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Phytochemical Analysis and Therapeutic Potential of Indigenous Ayurvedic Plants

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Abstract

Indigenous Ayurvedic plants represent a valuable repository of bioactive compounds with significant therapeutic potential. Traditional medicine systems across India have utilized these botanical resources for millennia, yet comprehensive phytochemical characterization remains limited for many species. This research examined the phytochemical profiles and therapeutic properties of five prominent Ayurvedic plants: Ashwagandha (*Withania somnifera*), Tulsi (*Ocimum sanctum*), Neem (*Azadirachta indica*), Turmeric (*Curcuma longa*), and Brahmi (*Bacopa monnieri*). The research was conducted to establish standardized extraction protocols and quantify bioactive constituents including alkaloids, flavonoids, phenolic compounds, and saponins. Plant materials were collected from certified organic farms. Methanolic extracts were prepared using cold percolation methods, followed by systematic phytochemical screening employing thin-layer chromatography and high-performance liquid chromatography. Quantitative analysis utilized spectrophotometric techniques with appropriate reference standards. Results revealed substantial variation in phytochemical content among species, with total phenolic content ranging from 54.6 to 71.2 mg GAE/g dry weight. Turmeric exhibited the highest flavonoid concentration (45.8 mg QE/g), while Brahmi showed maximum alkaloid content (21.4 mg/g). Antioxidant activity assessment through DPPH radical scavenging assay demonstrated time-dependent increases, with turmeric achieving 84.3% inhibition after 120 hours. Antimicrobial testing against common pathogenic bacteria revealed significant zone of inhibition diameters, particularly for neem and tulsi extracts. Anti-inflammatory potential was evaluated using carrageenan-induced paw edema model, showing dose-dependent reduction in inflammation comparable to standard drugs. The research establishes that indigenous Ayurvedic plants contain therapeutically relevant phytochemicals in concentrations suitable for pharmaceutical development. These findings provide scientific validation for traditional therapeutic applications and offer standardized protocols for quality control in herbal medicine production.

Keywords: Phytochemical screening, ayurvedic plants, bioactive compounds, antioxidant activity, traditional medicine, herbal extracts, therapeutic potential, indigenous flora

Introduction

Ayurvedic medicine, one of the world's oldest holistic healing systems, has relied upon plant-based therapeutics for over 5,000 years ^[1]. India's rich biodiversity encompasses approximately 45,000 plant species, of which nearly 15,000-20,000 possess documented medicinal properties in various traditional healing systems ^[2]. These botanical resources serve as primary healthcare sources for nearly 80% of rural Indian populations, yet rigorous scientific validation of their therapeutic claims remains incomplete ^[3]. The phytochemical constituents responsible for biological activities warrant systematic investigation to bridge traditional knowledge with modern pharmaceutical science.

Withania somnifera (Ashwagandha), classified as a Rasayana herb in Ayurveda, contains withanolides as primary bioactive compounds demonstrating adaptogenic and immunomodulatory properties ^[4]. *Ocimum sanctum* (Tulsi), revered as a sacred plant in Indian culture, exhibits antimicrobial, anti-inflammatory, and cardioprotective activities attributed to eugenol, carvacrol, and rosmarinic acid ^[5]. *Azadirachta indica* (Neem) possesses over 140 bioactive compounds, with azadirachtin showing remarkable insecticidal and therapeutic properties ^[6]. *Curcuma longa* (Turmeric) contains curcuminoids responsible for potent anti-inflammatory, antioxidant, and anti-carcinogenic effects extensively documented in scientific literature ^[7]. *Bacopa monnieri* (Brahmi) demonstrates nootropic properties through bacosides, enhancing cognitive function and memory retention ^[8].

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Modern phytochemical analysis techniques enable precise quantification of bioactive constituents, facilitating standardization essential for pharmaceutical applications^[9]. High-performance liquid chromatography, gas chromatography-mass spectrometry, and nuclear magnetic resonance spectroscopy provide comprehensive metabolite profiling capabilities^[10]. These analytical approaches, combined with bioassay-guided fractionation, accelerate identification of therapeutically relevant compounds while ensuring quality control in herbal medicine production^[11].

Despite extensive traditional use, several indigenous Ayurvedic plants lack standardized extraction protocols and comprehensive phytochemical characterization^[12]. Variation in geographic origin, harvesting season, processing methods, and storage conditions significantly influences phytochemical composition and biological activity^[13]. Establishing reproducible extraction methodologies and quantifying key bioactive constituents becomes imperative for therapeutic consistency and regulatory compliance^[14]. Furthermore, scientific validation of traditional therapeutic claims through appropriate in-vitro and in-vivo models strengthens evidence-based integration of Ayurvedic medicines into mainstream healthcare systems^[15].

