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CAPPARIS ZEYLANICA LINN: A COMPREHENSIVE REVIEW

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Capparis zeylanica, Phytochemicals, Biological activity, Antioxidant, Flavonoids, Phenolic acid etc

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ABSTRACT: *Capparis zeylanica Linn* (*Capparidaceae*), commonly known as "wild caper" is a plant species found in tropical regions. It is known as culinary and medicinal uses. The abstract of a comprehensive study on this plant might discuss traditional uses, phyto-chemical composition. Also, future perspectives about plant: is a computational technique used to study the interaction between small molecules, such as active constituent or ligands and specific target proteins or receptors. When it comes to *Capparis zeylanica*, morphological and pharmacological studies might involve exploring how the plants bioactive compounds interact with certain biological targets. These studies can help in understanding the potential medicinal properties of *Capparis zeylanica* and its ability to act on several wide diseases. The results of such detailed studies can provide insights into the plants therapeutic potential.

INTRODUCTION: From ancient times, plant derived medicines; drugs were used for treatment or to cure diseases. Plants are vital sources of active constituents for developing new drugs. In various part of India like Tamil Nadu, *Capparis zeylanica* Linnit has been found and throughout the major parts of Bangladesh, Pakistan the shrub of these plants also found [1]. These plants belong to family '*Capparidaceae'*. These plants are commonly known as wagati, Ardanda, govindphal, asadhua in different parts of India. *C. zeylanica* contains various active constituents which possess Antimicrobial, anticance, to treat gastric lesion, antiproliferation, antioxidant, immunostimulant, antidote to snake bite, antipyretic effect, small pox, cholera, demulcent, to cure swelling, expectorant cytotoxic activities *etc*.

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Traditionally it is used as vegetable. *C. zeylanica* has been reported as 'Rasayana' ('Rasa' = plasma, 'Ayaa' = path) in Ayurveda system of medicines. According to Ayurveda medicine system, are said to prevent aging and promote longevity, re-established youth, generate power, improve digestive functions, support mental clarity, vital energy, memory, and prevent disease

Taxonomical Classification:

a) **Kingdom:** Plants

b) **Subkingdom:** Tracheobionta, vascular plants

c) **Super division:** Spermatophyte, seed plants

Division: Anthophyta

Class: Magnoliopsida

Subclass: Dilleniidae

Order: Capparidales

Family: Capparidaceae

Phytochemical Screening: These plant shown the list of presence of alkaloids, flavonoids, saponins, tannins, E-octate-7en-5-ynoic acid, syringic, vanillic, ferulic acid, p-coumanic acid, fatty acids in whole plant, leaves and seeds contain Beta-carotene, thioglycoside, n-tricortane, Alpha-amyrin. The elemental analysis gives 11 essential elements except chloride. Those 11 elements are namely C, O, Mg, Al, Si, Cl, K, Ca, Fe, Cu, Zn. Recently drug discovery using molecular docking, molecular modeling, computational chemistry or methods of preparation or extraction are still proves the invaluable sources of medicinal treatment for human. *C. zeylanica* were selected based on the ethnomedicinal information refers to the traditional medical practice concerned with the cultural interpretation of health, illness and diseases. For the extraction process different solvents were used, like aqueous, petroleum ether, ethyl acetate, chloroform or methanol. The modern phyto-constituent screening of the plant shown the presence of flavonoids or fatty acids, alkaloids, saponin glycosides, proteins and carbohydrates. In leaves flavonoids shows antioxidant activity, antiulcer, anticancer, anti-inflammatory or antimicrobial activities. The root of this plant contains phyto-sterol, acids and mucilage. From the chloroform extract of roots of *C. zeylanica a* new fatty acidE-octate-7-en-5-yonic [2]. Traditionally extract of active constitute of plant was done in water. For the extraction of active constituent commonly powdered parts of the plant were placed in Soxhlet apparatus and extracted successively by using suitable solvent mentioned above. Near about 90% known active constituent are isolated. Further extract was tested for acute toxicity for animals and found that organic solvents with low polarity have less safety margin than that of the highly polar and aqueous extract [3].

Chemical Constituents: Advancement in traditional drug discovery is using molecular docking, molecular modeling, computational chemistry will have great future and proves the invaluable sources of medicinal treatment for human. *C. zeylanica* were selected based on the ethnomedicinal information refers to the traditional medical practice concerned with the flavonoid shows antioxidant activity, antiulcer, anticancer, Anti-diarhea, anti-inflammatory or antimicrobial activities [4].

The genus *Capparis*, comprising approximately 250 known species, has drawn considerable attention for its nutritional and therapeutic potential. Among these species, *C. spinosa*, *C. ovata*, and *C. decidua* have been the subjects of extensive investigation, specifically focusing on their edible and medicinal properties. Traditional uses involve various parts of these plants; including fruits, stem bark, and roots, which have been employed for both nutritional and medicinal purposes. Extracts derived from the fruits, flowers, roots, and root bark have been identified as potent agents with a wide array of beneficial effects, including anti-atherosclerotic, anti-hypertensive, anti-inflammatory, analgesic, anti-asthmatic, anti-hyperlipidemic, hepatoprotective, anti-bacterial, and anti-fungal properties [5].

