RESEARCH PAPER

Pharmacognostic, Phytochemical and In Vitro Antioxidant Evaluation of Selected Medicinal Plants: Azadirachta Indica, Terminalia Belerica and Psidium Guajava

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ABSTRACT

Medicinal plants are recognized as important reservoirs of bioactive phytoconstituents with remarkable therapeutic potential. The present investigation aimed to evaluate the pharmacognostic characteristics, physicochemical standards, phytochemical constituents, and in vitro antioxidant activity of three traditionally important medicinal plants, namely Azadirachta indica, Terminalia belerica, and Psidium guajava. Macroscopic and microscopic examinations confirmed the identity and purity of the selected crude drugs through the observation of diagnostic features such as multicellular trichomes, sclereids, vascular bundles, and calcium oxalate crystals. Physicochemical parameters including moisture content, total ash, acid-insoluble ash, and extractive values were found within acceptable pharmacopoeial limits, indicating good quality and stability of the plant materials.

Preliminary phytochemical screening revealed the presence of alkaloids, flavonoids, tannins, glycosides, saponins, terpenoids, and phenolic compounds. Quantitative analysis demonstrated that Terminalia belerica possessed the highest total phenolic content (82.7 ± 1.5 mg GAE/g) and total flavonoid content (60.5 ± 1.4 mg QE/g), suggesting superior antioxidant potential.

The antioxidant activity of methanolic extracts was evaluated using DPPH, ABTS, and FRAP assays. All extracts exhibited concentration-dependent free radical scavenging activity. Among the investigated plants, Terminalia belerica showed the highest antioxidant activity, followed by Psidium guajava and Azadirachta indica. The enhanced antioxidant potential was strongly correlated with higher phenolic and flavonoid contents.

The findings of the study confirm that the selected medicinal plants are rich sources of natural antioxidants and possess significant pharmaceutical potential for the management of oxidative stress-associated disorders. The study further supports the traditional therapeutic applications of these medicinal plants and highlights their importance in herbal drug standardization and future phytopharmaceutical development.

Keywords: Pharmacognostic evaluation, phytochemical screening, antioxidant activity, DPPH assay, FRAP assay, ABTS assay, medicinal plants, phenolic compounds, flavonoids.

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INTRODUCTION

Medicinal plants have served as one of the oldest and most reliable sources of therapeutic agents for the prevention and treatment of various human diseases since ancient civilization. Herbal medicines continue to play a significant role in healthcare systems worldwide because of their accessibility, affordability, and relatively lower incidence of adverse effects compared with synthetic drugs. According to the

World Health Organization, nearly 80% of the global population relies partially or entirely on traditional plant-based medicines for primary healthcare needs. The growing awareness regarding the toxicological limitations

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of synthetic drugs has further increased scientific interest in medicinal plants and their bioactive constituents [1,2].

Medicinal plants are rich reservoirs of secondary metabolites such as alkaloids, flavonoids, tannins, glycosides, phenolic compounds, terpenoids, and saponins. These phytoconstituents are responsible for a wide range of pharmacological activities including antioxidant, antimicrobial, anti-inflammatory, antidiabetic, anticancer, hepatoprotective, and immunomodulatory effects [3,4]. Among these biological properties, antioxidant activity has gained substantial importance due to the involvement of oxidative stress in the pathogenesis of numerous chronic disorders.

Oxidative stress is primarily caused by the excessive generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS), which disturb the balance between oxidants and endogenous antioxidant defense mechanisms. Free radicals generated during oxidative metabolism can damage cellular lipids, proteins, carbohydrates, and nucleic acids, ultimately contributing to the development of diseases such as cancer, diabetes mellitus, cardiovascular disorders, neurodegenerative diseases, arthritis, and premature aging [5,6]. Natural antioxidants obtained from medicinal plants can effectively neutralize free radicals by donating electrons or hydrogen atoms, thereby preventing oxidative damage and maintaining cellular integrity [7].

Phenolic compounds and flavonoids are considered major contributors to the antioxidant potential of medicinal plants. These compounds exhibit strong radical scavenging activity due to their redox properties and ability to chelate metal ions. Previous studies have demonstrated a positive relationship between total phenolic content and antioxidant efficiency in herbal extracts [8,9]. Therefore, evaluation of antioxidant activity using standard in vitro methods such as DPPH, ABTS, and FRAP assays has become an essential approach for determining the therapeutic significance of medicinal plants.

