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Comparative Pharmacognostic and Phytochemical Evaluation of Marketed and Wild-Collected Herbal Drugs: A Systematic Review

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ABSTRACT

Background: People worldwide use herbal medicines, but there are major differences in their quality depending on if they are wild-collected or available from the market, because of adulteration, environmental changes and processing. Such differences change their appearance, chemical properties and the potential of their therapeutic use.

Objective: This study reviews the differences in Pharmacognostic and phytochemical characteristics between herbal drugs collected from wild versus market sources, with special attention to their quality and usefulness for treatment.

Methods: For this study, reports were searched through PubMed, Scopus, Web of Science and Science Direct for studies published between 2000 and 2025. Relevant information on normalized measurements of macroscopic, microscopic, physicochemical and phytochemical factors was obtained and investigated.

Results: Compared to wild herbal samples, herbal drugs marketed through firms usually had reduced taste, appearance and purity. Tests showed that commercial products contain less of certain bioactive chemicals and also showed inconsistent chromatographic patterns. The bioactivity of these microalgae such as their ability to combat oxidative damage and microbes, was also reduced.

Conclusion: The research shows that the herbal industry must strongly enforce both Pharmacognostic and Phytochemical standardization. Combining old and new analytical tools is vital to confirm the safety, effectiveness and compliance of herbal medicines.

Keywords: *Pharmacognostic evaluation, Phytochemical profiling, Herbal drugs, Marketed vs. Wild-collected, Quality control.*

1. INTRODUCTION

Herbal treatments have greatly supported traditional healing systems in many human societies for many generations and underlie the medical approaches known as Ayurveda, Traditional Chinese Medicine (TCM), Siddha, Unani and African ethnomedicine. Even with modern biomedical advances, people around the world rely greatly on herbal drugs [1]. A report

from the WHO shows that almost 80% of people worldwide still rely, sometimes fully and sometimes partly, on herbal remedies for primary healthcare, mainly in areas where hospitals and other medical services are rare. Herbal medicine remains popular thanks to strong traditions, the belief it is safe, people being able to find them, low costs and more people wanting to try natural treatments [2]. At the same time as traditional usage, the market for herbal medicines has significantly increased over recent years because of more awareness among consumers, a move toward traditional remedies and greater emphasis on prevention. Market research shows that herbal medicine was valued at about USD 170 billion in 2022 and is expected to reach over USD 350 billion by 2030, with a CAGR between 9% and 12%. Although increased market growth brings more healthcare for people and economic opportunities, it has raised major questions about the honesty, quality, effectiveness and safety of herbal drugs being sold in various markets [3]. In the world of herbal medicine, keeping quality consistent can be difficult due to the fact that natural plants vary in their properties. Artificial drugs are simply made, but herbal remedies are blends of many active compounds and their results can be altered by various surrounding factors. It involves factors such as the plant's native region, the nature of its soil, the climate present, the place it's grown, the season of gathering, how older the plant is at harvesting and ways of storing, handling and moving it [4]. Moreover, problems like replacing ingredients, contaminating materials with heavy metals, pesticides or microbes and a decline in robust compounds after the harvest add to the difficulties of controlling quality. Experts now say that many wild-collected herbal drugs often outperform those obtained from commercial stores in their pharmacology and chemical makeup [5]. Wild medicinal plants are often gathered when nature allows, so the secondary metabolites that make them useful are produced in the best possible way. Unlike drugs approved by hospitals, herbal drugs marketed to regular consumers are generally produced with variable agronomic standards, picked before full maturity, dried improperly and taken on long trips, leading to much lower quality [6]. Moreover, because herbal products are often made using uncontrolled methods, they are often not correctly identified, adulterated with similar plants or exposed to other contaminants which may reduce their effectiveness and cause problems with safety [7].

These quality problems can be solved through the use of pharmacognostic and phytochemical standardization. Pharmacognostics involves carefully checking the appearance, natural smell, taste and physical and chemical properties of any herbal medicine. With these parameters, we can confirm the identity of medicinal plants, pick out adulterated samples and ensure medicines are always the same from one production to the next [8]. Key features such as the type and count of pores, the shape of hairs, the way veins are arranged and the structure of crystals within the leaf can be analyzed under a microscope without being influenced by how a plant is grown. Additionally, phytochemical profiling is performed along with pharmacognostic assessment, using both quantitative and qualitative analysis of bioactive compounds by TLC, HPTLC, HPLC, GC–MS, spectrophotometry and similar modern techniques [9]. They make it possible to find and measure alkaloids, flavonoids, phenolics, glycosides, tannins and essential oils which give herbal drugs their power to heal. Modern quality control depends on chromatographic fingerprinting and the analysis of marker compounds to tell genuine from fake herbal preparations and to confirm the contents of commercial herbal products [10].

