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Review Article

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Ethnomedicinal use, phytochemistry, pharmacology, and toxicology of *Chamaerops humilis*: A review

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Abstract

Chamaerops humilis L. is a widespread species in the western and central Mediterranean region. It is used in traditional medicine to treat numerous diseases, particularly diabetes. *Aim of the review:* This review was devoted to provide valuable information on *C. humilis* various aspects including its botanical description, taxonomy, geographical distribution, medicinal use, phytochemistry, pharmacological properties, and toxicity. *Materials and methods:* We searched various scientific databases, such as Scopus, PubMed, Web of Science, SpringerLink, SciFinder, Wiley Online, and Google Scholar, to collect data on *C. humilis*. The presented data on *C. humilis* were organized according to botanical description, ethnomedicinal use, bioactive compounds, pharmacology, and toxicological investigation. *Results:* In traditional medicine, *C. humilis* was used to treat diabetes, diarrhea, gastritis, gastralgia, constipation, neuronal diseases, and anemia. The extracts and essential oil derived from *C. humilis* demonstrated various beneficial properties, such asantibacterial, anticholinesterase, antidiabetic, antilithiasic, anti-inflammatory, antitumoral, antioxidant, antityrosinase, and antihyperlipidemic activities. Phytochemical investigations identified several chemical classes of secondary metabolites in *C. humilis* essential oil and extracts including phenols, sterols, terpenoids, polysaccharides, and fatty acid. *Conclusion:* Based on the critical analysis of previous studies, further exploration of *C. humilis* and its bioactive compounds should be conducted for potential medical applications. This may involve isolating and characterizing specific compounds from *C. humilis* and evaluating their therapeutic potential through preclinical and clinical studies.

Keywords: biological activities; *Chamaerops humilis*; ethnomedicinal use; phytochemistry compounds

Introduction

Chamaerops humilis L. belongs to the family *Arecaceae*, the sub-family *Coryphoideae*, and *Chamaerops* the genus (Dransfield *et al*., 2005). *C. humilis* is a widespread species in the western Mediterranean region (Maire, 1957). The nomenclature *C. humilis* is etymologically derived from the Greek terms ‘chamai’ and 'rhopos', signifying dwarf and bush respectively (Hasnaoui, 2008). This species is a shrub-like clumping palm with several stems growing from a single base (Tuley, 1995) with height between 1 to 1.5 m but can have a height of 9 to 12 m in protected areas (Hasnaoui, 2008; Benmehdi *et al*., 2012). The plant in question is

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commonly referred to as the Mediterranean dwarf palm and the European fan palm. In Morocco, the plant is referred to as "Doum" (Tassin, 2012), while in the Mediterranean region it is commonly known as "Dwarf Palm" (Herrera, 1989).

In folk medicine, several ethnobotanical researches reported the use of *C. humilis* in traditional medicine to treat numerous diseases, essentially diabetes (Nekhla *et al.*, 2021). It is used to treat other diseases such as gastrointestinal disorders, diarrhea, gastritis, gastralgia, constipation, neuronal diseases, and anemia (Bouyahya *et al.*, 2017; Hasnaoui *et al.*, 2011, 2013; Medjati *et al.*, 2019).

Phytochemical investigations of *C. humilis* extracts and essential oils have revealed the presence of various classes of phytocompounds, such as phenols, sterols, terpenoids, polysaccharides, and fatty acids (Left *et al.*, 2013; Nehdi *et al.*, 2014; Siles *et al.*, 2015; Khoudali *et al.*, 2016; Coelho *et al.*, 2017; Gonçalves *et al.*, 2018; Mokbli *et al.*, 2018; Aicha *et al.*, 2019; Cadi *et al.*, 2021; Rincón-Cervera *et al.*, 2023). These different classes of phytocompounds play a role in the pharmacological activities of *C. humilis*. Many researchers have reported a wide range of potential activities associated with *C. humilis* extracts and essential oils including antibacterial, anticholinesterase, antidiabetic, antilithiasic, anti-inflammatory, antitumoral, antioxidant, antityrosinase, and antihyperlipidemic activities (Figure 1) (Beghalia *et al.*, 2008; Bennaceur *et al.*, 2010; Gaamoussi *et al.*, 2010; Hasnaoui *et al.*, 2013; Miguel *et al.*, 2014; Belhaoues *et al.*, 2017; Gonçalves *et al.*, 2018; Aicha *et al.*, 2019; Dawood *et al.*, 2020; Attaallah *et al.*, 2021; Lachkar *et al.*, 2022; Rincón-Cervera *et al.*, 2023). However, there are scarcely those reported the toxicity effect of this plant (Lachkar *et al.*, 2022).

To the best of our knowledge, no review was published to critically summarize these results and suggested future clinical applications of this plant. Thus, this motivated us to write the current review, which highlighted *C. humilis* ethnomedicinal use, geographic distribution, taxonomy, phytochemical compounds, pharmacology activities, and toxicology effects.

