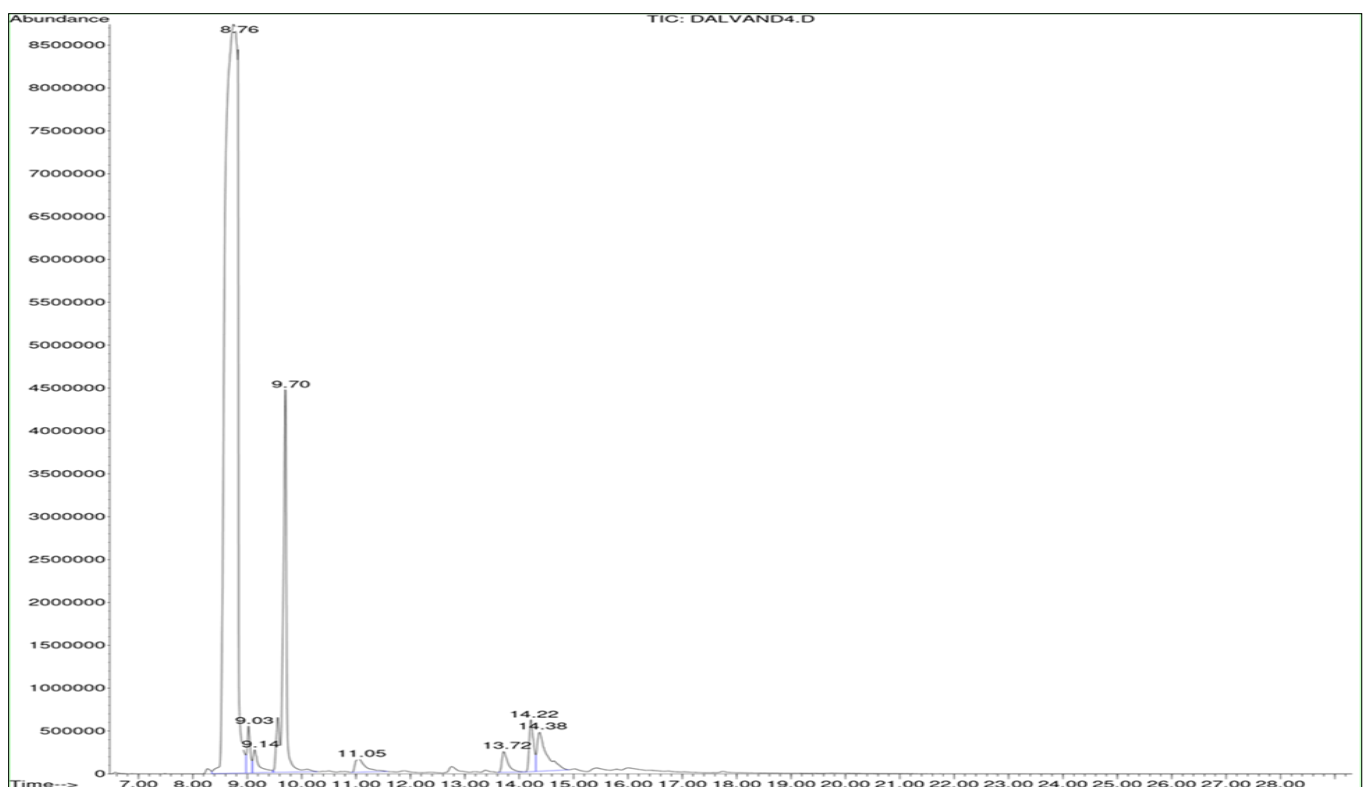
**Fig. 1.** GC-MS chromatogram of the essential oil of *P. atlantica*.**Fig. 2.** GC-MS chromatogram of the essential oil of *P. khinjuk*.

Table 3. Mean and standard deviation of total phenol and flavonoid content, total antioxidant potential and IC₅₀ (DPPH) of the hydroalcoholic extracts of *P. atlantica* and *P. khinjuk*.

