

Traditional Herbal Infusions of Northeast India as Functional Beverages: Nutritional, Phytochemical, and Preventive Health Perspectives

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Abstract:

Herbal infusions have long been integral to the dietary and health practices of indigenous communities in Northeast India, where exceptional plant biodiversity and traditional knowledge systems converge. Consumed routinely as part of daily life, these herbal teas function not merely as therapeutic remedies but as preventive, food-based health interventions. This article examines herbal infusions from Northeast India through the contemporary framework of functional foods and nutraceutical science, highlighting their relevance to gut health, immune modulation, metabolic regulation, and preventive healthcare. Focusing on commonly consumed regional plants—*Spondias pinnata* (heining), *Meyna laxiflora* (heibi), *Dillenia indica* (heigri), *Garcinia pedunculata* (heibung), and *Rhus chinensis* (heimang)—the review synthesizes traditional usage patterns with current scientific understanding of their bioactive constituents. The findings underscore that these herbal infusions are rich in polyphenols, flavonoids, organic acids, and tannins, which contribute to antioxidant, anti-inflammatory, digestive, and immunomodulatory effects. Regular, low-dose consumption through simple infusion or decoction aligns closely with modern preventive nutrition strategies and supports long-term physiological balance. The article further discusses opportunities and challenges associated with integrating indigenous herbal beverages into functional food markets, emphasizing the need for standardization, sustainability, and ethical commercialization. By bridging indigenous wisdom and modern nutrition science, this work highlights the potential of Northeast Indian herbal infusions as culturally rooted, sustainable functional beverages for contemporary health promotion.

Keywords: Herbal infusions; Northeast India; Functional beverages; Indigenous knowledge; Preventive nutrition.

INTRODUCTION

Northeast India is globally recognized as one of the world's most important biodiversity hotspots, characterized by complex ecosystems, high rainfall, varied altitudes, and an extraordinary richness of plant species. This ecological diversity, spread across its hills, valleys, forests, and wetlands, has fostered a deep and enduring relationship between local communities and their natural environment. Over centuries, indigenous populations of the region have developed sophisticated systems of plant-based knowledge, particularly in the use of herbs for food, medicine, and everyday well-being.

Among these practices, the preparation and consumption of herbal infusions occupy a central place. Herbal teas in Northeast India are not merely occasional remedies but form an integral part of daily life. Leaves, flowers, rhizomes, bark, and seeds of locally available plants are routinely infused or decocted and consumed to maintain digestive balance, enhance immunity, manage seasonal ailments, and promote overall vitality. These infusions are often consumed without rigid distinction between food and medicine, reflecting a holistic understanding of health in which nourishment and therapy coexist seamlessly.

Traditionally, herbal infusions have been used as preventive measures rather than reactive treatments. Communities consume specific teas during seasonal transitions, periods of physical exertion, or climatic stress, demonstrating an intuitive grasp of preventive healthcare principles long before the emergence of modern nutrition science. This habitual, low-dose, long-term consumption aligns closely with contemporary recommendations for functional foods—foods and beverages that provide health benefits beyond basic nutrition.

In recent decades, there has been a marked global rise in interest in plant-based functional beverages, driven by increasing awareness of lifestyle-related disorders, concerns over synthetic additives, and a renewed emphasis on natural and sustainable health solutions. Consumers and researchers alike are turning toward traditional food systems in search of evidence-based, culturally rooted alternatives. In this context, the herbal infusions of Northeast India represent a largely underexplored yet highly relevant resource.

The rationale for focusing on Northeast India within modern nutrition science lies in the convergence of three key factors: exceptional botanical diversity, well-preserved indigenous knowledge systems, and long-standing dietary practices centered on herbal beverages. These elements together position the region as a living repository of functional beverage traditions.

The aim of this article is to critically evaluate herbal infusions of Northeast India through the framework of modern functional foods and nutraceutical science, with particular emphasis on gut health, immune modulation, and preventive healthcare. By bridging indigenous wisdom and contemporary nutritional perspectives, this work seeks to highlight the relevance of these traditional beverages in addressing present-day health challenges.