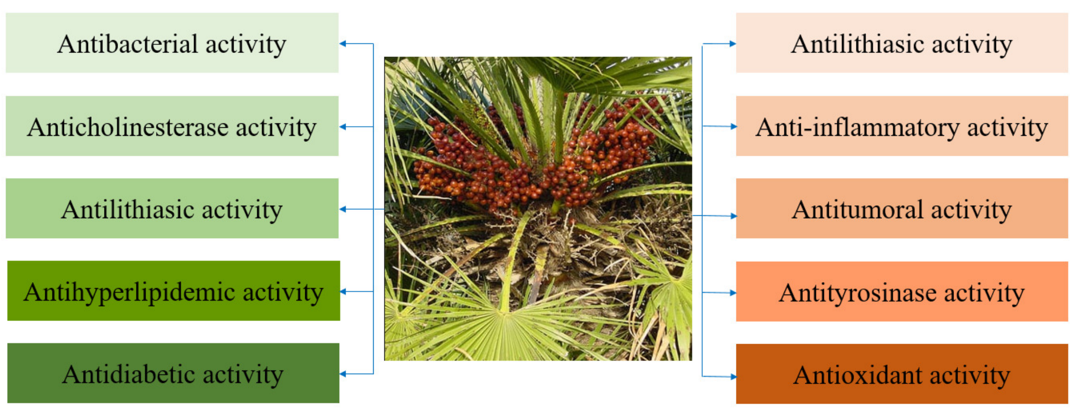


Figure 1. Pharmacological properties of *Chamaerops humilis*

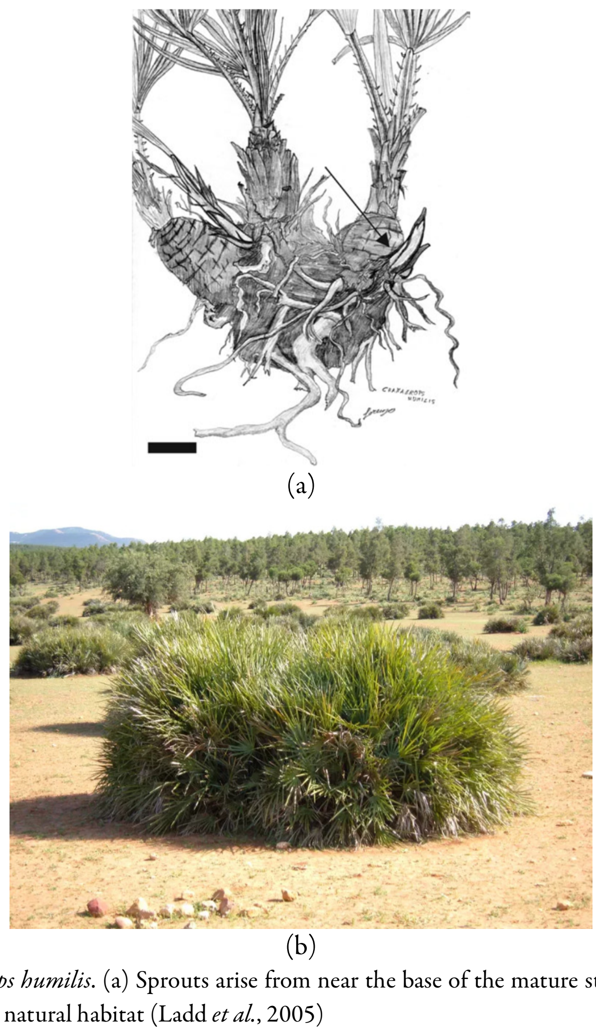
Materials and Methods

Using a variety of scientific search engines such as Scopus, Wiley Online, Web of Science, ScienceDirect, SpringerLink, SciFinder, Google Scholar, and PubMed, gather comprehensive information on *C. humilis* was found in a wide range of scientific articles, journals, and research papers, enabling as to explore various aspects of this plant, including its botanical description, distribution, taxonomy, ethnobotany, phytochemistry, and pharmacology. Each field in this review has been organized, analysed, and summarized from the data collected from these scientific search engines. Different keywords related to *C. humilis*, such as '*Chamaerops humilis*', '*Chamaerops humilis* extract', '*Chamaerops humilis* essential oils', 'Chemical composition of *Chamaerops* *humilis*', 'biological activities of *Chamaerops humilis*" were used to cover a wide range of topics and aspects related to this plant.

Results

Botanical description

Perennial plant (survives for several years), with long tracing roots. Stipe (= Stem) usually very short, but may reach several metres in sheltered places. Leaves palmate, with slender stalk, 10-100 cm long, with strong, voluminous spines, especially in the lower part; blade fan-shaped, with free stripes in the upper third or half; tips of stripes usually rigid, sometimes slightly drooping (Figure 2). Flowers polygamous or diclinous. Male inflorescences golden yellow, 5-20 cm long; flowers numerous, densely packed; perianth with 6 fleshy divisions; stamens 6; anthers oblong. Female inflorescence greenish; flowers with 3 carpels, 1-2 of which often abort (Figure 3). The fruit resembles a bunch of grapes (Arabian jackalberry). The fruits are globular, yellowish ochre when ripe, 12 x 12-16 mm, with a fibrous flesh, sweet taste and unpleasant smell. The seed is hard, large, 1 cm in diameter, brown in colour, with a horny albumen and dorsal embryo. (see also Maire, 1957). According to Hasnaoui (2008), the fruits reach maturity during the late summer and early autumn period (Figure 2).



(a)

(b)

Figure 2. *Chamaerops humilis*. (a) Sprouts arise from near the base of the mature stems (arrow), bar ¼ 6 cm, (b) *C. humilis* in natural habitat (Ladd *et al.*, 2005)

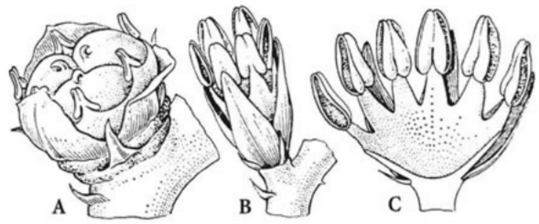


Figure 3. *Chamaerops humilis* (A-C): A: Pistillate flower; note free styluli. B: Staminate flower. C: Staminate flower opened out, showing androecial ring (Dransfield and Uhl, 1998)

Taxonomy and geographic distribution

Chamaerops humilis belongs to the family *Arecaceae* and to the sub-family *Coryphoideae* which includes eight tribes and 44 genera (Rashid *et al.*, 2008). The drawn palm is part of the tribe Livistoneae, subtribe Raphidinaes, genus *Chamaerops* (Dransfield *et al*., 2005). *C. humilis* is a widespread species in the western and central Mediterranean region (Maire, 1957). The plant's geographical distribution encompasses southern Europe, including Italy, Spain, Malta, and the southern region of France, as well as North Africa, specifically Algeria, Tunisia, and Morocco (Garcia-Castano *et al.*, 2014). From an ecological perspective, it serves as a significant biological indicator of the thermo-Mediterranean vegetation level (Ozenda *et al*., 1981). . Within its natural habitat, *C. humilis* demonstrates thermophilic characteristics, exhibiting a remarkable ability to withstand elevated average annual temperatures surpassing 30 °C. *C. humilis* has the ability to withstand precipitation levels exceeding 700 mm in terms of water tolerance. It exhibits a preference for calcareous soils, although it has the ability to thrive in various soil types (Merlo *et al*., 1993).

Ethnobotanical use

Despite the distribution of *C. humilis* in the western Mediterranean region, few studies reported the traditional use of this plant. Several parts of *C. humilis* have been reported in different traditional folk medicine to treat numerous diseases. The traditional use of *C. humilis* in global systems is documented in Table 1. The utilization of the leaves of *C. humilis* for the treatment of hepatitis, diabetes, and various gastrointestinal disorders has been documented in the Tlemcen region, specifically in the areas of Fillaoucène, Djebala, Azails, Oued Chouly, and Honaine (Hasnaoui *et al*., 2011). In a study conducted in 2013, researchers examined the traditional utilization of *C. humilis* in the mountainous regions of Tlemcen, specifically the mounts of Tlemcen and mounts of Traras located in the North-West of Algeria. The findings of this investigation revealed that the heart of palm and spadice of this palm were employed for the treatment of various ailments including stomach wounds, diarrhea, gastro-enteritis, gastritis, gastralgia, constipation, and as a carminative (Hasnaoui *et al.*, 2013). In 2017, an ethnobotanical survey was undertaken within the geographical boundaries of the province of Ouezzane, Morocco, by Bouyahya *et al*. (2017). The study's findings provide credence to the traditional usage of C. humilis rhizome for the treatment of neurological diseases. In a recent study conducted by Medjati *et al*. (2019), the authors identified the utilization of fruits and roots of *C. humilis* by the population of Beni Snous in Tlemcen, Algeria, for various therapeutic purposes. These purposes encompass the treatment of dyspepsia, anaemia, intestinal worms, diabetes, asthma, antiseptic properties, gingivitis, influenza, cough, and digestive tract ailments.