Parameter	Plant Sample		P-Value
	<i>P. atlantica</i>	<i>P. khinjuk</i>	
Total Phenol Content (mg GAE /100 g dry extract)	723.3750 ± 102.49957	689.6250 ± 87.73104 ^{ns}	0.6935
Total Flavonoid Content (mg of quercetin equivalent /100 g dry extract)	5.0485±0.60374	4.2379±0.14854 [*]	0.0396
Total Antioxidant Capacity (µmol ascorbic acid equivalent /100 g dry extract)	0.2427±0.06296	0.7943±0.13071 [*]	<0.0001
IC ₅₀ (DPPH) (µg/mL)	872.94	1094.14	-

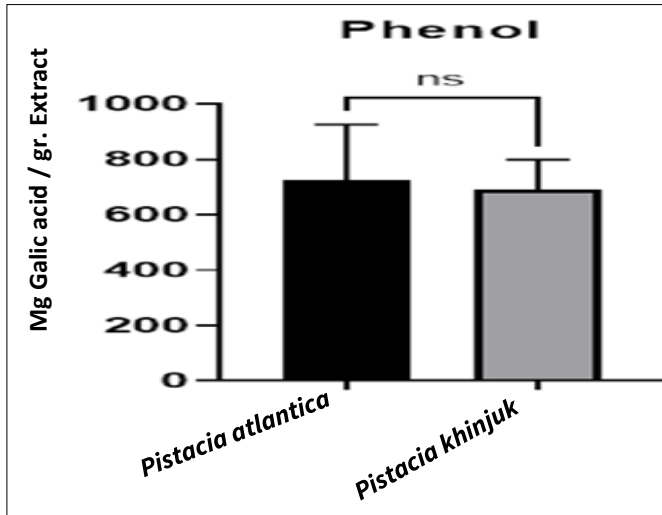


Fig. 3. Mean and standard deviation of total phenol content (mg GAE/100 g dry extract) of the hydroalcoholic extracts of *P. atlantica* and *P. khinjuk*. ns: non-significant.

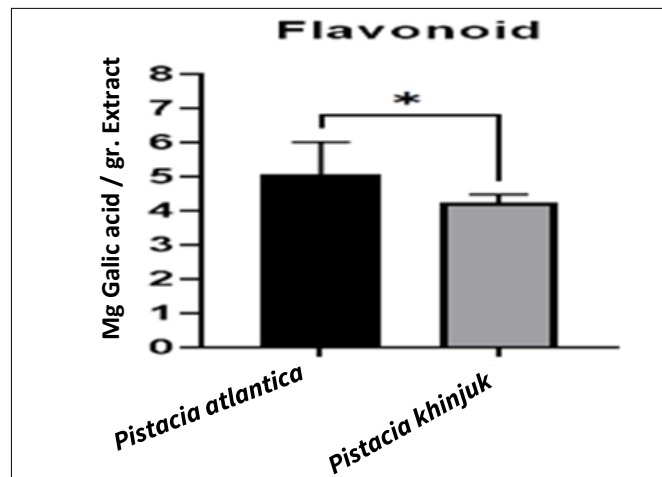


Fig. 4. Average of total flavonoid content (mg QE/100 g dry extract) of the hydroalcoholic extracts of *P. atlantica* and *P. khinjuk*. *: P<0.05

