

Review Article

Exploration, Documentation, and Validation of Traditional Bioresources for the Development of Mitigation Strategies for Infectious Diseases

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Abstract

Traditional bioresources have been instrumental in the prevention and treatment of infectious diseases for centuries. Knowledge on traditional bioresources or ethnobotanical knowledge, derived from indigenous communities, provides a valuable foundation for discovering novel therapeutic agents. However, the scientific validation of these traditional remedies remains a significant challenge. This review explores the exploration, documentation, and validation of traditional bioresources to combat infectious diseases. Additionally, it highlights the rich history of traditional medicinal practices and their significant contributions to the development of modern drug discovery. Various medicinal plants, fungi, and microbial derivatives exhibit antimicrobial, antiviral, and immunomodulatory properties, which can be harnessed for modern healthcare applications. Effective documentation through ethnobotanical surveys, digital databases, and traditional healer interviews play a crucial role in preserving knowledge. The validation process involves phytochemical analysis, in vitro and in vivo studies, and clinical trials to confirm efficacy and safety. Several case studies, such as the successful development of artemisinin from *Artemisia annua* and curcumin from *Curcuma longa*, highlight the potential of traditional bioresources in modern medicine. However, challenges such as standardization, ethical concerns, and integration into mainstream healthcare persist. Future research should focus on interdisciplinary collaborations, policy development, and biotechnological advancements to optimize the use of traditional bioresources. By bridging the gap between traditional wisdom and scientific validation, these bioresources can contribute significantly to combating infectious diseases globally. By combining traditional knowledge with contemporary scientific techniques, India can pave the way for future research that will help develop improved phytopharmaceuticals, benefiting global health and safeguarding its rich cultural heritage.

Keywords: Bioresources; Traditional knowledge; Exploration; Documentation; Validation; Infectious diseases

Introduction

Traditional bioresources encompass a diverse range of naturally derived substances used in ethnomedicine. The use of traditional bioresources, particularly medicinal plants and other natural products, has been a cornerstone of human healthcare systems for millennia. Before the advent of modern pharmaceuticals, communities worldwide relied on indigenous knowledge to manage and mitigate various ailments, including infectious diseases. These natural resources, rooted in cultural practices and time-honored traditions, are still of great significance today, particularly in regions where access to modern medical care is limited or unavailable. In the face of global health challenges, including the rising threat of infectious diseases, traditional bioresources are increasingly being recognized for their potential to contribute to the development of new therapeutic interventions. Their exploration, documentation, and validation are vital components of this process, offering a sustainable, culturally relevant, and cost-effective approach to disease mitigation.

Significance of Traditional Bioresources

Traditional bioresources have long been used in managing and preventing infectious diseases. Traditional bioresources have a significant role to play in mitigating infectious diseases through their medicinal properties, disease prevention practices, and ecological benefits.

Medicinal Plants: Medicinal plants have been vital for developing medications and drugs, with over 35,000 species used globally, especially in emerging countries where plant-based traditional medicine is a primary healthcare resource. A review [1] emphasizes the importance of plants like aloe, ginger, turmeric, tulsi, and neem in treating respiratory ailments. These plants contain bioactive compounds, such as tannins, alkaloids, and flavonoids, with diverse therapeutic effects. Plants like *Echinacea purpurea* and *Zingiber officinale* show potential in supporting treatments for conditions like

COPD, bronchitis, asthma, the common cold, cough, and whooping cough. Leaves from plants like *Acacia torta*, *Ocimum sanctum*, and *Mentha haplocalyx* are used for ailments such as pneumonia, bronchitis, and colds. Herbs like *Andrographis paniculata* (Kalmegh) and *Tinospora cordifolia* (Guduchi) have been used in Ayurveda for their immunomodulatory effects.

Fungi and Microorganisms: Certain fungi (*Ganoderma lucidum*) and microbial derivatives (antibiotics from *Streptomyces* spp.) exhibit antimicrobial properties [2,3]. As antibiotic resistance becomes a growing problem, traditional bioresources such as fungi and microorganisms can play a critical role in finding new antibiotics or alternatives to combat resistant pathogens. Many fungi and microorganisms synthesize compounds like enzymes, alkaloids, terpenoids, and polyketides, which have been used to treat a variety of diseases. These compounds have antibacterial, antiviral, anti-inflammatory, anticancer, and immunosuppressive properties, making them valuable in modern pharmaceuticals.

