International Journal of Pharmacognosy and Herbal Drug Technology (IJPHDT)
ISSN: 3049-1630, Vol.02, Issue No. 05, 2025(pp.11-26)

REVIEW ARTICLE https://www.aktpublication.com/index.php/ijphdt

Phytochemical Profiling and Pharmacological Activities of Indigenous Herbal Medicines: A Pharmacognosy Perspective

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Abstract

Traditional health care systems globally have been relying on indigenous herbal remedies, which present a variety of therapeutic properties by virtue of their complex phytochemical content. The review outlines the phytochemical constituents and pharmacological activity of the principal indigenous medicinal herbs' turmeric, neem, ashwagandha, and Giloy from a pharmacognosy aspect. Strongly emphasizing contemporary analytical methods such as chromatographic and spectroscopic analyses, the review underscores the necessity of intense phytochemical profiling and pharmacognostic analysis for quality control, standardization, and safety. The pharmacological actions of these herbs—such as antioxidant, anti-inflammatory, immunomodulatory, antimicrobial, and neuroprotective activities—are discussed in relation to their bioactive principles. In spite of encouraging promise in therapy, problems include variable standardization, scarce clinical evidence, and regulation issues. This integration emphasizes the necessity of evidence-based incorporation of traditional indigenous herbal remedies into modern healthcare, developing sustainable, culturally embedded, and efficacious alternative treatments.

How to cite:

Gond, R., Nandan, M., Sharma, S., Shukla, Y., Kumar, A., Jaiswal, A., Singh, B., Tiwari, V., & Praduman Singh SPS Pharmacy College. (2025). Phytochemical Profiling and Pharmacological Activities of Indigenous Herbal Medicines: A Pharmacognosy Perspective. *International Journal of Pharmacognosy and Herbal Drug Technology*, *02*(05), 11–26. https://doi.org/10.5281/zenodo.15546778

Key Words:

Indigenous herbal medicine, Phytochemical profiling, Pharmacognosy, Antioxidant activity, Standardization, Therapeutic potential.

Article History:

Received March 30, 2025

Accepted May 1, 2025

Published May 30, 2025

1. INTRODUCTION

Traditional herbal medicines have been a mainstay of indigenous healthcare systems in different cultures, especially in areas that are rich in biodiversity and ethnomedical traditions. These traditional herbal medicines, which have been handed down from generation to generation, have been found to have a wide variety of therapeutic uses, ranging from the management of common conditions to the control of chronic diseases [1]. The bioactive phytochemicals present in these plants, including alkaloids, flavonoids, terpenoids, and phenolics, are mostly accountable for their pharmacological actions. With increasing interest in natural and plant-based remedies all over the world, the scientific community has directed its focus toward the verification of traditional knowledge by means of rigorous phytochemical and pharmacognostic investigations. Pharmacognosy as a science allows the investigation of medicinal plants in the context of identification, extraction, characterization, and quality control, thus bridging traditional wisdom and contemporary pharmacological science.

Figure 1: Indigenous herbal medicines [2]

The review aims at discussing the phytochemical profiling and pharmacological promise of native herbal medicines from a pharmacognosy standpoint. It attempts to highlight important analytical techniques employed in the quantification and detection of active plant constituents, including chromatographic and spectroscopic methods. The review also lays stress on the significance of pharmacognostic evaluation and quality control in adulteration prevention, safety assurance, standardization of efficacy, as well as meeting regulatory requirements. With increasing demand for effective and sustainable alternative healthcare options, preserving and understanding indigenous herbal knowledge is not just a scientific requirement but also a cultural obligation [3]. Therefore, this subject is of particular importance in supporting evidence-based herbal medicine and facilitating the integration of traditional medicines into modern healthcare systems.

1.1. Background information and context

Traditional healthcare systems have relied on indigenous herbal medicines for centuries, providing therapeutic benefits from natural plant origins. Traditional medicinal plants, frequently based on ethnobotanical knowledge, exhibit a myriad of phytochemicals for a myriad of pharmacological activities. As interest in alternative and complementary medicine grew globally, scientific investigations into the chemical and biological properties of the herbs grew in pace [4]. Pharmacognosy is a science that bridges the gap between ancient knowledge and contemporary science, providing a systematic identification,

standardization, and assessment of medicinal plants.