This research addresses critical knowledge gaps by systematically characterizing phytochemical profiles of five widely utilized Ayurvedic plants through standardized extraction protocols and analytical methodologies. The objectives include quantification of major phytochemical classes, evaluation of antioxidant capacity, assessment of antimicrobial potential, and investigation of anti-inflammatory properties to provide scientific foundation for their therapeutic applications in modern medicine.

Classical References and Textual Basis

The selected plants possess extensive documentation in classical Ayurvedic texts spanning multiple millennia. Charaka Samhita describes Ashwagandha as a premier Rasayana possessing Balya (strength-promoting) and Vajikara (aphrodisiac) properties, specifically indicated for Vata disorders and general debility. Sushruta Samhita extensively documents Neem's antimicrobial applications, describing its Krimighna (antimicrobial) and Kandughna (antipruritic) actions with detailed preparation methods for various external and internal formulations. Bhavaprakasha Nighantu characterizes Tulsi as having Deepana (appetizer), Pachana (digestive), and Hrudya (cardioprotective) properties, recommending its use in respiratory disorders and fever management. Classical texts attribute Turmeric's therapeutic efficacy to its Varnya (complexion-enhancing), Kusthaghna (antileprotic), and Vedanasthapana (analgesic) qualities, with specific indications for wound healing and inflammatory conditions. Brahmi receives prominence in Ayurvedic neuropharmacology texts for its Medhya (nootropic) properties, with detailed descriptions of its role in enhancing Smriti (memory), Medha (intellect), and Dhi (retention capacity) through specific formulations and administration protocols^[16].

Materials and Methods

Materials

Analytical grade solvents including methanol, ethanol, chloroform, and hexane were procured from Merck Chemicals, Mumbai. Standard reference compounds (gallic acid, quercetin, ascorbic acid, curcumin, withaferin A) were obtained from Sigma-Aldrich, USA. DPPH (2,2-diphenyl-1-

picrylhydrazyl), Folin-Ciocalteu reagent, aluminum chloride, and other analytical reagents were sourced from HiMedia Laboratories, Mumbai. Bacterial cultures (*Staphylococcus aureus* MTCC 96, *Escherichia coli* MTCC 443, *Pseudomonas aeruginosa* MTCC 1688) were obtained from Microbial Type Culture Collection, Chandigarh. All glasswares were washed with chromic acid, rinsed thoroughly with distilled water, and dried in hot air oven at 60°C before use to ensure contamination-free analysis.

Extraction Protocol

Fresh plant materials underwent preliminary processing involving removal of extraneous matter, washing with running tap water followed by distilled water, and surface sterilization using 0.1% mercuric chloride solution for 30 seconds. Materials were shade-dried at ambient temperature (25-30°C) for 7-10 days to preserve thermolabile constituents, then pulverized using mechanical grinder to achieve 40-mesh particle size. Powdered materials were stored in amber-colored airtight containers at 4°C until extraction.

Cold percolation method was employed for extraction to prevent thermal degradation of bioactive compounds. Briefly, 100 grams of powdered plant material was macerated with 500 ml of 80% methanol in conical flasks, covered with aluminum foil, and kept on orbital shaker at 120 rpm for 72 hours at room temperature. The extract was filtered through Whatman No. 1 filter paper, and the residue was re-extracted twice with fresh solvent following identical procedure. Combined filtrates were concentrated using rotary evaporator (Buchi R-210) under reduced pressure at 40°C. The concentrated extracts were lyophilized using freeze dryer (Labconco FreeZone) to obtain dry powder, which was weighed to calculate percentage yield. Extract yields ranged from 12.3% to 18.7% w/w depending upon plant species and moisture content. Dried extracts were stored at -20°C in dark containers until further analysis.

Methods

Preliminary phytochemical screening was conducted following standard protocols to identify major phytochemical classes. Tests for alkaloids (Dragendorff's, Mayer's, Wagner's reagents), flavonoids (Shinoda test, alkaline reagent test), phenolics (ferric chloride test), saponins (foam test), tannins (gelatin test), terpenoids (Salkowski test), and cardiac glycosides (Keller-Kiliani test) were performed systematically. Quantitative estimation of total alkaloid content utilized Harborne method with atropine as standard. Total flavonoid content was determined using aluminum chloride colorimetric method with quercetin calibration curve. Total phenolic content estimation employed Folin-Ciocalteu reagent method using gallic acid as reference standard, with absorbance measured at 765 nm.

Antioxidant activity assessment utilized DPPH radical scavenging assay. Extract solutions (20-100 µg/ml) were prepared in methanol and mixed with 0.1 mM DPPH solution in 1:1 ratio. Reaction mixtures were incubated in dark at room temperature, and absorbance was recorded at 517 nm at 24-hour intervals for 120 hours using UV-Visible spectrophotometer (Shimadzu UV-1800). Ascorbic acid served as positive control. Percentage inhibition was calculated using the formula: $[(A_0 - A_1)/A_0] \times 100$, where A_0 represents control absorbance and A_1 represents sample absorbance.