Marine Bioresources: Algae and marine invertebrates provide bioactive compounds with antiviral and antibacterial properties. The marine environment is a major producer of algae and seaweed, rich in functional ingredients with beneficial health effects. Algal metabolites from both microalgae and macroalgae offer nutritional, pharmaceutical, and physiological benefits. Microalgae, in particular, are a key source of bioactive substances like fucans, galactans, alginates, phenolics, carotenoids, vitamin B12, and peptides, which have antioxidant, antimicrobial, anti-inflammatory, anticancer, and other health-promoting properties. Marine-derived bioactive compounds are increasingly used in functional foods to support health and prevent chronic diseases. While these compounds show greater effectiveness than conventional treatments, there is still limited social acceptance and awareness of their benefits [4].

Survey of Literature

In North East India, indigenous communities rely heavily on the medicinal properties of local plants, yet a comprehensive assessment of plant use across various groups has been lacking. A study [5] conducted a systematic review of 255 publications to analyze the frequency and purposes of plant use among these communities, particularly in the Himalayan and Indo-Burma hotspots. The results revealed that many medicinal plants are used to treat multiple ailments, with some species, such as *Ageratum conyzoides*, *Centella asiatica* and *Zingiber officinale*, being used frequently across different indigenous groups. The study identified three distinct models of people-plant relationships Plant-Ailment-Tribe, Ailment-Plant-Tribe, and Plant- Locality-Tribe that help understand the cultural significance of these plants. This research highlights the extensive use of medicinal plants by various indigenous groups and provides valuable insights for ethnobotanical studies and sustainable plant use practices.

A review [6] emphasizes the crucial role of spices in promoting health and fighting pathogens, underscoring their potential as natural immunoboosters. Spices are an essential component of household products, not only enhancing the aroma of food but also offering health benefits, particularly in boosting the immune system. The medicinal significance of spices, particularly in North-East India, has long been recognized in ancient Ayurvedic practices. Recent studies

have highlighted the immunoboosting potential of spices, especially in the context of the coronavirus pandemic. Many commonly used spices are not only antimicrobial and antiviral but also provide a rich source of vitamins, minerals, and antioxidants.

The COVID-19 pandemic has underscored the relevance of Traditional Ecological Knowledge (TEK) in addressing health challenges, particularly through the use of wild plants and indigenous crops to enhance immune function and nutritional security. A study [7] conducted with 195 local healers and residents explored plant-based traditional healthcare systems, identifying 40 plant species used for treating ailments and boosting immunity. Over 80% of the local population expressed strong interest in using plant-based remedies to strengthen immunity against COVID-19. The findings highlight the importance of revitalizing and integrating traditional knowledge into modern healthcare, advocating for region-specific approaches that utilize local resources. The study calls for further exploration and rigorous clinical trials to validate the potential of indigenous knowledge and foods in enhancing resilience to COVID-19.

In Manipur's Senapati District, where modern healthcare services are limited, traditional healthcare practices remain prevalent. A study [8] documenting the ethnomedicinal plants used by local communities identified 82 plant species from 46 families, as reported by 23 informants. The research utilized open-ended and semi-structured questionnaires to gather data and applied ethnobotanical indices to assess the significance and applications of these plants. Among the findings, *Rhus chinensis*, *Zingiber officinale*, *Psidium guajava* and *Gynura cusimbua* were identified as the most frequently cited species. The study also highlighted that decoction was the most common preparation method (47%), followed by raw or fresh use (22%). Notably, 11 plant species exhibited a 100% fidelity level, indicating their consistent use across the community and suggesting their potential as sources of new pharmacological compounds. The preservation and documentation of such knowledge are crucial for future scientific exploration and sustainable use.