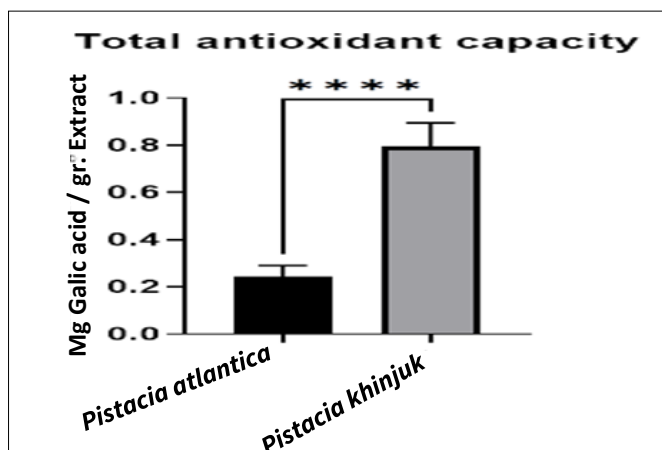


Fig. 5. Average of total antioxidant capacity (µmol AAE/100 g dry extract) of the hydroalcoholic extracts of *P. atlantica* and *P. khinjuk*. *: P<0.05.

In our study, we extensively examined the phytochemical constituents and antioxidant properties of *Pistacia atlantica* and *P. khinjuk*. Our focus included determining the total phenol and flavonoid content, total antioxidant activity and IC₅₀ (DPPH) of the hydroalcoholic extracts of *P. atlantica* and *P. khinjuk*. The results revealed that α -pinene, camphene, β -Pinene, cyclohexene, D-limonene, and careen were the primary phytoconstituents in *P. atlantica* essential oil. Consistent with other studies, our findings align with the presence of important phytochemicals like terpenes, terpenoids, and gallic acid in *P. atlantica* essential oil (19). Our findings align with previous studies that have identified various chemical compounds in *P. atlantica*. Gourine *et al.* (20) reported results consistent with ours, indicating α -pinene, camphene, β -pinene, and p-cymene as major phytochemical compounds in *P. atlantica*. While there are similarities in the types of chemical compounds between our study and Gourine's, variations in percentages may be attributed to differences in the geographical source of the herb and the specific plant part under investigation (18). Our results are also consistent with other investigations. For example, Mahmoudvand *et al.* (21) found that the main phytoconstituents in the methanolic extract of *P. atlantica* were limonene, β -myrcene, and α -pinene. Turning to *P. khinjuk*, our data demonstrated that α -pinene, β -Pinene, camphene, cyclohexene, D-limonene, and careen were major phytochemical components in the essential oil. This is in line with a study by Taghizadeh *et al.* (11), where α -pinene, myrcene, and limonene were identified as main phytoconstituents in *P. khinjuk*. Several investigations have indicated that medicinal plants of the *Pistachio* genus, particularly *P. atlantica* and *P. khinjuk*, boast a high content of phenolic compounds (12, 22). Our findings support this, revealing a high content of total phenol for both the plants.

Importantly, no significant difference was observed in total phenolic content between the two species. Hatamnia *et al.* (23) also reported a high content of phenolic compounds in *P. atlantica* in a similar study. The data obtained are consistent with the results of our study, reinforcing the understanding that *P. atlantica* contains a variety of phenolic compounds, such as caffeic acid, coumaric acid, cinnamic acid, and ferulic acid (24). A study was conducted by Hazrati and colleagues, which determined that *P. khinjuk* plant contains phenolic compounds. Similarities in the high content of phenolic compounds between our study and Hazrati and colleagues work are evident. In Hazrati *et al.*'s research, a significant difference in total phenolic con-