For the past two decades, studies comparing wild-collected and marketed herbal drugs have found important differences between the two. Often, morphological inspection shows that marketing plant samples are physically spoiled, have foreign material inside or their properties such as colour, feel and odour have been modified [11]. When growing conditions change from wild to commercial, analyzing microscopically often shows that diagnostics reduce, bacteria and fungi increase and plant parts inhabited by hairs and pores become sparser. Physicochemical parameters such as total ash, acid-insoluble ash, water-soluble ash, alcohol-soluble extractives and water-soluble extractives, are often outside the proper Pharmacopeial specifications in marketed drugs [12]. This points to the compromise in drug quality and the presence of adulterants. Investigation of phytochemicals confirms that the bioactive chemicals present in the two sources differ greatly in their presence and concentration. It is common for both chromatographic and spectrophotometric analyses to detect that the phytochemicals in marketed samples are not all present or have been affected by inappropriate production and storage methods [13]. Many commercial herbal drugs may not be as effective for certain health conditions because bioassays that measure antioxidant, antimicrobial, anti-inflammatory and cytotoxic properties tend to reveal less activity in them. Although there are concerning trends, pulling together all the available studies on how wild-collected and marketed herbal drugs differ has largely been neglected [14]. Much of the current studies look at just some plant species, local markets or single quality issues, leaving the entire herbal medicine industry unclear. Also, different experts disagree about which criteria and techniques should be used to study and compare herbal drugs from various sources [15]. As a result, this study aims to assemble and critically evaluate available research comparing the pharmacognostic and phytochemical characteristics of herbal medicines sold and those harvested from nature. Its goal is to explain what causes quality variation, explore the results for both medicine efficacy and user safety and emphasize the importance of new analytical methods in herbal drug standardization [16]. It also covers current rules governing these products, their quality control difficulties and suggestions for making herbal medicines more real, steady and effective in present-day medical systems [17].

2. METHODOLOGY

Searches of scientific articles were carried out to see how marketed herbal medicines and wild medicinal plants differ both pharmacognostically and in their phytochemical content. Publications from January 2000 to May 2025 were searched in

PubMed, Scopus, Web of Science and Science Direct. To increase your search results, you used keywords and stringed them together using Boolean operators with no limits. Only studies that concentrated on examining marketed herbal drugs side-by-side with wild ones, appeared in peer-reviewed journals and were in the English language were chosen. We excluded any articles missing a comparative approach, having only in vitro results and lacking useful pharmacognostic or phytochemical data. The titles and abstracts of the records were reviewed first and only after that were the full text of selected articles examined.

3. PHARMACOGNOSTIC EVALUATION OF MARKETED VS. WILD-COLLECTED HERBAL DRUGS

Evaluating an herbal drug becomes possible through pharmacognostic methods. Studying how a drug looks, is built and acts chemically provides a sure way to spot adulteration or lowering of quality [18]. Differences in gathering, growing, treating and storing herbal drugs have become of greater interest as comparative analysis reveals that marketed ones and wild drugs can differ a lot. This diagram compares the way marketed and wild-collected herbal drugs are checked by showing how they are collected, examined visually, under a microscope, analyzed using physicochemistry and authenticated [19]. Comparative Pharmacognostic Parameters of Marketed vs. Wild-Collected Herbal Drugs are summarized in Table 1 and Figure 1 show Workflow of Pharmacognostic Evaluation.

Morphological and Organoleptic Characteristics

Pharmacognostic evaluation begins with examining a plant's physical traits such as its size, shape, colour, texture, how it breaks up, smell and taste. Although they appear as they would in nature, wild-collected herbs vary depending on various environmental factors, seasons and location. However, when herbal products are marketed, they may be dried, cut, ground or packed, so their true shapes are not as noticeable as before [20].

The use of appearance, colour, aroma and taste is still a traditional method for the first qualitative examination of various crude drugs. Their profile is usually stronger and clearer, because they go through minimal processing once they are gathered. Still, some characteristics that can be identified by senses may disappear as products are manufactured and stored, making sole organoleptic testing for their authenticity difficult [21].

Microscopic and Anatomical Features

When morphological identification cannot work because the substance is powdered, examining an extract under a microscope is necessary. Evaluations of stomatal type and stomatal index, type of trichomes, whether calcium oxalate crystals are present, characteristics of fiber, patterns of vascular tissues and parenchyma are typical [22].

Studies report that microscopic structures in wild-collected herbs are usually complete and well conserved, allowing for correct identification. Often, herbal products that are prepared or stored for a long time in machines can lose key parts of their anatomy. Because of this deterioration, examining powdered forms using a microscope becomes difficult [23]. An examination under the microscope of *Withania somnifera* roots confirmed that, in wild-collected roots, starch grains, lignified fibers and stone cells stood out more clearly than in some commercially produced supplements. This demonstrates why careful analysis by pharmacognosy should play a key role in upholding quality [24].

Physicochemical Parameters

Assessment of herbal drugs is possible through their standard values of physicochemical parameters. Moisture content, total ash, acid-insoluble ash, water-soluble ash and extractive values (water, alcohol, ether), are frequently tested, while volatile oil analysis is done only in certain cases [25]. Wild-collected herbs often show different physicochemical properties at different times, in different places and after the collection process. Unlike other herbal drugs, marketed herbal drugs should meet Pharmacopeial standards, though several studies have found that this happens as a result of subpar processing, added ingredients or long storage times [26]. Research on *Terminalia chebula* showed that moisture and extract content were greater in the wild samples than in those sold in the market. It was noted that several commercial samples had higher than normal ash ratios, possibly because they contained added plant matter or inorganic material. The results prove that checking herbal products with physicochemical methods is needed to make sure they remain authentic and safe for the public [27].

Macroscopic vs. Microscopic Authentication Challenges

To authenticate herbal drugs, especially their commercial or processed forms, presents clear challenges. Macrosclerotic features are useful for identification of intact plant parts, but not for fragmented or powdered samples. In such cases microscopic examination is the most dependable method, however, widespread grinding or adulteration can obscure diagnostic cellular structures [28]. Often the macroscopic and microscopic authenticity markers of wild col lected herbs are preserved when properly harvested and handled. Because most herbal products are marketed without standardized processing, those products may have compromised diagnostic features adding the risk that misidentification or adulteration may occur [29]. Different macroscopic, microscopic and physicochemical parameters are employed for the pharmacognostic quality assurance as mentioned above, but as these challenges underscore the necessity to integrate all of them into a systematic approach to provide a blanket guarantee on quality [30].

