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Review

The Nutraceutical Value of Foods and Its Health Benefits: A Review

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ABSTRACT
The increasing interest in nutraceuticals has spotlighted the potential of local foods as sources of health-promoting bioactive compounds. This narrative review explores the nutraceutical value of local foods, emphasizing the processing methods that enhance their health benefits. By examining a variety of indigenous food sources, we delve into the specific bioactive components they contain, such as polyphenols, flavonoids, vitamins, and minerals. Advanced processing techniques, including fermentation, encapsulation, and enzymatic treatments, are discussed for their roles in maximizing the bioavailability and efficacy of these compounds. Furthermore, the health impacts of these nutraceuticals are analyzed, focusing on their potential to prevent and manage chronic diseases such as diabetes, cardiovascular diseases, and cancer. This review underscores the importance of leveraging local biodiversity to develop sustainable and effective nutraceutical products, offering insights into future research directions and applications in the nutraceutical industry. By integrating traditional knowledge with modern processing technologies, the potential of local foods as nutraceuticals can be fully realized, contributing to both public health and local economies.

Keywords: Nutraceuticals; local food; nutritious food; health benefits

1. INTRODUCTION

Nutraceuticals, a portmanteau of "nutrition" and "pharmaceuticals," represent a burgeoning field that bridges the gap between food and medicine.(1) These products, derived from natural food sources, offer both nutritional and therapeutic benefits, contributing to the prevention and management of various health conditions. As the global population increasingly seeks natural and holistic approaches to health, the demand for nutraceuticals has surged. In this context, local foods, with their rich array of bioactive compounds, emerge as promising candidates for nutraceutical development.

The concept of utilizing food for health benefits is not new; traditional systems of medicine such as Ayurveda and Traditional Chinese Medicine have long recognized the therapeutic potential of various foods. However, modern nutraceuticals bring a scientific rigor to these age-old practices, isolating and enhancing specific bioactive compounds to maximize their health benefits. Local foods, in particular, are rich in unique phytochemicals, vitamins, and minerals that are often not found in conventional food sources or supplements.[2] These indigenous foods, adapted to local climates and soils, offer a treasure trove of nutraceutical potential that remains largely untapped.

Processing plays a crucial role in the development of nutraceuticals from local foods. Advanced processing techniques can enhance the bioavailability, stability, and efficacy of bioactive compounds. Traditional methods such as drying and fermentation, as well as modern techniques like encapsulation, enzymatic treatments, and nanoencapsulation, are pivotal in transforming raw local foods into potent nutraceutical products.[3] Each processing method affects the nutritional and therapeutic properties of the final product differently, making it essential to choose the appropriate technique to preserve and enhance the desired health benefits.

Local foods such as moringa (Moringa oleifera), turmeric (Curcuma longa), and amaranth (Amaranthus spp.) have shown significant potential as nutraceuticals. Moringa, often referred to as the "miracle tree," is rich in vitamins, minerals, and antioxidants. Its leaves, pods, and seeds have been used traditionally to combat malnutrition and various health ailments.[4] Turmeric, renowned for its anti-inflammatory and antioxidant properties, contains curcumin, a compound extensively studied for its potential to prevent and treat a range of diseases, including cancer and Alzheimer's disease.[5] Amaranth, a pseudocereal, is packed with proteins, fibers, and essential amino acids, making it a valuable addition to the nutraceutical arsenal for its role in managing cholesterol levels and supporting cardiovascular health.[6] The health benefits of nutraceuticals derived from local foods are vast and varied. These products have shown promise in preventing and managing chronic diseases such as diabetes, cardiovascular diseases, and cancer. For instance, the antioxidant properties of flavonoids and polyphenols can mitigate oxidative stress, a key factor in the pathogenesis of many chronic conditions. Additionally, certain bioactive compounds can modulate immune responses, reduce inflammation, and improve gut health, further enhancing overall well-being.

