DOI: https://doi.org/10.52756/ijerr.2024.v40spl.002 ***Int. J. Exp. Res. Rev.*, Special Vol. 40: 11-23 (2024)**

Original Article | *Peer Reviewed* | *Open Access*

International Journal of Experimental Research and Review (IJERR)

ISSN: 2455-4855 (Online)
www.iaph.in
ISSN 2455-4855

A FTIR Evident-Based Exploration of the Antioxidant Activity of Five Threatened Cactus Species

Sheerin Bashar[1], Naga Jogayya Kothakota[2*], Satheesh Ampolu[3], Nisruti Anuja[1], Venkata Kalyan Kanakala[4] and J. Chandrasekhar Rao[5]

[1]School of Forensic Sciences, Centurion University of Technology and Management, Bhubaneswar, Odisha, India; [2]Department of Forensic Sciences, Centurion University of Technology and Management, Vizianagaram, Andhra Pradesh, India; [3]Department of Chemistry, Centurion University of Technology and Management, Vizianagaram, Andhra Pradesh, India; [4]School of Paramedics and Allied Health Sciences, Centurion University of Technology and Management, Vizianagaram, Andhra Pradesh, India; [5]Department of Physics, Government Degree College, Rajam, Andhra Pradesh, India

E-mail/Orcid Id:

SB, 220506182003@cutm.ac.in, https://orcid.org/0000-0001-7530-9828; *NJK,* naga.kothakota@cutm.ac.in, https://orcid.org/0000-0002-7536-4680; *SA,* satheeshampolu@gmail.com, https://orcid.org/0000-0001-9191-3179; *NA,* 230506322001@centurionuniv.edu.in, https://orcid.org/0009-0002-6839-4117; *VKK,* kankanalakalyan8@gmail.com, https://orcid.org/0009-0002-3079-5708; *JCK,* chandujoga1@gmail.com

Article History:

Received: 09th Jan., 2024
Accepted: 11th June., 2024
Published: 30th June, 2024

Keywords:

Antimicrobial activity, Antioxidant activity, Cactus, Fourier-transform infrared spectroscopy (FTIR), Phytochemicals, Threatened species

How to cite this Article:

Sheerin Bashar, Naga Jogayya Kothakota, Satheesh Ampolu, Nisruti Anuja, Venkata Kalyan Kanakala and J. Chandrasekhar Rao (2024). A FTIR Evident Based Exploration of the Antioxidant Activity of Five Threatened Cactus Species. *International Journal of Experimental Research and Review*, *40(spl.)*, 11-23.

DOI:

https://doi.org/10.52756/ijerr.2024.v40spl.002

Abstract: Cacti, members of the botanical family Cactaceae, comprise approximately 127 genera and approximately 1,850 known species within the Caryophyllales order. Presently, various anthropogenic activities are causing the endangerment of several cactus species. Among the reasons cited for this threat, the aesthetic and medicinal values of cacti have garnered notable attention. This study aims to explore the medicinal potential, particularly in terms of antimicrobial, antioxidant, and phytochemical properties, of five threatened cactus species listed by the International Union for Conservation of Nature (IUCN) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES): *Micranthocereus estevesii*, *Euphorbia lactea*, *Haageocereus crestata*, *Ferocactus acanthodes* and *Mammillaria huitzilopochtli*. A Fourier-transform infrared (FTIR) analysis was conducted to substantiate and corroborate the findings. Notably, no prior studies have investigated the medicinal properties of these five species, underscoring the novelty of our research. Initially, specimens of the five cacti were collected from the Regional Plant Resource Center, Bhubaneswar, air-dried, and milled into powder. Phytoconstituents were then extracted individually using polar (water) and non-polar (methanol) solvents. The antimicrobial properties were assessed using agar well diffusion assays against *Candida albicans*, *Escherichia coli* and *Staphylococcus aureus*. Results indicated that methanol extracts of *Micranthocereus estevesii* and *Euphorbia lactea* inhibited *Candida albicans*, while aqueous extracts of *Micranthocereus estevesii* and *Ferocactus acanthodes* inhibited *Escherichia coli* and *Staphylococcus aureus*. Methanol extracts exhibited superior antioxidant activity compared to aqueous extracts. FTIR spectroscopy revealed distinctive peak values representing various functional groups in the extract components, including alcohols, carboxylic acids, phenols, aldehydes, alkanes, alkenes, ketones, aromatics, aliphatic amines, primary amines, ethers, alkyl halides, and esters. Both aqueous and methanolic extracts demonstrated promising antibacterial efficacy among the five cactus species studied, suggesting their potential application in pharmaceuticals and medication development. However, habitat degradation and illegal commerce pose significant threats to these species, emphasizing the urgent need for conservation efforts.

Introduction

Plants have long been revered for their nutritional and medicinal properties, serving as essential resources for human sustenance and healthcare (Sarkar et al., 2022; Roy and Ray, 2023; De et al., 2023; Sarkar et al., 2024; Verma et al., 2024). Among the diverse array of plant

***Corresponding Author:** naga.kothakota@cutm.ac.in

species utilized for their therapeutic benefits, medicinal and aromatic plants hold particular significance due to leaves and fruits valued for their nutritional content and culinary versatility (Nath et al., 2024) (Figure 1).

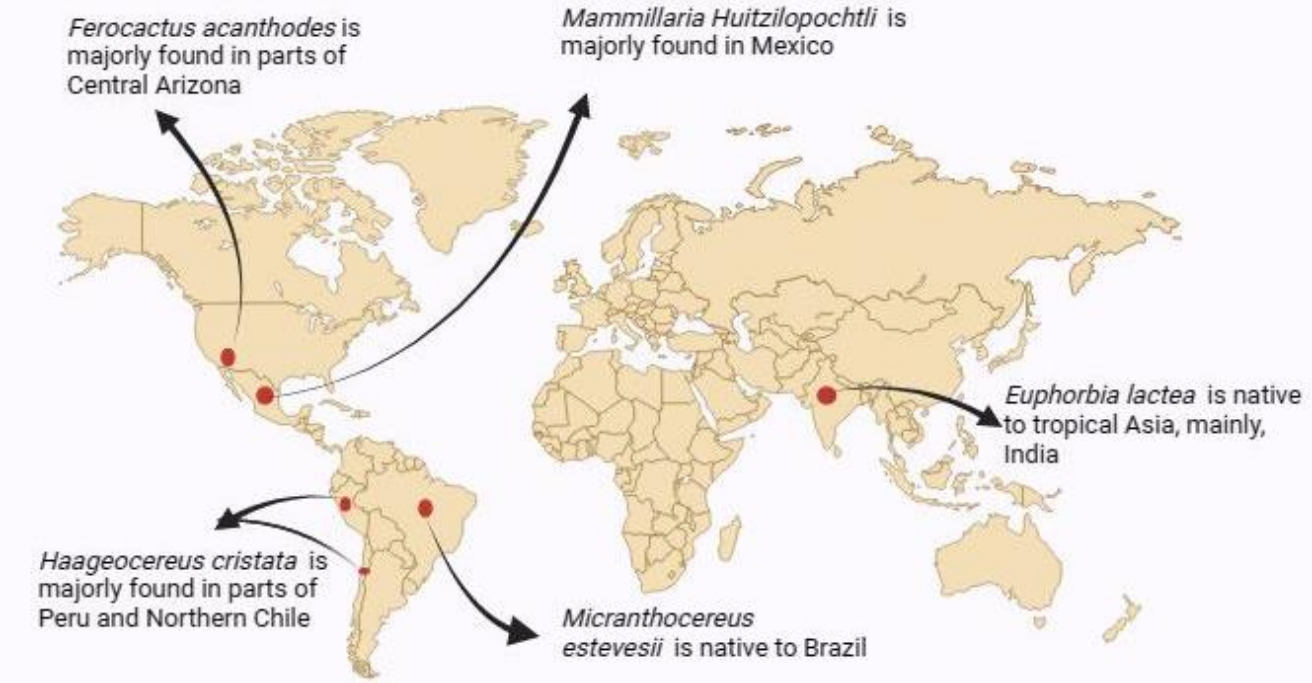

Figure 1. Map indicating the geographic regions of origin for the selected cactus species.