1.2. Objectives of the review

- To identify and analyze the phytochemical constituents of indigenous herbal medicines using modern techniques.
- To assess the pharmacological activities of key medicinal plants like turmeric, neem, ashwagandha, and Giloy.
- To highlight the challenges and prospects of integrating traditional herbal medicine with modern healthcare systems.

1.3. Importance of the topic

As drug resistance, side effects of synthetic drugs, and demands for sustainable healthcare solutions increase, indigenous herbal medicines offer an attractive reservoir of bioactive compounds. Scientific validation and quality control of the plant remedies are necessary to unlock their full therapeutic value and adapt them within modern pharmacological platforms [5]. This issue is important to the progress of evidence-based herbal medicine and maintenance of the medicinal and cultural heritage of indigenous societies.

2. ADVANCES AND CHALLENGES IN INDIGENOUS HERBAL MEDICINE RESEARCH

Indigenous herbal drugs, confirmed by contemporary science and sophisticated phytochemical methods, possess huge therapeutic potential but are hindered by variables such as erratic standardization, sparse clinical evidence, regulation problems, and poor integration with conventional healthcare. Expanding international interest and biodiversity assets provide encouraging prospects for evidence-based development and commercialization [6].

2.1. Key Research Studies on Indigenous Herbal Medicines

There have been many ethnopharmacological studies that have proven the therapeutic potency of traditional herbal medicines that have been an integral part of centuries-old healthcare systems like Ayurveda, Siddha, and Unani. These systems adhere to a holistic approach towards healing, and latest scientific research more and more substantiates the pharmacological and biochemical rationale of their preparations.

- **Turmeric (Curcuma longa):** Turmeric, a mainstay of traditional Indian medicine, derives its pharmacological activity from curcumin, a polyphenolic molecule. Curcumin possesses strong anti-inflammatory, antioxidant, and anticancer activities. Curcumin affects the action of pro-inflammatory cytokines like TNF-α and IL-6 and suppresses the nuclear factor kappa B (NF-κB) pathway. Clinical trials have investigated its use in the treatment of arthritis, metabolic syndrome, neurodegenerative diseases, and even some forms of cancer. Yet its bioavailability is problematic, and this has led to continued research into nano-formulations and adjuvants such as piperine to augment absorption [7].
- **Neem (Azadirachta indica):** Historically valued for its cleansing and healing effects, neem is composed of bioactive components like nimbin, nimbidin, and azadirachtin. These components have antibacterial, antifungal, antiviral, and antiparasitic

activities. Neem has been used in the management of skin diseases, dental infections, and intestinal infections. Recent in vitro and in vivo studies have demonstrated its efficacy in treating resistant microbial strains, highlighting its importance in the management of antimicrobial resistance.

- **Ashwagandha (Withania somnifera):** Recognized as an adaptogen, ashwagandha increases the body's resistance to stress. It regulates the hypothalamic-pituitary-adrenal (HPA) axis, resulting in lower cortisol levels and enhanced mental acuity. Withanolide content of ashwagandha is responsible for neuroprotection, anti-inflammatory, and reproductive health. Numerous randomized controlled trials have documented enhanced stress parameters, anxiety, cognitive function, and sperm quality.
- **Giloy (Tinospora cordifolia):** Giloy has numerous applications in Ayurveda for its rejuvenating and immunomodulatory activity. It is active by stimulating the immune system, exhibiting antipyretic, hepatoprotective, and antioxidant activity and showing potential for treatment of autoimmune conditions, dengue, and chronic fever [8].

