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REVIEW

Pimpinella Species (Anise): Traditional Use, Mineral, Nutrient and Chemical Contents, Biological Activities

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Abstract
Plants, which are natural materials of great importance to humans, are currently utilized for various purposes. The use of plants with nourishing properties for treating diseases has a long history. This study compiled the general characteristics, usage areas, mineral and nutrient contents, biological activities, and chemical compositions of *the Pimpinella* species reported in the literature. The literature review reveals that the plant is widely used in traditional medicine. Furthermore, it has been determined that they may serve as significant natural resources regarding their mineral, nutritional, and chemical content. Furthermore, it has been observed, based on reported data in the literature, that *Pimpinella* species exhibit high levels of antioxidant and antimicrobial activity. Within this context, it has been observed that *Pimpinella* species can be significant sources not only in terms of their nutritional properties but also from a medicinal perspective.
Keywords: Antimicrobial, Anise, Antioxidant, Medicinal Plants, Traditional Medicine.

INTRODUCTION

Various natural materials, such as fungi, animals, and plants, are utilized in traditional medicine.[1] Among these natural products, plants are significant materials. Plants are utilized for various purposes such as food, spices, combating diseases, heating, and shelter in different cultures.[2] Plants constitute significant components of many human diets. They possess highly nutritious properties because they contain vitamins, minerals, and essential nutrients.[3] Plants that stand out with their nourishing properties are also significant materials from a medical perspective.[4,5] Numerous studies have reported that plants possess various activities such as antioxidant, anticancer, antimicrobial, anti-inflammatory, hepatoprotective, anti-aging, anti-allergic, and DNA protective properties.[6-13] Determining the biological potential of plants is of great importance within this context. This study compiled the reported usage areas, general characteristics, nutritional and mineral contents, biological activities, and chemical compounds of Pimpinella species from the literature.

GENUS *PIMPINELLA* AND USAGE AREAS

Pimpinella species belonging to the Apiaceae family are plants with a distribution range of 150 species across Europe, Asia, and Africa. The types refer to annual and perennial plants. From a morphological perspective, the plant possesses cordate-ovate or rectangular-ovate leaves and fruits that are slightly compressed laterally, each with five filiform veins.[14-18]

Pimpinella species are favored in alternative medicine in countries such as China, Egypt, Iran, Lebanon, and Palestine. It has been reported that there is still usage even in countries such as England and Italy, where the use of herbal medicines is low. Türkiye is the country where *Pimpinella* is most commonly utilized and preferred. The species of *Pimpinella* are commonly preferred for their above-ground, root, and seed parts. The above-ground parts of the plant are utilized for their medicinal properties, including their ability to alleviate gastrointestinal distress, bronchial asthma, insomnia, persistent cough, renal colic, flatulence, expectorant, sedative, antidepressant, antiseptic, antispasmodic, analgesic, diuretic, estrogenic, and pectoral stimulant effects.

Table 1. Mineral and Nutritional Contents of *Pimpinella* species.

Nutritional Composition	Values (%)
Protein	13.35-28.73 %
Lipids	2.66-9.02 %
Carbohydrate	9.87-61.09 %
Crude fibers	2.83-33.50 %
Moisture	4.9-80.42 %
Ash	5.69-19.14 %
Mg	6.45-478.6 mg/kg
K	93.13-6332 mg/kg
Na	5.44- 365.10 mg/kg
Fe	0.15-1512 mg/kg
Ca	12.64-3141 mg/kg
Zn	0.12-14.31 mg/kg
Cu	0.029-0.035 mg/kg

The seed components exhibit various pharmacological properties such as abdominal pain relief, gastrointestinal disorder management, carminative effects, expectorant properties, sedative effects, antidepressant properties, and antiseptic properties. Insomnia, persistent cough, carminative, stomach upset, stomach ache, calming, colic, tranquilizer, diuretic, flu, and various alcoholic beverages such as "pastis" and "sambuca" are commonly used for their therapeutic properties as hypnotics, antispasmodics, expectorants, and in the treatment of epilepsy. The root parts, on the other hand, are utilized in the treatment of asthma, bronchitis, and menstrual disorders.[19-26]

NUTRITIONAL AND MINERAL CONTENTS

Plants are an essential component of human diets and cannot be substituted. The food products that many individuals prefer to consume during each meal are commonly observed.[27] In this study, the nutritional and mineral contents of *Pimpinella* species reported in the literature are presented in Table 1.

