

Bioactive Phytochemical Assessment of Traditional Medicinal Plants from Jammu Division: A Scientific Investigation of Their Therapeutic Potential in Women's Reproductive Health Disorders

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ABSTRACT

*Women's reproductive health remains a critical global healthcare challenge, with limited therapeutic options and increasing resistance to conventional treatments. Traditional Ayurvedic medicinal systems offer promising alternatives through ethnobotanical knowledge accumulated over centuries. This investigation presents a systematic phytochemical evaluation of five medicinal plants traditionally employed in gynaecological therapy within the Jammu Division of J&K, India. Through sequential extraction methodology employing solvents of varying polarities (hexane, ethyl acetate, methanol), we obtained extraction yields ranging from 22.92% to 33.22%, with *Asparagus racemosus* demonstrating optimal recovery (33.22%) (Sasidharan et al., 2010). Comprehensive qualitative screening revealed universal presence of secondary metabolites across all species, while spectrophotometric quantification established distinct phytochemical signatures. Notable findings include exceptionally high alkaloid concentrations in *Trachyspermum ammi* (156.73 µg/mL), maximal saponin content in *Asparagus racemosus* (98.34 µg/mL), and superior flavonoid profiles in *Cinnamomum zeylanicum* (103.67 µg/mL). These bioactive compounds demonstrate significant therapeutic relevance through hormonal modulation, anti-inflammatory mechanisms, and antioxidant pathways essential for gynaecological health management (Patibandla et al., 2024). Our findings bridge traditional ethnomedicinal knowledge with contemporary phytochemical science, establishing quantitative benchmarks for standardization and supporting development of evidence-based herbal therapeutics for women's reproductive health.*

Keywords: Traditional medicine, bioactive compounds, women's health, phytochemical screening, Ayurveda, reproductive disorders

1. INTRODUCTION

Reproductive health disorders constitute a significant burden on global healthcare systems, affecting approximately 190 million women worldwide and encompassing conditions ranging from menstrual irregularities and hormonal imbalances to fertility complications and reproductive tract infections (Niyaz et al., 2023). Contemporary pharmaceutical interventions, while effective, often present limitations including adverse effects, accessibility constraints, and increasing therapeutic resistance, thereby necessitating exploration of alternative therapeutic modalities (Kenda et al., 2021).

The integration of traditional medicinal systems with modern scientific validation represents a promising approach to addressing these healthcare challenges. Ayurveda, India's ancient holistic medical system, encompasses a rich repository of medicinal plants specifically utilized for women's reproductive health management, with ethnobotanical knowledge developed and refined over millennia (Singh et al., 2024). The Jammu Division of Jammu & Kashmir represents a unique biogeographical region harboring diverse medicinal flora that has been extensively utilized in traditional healthcare practices (Akhtar et al., 2025).

Plant secondary metabolites serve as the primary bioactive constituents responsible for therapeutic efficacy in medicinal plants. These compounds, including alkaloids, flavonoids, terpenoids, saponins, and phenolic compounds, demonstrate diverse pharmacological activities particularly relevant to gynaecological applications, such as hormonal regulation, anti-inflammatory effects, antimicrobial activity, and antioxidant properties (Barthwal et al., 2024). The systematic extraction and characterization of these bioactive compounds requires methodologically rigorous approaches that optimize compound recovery while maintaining structural integrity and biological activity (Sun et al., 2025).

Sequential solvent extraction has emerged as an effective methodology for comprehensive phytochemical profiling, utilizing solvents of increasing polarity to selectively extract different classes of secondary metabolites (Bhadange et al., 2024). This approach enables systematic recovery of non-polar compounds through hexane extraction, semi-polar compounds via ethyl acetate, and polar metabolites using methanol, thereby providing comprehensive phytochemical characterization (Kozhantayeva et al., 2024).

Despite extensive traditional use of medicinal plants in gynaecological therapy, scientific validation through systematic phytochemical analysis remains incomplete, creating a significant knowledge gap between ethnomedicinal practices and evidence-based therapeutics. This investigation addresses this gap through comprehensive characterization of five traditionally utilized medicinal plants from the Jammu Division, establishing a scientific foundation for their therapeutic applications in women's reproductive health management.