their extensive applications in various industries, including cosmetics, fragrances and pharmaceuticals (Samarth et al., 2017; Acharya et al., 2022; Bhatta et al., 2023; Rami et al., 2023; Ghosh et al., 2023; Hore and Bhaben, 2023; Hijam et al., 2024; Sarkar et al., 2023; Jakkana and Yamala, 2024). Succulent plants constitute a small yet ecologically significant portion of the plant kingdom, thriving in arid and semi-arid habitats worldwide (Gurrero et al., 2019). Cacti, belonging to the family Cactaceae, represent approximately 1,850 species distributed across arid regions spanning from southern Canada to the Patagonian steppe in Argentina (Khan et al., 2024). Renowned for their cultural, economic, and ecological importance, cacti serve as foundational species supporting diverse ecosystems by providing habitat and sustenance for specialized pollinators, seed dispersers, and frugivores (Vinceti et al., 2012).

In recent years, the interest in phytomedicines and Ayurvedic medicines has surged due to their safety, affordability, and perceived health benefits, leading to the exploration of various plant species for medicinal purposes (Sen et al., 2011). Cacti have emerged as a significant focus in this regard, with their utilization expanding beyond ornamental and agricultural purposes (Novoa et al., 2014). While native to North America, South America, and the West Indies, several cacti species have found habitat in dry and semi-arid regions of India, where they thrive as wild plants. Moreover, cacti feature prominently in the diets of people in Mexico, the United States, Spain, Italy, and northern Africa, with their young

The remarkable adaptability of cacti to hot and arid environments is attributed to their unique morphological and physiological adaptations, including the Crassulacean Acid Metabolism (CAM), which enhances water use efficiency (Lüttge, 2010). Their succulent stems serve as reservoirs for water storage, while their modified leaves, often reduced to spines, aid in water retention and protection against herbivores. Beyond their ecological roles, cacti have been traditionally utilized for both medicinal and culinary purposes, reflecting their diverse cultural and practical significance (Mohanta et al., 2024).

However, despite their ecological and cultural importance, cacti face severe threats from environmental degradation and non-environmental factors (Hultine et al., 2023). Recent assessments by the International Union for Conservation of Nature (IUCN) highlight cacti as one of the most imperilled taxonomic groups globally, with over thirty percent of species classified as imperilled or endangered (Betts et al., 2020). Habitat degradation, invasive species, climate change, and illegal trade pose significant risks to cacti populations, necessitating urgent conservation efforts. Notably, the family Cactaceae presents unique challenges in conservation due to its popularity in horticulture and its susceptibility to overexploitation and invasive spread (Kosloff et al., 1987).

In addition to traditional uses, cacti are increasingly being explored for innovative applications, such as cactus leather, which offers a sustainable alternative to conventional leather products (Wjunow et al., 2023).

DOI: https://doi.org/10.52756/ijerr.2024.v40spl.002

Furthermore, the carbon sequestration potential of cacti makes them valuable assets in mitigating climate change (Buotte et al., 2020). However, the burgeoning illegal trade in cacti poses a growing threat to their conservation and sustainability (Koul et al., 2022).

Against this backdrop, this study focuses on the medicinal properties of five threatened cactus species: *Micranthocereus estevesii, Euphorbia lactea, Haageocereus crestata, Ferocactus acanthodes*, and *Mammillaria Huitzilopochtli*. These species, identified as threatened by CITES and IUCN databases, are rapidly disappearing from their native habitats due to illegal trade for commercial and ornamental purposes. Despite their vulnerability, these species have received limited scientific attention, prompting our investigation into their medicinal potential, particularly in terms of antioxidant activity. Through a comprehensive analysis encompassing antibacterial activity, antioxidant activity, phytochemical composition, and compound analysis, we aim to elucidate the therapeutic value of these cactus species by extracting their phytoconstituents in polar as well as non-polar solvents. The obtained results indicated that five cacti specimens that were considered in this study have notable antimicrobial properties against a spectrum of bacteria and fungi. The findings of this study not only contribute to our understanding of cactus biodiversity but also highlight their potential applications in pharmaceutical and medicinal development that in turn highlight the novelty of the study.

Materials and methods

Sample collection and description

Five cactus samples (designated as A, B, C, D and E) were sourced from the Regional Plant Resource Centre (RPRC) in Bhubaneswar, India, for inclusion in this study. Expert botanists at RPRC verified the identification of each specimen, ensuring accurate species classification. Table 1 provides a concise overview of the key characteristics of each cactus species. Standard protocols outlined in existing literature were strictly followed during the collection process to maintain consistency and reliability (Roy et al., 2022). Upon collection, the samples were carefully tended to and nurtured in the university's cactus nursery, allowing them to acclimate to their new surroundings before further experimentation. To prepare the samples for analysis, they were thoroughly washed with mild saline water to remove any impurities, followed by sun-drying to ensure complete dehydration. Subsequently, the dried samples were finely powdered using a 40-mesh size Willey mill (SGMLAB Solutions Private Limited, New Delhi, India) to achieve a uniform consistency. The powdered biomass was then stored under hermetically sealed and aseptic conditions to preserve its integrity until further analysis (Roy and Ray, 2022).

Preparation of the extract

To extract phytochemicals from each powdered cactus specimen (designated as A-E), the specimens were first thawed to room temperature and then placed in a desiccator. A simple maceration method was employed, utilizing distilled water (as the polar solvent) and methanol (as the non-polar solvent) in the extraction process. Each extraction involved combining 10 g of desiccated sample powder with 100 mL of the respective solvent. The mixture was then subjected to continuous shaking using an orbital shaker (REMI RIS 24 Plus Orbital Shaking Incubator, Maharashtra, India) at room temperature and 200 rpm for 8 hours. Following extraction, the mixture was filtered through Whatman filter paper 1. The resulting filtrate was then concentrated using a Rotary Evaporator (Deeksha Analytical Private Limited, Bengaluru, India) under reduced pressure (Roy et al., 2022). The concentrated extract was finally stored at 4°C until further analysis (Hijam et al., 2024). The percent yield of each extract was calculated using the following formula:

$$\textbf{Yield (\%)} = \frac{\boldsymbol{Weight\ of\ Solvent\ Free\ Extract\ (grams)}}{\boldsymbol{Dried\ Extract\ Weight\ (grams)}} \times 100 \ldots \quad \text{(i)}$$

Determination of antimicrobial activity

The efficacy of various solvent extracts derived from each cactus sample in inhibiting the growth of bacteria and fungi responsible for infections was investigated.