Pharmacognostic evaluation is another important aspect of herbal drug standardization. Pharmacognosy involves the study of the morphological, microscopic, physicochemical, and biological characteristics of crude drugs obtained from natural sources. Standardization helps in confirming the identity, purity, and quality of plant materials while minimizing the possibility of adulteration and substitution [10,11]. In the modern pharmaceutical industry, pharmacognostic evaluation plays a crucial role in ensuring the safety, efficacy, and reproducibility of herbal formulations.

Phytochemical screening is equally important in medicinal plant research because it helps identify biologically active secondary metabolites responsible for therapeutic action. Qualitative and quantitative phytochemical investigations provide valuable information regarding the chemical composition of medicinal plants and establish correlations between phytoconstituents and pharmacological activity [12].

The present study focuses on three widely used medicinal plants: Azadirachta indica, Terminalia belerica, and Psidium guajava. *Azadirachta indica* (Neem) is traditionally recognized for its antimicrobial, anti-inflammatory, antioxidant, and wound-healing properties owing to the presence of limonoids, flavonoids, and tannins [13]. *Terminalia belerica* (Baheda), an important component of Triphala, is rich in phenolic compounds and tannins that contribute significantly to its antioxidant and hepatoprotective activities [14]. *Psidium guajava* (Guava) leaves are known for their antidiabetic, antimicrobial, anti-inflammatory, and antioxidant properties due to the abundance of flavonoids and polyphenolic compounds [15].

The evaluation of antioxidant activity through in vitro assays provides a rapid, reliable, and reproducible method for determining free radical scavenging potential. Among the commonly used methods, the DPPH assay measures hydrogen-donating ability, the ABTS assay evaluates radical cation scavenging activity, and the FRAP assay determines ferric ion reducing capacity [16–18]. These assays collectively provide comprehensive information regarding the antioxidant efficiency of plant extracts.

Therefore, the present study was undertaken to perform detailed pharmacognostic, physicochemical, phytochemical, and in vitro antioxidant evaluation of selected medicinal plants in order to establish scientific evidence supporting their traditional medicinal applications and potential pharmaceutical importance.

MATERIALS AND METHODS

Collection and Authentication of Plant Materials

Fresh plant materials of Azadirachta indica leaves, Terminalia belerica fruits, and Psidium guajava leaves were collected from local regions under suitable environmental conditions during the early morning hours to minimize phytochemical degradation. Healthy, mature, and disease-free plant parts were selected to ensure the quality and authenticity of crude drugs. The collected materials were thoroughly washed with distilled water to remove dirt, dust, and foreign particles.

Botanical authentication of the plant materials was carried out by a qualified taxonomist in the Department of Botany. After authentication, the plant samples were shade-dried at room temperature (25–30°C) for approximately 10–15 days to preserve thermolabile phytoconstituents. The dried materials were stored in airtight containers until further use [19,20].

Preparation of Plant Powder

The dried plant materials were coarsely powdered separately using a mechanical grinder. The powdered materials were passed through sieve No. 80 to obtain uniform particle size and improve extraction efficiency. The powdered samples were stored in airtight amber-colored glass containers protected from moisture and

direct sunlight for further pharmacognostic and phytochemical studies [21].

Preparation of Methanolic Extracts

Methanolic extracts of the selected medicinal plants were prepared using the Soxhlet extraction method. Approximately 50 g of each powdered sample was packed separately in Whatman filter paper thimbles and extracted with methanol as solvent for 6–8 hours until complete exhaustion of the plant material was achieved.

The obtained extracts were filtered and concentrated under reduced pressure using a rotary vacuum evaporator. The concentrated extracts were then dried on a water bath at controlled temperature and stored in desiccators for further phytochemical and antioxidant evaluation [22].

Pharmacognostic Evaluation

Macroscopic Evaluation

Macroscopic or organoleptic evaluation of crude plant materials was carried out by observing color, odor, taste, size, shape, and surface characteristics using standard pharmacognostic procedures. These parameters are essential for identification and authentication of medicinal plants [10].