FUNCTIONAL FOODS AND BEVERAGES: CONTEMPORARY NUTRITION FRAMEWORKS

The concept of functional foods has emerged as a central pillar of modern nutrition science, reflecting a paradigm shift from meeting basic dietary requirements to promoting optimal health and disease prevention through everyday foods. Functional foods are broadly defined as foods or beverages that, beyond providing essential nutrients, exert specific physiological benefits that can reduce the risk of chronic diseases or enhance bodily functions. Within this category, functional beverages have gained particular prominence due to their convenience, bioavailability, and ease of regular consumption.

Nutraceuticals represent a closely related but more specialized category, often referring to isolated or concentrated bioactive compounds derived from foods and used in medicinal forms such as capsules, powders, or extracts. While nutraceuticals emphasize targeted therapeutic effects, functional beverages occupy an intermediate space between conventional foods and medicinal products. They are designed for habitual intake, supporting long-term health rather than immediate clinical intervention. This

distinction is critical when evaluating traditional herbal infusions, which are consumed daily and embedded within dietary routines rather than prescribed as short-term remedies.

From a scientific perspective, functional beverages are characterized by the presence of bioactive compounds such as polyphenols, flavonoids, alkaloids, terpenoids, and essential oils. These compounds exhibit antioxidant, anti-inflammatory, antimicrobial, immunomodulatory, and metabolic regulatory activities. The efficacy of a functional beverage depends not only on the presence of these compounds but also on their bioavailability, synergistic interactions, and safety during long-term consumption.

Modern nutrition frameworks increasingly recognize beverages as effective delivery systems for functional compounds. Compared to solid foods, liquids allow for faster absorption, easier digestion, and consistent dosing. Herbal infusions, in particular, provide a water-based medium that efficiently extracts hydrophilic bioactives without the need for synthetic solvents or complex processing. This aligns with the growing consumer preference for “clean-label” products that are minimally processed and naturally derived.

The global rise in non-communicable diseases such as diabetes, obesity, cardiovascular disorders, and gastrointestinal ailments has further strengthened interest in functional beverages. Preventive nutrition strategies emphasize regular intake of antioxidant-rich, anti-inflammatory, and gut-supportive foods as part of daily dietary patterns. As a result, traditional dietary systems are increasingly being re-examined through a scientific lens to identify practices that inherently meet these criteria.

Within this contemporary framework, traditional herbal infusions of Northeast India emerge as natural prototypes of functional beverages. Their long history of safe consumption, reliance on whole-plant materials, and emphasis on preventive health place them squarely within modern definitions of functional foods. Understanding these traditional beverages through current nutritional science not only validates indigenous practices but also expands the scope of functional beverage research beyond industrial formulations to culturally embedded dietary traditions.

INDIGENOUS HERBAL TEA TRADITIONS OF NORTHEAST INDIA

Northeast India is renowned for its rich biological diversity and the deep-rooted ethnobotanical knowledge of its indigenous communities. Within this cultural and ecological landscape, herbal teas represent a long-standing dietary practice that integrates nutrition, medicine, and preventive healthcare. These infusions are not consumed merely as therapeutic interventions but are embedded in everyday life as functional beverages that support physiological balance and resilience.

In Manipur and neighboring regions, herbal teas are traditionally prepared from locally available medicinal plants that are seasonally harvested and culturally significant. Fruits, leaves, and bark are selectively used based on their perceived health benefits and sensory properties. One such example is *Heining* (*Spondias pinnata*), a wild fruit-bearing tree whose sour and aromatic fruits are traditionally infused or decocted to stimulate digestion and improve appetite. Similarly, *Heibi* (*Meyna laxiflora* Robyns) is valued for its mildly astringent fruits, which are consumed as infusions for digestive regulation and general wellness.

Aquatic and semi-wild plant species also feature prominently in herbal tea traditions. *Heigri* (*Dillenia indica*), commonly found in wetland and forest-edge ecosystems, is traditionally used in infusion form for its cooling and soothing properties, particularly during warmer seasons. The fruit-based infusions of

Heibung (*Garcinia pedunculata*), known for their sour taste, are widely consumed to support metabolism, hydration, and digestive comfort. These beverages are often taken after meals or during periods of dietary imbalance.

Leaf-based herbal infusions are equally important in daily consumption practices. *Heimang* (*Rhus chinensis* Mill), traditionally used in various culinary and medicinal contexts, is infused for its digestive, circulatory, and antioxidant-supporting properties. Herbal teas prepared from these plants are typically consumed once or twice daily, either independently or alongside meals, often replacing commercially sweetened beverages.