tent between *P. atlantica* and *P. khinjuk* was observed with higher phenolic content in *P. khinjuk* than in *P. atlantica* (22). However, in our study, no significant difference was found in total phenolic content between *P. atlantica* and *P. khinjuk*. This inconsistency could be attributed to variations in the geographical source of the herb and the tested part of the plants (18). Our findings demonstrated a higher content of total flavonoids for both *P. atlantica* and *P. khinjuk*. There was also a significant difference in the total flavonoid content between *P. atlantica* and *P. khinjuk*. A number of recent studies have suggested elevated levels of total flavonoids for *P. atlantica* and *P. khinjuk* (23, 25, 26). Flavonoids, a class of polyphenols abundant in plants, vegetables, and fruits, encompass various subgroups such as flavonol, flavone, flavonone, and anthocyanin families. A wealth of evidences supports multifaceted benefits of flavonoids, including anti-microbial, anti-viral, anti-atherosclerotic, cardiogenic, anti-diabetic, antioxidant and anti-inflammatory properties (27). A recent study reported a significant difference in total flavonoid content between *P. atlantica* and *P. khinjuk* (22). Interestingly, our study did not find a significant difference in total flavonoid content between *P. atlantica* and *P. khinjuk*. Various factors, such as differences in growth conditions and the tested parts of these plants, may contribute to such discrepant results (18). In addition to studying flavonoids, we explored the total antioxidant potential of the hydroalcoholic extracts of *P. atlantica* and *P. khinjuk*. Our results revealed a high capacity of the total antioxidant in *P. atlantica* and *P. khinjuk*. This aligns with the extensive research conducted in recent years, with studies such as Fathollahi *et al.* (28) emphasizing the high antioxidant activity of *P. atlantica*. Additionally, Ahmed *et al.* (29) and Azadpour *et al.* (30) independently confirmed the robust antioxidant activity of *P. atlantica* and *P. khinjuk*, respectively. These findings support our own observations of high total antioxidant capacity in both the plants. The prevalence of chronic and non-chronic, infectious and non-infectious diseases has surged in recent times (31-36). Recognizing the therapeutic potential of medicinal plants, the human society has increasingly turned to them for disease treatment. Medicinal plants are known for their richness in antioxidants, flavonoid compounds, phenols, flavones, anthocyanins, and tannins (37-41).

Scientific studies have consistently demonstrated the antioxidant effects of many medicinal plants, making them valuable candidates for disease treatment (42-48). In our investigation, we observed that the total antioxidant capacity of *P. khinjuk* was notably higher than that of *P. atlantica*. This aligns with the findings of Hazrati and colleagues, who similarly reported a significantly higher total antioxidant capacity for *P. khinjuk* compared to *P. atlantica*. The widely accepted notion is that the high contents of phenolic compounds play a pivotal role in conferring antioxidant potential to various medicinal plants (22). In another facet of our study, we assessed antioxidant activity using the DPPH assay, revealing *P. atlantica* as a potent antioxidant through the efficient scavenging of

DPPH free radicals. The IC₅₀ value, representing the concentration of extract required for 50% quenching of DPPH free radicals, was notably lower, indicative of increased antioxidant power (18). This aligns with the consensus among several researchers who have independently confirmed the remarkable antioxidant activity of both *P. atlantica* and *P. khinjuk*, particularly in their ability to quench DPPH free radicals (28, 30). We recognize several limitations in our study that warrant acknowledgment. A primary limitation lies in the potential inadequacy of the methods employed to measure the antioxidant capacity of plants, which could impact the precision of our experimental results. Additionally, it is crucial to note that solely examining chemical compounds may not always be sufficient for a comprehensive evaluation of the antioxidant properties of herbs.

Conclusion

Based on the conducted research, it can be concluded that *Pistacia atlantica* and *P. khinjuk* are rich sources of phytochemical constituents, including phenolic and flavonoid compounds. The results indicate that *P. atlantica* and *P. khinjuk* exhibit significant antioxidant properties, as evidenced by their total antioxidant capacity and their ability to quench DPPH free radicals. These findings suggest that *P. atlantica* and *P. khinjuk* hold promise for medicinal and pharmaceutical purposes. However, further experiments will be needed to validate the therapeutic aspects of these plants.

Acknowledgements

The authors would like to thank the Central Tehran Branch, Islamic Azad University for the financial support of this project.

Authors contributions

HD, SMMH supervised the project. FN, HA perform and analyze the experiments, all the authors have written the manuscript, reviewed the manuscript and agreed to submit it.

Compliance with ethical standards

Conflict of interest: No conflict of interest was stated by the authors.

Ethical issues: None.