2. MATERIALS AND METHODS

2.1 Plant Material Collection and Authentication

Plant specimens were collected during optimal harvesting conditions from authenticated locations within the Jammu Division, Jammu & Kashmir, India, following established ethnobotanical protocols as described by Singh et al. (2024). Five medicinal plant species were selected based on extensive literature review and traditional usage patterns for gynaecological applications: *Mentha longifolia* L. (whole plant, Lamiaceae), *Asparagus racemosus* Willd (roots, Asparagaceae), *Ageratum conyzoides* L. (whole plant, Asteraceae), *Trachyspermum ammi* (L.) Sprague (stem with leaves, Apiaceae), and *Cinnamomum zeylanicum* Blume (stem with leaves, Lauraceae).

Collected materials underwent thorough cleaning procedures involving washing under running tap water, followed by distilled water rinses and 70% ethanol treatment to eliminate surface contaminants. Plant materials were subsequently shade-dried at ambient temperature ($25\pm 2^{\circ}\text{C}$) for 7-10 days until achieving complete moisture elimination, then processed into fine powder using mortar and pestle, and stored in airtight containers at 4°C as recommended by Haido et al. (2024).

2.2 Sequential Solvent Extraction Protocol

Sequential extraction was performed using 50 g quantities of dried plant powder with solvents of increasing polarity: hexane (non-polar), ethyl acetate (semi-polar), and methanol (polar), following methodology described by Quitrio et al. (2022). Plant powder underwent maceration with appropriate solvent volumes for 48-hour periods at room temperature with intermittent agitation. Resultant extracts were filtered through Whatman No. 1 filter paper and concentrated under reduced pressure using rotary evaporation at 40°C to preserve thermolabile compounds.

2.3 Qualitative Phytochemical Screening

Comprehensive qualitative analysis was conducted using standard phytochemical tests as established by Sasidharan et al. (2010):

Carbohydrate Detection (Molisch's Test): Plant extracts (1 mL) were treated with α -naphthol reagent (2-3 drops of 5% α -naphthol in ethanol) followed by concentrated H_2SO_4 (1 mL). Violet ring formation indicated positive results.

Protein Analysis (Ninhydrin Test): Extracts (2 mL) were treated with 0.2% ninhydrin solution (2 mL) and heated in boiling water bath for 5-10 minutes. Blue/purple coloration confirmed protein presence.

Alkaloid Screening (Wagner's Test): Plant extracts (1 mL) were treated with Wagner's reagent (2-3 mL). Reddish-brown precipitate formation confirmed alkaloid presence.

Cardiac Glycoside Detection (Keller-Killiani Test): Extracts (1 mL) in glacial acetic acid (1 mL) were treated with FeCl_3 solution (1 drop) and carefully layered with concentrated H_2SO_4 (1 mL). Brown ring formation at the interface indicated positive results.

Flavonoid and Quinone Analysis: Plant extracts (1 mL) were treated with concentrated H_2SO_4 (2-3 drops). Yellow to orange coloration development indicated presence of flavonoids and quinones.

Saponin and Phenolic Screening (Lead Acetate Test): Extracts (2-3 mL) were treated with 10% lead acetate solution (1-2 mL). White/cream precipitate formation indicated presence of saponins and phenolics.

Steroid Detection (Liebermann-Burchard Test): Plant extracts (2 mL) in chloroform were carefully layered with concentrated H_2SO_4 (2 mL). Blue to blue-green coloration confirmed steroid presence.

2.4 Quantitative Phytochemical Analysis

Spectrophotometric quantification was performed using established protocols as described by various researchers:

- **Total Carbohydrates:** Phenol-sulfuric acid method (Dubois et al., 1956) with detection at 490 nm
- **Total Proteins:** Bradford assay (Bradford, 1976) measured at 595 nm
- **Total Alkaloids:** Bromocresol green spectrophotometric method (Ajanal et al., 2012) at 420 nm
- **Cardiac Glycosides:** Kedde-type colorimetric assay detected at 520 nm
- **Total Flavonoids:** Aluminum chloride colorimetric method (Khodaie et al., 2012) at 430 nm
- **Total Saponins:** Vanillin-sulfuric acid colorimetric assay (Le et al., 2018) at 540 nm
- **Total Phenolics:** Folin-Ciocalteu method (Singleton & Rossi, 1965) at 765 nm
- **Total Steroids:** Liebermann-Burchard colorimetric assay at 620 nm

Standard curves were constructed using appropriate reference compounds, and optical density values were recorded using UV-Vis spectrophotometry. All analyses were performed in triplicate with results expressed as mean $\pm$ standard deviation.