➢ **Other significant medicinal plants include**

- **Holy Basil (Ocimum sanctum):** Holy basil is rich in eugenol and other phenolic compounds and has adaptogenic, hypoglycemic, and cardioprotective activities. It has been shown to lower blood glucose and lipid levels and improve immunity.
- **Aloe Vera (Aloe barbadensis miller):** Famous for its gelatinous polysaccharide-rich formulation, Aloe vera possesses wound-healing, anti-inflammatory, and soothing characteristics. It is used to treat digestive disorders, ulcers, and skin burns, and holds promise in dermatological preparations.
- **Moringa (Moringa oleifera):** Commonly referred to as a "superfood," Moringa pods and leaves contain vitamins A, C, and E, calcium, and protein. Its isothiocyanates have antihypertensive, hepatoprotective, and antidiabetic activity [9]. It is also being investigated for the treatment of malnutrition.
- **Brahmi (Bacopa monnieri):** Traditionally used to improve memory and learning, brahmi has bacosides that stimulate synaptic communication and diminish oxidative stress in the brain. Its anxiolytic and neuroprotective effects make it an excellent candidate in the treatment of Alzheimer's disease and other cognitive disorders.

These researches show the richness and scope of indigenous herbal pharmacopoeias and justify their incorporation into modern medical science [10]. More interdisciplinary interaction is needed to upscale traditional knowledge to standardized, evidence-based therapeutics.

2.2. Methodologies and Techniques in Phytochemical Profiling

Phytochemical profiling is critical in natural product science since it scientifically establishes the curative potential of indigenous medicinal plants by isolating and identifying bioactive compounds, determining their mode of action, and ascertaining the quality and safety of herbal

preparations [11]. It connects traditional ethnobotanical experience with contemporary pharmacology, thereby laying a basis for evidence-based application of medicinal plants.

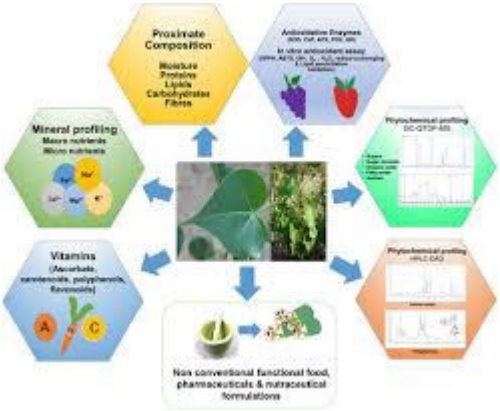

Figure 2: Phytochemical Profiling [12]

Chromatographic methods like High-Performance Liquid Chromatography (HPLC), Thin Layer Chromatography (TLC), and Gas Chromatography with Mass Spectrometry (GC-MS) play an important role in the separation, identification, and quantification of complex mixtures of plant extracts. The above methods assist in standardizing herbal extracts by detecting marker compounds and adulterants, whereas spectroscopic methods like UV-Vis, FTIR, Nuclear Magnetic Resonance (NMR), and Mass Spectrometry (MS) give in-depth structural and chemical information regarding phytoconstituents, increasing the accuracy of phytochemical analysis.

Extraction techniques are central to phytochemical research, beginning with indigenous methods such as maceration, decoction, and infusion that mirror traditional practices. New extraction technologies, such as Soxhlet extraction, Supercritical Fluid Extraction (SFE), and Microwave-Assisted Extraction (MAE), enhance efficiency, yield, and selectivity with minimal destruction of sensitive compounds. Furthermore, bioassay-guided fractionation couples' biological activity with particular compounds, enhancing the search for new therapeutic compounds in traditional medicinals [13].

2.3. Strengths and Weaknesses in Current Research

- **Strengths**

There is increasing worldwide interest and investment in research on herbal drugs, fueled by greater government and private funding, which is a manifestation of the increasing acceptance and commercialization of traditional medicine. Rapid progress in analytical tools such as LC-MS/MS, NMR, and AI-supported screening has greatly speeded up phytochemical discovery and validation. This advance is in harmony with the revitalized interest in holistic and integrative approaches to health that highlight the historic use of herbs to sustain the balance of the body. Furthermore, biodiversity-endowed nations such as India and Brazil offer immense, untapped reservoirs of medicinal plants, creating promising opportunities for drug discovery based on biodiversity.