Antifungal Assessment

To evaluate the antifungal potential of the five cactus species, we employed the ATCC (American Type Culture Collection) 10231 strain of *Candida albicans* (*C. albicans*). This strain was chosen based on a thorough literature review, which indicated its widespread use in previous studies assessing the antifungal properties of various cactus species. The well-diffusion susceptibility method, adhering to industry standards, was utilized to test different extracted samples for antifungal activity. In this method, wells with a diameter of 8 mm were created in solidified potato dextrose agar media using a sterilized cork borer. Cultures of microbial inocula aged 18 to 24 hours were then inoculated into these wells. Subsequently, 100 µL aliquots of extract at a concentration of 10mg/mL were added to the wells (Akullo et al., 2022).

DOI: https://doi.org/10.52756/ijerr.2024.v40spl.002

Table 1. Systematic classification and description of the different cacti specimens evaluated in this study

Sl. No.	Scientific Name	Common Name	Family	Description	Part Used
A	*Micranthocereus estevesii*	-	Cactaceae	Tall, blueish columnar cactus, no branches, spiny, lateral cephalium, average flowers typical of cerei, reaching several meters.	Stem (without spines)
B	*Euphorbia lactea*	Mottled spurge	Euphorbiaceae	Small perennial succulent with spiky branches, yellowish-green, clustered above ground, tiny unisexual blooms in cup-like formations, poisonous latex, fruit capsule with seeds.	Stem (without spines)
C	*Haageocereus cristata*	Crested Golden Ball Cactus	Cactaceae	Uncommon crested cactus with long golden hairs, providing sun protection and thermal regulation, resembling a finger in size.	Stem (without spines)
D	*Ferocactus acanthodes (syn. Ferocactus cylindraceus)*	Spiny Barrel Cactus, Golden-spined Barrel Cactus, Desert Barrel Cactus, Compass cactus, Cliff Barrel Cactus, Fire Barrel	Cactaceae	Ferocactus acanthodes, a tall, unbranched barrel cactus, features a green stem reaching 2 meters in height and 30 cm in diameter. Characterized by a crucifix-shaped spine structure, including a long central spine and shorter auxiliary centrals. Spine color shifts with age.	Stem (without spines)
E	*Mammillaria huitzilopochtli*	Pincushion cactus; globe cactus; fishhook cactus	Cactaceae	This cactus species grows individually or in sparse clusters, with stems initially spherical and later cylindrical, reaching 8 cm in height and 6 cm in diameter. It bears 22 glassy radial spines and up to four curved central spines.	Stem (without spines)

Antibacterial activity

To assess the antifungal activity of the samples, we employed the *Staphylococcus aureus* (*S. aureus*) MTCC (Microbial Type Culture Collection and Gene Bank) 96 strain and the *Escherichia coli* (*E. coli*) MTCC 443 strain. The Agar well diffusion method was utilized for testing the antibacterial activity of the extracts. The surface of the solidified petri plate was perforated with wells (6 mm in diameter) using a sterilized cork borer.

DOI: https://doi.org/10.52756/ijerr.2024.v40spl.002

Each well was then inoculated with a 100 µL aliquot of the extract, while the corresponding solvents served as controls. After a diffusion period of 12–15 minutes at room temperature, the inoculated plates were incubated for 48 hours at 37°C. The antibacterial activity was evaluated by measuring the diameter of the inhibition zones, expressed in millimeters (mm) (Ghosh et al., 2008).

Phytochemical screening

Phytochemical screening was conducted on the methanolic and aqueous extracts of the five cactus species to determine the presence of alkaloids, carbohydrates, amino acids, tannins, saponins, gum mucilage, flavonoids, terpenoids, and glycosides. Standard protocols from the existing literature were followed for this analysis (Khan, 2017; Sofowara, 1993).

Ferric Reducing Antioxidant Power (FRAP) analysis

The antioxidant potential in plant specimens can be assessed via spectrophotometric analysis, as indicated in existing literature. To evaluate the presence of antioxidants in the selected cactus specimens, we conducted FRAP analysis. This method relies on the reduction of the colorless Fe^{3+} TPTZ (Tris(2-pyridyl)-s-triazine) complex to the blue Fe^{2+}-tripyridyltriazine complex, facilitated by antioxidants through electron donation under low pH conditions. The change in absorbance at 593 nm monitors this process. The FRAP reagent was prepared by combining 300 mM acetate buffer, 10 ml TPTZ in 40 mM HCl, and 20 mM $FeCl_3.6H_2O$ at a ratio of 10:1:1, and freshly prepared working FRAP reagent was added to 100 µl of properly diluted plant sample using a 3 ml variable micropipette. The resulting strong blue color complex indicated the reduction of ferric tripyridyl triazine (Fe^{3+} TPTZ) to ferrous (Fe^{2+}) form. Absorbance at 593 nm was measured against a blank solution (3 ml FRAP reagent + 100 µl distilled water) immediately (0 min) and after 4 min of incubation at 37 °C. A calibration curve was generated by plotting absorbance at 593 nm against various solvents (Yahia et al., 2011). The FRAP values of the samples were calculated using the formula below:

FRAP (µM) =

$$\frac{\textit{Change in the absorbance of the sample from 0–4 minutes}}{\textit{Change in the absorbance of the standard from 0–4 minutes}} \times \text{FRAP (standard)}\ldots\text{(ii)}$$

FTIR analysis

FTIR analysis is widely recognized in existing literature as the most effective method for identifying the types of functional groups and chemical bonds present within a compound. This technique distinguishes chemical bonds based on the light wavelength at which they absorb energy, allowing for the identification of molecular bonds through analysis of the infrared absorption spectra. In this study, dried powder containing various solvent extracts of cactus specimens (A-E) was processed for FTIR analysis. Translucent sample discs were prepared using KBr pellets, each encapsulating 10 mg of the desiccated extract powder. The pulverized samples of each plant