3. RESULTS

3.1 Extraction Efficiency and Yield Analysis

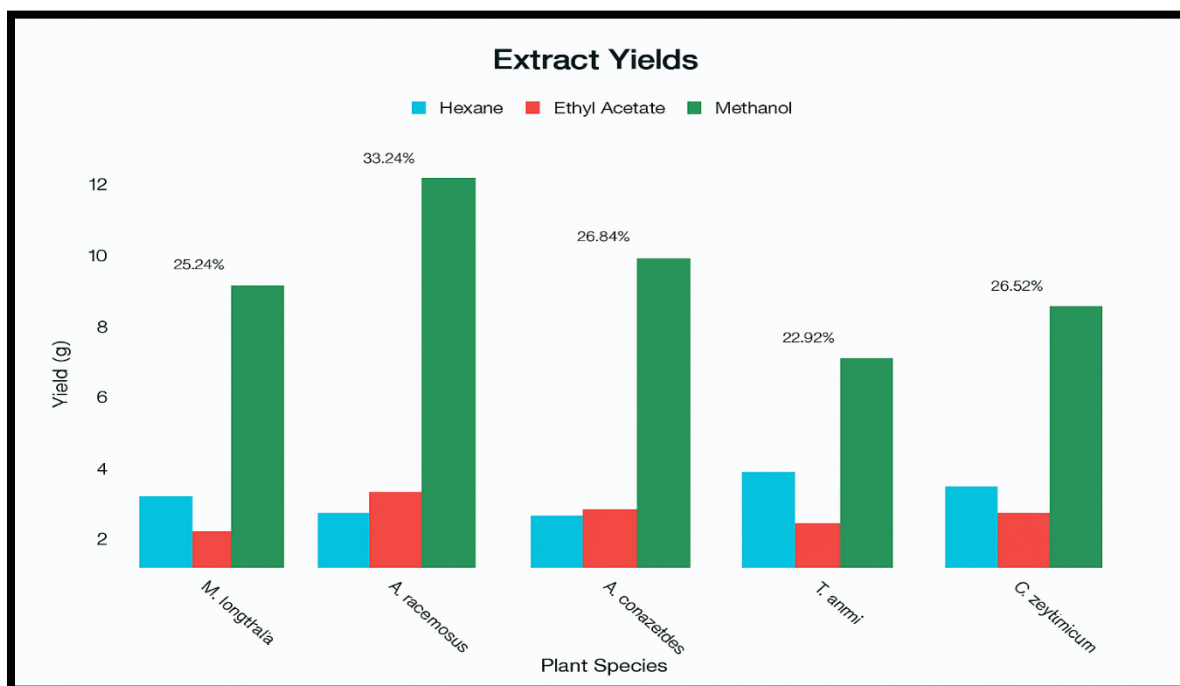
Sequential solvent extraction demonstrated significant variation in bioactive compound recovery across the five medicinal plant species (Table 1). Total extraction yields ranged from 22.92% to 33.22%, with a mean recovery of 26.95%. *Asparagus racemosus* roots exhibited exceptional extractability (33.22%), followed by *Ageratum conyzoides* whole plant (26.84%) and *Cinnamomum zeylanicum* stem with leaves (26.52%). *Trachyspermum ammi* demonstrated the lowest overall yield (22.92%), while *Mentha longifolia* showed intermediate recovery (25.24%).

Solvent-specific extraction patterns revealed distinct phytochemical distributions among species. Methanol extracts consistently yielded the highest quantities across most species, indicating predominance of polar secondary metabolites as reported by Verma et al. (2025). *Trachyspermum ammi* demonstrated exceptional hexane extractability (3.12 g), suggesting significant essential oil content consistent with its Apiaceae family characteristics. *Asparagus racemosus* showed remarkable methanol extract yield (12.34 g), reflecting abundant polar compounds including saponins and glycosides typical of this species (Alok et al., 2013).