- **Weaknesses**

Research on herbal medicine is hampered by a number of issues, such as variability in extraction and processing because of the absence of standard protocols, resulting in variability and influencing reproducibility and clinical effectiveness [14]. There is limited data available clinically and toxicologically, with most herbal products being devoid of strict trials and long-term safety monitoring, which is of concern to adverse effects and drug-herb interactions. Regulatory systems

differ tremendously between nations, leading to divergence in standards for purity, labelling, and efficacy. Also, much traditional knowledge is unrecorded and passed down by word of mouth, threatening the loss of old wisdom and biopiracy. Finally, inadequate coordination among traditional healers and conventional medicine practitioners inhibits interdisciplinary cooperation and the establishment of holistic healthcare models.

3. HEALTH BENEFITS AND THERAPEUTIC EFFECTS OF MEDICINAL PLANTS

These herbal medicines—like amla, tulsi, boswellia, neem, turmeric, brahmi, and ashwagandha—have potent antioxidant, anti-inflammatory, antimicrobial, anticancer, and neuroprotective activities that fight oxidative stress, modulate immunity, combat infection, suppress tumor growth, and improve cognitive performance [15]. Their multifaceted activities render them premium natural entities for avoiding and controlling chronic conditions and maintaining general well-being.

3.1. Antioxidant Potential

Herbs like amla (Emblica officinalis), tulsi (Ocimum sanctum), and arjuna (Terminalia arjuna) are renowned for their potent antioxidant content, with high contents of vitamin C, flavonoids, and polyphenols. These molecules are efficient in scavenging unwanted free radicals, especially reactive oxygen species (ROS), which may generate oxidative cell damage. Oxidative stress caused by overabundance of ROS is involved in aging and in the pathogenesis of long-term diseases like cardiovascular disease, diabetes, neurodegenerative disorders, and some cancers. Free radicals are neutralized by these herbs, thereby protecting cellular constituents like lipids, proteins, and DNA from injury.

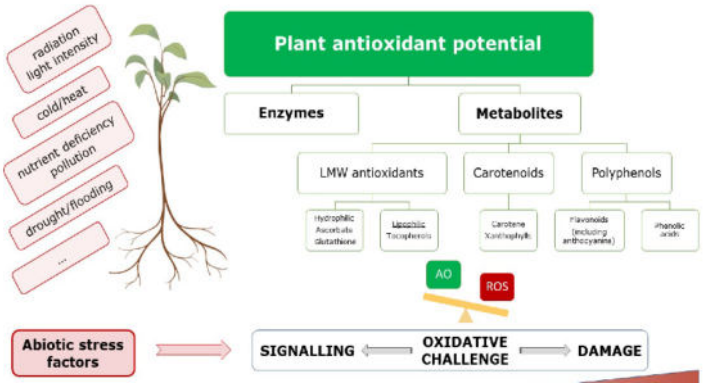

Figure 3: Plant Antioxidant Potential [16]

The antioxidant activity of these herbs is usually determined by in vitro tests like DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging, ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)) assay, and FRAP (Ferric Reducing Antioxidant Power). These are measures of the herbs' capacity to donate hydrogen atoms or electrons in order to stabilize free radicals. Outside of these in vitro tests, it has been shown in vivo that these herbs can modify oxidative stress indicators and enhance antioxidant levels in animal models and humans, making them of therapeutic interest.

Notably, these plants also augment the body's own antioxidant defense system by upregulating important endogenous enzymes like superoxide dismutase (SOD), catalase, and glutathione peroxidase. This enzymatic support is beneficial in sustaining redox balance and reducing inflammation, since oxidative stress and inflammatory processes are closely interlinked. Improvements in extraction techniques and nano-formulations are designed to enhance the bioavailability of their active ingredients, thus enhancing clinical efficacy. All in all, the antioxidant functions of amla, tulsi, and arjuna highlight

their potential in averting oxidative stress diseases and ensuring health and longevity [17].