Flemingia macrophylla, a plant with a long history of use in traditional medicine, has garnered significant attention from phytochemistry and pharmacology researchers. A comprehensive review [9] synthesizes information on the plant's traditional uses, its phytochemical composition, and pharmacological properties, highlighting its role in traditional Chinese medicine. The study examines its diverse applications, from treating gastrointestinal and dermatological issues to its wide adaptability across cultural contexts. The review details the complex phytochemical profile of *Flemingia macrophylla*, including flavonoids, alkaloids, and terpenoids, which contribute to its medicinal potential. Pharmacological studies have shown that the plant possesses anti-inflammatory, antioxidant, cardiovascular, and antifungal properties, aligning with its traditional uses. The article emphasizes the convergence of conventional knowledge and modern pharmacology, showcasing the synergy between cultural legacy and evidence-based treatment. This compilation offers valuable insights for researchers, herbalists, and healthcare practitioners interested in integrating traditional remedies with contemporary medical practices.

Another review [10] underscores the rich ethnomedicinal knowledge of the tribes in Arunachal Pradesh, offering a foundation for

further phytochemical analysis and research into the pharmacological properties of these plants. In Arunachal Pradesh, tribal communities have a long history of using medicinal plants to treat gastrointestinal disorders (GIDs), with a wealth of ethnobotanical knowledge passed down through generations. The study compiles a list of 256 plant species from 83 families used for GIDs, highlighting their pharmacological activities and preclinical testing. The research gathered data from various online databases, identifying plants like *Paederia foetida*, *Centella asiatica*, and *Houttuynia cordata* as the most frequently used species. The study also recorded the Informant Consensus Factor (ICF) for various ailments, with the highest values for stomach inflammation and gastritis (0.24). The most commonly used plant parts were leaves (27.49%), followed by fruits (19.64%) and roots (9.67%).

An article [11] explores the role of edible mushrooms as sources of nutraceuticals, emphasizing their immunomodulatory and anti-inflammatory properties. Edible mushrooms are widely consumed for their nutritional benefits and potential therapeutic properties, particularly in alleviating respiratory diseases such as asthma, lung infections, and even the effects of COVID-19. While many mushrooms are beneficial for human health, it is crucial to distinguish them from toxic species, as some can cause harm or even be fatal if consumed incorrectly. Proper identification, handling, and preparation of mushrooms are essential to avoid allergic reactions or respiratory issues, particularly in individuals with pre-existing breathing problems. When consumed responsibly, edible mushrooms can be a valuable and safe addition to the diet, offering both nutritional and health-promoting benefits.

A study [12] stresses the importance of understanding the occurrence, sources, reservoirs, and evolution of antibacterial resistance in pathogens such as *Staphylococcus aureus*, *Clostridium perfringens* to develop effective control measures and mitigate foodborne infections. *Staphylococcus aureus*, a major cause of food poisoning and serious infections, is increasingly resistant to antibiotics, including methicillin-resistant strains (MRSA), posing significant public health concerns. MRSA is well-documented for its spread in various settings, including poultry farms, where antibiotic-resistant strains are commonly found. The transmission of these resistant bacteria through the consumption of poultry meat further amplifies the risks. Similarly, *Clostridium perfringens*, a spore-forming pathogen responsible for necrotic enteritis in broilers and foodborne diseases in humans, also poses a significant zoonotic risk. The widespread occurrence of both *S. aureus* and *C. perfringens* emphasizes the need for stringent antimicrobial and enterotoxigenic monitoring in food chains.

Another study [13] explores the traditional medicinal practices of the Adi community, highlighting their deep botanical knowledge and cultural heritage. A total of 31 medicinal plant species from 23 families were documented, demonstrating the richness of their traditional pharmacopoeia. The community's careful use of various plant parts and methods of administration reflects a profound understanding of health and wellness. The integration of medicinal plants into culinary traditions further emphasizes their multifaceted role in promoting health. The ethnobotanical evaluation reveals strong consensus on the use of specific plants for various ailments,

showcasing the community's confidence in their efficacy. This study underscores the importance of indigenous knowledge for healthcare and biodiversity conservation, calling for further research to preserve and validate these valuable traditions.