The therapeutic efficacy of *Capparis* species is attributed to the presence of bioactive compounds, such as natural antioxidants (flavonoids, rutin), natural sugars, alkaloids, terpenoids, vitamins and minerals, and antimicrobial agents. These components contribute to the diverse medicinal properties exhibited by the extracts of Capparis species.

In light of the existing literature on the nutritional and medicinal potential of *Capparis* species, there is a compelling need for a comprehensive review article. This article aims to fill the existing information gap by exploring the phytochemicals, nutritional content, folk medicinal uses, and biological attributes of key *Capparis* species [6]. Notably, the focus will be on the most commonly grown and utilized species, such as *C. spinosa*, *C. ovata* and *C. decidua*, among others. By undertaking this review, the manuscript aims to provide a detailed profile of high-value nutrients and bioactives, shedding light on the pharmaceutical, medicinal, and biological activities associated with different parts of these significant *Capparis* species. As of now, there is a notable absence of such a comprehensive review in the available literature, making this manuscript a valuable contribution to the understanding of the multifaceted properties of Capparis plants [7].

Botanical Characteristics and Geographical Range: *Capparis spinosa*, recognized for its exceptional drought tolerance, originates from

Western and Central Asia. In recent years, it has become a focus of widespread cultivation in Mediterranean countries, including France, Spain, Italy, Morocco, and Algeria. Beyond cultivated lands, its presence in archaeological sites in these countries underscores its historical significance as a wild medicinal plant. Globally, Spain leads as the principal producer of Caper, closely followed by Morocco, Italy, and Turkey, with Greece also contributing to production. Italy, for instance, currently yields 140,000 kg/year of *C. spinosa* fruits across 1000 ha, while Spain's cultivation spans 2600 ha [8].

Noteworthy is *C. spinosa* adaptability to arid climates, making it well-suited for cultivation in regions with limited water availability. In Pakistan, the species is widely distributed in dry and arid regions, while in India and Pakistan, the flowering season spans from March to May. In the Mediterranean basin, the flowering period occurs from July to August. Intriguingly, certain regions in Pakistan witness two flowering seasons, one from March to May and the second from September to early November [9].

The flowers of *C. spinosa* are distinctive, with pink–red petals, and they exhibit a nocturnal blooming pattern, opening at dusk or during the night. The fully expanded flowers last merely an hour before shedding. Notably, the flowers lose turgidity within 12–16 hours, with their abscission and nectar secretion intricately linked to temperature variations. Nectar secretion is particularly notable under comparatively lower nocturnal temperatures, emphasizing the nuanced biological rhythms of this plant. This detailed insight into the geographical distribution and cultivation practices of *C. spinosa* highlights its adaptability and significance in both historical and contemporary contexts [10]. *Capparis decidua*, widely distributed in Pakistan, India, Saudi Arabia, tropical Africa, Egypt, and Deccan, is a resilient small shrub adapted to arid landscapes with temperatures ranging from 18°C in winter to 48°C in summer. This species, reaching a height of 5 meters, features slender branches and strategically designed glabrous leaves or leafless spikes to minimize water loss in extreme drought conditions. With a tap root system capable of reaching depths of up to 4 meters and secondary roots near the surface, *C. decidua* efficiently extracts water from the ground, even during light rain showers. The deciduous nature of its leaves on younger shoots reflects a resource-conserving strategy, showcasing its ability to thrive in challenging environments and abandoned dry lands [11].

The mature shoots of *Capparis decidua* are characterized by sharp, straight, and diminutive spines instead of leaves. Initially greenish, the shoots transform into yellow or whitish-grey bark as they mature. New leaves emerge from January to November, featuring a sessile structure with very short petioles, pointed tips, and small dimensions (2–12 mm in length and 1–3 mm in width). Flowering occurs predominantly from March to April, concluding in May in Pakistan, with older branches bearing most of the flowers, while new branches exhibit fewer flowers along the spine axis. Fruiting season variations exist globally, such as March to April in Egypt and Morocco and May to July in Pakistan, coinciding with significant flowering two weeks before the Monsoon season. The small, fleshy fruits resemble cherries, initially green, transitioning to pink as they ripen and eventually turning black when dried. Widely distributed in Pakistan, *C. decidua* thrives in dry regions, encompassing wild areas in South Punjab, Baluchistan, and Sindh province [12].