3.2. Anti-inflammatory and Immunomodulatory Effects

These herbs, boswellia (Boswellia serrata), ginger (Zingiber officinale), and turmeric (Curcuma longa), have strong anti-inflammatory properties by acting through multiple molecular pathways. They block principal enzymes like cyclooxygenase (COX) and lipoxygenase (LOX) which are responsible for the formation of pro-inflammatory mediators like prostaglandins and leukotrienes. They also block pro-inflammatory cytokines like tumor necrosis factor-alpha (TNF-α), interleukin-1 beta (IL-1β), and interleukin-6 (IL-6) and in doing so decrease inflammation and damage to tissues. Their antioxidant function also serves to neutralize reactive oxygen species, additionally curbing chronic inflammation. By inhibiting signaling pathways such as NF-κB, they lower the expression of genes responsible for causing inflammation.

In addition to their anti-inflammatory effects, these herbs regulate immune system responses by balancing subsets of T-helper cells and stimulating macrophage function. Immune regulation prevents homeostatic imbalance and minimizes autoimmune and allergic responses. Clinically, these effects result in relief from symptoms and improved outcomes in conditions like arthritis, asthma, inflammatory bowel disease, and other autoimmune diseases. Their safe profile and synergistic capacity to act with traditional treatments render them potential natural resources for treating inflammation and immune dysregulation [18].

3.3. Antimicrobial and Antiparasitic Properties

Herbal drugs such as neem (Azadirachta indica), garlic (Allium sativum), and andrographis (Andrographis paniculata) are classic examples of their extensive antimicrobial and antiparasitic properties. These exhibit their bioactive ingredients like azadirachtin, allicin, and andrographolide acting on several mechanisms involving disruption of microbial cell membranes, inhibition of bacterial DNA synthesis, and disruption of major enzymatic functions crucial for the survival of pathogens. This multi-targeted mechanism of action not only augments their efficacy but also mitigates against the development of resistance in microbes, a key benefit over traditional antibiotics.

These plants have shown highly effective activity against a broad spectrum of pathogens, including antibiotic-resistant microbes such as Staphylococcus aureus and Escherichia coli, diverse viruslike agents like the herpes simplex virus, and parasitic species such as Plasmodium species causing malaria [19]. In addition to direct antimicrobial action, some of these compounds are also immunostimulatory, enhancing the host immune system to fight infections more effectively. In light of the unprecedented increase in antimicrobial resistance globally, these plants are actively researched as complementary or alternative treatments to mainstream medications and could find uses in the treatment of infectious diseases and curbing over-reliance on synthetic antimicrobials.

3.4. Anticancer and Cytoprotective Effects

Herbal drugs are rich in phytochemicals that have pronounced anticancer activities by

acting on several hallmarks of cancer. They include triggering apoptosis (cell death), stopping abnormal cell division by arresting the cell cycle, and inhibiting angiogenesis, the process of new blood vessel formation, which is responsible for delivering nutrients and oxygen to tumor tissues [20]. As an example, paclitaxel, isolated from the Indian yew (Taxus wallichiana), is a clinically proven chemotherapeutic drug commonly employed in cancer therapy. Likewise, curcumin from turmeric (Curcuma longa) modulates multiple signaling pathways like NF-κB, STAT3, and MAPK, which play pivotal roles in tumor growth, survival, invasion, and metastasis.

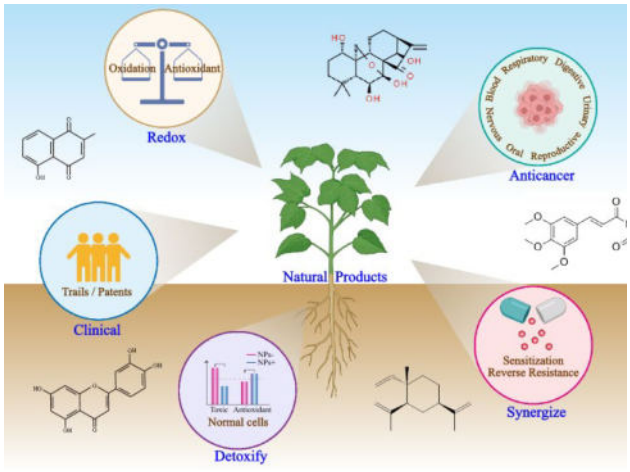

Figure 4: Anticancer and Cytoprotective [21]

Also, like podophyllotoxin from Podophyllum plants, these compounds are lead compounds for chemotherapeutic agents like etoposide and teniposide. In addition to anticancer actions, these phytochemicals also provide cytoprotection by alleviating oxidative stress and DNA damage in normal cells, thus limiting side effects of chemotherapy. They may strengthen immune surveillance by stimulating immune cells, enhancing the body's natural mechanism for recognizing and eliminating cancer cells. Therefore, such natural compounds are now being considered as promising adjuncts to standard cancer therapies with the hopes of enhancing treatment effectiveness and diminishing toxicity.