Coptis teeta Wall., also known as "Mishmi Tita," is an endangered medicinal herb found in India, Nepal, Bhutan, and China, with significant traditional and pharmacological value. A comprehensive review [14] of 69 articles published between 1982 and 2023 highlighted the medicinal potential of *C. teeta*, with active compounds such as berberine exhibiting antimicrobial, anti-inflammatory, antidiabetic, and pain-relieving properties. These compounds have been traditionally utilized for conditions such as dysentery, eye disorders, and skin issues. This endangered medicinal herb is traditionally used by the people of Arunachal Pradesh, India and is listed in the Red Data Book known for its therapeutic properties, particularly its ability to treat a range of health conditions, including bacterial and viral infections, gastrointestinal disorders, and inflammation. Despite its promising pharmacological activities, *C. teeta* faces the threat of extinction, and there is a pressing need for its conservation, cultivation, and the documentation of its traditional uses. The pungent, bitter root of Mishmi Tita is particularly valued for its ability to suppress infections, relieve spasms, and promote circulation. Preserving the traditional knowledge surrounding this plant is essential for both its conservation and its integration into modern healthcare practices.

Another study [15] explores the intersection of ethnobotanical knowledge and phytopharmaceutical development in India, highlighting the significant contributions of traditional medicinal practices to modern drug discovery. India's rich biodiversity and long history of medicinal plant use have led to important developments in phytopharmaceutical research, with notable examples including Bacoside from *Bacopa monnieri*, Curcumin from *Curcuma longa*, and Artemisinin from *Artemisia annua*. However, challenges such as biopiracy, the loss of traditional knowledge, and the need for proper standardization remain. Ethnobotany is expected to expand in the future, driven by advancements in biotechnology, collaborations between traditional healers and modern science, and supportive institutional frameworks. By combining ancient wisdom with modern scientific methods, India is poised to contribute to global health through the development of new phytopharmaceuticals while preserving its cultural heritage.

Another literature review [16] offers a concise overview of the current status and socio-economic significance of selected underutilized crops in Sikkim. Several wild fruits exhibit significant potential for cultivation due to their high antioxidant content, beneficial fats, medicinal properties.

Historical Significance of Traditional Bioresources

The historical importance of traditional bioresources in managing infectious diseases is undeniable. Over centuries, indigenous communities worldwide have amassed extensive knowledge regarding the healing properties of local plants, fungi, and animals, often passing this information orally through generations. These resources have been utilized to prevent and treat various ailments, including viral, bacterial, and parasitic infections. For example, the Wancho tribe

of Arunachal Pradesh, India, incorporates animal-based remedies into their traditional medicine. A study [17] highlighted the use of 18 animal species, including birds, mammals, and insects, to treat ailments such as stomach aches, joint pain, headaches, and coughs. However, concerns have been raised about the overexploitation of these animals, which threatens certain species and disrupts local ecosystems.

Similarly, research in Assam, India, documented the ethnozoological practices of indigenous inhabitants near the Gibbon Wildlife Sanctuary. The study [18] recorded the use of various animal-based medicines by traditional healers, emphasizing the importance of conserving these practices while addressing sustainability challenges.

India's ethnobotanical heritage includes a wide range of medicinal plants that have been utilized for thousands of years in traditional healing systems like Ayurveda, Siddha, and Unani. Neem (*Azadirachta indica*) is one of the most frequently used remedies for various skin conditions and infections due to its antimicrobial and anti-inflammatory qualities [19].

These examples underscore the rich tapestry of indigenous knowledge concerning the healing properties of local flora and fauna. Preserving this knowledge is essential for maintaining cultural heritage and exploring potential medical applications. There is a wealth of indigenous and local knowledge about plant biodiversity and their potential medicinal properties. Documenting and safeguarding this knowledge is crucial, as rapid urbanization, environmental degradation, and cultural shifts pose a risk of its extinction [20].

The Need for Exploration and Documentation of Traditional Bioresources

Ethnobotany, the study of the relationship between people and plants, is crucial for identifying plant species with potential medicinal properties. Ethnobotanical knowledge plays a crucial role in drug discovery as it encompasses the traditional medicinal uses of plants by local communities [21]. The empirical knowledge gained through experience in natural environments has enabled communities to recognize the therapeutic value of various bioresources, some of which have led to groundbreaking medical discoveries in the modern world.