References

1. Jamal A. Embracing nature's therapeutic potential: Herbal medicine. *International J Multidisc Sci Arts*. 2023;2(1):117-26. <https://doi.org/10.47709/ijmdsa.v2i1.2620>
2. Agbor GA, Dell'Agli M, Kuate JR, Ojo O. The role of medicinal plants and natural products in modulating oxidative stress and inflammatory related disorders. *Frontiers in Pharmacology*. 2022;13:957296. <https://doi.org/10.3389/fphar.2022.957296>

3. Mao JJ, Pillai GG, Andrade CJ, Ligibel JA, Basu P, Cohen L, Salicrup LA. Integrative oncology: Addressing the global challenges of cancer prevention and treatment. CA: A Cancer J CLIN. 2022;72(2):144-64. <https://doi.org/10.3322/caac.21706>
4. Noor F, Tahir ul Qamar M, Ashfaq UA, Albutti A, Alwashmi AS, Aljasir MA. Network pharmacology approach for medicinal plants: Review and assessment. Pharmaceuticals. 2022;15(5):572. <https://doi.org/10.3390/ph15050572>
5. Jongrungraungchok S, Madaka F, Wunnakup T, Sudsai T, Pongphaew C, Songsak T, Pradubyat N. *In vitro* antioxidant, anti-inflammatory and anticancer activities of mixture Thai medicinal plants. BMC Complement Med Therap. 2023;23(1):43. <https://doi.org/10.1186/s12906-023-03862-8>
6. Rudrapal M, Khairnar SJ, Khan J, Dukhyil AB, Ansari MA, Alomary MN, Devi R. Dietary polyphenols and their role in oxidative stress-induced human diseases: Insights into protective effects, antioxidant potentials and mechanism (s) of action. Front Pharmacol. 2022;13:283. <https://doi.org/10.3389/fphar.2022.806470>
7. Burton GJ, Jauniaux E. Oxidative stress. Best Practice Res Clin Obst Gynaecol. 2011;25(3):287-99. <https://doi.org/10.1016/j.bpobgyn.2010.10.016>
8. Saxena M, Saxena J, Nema R, Singh D, Gupta A. Phytochemistry of medicinal plants. J Pharmacog Phytochem. 2013;1(6):168-82.
9. Ahmed ZB, Yousfi M, Viaene J, Dejaegher B, Demeyer K, Vander Heyden Y. Four *Pistacia atlantica* subspecies (*atlantica*, *cabulica*, *kurdica* and *mutica*): A review of their botany, ethnobotany, phytochemistry and pharmacology. J Ethnopharmacol. 2021;265:113329. <https://doi.org/10.1016/j.jep.2020.113329>
10. Mahjoub F, Rezayat KA, Yousefi M, Mohebbi M, Salari R. *Pistacia atlantica* Desf. A review of its traditional uses, phytochemicals and pharmacology. J Med Life. 2018;11(3):180. <https://doi.org/10.25122/jml-2017-0055>
11. Taghizadeh SF, Davarynejad G, Asili J, Riahi-Zanjani B, Nemati SH, Karimi G. Chemical composition, antibacterial, antioxidant and cytotoxic evaluation of the essential oil from pistachio (*Pistacia khinjuk*) Hull. Microbial Pathogen. 2018;124:76-81. <https://doi.org/10.1016/j.micpath.2018.08.039>