In 2021, *C. humilis* was reported as a medicinal plant for the treatment of urinary tract infections, digestive disorders, and diabetes (Nekhla *et al*., 2021).

Table 1. Traditional use of *Chamaerops humilis*

Used part	Mode of preparation	Traditional use	References
Rhizome	Infusion	Neuronal diseases	Bouyahya *et al.*, 2017
Fruits	Maceration, decoction, powder, salad	Antiseptic, gingiva, influenza, coughing, asthma, attacks of the digestive tract, dyspepsia	Medjati *et al.*, 2019
Roots	Maceration, decoction, powder	Anemia, cleaning the uterus after childbirth, rheumatism, diabetes, and intestinal worms	
Leaves	Maceration	Diabetes, hepatitis, and other gastrointestinal disorders	Hasnaoui *et al.*, 2011; Hasnaoui *et al.*, 2013; Medjati *et al.*, 2019
Heart of palm, and spadice	Maceration, decoction	Carminative, gastritis, gastro-enteritis, gastralgia, stimulant, diarrhoea, wound of stomach, constipation	Hasnaoui *et al.*, 2013
Leaves, fruits, and heart of palm	Decoction, infusion	Urinary tract infections, digestive disorders, and diabetes	Nekhla *et al.*, 2021

Numerous researchers reported *C. humilis* secondary metabolites collected in different region including phenols, sterols, terpenoids, polysaccharides, and fatty acid (Left *et al.*, 2013; Nehdi *et al.*, 2014; Ahmed *et al.*, 2015; Siles *et al.*, 2015; Khoudali *et al.*, 2016; Coelho *et al.*, 2017; Gonçalves *et al.*, 2018; Mokbli *et al.*, 2018; Aicha *et al.*, 2019; Cadi *et al.*, 2021; Rincón-Cervera *et al.*, 2023). Table 2 summarized the plant organs, the country of origin, the class of bioactive compounds, and the most abundant compounds of *C. humilis*.

Table 2. Chemical composition of the extracts and essential oils of *Chamaerops humilis*

Country	Part	Extracts	Compounds groups	Compounds	References
Morocco	Leaves	Methanol extract	Phenol	9-hexadecenoic acid; Dasycarpidan-1-methanol; Spirost-8-en-11-one, 3-hydroxy-, (3a,5a,14a,20a,22a,25R) Glycine,N-[(3a,5a,7a,12a)-24-oxo-3,7,12-trioxycholan-24-yl]-, methyl ester; Lucenin 2; 9,12,15-octadecatrienoic acid, 2,3-bisoxypropyl ester, (z,z,z)-; 1,3-D-5-hexan-2-one-2,4-dinitrophenylhydrazone	Left *et al.*, 2013
Bulgaria	Seed	Methanol: water	Phenol	Quinic acid (19.9 mg/100g) Protocatechuic Acid (16.1 mg/100g) Salicylic Acid (8.4 mg/100g)	Rincón-Cervera *et al.*, 2023
Brazil				Quinic acid (5.6 mg/100g) Protocatechuic Acid (4.9 mg/100g) Salicylic Acid (7.4 mg/100g)	
Spain				Quinic acid (5.7 mg/100g) Protocatechuic Acid (1.5 mg/100g) Salicylic Acid (10.3 mg/100g)	
Bulgaria		Oil	Fatty acid	Oleic acid (39.5 g/100g dry seeds) Linoleic acid (24.1 g/100g dry seeds)	

Brazil				Oleic acid (46.5 g/100 g dry seeds) Linoleic acid (17.7 g/100 g dry seeds)	
Spain				Oleic acid (24.1 g/100 g dry seeds) Linoleic acid (42.9 g/100 g dry seeds)	
Portugal	Leaves	Methanol extracts	Phenol	Procyanidin isomers Luteolin-7-O-glucopyranosil-8-C-glucopyranoside Isoorientin and orientin 3- and 5-caffeoylquinic acid isomers	Coelho *et al.*, 2017
Spain	Seed	Methanol extract	Phenol	Tocotrienols Total tocopherols	Siles *et al.*, 2015
Tunisia	Seed	-	Phenol	Tocopherols δ-tocotrienol (31.91%) α-tocotrienol (29.37%) γ -tocopherol (20.16%) γ -tocotrienol (11.86%)	Nehdi *et al.*, 2014
			Fatty acid	Oleic acid (38.71%)	
Portugal	Leaves	Methanol extract	Phenol	3-O-cafeoylquinic acid 4-O-cafeoylquinic acid 5-O-cafeoylquinic acid Apigenin-8-C-glucoside Luteolin-8-C-glucoside	Gonçalves *et al.*, 2018
Egypt	Pollen grains	Petroleum ether	Sterols and triterpenes	Stigmasterol Cholesterol	Ahmed *et al.*, 2015
	Leaves			Campesterol β-sitosterol	
Morocco	Leaves	Essential oils	Terpenoids	Spathulenol (25.49 %) β-eudesmol (9.19 %) Caryophyllene oxide (5.23 %) α-santalol (3.72 %)	Khoudali *et al.*, 2016
Morocco	Seed	Hexane extract	Phytosterol	β-sitosterol Δ-5-Avenosterol Compesterol Stigmasterol Cholesterol	Eddahhaoui *et al.*, 2022
Italy	Seed	Hexane extract	Fatty acid	Oleic acid (478 g/kg oil) Linoleic (230 g/kg oil)	Giovino *et al.*, 2015
Tunisia	Seed	Hexane extract	Fatty acid	Oleic acid (44%) Linoleic acid (20%) Lauric acid (13%) Myristic acid (6.2%)	Mokbli *et al.*, 2018
Morocco	Seed	Hexane extract	Fatty acid	Oleic acid (32.55% to 43.29%) Linoleic acid (13% to16%) Lauric acid (21%)	Eddahhaoui *et al.*, 2022
Morocco	Fruit	Hexane fraction	Fatty acid	n-hexadecanoic acid (21.75%)	Cadi *et al.*, 2021
Egypt	Fruit	Petroleum ether	Heteropolys accharides	Mannose Galactose Arabinose	Dawood *et al.*, 2020