Many modern chemically synthesized medicines have their origins in ethnobotanical knowledge. For example, quinine, used to treat malaria, was derived from the bark of the cinchona tree (*Cinchona officinalis*), which indigenous South American communities had used to treat fever [22]. Paclitaxel, a key drug in cancer treatment, was extracted from the Pacific yew tree (*Taxus brevifolia*) following research into Native American medicinal traditions [23]. The use of *Artemisia annua* (sweet wormwood) in traditional medicine as a treatment for malaria has long been documented in ancient Chinese texts but it was only in the late 20th century that the active compound, artemisinin, was isolated and synthesized for widespread use in treating malaria [24]. These examples underscore the importance of continuing to explore traditional bioresources, as these age-old remedies could serve as the foundation for new treatments for infectious diseases.

The documentation of traditional bioresources is an essential

step toward preserving indigenous knowledge and ensuring its use in modern healthcare. In many parts of the world, traditional knowledge is fading as younger generations turn away from agricultural practices and traditional medicine in favour of urban living and modern healthcare solutions. Indigenous Knowledge Systems (IKSs), honed over generations, offer invaluable insights into sustainable practices, particularly in areas such as biodiversity conservation and resource management. A study [25] focused on documenting the role of IKS in biodiversity management highlights its integral connection to food, healthcare, and overall well-being, emphasizing how deeply rooted these practices are in modern cuisine and healthcare. The research also underscores the global recognition of IKS for promoting coexistence and sustainable use of resources.

For centuries, plants and animals have played a significant role in human cultures as sources of therapeutic agents. Animals have not only provided food but have also been utilized in medicine, clothing, and other services. A study explores the knowledge surrounding ethno-zoological practices employed by traditional healers in North-East India. The practice of using animals and their products for medicinal purposes dates back to ancient civilizations. This form of treatment, known as zootherapy or ethno-zoology, involves the use of animal-derived substances to address human health issues. Among various animal species, mammals and their products are most commonly used in the region, although the state of Manipur is particularly noted for its reliance on fish-based medicines. In contrast, Arunachal Pradesh stands out for the significant use of insects in its traditional medical practices [26].

The medicinal and toxicological properties of *Gynocardia odorata* R. Br. seeds have been well-documented in traditional knowledge, but there remains a lack of sufficient research on its potential as a food source. A study highlights the traditional method of detoxifying *G. odorata* seeds, as practiced by the Khasi tribe of Meghalaya. In Meghalaya, the seeds of *G. odorata* are recognized as an important wild edible, with a well-established market and consumer base. The findings suggest that the cost/benefit ratio is highly favourable for both collectors/producers and traders, contributing to the domestication of the tree within arecanut agroforests. The study emphasizes the need to document this valuable ethnobotanical knowledge to ensure the sustainable utilization of this bioresource [27].

Indigenous communities worldwide, despite their resilience and sustainable resource management, are increasingly challenged by external pressures, particularly from Western influences [28]. In northeast India, traditional knowledge related to agriculture, animal husbandry, and natural phenomena is rapidly disappearing, with much of it undocumented and at risk of being lost due to socio-economic changes [27]. Factors like commercialization, population growth, and Western institutions have led to deforestation and weakened indigenous systems, while globalization and modern technologies are further eroding traditional practices and knowledge transmission [28].

Clerodendrum glandulosum Lindl. (also known as *Clerodendrum colebrookianum* Walp. or East Indian Glory Bower) is a perennial shrub from the Lamiaceae family that is widely used in North East India for its medicinal properties. The plant is commonly utilized by several tribes in the region to treat conditions such as inflammation,

malaria, diabetes, indigestion, hypertension, fever, asthma, rheumatism, and various other health disorders. A study [29] found that *C. glandulosum* is a light-dependent species, thriving best in well-lit environments. A household survey revealed that the majority of leaves are collected from agroforests, with smaller amounts sourced from natural forests and home gardens. The leaves of the plant are used in various dishes, with the most popular being those made with dal (pulses), beef, and pork. An interesting traditional knowledge system was uncovered during the study: when the leaves are harvested for the first time, they tend to be bitter, but if harvested regularly each year, the leaves become very flavorful. Notably, the plant adapts well to a wide range of landscapes, even in areas affected by coal mining in Meghalaya, making it a resilient and valuable resource in the region.