12. Mohammadi B, Maboud HE, Seyedi SM. Nutritional value and antioxidant properties of hull and kernel in *Pistacia atlantica* and *Pistacia khinjuk* fruits. J Food Sci Technol. 2019;56:3571-78. <https://doi.org/10.1007/s13197-019-03881-9>
13. Tohidi M, Khayami M, Nejati V, Meftahizade H. Evaluation of antibacterial activity and wound healing of *Pistacia atlantica* and *Pistacia khinjuk*. J Med Plants Res. 2011;5(17):4310-14. <https://doi.org/10.22034/CAJMPSI.2021.06.03>
14. Kamal F, Shahzad M, Ahmad T, Ahmed Z, Tareen RB, Naz R *et al.* Antihyperlipidemic effect of *Pistacia khinjuk*. Biomed Pharmacother. 2017;96:695-99. <https://doi.org/10.1016/j.biopha.2017.10.061>
15. Ezatpour B, Saedi Dezaki E, Mahmoudvand H, Azadpour M, Ezatkhah F. *In vitro* and *in vivo* antileishmanial effects of *Pistacia khinjuk* against *Leishmania tropica* and *Leishmania major*. Evidence-Based Complement Altern Med. 2015; <https://doi.org/10.1155/2015/149707>
16. Bagheri S, Sarabi MM, Khosravi P, Khorramabadi RM, Veiskarami S, Ahmadvand H *et al.* Effects of *Pistacia atlantica* on oxidative stress markers and antioxidant enzymes expression in diabetic rats. J Am College Nutr. 2019;38(3):267-74. <https://doi.org/10.1080/07315724.2018.1482577>
17. Bagheri S, Khorramabadi RM, Assadollahi V, Khosravi P, Cheraghi Venol A, Veiskarami S *et al.* The effects of pomegranate peel extract on the gene expressions of antioxidant enzymes in a rat model of alloxan-induced diabetes. Arch Physiol Biochem. 2021;1-9. <https://doi.org/10.1080/13813455.2021.1877308>
18. Falahi E, Delshadian Z, Ahmadvand H, Shokri Jokar S. Head space volatile constituents and antioxidant properties of five traditional Iranian wild edible plants grown in west of Iran. AIMS Agricult Food. 2019; <https://doi.org/10.3934/agrfood.2019.4.1034>
19. Yousfi M, Djeridane A, Bombarda I, Duhem B, Gaydou EM. Isolation and characterization of a new hispolone derivative from antioxidant extracts of *Pistacia atlantica*. Phytother Res. 2009;23(9):1237-42. <https://doi.org/10.1002/ptr.2543>
20. Gourine N, Yousfi M, Bombarda I, Nadjemi B, Stocker P, Gaydou E. Antioxidant activities and chemical composition of essential oil of *Pistacia atlantica* from Algeria. Ind Crops Prod. 2010;31(2):203-08. <https://doi.org/10.1016/j.indcrop.2009.10.003>
21. Mahmoudvand H, Kheirandish F, Ghasemi Kia M, Tavakoli Karreshk A, Yarahmadi M. Chemical composition, protoscolicidal effects and acute toxicity of *Pistacia atlantica* Desf. fruit extract. Nat.Prod.Res.2016;30(10):1208-11. <https://doi.org/10.1080/14786419.2015.1046868>