Preparation methods remain simple and sustainable, most commonly involving infusion or mild decoction. Fruits are sliced and steeped in hot water, while tougher plant materials may be gently boiled to enhance extraction of water-soluble phytochemicals. These low-technology methods, refined through generations of empirical observation, allow for effective extraction of bioactive compounds while ensuring safety for long-term, habitual consumption.

A defining feature of herbal tea traditions in Northeast India is the absence of a rigid distinction between food and medicine. Herbal infusions are perceived as nourishing agents that maintain internal balance and reduce susceptibility to seasonal and lifestyle-related disorders. This preventive, food-based approach closely parallels contemporary functional food frameworks, reinforcing the relevance of indigenous herbal teas within modern nutrition science.

Table 1. Medicinal Plants Traditionally Used as Herbal Infusions in Manipur (Northeast India)

Local Name	Scientific Name	Plant Part Used	Traditional Health Role	Functional Beverage Relevance
Heining	<i>Spondias pinnata</i>	Fruit	Digestion, appetite stimulation	Gut health, digestive support
Heibi	<i>Meyna laxiflora</i> <i>Robyns</i>	Fruit	Digestive regulation, wellness	Metabolic and digestive aid
Heigri	<i>Dillenia indica</i>	Fruit	Cooling, soothing	Anti-inflammatory, hydration
Heibung	<i>Garcinia pedunculata</i>	Fruit	Metabolism, digestion	Antioxidant, cardiometabolic support
Heimang	<i>Rhus chinensis</i> Mill	Leaves / fruit	Digestion, circulation	Antioxidant, functional infusion

BIOACTIVE CONSTITUENTS OF NORTHEAST INDIAN HERBAL INFUSIONS AND THEIR FUNCTIONAL ROLES

The health-promoting potential of herbal infusions from Northeast India is largely attributable to their rich composition of bioactive phytochemicals. These compounds, naturally present in medicinal plants and efficiently extracted through traditional infusion or decoction methods, play a crucial role in defining these beverages as functional foods. Modern nutritional and pharmacological research increasingly recognizes that regular, low-dose consumption of such bioactives can support physiological functions and reduce the risk of chronic diseases.

Fruits commonly used in regional herbal infusions are rich sources of organic acids, polyphenols, flavonoids, and tannins. *Spondias pinnata* (heining), for instance, contains phenolic acids and flavonoids that contribute to its antioxidant and digestive-stimulant properties. The sour taste characteristic of heining infusions reflects the presence of organic acids, which are known to enhance digestive secretions and support gastrointestinal motility. These properties align with its traditional use as a post-meal functional beverage.

Meyna laxiflora Robyns (heibi) fruits are characterized by the presence of tannins and flavonoids. Tannins impart mild astringency and have been associated with regulation of gastrointestinal function and reduction of intestinal irritation. From a functional nutrition perspective, such compounds contribute to gut health by supporting mucosal integrity and modulating microbial activity, reinforcing the role of heibi-based infusions as digestive-support beverages.

Dillenia indica (heigri) is notable for its polyphenolic content and antioxidant capacity. Infusions prepared from its fruits are traditionally consumed for their cooling and soothing effects, particularly in warmer seasons. These effects are consistent with the anti-inflammatory and oxidative stress-modulating properties of its bioactive constituents, which support hydration-related metabolic balance and overall physiological comfort.

Garcinia pedunculata (heibung) contains hydroxycitric acid, xanthenes, and flavonoids—compounds widely studied for their antioxidant and metabolic regulatory effects. Traditional heibung infusions, often consumed after meals, correspond with modern evidence suggesting a role for these compounds in lipid metabolism, glycemic regulation, and cardiovascular health. Such beverages exemplify how traditional diets incorporate nutraceutical-like benefits without reliance on isolated compounds.

Leaf- and fruit-based infusions prepared from *Rhus chinensis* Mill (heimang) contain phenolic acids, flavonoids, and gallotannins, which contribute to antioxidant, antimicrobial, and circulatory-supportive effects. These compounds enhance the functional value of heimang-based teas in maintaining digestive efficiency and reducing oxidative stress.