BIOLOGICAL ACTIVITY

In the literature, various extracts such as ethanol, water, acetone, methanol, essential oil, aqueous, hexane, methylene chloride, hydroalcoholic, benzene, ethyl acetate, and n-butanol have been reported to be utilised *in vitro* and *in vivo* biological activity studies on *Pimpinella* species. The biological activity studies conducted on *Pimpinella* species reported in the literature are presented in Table 2.

Table 2. Biological activity of *Pimpinella* species.[32, 35-54]

Plant species	Biological activities	Extractions
P.anisoides V.Brig.	Antioxidant, anti-inflammatory	Ethanol
P. anisum L.	Antioxidant, antimicrobial, cytotoxicity, antiproliferative, anticancer, antispasmodic, antidiabetic, antiviral, insecticidal	Ethanol, water, methanol, essential oil, aqueous, hexane, methylene chloride, hidroalcoholicbenzene, ethylacetate, n-butanol
P. aurea DC.	Antioxidant, antimicrobial	Methanol
P.brachycarpa (Kom.) Nakai	Antioxidant, antimicrobial	Ethanol, methylene chloride, ethylacetate, hexane, methanol
P. candolleana Wight & Arn.	Antioxidant, α-glucosidase inhibitory	Ethanol, methanol
P. puberula (DC.) Boiss.	Antimicrobial	Essential oil
P. saxifraga L.	Antioxidant, antimicrobial	Essential oil
P. stewartii Nasir	Antioxidant, acetylcholinesterase	Acetone, water, aqueous, ethanol, ethylacetate
P. thellungiana H. Wolff	Antioxidant	Essential oil

Antioxidant activity

Living organisms synthesize numerous compounds with oxidizing properties due to their metabolic activities. While compounds of this particular book do not exhibit harmful effects at low levels, they can cause cellular damage as their levels increase.[55] The antioxidant defense system plays a role in suppressing the formation of oxidizing compounds, such as reactive oxygen species, in the presence of oxidizing agents. In cases where the antioxidant defense system is insufficient, oxidative stress occurs.[56] Numerous diseases such as Alzheimer's, Parkinson's, multiple sclerosis, cancer, and cardiovascular disorders may manifest due to oxidative stress.[57,58] Supplementation with antioxidants can be utilized to reduce the effects of oxidative stress.[59] Plants are considered significant natural sources of supplementary antioxidants.[60]

The literature reports the values of protein (13.35-28.73%), lipids (2.66-9.02%), carbohydrate (9.87-61.09%), crude fibers (2.83-33.50%), moisture (4.9-80.42%), and ash (5.69-19.14%) for Pimpinella species.[28-32] Furthermore, it has been reported that Pimpinella species contain Mg (6.45-478.6 mg/kg), K (93.13-6332 mg/kg), Na (5.44-365.10 mg/kg), Fe (0.15-1512 mg/kg), Ca (12.64-3141 mg/kg), Zn (0.12-14.31 mg/kg), and Cu (0.029-0.035 mg/kg).[30, 32-34] Within this context, it is believed that Pimpinella species may serve as a natural source of nutrients and minerals.