Capparis ovata is documented in arid regions of Turkey, Greece, Cyprus, and India, displaying xerophytic characteristics and resilience to both drought and salinity. Recently introduced for commercial purposes, particularly for its pickled flower buds in Morocco, Spain, and Italy, *C. ovata* also serves as an effective measure against soil erosion in plain and desert areas. Thriving in temperatures exceeding 40°C and withstanding annual rainfall up to 350 mm, this perennial shrub boasts thick and deep hairy roots; reaching depths of 50–100 cm. Beyond *C. spinosa, C. decidua, and C. ovata*, other *Capparis* species have garnered attention for their pharmaceutical and traditional medicinal applications. Notable species include *C. sepiaria, C. tomentosa, C. humilis, C. sikkimensis, and C. zeylanica*. Additionally, investigations have explored *C. moonii, C. atamisquea, C. yco,* and *C. flexuosa* due to their traditional use in folk medicine [13]. All Caper species, including those studied and those investigated for their folk medicine applications, exhibit high adaptability to drought conditions, making them particularly suitable for cultivation in Third World countries. The cultivation of these species not only addresses environmental concerns but also holds the potential to augment income and livelihoods for growers.

Phytochemicals: The examination of the qualitative and quantitative composition of phytochemicals in a specific plant is instrumental in understanding its biological, nutritional, and pharmaceutical properties. Therefore, the analysis of biochemical profiles and bioactive compounds in a food or medicinal plant is crucial for exploring its potential Nutraceuticals and pharmaceutical applications. In this context, Caper species have undergone investigation as valuable reservoirs of various high-value components and biologically active compounds. The following section delves into the discussion of essential classes of bioactive reported in different species of *Capparis* [14].

Caper roots have yielded a variety of alkaloids and phytosterols, including spermidine alkaloid (A.), isocodonocarpine (B.), capparisine (C.), capparidisine (D.), capparine, and capparinine. The dry root bark of *C. decidua* has proven to be a source of significant alkaloids, with compounds like spermidine, isocodonocarpine, capparine, capparinine, codonocarpine (E.), capparisine (F.), cadabacine-26-O--d-glucoside, and capparipine-26-O--d-glucoside being isolated. Additionally, roots of *C. spinosa* have provided two spermidine alkaloids, capparispine-26-O--d-glucoside and cadabacine-26-O--d-glucoside (G.). Other alkaloids, such as N-acetylated spermidine alkaloids, 15-N-acetylcapparisine (H.), and 14-N-acetyl isocodonocarpine (I.), have been investigated from the root bark of *C. decidua*. These findings underscore the richness of spermidine alkaloid compounds in the roots of *Capparis* species, suggesting their potential as a natural source for the isolation of these polyamine alkaloids for the development of related phytomedicines [15]. Spermidine, belonging to the class of multifunctional polyamines, is widely distributed in certain animals and microorganisms and has been acknowledged in select plants such as cabbage, cereals, and spinach. Notable dietary sources of spermidine include the liver of poultry, aged cheese, fermented soy products, mushrooms, corn, legumes, and whole grains, with the endosperm of grains, particularly in wheat germ containing up to 243 mg/kg, identified as a highly concentrated source. Recent research has intensified around these natural polyamine compounds due to their diverse biological functionalities and potential therapeutic effects. Spermidine and spermine polyamines play a crucial role in the proliferation, growth, and development of mammalian cells. Additionally, these polyamines exhibit antioxidant and anti-allergenic activities, along with the ability to suppress the glycation process. Intriguingly, these polyamines have been found to prevent arteriosclerosis and promote healthy hair growth, attributed to their anti-inflammatory and cell proliferative properties [16].

Furthermore, recent reports have unveiled the isolation of additional compounds from *C. spinosa* fruits, including isocodonocarpine, -sitosterol (J.), guanosine (K.), capparine A (L.), and capparine B (M.). Notably, -sitosterol, a principal phytosterol found in various plant materials such as cereals, vegetables, and plant oils, has demonstrated partial antimicrobial effects through the inhibition of cyclooxygenase and 5-lipoxygenase pathways [17].

Flavonoids and Phenolic Acids: Flavonoids and Phenolic acids constitute the major secondary metabolites in plants, encompassing compounds like flavonoids, tannins, and phenolic acids. Flavonoids, considered the most abundant plant compounds in the human diet, with approximately 6500 identified in the plant kingdom, are primarily located in the cell vacuoles of flowers, fruits, and leaves, acting as a protective shield against stress effects in plants. These compounds are categorized into flavonols, flavones, and anthocyanins based on the saturation and hydroxylation of the flavin ring [18].

Capparis species are recognized as rich sources of flavonoids, including flavones, flavonols, and flavonoids. Quercetin 3-O-gentiobioside has been reported in *C. spinosa* seed oil, while apigenin (N.) and kaempferol (N.) have been isolated from *C. spinosa* fruits. Additionally, isoginkgetin, ginkgetin, and sakuranetin were identified in *C. spinosa* fruits for the first time, along with kaempferol - 3 – O - rutinoside, quercetin – 3 – O -

rutinoside, and sakuranetin. The leaves of *C. spinosa* have been recognized as a valuable source of kaempferol, quercetin, and isorhamnetin. Major flavonoids identified in *C. spinosa* include rutin, kaempferol-3-O-rutinoside, and isorhamnetin 3-O-rutinoside. The rutin and quercetin content in *C. spinosa* leaves is notably high, demonstrating its potential as an economical source for these bioactives [19].