A defining feature of these herbal infusions is the synergistic action of multiple bioactive compounds consumed within their natural plant matrix. Unlike isolated nutraceutical supplements, traditional herbal teas deliver complex phytochemical mixtures that may act additively or synergistically, enhancing efficacy while supporting long-term safety. This synergy, combined with water-based extraction and habitual intake, reinforces the relevance of Northeast Indian herbal infusions as functional beverages.

Table 2. Bioactive Compounds and Functional Roles of Selected Herbal Infusions from Northeast India

Scientific Name	Major Bioactive Compounds	Primary Functional Roles
<i>Spondias pinnata</i>	Phenolic acids, flavonoids, organic acids	Digestive stimulation, antioxidant support
<i>Meyna laxiflora</i> Robyns	Tannins, flavonoids	Gut regulation, anti-inflammatory support
<i>Dillenia indica</i>	Polyphenols, flavonoids	Antioxidant activity, cooling effect
<i>Garcinia pedunculata</i>	Hydroxycitric acid, xanthenes, flavonoids	Metabolic regulation, cardiometabolic support
<i>Rhus chinensis</i> Mill	Phenolic acids, gallotannins, flavonoids	Antioxidant, digestive and circulatory support

ROLE OF NORTHEAST INDIAN HERBAL INFUSIONS IN GUT HEALTH

Gut health has emerged as a central focus of modern nutrition science due to its close association with digestion, nutrient absorption, immune regulation, and overall metabolic health. Increasing evidence links gut imbalance to a wide range of chronic conditions, including metabolic disorders, inflammatory diseases, and compromised immunity. In this context, traditional dietary practices that support gastrointestinal function are gaining renewed attention. Herbal infusions from Northeast India represent such practices, having long been consumed to maintain digestive balance and gastrointestinal comfort. Indigenous herbal teas in the region are traditionally selected and consumed based on their perceived effects on digestion, appetite, and bowel regulation. Sour and mildly astringent fruit-based infusions, such as those prepared from *Spondias pinnata* (heining), *Meyna laxiflora* (heibi), and *Garcinia pedunculata* (heibung), are commonly taken after meals. These beverages are believed to stimulate digestive secretions, reduce postprandial discomfort, and improve appetite. From a scientific perspective, the organic acids, tannins, and polyphenols present in these plants are known to influence gastric enzyme activity, intestinal motility, and microbial balance.

Polyphenols, a dominant class of bioactive compounds in these herbal infusions, play a particularly important role in gut health. While not fully absorbed in the upper gastrointestinal tract, many polyphenols reach the colon, where they interact with gut microbiota. These interactions can promote the growth of beneficial microbial populations while suppressing pathogenic bacteria, thereby contributing to a healthier gut ecosystem. This prebiotic-like effect aligns closely with traditional uses of herbal teas to maintain digestive harmony and prevent gastrointestinal disturbances.

Infusions prepared from *Dillenia indica* (heigri) are traditionally consumed for their soothing and cooling effects on the digestive system, especially during warmer seasons or episodes of gastric irritation. Such effects can be associated with the plant's antioxidant and anti-inflammatory constituents, which may help reduce low-grade gut inflammation and oxidative stress—key factors implicated in many digestive disorders. Similarly, *Rhus chinensis* (heimang)—based infusions are traditionally valued for supporting digestion and circulation, with phenolic compounds contributing to mucosal protection and antimicrobial activity within the gut.

A notable strength of these traditional herbal beverages lies in their mode of consumption. Taken regularly in low doses, often as part of daily meals, they support long-term gut health rather than acting as acute interventions. This pattern mirrors modern dietary recommendations that emphasize sustained intake of gut-supportive foods rather than reliance on short-term supplements.

Overall, the gut health benefits attributed to herbal infusions of Northeast India demonstrate a strong convergence between indigenous dietary wisdom and contemporary microbiome science. By supporting digestion, modulating gut microbiota, and reducing gastrointestinal inflammation, these traditional beverages exemplify food-based strategies for maintaining gut health and preventing digestive dysfunction within a holistic nutrition framework.

IMMUNE-MODULATORY POTENTIAL OF NORTHEAST INDIAN HERBAL INFUSIONS

The immune system is profoundly influenced by dietary patterns, with increasing emphasis placed on regular consumption of foods and beverages that support immune resilience. Traditional herbal infusions of Northeast India have long been valued for their role in strengthening the body's natural defences, particularly during seasonal changes, periods of physical stress, and recovery from illness. These practices reflect an indigenous understanding of immune health that aligns closely with modern preventive nutrition strategies.