Phenols

Left *et al.* (2013) identified the presence of seven molecules with heteroatoms from methanolic extract of *C. humilis* collected from Benslimane (Morocco), these seven compounds are 9-hexadecenoic acid; dasycarpidan-1-methanol, acetate (ester); spirost-8-en-11-one, 3-hydroxy-, (3a,5a,14a,20a,22a,25R); glycine,N-[(3a,5a,7a,12a)-24-oxo-3,7,12-trioxycholan-24-yl]-, methyl ester; lucenin 2; 9,12,15-octadecatrienoic acid, 2,3-bisoxypropyl ester, (z,z,z)-; and 1,3-D-5-hexan-2-one-2,4-dinitrophenylhydrazone. One year later, Nehdi *et al.* (2014) identified the presence of tocol (tocotrienols, and tocopherols) with a value of 74 mg/100 g in *C. humilis* seed (Tunisia). δ-tocotrienol was the major tocol identified followed by α-tocotrienol, γ -tocopherol, and γ -tocotrienol (31.91%, 29.37%, 20.16%, and 11.86%, respectively). In addition, Siles *et al*. (2015) evaluated tocol (tocotrienols, and tocopherols) during germination of *C. humilis* seeds (Córdoba, Spain) and showed that the absence of tocopherol content in quiescent seeds and increased during germination. In contrast, the content of tocotrienol was constant and decreased during germination. Furthermore, total tocotrienols and total tocopherols content in embryo were 138 µg/g seed (99.4%), and 138 µg/g seed (0.6%), respectively. α-tocotrienol represented the major tocochromanols identified in the embryo with a value of 90%. The authors from this study reported that the essential cause of those difference in tocochromanol content were ecotype, genotype, storage conditions, and type of extraction. The quantification and identification of phenols compounds were established by liquid chromatography coupled with mass spectrometry (LC-ESI-MS/MS) on the fruits, rachis, and leaflets water, and methanol extracts of Algerian *C. humilis* (Bouhafsoun *et al*., 2018). The results of this study identified twenty-seven compounds (phenolic acids and flavonoids) with quinic, chlorogenic, and malic acids as a major component in fruits, and leaflets extracts of this plant. In addition, the major flavonoids identified were hesperidin, and rutin with a content of 35 µg analyte/g extract, and 33 µg analyte/g extract in leaflets methanolic extract, respectively (Bouhafsoun *et al*., 2018) (Bouhafsoun *et al*., 2017). In the same year, Coelho *et al*. (2017) evaluated the phenolic composition leaves methanolic extracts of *C. humilis* (Algarve, Portugal) using HPLC-DAD-MS. This phenolic identification led the identification of procyanidin isomers; luteolin-7-O-glucopyranosil-8-C-glucopyranoside; isoorientin and orientin; 3- and 5-caffeoylquinic acid isomers; luteolin-6-Cpentosyl- 8-glucopyranoside isomer; luteolin-di-glycoside derivate; tricin-7-O-neohesperidoside; apigenin-6,8-Cglucoside; luteolin-Orutinoside; and rutin. The leaf and pulp of *C. humilis* extracts (Algarve, Portugal) revealed the presence of favonoids and phenolic acids using HPLC-DAD (Gonçalves *et al*., 2018) (Gonçalves *et al*., 2018). 3-O-cafeoylquinic acid; 4-O-cafeoylquinic acid; and 5-O-cafeoylquinic acid (3.27 mg/g dry extract, 4.81 mg/g dry extract, and 2.97 mg/g dry extract; respectively) were identified in leaf extract. In the same extract (leaf extract), the flavonoids identified were apigenin-8-C-glucoside, and luteolin-8-C-glucoside with a value of 7.16 mg/g dry extract, and 3.88 mg/g dry extract, respectively. In 2021, the polyphenolic profile of *C. humilis* (North-West of Morocco) was determined using HPLC-PDA/MS. The ethyl acetate extract showed sixteen different compounds with ferulic acid as a major molecule with a value of 104.7 µg/g (Cadi *et al*., 2021). In addition, the methanol-water extract presented thirteen compounds with chlorogenic acid as a major component present (45.4 µg/g). Recently, Rincón-Cervera *et al*., (2023) identified and quantified total phenolic compounds of *C. humilis* seed collected in three city (Bulgaria, Brazil, and Spain) using HPLC-DAD. In terms of organic acids, all samples showed a highest value of quinic acid with a value at 19.9 mg/100g observed in *C. humilis* collected from Brazil.

Sterols and terpenoids

Different researches identified a wide range of sterols and terpenoids of *C. humilis* extracts and essential oils (Table 2). Ahmed *et al*. (2015) identified the presence of sterols and triterpenes of petroleum ether extract of *C. humilis* collected from Egypt using Gaz-liquid Chromatography (GLC). They identified the presence of stigmasterol, and cholesterol in the pollen grains and the presence of campesterol, and β-sitosterol in leaves of *C. humilis*. In 2016, Khoudali *et al*. (2016) identified twelve terpenoids from *C. humilis* essential oils of leaves (Benslimane, Morocco) using GC-MS and the main compounds reported were spathulenol, β-eudesmol, caryophyllene oxide, and α-santalol with a value of 25.49%, 9.19%, 5.23 %, and 3.72%, respectively. Six year later, Eddahhaoui *et al*. (2022) identified phytosterol in *C. humilis* (Rabat, Morocco) using GC and revealed the presence of β-sitosterol as a major sterol in oil using cold and hot extraction with a value of 55.38% and 57.79%, respectively. Δ-5-Avenosterol was the second most abundant phytosterol found in the pulp oil of *C. humilis* (17%), followed by compesterol (6%), stigmasterol, and cholesterol (Eddahhaoui *et al*., 2022).

Fatty acids

Giovino *et al*. (2015) identified the composition of fatty acid in seed of *C. humilis* in different region distributed in Sicily (Italy). Oleic acid and linoleic acid were the most represented fatty acid identified in *C. humilis* seed with a value of 478 g/kg oil, 230 g/kg oil, respectively. From this study, the authors reported that lipids content showed a significant correlation with climatic traits due to genotypic adaptation. One year later, the work of Nehdi *et al*. (2014) indicated the same majority compound in seed of *C. humilis* (Tunisia) (oleic acid with a value of 38.71%) followed by lauric acid, and linoleic acid (21.27%, and 15.15%, respectively). In 2015, Ahmed *et al*. (2015) identified the presence of fatty acid methyl esters with 10, 8, and 6 fatty acid in leaves, pollen grains, and fruits of *C. humilis* (Egypt), respectively. From this study, the authors reported that oleic acid was the main fatty acid in fruit and pollen (43.7%, and 13.6%, respectively). The effect of tocol in lipid peroxidation during germination of seeds of this plant (Córdoba, Spain) was evaluated by Siles *et al*. (2015) and reported that, during germination, the tocopherols was synthesized in seed of *C. humilis* to protect lipids from peroxidation events. Phytochemical analysis of the seeds of *C. humilis* hexane extract (Tunisia) using GC-MS revealed the presence of oleic acid, linoleic acid, lauric acid, and myristic acid as the main fatty acids (44%, 20%, 13%, and 6.2%, respectively) (Mokbli et al., 2018) (Mokbli *et al*. 2018). The analysis of the leaflets, rachis, and fruits of *C. humilis* (Oran, Algeria) revealed a total lipids content of 2.13%, 0.53%, 1.13%, respectively. However, further research are necessary for the identification of the fatty acid composition of this plant collected from Oran (Algeria) (Bouhafsoun *et al*., 2018). The work of Eddahhaoui *et al*. (2022) indicated the presence of monounsaturated fatty acids, and polyunsaturated fatty acids in seeds of *C. humilis* (Rabat, Morocco) using capillary gas chromatography (CGC). The fatty acids composition showed a high content of oleic acid (32.55% to 43.29%), followed by linoleic acid (13% to 16%), and lauric acid (21%). In the hexane fraction of this plant (North-West of Morocco), GC-MS analysis revealed the presence of 69 compounds with n-hexadecanoic acid as a major compound (21.75%) (Cadi *et al*., 2021). Recently, Rincón-Cervera *et al*. (2023) evaluated the fatty acid composition of *C. humilis* seed collected in three city (Bulgaria, Brazil, and Spain) using GC-FID. From this study, it appears that there were no significant differences found among those samples of *C. humilis* in terms of their fatty acid content. The fatty acids composition showed a high content of oleic acid (32.55% to 43.29%), followed by linoleic acid in all samples with a high content in *C. humilis* seed from Brazil (46.5 g/100 g dry seeds, and in *C. humilis* seed from Bulgaria (21.1 g/100 g dry seeds) respectively (Rincón-Cervera *et al*., 2023). Based on the analysis of the seeds, it was reported that *C. humilis* had interesting nutritional properties that make it suitable for oil production.