Table 1: Macroscopic Characteristics of Selected Medicinal Plants

Parameter	*Azadirachta indica*	*Terminalia belerica*	*Psidium guajava*
Color	Green	Brown	Dark green
Odor	Characteristic	Slight	Characteristic
Taste	Bitter	Astringent	Slightly bitter
Size	Medium	Large fruit	Medium
Shape	Lanceolate leaves	Round fruit	Oval leaves
Surface	Smooth	Rough	Slightly rough

Result Interpretation

Macroscopic examination demonstrated distinct organoleptic features characteristic of each medicinal plant. *Azadirachta indica* showed green lanceolate leaves with a characteristic bitter taste, while *Terminalia belerica* fruits possessed a brown rough surface and astringent taste suggestive of high tannin content. *Psidium guajava* leaves were dark green, oval-shaped, and slightly rough in texture. These observations confirmed the identity and purity of the crude drugs and indicated their suitability for further analysis.

Microscopic Evaluation

Microscopic studies were carried out using transverse sections and powdered drug microscopy after staining with suitable reagents. Diagnostic microscopic features such as trichomes, vascular bundles, fibers, sclereids, calcium oxalate crystals, and epidermal cells were observed under a compound microscope [11,23].

Table 2: Microscopic Characteristics of Selected Medicinal Plants

Plant	Observed Microscopic Features
Azadirachta indica	Multicellular trichomes, stomata, and well-defined vascular bundles
Terminalia belerica	Stone cells, thick-walled fibers, and sclereids
Psidium guajava	Calcium oxalate crystals, vascular bundles, and epidermal cells

Result Interpretation

Microscopic analysis revealed characteristic anatomical markers for each medicinal plant. *Azadirachta indica* exhibited multicellular trichomes and organized vascular tissues. *Terminalia belerica* demonstrated the presence of stone cells and sclereids that provide structural rigidity. *Psidium guajava* contained calcium oxalate crystals and distinct vascular bundles. These diagnostic features are important criteria for pharmacognostic standardization and authentication of herbal drugs.

Physicochemical Evaluation

Physicochemical parameters including loss on drying, total ash, acid-insoluble ash, water-soluble extractive value, and alcohol-soluble extractive value were determined according to standard pharmacopoeial procedures [24].

Table 3: Physicochemical Parameters of Selected Medicinal Plants

Parameter	*A. indica* (%)	*T. belerica* (%)	*P. guajava* (%)
Moisture content (LOD)	5.2	4.8	5.5
Total ash	6.5	7.2	6.8
Acid-insoluble ash	1.2	1.5	1.3
Water-soluble extractive	10.2	11.5	10.8
Alcohol-soluble extractive	12.5	14.2	13.8

Result Interpretation

The physicochemical parameters were found within acceptable limits, indicating good quality and purity of the plant materials. Low moisture content suggested reduced chances of microbial contamination and enhanced shelf stability. Ash values indicated minimal inorganic contamination, whereas higher extractive values reflected the presence of considerable amounts of bioactive constituents. Among the selected plants, *Terminalia belerica* showed comparatively higher extractive values, suggesting greater phytochemical richness.

Phytochemical Screening

Phytochemical investigation of medicinal plants is an essential step in identifying bioactive secondary

metabolites responsible for therapeutic activities. In the present study, methanolic extracts of Azadirachta indica, Terminalia belerica, and Psidium guajava were subjected to qualitative and quantitative phytochemical evaluation using standard analytical procedures.

The analysis focused on major classes of phytoconstituents including alkaloids, flavonoids, tannins, saponins, glycosides, terpenoids, and phenolic compounds. These phytochemicals are known to possess antioxidant, antimicrobial, anti-inflammatory, and free radical scavenging activities that contribute significantly to the medicinal value of herbal drugs [25,26].

Qualitative Phytochemical Analysis

Preliminary phytochemical screening was performed using standard chemical tests to identify the presence or absence of major bioactive constituents in the methanolic extracts of selected medicinal plants [27].

Table 4: Qualitative Phytochemical Screening of Selected Medicinal Plants

Phytoconstituent	*A. indica*	*T. belerica*	*P. guajava*
Alkaloids	+	+	+
Flavonoids	++	+++	++
Tannins	++	+++	++
Saponins	+	+	+
Glycosides	+	+	+
Terpenoids	++	+	++
Phenolic compounds	++	+++	++

Note:

- + = Present,++ = Moderately present,+++ = Highly present

Result Interpretation

The qualitative phytochemical analysis confirmed the presence of important secondary metabolites in all three medicinal plant extracts. Alkaloids, flavonoids, tannins, glycosides, saponins, terpenoids, and phenolic compounds were detected in varying concentrations.