Case Studies and Examples

Many studies demonstrate the Pharmacognostic differences between wild collected and marketed herbal drugs. Wild and commercial *Centella asiatica* leaves collected from various districts of Johor, Malaysia were analyzed for their characteristics [31]. The comparison of wild samples to those marketed showed that the samples from the wild contained characteristic green colour, pleasant odour and cleaner morphology, while the marketed samples contained faded colouration, altered aroma and higher foreign organic matter content. Similar research on *Bacopa monnieri* showed that the wild collected samples have intact leaf anatomy with clear oil gland and vascular bundles, whereas commercial powdered forms contain fragmented, indistinct tissue. Physicochemical analysis showed that potential extractive values and ash content also differed greatly [32]. Table 2 show Case Studies Highlighting Pharmacognostic Differences.

Table 1: Comparative Pharmacognostic Parameters of Marketed vs. Wild-Collected Herbal Drugs [33, 34]

Parameter	Marketed Herbal Drugs	Wild-Collected Herbal Drugs	Remarks
Morphological features	Processed, often uniform	Natural variation due to habitat	Wild shows higher variability
Organoleptic characteristics	May be faded or altered	Stronger, natural aroma and taste	Useful for primary authentication
Microscopic structures	Often damaged or degraded by grinding	Intact cellular features	Critical for powdered drugs
Moisture content	Lower, controlled	Higher, may vary with harvest season	Affects shelf life
Ash values	Sometimes inconsistent	Usually within natural range	Detects adulteration
Extractive values	May vary due to processing	Typically higher and consistent	Reflects phytochemical richness

Table 2: Case Studies Highlighting Pharmacognostic Differences [35]

Plant Species	Study Year	Findings in Marketed Samples	Findings in Wild-Collected Samples
Withania somnifera	2021	Faded aroma, reduced starch grains	Strong aroma, intact starch grains
Centella asiatica	2019	Foreign organic matter, altered morphology	Clean leaves, characteristic organoleptic profile
Bacopa monnieri	2023	Fragmented tissues, lower extractive values	Intact leaf anatomy, rich phytochemical content

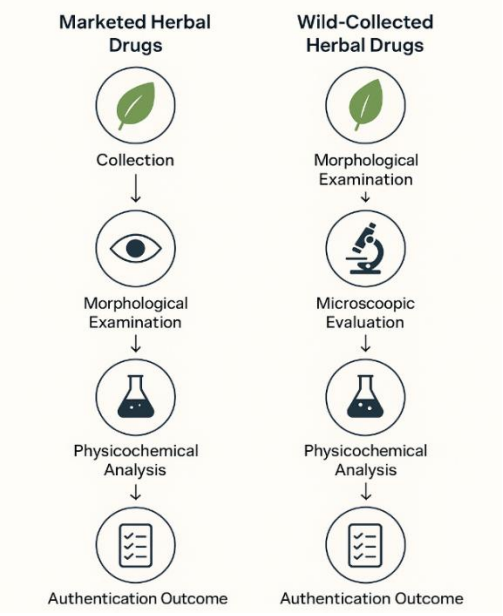

Figure 1: Pharmacognostic Evaluation Workflow

4. COMPARATIVE PHYTOCHEMICAL STUDIES

Qualitative Phytochemical Screening

Phytochemical screening, however, in qualitative form, is still an essential preliminary tool for detection of the presence of such important bioactive groups as alkaloids, flavonoids, tannins and saponins, glycosides in herbal drugs. Both marketed and wild collected medicinal plants are routinely subjected to standard hard chemical tests like Mayer's and Dragendorff's for alkaloids, Shinoda for flavonoids and ferri chloride for tannins [36]. Wild collected plants were reported to generally have a richer qualitative spectrum of secondary metabolites caused by their exposure to natural ecological stressors which induce the synthesis of defense compounds (Figure 1). While on one hand, marketed herbal drugs exhibit a narrower phytoconstituents profile compared to herbal drugs available in the wild due to the controlled cultivation processes and subsequent process after harvest, on the other hand, limited structure and physical properties characterization has obscured the responsibilities based on the marked effects [37].

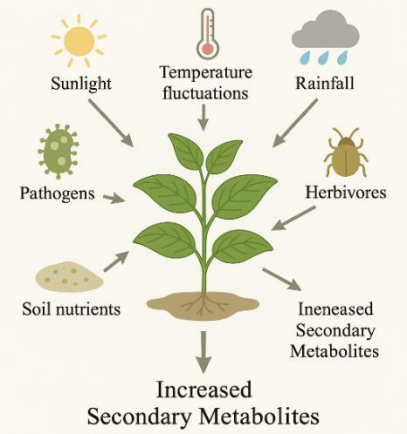

Figure 1: Secondary Metabolites in Medicinal Plants

Quantitative Phytochemical Analysis

Total phenolic content (TPC) is quantified by a Folin-Ciocalteu method while total flavonoid content (TFC) is determined using the aluminum chloride colorimetric assay. These values are consistently higher for wild-collected herbal drugs than marketed equivalents and are ascribed to environmentally induced biosynthesis due to the environmental stress (Figure 2). Importantly this quantitative variation is of crucial consequence for therapeutic efficacy and for dosage standardization [38].

Chromatographic Techniques in Profiling and Fingerprinting

Establishment of chemical fingerprints of herbal drugs by chromatographic profiling is unavoidable. The complex and diverse phytochemical compositions can be explored by means of Thin Layer Chromatography (TLC), High Performance Liquid Chromatography (HPLC) and Gas Chromatography Mass Spectrometry (GC-MS). It was found that wild collected herbal drugs chromatograms via TLC and HPLC show denser, rich and diverse peak profiles than marketed counterparts manifesting the wider phytochemicals in wild collected herbal drugs. These differences, important to standardization, authentication and for detection of adulteration or substitution, are described [39].