Polysaccharides

The polysaccharide composition of *C. humilis* extract has, to our knowledge, only been documented in one study by Dawood *et al*. (2020). In their study, Dawood *et al*. (2020) used a Dionex system (Dx-120) with an electrochemical detector (model ED40) to successfully identify and separate crude heteropolysaccharides from the fruit of *C. humilis* in Cairo, Egypt. From this study, the authors identified mannose, galactose and arabinose to be the primary monosaccharides.

Pharmacological investigation

Antioxidant activity

Several researchers investigated the potential of antioxidant capacity of *C. humilis* essential oil, oil, and aqueous and organic extracts (Table 3). In a study conducted by Bennaceur *et al.* (2010), the leaves aqueous extract of *C. humilis* cultivar from Algeria were investigated for their antioxidant effect using DPPH assay. The aqueous extract possessed a weak antioxidant capacity (IC50 = 94.55 μg/mL) compared to ascorbic acid (IC_{50} = 14.37 μg/mL). In 2013, the antioxidant effect of methanolic extract of *C. humilis* collected from Oran was studied using DPPH assay by Benmehdi *et al*. (2013). The methanolic extract showed a potent antioxidant capacity with an IC_{50} value of 180.71 µg/mL. Khoudali *et al*. (2014) tested the antioxidant effect of Moroccan *C. humilis* leaves collected from Benslimane using DPPH assay. Using different concentrations (5, 10, 15, 25, 50, and 60 µg/mL), the methanol extract showed an important antioxidant effect similar to tocopherol (IC_{50} = 24.5 µg/mL, and IC_{50} = 26 µg/mL, respectively). In the same year, another study evaluated the antioxidant capacity of *C. humilis* aerial parts (Morocco) using different methods including TBARS, DPPH, ABTS, chelating metal ions, and hydroxyl radical scavenging activity. The ethanol extract showed interesting free radical scavenging effect for ABTS and DPPH assays (IC_{50} = 0.035±0.079 mg/mL, and IC_{50} = 0.035±0.061 mg/mL, respectively) while, using TBARS assay, the ethanol extract was IC_{50} = 2.163±0.120 mg/mL. In another study, numerous antiradical potential (DPPH, FRAP, and BCB) different extracts of *C. humilis* leaf, and fruit (Algeria) was studied by Belhaoues *et al*. (2017). From this study, the authors reported that fruits and leaves of ethyl acetate extract has the highest antioxidant activity using DPPH assay with an IC_{50} value of 0.76 mg/ml, and 0.12 mg/mL, respectively. Another group conducted by Coelho *et al*. (2017) demonstrated that methanol extract of *C. humilis* leaves collected from Algarve (South Portugal) showed a potent antiradical activity using DPPH, and ABTS assays (IC_{50} = 0.455 mg/mL, IC_{50} = 0.354 mg/mL, respectively). One year later, Gonçalves *et al*. (2018) studied the antioxidant effect of *C. humilis* leaves and ripe fruits collected from the same region (Algarve, South Portugal). They evaluated *in vitro* the antioxidant effect of methanol extract using ABTS, DPPH, and FRAP assays and showed that seeds methanol extract demonstrated a potent antiradical effect against ABTS, DPPH, and FRAP with a value of IC_{50} = 1440.42 µmol TE/g extract, IC_{50} = 81.28 µg/mL, and IC_{50} = 1142.46 µmol AAE/g extract, respectively (Gonçalves *et al*., 2018). In the same year, Mokbli *et al*. (2018) evaluated *in vitro* the antioxidant capacity of seed oil extracted from *C. humilis* var. humilis collected from Tunis (Tunisia) and reported that DPPH and ABTS assays were 4.3 mM TEAC/g DW, and 210 µM TEAC/g DW, respectively. In 2019, Aicha *et al*. (2019) investigated the Algerian *C. humilis* methanol and water extracts of fruits and leaves for their antiradical effect using CUPRAC (cupric reducing antioxidant capacity) and ABTS assays. The authors reported that water fruit extract has a potent CUPRAC assay with a value of 0.53 ± 0.50 µg/mL. In addition, at 100 µg/mL, the methanol leaves extract reduced 50.11% of radical using ABTS radical-scavenging activity. Dawood *et al*. (2020) investigated the antioxidant capacity of *C. humilis* (Egypt) polysaccharides extracted from fruit using FRAP and DPPH scavenging activity and showed an IC_{50} = 0.44 µmol Fe++/g, and IC_{50} = 630.0 µg/mL, respectively. From this study, the authors suggested that antiradical effect of polysaccharides was related to hydroxyl group of the monosaccharide unit can donate the proton (Dawood *et al*., 2020). Eddahhaoui *et al*. (2022) studied the antioxidant properties of methanol extract of *C. humilis* root (Morocco) using FRAP, ABTS, and DPPH assay and reported a radical scavenging activities with a IC_{50} value of 279.61 ± 4.90 µg/mL, 37.65 ± 0.66 µg/mL, and 1.99 ± 0.02 µg/mL, respectively. In the same year, Cadi *et al*. (2021) studied *in vitro* the radical scavenging activities of methanol-water and ethyl acetate extracts using DPPH assay and showed an IC_{50} value of 0.4 ± 0.1 mg/mL, and 1.9 ± 0.1 mg/mL, respectively. Recently, the methanol extracts of fruits and seeds of *C. humilis* (Morocco) obtained by maceration and Soxhlet have been studied *in vitro* for their antioxidant effect using FRAP, ABTS, and DPPH assays (Eddahhaoui *et al*., 2022). From this study, the seeds methanol extract of this plant a potent antioxidant effect with an IC_{50} value of 137.55 ± 0.85 µg/mL, 22.14 ± 0.60 µg/mL, and 0.99 ± 0.01 µg/mL, respectively. The authors prove that the type of extraction influences the result of the antioxidant effect and reported that maceration present the active ingredient (Eddahhaoui *et al*., 2022). In 2021, Babili *et al*. (2022) investigated the antioxidant properties of *C. humilis* (Morocco) using two methods, spectrophotometric DPPH assay, and colorimetric DPPH assay and showed an EC50 value of 0.21 g/L and 0.208 g/L, respectively.