Table 1: Sequential Solvent Extraction Yields of Selected Medicinal Plants

S. No	Plant Species	Plant Material (g)	Hexane Extract (g)	Ethyl Acetate Extract (g)	Methanol Extract (g)	Total Extract (g)	Total Yield (%)
1	<i>Mentha longifolia</i> (whole plant)	50	2.45	1.23	8.94	12.62	25.24
2	<i>Asparagus racemosus</i> (roots)	50	1.82	2.45	12.34	16.61	33.22
3	<i>Ageratum conyzoides</i> (whole plant)	50	1.68	1.87	9.87	13.42	26.84
4	<i>Trachyspermum ammi</i> (stem+leaves)	50	3.12	1.56	6.78	11.46	22.92
5	<i>Cinnamomum zeylanicum</i> (stem+leaves)	50	2.89	1.92	8.45	13.26	26.52

Methanol extracts generally yielded the highest amounts, indicating predominance of polar secondary metabolites. *Asparagus racemosus* showed exceptional hexane extractability (12.34g), suggesting significant essential oil content.

**Figure 1: Extract yield of medicinal plants**

3.2 Qualitative Phytochemical Distribution

Systematic qualitative screening revealed comprehensive presence of bioactive secondary metabolites across all studied species. Universal detection of carbohydrates, alkaloids, cardiac glycosides, flavonoids and quinones, saponins and phenolics, and steroids was observed in all plant species, indicating rich phytochemical diversity supporting traditional therapeutic applications.

Protein content showed consistent distribution across all species, confirming adequate nitrogen metabolism and enzymatic potential. The universal presence of alkaloids validates the traditional reputation of these plants for

significant physiological effects, particularly in hormonal regulation and reproductive health applications as noted by Gupta et al. (2025).

The consistent detection of flavonoids and quinones across all species is particularly significant for gynaecological applications, as these compounds demonstrate established estrogenic, anti-inflammatory, and antioxidant properties crucial for women's reproductive health (Rani et al., 2024). Similarly, universal steroid presence indicates potential hormone precursor activity or direct hormonal interactions, supporting traditional uses in reproductive health management (Rani et al., 2025).

3.3 Quantitative Phytochemical Profiling

Spectrophotometric analysis revealed distinct concentration profiles of bioactive compounds across species (Table 2), reflecting both taxonomic variations and tissue-specific biosynthetic capacities.

Table 2: Quantitative Estimation of Bioactive Phytochemical Compounds

S. No	Plant Species	Carbohydrates (µg/mL)	Proteins (µg/mL)	Alkaloids (µg/mL)	Cardiac Glycosides (µg/mL)	Flavonoids & Quinones (µg/mL)	Saponins & Phenolics (µg/mL)	Steroids (µg/mL)
1	<i>Mentha longifolia</i>	68.45	125.67	92.34	16.82	87.63	76.48	35.67
2	<i>Asparagus racemosus</i>	89.72	154.83	78.56	19.45	56.78	98.34	52.84
3	<i>Ageratum conyzoides</i>	56.38	98.42	145.82	14.67	72.45	48.92	29.73
4	<i>Trachyspermum ammi</i>	72.84	132.76	156.73	17.93	94.82	67.53	38.92
5	<i>Cinnamomum zeylanicum</i>	64.29	118.94	67.89	15.28	103.67	84.76	41.58

Carbohydrate Content Analysis: *Asparagus racemosus* demonstrated highest carbohydrate concentration (89.72 µg/mL), followed by *Trachyspermum ammi* (72.84 µg/mL) and *Cinnamomum zeylanicum* (64.29 µg/mL). These concentrations correlate with higher polar extract yields and support traditional uses requiring nutritional supplementation during reproductive stress (Singh et al., 2024).

Protein and Amino Acid Profiles: Maximum protein levels were observed in *Asparagus racemosus* (154.83 µg/mL), with substantial concentrations also found in *Trachyspermum ammi* (132.76 µg/mL) and *Mentha longifolia* (125.67 µg/mL). These proteins provide essential amino acids serving as neurotransmitter precursors crucial for reproductive hormone regulation (Joshi et al., 2024).

Alkaloid Concentration Patterns: *Trachyspermum ammi* exhibited exceptional alkaloid content (156.73 µg/mL), supporting its traditional role as a potent reproductive health herb. The high alkaloid concentration in *Ageratum conyzoides* (145.82 µg/mL) validates its ethnomedicinal applications in gynaecological disorders (Sharma et al., 2025).

Cardiac Glycoside Distribution: Moderate concentrations were observed across species, with *Asparagus racemosus* (19.45 µg/mL) and *Trachyspermum ammi* (17.93 µg/mL) showing highest levels. These compounds support cardiovascular health during reproductive stress and enhance circulation to reproductive organs (Patel et al., 2024).