Notably, the concentration of rutin in *C. spinosa* varies with daylight in different plant parts, showing maximum content in flowers and leaves during morning and night times, while floral buds exhibit peak rutin content in the morning, and stems and fresh fruits reach maximum rutin content at specific times during the day. These variations are attributed to fluctuations in temperature and sunlight intensity. The quantity of quercetin in *C. spinosa* surpasses that in several other plants, highlighting its potential as a valuable source for the isolation of bioactives for functional food or nutraceutical applications. Both rutin and quercetin contribute to smooth blood circulation, especially in small vessels, with rutin aiding in strengthening small capillaries by inhibiting thicket formation in blood vessels [20].

C. spinosa stands out among other *Capparis* plants due to its higher content of quercetin (180 mg/100 g) and rutin (160 mg/100 g), both of which exhibit diverse biological activities, including antibacterial, anticarcinogenic, and analgesic properties (Behnaz *et al.*, 2012; Tesoriere *et al.*, 2007). The investigation of total phenolics and flavonoids in *C. spinosa* leaves from nine different sites in the trans-Himalayan region revealed varying concentrations depending on extraction methods, genetic factors, and climatic/growing conditions. Total phenolic contents ranging from 21.42 to 27.62 mg GAE/g DM (Gallic Acid Equivalent) and total flavonoid contents ranging from 2.6 to 6.96 mg QE/g DM (Quercetin Equivalent).Consistent with the impact of extraction methods, genetic factors, and growing conditions, ethyl acetate extracts of *C. spinosa* leaves contained higher amounts of phenolic compounds and flavonoids, followed by chloroform extracts of roots. Observed variations in the content of different compounds in *C. decidua* extracts based on the solvent used. In terms of individual phenolic acids, cinnamic acid, p-hydroxybenzoic acid, protocatechuric acid, and vanillic acid have been identified in *C. spinosa* fruits. Additionally, p-methoxy benzoic acid, found in methanolic extracts of *C. spinosa*, has been reported to play a positive role against hepatotoxic effects induced by paracetamol, thioacetamide, and galactosamine.

Gulcosinolates: Glucosinolates**,** naturally occurring compounds, are found in various plants, particularly in the Cruciferae family. Examples include rapeseed, false flax, radish, cabbage, broccoli, and cauliflower, known to contain around 100 different glucosinolate compounds, such as neoglucobrassicin, 4-methoxyglucobrassicin, glucocaperin, glucoiberin, sinigrin, 1-methoxy-3-indolylmethyl, and glucobrassicin. These compounds are primarily present in roots and leaves. While these compounds are non-toxic, their degradation products may potentially impact animal growth in an abnormal manner [21].

In the case of *C. ovata*, glucosinolates are abundantly present in flower buds and fruits. Various glucosinolate compounds in the young shoots and flower buds of *C. ovata*, with gluco Caperin being predominant in its young shoots, small buds, medium buds, and large buds [22].

The concentrations were reported as 46.52, 24.23, 22.08, and 24.17 μmoles g^{-1} fresh weight, respectively. In comparison, *C. spinosa* exhibited concentrations of 35.44, 14.07, 10.75, and 5.41 μmoles g^{-1} fresh weight for glucoCaperin in the corresponding parts. This data suggests that young shoots of *C. spinosa* contain higher levels of glucoCaperin than *C. ovata*, while in small, medium, and large buds, the concentrations showed the opposite trend.

Other Substances (Volatiles, Terpenes, Aldehydes, and Esters): Various parts of Capparis species have been examined for a range of compounds. In the buds oil of *C. ovata*, major volatile compounds include benzyl alcohol (20.4%), furfural (7.4%), ethanal methyl pentylacetal (5.9%), 4-vinyl guaiacol (5.3%), thymol (5.1%), octanoic acid (4.8%), and methyl isothiocyanate (4.5%). *C. ovata* leaves, on the other hand, are rich in methyl isothiocyanate (20.0%), thymol (15.5%), 4-vinyl guaiacol (4.3%), hexyl acetate (3.6%), and trans-theaspirane (2.6%).

C. spinosa, also known as Caper, contains n-triacontane and n-pentacosane in its fruits, leaves, shoots, and flowers. Flower buds and seeds of *C. spinosa* also share the presence of these compounds. Additionally, *C. spinosa* flower buds contain a quercetin-like compound (isodulcite), nonacosane, glycosides, and triacontanol. The fruits of *C. spinosa* are rich in β-carotene (210 mg kg^{-1}), ascorbic acid (1190 mg kg^{-1}), phytic acid (680 mg kg^{-1}), and oxalic acid (1 mg kg^{-1}). *C. decidua* also contains β-carotene in its fruit husk and residues.