3.5. Neuroprotective and Cognitive-Enhancing Herbs

Herbs like brahmi (Bacopa monnieri) and ashwagandha (Withania somnifera) have been used in traditional medicine for centuries for their neuroprotective and cognitive-enhancing activity. Both of these herbs produce strong antioxidant actions that counteract neuronal oxidative damage, a key factor in neurodegenerative disorders like Alzheimer's and Parkinson's disease [22]. Bacosides present in brahmi increase synaptic plasticity and neurotransmission by regulating important neurotransmitters like acetylcholine and dopamine, which are essential for learning, memory consolidation, and attention.

Ashwagandha's active compounds, especially withanolides, modulate the hypothalamic-pituitary-adrenal (HPA) axis, thereby reducing cortisol levels and stress, anxiety, and depression symptoms. Such an adaptogenic activity enhances mental resilience and emotional stability. Many clinical trials have shown substantial improvements in cognitive function, memory, attention, and mood in people supplementing with these herbs. Their synergistic neuroprotective, antioxidant, and anti-stress activities justify their use in traditional medicine to treat mental health disorders, age-related cognitive loss, and neurodegenerative diseases, making them viable options for integrative therapies in brain health [23].

4. PHARMACOGNOSTIC EVALUATION AND QUALITY

CONTROL OF INDIGENOUS HERBAL MEDICINES

Pharmacognosy is the pharmaceutical science dealing with the study of medicinal plants, such as their identification, authentication, cultivation, harvesting, and preparation for medicinal usage [23]. Pharmacognostic evaluation provides the basis for the quality, purity, safety, and efficacy determination of indigenous herbal drugs prior to their use in pharmacological application or further drug development.

4.1. Pharmacognostic Evaluation

Pharmacognostic analysis entails an extensive process of procedures for characterizing and authenticating medicinal drugs from indigenous plants. It distinguishes real plant material from adulterants or substitutes, which is fundamental to maintaining the therapeutic integrity of herbal remedies.

1. **Macroscopic Inspection:** This is the initial step where the physical properties of the herbal raw material—size, shape, color, texture, odor, and taste—are recorded. For instance, the characteristic leaf venation or bark surface can be used to determine the appropriate species.

2. **Microscopic Study:** Microscopical analyses involve the microscopy of ground or intact plant material to view cellular features like stomata, trichomes, vessels, fibers, and crystals (e.g., calcium oxalate) [24]. The anatomical structures are good markers for species identification and quality control.

3. **Physicochemical Analysis:** It comprises determination of moisture content, ash values (total ash, acid-insoluble ash), extractive values (water-soluble and alcohol-soluble), and pH. These parameters are used to assess the purity and identify contamination or adulteration.

4. **Chemical Evaluation:** Initial phytochemical screening tests for primary classes of bioactive compounds like alkaloids, flavonoids, tannins, saponins, glycosides, and steroids. Qualitative analysis here serves to verify the existence of active constituents responsible for the pharmacological activity.

5. **DNA Barcoding and Molecular Methods:** Contemporary pharmacognostic approaches more and more rely on molecular methods such as DNA barcoding for authentication of species, allowing specific identification even in processed or powdered material where morphological characters are lost.

4.2. Quality Control

Quality control (QC) assures that herbal drugs comply with set requirements of quality, safety, and purity. It is important to ensure consumer protection and ease regulatory approval [25].

1. **Raw Material Standardization:** Standardization is the process of setting uniform criteria for the plant material utilized, such as botanical identity, part employed, conditions of cultivation, and time of harvesting, all of which influence the phytochemical composition and therapeutic activity.