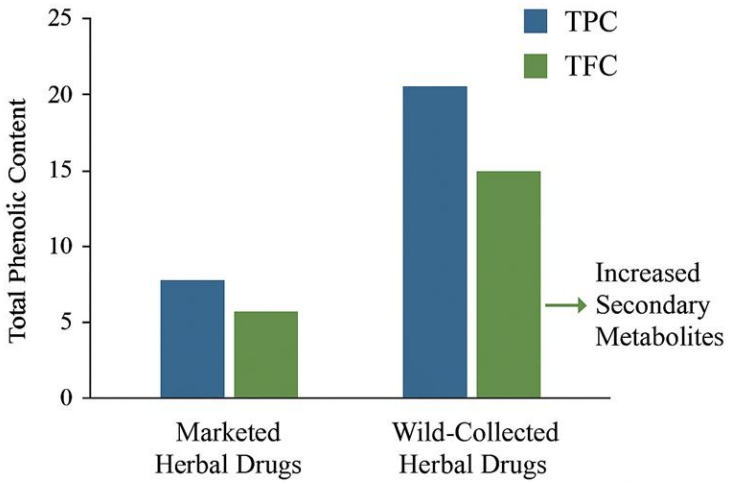

Figure 2: Correlation Between TPC and TFC

Variability in Bioactive Constituents Based on Source

The source and environmental conditions of plant collection have extremely large impacts on the variability of plant phytoconstituent content. Secondary metabolites produced by wild plants are subjected to natural temperature, light, soil nutrient and herbivory fluctuations which often results in a more diverse suite of secondary metabolites that represent adaptive biochemical response to these natural fluctuations. By contrast, cultivated plants grown routinely in controlled conditions are lower in variability and lower in concentrations of defense related compounds which can affect total phytochemical profile and medicinal potency of the plants [40].

Impact of Harvesting, Processing, and Storage

We have found postharvest practices like timing of collection, drying methods and storage duration profoundly influence the stability and concentration of phytoconstituents. Harvesting at the wrong time can result in too aggressive or too little harvesting and therefore significant fluctuations in content of these compounds. They also enhance the degradation of such sensitive metabolites as flavonoids and essential oils by improper drying and storage. The effects are exacerbated in marketed herbal drugs where bulk processing and long storage under suboptimal conditions degrade such integrity (Figure 3).

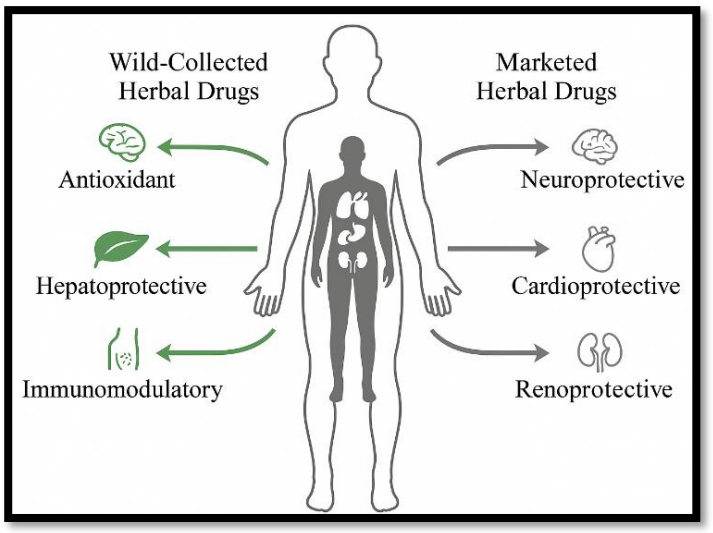

Figure 3: Human Body Illustration of Herbal Drug Quality Impact

5. FACTORS AFFECTING QUALITY DIFFERENCES

A complex interplay of multiple factors affecting the chemical and Pharmacognostic profile of plant material controls its quality and therapeutic efficacy as an herbal drug. Market- and wild- collected herbal drugs are often compared and extensive natural and anthropogenic variation is recognized that can closely resemble marketing differences [41].

Environmental Influences on Wild Plants

The phytochemical composition of wild medicinal plants is dynamically and uncontrollably exposed to environmental conditions. All these secondary metabolite biosynthesis is shaped by soil fertility, micro- and macronutrient availability, climate variability, geographical location and altitude as well as rainfall patterns. The production of flavonoids, alkaloids and phenolics as bioactive compounds is stimulated by drought, herbivore attack or UV radiation, resulting in richer phytochemical profiles from wild plants than from cultivated plants. More simplistically, differences in ecological niche lead even to chemotypic variation within the same species, rendering standardization efforts difficult [42].

Cultivation and Harvesting Practices for Marketed Herbal Drugs

Herbal drugs are typically marketed as products of cultivated sources in which agronomic practices such as irrigation, fertilization and pesticide use have been utilized to maximise yield. These methods have been shown to increase uniformity in plant growth while frequently decreasing environmental stress mediated phytochemical biosynthesis. In addition, high yield varieties selected through genetic choices may have been inadvertently selected for loss in secondary metabolite diversity. The valorization is also dependent on harvesting time, as it does not represent the same concentration of bioactive constituents at diverse growing stages. The suboptimal phytochemical content of herbal cannabis may adversely affect therapeutic potency, both prematurely and delayed harvesting [43].