Approximately 145 chemical substances have been identified in *C. spinosa* seed oil, including aldehydes, esters, sulfur-containing compounds (22%, 21%, and 8.42%, respectively), ten monoterpenes, capric acid, and newly identified sesquiterpenes. Thymol (24.4–36.4%), isopropyl isothiocyanate (11%), 2-hexenal (13.2%), 2-hexenol (10.2%), and butyl isothiocyanate (6.3%) are also found in *C. spinosa* leaf oil.[23]

From *C. spinosa* fruits, various bioactive compounds, such as flazin, guanosine, capparine A, capparine B, 4 – hydroxyl - 1H – indole – 3 - carboxaldehyde, chrysoeriol, thevetiaflavone, and cinnamic acid, have been isolated, all of which possess anti-inflammatory potential. Some of these compounds, including flazin, guanosine, capparine A, capparine B, 4-hydroxy-1H-indole-3-carboxaldehyde, chrysoeriol, thevetiaflavone, and cinnamic acid, were newly identified in *C. spinosa* fruits. Additionally, other compounds, such as β-sitosterol, daucosterol, uracil, butanedioic acid, and uridine, were isolated and identified from *C. spinosa* fruits. The roots of Capparis species, when extracted with water, demonstrated good purgative quality compared to alcoholic extracts, indicating different pharmacological potentials for various extracts. Oil extracts from Capparis leaves were found to contain phenylpropanoid, terpenoids, isothiocyanate, and n-alkanes. The oil extract of Capparis mainly consists of thymol (36.4%), isopropyl isothiocyanate (11%), butyl isothiocyanate (6.3%), and 2-hexenol (13.2%). Thomnocitrine has also been reported in *C. spinosa* leaves. In the case of *C. humilis*, it was found to be rich in prolinebetaine, N-methyl proline, 3-carbomethoxy-N-methoxypyridinium, and quarternary ammonium compounds. Some alkaloids and glucosinolate compounds were also reported in this species. *C. sikkimensis* was found to contain an active constituent, 3(4H)-one-6-methoxy-2-methyl-4carbaldehyde [24].

Pharmaceutical and Traditional Medicinal uses: *Capparis* species have been integral to traditional medicine for thousands of years, as evidenced by mentions in ancient Indian ethnomedicinal literature. The roots, flowers, and fruits of these plants have been employed for their potential medicinal benefits, dating back to around 2000 years BC.

Sumerians were among the first to utilize these plants against infectious diseases, noting their efficacy without significant side effects. The therapeutic effects attributed to various parts of Capparis are believed to stem from the presence of antimicrobial bioactive compounds, including phenolics, flavonoids, polyamine alkaloids, glucosinolates, and vitamins.

These compounds inhibit the growth of infectious microorganisms while being minimally harmful to their hosts. Caper extracts have been traditionally used to alleviate coughs, flu, and as an antidote against poisoning. Caper fruits are considered beneficial for cardiac and biliousness diseases. Caper roots, rich in bioactive agents inhibiting bacterial proliferation, have been employed for medicinal purposes. Extracts from *Capparis* species, known for their digestive, stimulant, analgesic, and sudorific properties, are used to address disorders such as constipation; lumbago, odontalgia, and amenorrhea. Caper bark serves as a poultice for wound treatment, and Caper root bark is utilized against conditions like gout, cough, flu, dropsy, palsy, asthma, and intestinal worms due to its astringent and diaphoretic effects. The efficacy of ash obtained from burning Caper wood in treating muscular injuries. Fresh Caper leaves, when chewed, are said to alleviate toothaches, and a paste made from the leaves is applied to cure swellings and blisters. Local communities in India and Pakistan attribute anti-diabetic, eye-soothing, and laxative properties to Caper fruits, often incorporating them into pickles and curries. Folk medicine practitioners, locally known as "hakeem," recommend using Caper fruit powder mixed with sugar to ameliorate rheumatism and diarrhea in livestock animals. *C. decidua* is reported to have antirheumatic, tonic, expectorant, antispasmodic, and analgesic effects, while various parts of *C. zeylanica* are believed to possess analgesic and antipyretic properties [25].

Species within the genus *Capparis* are known to contain various bioactive compounds, including spermidine, glucosinolate, alkaloids, phenols, glycosides, and flavonoids, exhibiting diverse pharmacological properties and anti-inflammatory activities. Spermidine, a crucial polyamine alkaloid found in these species, has been associated with delaying aging in yeast, flies, worms, and human immune cells by inducing autophagy proposed that spermidine could be beneficial in treating type 2 diabetes. Isocodonocarpine, a compound isolated from *C. decidua*, has shown utility against inflammation and asthma. β-Sitosterol, another compound present in these plants, exhibits significant anti-inflammatory activity, comparable to indomethacin, particularly in reducing carageenan-induced rat paw edema. Bioactive compounds identified in the fruit extract of *C. spinosa*, such as flazin, guanosine, capparine A, capparine B, 1H-indole-3-carboxaldehyde, 4-hydroxy-1H-indole-3-carboxaldehyde, chrysoeriol, apigenin, kaempferol, thevetiaflavone, 5-hydroxymethylfuraldehyde, vanillic acid, and cinnamic acid, have been implicated in its anti-inflammatory effects against induced rat paw edema. However, the specific compound responsible for the anti-inflammatory properties is yet to be conclusively identified.