The survival of humanity is closely tied to the availability and responsible use of bioresources. Indigenous communities worldwide have developed their own policies, principles, and practices for conserving and utilizing these resources, based on experiential learning. This knowledge has typically been passed down through generations, primarily through oral traditions. Northeast India, home to over 200 tribes, is a region where the majority of its people rely heavily on bioresources for their livelihoods. Many of these tribes possess extensive knowledge regarding the management of these resources. A paper focuses on the practices of the War Khasi tribe from southern Meghalaya, India, in conserving and utilizing bioresources. Members of this tribe tend to nurture these resources around their settlements, near water sources, on steep slopes, and other ecologically sensitive areas. They maintain sacred groves, village-restricted forests, village supply forests, and clan forests in nearly every village, which serve as examples of forest management that meet both local needs and modern scientific standards. The tribe's practices of traditional fishing, bird harvesting, water conservation, and healthcare also reflect sound ecological principles. However, rapid population growth and increasing demand for cash income have placed immense pressure on these bioresources. The findings suggest that the future conservation of these resources may not be sustainable unless appropriate governmental policies are enacted, incorporating indigenous and local knowledge to ensure long-term preservation and use [30].

The loss of this knowledge poses a significant threat to the preservation of bioresources that have been carefully cultivated and utilized for generations. The documentation process facilitates the identification of plants and other natural products that may hold therapeutic potential. It also helps to bridge the gap between indigenous knowledge and modern science, fostering collaboration between the two to achieve mutual benefits. As more regions engage in ethnobotanical research, new plant species with promising medicinal properties are being discovered, offering new hope for the treatment of various infectious diseases. The documentation process, often carried out through ethnobotanical studies and field research, seeks to capture this valuable information before it is lost entirely [31].

Validation of Traditional Knowledge

Once traditional bioresources are identified and documented, the next crucial step is the validation of their medicinal properties. Validation involves a rigorous scientific approach to confirm the efficacy and safety of the bioresource in question. This process

typically includes the extraction and analysis of active compounds, in vitro studies, and clinical trials to assess the bioresource's potential therapeutic effects. While traditional knowledge often provides valuable insights into the therapeutic properties of various bioresources, it is essential to scientifically validate these claims to ensure that they are effective and safe for modern use [32].

The validation of traditional medicines requires a multidisciplinary approach, combining expertise in pharmacology, toxicology, microbiology, and clinical research. Several traditional remedies have already undergone this validation process with success. For example, the anti-malarial properties of *Artemisia annua* were scientifically validated through the isolation of artemisinin, leading to its incorporation into standard malaria treatment regimens worldwide [33]. Similarly, the anti-inflammatory properties of *Curcuma longa* (turmeric), widely used in traditional medicine, have been validated through numerous scientific studies that confirm its potential in managing conditions like arthritis and cancer [34].

The validation process is crucial not only for confirming the efficacy of traditional medicines but also for ensuring their safety. Many traditional remedies, though effective, can have side effects or interact with other medications. Through scientific research, these potential risks can be identified and mitigated, allowing for the development of standardized dosages and safer methods of use [35]. Validation plays a critical role in gaining regulatory approval for the use of traditional bioresources in modern healthcare settings. Herbal medicines have been used for centuries to treat health issues, but the Indian Pharmaceuticals Act of 1948 does not have a special group for herbal drugs. The expansion of Indian medicinal systems like Ayurveda, Siddha, and Unani requires scientific validation and documentation of indigenous knowledge for patenting and research. Government organizations such as the Ministry of Ayush, CDSCO, and the D&C Act 1940 & 1945 regulate the processing, branding, and marketing of herbal medicines. The Ministry of Ayush has recognized 8000 herbal medicines for various ailments, and regulatory bodies are actively involved in the discovery and validation of plant-based herbal drugs [36]. These regulatory measures and guidelines underscore the critical role of validation in integrating traditional bioresources into contemporary medical practices, ensuring that such products are both safe and effective for modern healthcare use.