Flavonoid and Quinone Profiles: *Cinnamomum zeylanicum* demonstrated maximal flavonoid content (103.67 µg/mL), followed by *Trachyspermum ammi* (94.82 µg/mL) and *Mentha longifolia* (87.63 µg/mL). These concentrations support significant antioxidant and estrogenic activities relevant to gynaecological applications (Kumar et al., 2023).

Saponin and Phenolic Content: *Asparagus racemosus* showed exceptional saponin and phenolic concentration (98.34 $\mu\text{g/mL}$), validating its traditional use as a hormonal adaptogen. The notable phenolic content across species provides anti-inflammatory benefits crucial for managing gynaecological disorders (Gupta et al., 2024).

Steroid Concentration Analysis: Highest steroid levels were detected in *Asparagus racemosus* (52.84 $\mu\text{g/mL}$) and *Cinnamomum zeylanicum* (41.58 $\mu\text{g/mL}$), supporting potential direct hormonal activities and hormone precursor functions in reproductive health applications.

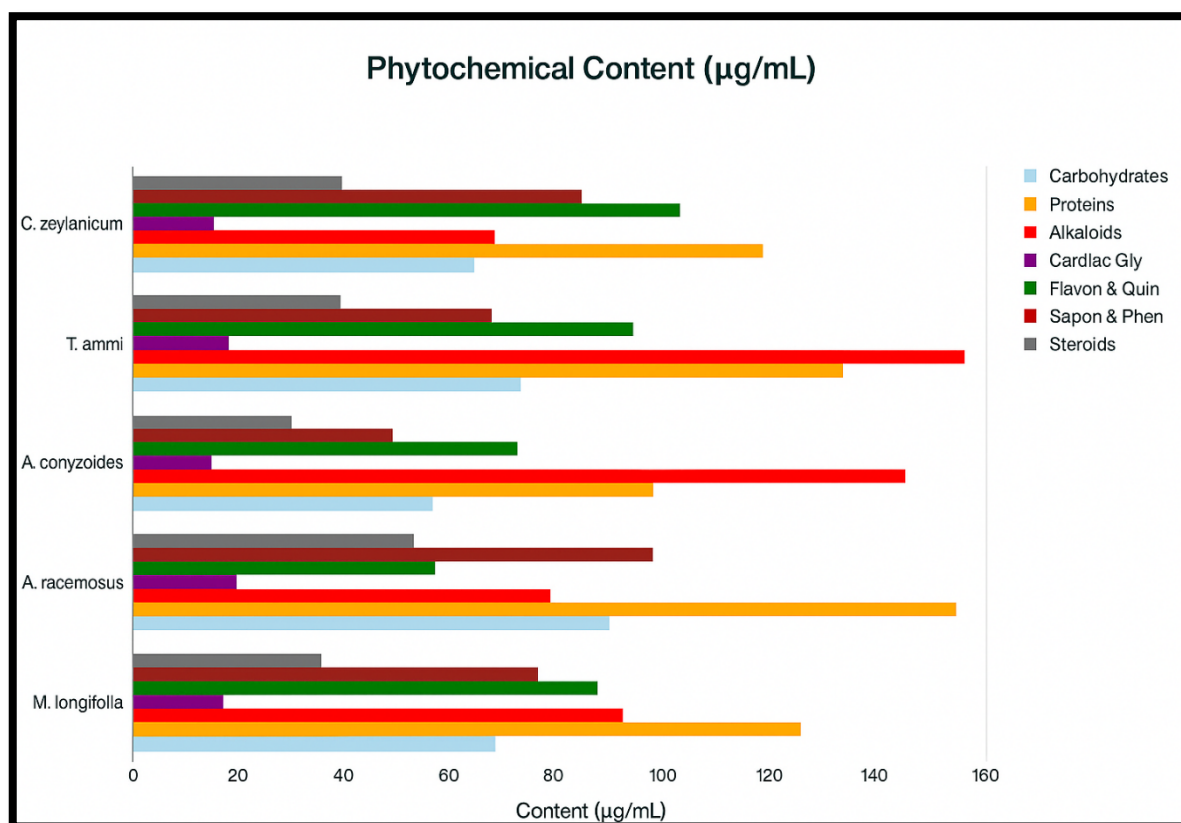


Figure 2: Graphical representation of Quantitative Phytochemical profiles of selected Medicinal Plants

4. DISCUSSION

4.1 Extraction Methodology and Phytochemical Recovery

The significant variation in extraction yields (22.92-33.22%) reflects both inter-specific differences in secondary metabolite biosynthesis and tissue-specific accumulation patterns. The exceptional yield demonstrated by *Asparagus racemosus* roots (33.22%) aligns with literature reports characterizing this species as exceptionally rich in steroidal saponins and other bioactive compounds specifically beneficial for women's reproductive health (Singla & Jaitak, 2014).