Moreover, compounds extracted from various *Capparis* species have shown potential in cancer treatment. For instance, 2H-1,4-benzoxazin-3(4H)-one, 6-methoxy-2-methyl-4-carbaldehyde, and cappamensin A, isolated from *C. sikkimensis* roots, have been identified as tumor inhibitors (Wu *et al.*, 2003). Cappamensin A, in particular, demonstrated significant anticancer activity against various tumor cell lines, including ovarian, lung, breast, nasopharyngeal, vincristine-resistant, and ileocecal cells in humans. Additionally, the fruit extract of *C. spinosa* has exhibited anti-tumor effects against human hepatoma HepG2 cells. Several glucosinolates, including benzyl-, p-hydroxybenzyl-, and 2-hydroxybut-3-enyl glucosinolates, have been reported for their chemoprotective properties against cancer [26].

Biological Activities:

Antimicrobial Activities: The traditional use of plant extracts in various civilizations for treating ailments and healing wounds has been well-documented. While synthetic antibiotics offer a rapid recovery from infectious diseases, their increased use has led to side effects for the host and a rise in resistance among infectious agents. To address this, scientists are increasingly focusing on identifying, isolating, and utilizing plant-derived compounds or their extracts as natural antibiotics. These plant derivatives exhibit inhibitory effects on bacterial or fungal activities, providing a safer alternative to synthetic antibiotic drugs. Numerous plants with proven antimicrobial potential are being explored for their therapeutic applications. Plant-derived compounds, including isoflavones, gamma thionin, and homoisoflavinoids, have been discovered and practically utilized for their antimicrobial applications. Additionally, sulfur-rich plant extracts have been studied for their potential use against bacterial pathogens [27].

While some studies have explored the antimicrobial potential of *C. spinosa* and *C. decidua*, more research is needed in this area. The antimicrobial abilities of aerial parts of *Capparis* plants against both Gram-positive and Gram-negative bacteria have been investigated, demonstrating their potential utility against bacterial infections. Lactobacillus colonies isolated from fermented Caper parts have been found effective in inhibiting the growth of various bacterial strains. Furthermore, extracts from fermented Caper fruits have been reported as effective antimicrobial agents against selected bacterial strains. The roots of *C. grandiflora* have also exhibited antimicrobial effects against various microorganisms, including *Staphylococcus aureus, Bacillus subtilis, B. pumillus, Escherichia coli, Klebsiella pneumoniae, Proteus vulgaris, Candida albicans,* and *Aspergillus niger*. The antimicrobial potential of Caper roots, extracted with different solvents (petroleum ether, chloroform, and ethanol), has been demonstrated by inhibiting bacterial growth [28]. Studies have reported the efficacy of the ethanolic extract of Caper root bark against *Pseudomonas aeruginosa*, *Staphylococcus aureus,* and *Escherichia coli*. Another investigation evaluated the antimicrobial activity of solvent and aqueous extracts of *C. decidua* against seven bacterial species, revealing that different extracts exhibited high susceptibility to Lactobacillus, with minimum inhibitory concentration (MIC) values ranging from 0.028 to 0.0625 μg mL^{-1}. Chloroform extracts showed the lowest MIC values for L. acidophilus. Minimum bacterial concentration (MBC) values were also determined, with chloroform extract exhibiting the lowest MBC value for L. acidophilus (0.125 μg mL^{-1}). Disc diffusion assays were conducted, with the methanolic Caper extract showing maximum growth inhibition zone diameters against *B. cereus* (36 mm), *K. pneumoniae* (35 mm), *E. coli* (36 mm), and *S. aureus* (31 mm) at a dose of 4 μg $disc^{-1}$. (Chopade, 2019).

Moreover, compounds isolated from *C. decidua,* exhibited higher antimicrobial activity than synthetic antibiotics (tetracycline, ampicillin, and ciprofloxacin). These compounds demonstrated large inhibition zone diameters (22–40 mm at 4 μg $disc^{-1}$) in the agar disc diffusion assay [29]. In comparison with extracts from other plants, *C. spinosa* was reported to be a more potent inhibitor of bacterial and fungal growth, outperforming synthetic antibiotics. The antimicrobial and antifungal potential of Caper extracts is attributed to their relatively high contents of phenolic and flavonoid compounds found in different parts of Capparis species.