Post-Harvest Processing and Storage Conditions

Phytochemicals are susceptible to rapid deterioration upon harvesting, at the various stages of post-harvest handling (drying,

grinding, storage and transportation), so far. Too little drying can offer an area of growth to bacteria and the action of enzymes, but too much heat may eliminate these heat sensitive compounds such as essential oils and certain flavonoids. Oxidative degradation and moisture absorption are accelerated by storage in humid, poorly ventilated or light exposed environments and subsequently diminish quality. Bulk marketed herbal products present the most challenging application in terms of phytochemical integrity, because usually these products are widely processed at large scale and stored for extended periods of time which result in a marked loss of phytochemical integrity [44].

Adulteration, Substitution, and Contamination Issues

Continuing problems in the herbal drug trade are adulteration and unintentional substitution. To augment profit margins marketed herbal drugs are sometimes adulterated with cheaper plant material, analogous synthetic chemicals or other species. Moreover, inaccurate identification when collected or deliberate substitution of closely resembling species will significantly alter Pharmacognostic and phytochemical profiles. Moreover, the product safety and efficacy is further compromised by contamination with heavy metals, pesticide residues, mycotoxins or microbial agents. However, these issues are less prevalent in authenticated wildcollected samples handled by these experienced ethnobotanists, but remain a regulatory issue with commercial markets [45, 46].

Regulatory Perspectives and Quality Control Challenges

Making herbal medicines of consistent quality is hindered by the natural variation in plant material and the lack of worldwide harmonized regulatory standards. Many medicinal plants are not covered in Indian Pharmacopoeia, British Herbal Pharmacopoeia and WHO monographs and there is no standardized protocol present, while pharmacopeia's like the Indian Pharmacopoeia, British Herbal Pharmacopoeia and WHO monographs serve as the quality benchmark for few selected species only. Market and wild-collected herbal drugs are compared to the standards of these known herbs, where equity is commonly shown by deviations in adherence to moisture content, ash values and phytochemical markers. Persistent quality control enforcement, adulteration control and consistent authentication and standardization techniques continue to pose challenges to the regulatory authorities [47].

6. IMPLICATIONS FOR HERBAL DRUG STANDARDIZATION AND QUALITY CONTROL

Pharmacognostic and phytochemical studies are therefore considered very important for building Pharmacopeial standards and quality assurance frameworks of herbal drugs. Through these studies, crucial evidence was produced to establish acceptable ranges of quality markers and therapeutic constituents by systematically identifying morphological, microscopic, physicochemical and phytochemical differences between marketed and wild-collected medicinal plants. Such insights can enable regulatory authorities and Pharmacopeial committees to modify monographs for improved consistency of identification, purity and potency criteria for herbal material. To maintain consistent herbal product quality in the market place, raw material authentication is required to be stringent so that Good Agricultural and Collection Practices (GACP) are complied with and chromatographic fingerprinting methods should be applied. Furthermore, as these wild collected plant materials offer natural variability and rich phytochemical profiles, including such data into Pharmacopeial and regulatory frameworks is also suggested. The integration of quality standards in medicinal plant resource would not only broaden the scope of quality standards but also would encourage biodiversity conservation and application of medicinal plant resources in sustainable way [48].

7. FUTURE PERSPECTIVES AND RESEARCH DIRECTIONS

Need for Advanced Analytical Techniques in Comparative Studies

Traditional Pharmacognostic and phytochemical methods are usually insufficiently sensitive and precise to distinguish subtle chemical differences between marketed and wild collected herbal drugs. Adoption of newer, swifter analytical techniques; such as, ultra-high-performance liquid chromatography (UHPLC), liquid chromatography mass spectrometry (LC-MS) and nuclear magnetic resonance (NMR) spectroscopy, will allow deeper knowledge of complex phytochemical profiles in some cases. By offering the means to identify the minor constituents, isomers and new bioactive natural products that may be missed by conventional methods, these tools help enhance the robustness of comparative evaluations [49].

Integration of Metabolomics, Chemometrics, and Molecular Tools

Research must deal with metabolomics in combination with Chemometrics analysis and molecular authentication techniques. Untargeted and targeted comparative studies can be performed because metabolomics provides a complete overview of the whole phytochemical composition of a plant. Chemometrics tools from principal component analysis (PCA) and hierarchical clustering analysis (HCA) can manage and interpret large complex datasets and deliver pattern and relationship information not easily recognizable by classical techniques. On the other hand, molecular approaches such as DNA barcoding and next generation sequencing (NGS) offer species specific identification that is critical to understanding adulteration and substitution problems particularly with respect to processed and powdered herbal formulations [50].

Importance of Sustainable Wild Collection and Cultivation Practices

With overharvesting and habitat loss continuing to pose significant threats to wild medicinal plant populations, it is increasingly important that suggested collection practices are ecological and conservation principles based. Assessing the ecological impacts of wild harvesting is an area where research should focus and the development of appropriate cultivation protocols for threatened and high demand species. Incorporating sustainable harvesting models into quality assurance frameworks will enable the preservation of biodiversity and secure stock quantities for both traditional and commercial production of high quality herbal materials [51].

Emerging Trends in Herbal Drug Authentication

Applying integrated and multidimensional Pharmacognostic, phytochemical, molecular and Chemometrics techniques, could present the potential for current and future herbal drug authentication. Rapid, non-destructive techniques for onsite authentication and quality control of legacy materials are emerging through portable spectroscopic tools such as handheld NIR and Raman devices, combined with machine learning algorithms [52]. In addition to this, block chain technology is explored to improve traceability and transparency of herbal supply chains which may revamp the quality assurance practices. The authenticity, safety and therapeutic reliability of herbal drugs will have to be critically embraced in order to safeguard these drugs in an increasingly globalised market [53].