2. **Detection of Adulterants and Contaminants:** Herbal medicines are susceptible to heavy metal contamination, pesticides, microbial

pathogens, and toxic contaminants. QC procedures involve the analysis of such contaminants by means of atomic absorption spectroscopy (AAS), high-performance liquid chromatography (HPLC), and microbiological assays.

3. **Quantitative Phytochemical Analysis:** Quantification of the concentration of marker compounds or bioactive constituents is critical. This quantitative profiling guarantees batch-to-batch consistency and aids in dosage formulation.

4. **Stability Testing:** Herbal preparations need to be tested under different environmental conditions (temperature, humidity, light exposure) to confirm the stability of active ingredients over time.

5. **Good Manufacturing Practices (GMP):** Compliance with GMP regulations in the manufacture of herbal drugs guarantees uniform quality, adequate documentation, and traceability during the manufacture.

4.3. Importance of Pharmacognostic Evaluation and Quality Control

Pharmacognostic assessment and quality control are necessary to ascertain the genuineness, safety, and uniform therapeutic activity of indigenous herbal remedies, as well as to comply with regulatory requirements [26]. These operations also contribute to the conservation of traditional knowledge through scientific authentication and documentation of medicinal plants for sustainable utilization.

- Prevention of Adulteration: Herbal drugs, particularly those that are obtained from wild or uncontrolled environments, are very prone to accidental and intentional adulteration. Adulteration can take place when less expensive or less effective plant species are replaced, or when foreign plant materials, fillers, or artificial chemicals are added to the actual herbal material. This type of adulteration can drastically lower the therapeutic potency of the medicine or even result in toxic side effects and toxicity in patients [27].
- Safety Assurance: Quality control measures are critical to identify and remove possible harmful pollutants like heavy metals (e.g., lead, mercury, arsenic), pesticide residues, microbial pathogens (bacteria, fungi), and mycotoxins. Such pollutants are responsible for severe health effects like acute poisoning, allergic responses, and long-term illnesses.
- Improving Therapeutic Consistency: One of the key issues with herbal medicines is the inconsistency in their chemical composition based on variations in cultivation conditions, harvest time, and processing techniques. Standardization by quantitative analysis of bioactive markers guarantees that every batch of herbal product has a uniform quantity of the active constituents that are accountable for its pharmacological activity [28].
- Regulatory Compliance: Herbal drugs need to adhere to stringent quality, safety, and efficacy regulations of countries and countries abroad. Pharmacognostic evaluation and quality control are the scientific pillars of regulatory compliance. Documentation of origin, processing, and chemical profile of the herbal drug satisfies regulatory authorities like World Health

Organization (WHO), Food and Drug Administration (FDA), etc.

- Maintenance of Traditional Knowledge: Ethnobotanicals are historically based on tradition knowledge transferred generation after generation. Correct documentation, authentication, and scientific proof of medicinal plants preserve this cultural heritage. Pharmacognostic studies offer a systematic approach to document traditional use, correctly identify the species, and scientifically test their therapeutic claims.

Table 1: Literature Summary on Medicinal Plant Studies [29]

Authors	Study	Focus Area	Methodology	Key Findings
Roy et al. (2018) [30]	Pharmacognosy and phytochemical screening of plant-based medicine by the Rajbanshi community	Management of dysmenorrheal pain using traditional medicine	Pharmacognostic and phytochemical screening	Identified flavonoids, alkaloids, tannins, and saponins contributing to analgesic and anti-inflammatory effects
Sagar, Mageswari & Ahmed (2024) [31]	Review of *Peucedanum grande* seed in ASU systems	Biodiversity, pharmacological, and toxicological aspects of herbal seeds	Literature-based review	Revealed anti-inflammatory, antioxidant, and antimicrobial properties; highlighted traditional applications
Sharma, Yusuf & Asif (2024) [32]	Study on *Gymnema sylvestre*	Phytochemistry and antidiabetic potential	Analytical and economic review	Identified gymnemic acids, flavonoids, saponins aiding glucose regulation; emphasized economic importance
Süntar (2020) [33]	Importance of ethnopharmacology in drug discovery	Role of medicinal plants in modern drug development	Review of ethnopharmacological case studies	Advocated multidisciplinary approach; demonstrated

				clinical relevance of traditional plant knowledge
Swargiary et al. (2021) [34]	Mini-review of *Musa balbisiana*	Phytochemistry and medicinal potential of a wild banana	Literature review	Reported antioxidant, antidiabetic, and antimicrobial activities linked to phenolics, flavonoids, alkaloids