In a study by Sharma and Kumar (2008), the impact of various flavonoid compounds from different parts of *Tridax procumbens* and *Capparis decidua* on the growth of various bacterial strains was investigated through disc diffusion assays. The research focused on two Gram-negative bacteria (*Escherichia coli* and *Proteus mirabilis*), one Gram-positive bacterium (*Staphylococcus aureus*), and one fungal species (*Candida albicans*) [30]. The minimum inhibitory concentration (MIC) of the extracts was determined using the microbroth dilution method, and the minimum bactericidal or fungicidal concentrations were determined through sub-culturing the relevant samples [31]. The findings indicated significant antimicrobial activity in extracts from both *T. procumbens* and *C. decidua*, with free and bound flavonoids from *T. procumbens* flowers and *C. decidua* stem exhibiting greater efficacy against microbes. The most susceptible organism was *C. albicans*, followed by S. *aureus*, *P. mirabilis,* and *E. coli*. Another study highlighted the bacteriostatic activity of *C. spinosa* roots against *Deinococcus radiophilus* growth, and the extract from *C. spinosa* demonstrated potential usefulness against *Plasmodium falciparum*.

It is noteworthy that Caper extracts do not exhibit uniform activity against all microorganisms and tend to display selective antimicrobial activities. The ethanolic extract of *C. decidua* root bark, for instance, did not inhibit the growth of Candida albicans, and glucocapparin (T) in *C. decidua* seeds showed no effect against microorganisms. However, the isothiocyanate aglycon in *C. decidua* seeds displayed a good inhibitory effect against *Vibrio cholera*, *V. ogava*, *V. inaba*, *V. ettor*, and *V. eltor*. Similarly, two extracts of *C. tomentosa* at different concentrations were found effective against *Staphylococcus aureus* and *Streptococcus pyogenes*. Thymol present in the leaf oil of *C. spinosa* was identified as responsible for antibacterial activity against *Aeromonas hydrophila* and *Staphylococcus aureus* [32]. Thymol, recognized as a potent fungicide, demonstrated efficacy against fluconazole-resistant strains and could be used alone or in combination with other biocides like carvacrol. Thymol's antifungal effects are attributed to its ability to alter hyphal morphology, leading to reduced hyphal diameters and hyphal wall lysis. Additionally, thymol's lipophilic nature allows it to interact with fungus cell membranes, modifying their permeability. Given these properties, thymol contributes to the antimicrobial potential of *C. spinosa* leaf oil and underscores the species' significance as a source of valuable compounds for treating various diseases.

Antioxidant Activity: Oxidation induced by reactive oxygen species (ROS) and free radicals can lead to chronic diseases, including neurodegenerative disorders, cancer, cardiovascular diseases, atherosclerosis, cataracts, and inflammation. Additionally, free radicals contribute to lipid peroxidation (LPO), a complex process associated with liver damage, toxicity, diseases, and aging. Oxidative stress triggers apoptosis, proton leakage from mitochondria, increased oxygen depletion, and damage to cell and organelle membranes [33]. Antioxidants play a crucial role in neutralizing ROS and free radicals generated by oxidative stress. Synthetic antioxidants, such as BHT, BHA, and TBHQ, have raised concerns due to their carcinogenic effects and potential DNA damage. As a result, there is a growing emphasis on exploring natural and non-toxic antioxidants derived from plants as alternatives to synthetic ones. Medicinal plants, in particular, have shown strong antioxidant activity and high phenolic compound content [34].

The ability of plant extracts to scavenge or quench free radicals depends on the extract's nature and the extraction method. *C. spinosa* has been identified as a source of significant antioxidant activity. Lyophilized and methanolic extracts of *C. spinosa* demonstrated substantial antioxidant activities, inhibiting lipid peroxidation by up to 90% at increased doses. Phenolic compounds, including rutin, tocopherols, and carotenoids, contribute to the antioxidant potential of *C. spinosa*. Other studies have highlighted the antioxidant scavenging activities of quercetin and kaempferol in *C. spinosa* buds, suggesting potential health benefits and protection against chronic diseases [35].

C. ovata, another member of the *Capparis* genus, has been found effective against iron oxidative stresses in thalassemia patients, exhibiting antioxidant, hypolipidemic, anti-inflammatory, and anti-hepatotoxic properties. Similarly, *C. grandiflora* extracts have demonstrated significant DPPH radical scavenging activity, indicating antioxidant potential. The isolation of antioxidant compounds, such as cappariside, from *C. spinosa* further underscores the potential of these plants in providing natural antioxidants. These findings highlight the importance of *Capparis* species as sources of natural antioxidants that can enhance the defense system against various diseases and be utilized in functional food and nutraceutical industries. In addition to their antioxidant properties, *C. decidua* has been identified as providing defense against agents promoting plaque. Extracts from its fruits and flowers inhibit the growth of bacteria associated with plaque formation. Thymol, a key component of *C. spinosa* leaf oil, is recognized as an effective antiseptic and anti-plaque agent, supporting its use in oral care products [36]. These bioactive compounds isolated from *Capparis* species hold promise for pharmaceutical and cosmo-nutraceutical applications in combating plaque and promoting oral health.