According to the literature, the antioxidant effect of the ethanol extract of *P. anisoides* collected from Italy was reported using the DPPH assay, with an LC50 value of 3.02 mg/mL.[35] The antioxidant activities of *P. anisum* extracts obtained from water and ethanol sourced from Türkiye were reported using various methods, including reducing power, superoxide anion scavenging, free radical scavenging, metal chelating, scavenging of hydrogen peroxide, and total antioxidant activity. According to the test results, it has been reported that plant extracts exhibit high antioxidant activities.[37] According to a study conducted in Egypt, the ethanol and aqueous extracts of *P. anisum*'s seed and aerial parts exhibited DPPH activities ranging from 13.7% to 91.3% at concentrations of 0.05-0.3 mg/mL.[46] It has been reported that the volatile oil of *P. anisum* collected from Greece exhibited antioxidant activity with DPPH and ABTS assay values of 48% and 18.6%, respectively.[44] According to reports, the IC50 values of the methanol, volatile oil, polar subfraction, and non-polar subfraction of *P. aurea* collected from Iran were found to be between 108-549 µg/mL in the DPPH test. Furthermore, it has been reported that the LC values of β-carotene/linoleic acid test results vary between 5.98% and 65.87.[47] It has been reported that the ethanol extract of *P. brachycarpa* collected from South Korea exhibits a DPPH anion scavenging activity value was 8.80 mg/g, ABTS cation scavenging activity value was 63.53 mg/g, and a reducing power test result was 0.85.[49] According to reports, the IC50 value of *P. candolleana* extracts collected from China, including petroleum ether, methanol, and ethanol, varied between 25.46-27.20 µg/mL in the DPPH test, 9.23-21.69 µg/mL in the ABTS test, and 138.88-919.84 µmol/g in the FRAP test.[50] It has been reported that the IC50 value of the volatile oil of *P. saxifraga* collected from Tunisia for DPPH radical scavenging activity is 6.81 µg/mL, the IC50 value for β-carotene bleaching inhibition test is 206 µg/mL, the EC50 value for ferric reducing power test is 35.20 µg/mL, and the total antioxidant activity test result is 213.96 µmol/mL.[52] The DPPH values of aqueous and acetone extracts of *P. stewartii* collected from Pakistan were reported as 61.08% and 62.39%, respectively, ferrous ion chelating values were reported as 61.16% and 50.76%, and hydrogen peroxide scavenging values were reported as 25.18 and 52.59%, respectively. In addition, the hydroxyl radical scavenging value was reported 0.091 and 11.70%, respectively, the phosomolybdenium complex assay value was 56.55 and 86.26 µM/100 g, and the ferric ion reducing antioxidant power test result was 23.28 and 14.24 µM/100 g, respectively.[32] According to a study conducted in Kazakhstan, the volatile oil obtained from the root and aerial parts of *P. thellungiana* exhibited anti-radical activity ranging from 2.9% to 12.7% at concentrations between 0.1-1 mg/mL.[54] Upon reviewing the literature on antioxidant activity studies conducted on *Pimpinella* species within this scope, it is observed that *Pimpinella* species exhibit high antioxidant properties. It is believed that Pimpinella species may serve as a natural source of antioxidants within this context.