Table 3. Antioxidant activity of *Chamaerops humilis*

Use part	Extracts	Used method	Key results	References
Leaves	Methanol extract	ABTS	IC50 = 100 µg/mL	Aicha *et al*., 2019
Fruit	Water extract	CUPRAC	IC50 = 0.53 ± 0.50 µg/mL	
Seeds	Methanol extract	FRAP	EC50 = 137.55 ± 0.85 µg/mL	Cadi *et al*., 2021
		ABTS	IC50 = 22.14 ± 0.60 µg/mL	
		DPPH	IC50 = 0.99 ± 0.01 µg/mL	
Pulp	Methanol extract	FRAP	EC50 = 436.75±1.08 µg/mL	
		ABTS	IC50 = 228.90±0.22 µg/mL	
		DPPH	IC50 = 86.06±1.07 µg/mL	
Root	Methanol extract	FRAP	IC50 = 279.61±4.90 µg/mL	Eddahhaoui *et al*., 2022
		ABTS	IC50 = 37.65±0.66 µg/mL	
		DPPH	IC50 = 1.99±0.02 µg/mL	
Fruit	Crude polysaccharides	FRAP	IC50 = 0.44 µmol Fe++/g	Dawood *et al*., 2020
		DPPH	IC50 = 630.0 µg/mL	
Leaves	Ethyl acetate extract	DPPH	IC50=0.12 mg/mL	Belhaoues *et al*., 2017
Fruits	Ethyl acetate extract	DPPH	IC50=0.76 mg/mL	
Leaves	Methanol extract	DPPH	IC50 = 0.455 mg/mL	Coelho *et al*., 2017
		ABTS	IC50 = 0.354 mg/mL	
Leaves	Methanol extract	DPPH	IC50 = 346.08 µg/mL	Gonçalves *et al*., 2018
		ABTS	IC50 = 593.23 µmol TE/g	
		FRAP	IC50 = 434.34 µmol TE/g	
Peel	Methanol extract	DPPH	IC50 = 180.97 µg/mL	
		ABTS	IC50 = 550.08 µmol TE/g	
		FRAP	IC50 = 580.29 µmol TE/g	
Pulp	Methanol extract	DPPH	IC50 = 325.03 µg/mL	
		ABTS	IC50 = 351.06 µmol TE/g	
		FRAP	IC50 = 369.56 µmol TE/g	
Seed	Methanol extract	DPPH	IC50 = 81.28 µg/mL	
		ABTS	IC50 = 1440.42 µmol TE/g	
		FRAP	IC50 = 1142.46 µmol TE/g	
Seed	Oil	DPPH	IC50 = 4.3 mM TEAC/g DW	Mokbli *et al*., 2018
		ABTS	IC50 = 210 µM TEAC/g DW	

Antibacterial activity

The first antibacterial effect of *C. humilis* essential oil was conducted in 2013 by Hasnaoui *et al*. (2013). The antibacterial activities of *C. humilis* essential oil was carried out against *Pseudomonas aeruginosa*, *Listeria monocytogenes*, *Escherichia coli*, *Staphylococcus aureus* and *Bacillus subtilis* using technical agar diffusion Mueller Hinton, and micro-dilutions method. From this study, the authors reported that *C. humilis* essential oil have an inhibitory effect at a concentration of 250 mg/ml for *P. aeruginosa*, *S. aureus*, and *E. coli*. Belhaoues and co-workers (2017) studied the inhibition of *C. humilis* leaf and fruit organic extract (dichloromethane, ethyl acetate, n-butanol, and water) (collected from Algeria) against both Gram+ and Gram- bacteria (*S. aureus, E. coli, P. aeruginosa, Klebsiella pneumonia, Enterococcus faecalis, and Salmonella typhimurium*) using agar disc diffusion technic and minimum inhibitory concentrations (MIC) (Table 4). At 20 mg/mL, the inhibition zone of ethyl acetate extract showed an inhibition zone of 20 mm and 18 mm against *K. pneumonia*, and *P. aeruginosa*, respectively while *E. coli* showed a less sensitive effect with 13 mm zone of inhibition. Furthermore, the authors reported that ethyl acetate showed the highest MIC against *E. faecalis* with a value of 0.25 mg/mL. Less activity has been reported for Gram- bacteria. This can be explain by the permeability barrier of the bacteria due to their protein cell wall and extra lipopolysaccharide (Bouyahya *et al*., 2017; El Idrissi *et al*., 2020).

Table 4. Antibacterial activities of *Chamaerops humilis* extracts was determined by agar well diffusion (Ø mm)

Plant part used	Extract tested	Method used	Tested strains	Key results	References
Leaf	Dichloromethane	Disc diffusion method	*Pseudomonas aeruginosa*	8.33 mm	Belhaoues *et al*., 2017
			Salmonella typhimurium	10.00 mm	
			Klebsiella pneumonia	13.33 mm	
	Ethyl acetate		*Escherichia coli*	13.33 mm	
			Pseudomonas aeruginosa	18.33 mm	
			Enterococcus faecalis	16.33 mm	
	n-butanol		*Escherichia coli*	11.33 mm	
			Pseudomonas aeruginosa	11.66 mm	
			Staphylococcus aureus	12.66 mm	
	Water		*Pseudomonas aeruginosa*	13.66 mm	
			Klebsiella pneumonia	12.33 mm	

Ø: Zone of inhibition

Anticholinesterase activity

According to the available literature, the anticholinesterase activity of *C. humilis* has only been investigated in two studies, Gonçalves *et al*. (2018) and Aicha *et al*. (2019). In this context, the capacity of methanolic extracts of *C. humilis* from different parts (seeds, leaves, pulp, and fruit peel) from Portugal was evaluated *in vitro* for their neurodegenerative effect against acetylcholinesterase, and butyrylcholinesterase (Gonçalves *et al*., 2018*)* (Table 5). The methanolic extracts of peel and seed exerted strong inhibition of acetylcholinesterase (IC_{50} = 653.68 µg/mL and 660.16 µg/mL, respectively), and butyrylcholinesterase (IC_{50} = 701.54 and 304.86 µg/mL, respectively). One year later, Aicha *et al*. (2019) investigated *in vitro* the anticholinesterase inhibition assay of methanol and water extracts of fruits and leaves extracts of *C. humilis* using a microplate-reader assay. Water and methanol fruit extract were active for butyrylcholinesterase inhibition with a value of 30.19 ± 0.56%, and 31.65 ± 0.37%, respectively. However, all extracts were not active against anticholinesterase. The authors indicated that *C. humilis* could be beneficial in the Alzheimer's disease treatment.