Among the investigated plants, *Terminalia belerica* demonstrated comparatively higher levels (+++) of tannins, flavonoids, and phenolic compounds, indicating stronger antioxidant potential. *Azadirachta indica* and *Psidium guajava* also exhibited significant levels of phytoconstituents that may contribute to their therapeutic efficacy. The abundance of phenolics and flavonoids suggests that the selected medicinal plants possess substantial free radical scavenging properties and pharmacological importance [28].

Quantitative Phytochemical Analysis

Quantitative estimation of total phenolic content (TPC) and total flavonoid content (TFC) was carried out using spectrophotometric methods because phenolic compounds and flavonoids are considered primary contributors to antioxidant activity [29].

Determination of Total Phenolic Content (TPC)

The total phenolic content of the plant extracts was determined using the Folin–Ciocalteu reagent method and expressed as milligrams of gallic acid equivalent per gram of extract (mg GAE/g) [30].

Table 5: Total Phenolic Content of Selected Medicinal Plants

Plant	TPC (mg GAE/g extract)
Azadirachta indica	65.4 ± 1.2
Terminalia belerica	82.7 ± 1.5
Psidium guajava	74.3 ± 1.3

Calculation Formula

$$TPC = C \times V / M$$

Where:

- **C** = Concentration obtained from calibration curve (mg/mL)
- **V** = Volume of extract (mL)
- **M** = Mass of extract used (g)

Result Interpretation

The quantitative estimation revealed that *Terminalia belerica* possessed the highest total phenolic content (82.7 ± 1.5 mg GAE/g), followed by *Psidium guajava* and *Azadirachta indica*. The higher phenolic content observed in *Terminalia belerica* may contribute significantly to its superior antioxidant activity because phenolic compounds effectively neutralize free radicals through hydrogen donation and metal ion chelation mechanisms [31].

Determination of Total Flavonoid Content (TFC)

The total flavonoid content of the extracts was estimated using the aluminum chloride colorimetric method and expressed as milligrams of quercetin equivalent per gram of extract (mg QE/g) [32].

Table 6: Total Flavonoid Content of Selected Medicinal Plants

Plant	TFC (mg QE/g extract)
Azadirachta indica	48.2 ± 1.0
Terminalia belerica	60.5 ± 1.4

Psidium guajava	55.8 ± 1.2

Calculation Formula

TFC=C×V/ M Where:

- **C** = Concentration obtained from calibration curve (mg/mL)
- **V** = Volume of extract (mL)
- **M** = Mass of extract used (g)

Result Interpretation

The results indicated that *Terminalia belerica* contained the highest flavonoid content (60.5 ± 1.4 mg QE/g), followed by *Psidium guajava* and *Azadirachta indica*. Flavonoids are known to exhibit potent antioxidant activity through free radical scavenging and inhibition of lipid peroxidation. The higher flavonoid concentration observed in *Terminalia belerica* further supports its enhanced antioxidant efficiency [33].

The quantitative phytochemical findings clearly demonstrated a positive association between phenolic/flavonoid content and antioxidant activity. The presence of substantial amounts of these phytoconstituents suggests that the selected medicinal plants possess promising therapeutic potential against oxidative stress-related disorders.

In Vitro Antioxidant Activity

The antioxidant potential of medicinal plants is primarily associated with their ability to neutralize free radicals and reduce oxidative stress. In the present study, the methanolic extracts of Azadirachta indica, Terminalia belerica, and Psidium guajava were evaluated for antioxidant activity using standard in vitro assays including DPPH radical scavenging assay, ABTS radical cation decolorization assay, and Ferric Reducing Antioxidant Power (FRAP) assay.

These methods are widely accepted for evaluating the hydrogen-donating ability, radical scavenging capacity, and reducing power of plant extracts [34–36]. The antioxidant activity of the extracts was assessed at different concentrations ranging from 20–100 µg/mL.

DPPH Radical Scavenging Assay

The DPPH assay is based on the reduction of the stable purple-colored DPPH radical into a yellow-colored diphenylpicrylhydrazine molecule in the presence of antioxidant compounds. The decrease in absorbance indicates the radical scavenging activity of plant extracts [34].