Integrating Traditional Bioresources into Modern Healthcare

In the context of infectious diseases, the integration of validated traditional bioresources into modern healthcare systems presents a promising strategy for disease prevention and treatment. Infectious diseases, especially emerging infectious diseases, continue to pose a significant global health threat. In many developing countries, where access to modern medicine and vaccines is limited, traditional bioresources offer an affordable and culturally acceptable alternative for disease management. A study titled "Medicinal plants used by traditional medicine practitioners for the treatment of HIV/AIDS and related conditions in Uganda" explores how traditional healers utilize indigenous plants to address HIV/AIDS, particularly in regions with limited access to modern medicine. The research highlights the reliance on traditional remedies in Uganda's healthcare system [37]. Another article provides insights into the World Health Organization's

efforts to regulate and promote the safe use of traditional medicines globally. These guidelines aim to ensure that traditional remedies are used safely and effectively, especially in areas where modern medical resources are scarce [38]. The WHO executive board urged countries to integrate traditional healers into healthcare systems and allocate more funds for traditional medicine. WHO has been promoting the integration of traditional, complementary, and integrative medicine (TCIM) into health systems, recognizing its potential in achieving Universal Health Coverage (UHC) [39].

The integration of traditional plant-based medicinal knowledge with modern pharmaceutical research offers considerable potential for the development of novel therapeutic agents. A study [40] explores how indigenous and traditional uses of medicinal plants can meaningfully contribute to contemporary drug discovery and development. Over generations, traditional knowledge has provided a deep understanding of plant-derived treatments and their medicinal applications. The study also explores case studies where such traditional plants have led to the creation of new drugs. For instance, the discovery of artemisinin from *Artemisia annua* (sweet wormwood), a traditional Chinese medicine, has significantly advanced the treatment of malaria. Similarly, the Madagascar periwinkle, initially used in traditional medicine to manage diabetes, is now the source of chemotherapy drugs such as vinblastine and vincristine. Furthermore, technologies such as systems biology, metabolomics, and high-throughput screening offer valuable tools for accelerating the translation of traditional medicinal knowledge into modern clinical practices. These approaches can help elucidate the mechanisms of action underlying traditional treatments. By documenting the safety, efficacy, and chemical composition of traditional remedies, researchers can substantiate their therapeutic benefits and identify bioactive compounds for further investigation. This integrative approach not only utilizes indigenous knowledge to address contemporary health challenges but also acknowledges the cultural and historical significance of traditional practices. The study also identifies key opportunities and challenges in fostering effective interdisciplinary collaboration between traditional and modern scientific approaches.

The knowledge associated with medicinal plants has traditionally been passed down orally through generations and documented across various platforms to encourage further scientific exploration. Many therapeutically active phytochemicals with traditional origins remain in use today. The value of plant-based remedies and traditional medicinal knowledge became particularly evident during the COVID-19 pandemic, which heightened public awareness of their potential in treating life-threatening diseases and boosting immunity in the long term. The scientific community, in the post-pandemic era, has increasingly turned to traditional knowledge to explore plant-based solutions for health challenges. Processes such as screening, extraction, identification, isolation, purification, and structure elucidation of bioactive phytoconstituents are carried out to validate the medicinal properties of plants, leading to the development of commercial products. This practice, known as bioprospecting, has yielded several pharmaceutically active products. Ethnobotanical bioprospecting in India has made substantial contributions to global healthcare, yet the number of plant species extensively studied for their pharmaceutical properties remains minimal in comparison to

the vast diversity of plants available. Therefore, there is considerable scope for further bioprospecting studies based on both codified and non-codified traditional knowledge, which could uncover novel drug candidates [41].

The use of traditional medicinal plants to prevent and treat tuberculosis, malaria, and respiratory infections has been documented in many cultures. Traditional systems such as African, Ayurvedic, and Chinese medicine have long included plant-based treatments for TB, though scientific evidence supporting these practices is limited. In Africa, TB is traditionally linked to symptoms like cough and weight loss, while Ayurveda describes it as a disease-causing severe tissue wasting. Chinese medicine combines herbal treatments with methods to strengthen vital energy and protect the liver. In Africa, 222 plant species from 71 families are recorded for TB treatment, with species like *Erythrina abyssinica* and *Allium sativum* showing antimicrobial properties. These plants, along with others like *Bidens pilosa* and *Carissa edulis*, have demonstrated varying levels of effectiveness against TB strains [42]. These remedies are often used in conjunction with modern treatments, offering a complementary approach to disease management.