Table 5. Anticholinesterase inhibition of *Chamaerops humilis*

Part used	Extract tested	Methods used	Keys results	References
Peel	Methanolic extract	*In vitro* butyrylcholinesterase assay	IC50 = 701.54 µg/mL	Gonçalves *et al*., 2018
		In vitro acetylcholinesterase assay	IC50 = 653.68 µg/mL	
Seed	Methanolic extract	*In vitro* butyrylcholinesterase assay	IC50 = 304.86 µg/mL	
		In vitro acetylcholinesterase assay	IC50 = 660.16 µg/mL	
Fruits	Methanol extract	*In vitro* butyrylcholinesterase assay	31.65 ± 0.37 %	Aicha *et al*.,2019
		In vitro acetylcholinesterase assay	NA*	
	Water extract	*In vitro* butyrylcholinesterase assay	30.19 ± 0.56 %	
		In vitro acetylcholinesterase assay	NA	
Leaves	Methanol extract		NA	

	Water extract	*In vitro* acetylcholinesterase and butyrylcholinesterase assay		

*NA: Not active

Antidiabetic activity

Gaamoussi *et al*. (2010) studied *in vivo* the antidiabetic effect of leaves aqueous extract of *C. humilis* (Taounate, Morocco) as an acute and sub-chronic hyperglycemia model. At 10 mg/kg, a single dose of leave aqueous extract of *C. humilis* decreased plasma glucose levels with a value of 6.88 mmol/L compared to initial value (12.04 mmol/L) after 4 hours of the treatment. Furthermore, daily oral administration of leave aqueous extract of *C. humilis* reduced significantly plasma glucose levels from 12.04 mmol/L to 4.84 mmol/L after 30 days of treatment. In this study, the authors suggested that the aqueous extract of *C. humilis* exhibited several mechanism of action, including b) enhanced secretion of insulin from the β-cells of the pancreas, a) direct insulin-mimetic effect, and c) increased tissue uptake of glucose by enhancement of insulin sensitivity (Gaamoussi *et al*., 2010). In 2021, Attaallah *et al*. (2021) evaluated *in vitro* the enzymatic inhibition of root aqueous extract of *C. humilis* against α-amylase and α-glucosidase enzymes. They showed that aqueous extract of *C. humilis* (roots) inhibited α-amylase and α-glucosidase with a value of IC50 = 5.9 mg/mL, and IC50 = 4.34 mg/mL, respectively. Recently, Lachkar *et al*. (2022) studied *in vitro* the antidiabetic activity aqueous (decoction, infusion, and maceration) and organic extracts (ethanolic extract, ethanolic maceration, chloroformic extract, chloroformic maceration, hexanic extract, and hexanic maceration) from the leaves of *C. humilis* against α-amylase, α-glucosidase, and β-galactosidase. A higher inhibitory activity was observed for the aqueous decoction of this plant against α-amylase, α-glucosidase, and β-galactosidase with a value of IC_{50} = 1.781 105 μg/mL, IC_{50} = 2.540 102 μg/mL, and IC_{50} = 7.118 102 μg/mL, respectivement. Using organic extract, the ethanolic extract showed a highest inhibitory activity against α-amylase (IC_{50} = 8.902 103 μg/mL), α-glucosidase (2.216 102 μg/mL), and β-galactosidase (2.003 102 μg/mL). In addition to this activity, the authors studied the correlation between the chemical composition and the antidiabetic activity of *C. humilis* leaves. It has been showed a correlation between β-galactosidase inhibitory activity and the content flavonoids (r = 0:6345) and of catechic tannins (r = 0:7092). From this study, the authors suggested that the antidiabetic activity is attributed to the active ingredients of different chemical nature (Lachkar et al., 2022). In addition, the formation of hydrogen bonds between the residues of the enzyme binding site and the hydroxyl groups of bioactives compounds explain the inhibitory α-amylase effect (Sales *et al*., 2012).

Antilithiasic activity

In a study conducted by Beghalia *et al*. (2008), the antilithiasic effect of *C. humilis* sheath aqueous extract from Algeria was tested on synthetic urine by simulating oxalate crystallisation at different stages, including nucleation, development, and aggregation. Using aqueous extract of *C. humilis*, the inhibition of calcium oxalate crystallization was observed only for growth phase. In the same year, the same research team studied in vitro the antilithiasic effect of *C. humilis* bark (Algeria) using the same method. *C. humilis* bark aqueous extract inhibited *in vitro* the formation of calcium oxalate crystallization only for growth phase (Beghalia *et al*., 2008).

Antitumoral activity

Data on the antiproliferative effects of *C. humilis* are scarce. In 2020, Dawood *et al*. (2020) evaluated the antitumoral effect of a heteropolysaccharide isolated from *C. humilis* (Egypt) using HepG2 and MCF-7 human cell lines. This heteropolysaccharide was constituted with galactose, mannose, and arabinose. Using concentrations between 6.25 and 100 μg/ml, the anticancer activity showed IC_{50} values of 38.00 and 64.4 μg/ml in HepG2 and MCF-7 assays, respectively. Compared to standard aforesaid 5.6 μg/ml in MCF-7 assays and 5-

fluorouracil 7.9 µg/ml in HepG2 (Dawood *et al*., 2020). Two years later, the antimitotic effect was evaluated *in vitro* using biotest with *Lepidium sativum*. The rootlet length of seed germination of *L. sativum* was measured in a medium containing the aqueous and organic extracts of *C. humilis* (Taza, Morocco) (Lachkar *et al*., 2022). From this study, the authors reported that the decocted extract and the ethanolic extract showed a higher antimitotic activity with a value of IC_{50} = 9.624 103 µg/mL, and IC_{50} = 5.638 103 µg/mL, respectively. In addition, the authors reported that the high content of total polyphenols, flavonoids, and catechic tannins of *C. humilis* leaves in explain the antimitotic activity of those extracts. Recently, the antitumor effect of the hydroalcoholic extract of *C. humilis* leaves (Almería, Spain) against the HT-29 colorectal cancer cell line by (Rincón-Cervera *et al*. (2023) using MTT assay. It showed that this extract exhibited the most active antiproliferative activity with 47.6% of cell viability at 1600 µg/mL. No significant relation with phenolic composition and seed extracts was attributed to the cancer cell growth. In this condition, the authors suggested a synergistic action of several compounds in these extracts. Furthermore, in-depth *in vivo* tests should be conducted to investigate the mechanistic pathways responsible for the action.

Anti-inflammatory activity

In a single study conducted in 2014, researchers investigated the potential anti-inflammatory benefits of an ethanolic extract of the leaves of *C. humilis*. Indeed, Miguel *et al*. (2014) studied *in vitro* the capacity of *C. humilis* ethanolic extract (Morocco) to inhibit lipoxygenase. The leaves ethanolic extract exerted relevant antilipoxygenase activity with an IC_{50} = 0.616 ± 0.030 mg/ml. From this study, the authors reported a correlation between phenolic content and scavenging free radicals assayed (ABTS, hydroxyl, and DPPH) with the capacity to inhibit lipoxygenase.