Table 7: DPPH Radical Scavenging Activity of Selected Medicinal Plants

Concentration (µg/mL)	*A. indica* (% inhibition)	*T. belerica* (% inhibition)	*P. guajava* (% inhibition)
20	35 ± 1.2	40 ± 1.4	38 ± 1.3
40	50 ± 1.3	58 ± 1.5	55 ± 1.4
60	65 ± 1.4	72 ± 1.6	70 ± 1.5
80	78 ± 1.5	85 ± 1.7	82 ± 1.6
100	88 ± 1.6	92 ± 1.8	90 ± 1.7

Calculation Formula

$$\% \text{ Inhibition} = A_0 - A_1 / A_0 \times 100$$

Where:

- A_0 = Absorbance of control
- A_1 = Absorbance of sample extract

Result Interpretation

All plant extracts demonstrated concentration-dependent DPPH radical scavenging activity. Among the investigated samples, *Terminalia belerica* exhibited the highest percentage inhibition at all tested concentrations, reaching 92 ± 1.8% inhibition at 100 µg/mL. *Psidium guajava* showed moderate antioxidant activity, whereas *Azadirachta indica* exhibited comparatively lower but still significant scavenging potential.

The enhanced antioxidant activity of *Terminalia belerica* may be attributed to its higher phenolic and flavonoid contents, which are capable of donating hydrogen atoms to stabilize free radicals [37].

ABTS Radical Cation Decolorization Assay

The ABTS assay evaluates the ability of antioxidants to scavenge ABTS radical cations generated during the reaction. Reduction of the blue-green ABTS radical results in decreased absorbance proportional to antioxidant capacity [35].

Table 8: ABTS Radical Scavenging Activity of Selected Medicinal Plants

Concentration (µg/mL)	*A. indica* (% inhibition)	*T. belerica* (% inhibition)	*P. guajava* (% inhibition)
20	30 ± 1.1	38 ± 1.3	35 ± 1.2
40	48 ± 1.3	55 ± 1.4	52 ± 1.3
60	62 ± 1.4	70 ± 1.5	68 ± 1.4
80	75 ± 1.5	82 ± 1.6	80 ± 1.5
100	85 ± 1.6	90 ± 1.7	88 ± 1.6

Result Interpretation

All extracts exhibited significant ABTS radical scavenging activity in a concentration-dependent manner. *Terminalia belerica* demonstrated maximum inhibition, followed by *Psidium guajava* and *Azadirachta indica*.

The results obtained from the ABTS assay were consistent with DPPH findings, indicating that the selected medicinal plants possess effective antioxidant compounds capable of neutralizing both hydrophilic and lipophilic free radicals. The superior activity of *Terminalia belerica* further confirms the role of phenolic compounds and tannins in antioxidant defense mechanisms [38].

Ferric Reducing Antioxidant Power (FRAP) Assay

The FRAP assay measures the ability of antioxidants to reduce ferric ions (Fe^{3+}) into ferrous ions (Fe^{2+}). Increased absorbance indicates greater reducing power and antioxidant potential [36].

Table 9: FRAP Assay of Selected Medicinal Plants

Concentration (µg/mL)	*A. indica* (Absorbance)	*T. belerica* (Absorbance)	*P. guajava* (Absorbance)
20	0.45 ± 0.01	0.52 ± 0.02	0.48 ± 0.01
40	0.60 ± 0.02	0.68 ± 0.02	0.63 ± 0.02
60	0.75 ± 0.02	0.82 ± 0.03	0.78 ± 0.02
80	0.88 ± 0.03	0.95 ± 0.03	0.90 ± 0.03
100	0.98 ± 0.03	1.05 ± 0.04	1.00 ± 0.03

Result Interpretation

The FRAP assay demonstrated a gradual increase in reducing power with increasing extract concentration. Among all tested samples, *Terminalia belerica* exhibited the highest reducing capacity with absorbance value of 1.05 ± 0.04 at 100 µg/mL. *Psidium guajava* also showed considerable reducing power, whereas *Azadirachta indica* demonstrated moderate activity.

The observed reducing potential indicates that the extracts possess electron-donating ability, which contributes significantly to antioxidant action. The higher FRAP activity of *Terminalia belerica* may be associated with its elevated phenolic and flavonoid content [39].

Correlation Between Phytochemical Content and Antioxidant Activity

The study demonstrated a strong positive correlation between total phenolic/flavonoid content and antioxidant activity of the selected medicinal plants. Plant extracts rich in phenolic compounds exhibited greater free radical scavenging ability and reducing power. Phenolic compounds act through multiple antioxidant mechanisms including hydrogen atom transfer, single electron transfer, and metal ion chelation [40].