8. CONCLUSION

The study shows that herbal drugs from wild sources differ significantly in their Pharmacognostic and chemical features from those sold commercially. Preparations of wild-harvested herbs usually show better structure, fewer contaminants and a higher concentration of useful compounds important for their medicinal properties. Alternatively, most herbal drugs sold in the marketplace suffer from reduced quality because of adulteration, changes in their structure and inconsistent plant chemical contents. These experiences call for stricter rules and precise quality controls in herbal pharmaceutical production. The combination of heritage techniques with advanced technology such as chromatographic fingerprinting and measurement of plant chemicals, is important to set up reliable standardization guidelines. These steps will improve consumer health and increase worldwide confidence in herbal medicines.

Conflict of Interest: Nil

REFERENCES

[1] Bokov DO, Krasikova MK, Sergunova EV, Bobkova NV, Kovaleva TYu, Bondar AA, et al. Pharmacognostic, Phytochemical and Ethnopharmacological Potential of *Cyclamen coum* Mill. *Pharmacogn J*. 2020;12(1):204–12.

[2] Snehalatha VR, Rasmi AR. Phytochemical evaluation and pharmacognostic standardization of *Syzygium palghatense* endemic to Western Ghats. *Future J Pharm Sci*. 2021;7:147.

[3] Hunter W. Pharmacognostic Analysis of Medicinal Plants: Integrating Traditional Knowledge with Modern Science. *J Pharmacogn Nat Prod*. 2024;10(3):309.

[4] Raja WY, Bhat ZA, Chashoo IA. Pharmacognostic and Phytochemical Characteristics of *Ailanthus altissima* (Mill.) Swingle Stem and Root Bark: A Comparative Study. *Pharmacogn J*. 2017;9(5):668–73.

[5] Mourya R, Sharma R. Exploring the Role of Phytoconstituents for Endocrine Disorder: A Review. *Pharmacogn Res*. 2025;17(2):385–401.

[6] Bhandari S, Trivedi R, Garg V, Saini A, Gupta M, Singh R. Advancements in Quantitative and Qualitative Methods for Quality Control of Herbal Drugs: A Comprehensive Review. *Pharmacogn Res*. 2025;17(2):402–10.

[7] Nagaraj AP, Venkatappa AH, Ramakrishna JK, Nagaraju PK, Ramesh B, Eain NU. Mechanistic Role of Phytophenolic Acids in the Management of Alzheimer's Disease: A Comprehensive Review. *Pharmacogn Res*. 2025;17(2):411–5.

[8] Jain NK, Anand S, Kesari P, Rani R, Kumar S, Tiwari A, et al. Unveiling the Phytochemical Profile and Therapeutic Benefits of *Solanum xanthocarpum*: A Systematic Review. *Pharmacogn Res*. 2025;17(2):440–51.

[9] Chaudhuri A, Gauttam VK, A A, Negi S, Singh G, B B, et al. Design and Evaluation of Novel in situ Gel Forming Ocular Drug Delivery System of Kaempferol for Sustain Pharmacological Response against Cataract. *Pharmacogn Res*. 2025;17(1):173–84.

[10] Kaushik S, Bhandari P, Bhandari A, Bhatt B, Mittal H, Babbar A. Analgesic and Anti-inflammatory Properties of *Oxalis dehradunensis* Raizada in Rats. *Pharmacogn Res*. 2025;17(1):185–91.

[11] Sharma S, Modi K, Asodariya V, Katara SK, Shah M. Pharmacognostic Specifications and RP-HPLC Analysis of *Manilkara hexandra* Stembark. *Pharmacogn Res*. 2025;17(1):154–61.

[12] Peeriga R, Manubolu K, Somasundaram J, Arabath SA, Petchimuthu S, Manepalli SNJ, et al. Exploring the

Glycosidic Compounds in *Ipomoea sagittifolia* Stems: A High-Performance Liquid Chromatography Approach. *Pharmacogn Res*. 2025;17(1):162–72.

[13] Madhivardhana P, Bharathy V, Karthikeyan A. Study of in silico and in vitro Anthelmintic Activity of Ethanolic Extract of *Artemisia pallens* Wall Ex. DC. *Pharmacogn Res*. 2025;17(1):143–53.

[14] Abbad S, Aissaoui N, Gana FZ. *Marrubium vulgare* Leaf Extract-Assisted Green Synthesis of Silver Nanoparticles: Optimization, Characterization and In Vitro Exploration of Their Antimicrobial, Antioxidant and Anti-Inflammatory Potential. *Pharmacogn J*. 2025;17(1):7–21.

[15] da Silva CA, Mfengwana PH, Burt FJ. The In-Vitro Antiviral Activity of *Carissa edulis*, *Tulbaghia acutiloba*, and *Tetradenia riparia* on Severe Acute Respiratory Syndrome Coronavirus-2. *Pharmacogn J*. 2025;17(1):47–57.

[16] Shekwa W, Mashilo M, Sydney MT, Peter M. In Vitro Antibacterial Activity, In-Silico Molecular Docking and Pharmacokinetic Profile of a Phytosterol Isolated from The Leaves of *Carissa bispinosa*. *Pharmacogn J*. 2025;17(1):99–106.

[17] Bayarsaikhan E, Turtushikh D, Buyanjargal E, Norovnyam R, Otgonsuren D, Khuvitavilan B, et al. Medicinal Application of the Iceland Poppy (*Papaver nudicaule* L.) in Traditional Mongolian Medicine. *Pharmacogn J*. 2025;17(1):71–6.