Hypolipidemic effect

Gaamoussi *et al*. (2010) studied *in vivo* the hypolipidemic effect of leaves aqueous extract of *C. humilis* (Taounate, Morocco) using hypercaloric diet induced hyperlidemia as sub-chronic hypolipidemic model. In the sub-chronic study, using the aqueous extract at 10 mg/kg for 30 days, the body weight has been significantly reduced compare to positive control, taurine (from 241 g to 165 g; $P<0.001$, and from 221 g to 189 g; $P<0.05$, respectively). In addition, plasma triglyceride levels has been significantly decreased compare to taurine (From 1.15 mmol/L to 0.37 mmol/L, and from 1.03 mmol/L to 1.08 mmol/L, respectively).

Cholesterol effect

Only one investigation (Gaamoussi *et al*., 2010) was conducted to evaluate *in vivo* the hypolipidemic effect aqueous extract of *C. humilis* leaves from Taounate, Morocco. The study utilized meriones shawi rats with hypercaloric diet-induced hyperlipidemia (Gaamoussi *et al*., 2010). After a duration 30 days, the aqueous extract of *C. humilis* demonstrated a significant reduction in triglycerides and total cholesterol Levels. Specifically, the triglyceride levels decreased from a baseline of 1.15 ± 0.17 mmol/L to 0.37 ± 0.03 mmol/L, while the total cholesterol levels decreased from 3.46 ± 0.21 mmol/L to 0.62 ± 0.02 mmol/L.

Antityrosinase activity

In their study, Gonçalves *et al*. (2018) examined the tyrosinase inhibition properties of various parts of *C. humilis*, including leaves, peel, pulp, and seeds. The plant samples were collected from the Algarve region in South Portugal. According to the findings of this study, the authors reported that the seed methanolic extract was the most potent inhibitor of tyrosinase with an IC_{50} value of 268.97 µg/mL while the leaves extract presented the lowest inhibition of this enzyme (IC_{50} =1633.62 µg/mL) compared to kojic acid used as standard (IC_{50} = 49.23 µg/mL). In addition, Gonçalves *et al*. (2018) reported a significant correlation between the abundance of total flavonoids content and tyrosinase inhibition ($r = 0.899$, $p < 0.01$) (Gonçalves *et al*., 2018).

Thus, total flavonoids content may play an important role in this enzymatic activity. However, more in-depth studies should be carried out, in particular the fractionation of flavonoids to determine the active molecule(s) responsible for this activity.

Corrosion activity

Anticorrosion activity of *C. humilis* extracts has been examined in two distinct studies conducted by Khoudali *et al*. (2014) and Fekkar *et al*. (2020). In 2014, Khoudali *et al*. (2014) evaluated the effect of methanol leaves extracts collected from Morocco using electrochemical test and evolution of the free potential techniques. Using methanol leaves extracts of *C. humilis* at 0.5 g/L, the anticorrosion effect showed an inhibition efficiency of 45% using chloride ions. In the study conducted by Fekkar *et al.* (2020), the effect of ethanol and hexane extracts of *C. humilis* fruits on the mitigation of mild steel corrosion in a 1 M HCl solution was investigated. Based on the results of this study, the authors reported that exhibited that ethanol and hexane extracts of *C. humilis* an anticorrosion property in a dose-dependent manner and showed an inhibitor effect of 88% and 80% at concentrations of 1 g/L, respectively.

Oxide film formed

Using electrochemical techniques, Benmehdi *et al*. (2013) evaluated the methanolic extract of *C. humilis* (Benslimane, Morocco) on the protective effect of the oxide film formed on the reinforcement steel surface in alkaline solution (pH > 13). At 0.5 g/L, the methanol extract showed an inhibition effect of 42% at 25 °C. From this research, the authors reported that donor-acceptor interactions are the mechanism of pathway by which molecules exert their oxide film inhibition. In addition, organic molecule polarity, size, and number of functional groups influenced the strongest bonding or rate of adsorptions of inhibitor compounds into the surface (Akbarzadeh *et al*., 2011).

Oxidative stability

Oils oxidative stability is an essential factors used by manufacturers to select (Pullen and Saeed, 2012). Oxidative stability of *C. humilis* var. humilis seeds oil collected from Tunisia were evaluated using a Professional Rancimat apparatus (Mokbli *et al*., 2018). According to the findings of this investigation, the oxidative stability index (OSI) of the oil was 16 h at 110 °C. In addition, *C. humilis* var. humilis seeds oil showed a low percentage of polyunsaturated fatty acid (PUFA) (20%) (Mokbli *et al*., 2018). According to Shahidi and Zhong (2005), this explains why this oil has the best oxidative stability. In addition, the authors reported that the strong resistance to oxidative rancidity is due to the more saturated character of HSO (Mokbli *et al*., 2018). Furthermore, the significant presence of tocols and carotenoids in the oil derived from *C. humilis* seeds makes it suitable for use in the fields of nutritional sciences, cosmetics, domestic cookery, and deep-frying.

Toxicity effect

Few studies have investigated the toxicity of *C. humilis*. In fact, the in vivo effects of aqueous and organic extracts of this species have only been investigated once (Lachkar *et al*., 2022). With an LD_{50} of 5 g/kg, both the decoction and the ethanolic extract of C. humilis were shown to be rather non-toxic.

Conclusions

In this review, we have described the ethnobotanical use, phytochemistry, biological activities, and the toxicity of *C. humilis*. The medicinal use of *C. humilis* varies among different countries, which suggests that the local population influences its uses. This diversity in medicinal use highlights the cultural significance and traditional knowledge associated with this plant. The phytochemical composition of *C. humilis* exhibited a wide range of diversity, encompassing chemical constituents belonging to multiple classes such as phenols, sterols, terpenoids, polysaccharides, and fatty acids. These compounds contribute to its medicinal properties. Further studies can focus on isolating and testing specific phytocompounds to better understand their individual contributions to the plant's therapeutic potential. The pharmacological properties of *C. humilis* have been studied and show promise in various areas including antimicrobial, anti-inflammatory, antioxidant, and anti-diabetic activities. These pharmacological properties make *C. humilis* a potential candidate for further exploration in drug development and natural medicine. However, there is limited research on the mechanistic investigations of the reported pharmacological effects of *C. humilis*. Thus, further research is needed to elucidate the detailed mechanisms of action for each reported pharmacological effect. This could involve studying the specific bioactive compounds present in *C. humilis*, their interactions with cellular and molecular targets, and the signalling pathways involved. These investigations are essential for a comprehensive understanding of the therapeutic potential of *C. humilis* extracts and essential oils and for the development of targeted therapies based on these natural products.

Authors' Contributions

The author read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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