Herbal teas consumed across the region are rich in antioxidants and anti-inflammatory phytochemicals, including polyphenols, flavonoids, tannins, and organic acids. These compounds play a critical role in protecting immune cells from oxidative stress, which can impair immune responses and increase susceptibility to infections. Infusions prepared from *Phyllanthus emblica* (heibi is earlier corrected as *Meyna laxiflora*—note: here avoid mislabeling) — Wait avoid mistakes. We must stick to the five plants. Don't introduce emblica. Let's proceed carefully.

Herbal infusions prepared from fruits such as *Spondias pinnata* (heining), *Meyna laxiflora* (heibi), *Dillenia indica* (heigri), and *Garcinia pedunculata* (heibung) provide a steady intake of antioxidant compounds that help maintain immune balance. These antioxidants neutralize reactive oxygen species generated during metabolic and inflammatory processes, thereby supporting optimal immune cell function. Regular consumption of such infusions contributes to a baseline level of immune readiness rather than acting as acute immune stimulants.

Traditional consumption patterns also reflect an awareness of immune modulation rather than immune overstimulation. Herbal teas are typically consumed in mild, diluted forms and taken consistently over time. This approach aligns with modern immunonutrition concepts, which emphasize the importance of maintaining immune homeostasis through diet. For instance, polyphenols and tannins present in *Meyna laxiflora* and *Rhus chinensis* (heimang) have been associated with antimicrobial and anti-inflammatory activities, supporting the body's ability to manage low-grade infections and inflammatory responses without excessive immune activation.

Seasonal consumption of herbal infusions further underscores their immune-supportive role. Sour and warming infusions are often preferred during colder or monsoon seasons, when susceptibility to infections is perceived to be higher. Cooling infusions derived from *Dillenia indica* are more commonly consumed during warmer periods to reduce physiological stress and inflammation, indirectly supporting immune stability. Such seasonal adaptability reflects a dynamic dietary strategy for immune resilience. The link between gut health and immunity provides an additional layer of relevance for these herbal beverages. As discussed earlier, polyphenol-rich infusions can modulate gut microbiota, which in turn plays a crucial role in immune regulation. By supporting a balanced gut environment, herbal teas contribute indirectly to both innate and adaptive immune responses.

In summary, herbal infusions of Northeast India function as immune-modulatory beverages that support resilience through antioxidant protection, inflammation control, and gut-mediated immune regulation. Their traditional use exemplifies a food-based, preventive approach to immune health that complements modern nutrition science and underscores the value of indigenous dietary practices in contemporary health frameworks.

HERBAL INFUSIONS IN PREVENTIVE AND LIFESTYLE MEDICINE IN NORTHEAST INDIA

Preventive and lifestyle medicine emphasizes the role of everyday dietary choices in reducing disease risk, improving quality of life, and supporting long-term health. In Northeast India, traditional herbal infusions represent an integral component of lifestyle-based health practices that have evolved over generations. These beverages are not consumed in response to specific diagnoses but are incorporated into daily routines to maintain physiological balance and resilience, reflecting a preventive approach to health that predates modern medical frameworks.

Herbal teas prepared from regionally available fruits and leaves are traditionally consumed to support digestion, metabolism, circulation, and stress regulation. Infusions made from *Garcinia pedunculata* (heibung), for example, are commonly taken after meals to aid digestion and manage dietary excesses. Such practices align with modern nutritional strategies aimed at metabolic regulation and prevention of lifestyle-related disorders such as obesity, dyslipidemia, and insulin resistance. The presence of organic acids and polyphenols in these infusions contributes to their metabolic-supportive functions by influencing lipid metabolism and glycemic balance.

Similarly, infusions prepared from *Spondias pinnata* (heining) and *Meyna laxiflora* (heibi) are traditionally used to stimulate appetite, improve digestive efficiency, and reduce gastrointestinal discomfort. By promoting efficient digestion and nutrient utilization, these beverages indirectly support energy balance and overall metabolic health. Regular consumption of such herbal teas may reduce reliance on processed foods and sugar-sweetened beverages, which are increasingly associated with lifestyle-related health risks.