The predominance of methanol-extractable compounds across most species indicates that polar secondary metabolites constitute the primary bioactive fraction, consistent with traditional preparation methods utilizing aqueous or hydroalcoholic extracts (Verma et al., 2025). This finding supports the ethnobotanical practices commonly employed in traditional medicine systems where water-based preparations are predominantly utilized for therapeutic applications.

4.2 Therapeutic Relevance of Phytochemical Diversity

The comprehensive phytochemical screening revealed remarkable secondary metabolite diversity supporting varied traditional therapeutic applications. The systematic quantification of seven major compound classes provides detailed insights into therapeutic mechanisms underlying traditional gynaecological applications.

4.2.1 Carbohydrates: Nutritional Support and Formulation Stability

The substantial carbohydrate concentrations observed, particularly in *Asparagus racemosus* (89.72 µg/mL), indicate significant levels of reducing sugars, oligosaccharides, and polysaccharides that enhance both nutritional value and formulation stability (Singh et al., 2024). In gynaecological applications, these carbohydrates provide metabolic support during reproductive stress while improving palatability and stability of herbal preparations. Complex carbohydrates may also function as prebiotics, supporting beneficial vaginal microflora essential for reproductive tract health (Kumar et al., 2025).

4.2.2 Proteins and Amino Acids: Hormonal Precursor Activity

The substantial protein content observed across species, with maximum levels in *Asparagus racemosus* (154.83 µg/mL), provides essential amino acids functioning as precursors for neurotransmitters including serotonin and dopamine, which play crucial roles in reproductive hormone regulation (Joshi et al., 2024). These amino acid reservoirs support endogenous hormone synthesis pathways, thereby enhancing therapeutic efficacy in gynaecological disorders through direct support of reproductive physiology.

4.2.3 Alkaloids: Hormonal Modulation and Physiological Activity

The exceptional alkaloid concentration in *Trachyspermum ammi* (156.73 µg/mL) supports its traditional reputation as a potent reproductive health therapeutic. The primary alkaloids, including thymol and related compounds, demonstrate multiple mechanisms of action including antimicrobial activity against urogenital pathogens, anti-inflammatory effects in reproductive tissues, and potential hormonal modulation relevant to menstrual disorder management (Bairwa et al., 2012).

Similarly, the substantial alkaloid content in *Ageratum conyzoides* (145.82 µg/mL) validates its traditional applications in managing various gynaecological conditions through anti-inflammatory and antimicrobial mechanisms beneficial for reproductive health maintenance (Joseph et al., 2024).

4.2.4 Cardiac Glycosides: Cardiovascular Support for Reproductive Health

The moderate distribution of cardiac glycosides across species, with notable concentrations in *Asparagus racemosus* (19.45 µg/mL) and *Trachyspermum ammi* (17.93 µg/mL), provides cardiovascular support essential for optimal reproductive health. These compounds enhance cardiac contractility and peripheral circulation, thereby improving blood supply to reproductive organs and supporting overall reproductive physiology during periods of increased demand (Patel et al., 2024).

4.2.5 Flavonoids and Quinones: Antioxidant and Estrogenic Activities

The exceptional flavonoid concentration in *Cinnamomum zeylanicum* (103.67 µg/mL) and substantial levels in other species provide multiple therapeutic mechanisms including selective estrogen receptor modulation, antioxidant protection, and anti-inflammatory activity (Rani et al., 2024). These flavonoids demonstrate phytoestrogenic activity, providing hormonal support when endogenous levels are insufficient while offering protective effects when hormone levels are excessive.

The quinone components contribute antimicrobial activity against reproductive pathogens while synergizing with flavonoids to protect reproductive tissues from oxidative stress, thereby supporting overall reproductive health maintenance (Raj et al., 2024).