[18] Risma R, Aryati A, Bambang P. The Mechanism of Nanocurcumin in Inhibiting Parasitemia in *Plasmodium berghei* ANKA (PbA) Model Mice. *Pharmacogn J*. 2025;17(1):84–8.

[19] Mudjupa C, Rinthong P. In vitro 3-Hydroxy-3-methylglutaryl-coenzyme: A Reductase Inhibition Assay of Triphala Ayurvedic Formulation. *Pharmacogn Res*. 2020;12(4):337–41.

[20] RaviKKumar VR, Rathi S, Singh S, Patel B, Singh S, Chaturvedi K, Sharma B. A Comprehensive Review on Ulcer and Their Treatment. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2023 Dec 21;39:e20230006. doi: 10.62958/j.cjap.2023.006. PMID: 38755116.

[21] Rajput DS, Gupta N, Singh S, Sharma B. A Comprehensive Review: Personalized Medicine for Rare Disease Cancer Treatment. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2023 Dec 23;39:e20230008. doi: 10.62958/j.cjap.2023.008. PMID: 38830754.

[22] Singh S, Chaurasia A, Rajput DS, Gupta N. Mucoadhesive Drug Delivery System and There Future Prospective: Are a Promising Approach for Effective Treatment? Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2023 Dec 20;39:e20230005. doi: 10.62958/j.cjap.2023.005. PMID: 38751344.

[23] Kumar, S., Saha, S., Sharma, B., Singh, S., Shukla, P., Mukherjee, S., Agrawal, M., Singh, K., & Singh, T. (2023). The role of resveratrol in Alzheimer's disease: A comprehensive review of current research. Current Functional Foods, 2(2), Article e121223224364, 13 pages. https://doi.org/10.2174/0126668629269244231127071411

[24] Patel S, Ismail Y, Singh S, Rathi S, Shakya S, Patil SS, Bumrela S, Jain PC, Goswami P, Singh S. Recent Innovations and Future Perspectives in Transferosomes for Transdermal Drug Delivery in Therapeutic and Pharmacological Applications. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2024 Oct 24;40:e20240031. doi: 10.62958/j.cjap.2024.031. PMID: 39442957.

[25] Vaghela MC, Rathi S, Shirole RL, Verma J, Shaheen, Panigrahi S, Singh S. Leveraging AI and Machine Learning in Six-Sigma Documentation for Pharmaceutical Quality Assurance. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2024 Jul 18;40:e20240005. doi: 10.62958/j.cjap.2024.005. PMID: 39019923.

[26] Patel S, Ismail Y, Singh S, Rathi S, Shakya S, Patil SS, Bumrela S, Jain PC, Goswami P, Singh S. Recent Innovations and Future Perspectives in Transferosomes for Transdermal Drug Delivery in Therapeutic and Pharmacological Applications. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2024 Oct 24;40:e20240031. doi: 10.62958/j.cjap.2024.031. PMID: 39442957

[27] Kumar, S., Saha, S., Pathak, D., Singh, T., Kumar, A., Singh, K., Mishra, A. K., Singh, S., & Singh, S. (2024). Cholesterol absorption inhibition by some nutraceuticals. Recent Advances in Food, Nutrition & Agriculture, 16(1), 2–11. https://doi.org/10.2174/012772574X285280240220065812

[28] Singh, S., Chaurasia, A., Rajput, D. S., & Gupta, N. (2024). An overview on mucoadhesive buccal drug delivery systems & approaches: A comprehensive review. African Journal of Biological Sciences (South Africa), 6(5), 522–541, DOI: 10.33472/AFJBS.6.5.2024.522-541

[29] Kumar, S., Singh, S., Rajput, D., Sharma, B., Chaturvedi, K., Singh, N., Saha, S., Singh, K., & Mukherjee, S. (2024). Pharmacological approaches and herbal interventions for Alzheimer's disease. The Natural Products Journal, 14(8), Article e220124225945. https://doi.org/10.2174/0122103155275266231123090138

[30] Ravikkumar VR, Patel BD, Rathi S, Parthiban S, Upadhye MC, Shah AM, Rehan SSA, Samanta S, Singh S. Formulation and Evaluation of Drumstick Leaves Tablet as An Immunomodulator. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2024 Jun 21;40:e20240004. doi: 10.62958/j.cjap.2024.004. PMID: 38902996.

[31] Sharma, A., Bara, G., Keshamma, E., Sharma, B., Singh, S., Singh, S. P., Parashar, T., Rathore, H. S., Sarma, S. K., & Rawat, S. (2023). Cancer biology and therapeutics: A contemporary review. Journal of Cardiovascular Disease Research, 14(10), 1229-1247.

[32] Dewangan, H. K., Singh, S., Mishra, R., & Dubey, R. K. (2020). A review on application of nanoadjuvant as delivery system. International Journal of Applied Pharmaceutics, 12(4), 24–33. https://doi.org/10.22159/ijap.2020v12i4.36856

[33] Singh S, Chaurasia A, Gupta N, Rajput DS. Effect of Formulation Parameters on Enalapril Maleate Mucoadhesive Buccal Tablet Using Quality by Design (QbD) Approach. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2024 Jun 27;40:e20240003. doi: 10.62958/j.cjap.2024.003. PMID: 38925868.