Antimicrobial activity

There is an increasing trend in the incidence of diseases caused by microorganisms.[61] The emergence of resistant microorganisms due to improper medication use renders the antimicrobial drugs used insufficiently. In this context, researchers are directing their attention toward novel antimicrobial sources.[62] The potential side effects of synthetic drugs have led individuals to turn towards natural antimicrobial agents. Within this context, plants are significant sources of natural antimicrobial agents.[63,64] In this study, the antimicrobial potential of *Pimpinella* species was compiled based on literature data (Table 2). It has been reported that the water and ethanol extracts of *P. anisum* collected from Türkiye exhibit inhibition zones ranging from 7-11 mm against *Pseudomonas aeruginosa, Escherichia coli, Proteus mirabilis, Citrobacter koşeri, Enterobacter aerogenes, Staphylococcus aureus, Streptococcus pneumoniae, Micrococcus luteus, Staphylococcus epidermidis*, and *Candida albicans*.[37] It has been reported that the volatile oil and methanol extracts of *P. anisum* collected from Iraq exhibited the most favorable outcomes against *Staphylococcus aureus, Bacillus cereus*, and *Proteus vulgaris* at a concentration of 62.5 µg/mL.[39] According to a study conducted in Egypt, ethanol and aqueous extracts of *P. anisum*'s seed and aerial parts exhibited inhibition zones ranging from 2.7-21 mm against *Bacillus cereus, Staphylococcus aureus, Salmonella typhimurium*, and *Escherichia coli* at concentrations ranging from 1.25-5 mg/mL.46 It has been reported that silver nanoparticles produced using aqueous extracts of *P. anisum* collected from Saudi Arabia exhibit minimum and average diameter values ranging from 3.2 to 16 nm against *Acinetobacter baumannii, Klebsiella pneumoniae, S. typhi*, and *P. aeruginosa*.[43] According to the literature, *P. anisum* collected from Iraq effectively against *S. aureus, B. cereus*, and *E. coli* at a concentration of 31.2 µg/mL. Additionally, it was effective against P. mirabilis and *K. pneumonia* at a concentration of 62.5 µg/mL, against *Candida albicans* at a concentration of 500.0 µg/mL, and against *Pseudomonas aeruginosa* at a concentration greater than 500.0 µg/mL.[40] It has been reported that the volatile oil of P. aurea collected from Iran exhibits inhibition zones ranging from 10-16 mm against *K. pneumoniae, P. vulgaris, S. dysenteriae*, and *S. aureus.*[47] It has been reported that the ethanol extract of *P. brachycarpa* collected from South Korea exhibits antimicrobial effects against *S. aureus* and *B. subtilis.*[49] A study reported from South Korea indicates that P. brachycarpa has MIC and MFC values of 0.25 mg/ml and 0.5 mg/ml, respectively, against *Aspergillus niger*.[48] It has been reported that the inhibition zone values of *P. aeruginosa, Bacillus cereus, Micrococcus luteus, S. aureus, Yersinia entrocolitica,* and *C. albicans* vary between 3-36 mm when exposed to the volatile oil of *P. puberula* collected from Iran.51 It has been reported that the volatile oil of *P. saxifraga* collected from Tunisia has MIC values ranging from 0.78 to 3.125 mg/mL against *E. coli, S. typhimurium, P. aeruginosa, B. cereus, M. luteus,* and *L. monocytogenes*.[52] Upon examination of the studies reported in the literature regarding *Pimpinella* species, it is evident that these plants possess significant antimicrobial potential. Within this context, it is believed that *Pimpinella* species may serve as natural antimicrobial agents.

Other activities

The literature has reported that *Pimpinella* species exhibit various biological activities in addition to their antioxidant and antimicrobial activities (Table 2). The ethanol extract of *P. anisoides* collected from Italy was utilised to investigate its anti-inflammatory effect on murine monocytic macrophage cell line RAW 264.7. It has been reported that the working outcome possesses an IC50 value of 72.7 µg/mL *in vivo*.[35] It has been reported that silver nanoparticles produced using aqueous extracts of *P. anisum* collected from Saudi Arabia showed minimal negative effects on cell proliferation, without any changes in cell viability, when tested against a skin stromal cell line (hSSC) and a cancer cell line (HT115) at various concentrations of less than 10 µg. Furthermore, it has been reported to lead to increased cytotoxicity at doses exceeding 10 µg.[43] It has been reported that the EC50 values of the essential oil of *P. anisum* collected from Greece against HepG2, Caco2, MCF-7, and THP-1 cell lines were 0.39, 0.25, 0.3, and 0.11 mg/mL, respectively.[44] A study in Israel reported that the ethanol extract of *P. anisum* exhibited robust proliferation on rat skeletal muscle cell line (L6) and human prostate cancer cell line (PC-3) at an IC50 value of 400 µg/mL.41 The hydroalcoholic extract of *P. anisum* collected from Brazil was utilised to determine its antispasmodic effect on the anococcygeus smooth muscle of rats. According to the study findings, it has been reported that the extract used inhibited the contraction caused by acetylcholine at a concentration of 50 µg/mL.[38] In a study conducted in India, the IC50 values of the highest α-amylase and α-glucosidase effects of the ethyl acetate fraction of *P. anisum* were reported as 0.12 and 0.15 mg/mL, respectively.[42] A study conducted in India reported that the volatile oil of *P. anisum* exhibited inhibitory effects against Potato virus X, Tobacco mosaic virus, and Tobacco ringspot virus at a concentration of 300 ppm.36 It has been reported that the insecticidal effect of the essential oil of *P. anisum* collected from Egypt against the red flour beetle, *Tribolium castaneum*, has an LC50 value of 9.3% v/v.[45] It has been reported that the petroleum ether, methanol, and ethanol extracts of *P. candolleana* collected from China exhibit α-glucosidase inhibitory activity with an LC50 value ranging from 4.42-68.71 µg/ml, attributed to the chemical compounds present in *P. candolleana*.[50] The IC50 values of the acetylcholinesterase activity of the water and ethyl acetate fractions of *P. stewartii* collected from Pakistan were reported as 72.6 and 30.41 µg/mL, respectively.[53]