22. Hazrati S, Govahi M, Ebadi MT, Habibzadeh F. Comparison and evaluation of oil content, composition and antioxidant properties of *Pistacia atlantica* and *Pistacia khinjuk* grown as wild. Int J Horticult Sci Technol. 2020;7(2):165-74. <https://doi.org/10.22059/ijhst.2020.287550.316>
23. Hatamnia AA, Abbaspour N, Darvishzadeh R. Antioxidant activity and phenolic profile of different parts of Bene (*Pistacia atlantica* subsp. *kurdica*) fruits. Food Chem. 2014;145:306-11. <https://doi.org/10.1016/j.foodchem.2013.08.031>
24. Hashemi L, Asadi-Samani M, Moradi MT, Alidadi S. Anticancer activity and phenolic compounds of *Pistacia atlantica* extract. International Journal of Pharmaceutical and Phytopharmacol Res. 2017;7(2):26-31. <https://doi.org/10.24896/eijppr.2017725>
25. Toul F, Belyagoubi-Benhammou N, Zitouni A, Atik-Bekkara F. Antioxidant activity and phenolic profile of different organs of *Pistacia atlantica* Desf. subsp. *atlantica* from Algeria. Natural Prod.Res..2017;31(6):718-23. <https://doi.org/10.1080/14786419.2016.1217205>
26. Hatamnia AA, Rostamzad A, Malekzadeh P, Darvishzadeh R, Abbaspour N, Hosseini M *et al.* Antioxidant activity of different parts of *Pistacia khinjuk* stocks fruit and its correlation to phenolic composition. Natural Prod Res. 2016;30(12):1445-50. <https://doi.org/10.1080/14786419.2015.1060593>
27. Ullah A, Munir S, Badshah SL, Khan N, Ghani L, Poulson BG *et al.* Important flavonoids and their role as a therapeutic agent. Molecules. 2020;25(22):5243. <https://doi.org/10.3390/molecules25225243>
28. Fathollahi M, Aminzare M, Mohseni M, Hassanzadazar H, editors. Antioxidant capacity, antimicrobial activities and chemical composition of *Pistacia atlantica* subsp. *kurdica* essential oil. Veterinary Research Forum. Faculty of Veterinary Medicine, Urmia University, Urmia, Iran. 2019. <https://doi.org/10.30466/vrf.2018.83910.2103>
29. Ahmed ZB, Yousfi M, Viaene J, Dejaegher B, Demeyer K, Mangelings D *et al.* Antioxidant activities of *Pistacia atlantica* extracts modeled as a function of chromatographic fingerprints in order to identify antioxidant markers. Microchem J. 2016;128:208-17. <https://doi.org/10.1016/j.microc.2016.04.023>
30. Azadpour M, Rezaei M, Taati M, Ghasemi Dehnoo M, Ezatpour B. Antioxidant, antibacterial and wound-healing properties of methanolic extract of *Pistacia khinjuk*. Comp Clin Pathol. 2015;24:379-85. <https://doi.org/10.1007/s00580-014-1908-8>
31. Mandil O, Sabri H, Manouchehri N, Mostafa D, Wang HL. Root coverage with apical tunnel approach using propolis as a root conditioning agent: A case report with 2 year follow up and review of the literature. Clin Experim Dental Res. 2023;9(4):568-73. <https://doi.org/10.1002/cre2.751>