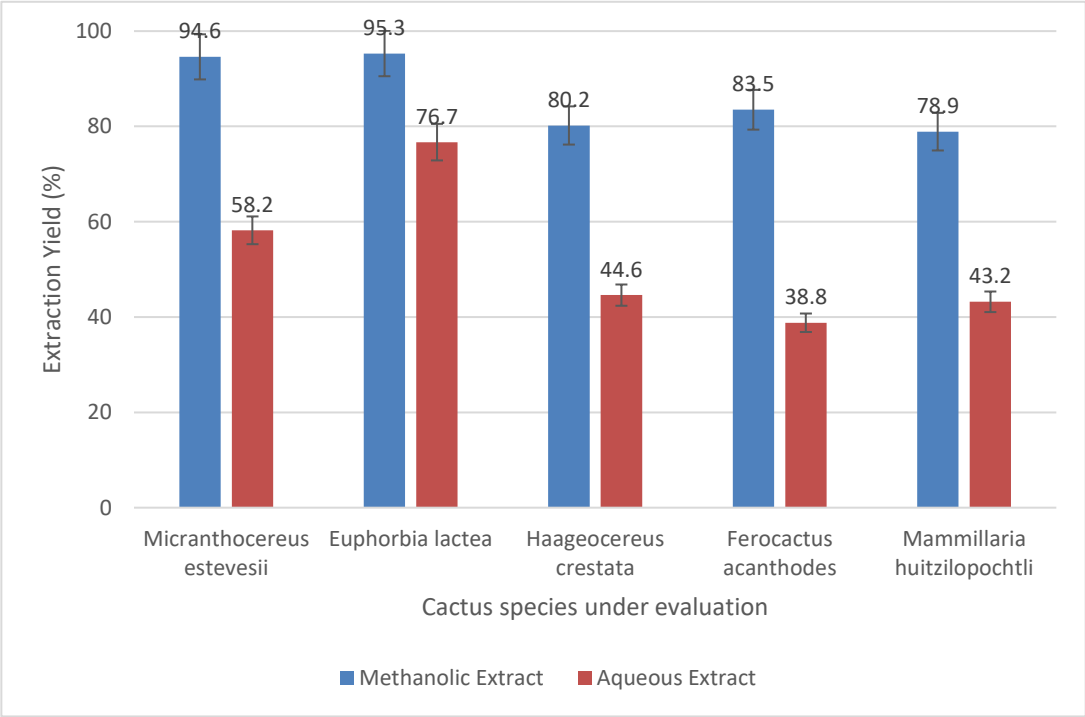

Figure 2. Extraction yield (of methanolic and aqueous extract) of different Cactus specimens evaluated in this study.

DOI: https://doi.org/10.52756/ijerr.2024.v40spl.002

specimen were then analyzed using a Perkin Elmer Spectrum 10.4.3 FTIR spectroscope, featuring a resolution of 4 cm^{-1} and a scan range of 400 to 4000 cm^{-1} (Roy and Ray, 2023).

Preliminary phytochemical analysis

The qualitative phytochemical analysis was conducted by observing either color changes or precipitation formation upon the addition of specific reagents (Gonfa et al., 2020; Behera et al., 2024). The results of this examination for both aqueous and methanol extracts of each cactus species are presented in Table 2. It was observed that the methanolic extracts generally contained slightly more phytochemical components compared to the aqueous extracts.

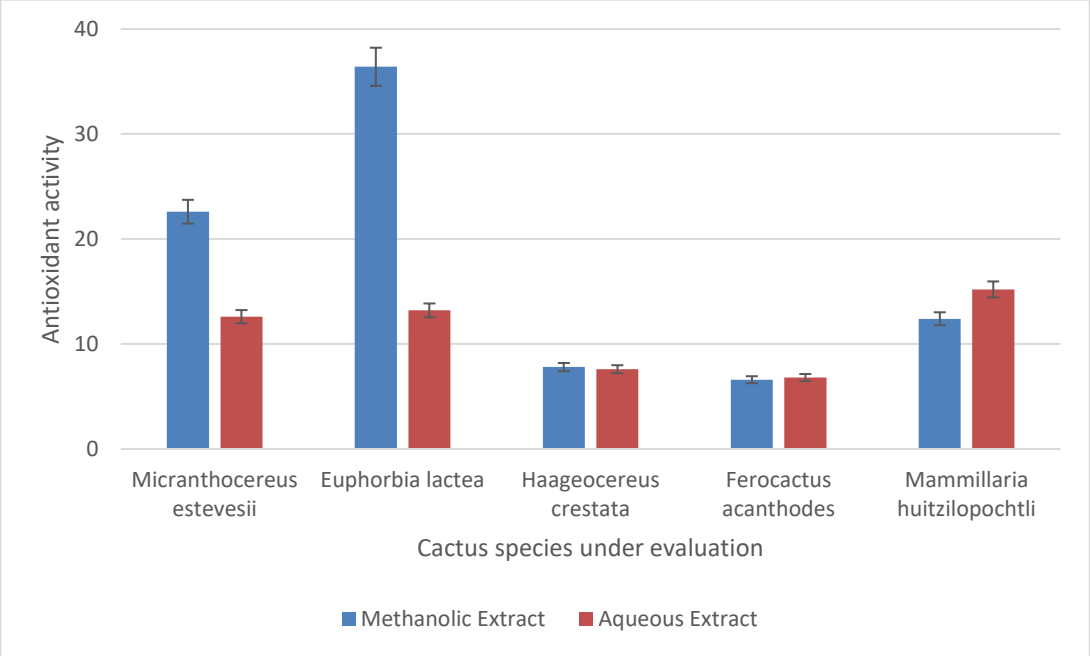

Figure 3. Comparison of the Antioxidant Capacity of the aqueous and methanolic extract of the 5 different cactus species evaluated in this study.

Table 2. Preliminary Screening of Phytochemicals of the different cactus species under evaluation.

Phytochemical	*M. estevesii*		*E. lactea*		*H. crestata*		*F. acanthodes*		*M. huitzilopochtli*	
	M	A	M	A	M	A	M	A	M	A
Alkaloids	+	+	+	+	+	+	+	+	+	+
Amino acids	-	-	-	-	-	-	-	-	-	-
Carbohydrates	+	+	+	+	+	+	+	+	+	+
Tannin	+	-	+	-	+	-	+	-	-	-
Glycosides	-	-	-	-	-	-	-	-	-	-
Saponins	-	+	-	+	-	+	-	+	-	+
Gum mucilage	+	+	-	-	-	-	-	-	+	+
Flavonoids	+	-	+	-	+	-	+	-	+	-
Terpenoids	+	-	+	-	+	-	+	-	+	-
Footnote: (+) = Presence (-) = Absence; A = aqueous, M = methanol										

Results

Extraction yield (%)

The phytochemicals from all five cactus species were efficiently extracted using both organic and aqueous solvents, resulting in satisfactory yields. Methanol extracts yielded 94.3%, 96.4%, 81.6%, 90.5%, and 81.2% (Specimen A- E, respectively) for dry samples, and 60%, 79.5%, 43.7%, 38.7%, and 42.6% (Specimen A- E respectively) for aqueous samples, respectively (Figure 2). The higher yields obtained with methanol indicate that highly polar solvents are more effective for extraction.

Ferric Reducing Antioxidant Power (FRAP) analysis

The FRAP assay measures the antioxidant's ability to reduce a colored ferrous tripyridyltriazine (Fe^{2+}-TPTZ) complex in the presence of a ferric tripyridyltriazine (Fe^{3+}-TPTZ) complex. The donation of a hydrogen atom disrupts the chain reaction of free radicals. The Fe^{3+}-

DOI: https://doi.org/10.52756/ijerr.2024.v40spl.002

TPTZ complex is then reduced to the blue Fe^{2+}-TPTZ form under acidic conditions around pH 3.6 (refer to Figure 4 and Figure 5), with absorbance measured at 593 nm. The FRAP values for both aqueous and methanol extracts of each cactus sample, calculated using a specific formula, are presented in Table 3, with 2M serving as the standard FRAP value (Benzie and Strain, 1999). Figure 3 illustrates the comparison of antioxidant capacity between the two extract types for the given samples.