Among the evaluated medicinal plants, *Terminalia belerica* consistently showed the highest antioxidant activity in DPPH, ABTS, and FRAP assays, which directly correlated with its elevated phenolic and flavonoid concentrations. These findings indicate that phenolic phytoconstituents are major contributors to the antioxidant potential of medicinal plants.

OVERALL DISCUSSION

The present investigation confirmed that all selected medicinal plants possess significant antioxidant activity. The antioxidant potential increased with increasing concentration of extracts in all assays, demonstrating dose-dependent activity.

The findings support previous reports indicating that medicinal plants rich in flavonoids, tannins, and phenolic compounds possess effective antioxidant properties capable of reducing oxidative stress and protecting cellular components from free radical-induced damage [41,42].

The superior antioxidant activity of *Terminalia belerica* suggests its potential use in the development of herbal antioxidant formulations and nutraceutical products for managing oxidative stress-related disorders such as diabetes mellitus, cardiovascular diseases, neurodegenerative disorders, and aging-associated complications.

CONCLUSION

The present study successfully established the pharmacognostic, physicochemical, phytochemical, and in vitro antioxidant profile of Azadirachta indica, Terminalia belerica, and Psidium guajava. The findings confirmed that all selected medicinal plants possess significant therapeutic potential due to the presence of biologically active phytoconstituents and strong antioxidant activity.

Pharmacognostic evaluation involving macroscopic and microscopic analysis confirmed the identity, purity, and authenticity of the selected crude drugs. Diagnostic microscopic characteristics such as multicellular trichomes, vascular bundles, sclereids, stone cells, and calcium oxalate crystals served as important parameters for herbal drug standardization and quality control. Physicochemical parameters including moisture content, ash values, and extractive values were found within acceptable limits, indicating good quality, stability, and minimal contamination of plant materials.

Preliminary phytochemical screening revealed the presence of major secondary metabolites such as alkaloids, flavonoids, tannins, glycosides, saponins, terpenoids, and phenolic compounds. Quantitative estimation demonstrated that *Terminalia belerica* possessed the highest total phenolic and flavonoid contents among the

selected medicinal plants. These phytochemicals are well known for their antioxidant and pharmacological properties, thereby contributing significantly to the therapeutic efficacy of herbal medicines.

The antioxidant evaluation carried out using DPPH, ABTS, and FRAP assays confirmed that all extracts exhibited concentration-dependent free radical scavenging activity and reducing power. Among the tested plants, *Terminalia belerica* demonstrated the strongest antioxidant activity, followed by *Psidium guajava* and *Azadirachta indica*. The enhanced antioxidant potential observed in *Terminalia belerica* showed a direct correlation with its elevated phenolic and flavonoid contents, suggesting that these phytoconstituents play a major role in antioxidant defense mechanisms.

The study highlights the importance of medicinal plants as natural sources of antioxidants capable of combating oxidative stress and preventing cellular damage associated with chronic disorders such as diabetes mellitus, cardiovascular diseases, neurodegenerative disorders, inflammation, and premature aging. The results scientifically support the traditional medicinal uses of the selected plants and indicate their potential application in the development of herbal formulations, nutraceuticals, and phytopharmaceutical products.

Overall, the present investigation provides valuable scientific data for the standardization and therapeutic validation of selected medicinal plants. Further advanced studies including isolation of active compounds, toxicity evaluation, in vivo pharmacological investigations, and clinical studies are recommended to explore their full pharmaceutical potential and therapeutic applications.

FUTURE SCOPE

1. Isolation and characterization of individual bioactive compounds responsible for antioxidant activity can be carried out using advanced chromatographic and spectroscopic techniques.
2. In vivo pharmacological studies may be conducted to validate the antioxidant potential observed in in vitro assays.
3. Toxicological and safety evaluation studies should be performed to establish the safe therapeutic dose of herbal extracts.
4. Development of standardized herbal formulations, capsules, syrups, or nutraceutical products using these medicinal plants may be explored for commercial pharmaceutical applications.
5. Molecular docking and mechanistic studies can be performed to understand the interaction of phytoconstituents with oxidative stress-related enzymes and pathways.
6. Clinical investigations may further establish the therapeutic efficacy of these medicinal plants in the management of oxidative stress-associated disorders.

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