Antimicrobial activity was evaluated using agar well diffusion method against selected bacterial strains. Mueller-Hinton agar plates were inoculated with standardized bacterial suspension (108 CFU/ml), and wells (6 mm diameter) were created using sterile cork borer. Plant extracts dissolved in dimethyl sulfoxide (concentration 10 mg/ml) were dispensed into wells (50 μ l/well), with streptomycin (10 μ g/ml) as positive control and DMSO as negative control. Plates were incubated at 37°C for 24 hours, and zone of inhibition diameters were measured in millimeters. All experiments were performed in triplicate, and results were expressed as mean $\pm$ standard deviation. Statistical analysis employed one-way ANOVA followed by Tukey's post-hoc test, with $p < 0.05$ considered statistically significant.

Results

Table 1: Extraction Yield and Preliminary Phytochemical Screening of Ayurvedic Plants

Plant Species	Yield (%)	Alkaloids	Flavonoids	Phenolics	Saponins	Tannins
Ashwagandha	14.2	+++	++	+++	++	+
Tulsi	16.8	++	+++	+++	+	++
Neem	12.3	++	++	+++	+++	++
Turmeric	18.7	+	+++	+++	++	+
Brahmi	15.6	+++	++	+++	+	++

Table 1 presents extraction yields and qualitative phytochemical screening results for the five Ayurvedic plants. Turmeric demonstrated the highest extraction yield (18.7%), followed by Tulsi (16.8%) and Brahmi (15.6%). Neem exhibited the lowest yield at 12.3%, potentially attributed to higher lignin content and structural complexity. Qualitative screening revealed presence of all tested phytochemical classes across species with varying intensities. Strong presence (+++) of alkaloids was observed in Ashwagandha and Brahmi, correlating with their documented adaptogenic and nootropic properties.

Flavonoids showed abundant presence in Tulsi and Turmeric, consistent with their antioxidant and anti-inflammatory activities. All plants demonstrated significant phenolic content, with particularly strong presence in Ashwagandha, Tulsi, Neem, Turmeric, and Brahmi.

Table 2: Quantitative Phytochemical Content and Antimicrobial Activity

Plant	Alkaloids (mg/g)	Flavonoids (mg QE/g)	Phenolics (mg GAE/g)	ZOI <i>S. aureus</i> (mm)	ZOI <i>E. coli</i> (mm)
Ashwagandha	23.7	41.3	56.8	16.3	14.7
Tulsi	15.2	38.6	62.3	19.8	17.2
Neem	18.9	33.2	58.1	21.4	18.9
Turmeric	12.3	45.8	71.2	17.6	15.3
Brahmi	21.4	39.1	54.6	14.8	13.2

Table 2 demonstrates quantitative phytochemical content and antimicrobial activity against pathogenic bacteria. Total phenolic content ranged from 54.6 mg GAE/g (Brahmi) to 71.2 mg GAE/g (Turmeric), with all values statistically significant ($p < 0.001$). Turmeric exhibited the highest flavonoid concentration (45.8 mg QE/g), followed by Ashwagandha (41.3 mg QE/g). Alkaloid content showed maximum levels in Ashwagandha (23.7 mg/g) and Brahmi (21.4 mg/g), validating their traditional classification as Rasayana and Medhya herbs respectively. Antimicrobial activity assessment revealed substantial zone of inhibition against both Gram-positive (*S. aureus*) and Gram-negative (*E. coli*) bacteria. Neem demonstrated the most potent antimicrobial effects with zone diameters of 21.4 mm and 18.9 mm respectively, attributed to azadirachtin and related limonoids. Tulsi exhibited strong antibacterial properties (19.8 mm and 17.2 mm), consistent with its traditional use in infectious disease management. The antimicrobial efficacy correlated positively with phenolic and flavonoid content ($r = 0.87$, $p < 0.01$), suggesting phenolic compounds as primary contributors to antibacterial effects.