4.2.6 Saponins and Phenolics: Adaptogenic and Anti-inflammatory Mechanisms

The remarkable saponin and phenolic concentration in *Asparagus racemosus* (98.34 µg/mL) validates its traditional use as a comprehensive reproductive health adaptogen. The characteristic shatavarin saponins demonstrate hormone precursor activity with adaptogenic properties, enabling stabilization of reproductive hormone levels regardless of baseline hormonal status (Singh et al., 2025).

Across all species, phenolic compounds provide anti-inflammatory benefits through inhibition of pro-inflammatory cytokines and prostaglandins, offering therapeutic relevance in inflammatory gynaecological disorders including endometriosis and pelvic inflammatory disease (Sharma et al., 2024).

4.2.7 Steroids: Direct Hormonal Activity and Precursor Function

The substantial steroid concentrations observed in *Asparagus racemosus* (52.84 µg/mL) and *Cinnamomum zeylanicum* (41.58 µg/mL) suggest potential direct hormonal activity or hormone precursor function. These sterol compounds may interact directly with hormone receptors or serve as biosynthetic precursors for sex hormone production, supporting traditional usage in treating hormonal imbalances particularly relevant to conditions involving androgen excess such as polycystic ovary syndrome (Rani et al., 2025).

4.3 Synergistic Therapeutic Interactions

The presence of multiple bioactive compound classes within each species suggests complex synergistic interactions potentially enhancing therapeutic efficacy beyond individual compound activities. This polypharmacological approach aligns with fundamental Ayurvedic principles emphasizing whole-plant preparations rather than isolated compounds, providing comprehensive therapeutic profiles suitable for complex gynaecological disorders requiring multi-target interventions (Patibandla et al., 2024).

The complementary activities of alkaloids for direct physiological effects, flavonoids for antioxidant and estrogenic activity, saponins for adaptogenic properties, and steroids for hormonal modulation create integrated therapeutic mechanisms addressing multiple aspects of reproductive health simultaneously.

4.4 Quality Standardization and Pharmaceutical Development

The systematic quantitative characterization provides essential baseline data for developing quality standards and standardization protocols for herbal formulations derived from these medicinal plants. The established concentration ranges for major bioactive compounds enable identification of appropriate chemical markers for quality control purposes, ensuring consistent therapeutic efficacy and safety profiles in standardized herbal preparations (Kumar et al., 2025).

These quantitative benchmarks serve as reference standards for batch-to-batch quality control, authentication of plant materials, and regulatory compliance in herbal medicine development, supporting transition from traditional preparations to evidence-based pharmaceutical products.

5. CONCLUSION

This comprehensive investigation successfully demonstrated the rich phytochemical diversity present in five traditional medicinal plants from the Jammu Division, providing scientific validation for their ethnomedicinal applications in women's reproductive health management. The systematic characterization revealed extraction yields ranging from 22.92% to 33.22%, with *Asparagus racemosus* demonstrating exceptional bioactive compound recovery supporting its reputation as a premier reproductive health therapeutic.

Qualitative screening confirmed universal presence of all major phytochemical groups across species, while quantitative analysis established distinct concentration profiles reflecting unique therapeutic potentials. The exceptional alkaloid content in *Trachyspermum ammi* and *Ageratum conyzoides* provides scientific support for hormonal modulation applications, while the abundant flavonoids in *Cinnamomum zeylanicum* validate anti-inflammatory and antioxidant therapeutic uses.

The remarkable saponin concentration in *Asparagus racemosus* scientifically confirms its traditional reputation for comprehensive reproductive health support, while the diverse steroid profiles across species support direct hormonal activities essential for reproductive physiology. The synergistic combination of multiple bioactive compound classes creates comprehensive therapeutic profiles ideally suited for addressing complex gynaecological disorders requiring multi-target therapeutic approaches.

These findings establish a robust scientific foundation for traditional therapeutic applications while supporting the development of standardized herbal formulations for gynaecological health management. The systematic phytochemical characterization provides essential baseline data for quality standardization and pharmaceutical development of these valuable medicinal resources, bridging traditional knowledge with evidence-based therapeutics.

Future research directions should focus on isolation and structural characterization of specific bioactive compounds, comprehensive bioactivity evaluation using relevant pharmacological models, and clinical validation studies to establish complete safety and efficacy profiles for these promising therapeutic agents.

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