Stress regulation and physiological comfort are additional dimensions of preventive healthcare addressed through herbal infusion practices. Cooling infusions derived from *Dillenia indica* (heigri) are traditionally consumed during warmer seasons or periods of physical strain to alleviate internal heat and discomfort. Such practices correspond with modern understandings of stress-related inflammation and oxidative stress, suggesting that these beverages contribute to maintaining homeostasis under environmental and lifestyle stressors.

Infusions prepared from *Rhus chinensis* (heimang) are also valued for their role in supporting circulation and digestive function. The antioxidant and anti-inflammatory properties of heimang-based teas may contribute to vascular health and reduced oxidative burden, both of which are critical factors in the prevention of chronic, lifestyle-related diseases.

A defining strength of these herbal infusion practices is their sustainability and cultural acceptability. Consumed regularly in mild forms, they encourage long-term adherence and integrate seamlessly into daily life. This contrasts with short-term dietary interventions or pharmacological approaches that may be difficult to sustain.

Overall, herbal infusions of Northeast India exemplify a culturally rooted model of preventive and lifestyle medicine. By supporting metabolic health, digestive efficiency, stress regulation, and physiological balance, these traditional beverages align closely with contemporary approaches to disease prevention and health promotion, reinforcing their relevance within modern nutrition and public health frameworks.

FROM INDIGENOUS PRACTICE TO FUNCTIONAL BEVERAGE MARKETS: OPPORTUNITIES AND CHALLENGES

The growing global demand for functional beverages presents significant opportunities for translating the traditional herbal infusions of Northeast India into value-added health products. As consumers increasingly seek natural, plant-based alternatives to sugar-laden and artificially formulated drinks, indigenous herbal teas—rooted in long-standing dietary practices—offer a compelling combination of cultural authenticity, functional benefits, and sustainability. However, the transition from indigenous practice to broader functional beverage markets is accompanied by several scientific, ethical, and logistical challenges.

One of the primary opportunities lies in the unique botanical diversity of Northeast India. Herbal infusions prepared from region-specific plants such as *Spondias pinnata*, *Meyna laxiflora*, *Dillenia indica*, *Garcinia pedunculata*, and *Rhus chinensis* possess distinct sensory profiles and bioactive compositions that differentiate them from mainstream herbal beverages. These characteristics provide strong potential for niche markets focused on digestive health, metabolic support, and preventive nutrition. Value-added products such as dried herbal tea blends, ready-to-infuse formulations, and minimally processed concentrates could enhance shelf life while retaining functional properties.

Despite this potential, standardization remains a major challenge. Traditional herbal infusions vary in plant part selection, harvesting season, preparation method, and dosage, all of which influence phytochemical content and efficacy. For functional beverage development, establishing quality control measures—such as botanical authentication, standardized processing protocols, and consistent bioactive profiles—is essential. Without such measures, variability may limit consumer trust and regulatory acceptance.

Safety and regulatory compliance present additional hurdles. While these herbal infusions have a long history of safe consumption within local communities, formal toxicological evaluations and compliance with national and international food safety regulations are often required for commercialization. Navigating diverse regulatory frameworks for functional foods and nutraceuticals can be complex, particularly for small-scale producers and community-based enterprises.

Sustainability and ethical considerations are equally critical. Overharvesting of wild plant resources poses risks to biodiversity and ecosystem stability. Scaling up production must therefore be accompanied by sustainable harvesting practices, domestication strategies, and community-led cultivation models. Moreover, ethical commercialization requires recognition of indigenous knowledge systems and fair benefit-sharing mechanisms to ensure that local communities are not marginalized in the commercialization process.

Market access and awareness also remain limited. Inadequate infrastructure, lack of branding expertise, and minimal exposure to national and global markets can constrain the growth of herbal beverage enterprises in the region. Strategic collaborations among researchers, policymakers, entrepreneurs, and indigenous communities are essential to bridge these gaps.

In summary, while the herbal infusions of Northeast India hold considerable promise as functional beverages, their successful integration into broader markets depends on addressing challenges related to standardization, safety, sustainability, and equity. Balancing commercial development with cultural preservation and ecological responsibility is crucial to ensuring that these traditional beverages contribute meaningfully to modern health systems without compromising their indigenous roots.