32. Widoyo H, Mohammed ZY, Ramírez-Coronel AA, Iswanto AH, Thattarauthodiyil US, Alkhayyat A, Karimi M, Bahmani M, Eftekhari Z. Herbal therapy in Covid-19: A systematic review of medicinal plants effective against Covid-19. *Caspian J Environm Sci.* 2022;1-10. <https://doi.org/10.22124/cjes.2022.6062>
33. Mogharrabi S, Ghodsi S, Kooti M, Ahmadzadeh A, Manouchehri N. Evaluation of patients' awareness regarding proper maintenance of removable partial prostheses. *Dent Med.* 2020;33(3):200-08.
34. Abdulhamid Qasim I, Alzubaidy, Mohamad W. Association between polymorphism of the CRP gene rs1130864 and hypertension among Iraqi hypertensive patients. *Adv Life Sci.* 2023;10(2):157-60. https://doi.org/10.4103/jcd.jcd_41_23
35. Salimi K, Atri F, Valizadeh S, Sahebi M, Ghodsi S, Manouchehri N. Influence of nonthermal argon plasma on the micro-shear bond strength between resin cement and translucent zirconia. *J Conserv Dent.* 2023;26(3):281. Available from: <https://www.jcd.org.in/text.asp?2023/26/3/281/376910>
36. Manouchehri N, Ghodsi S, Atri F, Sarraf P, Seyedi D, Valizadeh S. Effect of pretreatment of root dentin surface with cold atmospheric plasma on improving the bond strength of fiber post and resin cement: *In vitro* study. *Clin Exp Dent Res.* 2023 Aug;9(4):653-60. <https://doi.org/10.1002/cre2.744>. Epub 2023 Jun 8
37. Kakeshian S, Shirali S, Savari A, Najafzadehvarzi H, Zakeri M. Alterations in histological structure, blood estrogen and progesterone levels after oral administration of garlic extract in yellowfin seabream (*Acanthopagrus latus*). *Aquatic Animals Nutr.* 2022;8(2):1-10. <https://doi.org/10.22124/janb.2023.23692.1182>
38. Shafiq M, Farooqui Z, Iqbal MZ, Athar M, Kabir M. Influence of locomotive activities polluted soil on seedling growth performance of an evergreen false rosewood coastal tree species (*Thespesia populnea* (L.) *Soland ex Correa*). *Plant Biotechnol Persa.* 2023;5(1):8-13. <http://pbp.medilam.ac.ir/article-1-155-en.html>
39. Bazari Moghaddam S, Bagherzadeh Lakani F, Jalilpour J, Masoumzadeh M, Shenavar Masouleh A. Effects of *Echinacea purpurea* and *Allium sativum* powdered extracts on growth indices, survival rate and liver enzymes in farmed *Huso huso*. *Aquatic Animals Nutr.* 2022; 8(1): 25-39. <https://doi.org/10.22124/janb.2023.21942.1164>
40. Manouchehri N. Most important medicinal plants with anti-halitosis property: An overview. *J Biochem Phytomed.* 2023;2(1):1-2. <https://doi.org/10.34172/jbp.2023.1>
41. Oboodiat M, Bakhtiari R, Shakib P, Manoocheri N, Khakpour A. The most important native Iranian medicinal plants affecting the bacteria that cause tooth decay: A systematic review. *Indian J Forensic Med Toxicol.* 2021;15(3):3421-25. <https://doi.org/10.37506/ijfmt.v15i3.15830>
42. Ebrahimi Y, AL-Baghdady HFA, Hameed NM, Iswanto AH, Shnain Ali M, Hammoodi, HA, Hashim Kzar H, Aravindhyan S, Khodaei SM, Alikord M, Pirhadi M. Common fatty acids and polyphenols in olive oil and its benefits to heart and human health. *Caspian J Environmental Sci.* 2022; 1-7. <https://doi.org/10.22124/cjes.2022.5976>
43. Abbasi N, Ghaneialvar H, Moradi R, Zangeneh MM, Zangeneh A. Formulation and characterization of a novel cutaneous wound healing ointment by silver nanoparticles containing citrus lemon leaf: A chemobiological study. *Arabian J Chem.* 2021;14(7):103246. <https://doi.org/10.1016/j.arabjc.2021.103246>
44. Ebrahimi Y, Abdalkareem Jasim S, Mohammed BA, A. Salman N, Jabbar AM, M. Hameed N, Goudarzi MA, Parsaei P. Determination of Antioxidant Properties of *Mentha longifolia*, *Pistacia khinjuk* and *Eucalyptus globulus*. *Caspian J Environmental Sci.* 2022; (): 1-6. <https://doi.org/10.22124/cjes.2022.6065>
45. Manouchehri N. A review of the most widely used medicinal plants in the treatment of dental and oral disorders and diseases. *J Biochem Phytomed.* 2022;1(1):3-7. <https://doi.org/10.34172/jbp.2022.2>
46. Karimi E, Abbasi SH, Abbasi N. Thymol polymeric nanoparticle synthesis and its effects on the toxicity of high glucose on OEC cells: Involvement of growth factors and integrin-linked kinase. *Drug Des Develop Therap.* 2019;2513-32. <https://doi.org/10.2147/DDDT.S214454>
47. Kazempour M, Shahangian SS, Sariri R. *Dracocephalum kotschyi*: Inhibition of critical enzyme relevant to type-2 diabetes, essential oil composition, bactericidal and anti-oxidant activity. *Caspian J Environmental Sci.* 2023; 1-15. <https://doi.org/10.22124/cjes.2023.6256>
48. Baniesmaeili SY, Akbarzadeh A, Riazi G, Abdollahi F, Niromand M. Effects of dietary *Moringa oleifera* leaf powder and ethanolic extract on expression function of immune genes of *Litopenaeus vannamei*. *Aquatic Animals Nutr.* 2023;9(1):27-41. <https://doi.org/10.22124/janb.2023.24268.1201>