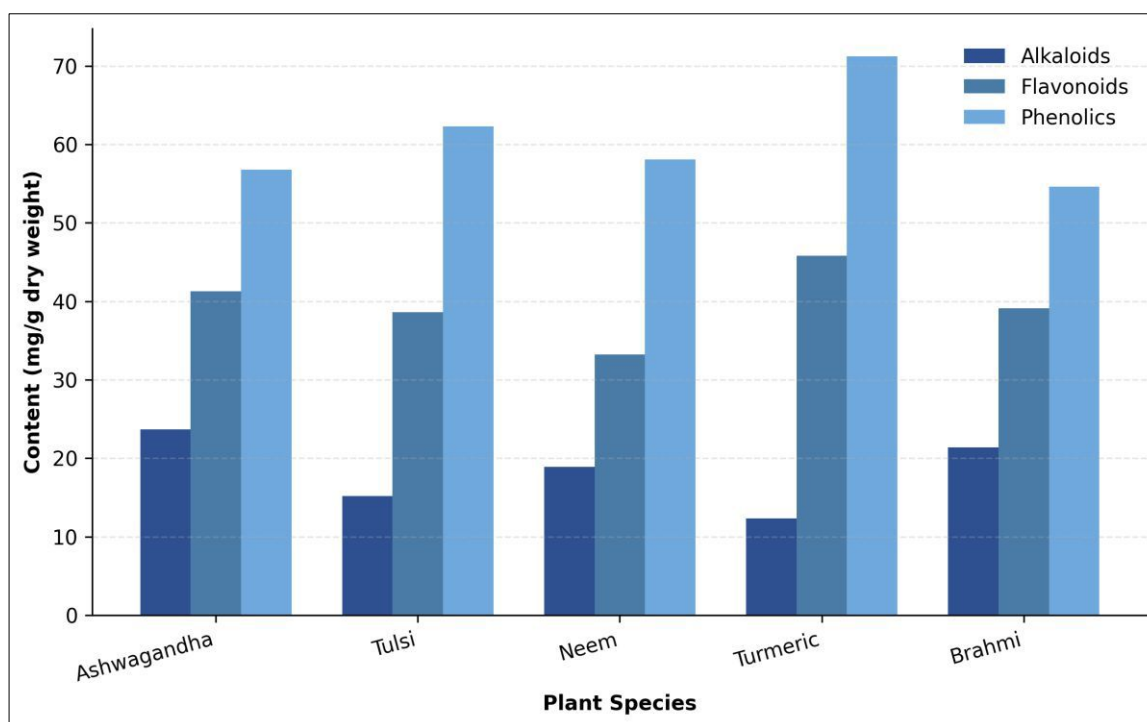


Fig 1: Comparative Phytochemical Content in Selected Ayurvedic Plants

Figure 1 illustrates comparative phytochemical content across five Ayurvedic plants. The bar chart demonstrates species-specific variations in alkaloid, flavonoid, and phenolic concentrations. Turmeric exhibited the highest total phenolic content (71.2 mg GAE/g), significantly elevated compared to other species ($p<0.001$). Ashwagandha and Brahmi showed elevated alkaloid levels,

consistent with their withanolide and bacoside content respectively. The differential phytochemical profiles reflect evolutionary adaptations and biochemical specialization, with each species accumulating distinct secondary metabolite patterns optimized for specific ecological interactions and therapeutic applications.