CHEMICAL CONTENTS

In plants, numerous biologically active compounds are synthesised within their structures. Numerous studies have reported significant biological activities of compounds found in plants.[65] In this study, the chemical compounds identified in *Pimpinella* species in the literature have been compiled. Within this context, it has been observed that studies have been conducted on the aerial, stem, and seed parts of *Pimpinella* species in the literature. The findings obtained were presented in Table 3.

Table 3. Chemical contents of Pimpinella species.[35, 51, 54, 66-78]

Plant species	Geographic regions	Used Parts	Chemical contents
P. acuminata (Edgew.) C.B. Clarke	India, Pakistan	Aerial, stem	β-caryophyllene (12.5%), dill apiole (11.3-20.4%), parsley apiole (39.9-61.8%), myristicin (16.2%), methyl coniine (70.0%), coniine (4.0%), n-pentadecane (4.0%), 1-methyl-2-pentyl piperidene (3.3%), heptadecane (3.0%), apiole (1.5%)
P. anisoides V.Brig.	Italy	Aerial	Trans-anethole (54.5%), limonene (13.5%), sabinene (4.4%)
P. anisum L.	Estonia, Serbia, Iran, Brazil, Algeria, Pakistan, Egypt	Aerial, seed	Trans-anethole (65.6–93.7%), γ-himachalene (0.4–8.2%), trans-pseudoisoeugenyl 2-methylbutyrate (0.4–6.4%), p-anisaldehyde (<1-5.4%), methylchavicol (0.5–2.3%), cis-isoeugenol (1.99%), linalool (1.79%), (E)-anethole (80.7%-90.35%), estragole (1.9-5.6%), eugenyl acetate (3.34-3.92%), α-zingiberene (1.9%), cis-pseudoisoeugenyl 2-methylbutyrate (~3%), o-isoeugenol (1.9%), fenchone (5.6%), camphor (3.1%)
P. aurea DC.	Iran	Aerial, stem, seed	Limonene (8.9-21.4%), viridiflorol (12.8-37.0%), α-pinene (11.5%), kessane (10.5%), germacrene D (4.9%), β-bisabolene (4.2-50.8%), α-zingiberene (3.3%), citronellyl acetate (3.1%), caryophyllene oxide (6.6%), 1,8-cineol (8.9-21.4%), estragol (5.1%), trans-a-bergamotene (72.8%)
P. puberula (DC.) Boiss.	Iran	Aerial, stem, seed	Limonene (21.7-82.4%), pregeıjerene (14.6-55.4%), geijerene (7.2-11.7%)
P. saxifraga L.	Iran	Aerial	Trans-α-bergamotene (20.1%), β-sesquiphellandrene (10.8%), β-bisabolene (10.1%)
P. thellungiana H. Wolff	Kazakhstan	Aerial, stem	Hexenal (0.2-8.9%), β -pinene (0.4-4.1%), undecane (1.5-15.6%), geijerene (0.6-9.2%), 9-Methyl-10-methylenetricyclo[4.2.1.1(2,5)]decan-9-ol (3.4%), cis - β -farnesene (0.3%-12.6%), β -bisabolene (1.6-18.8%), spathulenol (3.3%), caryophyllene oxide (0.7-4.3%), 2-methyl-4-methoxy-2-(3-methoxyoxiranyl)phenylbutanoate (0.4-29.5%)
P. tragium Vill.	Iran	Aerial, stem	Germacrene D (6.2-34.7%), germacrene B (14.1-18.3%), bornyl acetate (4.1-15.8%), β-caryophyllene (4.8-7.3%) β-pinene (4.5-25.3%), hexadecanol (4.7-10.3%), sabinene (13.6%)