RESEARCH, POLICY, AND INNOVATION PATHWAYS

Realizing the full potential of herbal infusions from Northeast India as functional beverages requires coordinated efforts across research, policy, and innovation domains. While indigenous knowledge systems provide a strong foundation, systematic scientific validation and supportive policy frameworks are essential for integrating these traditional beverages into modern nutrition and public health systems. From a research perspective, interdisciplinary studies are critical. Ethnobotanical documentation must be complemented by phytochemical analysis, nutritional profiling, and bioactivity assessments to establish evidence-based functional claims. Controlled studies examining bioavailability, dose-response

relationships, and long-term safety of commonly consumed herbal infusions would further strengthen their credibility within functional food and nutraceutical science. Additionally, clinical and population-based studies assessing their impact on gut health, metabolic markers, and immune function could provide valuable insights into their preventive healthcare potential.

Innovation in food technology also plays a key role in bridging tradition and modern consumption patterns. Developing low-impact processing techniques that preserve bioactive compounds while improving shelf life and convenience is essential. Approaches such as gentle drying, standardized infusion blends, and biodegradable packaging can enhance market readiness without compromising the integrity of traditional practices. Importantly, innovation should prioritize simplicity and sustainability rather than highly processed formulations that detach these beverages from their cultural origins.

Policy support is equally important in facilitating the integration of traditional herbal infusions into mainstream nutrition systems. Clear regulatory guidelines tailored to traditional functional foods can reduce barriers for small-scale producers and community-based enterprises. Policies that recognize and protect indigenous knowledge, including intellectual property rights and benefit-sharing mechanisms, are crucial to ensuring ethical commercialization. Furthermore, inclusion of traditional herbal beverages in public health nutrition programs could promote culturally appropriate preventive healthcare, particularly in rural and indigenous populations.

Capacity building at the local level is another vital pathway. Training programs for farmers, women's collectives, and local entrepreneurs can enhance skills related to sustainable cultivation, quality control, and value addition. Strengthening linkages between academic institutions, government agencies, and community organizations can foster knowledge exchange and collaborative innovation.

In summary, advancing herbal infusions of Northeast India from traditional practices to recognized functional beverages requires an integrated approach that combines rigorous research, thoughtful innovation, and inclusive policy frameworks. Such an approach not only enhances the scientific and commercial viability of these beverages but also ensures that their development remains culturally respectful, socially equitable, and environmentally sustainable.

CONCLUSION

Herbal infusions of Northeast India represent a unique convergence of indigenous knowledge, ecological diversity, and preventive nutrition practices. Consumed routinely as part of daily life, these traditional beverages exemplify a food-based approach to health that emphasizes balance, resilience, and long-term well-being rather than short-term therapeutic intervention. Through generations of empirical observation, indigenous communities have identified and preserved plant-based infusion practices that align closely with contemporary concepts of functional foods and lifestyle medicine.

This article has demonstrated that herbal teas prepared from regionally significant plants such as *Spondias pinnata* (heining), *Meyna laxiflora* (heibi), *Dillenia indica* (heigri), *Garcinia pedunculata* (heibung), and *Rhus chinensis* (heimang) possess bioactive compounds with documented antioxidant, anti-inflammatory, digestive, and metabolic-supportive properties. When consumed regularly in mild forms, these infusions contribute to gut health, immune modulation, metabolic balance, and stress regulation—key pillars of preventive healthcare in modern nutrition science.

Importantly, the functional value of these beverages lies not only in their phytochemical composition but also in their mode of consumption. Low-dose, habitual intake through simple water-based extraction

ensures safety, bioavailability, and long-term adherence. Unlike isolated nutraceuticals or highly processed functional drinks, these herbal infusions deliver complex mixtures of bioactive compounds within their natural matrix, allowing synergistic interactions that enhance efficacy while minimizing risk.

Despite their immense potential, the broader recognition and integration of Northeast Indian herbal infusions into modern nutrition systems require careful navigation of challenges related to standardization, sustainability, regulatory compliance, and ethical commercialization. Preserving indigenous knowledge and ensuring equitable benefit-sharing must remain central to any development efforts.

In conclusion, herbal infusions of Northeast India offer culturally grounded, scientifically relevant solutions to contemporary health challenges. By bridging traditional wisdom with modern nutritional frameworks, these beverages can contribute meaningfully to sustainable health promotion, preventive healthcare, and the global functional beverage landscape, while safeguarding the cultural and ecological heritage from which they originate.

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