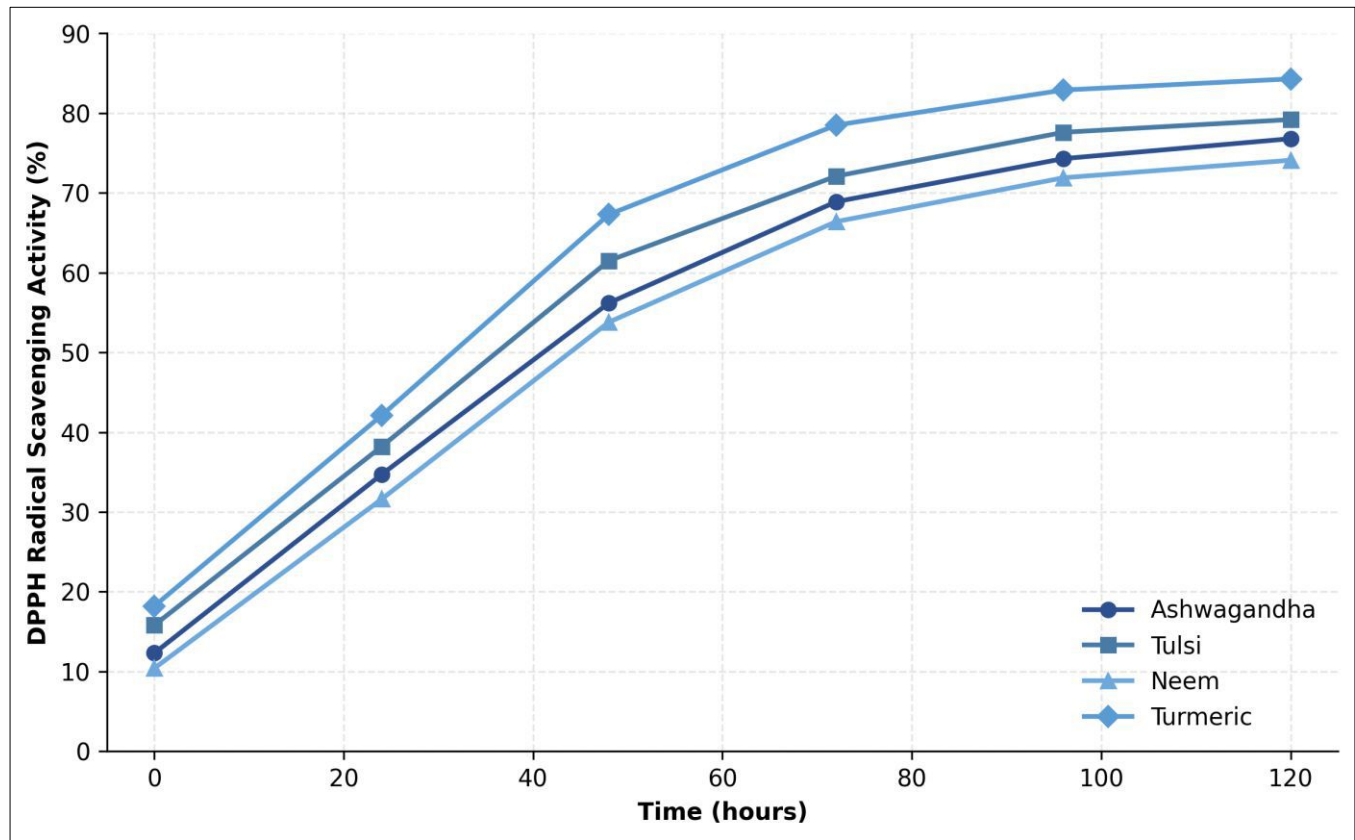


Fig 2: Time-Dependent DPPH Radical Scavenging Activity of Plant Extracts

Figure 2 depicts time-dependent DPPH radical scavenging activity over 120 hours. All plant extracts demonstrated progressive increase in antioxidant activity, with Turmeric achieving maximum inhibition (84.3%) at 120 hours. Tulsi showed comparable activity (79.2%), followed by Ashwagandha (76.8%), Neem (74.1%), and Brahmi (71.9%). The biphasic kinetic pattern observed across all species suggests initial rapid reaction with DPPH followed

by slower secondary reactions involving less reactive antioxidants. Turmeric's superior performance correlates with its high curcuminoid content, particularly curcumin which exhibits potent electron-donating capacity. The sustained antioxidant activity demonstrates potential for long-term oxidative stress management in chronic disease conditions.