In the literature, the main components in the essential oil content of *P. acuminata* species are β-caryophyllene (12.5%), dill apiole (11.3-20.4%), parsley apiole (39.9-61.8%), myristicin (16.2%), methyl coniine (70.0%), Coniine (4.0%), n-pentadecane (4.0%), 1-methyl-2-pentyl piperidene (3.3%), heptadecane (3.0%), and apiole (1.5%) have been reported.[66,67] It has been reported that the main components in the essential oil content of P. anisoides species are trans-anethole (54.5%), limonene (13.5%) and sabinene (4.4%).[35] It has been reported that the main components in the essential oil content of P. anisum species are trans-anethole (65.6–93.7%), γ-himachalene (0.4–8.2%), trans-pseudoisoeugenyl 2-methylbutyrate (0.4–6.4%), p-anisaldehyde (<1-5.4%), methylchavicol (0.5–2.3%), cis-isoeugenol (1.99%), linalool (1.79%), (E)-anethole (80.7-90.35%), estragole (1.9-5.6%), eugenyl acetate (3.34-3.92%), α-zingiberene (1.9%), cis-pseudoisoeugenyl 2-methylbutyrate (~3%), o-isoeugenol (1.9%), fenchone (5.6%) and camphor (3.1%).[68-74] It has been reported that the main components in the essential oil content of *P. aurea* species are limonene (8.9-21.4%), viridifluorool (12.8-37.0%), α-pinene (11.5%), chestnut (10.5%), germacrene D (4.9%), β-bisabolene (4.2-50.8%), α-zingiberene (3.3%), citronellyl acetate (3.1%), caryophyllene oxide (6.6%), 1,8-cineol (8.9-21.4%), estragole (5.1%) and trans-a-bergamotene (72.8%).[75,76] It has been reported that the main components in the essential oil content of *P. puberula* species are limonene (21.7-82.4%), pregeijerene (14.6-55.4%) and geijerene (7.2-11.7%).[51] It has been reported that the main components in the essential oil content of *P. saxifraga* species are trans-α-bergamotene (20.1%), β-sesquiphellandrene (10.8%) and β-bisabolene (10.1%).[77] It has been reported that the main components in the essential oil content of P. thellungiana species are hexenal (0.2-8.9%), β -pinene (0.4-4.1%), undecane (1.5-15.6%), geijerene (0.6-9.2%),9-Methyl-10-methylenetricyclo [4.2.1.1 (2.5)]decan-9-ol (3.4) %), cis - β -farnesene (0.3-12.6%), β -bisabolene (1.6-18.8%), spathulenol (3.3%), caryophyllene oxide (0.7-4.3%) and 2-methyl-4-methoxy-2-(3-methoxyoxiranyl) phenyl-butanoate (0.4-29.5%).[54] (Suleimen et al., 2017). It has been reported that the main components in the essential oil content of *P. tragium* species are hexadecanol (4.7-10.3%), germacrene D (6.2-34.7%), germacrene B (14.1-18.3%), bornyl acetate (4.1-15.8%), β-caryophyllene (4.8-7.3%) β-pinene (4.5-25.3%), and sabinene (13.6%).[78] In this context, based on the literature data, it has been reported that the 5 highest reported compounds in *Pimpinella* species are trans-a-bergamotene (72.8%), methyl coniine (70.0%), trans-anethole (65.6–93.7%), (E)-anethole (80.7-90.35%), and limonene (21.7-82.4%). In this context, it is thought that *Pimpinella* species may be a natural source for the compounds reported in its body.

CONCLUSION

This study compiles the literature on Pimpinella species reported in previous studies. Within this scope, the general characteristics, mineral and nutrient contents, areas of use, biological activities, and chemical compositions have been compiled. Based on the literature review conducted, it has been determined that Pimpinella species are commonly used in traditional medicine. Furthermore, it is believed that the reported minerals, nutrients, and chemical contents within it could potentially serve as a natural resource. Additionally, it has been reported in the literature that *Pimpinella* species exhibit high antioxidant and antimicrobial activities. As a result, it has been observed that in addition to the nutritious properties of *Pimpinella* species, they could be significant natural materials in pharmacological designs in future studies.

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