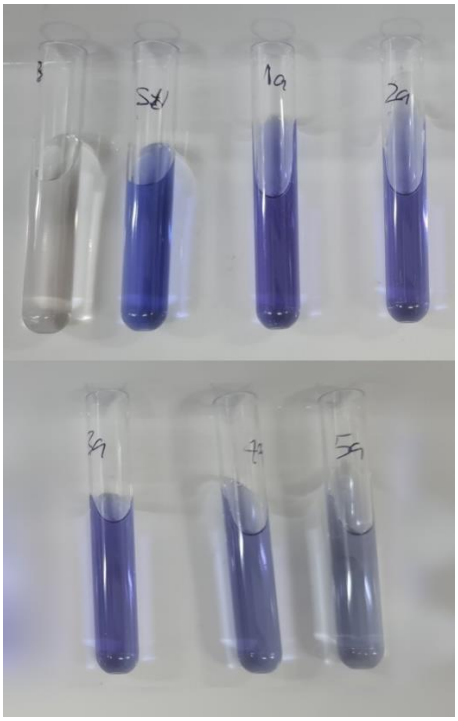

Figure 4. Development of the blue coloration after FRAP assay for aqueous extracts (From left to right: Blank, Standard, *M. estevesii*, *E. lactea*, *F. acanthodes*, *M. huitzilopochtli*, *H. crestata*).

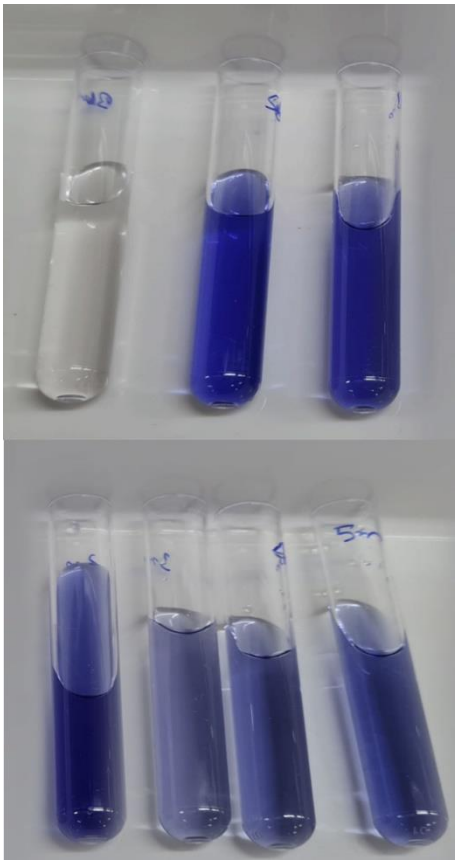

Figure 5. Development of the blue coloration after FRAP assay for methanol extracts (From left to right: Blank, Standard, *M. estevesii*, *E. lactea*, *F. acanthodes*, *M. huitzilopochtli*, *H. crestata*).

Table 3. FRAP values of different cactus specimens under evaluation.

Sample	Aqueous	Methanol
M. estevesii	10.05	20.00
E. lactea	10.71	34.38
H. crestata	8.41	8.19
F. acanthodes	6.61	12.00
M. huitzilopochtli	15.58	12.95

Antimicrobial activity

Antifungal stud

The antifungal activity of methanol and aqueous extracts from the cactus species, obtained via CSP, was assessed. The results against the tested fungi are presented in Table 4. Certain compounds such as tannins, flavonoids, saponins, steroids, and alkaloids are known to contribute to antifungal properties. This suggests that cactus species showing promising results may contain significant quantities of these chemicals, warranting further investigation. Interestingly, while aqueous extracts from each cactus showed no effect on the tested fungus (refer to Figure 6), methanol extracts exhibited varying degrees of inhibition, ranging from slight to substantial (refer to Figure 5) (Walia et al., 2022).

Table 4. Antifungal activity of the selected cactus species against *Candida albicans.*

Cactus Species	Aqueous extract	Methanol extract
M. estevesii	-	8 mm
E. lactea	-	8.5 mm
H. crestata	-	-
F. acanthodes	-	A thin inhibition zone is seen
M. huitzilopochtli	-	A thin inhibition zone is seen

DOI: https://doi.org/10.52756/ijerr.2024.v40spl.002

Figure 6. Antifungal efficacy of the chosen cactus species against *C. albicans*. (a): *Micranthocereus estevesii* aqueous extract (1A) and methanol extract (1M); *Euphorbia lactea* aqueous extract (2A) and methanol extract (2M) (b): *Ferocactus acanthodes* aqueous extract (3A) and methanol extract (3M); *Mammillaria huitzilopochtli* aqueous extract (4A) and methanol extract (4M) (c): *Haageocereus cristata* aqueous extract (5A) and methanol extract (5M).

Antibacterial Activity

As per the obtained results, the aqueous extract of *Mammillaria huitzilopochtli* exhibited potent antibacterial activity. *Micranthocereus estevesii's* aqueous extract demonstrated notable efficacy against E. coli, as shown in Table 5. Methanol extracts from all cactus species exhibited minimal inhibition zones against *E. coli*. However, *Ferocactus acanthodes* and *Mammillaria huitzilopochtli's* methanol extract showed slight inhibition zones against *S. aureus*, as illustrated in Figure 7.

Table 5. Antibacterial efficacy of the selected cactus species against *E. coli* and *S. aureus*.

Cactus Species	Aqueous extract		Methanol extract	
	E. coli	***S. aureus***	***E. coli***	***S. aureus***
M. estevesii	14 mm	-	A thin inhibition zone is seen	-
E. lactea	-	-	A thin inhibition zone is seen	-
H. crestata	-	-	A thin inhibition zone is seen	-
F. acanthodes	14 mm	16 mm	A thin inhibition zone is seen	A thin inhibition zone is seen
M. huitzilopochtli	-	-	A thin inhibition zone is seen	A thin inhibition zone is seen

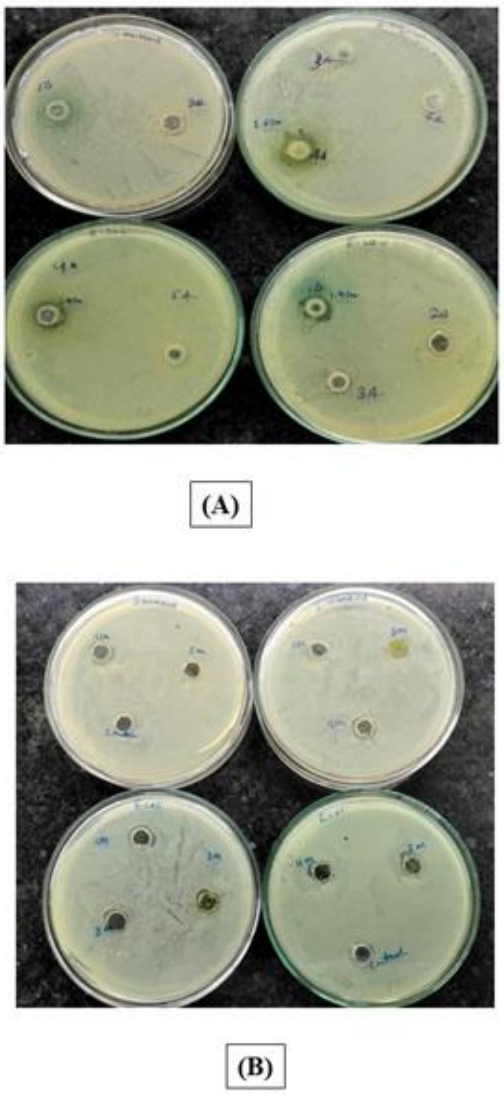

Figure 7. Antibacterial efficacy of the selected species of cactus. (a) Aqueous extracts against *E. coli* and *S. aureus*; (b) Methanol extracts against *E. coli* and S. *aureus*.