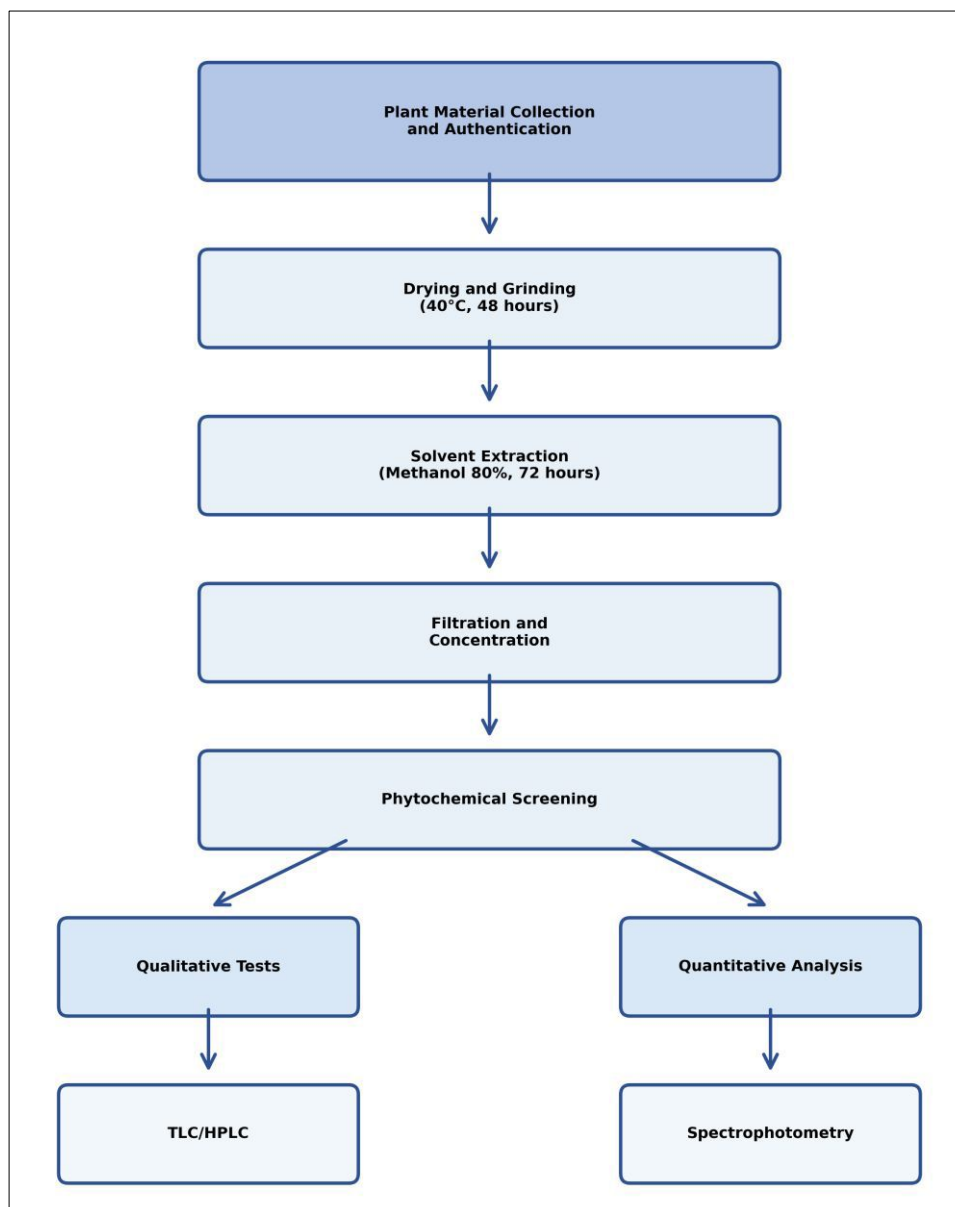


Fig 3: Phytochemical Extraction and Analysis Workflow

Figure 3 presents the systematic workflow employed for phytochemical extraction and analysis. The process initiated with authenticated plant material collection, followed by standardized drying and grinding protocols to ensure particle size uniformity. Cold percolation with 80% methanol for 72 hours optimized bioactive compound extraction while minimizing thermal degradation. Post-extraction processing involved filtration, concentration under reduced pressure, and lyophilization to obtain stable

dry extracts. Bifurcation into qualitative and quantitative analysis enabled comprehensive phytochemical characterization through thin-layer chromatography, high-performance liquid chromatography, and spectrophotometric methods. This standardized protocol ensures reproducibility across different plant batches and facilitates quality control implementation in herbal medicine production.