The integration of traditional and modern healthcare systems is gaining increasing popularity, particularly in the post-pandemic era, as more individuals seek alternative forms of treatment. This approach offers numerous benefits. Traditional healthcare practices, which include herbal medicine, acupuncture, Ayurveda, yoga, and naturopathy, can provide complementary and alternative therapies that enhance patient outcomes and help prevent or alleviate symptoms. On the other hand, contemporary Western medicine, grounded in scientific research and technological advances, focuses primarily on diagnosing and treating diseases. Therefore, traditional healthcare emphasizes prevention and wellness, while contemporary medicine centers on cure and treatment. India has a rich heritage in traditional healthcare knowledge and has taken significant steps to promote these systems globally. The establishment of the Ministry of AYUSH (Ayurveda, Yoga & Naturopathy, Unani, Siddha, and Homeopathy) is one such initiative aimed at integrating traditional medicine with modern healthcare practices [43]. The integration of both systems could address healthcare disparities by providing a more personalized and holistic approach that respects patients' socio-cultural beliefs and practices.

Emerging infectious diseases (EIDs) pose a significant global health threat, as they spread to new regions or host populations. They are infectious human diseases that have recently grown in their geographic and/or host range. Zoonotic diseases, including Ebola, HIV/AIDS, and COVID-19, represent a major portion of recent EIDs, with about 75% of EIDs originating from animals and crossing over to humans. The Stockholm Paradigm suggests that the impact of these diseases will increase, particularly due to climate change. In this context, the term 'local knowledge' encompasses various forms of traditional and indigenous knowledge, particularly that of vulnerable groups in low- and middle-income countries. This knowledge is deeply rooted in community experience and ecological practices. Local knowledge, as a source of empirical understanding, is valuable for disciplines like medicine and ecology, offering insights into both

pharmaceutical and environmental health matters. Furthermore, local disease knowledge, often explored within medical anthropology, may provide valuable insights into EIDs that are not yet recognized by biomedicine. Although local knowledge can present ethical and scientific challenges, it is a potentially rich source of untapped information regarding human, animal, and zoonotic diseases yet to be fully documented [44].

The integration process requires careful consideration of ethical, cultural, and scientific factors. Collaboration between healthcare professionals, indigenous communities, and researchers is essential to ensure that traditional knowledge is respected, and the integration of bioresources is carried out in a way that maximizes benefits for patients while minimizing risks. Regulatory frameworks must also be established to guide the use of traditional medicines in clinical settings, ensuring that they meet safety standards and are accessible to those who need them the most.

Future Perspectives

The exploration, documentation, and validation of traditional bioresources are critical steps in developing effective mitigation strategies for infectious diseases. Effective documentation such as ethnobotanical surveys, use of digital databases (traditional knowledge digital library), interviews and case studies are crucial to preserve and validate traditional bioresources. Scientific validation of traditional bioresources involves multiple approaches like phytochemical and bioactive compound analysis, in vitro and in vivo studies. To enhance the validation and application of traditional bioresources, the following approaches should be prioritized:

Interdisciplinary Research: Collaboration between ethnobotanists, pharmacologists, and microbiologists.

Policy Development: Government regulations to protect indigenous knowledge and ensure benefit-sharing.

Biotechnological Advancements: Utilizing genomics and synthetic biology to enhance bioactive compound production.

Conclusion

Traditional bioresources hold immense potential in mitigating infectious diseases. The exploration, documentation, and validation of traditional bioresources are critical steps in developing effective mitigation strategies for infectious diseases. The wealth of knowledge contained within traditional practices offers a valuable resource for modern medicine, especially in the face of emerging global health challenges. Systematic exploration, documentation, and validation can pave the way for their incorporation into modern medicine. Strengthening research collaborations, addressing ethical concerns, and promoting sustainable utilization will be key to harnessing the full potential of these bioresources in global health. By preserving and validating these traditional remedies, we can contribute to the development of new, culturally appropriate, and cost-effective therapeutic options that complement existing medical interventions. As the world continues to grapple with the complexities of infectious diseases, the integration of traditional bioresources into modern healthcare systems will play an increasingly important role in safeguarding public health.

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