DOI: https://doi.org/10.52756/ijerr.2024.v40spl.002

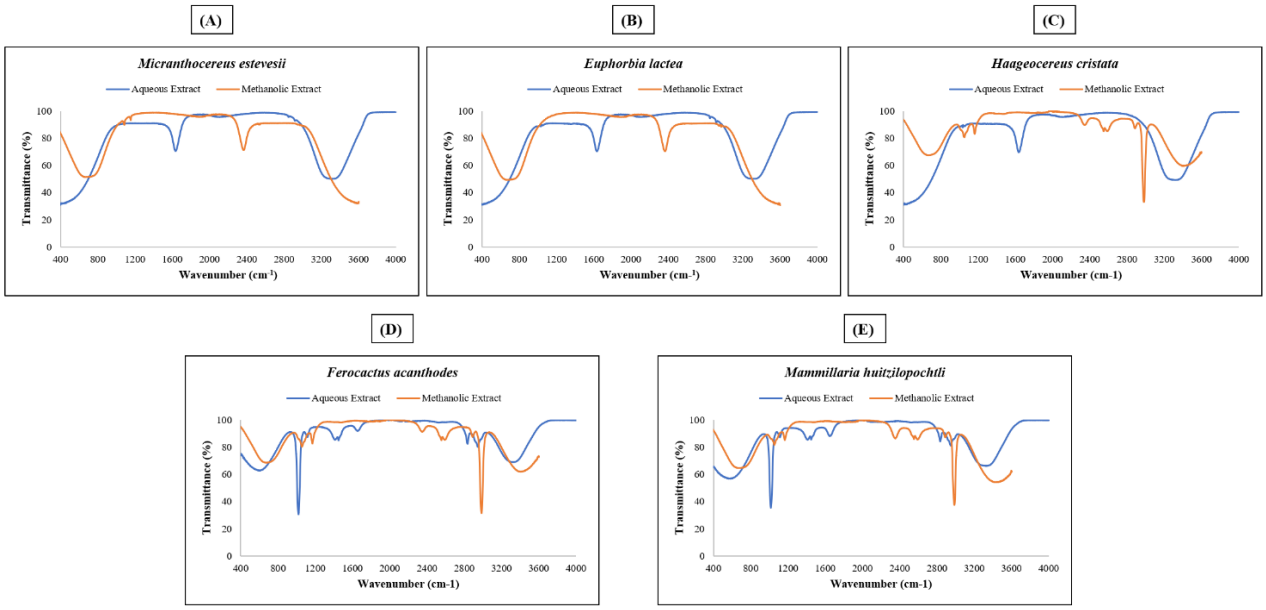

Figure 8. FTIR spectrum of the aqueous and the methanolic extracts of the five different cactus species under evaluation.

Functional group identification through FT-IR

By analyzing the peak values in the IR radiation region of the FTIR spectrum, the functional groups of the active components in the extract could be identified. FTIR spectroscopy is a powerful analytical technique used to identify chemical bonds and functional groups in organic molecules. By subjecting the cactus extracts to FTIR analysis, we aimed to elucidate the presence of various bioactive compounds and assess their potential medicinal properties. The separation of functional groups within the components was accomplished by examining the peak ratio of the extract following FTIR analysis (Figure 8). The FTIR analysis revealed distinct peak values corresponding to specific functional groups present in the extracts of the five cactus species. Functional groups such as phenols, aromatic compounds, alkanes, aldehydes, alcohols, aromatic amines, secondary alcohols, and halogen compounds were identified through FTIR spectra analysis (Table 6) (Sharma et al., 2021). Specifically, the presence of terpenes was indicated by C-H grouping, while polyphenols and flavonoids were identified through O-H stretching. Additionally, alkaloids were detected through N-H stretching in the extracts of *Micranthocereus estevesii*, *Euphorbia lactea* and *Ferocactus acanthodes*. The FTIR analysis provided valuable insights into the chemical composition of the cactus extracts, highlighting the presence of various bioactive compounds that may contribute to their antioxidant activity and potential medicinal properties. These findings contribute to our understanding of the phytochemical profile of these threatened cactus species and underscore their importance in pharmaceutical and medicinal applications (Roy and Ray, 2023).

Table 6. Identification of the functional groups associated with the respective wavenumbers for the five cactus specimens being evaluated.

Spectral Peak (cm-1)	Accredited Functional Group
480, 554	Aromatic rings, C-C stretching
625	C-H alkenes stretching
674	C-H alkynes bend, C-H alkenes, C-H phenyl ring substitution bands
782, 815	C-H alkynes bends, C-H phenyl ring substitution bands
903	C-H alkynes bends
1097	C-O-C symmetric stretching
1175	Alcohol C-O stretches, ethers, carboxylic acids
1280	Aromatic C-O stretching
1442	Aliphatic C-H stretching, alkanes C-H scissoring and bending
1516, 1616	Aromatic C-C ring stretching, N-H amines
1668	C=C alkene stretching, C-H phenyl ring substitution overtones
1745	Aldehydes C-O stretches, esters, ketones, carboxylic acids
2860, 2928	Alkanes/aliphatic C-H stretching
3200-3450	-OH stretching

Discussion

Preservation and restoration of threatened cactus species have become paramount for conservationists (Ureta et al., 2009). In this study, we focused on five genera of threatened cacti, for which limited scientific exploration had been conducted, particularly on the selected species. Consequently, our research aimed to fill this gap by conducting fundamental scientific investigations on these species.

DOI: https://doi.org/10.52756/ijerr.2024.v40spl.002

Phytochemical screening of both methanolic and aqueous extracts unveiled the presence of alkaloids, known for their diverse medicinal properties, including anti-diarrheal, anti-diabetic, anti-inflammatory, and anti-cancer effects. Additionally, alkaloids are renowned for treating urinary disorders. While flavonoids, terpenoids, and saponins were detected in aqueous extracts, they were absent in methanolic extracts. Flavonoids, also known as vitamin P, exhibit a myriad of medicinal effects, including anti-cancer, antioxidant, anti-diuretic, anti-hypertensive, anti-rheumatism, and antibacterial properties. Terpenoids, possessing antibacterial, anti-inflammatory, and immune-modulatory qualities, hold promise in cancer prevention and treatment. Tannins, present in methanolic extracts, are believed to have antibacterial properties. The preliminary phytochemical analysis underscores the potential of these substances in herbal therapy, where cacti are already utilized (Rana et al., 2019).

The zone of inhibition values served as a useful metric for estimating potential antibacterial actions. Our findings revealed that the aqueous extracts of *M. estevesii* and *F. acanthodes* were primary inhibitors of *E. coli* and *S. aureus*, common bacteria causing urinary tract infections. These extracts may serve as effective organic antibacterial agents. Methanolic extracts of *M. estevesii* and *E. lactea* demonstrated inhibitory effects against *Candida albicans*, suggesting potential as natural antifungal agents.

On FRAP analysis, *M. estevesii* and *E. lactea* exhibited the highest antioxidant capacity. Comparing aqueous and methanolic extracts, the former demonstrated superior antioxidant potential.