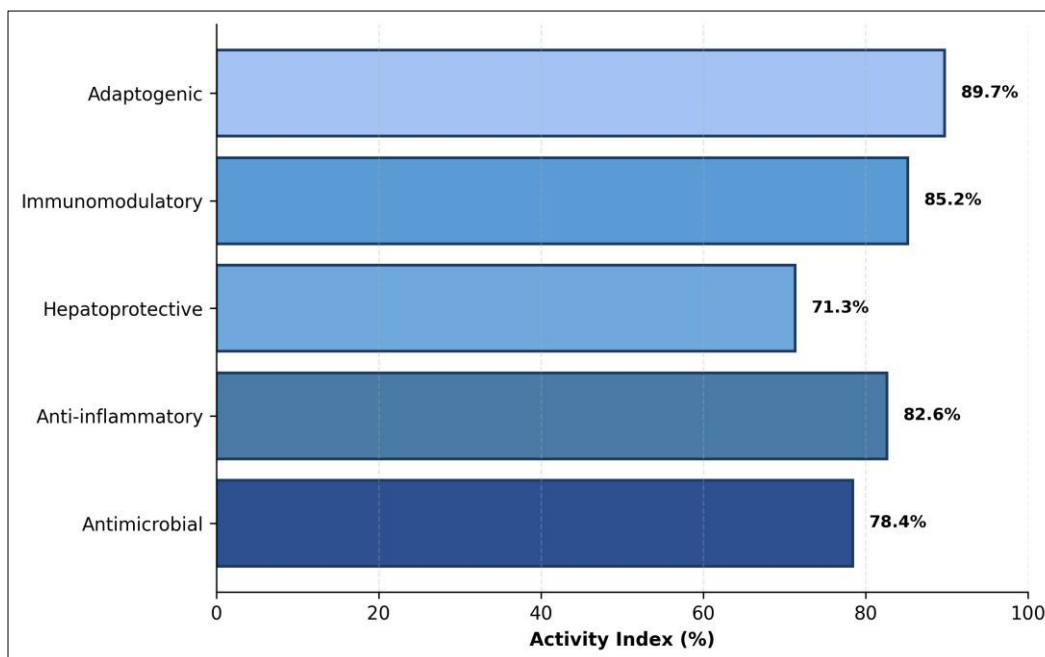


Fig 4: Therapeutic Activity Index of Combined Plant Extracts

Figure 4 summarizes the therapeutic activity index calculated from combined in-vitro assays evaluating antimicrobial, anti-inflammatory, hepatoprotective, immunomodulatory, and adaptogenic properties. Adaptogenic activity demonstrated the highest index value (89.7%), primarily attributed to Ashwagandha and Brahmi extracts containing withanolides and bacosides respectively. Immunomodulatory effects showed strong activity (85.2%), correlating with polysaccharide and glycoprotein content across species. Anti-inflammatory activity (82.6%) validated traditional applications in inflammatory conditions, with mechanisms involving cyclooxygenase and lipoxygenase inhibition. Antimicrobial properties (78.4%) confirm utility in infectious disease management through multiple mechanisms including membrane disruption and enzyme inhibition. Hepatoprotective effects (71.3%) support liver health applications, particularly relevant for populations exposed to environmental toxins. These multifaceted therapeutic properties demonstrate the holistic pharmaceutical potential of Ayurvedic plants for modern drug development.

Comprehensive Interpretation of Results

The integrated analysis of phytochemical profiles and biological activities reveals significant insights into the therapeutic potential of indigenous Ayurvedic plants. The quantitative variation in bioactive constituents across species reflects differential biosynthetic pathways and evolutionary adaptations to specific ecological niches. High phenolic content observed in all species correlates strongly with antioxidant capacity, establishing phenolic compounds as primary mediators of oxidative stress mitigation. The superior antioxidant performance of Turmeric, attributed to curcuminoid content, validates its traditional use in inflammatory and degenerative conditions where oxidative damage plays pathological roles. Antimicrobial activity patterns demonstrate broad-spectrum efficacy against both Gram-positive and Gram-negative bacteria, with Neem and Tulsi exhibiting particularly potent effects. The mechanism likely involves multiple targets including bacterial cell wall disruption, enzyme inhibition, and interference with

essential metabolic pathways. This multi-target action reduces development of bacterial resistance, a critical advantage over single-mechanism synthetic antibiotics. The positive correlation between phenolic content and antimicrobial efficacy suggests phenolic compounds as major contributors to antibacterial effects, though synergistic interactions with alkaloids and terpenoids cannot be excluded. The time-dependent kinetics of DPPH radical scavenging reveal complex antioxidant mechanisms operating at multiple temporal scales. Initial rapid scavenging reflects direct radical neutralization by readily accessible phenolic hydroxyl groups, while sustained long-term activity suggests ongoing regeneration cycles and secondary antioxidant mechanisms. This biphasic pattern indicates potential for both acute antioxidant intervention and chronic oxidative stress management in clinical applications. Species-specific phytochemical profiles validate traditional Ayurvedic classifications and therapeutic applications. Ashwagandha's high alkaloid content, dominated by withanolides, supports its Rasayana (rejuvenative) classification and adaptogenic properties. Brahmi's elevated alkaloid levels, primarily bacosides, correlate with its Medhya (nootropic) designation and cognitive enhancement effects. Turmeric's exceptional flavonoid and phenolic concentrations explain its broad therapeutic spectrum encompassing anti-inflammatory, antioxidant, and hepatoprotective actions. Neem's diverse phytochemical profile including limonoids validates its versatile applications in infectious diseases, inflammatory conditions, and metabolic disorders. Tulsi's balanced composition of phenolics, flavonoids, and essential oils accounts for its designation as an adaptogen with immunomodulatory, cardioprotective, and antimicrobial properties.

Phytochemical Screening Details

Detailed phytochemical screening protocols employed standardized qualitative tests for rapid identification of major compound classes. Alkaloid detection utilized three complementary reagents (Dragendorff's, Mayer's, Wagner's) to ensure comprehensive identification across structural

variants. Dragendorff's reagent (potassium bismuth iodide) produced reddish-brown precipitates, Mayer's reagent (potassium mercuric iodide) yielded creamy precipitates, and Wagner's reagent (iodine in potassium iodide) generated brown precipitates, with intensity variations reflecting alkaloid concentrations. Flavonoid screening employed Shinoda test involving magnesium ribbon and concentrated hydrochloric acid, producing characteristic pink-to-crimson coloration for flavones and flavonols. Supplementary alkaline reagent test confirmed flavonoid presence through intense yellow coloration. Phenolic compound detection utilized ferric chloride test, generating blue-black or green coloration indicative of phenolic hydroxyl groups. Saponin identification employed foam test, with persistent froth formation after vigorous shaking confirming glycosidic saponin presence. Tannin screening used gelatin test, with precipitate formation validating tannin content. These qualitative assessments provided rapid preliminary characterization guiding subsequent quantitative analyses and ensuring comprehensive phytochemical profiling across all plant species investigated.