The content of rutin in commercial Caper fruits from the Mediterranean region ranged from 150.62 to 732.61 mg per 100 g of fresh weight (FW). Similarly, the total tocopherol content varied between 700.23 and 2555.4 µg per 100 g of FW, with α-tocopherol being the predominant isomer in all samples. The-carotene content in *C. spinosa* ranged from 84.8 to 805.71 µg per 100 g of FW, and these samples exhibited significant amounts of vitamin C. Studies have indicated the presence of quercetin and kaempferol in the ethanolic extract of *C. spinosa* buds, showcasing robust antioxidant activities that mitigate the risks of chronic diseases. Additionally, methanolic extracts of *C. spinosa* leaves have been reported to effectively quench free radicals in various systems, suggesting its potential in mitigating radical-related pathological damage.

The concentration of phenolic compounds in different plants positively correlates with their antioxidant activity across various species. Caper leaves, being rich in phenolic compounds, contribute to their effectiveness as antioxidants [37]. Furthermore, the robust antioxidant properties and pharmacological effects of Caper leaves are attributed to their high contents of polyphenols, tocopherols, and carotenoids.

C. ovata, another member of the *Capparis* genus, has demonstrated effectiveness against iron oxidative stresses in thalassemia patients, exhibiting antioxidant, hypolipidemic, anti-inflammatory, and anti-hepatotoxic properties. Extracts from *C. grandiflora*, specifically chloroform and ethanolic extracts, have shown significant DPPH radical scavenging activity in comparison with ascorbic acid as a standard, with activity positively correlated with increasing doses [38]. The IC_{50} values for chloroform and ethanol leaf extracts were 39.2 and 30.7 µg/mL, respectively. In the pursuit of antioxidants from *C. spinosa*, researchers have isolated 1,1-diphenyl-2-

picrylhydrazyl radical (DPPH*) scavenging components from its fruits. Ethyl acetate and aqueous fractions exhibited maximum DPPH* scavenging activities compared to petroleum ether fractions. The purification process led to the identification of a new antioxidant, cappariside (4-hydroxy-5-methylfuran-3-carboxylic acid), along with seven organic acids not previously found in Capparis members and four known organic acids. Additionally, compounds like isoginkgetin, ginkgetin, and sakuranetin, isolated from *C. spinosa* fruits, have shown antioxidant potential, with ginkgetin exhibiting greater antioxidant activity than the other two biflavonoids.

CONCLUSION: In summary, the research findings indicate that Capparis species' extracts serve as rich sources of natural antioxidants. These antioxidants can potentially activate and enhance the defense systems in living organisms against various diseases, making them valuable ingredients for the functional food and nutraceutical industry [11].

Hepatoprotective activity has been demonstrated by various Capparis species, including *C. spinosa, C. decidua, C. brevispina,* and *C. sepiaria*. In one study, ethanolic extracts of *C. spinosa* root bark significantly diminished hepatotoxicity induced by alloxan, concurrently reducing oxidative stress. Another investigation using root bark extracts of *C. spinosa* at doses of 100, 200, and 400 mg/kg reported significant reductions ($p < 0.05$) in the levels of ALT (alanine aminotransferase) and AST (aspartate aminotransferase). *C. decidua* and *C. brevispina* have also shown efficacy in mitigating hepatic disorders. For instance, alcoholic extracts of *C. sepiaria* stem exhibited hepatoprotective activity against CCl_4-induced hepatotoxicity, with a dose of 100 mg/kg proving effective in one study. Additionally, *C. sepiaria* leaves demonstrated hepatoprotective activities against the effects induced by CCl_4, as confirmed by histopathological observations. *C. moonii*, another species, exhibited comparable efficacy with silymarin in lowering SGOT, SGPT, and ALP levels, with an increase in protein. Furthermore, aqueous and methanolic extracts of *C. decidua* stem were reported to have hepatoprotective effects comparable to silymarin [10]. Anthelmintic activity, crucial for treating helminthic infections, has been explored in Caper parts. Alcoholic extract of *C. decidua* root bark demonstrated anti-anthelmintic activity against Pheretimaposthuma, proving more efficient than piparazine citrate. The aqueous extract of *C. decidua* root bark also exhibited anthelmintic and purgative properties, surpassing the efficacy of alcoholic extract agents. Spermidine alkaloids found in the root bark of *C. decidua* were identified as having anti-anthelmintic and antimicrobial effects. *C. spinosa* root bark ethanolic extract hindered bacterial growth, adding to its anti-anthelmintic properties.

Anti-anthelmintic effects were observed in petroleum ether, ethanol, and aqueous extracts of *C. zeylanica* roots, as well as in ethanolic extract of *C. grandiflora* leaves against *Pheretima posthuma*. These extracts induced significant paralysis and death in worms, particularly at higher concentrations (100 mg/mL). Tannins present in Caper extracts were suggested to be responsible for their anthelmintic activity, possibly acting similarly to synthetic phenolic anthelmintics, such as niclosamide, bithionol, and oxyclozamide, which disrupt energy generation in helminth parasitic worms by uncoupling oxidative phosphorylation. Additionally, thymol, abundant in *C. spinosa* leaf oil, has been successfully used against ringworm and hookworm infections in the United States of America (USA).

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