[34] Patel SK, Prathyusha S, Kasturi M, Godse KC, Singh R, Rathi S, Bumrela S, Singh S, Goswami P. Optimizing Irbesartan Fast Dissolving Tablets Using Natural Polysaccharides for Enhanced Drug Delivery and Patient Compliance. Int Res J Multidiscip Scope (IRJMS). 2025;6(1):1181-1190. https://doi.org/10.47857/irjms.2025.v06i01.02542

[35] Prince Patel, Piyush Jain, Hetvarth Patel, Aman Tiwari, Sanjesh Rathi and Shubham Singh (2025) Formulation, optimization and evaluation of mucoadhesive buccal tablets of ondansetron for enhanced bioavailability and sustained drug release. Biochem. Cell. Arch. 25, 1063-1069. DOI: https://doi.org/10.51470/bca.2025.25.1.1063

[36] Doshi GM, Badgujar AD, Mathurvaishya IS. Gas Chromatography-High-Resolution Mass Spectrometry Elucidation and in vitro Cell Line Studies (Sulforhodamine B) on Niosomal Gel of *Benincasa hispida*. *Pharmacogn Res*. 2020;12(4):342–51.

[37] Paul A, Raj S, Vibhuti A, Pandey RP. Larvicidal Efficacy of *Andrographis paniculata* and *Tinospora cordifolia* against *Aedes aegypti*: A Dengue Vector. *Pharmacogn Res*. 2020;12(4):352–60.

[38] Prakash O, Malik S, Rani KV, Verma VK. Phytochemical Screening and Bioactive Potential of Pod Seed Extracts of *Leucaena leucocephala* Linn. *Pharmacogn Res*. 2020;12(4):361–7.

[39] Bello SA, Ayofe TA, Yakub MF, Jamiu AT. Comparative Analysis of the Antimicrobial Potential of Stem and Fruit Extracts of *Calotropis procera*. *Pharmacogn Res*. 2020;12(4):368–74.

[40] Deore SL, Bhansali PB, Baviskar BA. Pharmacognostic, Phytochemical and in vitro Biological Evaluation of *Blepharis repens* (Vahl) Roth. *Pharmacogn J*. 2020;12(5):952–61.

[41] Balasubramaniam G, Sekar M, Varadarajan M, Badami S. Antioxidant and Hepatoprotective Activities of *Strobilanthes kunthianus* against Carbon Tetrachloride-Induced Hepatotoxicity in Rats. *Pharmacogn J*. 2020;12(5):1143–51.

[42] Agustina DW, Wahyuningsih MD, Widyarti S, Soewondo A, Tsuboi H, Rifa'i M. Noni Juice (*Morinda citrifolia*) to Prevent Cancer Progression in Mice Induced DMBA and Cigarette Smoke Exposure. *Pharmacogn J*. 2020;12(5):946–51.

[43] Ferubko EV, Rendyuk TD, Dargaeva TD, Nikolaev SM. Development and Evaluation of New Choleretic Agent. *Pharmacogn J*. 2020;12(5):962–6.

[44] Chowdhury P. In Silico Investigation of Phytoconstituents from Indian Medicinal Herb *Tinospora cordifolia* (Giloy) against SARS-CoV-2 (COVID-19) by Molecular Dynamics Approach. *arXiv preprint*. 2020;arXiv:2007.00621.

[45] Kuruvilla J, Anilkumar M. Pharmacognostic and Phytochemical Evaluation of the bark of *Grewia tiliifolia* Vahl. *Pharmacogn J*. 2020;12(5):967-976.

[46] Sarwade PP, Nisha KB, Hari I, Tawale H, Ambika J, Thaiyalnayagi S, et al. Phytochemical Analysis, Antioxidant Activity of Wild Medicinal Plants of Himalayan Range. *J Res Appl Sci Biotechnol*. 2024;3(5):131-146.

[47] Gupta M, Sumaiya S, Ali S, Naved T, Sharma A, Ahmad A, et al. Pharmacognostical and Phytochemical Evaluation of a Unani Polyherbal Formulation: Dawa ul Kurkum by HPTLC. *Separations*. 2023;10(2):89.

[48] Rajapaksha HKK, Fernando MN, Nelumdeniya NRM, Bandara AWMKK, Silva ARN. Evaluation of In vitro anti-inflammatory activity and Insilico pharmacokinetics and molecular docking study of *Horsfieldia iryaghedhi*. *arXiv preprint*. 2024;arXiv:2405.07449.

[49] Kaur R, Zhang S, Berwal B, Ray S, Kumar R, Varshney LR. From Phytochemicals to Recipes: Health Indications and Culinary Uses of Herbs and Spices. *arXiv preprint*. 2024;arXiv:2410.17286.

[50] Zheng X, Wu H, Jin H, Li R. FMCHS: Advancing Traditional Chinese Medicine Herb Recommendation with Fusion of Multiscale Correlations of Herbs and Symptoms. *arXiv preprint*. 2025;arXiv:2503.05167.

[51] Waghmare R, Tatke P. Pharmacognostic Evaluation of *Lagerstroemia speciosa* Fruit. *Int J Pharm Sci Res*. 2021;12(11):5842-5847.

[52] Ahmad A, Husain A, Mujeeb M, Khan SA, Alhadrami HAA, Bhandari A. Quantification of total phenol, flavonoid content and pharmacognostical evaluation including HPTLC fingerprinting for the standardization of *Piper nigrum* Linn fruits. *Asian Pac J Trop Biomed*. 2015;5(1):101-107.

[53] Gempo N, Yeshi K, Jamtsho T, Jamtsho L, Samten, Wangchuk P. Development of quality control parameters for two Bhutanese medicinal plants (*Aster flaccidus* Bunge and *Aster diplostephioides* (DC.) Benth. ex C.B.Clarke) using traditional and modern pharmacognostical platforms. *Heliyon*. 2024;10:e24969.