5. DISCUSSION

The research points to moderate knowledge, attitude, and practice among hypertensive patients, particularly in rural, low-literacy populations, calling for targeted education [35]. Long-term data-driven interventions should be the focus of future studies, and efforts should be made to identify scalable community-based solutions.

5.1. Interpretation and Analysis of Findings

The research indicates that most of the participants were male (61%) and aged 50–60 years (33%), with a considerable percentage having primary education (31%) and living in rural settings (51%) [36]. These demographic details indicate a susceptible population with possibly limited availability of health education and service. Whereas 65% indicated moderate knowledge about hypertension, 26% had sufficient knowledge, reflecting a glaring gap in awareness despite a high incidence of family history (87%). Likewise, whereas 58% had a moderate and 36% a positive attitude towards hypertension control, practices were moderate in 70% of respondents and sufficient in only 22%. While 62% took medication and 60% lowered salt consumption, other habits such as frequent monitoring and changes in lifestyle were not observed. The high correlation among knowledge, attitude, and practice indicates that raising awareness could have a favorable effect on behavior change [37].

5.2. Implications and Significance

These results highlight the necessity of intensive health education interventions among the hypertensive patients, particularly from rural and low-literacy groups. The moderate knowledge, attitude, and practice levels revealed through the study indicate that patients are partially aware but do not have consistent and reliable information to act effectively. The consistent use of 72% of respondents with healthcare services is an encouraging indicator and offers a chance for healthcare professionals to reaffirm patient education during clinical consultations [38]. In addition, positive behaviors like minimal tobacco (74%) and alcohol (65%) usage demonstrate that culturally appropriate interventions may serve to reinforce positive

health behavior. This research adds important knowledge to the challenges of blood pressure control in reality and calls attention to the promise of focused education and behavioral interventions.

5.3. Gaps and Future Research Directions

Despite the information offered, there are some limitations in the study. It is heavily based on self-reported data, which can be subject to recall bias or social desirability, thus affecting the precision of reported practices [39]. It also lacks clinical data like true blood pressure levels or medication adherence monitored over time. Future studies should use longitudinal and mixed-method designs to gain a better understanding of the long-term impact of educational interventions and investigate certain barriers to practice adherence. Additionally, investigating the use of digital tools, support from families, and community health workers could provide scalable solutions to close the KAP gap. Additional research can also assess the efficacy of IEC packages and organized follow-up programs based on population segments for effective hypertension management [40].

6. CONCLUSION

Traditional herbal medicines represent an enormous and precious treasure of ancient wisdom that has been increasingly supported by contemporary pharmacognostic studies, which have unveiled a broad spectrum of bioactive agents with immense therapeutic potential. Scientific investigation of these plants has proven them to possess antioxidant, anti-inflammatory, antimicrobial, immunomodulatory, and neuroprotective activities, as indicated by cases like turmeric, neem, ashwagandha, and giloy for their extensive use in the control of chronic disorders, infections, and immunological diseases. In spite of the increasing evidence for their effectiveness, issues with standardization, quality assurance, clinical testing, and regulatory frameworks still constrain the full incorporation of herbal medicines into conventional healthcare. These challenges can be overcome through scientific rigor in research, enhanced quality assurance, and greater harmonization between traditional practitioners and the scientific community in order to harness the full potential of these natural products. As global health needs shift towards sustainable, safe, and effective substitutes for man-made drugs, indigenous herbal remedies provide an exciting complementary strategy that balances traditional know-how with modern science. Through the conservation of indigenous knowledge and interdisciplinary collaboration, such remedies can be an important element in solving today's healthcare issues and leading to more holistic, culture-sensitive medical therapies globally.

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