FTIR analysis of methanolic and aqueous extracts revealed the presence of various functional groups, including terpenes, polyphenols, flavonoids, and alkaloids. These functional groups render the extracts potentially valuable in the pharmaceutical sector.

Conclusion

Successful extraction of both aqueous and crude methanolic extracts was achieved, followed by comprehensive analyses of antimicrobial and antioxidant activities, as well as functional group characterization. Among the studied species, *M. estevesii*, *E. lactea* and *F. acanthodes* exhibited greater potency in microbial analysis compared to others. The findings of this study offer valuable insights into the phytoconstituents present in these cactus species, allowing for comparisons with bioactive plants of medicinal significance. It underscores the importance of protecting these endangered species from extinction. In order to conserve these threatened cactus species, advanced techniques such as genomic data storage and the development of PCR-based molecular markers are imperative. By employing such conservation strategies, we can safeguard these species and preserve their genetic diversity for future generations.

Conflict of Interest

The authors declare no conflict of interest.

References

Acharya, C.K., Khan, N.S., & Madhu, N.R. (2022). Traditional Phyto-therapeutic uses by Tribal People in Western Sundarbans: Henry Island, Fredric Island and Bakkhali, West Bengal, India. *Jour. Pl. Sci. Res.*, *38*(2), 513–523. https://doi.org/10.32381/JPSR.2022.38.02.8

Akullo, J. O., Kiage, B., Nakimbugwe, D., & Kinyuru, J. (2022). Effect of aqueous and organic solvent extraction on in-vitro antimicrobial activity of two varieties of fresh ginger (*Zingiber officinale*) and garlic (*Allium sativum*). *Heliyon*, *8*(9), e10457. https://doi.org/10.1016/j.heliyon.2022.e10457

Behera, A., Das, R., Mahanta, S., Akhtar, J., & Mohanty, G. (2024). Antioxidant Potential of Bioactive Peptides Derived from Fish Waste: A Focus on *Catla catla* Liver and Intestinal Tissue. *Int. J. Exp. Res. Rev.*, *39*(Spl Volume), 39-50. https://doi.org/10.52756/ijerr.2024.v39spl.003

Benzie, F. F., & Strain, J.J. (1999). [2]Ferric reducing/antioxidant power assay: Direct measure of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant power and ascorbic acid concentration. Methods in Enzymology, 299, 15-27. https://doi.org/10.1016/s0076-6879(99)99005-5

Betts, J., Young, R. P., Hilton-Taylor, C., Hoffmann, M., Rodríguez, J. P., Stuart, S. N., & Milner-Gulland, E. J. (2020). A framework for evaluating the impact of the IUCN Red List of threatened species. *Conservation Biology : the Journal of the Society for Conservation Biology*, *34*(3), 632–643. https://doi.org/10.1111/cobi.13454

Bhatta, K., Samal, H., & Mohanty, P. (2023). Isozyme profiling of Antioxidant Enzyme in Macrotyloma uniflorum. *Int. J. Exp. Res. Rev.*, 36, 156-165. https://doi.org/10.52756/ijerr.2023.v36.015a

Buotte, P. C., Law, B. E., Ripple, W. J., & Berner, L. T. (2020). Carbon sequestration and biodiversity co-benefits of preserving forests in the western

United States. *Ecological applications : a publication of the Ecological Society of America*, *30*(2), e02039. https://doi.org/10.1002/eap.2039

De, M., Sharma, L., & Acharya, C. (2023). A Comprehensive Chemical Characterization of Leaves of Five Potential Medicinal Plants in Paschim Medinipur District, W. B., India. *Int. J. Exp. Res. Rev.*, *36*, 20-36. https://doi.org/10.52756/ijerr.2023.v36.002

Ghosh, A., Das, B. K., Roy, A., Mandal, B., & Chandra, G. (2008). Antibacterial activity of some medicinal plant extracts. *Journal of Natural Medicines*, *62*, 259-262. https://doi.org/10.1007/s11418-007-0216-x

Ghosh, R., Basak, P., Ghosh, A., & Choudhury, B. (2023). Effect of Cadmium Toxicity on Different Antioxidant Enzymes in Growing Wheat (*Triticum aestivum* L.) Seedlings. *Int. J. Exp. Res. Rev.*, *36*, 198-208. https://doi.org/10.52756/ijerr.2023.v36.020

Gonfa, T., Teketle, S., & Kiros, T. (2020). Effect of extraction solvent on qualitative and quantitative analysis of major phyto-constituents and in-vitro antioxidant activity evaluation of *Cadaba rotundifolia* Forssk leaf extracts. *Cogent Food & Agriculture*, *6*(1), 1853867. https://doi.org/10.1080/23311932.2020.1853867

Guerrero, P. C., Majure, L. C., Romero, A. C. & Hernández, T. H. (2019) Phylogenetic Relationships and Evolutionary Trends in the Cactus Family. *Journal of Heredity*, *110*(1), 4–21. https://doi.org/10.1093/jhered/esy064

Hijam, A., Koijam, A., & Haobam, R. (2024). Methanol extract of Isodon ternifolius (D. Don) KUDO leaves has antimicrobial and antioxidant activities but no neuroprotective activity. *International Journal of Experimental Research and Review*, *39*(Spl Volume), 200-212. https://doi.org/10.52756/ijerr.2024.v39spl.016

Hijam, A., Koijam, A., & Haobam, R. (2024). Methanol extract of *Isodon ternifolius* (D. Don) KUDO leaves has antimicrobial and antioxidant activities but no neuroprotective activity. *International Journal of Experimental Research and Review*, *39*(Spl Volume), 200-212. https://doi.org/10.52756/ijerr.2024.v39spl.016

Hore, P., & Bhaben, T. (2023). Toxic Effect of 2,4-D on Cytology of *Vigna radiata* (L.) Wilczek. *Int. J. Exp. Res. Rev.*, *30*, 276-81. https://doi.org/10.52756/ijerr.2023.v30.025.

Hultine, K. R., Hernandez, T. H., Williams, D. G., Albeke, S. E., Tran, N., Puente, R. & Larios, E. (2023). Global change impacts on cacti (Cactacea): current threats, challenges and conservation solution. *Annals of Botany*, *132*(4), 671-683. https://doi.org/10.1093/aob/mcad040

Jakkana, V., & Yamala, S. (2024). Isolation, Identification and in-Silico Characterization of Bioactive Peptide from the Venom Sac of *Conus inscriptus*. *International Journal of Experimental Research and Review*, *38*, 1-14. https://doi.org/10.52756/ijerr.2024.v38.001

Khan, A. S. (2017). Medicinally important trees. Springer.