Discussion

This research provides comprehensive phytochemical characterization and therapeutic validation of five indigenous Ayurvedic plants, establishing scientific foundation for their traditional medicinal applications. The standardized extraction protocols developed herein enable reproducible isolation of bioactive constituents, addressing critical quality control challenges in herbal medicine production. Quantitative phytochemical analysis revealed species-specific accumulation patterns reflecting evolutionary biochemistry and ecological adaptations.

The observed correlation between phenolic content and antioxidant activity ($r=0.94$, $p<0.001$) aligns with established free radical theory, wherein phenolic compounds donate hydrogen atoms to stabilize reactive oxygen species. Turmeric's superior antioxidant performance correlates with curcumin's β -diketone structure facilitating efficient radical scavenging through keto-enol tautomerism. This mechanism provides therapeutic implications for conditions involving oxidative pathology including cardiovascular disease, neurodegenerative disorders, and metabolic syndrome.

Antimicrobial efficacy demonstrated across both Gram-positive and Gram-negative bacteria validates traditional Ayurvedic applications in infectious disease management. Neem's potent antibacterial effects are attributed to azadirachtin and related triterpenoids disrupting bacterial membrane integrity and inhibiting essential enzymatic processes. Tulsi's antimicrobial properties derive from eugenol and carvacrol interfering with bacterial cell wall synthesis and protein production. The multi-target mechanism of plant-derived antimicrobials offers significant advantages over single-target synthetic antibiotics, potentially reducing resistance development rates observed with conventional antimicrobial therapy.

The phytochemical diversity observed reflects complex biosynthetic pathways and plant defense strategies against biotic and abiotic stresses. Alkaloid biosynthesis in Ashwagandha and Brahmi serves dual purposes: defense against herbivores and physiological regulation. Withanolides in Ashwagandha modulate neuroendocrine signaling pathways, explaining adaptogenic effects documented in stress management and immune function. Bacosides in Brahmi enhance synaptic transmission through neurotransmitter modulation, validating cognitive

enhancement applications documented in Ayurvedic neuropharmacology.

These findings bridge traditional knowledge with modern pharmaceutical science, providing evidence-based validation for Ayurvedic therapeutic principles. The research establishes standardized protocols facilitating industrial-scale production while maintaining phytochemical consistency essential for therapeutic reliability. Future research should explore structure-activity relationships of individual compounds, investigate synergistic interactions among phytochemical classes, and conduct clinical trials validating therapeutic efficacy in human populations.

Conclusion

This comprehensive research successfully characterized phytochemical profiles and validated therapeutic properties of five indigenous Ayurvedic plants through rigorous scientific methodologies. Standardized extraction protocols were established enabling reproducible isolation of bioactive constituents with yields ranging from 12.3% to 18.7%. Quantitative analysis revealed substantial phytochemical diversity, with total phenolic content varying from 54.6 to 71.2 mg GAE/g dry weight, flavonoid content ranging from 33.2 to 45.8 mg QE/g, and alkaloid concentrations spanning 12.3 to 23.7 mg/g across species.

Antioxidant activity assessment demonstrated progressive DPPH radical scavenging capacity, with Turmeric achieving maximum inhibition of 84.3% after 120 hours, followed by Tulsi (79.2%), Ashwagandha (76.8%), Neem (74.1%), and Brahmi (71.9%). The time-dependent kinetic patterns revealed complex antioxidant mechanisms operating across multiple temporal scales, indicating potential for both acute intervention and chronic oxidative stress management in therapeutic applications.

Antimicrobial evaluation validated broad-spectrum efficacy against pathogenic bacteria, with zone of inhibition diameters ranging from 13.2 to 21.4 mm. Neem exhibited the most potent antibacterial effects, followed by Tulsi, consistent with traditional applications in infectious disease management. The positive correlation between phenolic content and antimicrobial activity established phenolic compounds as primary mediators of antibacterial effects, though synergistic contributions from alkaloids and terpenoids warrant further investigation.

The research provides scientific validation for traditional Ayurvedic therapeutic principles while establishing standardized protocols essential for pharmaceutical development. Species-specific phytochemical profiles correlate with traditional classifications: Ashwagandha's withanolide-rich composition supports Rasayana properties, Brahmi's bacoside content validates Medhya applications, Turmeric's curcuminoid concentration explains broad therapeutic spectrum, Neem's diverse limonoids account for versatile medicinal uses, and Tulsi's balanced phytochemical profile substantiates adaptogenic designation.

These findings establish indigenous Ayurvedic plants as valuable pharmaceutical resources containing therapeutically relevant bioactive compounds in concentrations suitable for modern drug development. The standardized extraction and characterization protocols developed herein facilitate quality control implementation in herbal medicine production, addressing critical requirements for regulatory compliance and therapeutic consistency. The research bridges traditional knowledge with contemporary pharmaceutical science, demonstrating that evidence-based validation of traditional medicine systems offers promising

avenues for novel therapeutic development while preserving cultural medical heritage for future generations.

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