Khan, D., Harris, A.J., Zaman, Q. U., Wang, H. X., Wen, J., Landis, J. B. & Wang, H. F. (2024). The evolutionary history and distribution of cactus germplasm resources, as well as potential domestication under a changing climate. *Journal of Systematics and Evolution*. https://doi.org/10.1111/jse.13042

Kosloff, L. H., & Trexler, M. C. (1987). The convention on international trade in endangered species: No carrot, but where's the stick. *Envtl. L. Rep. News & Analysis*, *17*, 10222. https://doi.org/10.26481/dis.20230612fs

Koul, B., Bhat, N., Abubakar, M., Mishra, M., Arukha, A. P., & Yadav, D. (2022). Application of natural coagulants in water treatment: A sustainable alternative to chemicals. *Water*, *14*(22), 3751. https://doi.org/10.3390/w14223751

Lüttge, U. (2010). Ability of crassulacean acid metabolism plants to overcome interacting stresses in tropical environments. *AoB Plants*, *2010*, plq005. https://doi.org/10.1093/aobpla/plq005

Mohanta, T. K., Mohanta, Y. K., Kaushik, P., & Kumar, J. (2024). Physiology, genomics, and evolutionary aspects of desert plants. *Journal of Advanced Research*, *58*, 63-78. https://doi.org/10.1016/j.jare2023.04.019

Nath, P. C., Sharma, R., Debnath, S., Nayak, P. K., Roy, R., Sharma, M., ... & Sridhar, K. (2024). Recent advances in production of sustainable and biodegradable polymers from agro-food waste: Applications in tissue engineering and regenerative medicines. *International Journal of Biological Macromolecules*, *259*(1), 129129.

Novoa, A., Le Roux, J. J., Robertson, M. P., Wilson, J. R., & Richardson, D. M. (2014). Introduced and

invasive cactus species: a global review. *AoB Plants*, *7*, plu078. https://doi.org/10.1093/aobpla/plu078

Rami, N., Kulkarni, B., Chibber, S., Jhala, D., Parmar, N., & Trivedi, K. (2023). In vitro antioxidant and anticancer potential of *Annona squamosa* L. Extracts against breast cancer. *Int. J. Exp. Res. Rev.*, *30*, 264-275. https://doi.org/10.52756/ijerr.2023.v30.024

Rana, A. C., & Gulliya, B. (2019). Chemistry and pharmacology of flavonoids-A review. *Indian Journal of Pharmaceutical Education & Research*, *53*(1). https://doi.org/10.5530/ijper.53.1.3

Roy, R., & Ray, S. (2022). Upgradation of an Agro-residue by Acid Pretreatment into a Solid Fuel with Improved Energy Recovery Potential: An Optimization Study. *Arabian Journal for Science and Engineering*, *47*(5), 6311-6323. https://doi.org/10.1007/s13369-021-06253-8

Roy, R., & Ray, S. (2023). Effect of various pretreatments on energy recovery from waste biomass. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *45*(3), 9616-9628. https://doi.org/10.1080/15567036.2019.1680767

Roy, R., Debnath, D., & Ray, S. (2022). Comprehensive assessment of various lignocellulosic biomasses for energy recovery in a hybrid energy system. *Arabian Journal for Science and Engineering*, *47*(5), 5935-5948. https://doi.org/10.1007/s13369-021-05723-3

Roy, R., Shil, S., Choudhary, D. K., Mondal, P., Adhikary, P., Manna, U., ... & Maji, M. (2022). Conversion of glucose into calcium gluconate and determining the process feasibility for further scaling-up: An optimization approach. *Int. J. Exp. Res. Rev*, *27*, 1-10. https://doi.org/10.52756/ijerr.2022.v27.001

Samarth, R. M., Samarth, M., & Matsumoto, Y. (2017). Medicinally important aromatic plants with radioprotective activity. *Future science OA*, *3*(4), FSO247. https://doi.org/10.4155/fsoa-2017-0061

Sarkar, B., Bhattacharya, P., Yen Chen, C., Maity, J., & Biswas, T. (2022). A comprehensive characterization and therapeutic properties in ripened Noni fruits (*Morinda citrifolia* L.). *Int. J. Exp. Res. Rev.*, *29*, 10-32. https://doi.org/10.52756/ijerr.2022.v29.002

Sarkar, B., Kotal, H.N., Giri, C.K., Mandal, A., Hudait, N., Madhu, N.R., Saha, S., Basak, S.K., Sengupta, J., & Ray, K. (2024). Detection of a bibenzyl core scaffold in 28 common mangrove and associate species of the Indian Sundarbans: potential signature molecule for mangrove salinity stress acclimation. *Front. Plant Sci.*, *14*, 1291805. https://doi.org/10.3389/fpls.2023.1291805

Sarkar, S., Sadhu, S., Roy, R., Tarafdar, S., Mukherjee, N., Sil, M., Goswami, A., & Madhu, N.R. (2023). *Contemporary Drifts in Diabetes Management*. *Int. J. App. Pharm.*, *15*(2), 1-9. https://doi.org/10.22159/ijap.2023v15i2.46792

Sen, S., Chakraborty, R., & De, B. (2011). Challenges and opportunities in the advancement of herbal medicine: India's position and role in a global context. *Journal of Herbal Medicine*, *1*(3-4), 67-75. https://doi.org/10.1016/j.hermed.2011.11.001

Sharma, M., & Kaushik, P. (2021). Vegetable phytochemicals: An update on extraction and analysis techniques. *Biocatalysis and Agricultural Biotechnology*, *36*, 102149. https://doi.org/10.1016/j.bcab.2021.102149

Sofowora, A. (1993). Medicinal plants and traditional medicine in Africa. 2nd ed. Sunshine house, Ibadan, Nigeria: Spectrum books Ltd., Screening plants for bioactive agents, pp. 134-156.

Ureta, C., & Martorell, C. (2009). Identifying the impacts of chronic anthropogenic disturbance on two threatened cacti to provide guidelines for population-dynamics restoration. *Biological Conservation*, *142*(10), 1992-2001. https://doi.org/10.1016/j.biocon.2008.12.031

Verma, M., S., Kotwal, S., & Kumar, A. (2024). Exploring the Influence of Arbuscular Mycorrhizal Symbology on the Antioxidant Potential of Liverwort *Asterella multiflora*: A Comprehensive Study on Rhizoid and Thallus Anatomy. *Int. J. Exp. Res. Rev.*, *37*(Special Vol.), 109-119. https://doi.org/10.52756/ijerr.2024.v37spl.009

Vinceti, B., Eyzaguirre, P., & Johns, T. (2012). The nutritional role of forest plant foods for rural communities. In Human Health and Forests. Routledge, pp. 63-96.

Walia, A., Kumar, N., Singh, R., Kumar, H., Kumar, V., Kaushik, R., & Kumar, A. P. (2022). Bioactive compounds in Ficus fruits, their bioactivities and associated health benefits: a review. *Journal of Food Quality*, *2022*, 1-19. https://doi.org/10.1155/2022/6597092

Wjunow, C., Moselewski, K.L., Huhnen, Z., Sultanova, S., & Sabantina, L. (2023). Sustainable Textiles from Unconventional Biomaterials—Cactus Based. *Engineering Proceedings*, *37*(1), 58. https://doi.org/10.3390/ECP2023-14652

Yahia, E. M., & Mondragon-Jacobo, C. (2011). Nutritional components and anti-oxidant capacity of ten cultivars and lines of cactus pear fruit (*Opuntia* spp.). *Food Research International*, *44*(7), 2311-2318. https://doi.org/10.1016/j.foodres.2011.02.042

How to cite this Article:

Sheerin Bashar, Naga Jogayya Kothakota, Satheesh Ampolu, Nisruti Anuja, Venkata Kalyan Kanakala and J. Chandrasekhar Rao (2024). A FTIR Evident Based Exploration of the Antioxidant Activity of Five Threatened Cactus Species. *International Journal of Experimental Research and Review*, *40*(spl.), 11-23.

DOI: https://doi.org/10.52756/ijerr.2024.v40spl.002