Despite the promising potential of local foods in nutraceutical development, several challenges remain. The variability in bioactive compound content due to differences in cultivation practices, environmental conditions, and genetic diversity poses a significant challenge. Standardizing processing methods to ensure consistent quality and efficacy of nutraceutical products is also crucial. Furthermore, there is a need for comprehensive clinical studies to validate the health claims associated with these products and to establish safe and effective dosage guidelines. The integration of local foods into the nutraceutical market not only has health benefits but also offers socio-economic advantages. It supports local agriculture, preserves biodiversity, and promotes sustainable development. By tapping into the rich biodiversity of local food sources, the nutraceutical industry can contribute to economic growth, especially in rural and indigenous communities.[7]

Local foods hold immense potential for nutraceutical development, offering a sustainable and holistic approach to health promotion. Advanced processing techniques are essential to harness this potential, enhancing the bioavailability and efficacy of bioactive compounds. As the demand for natural health products continues to grow, leveraging local foods for nutraceutical development can play a pivotal role in improving public health and supporting local economies. This review aims to explore the processing methods and health benefits of local foods, shedding light on their potential to revolutionize the nutraceutical industry.

2. NUTRACEUTICAL POTENTIAL OF LOCAL FOODS

2.1 Nutraceutical Classification

The concept of functional foods has grown substantially, underscoring the vital role of diet in boosting health and overall well-being. Proper classification of these foods is essential for scientific research, effective dietary planning, and educating consumers. Functional foods cover a wide array, including cereals, legumes, oilseeds, vegetables, fruits,

dairy products, beverages, fish, and herbs and spices, each contributing unique health-enhancing properties.[8] Furthermore, the integration of functional foods into daily diets can play a crucial role in disease prevention and health maintenance, making them a cornerstone of modern nutritional science. They can be classified into six main categories (Table 1).

Table 1. Classification of nutrition and example of source foods

Nutrients	Definition	Source example	Reference
Carbohydrates	These molecules, composed of carbon, hydrogen, and oxygen, serve as a major energy source. Carbs include simple sugars and complex forms like fiber, starch, and glycogen.	• Sweet Potatoes: High in complex carbohydrates and fiber. • Oats: Rich in carbohydrates and fiber. • Bananas: Packed with natural sugars and fiber. • Brown Rice: Provides complex carbohydrates and fiber.	[9]
Lipids	Insoluble in water, lipids provide energy, form cell membranes, protect organs, and regulate various functions. Types of lipids include triglycerides, phospholipids, and sterols.	• Avocados: High in monounsaturated fats and essential fatty acids. • Olive Oil: Rich in monounsaturated fats and antioxidants. • Nuts (e.g., almonds, walnuts): Omega-3 fatty acids. • Fatty Fish (e.g., salmon, mackerel): Omega-3 fatty acids. • Coconut Oil: High in saturated fats	[10]
Proteins	Composed of amino acids, proteins are crucial for growth, repair, and maintaining body structures. They are found in meats, dairy, seafood, and plant-based foods.	• Chicken Meat: Lean protein with minimal fat. • Eggs: Complete protein with all essential amino acids. • Lentils: Plant-based protein rich in fiber and iron. • Yogurt: High in protein and probiotics. • Tofu: Plant-based protein rich in all essential amino acids.	[11]
Water	Although not an energy-yielding nutrient, water is essential for hydration and various physiological processes.	Water and various fruits and vegetables, such as: cucumbers (about 95% water), watermelon (about 92% water), strawberries (about 91% water), lettuce (around 96%), celery (about 95% water), etc.	[11]
Vitamins	These organic compounds play vital roles in metabolism, immunity, and overall health. Vitamins are obtained from various foods.	• Carrots: Rich in Vitamin A (beta-carotene). • Oranges: High in Vitamin C. • Spinach: Packed with vitamins A, C, and K. • Sweet Red Peppers: Excellent source of Vitamins A and C. • Sunflower Seeds: High in Vitamin E.	[11]
Minerals	Inorganic nutrients like calcium, iron, and zinc are essential for bone health, enzyme function, and other processes.	• Spinach: Rich in iron, calcium, and magnesium. • Pumpkin Seeds: High in magnesium and zinc. • Salmon: Rich in iodine, selenium, and phosphorus. • Almonds: High in magnesium, calcium, and potassium.	[11]

Functional foods and nutraceuticals are essential for promoting health and preventing disease, offering products that enhance overall well-being. These items go beyond basic nutrition, incorporating bioactive compounds with therapeutic properties. Functional foods, part of many daily diets, are ordinary foods enriched with health benefits from antioxidants, fibers, and probiotics (Figure 1). These compounds combat oxidative stress, support digestive health, and promote a balanced gut microbiome.[12]

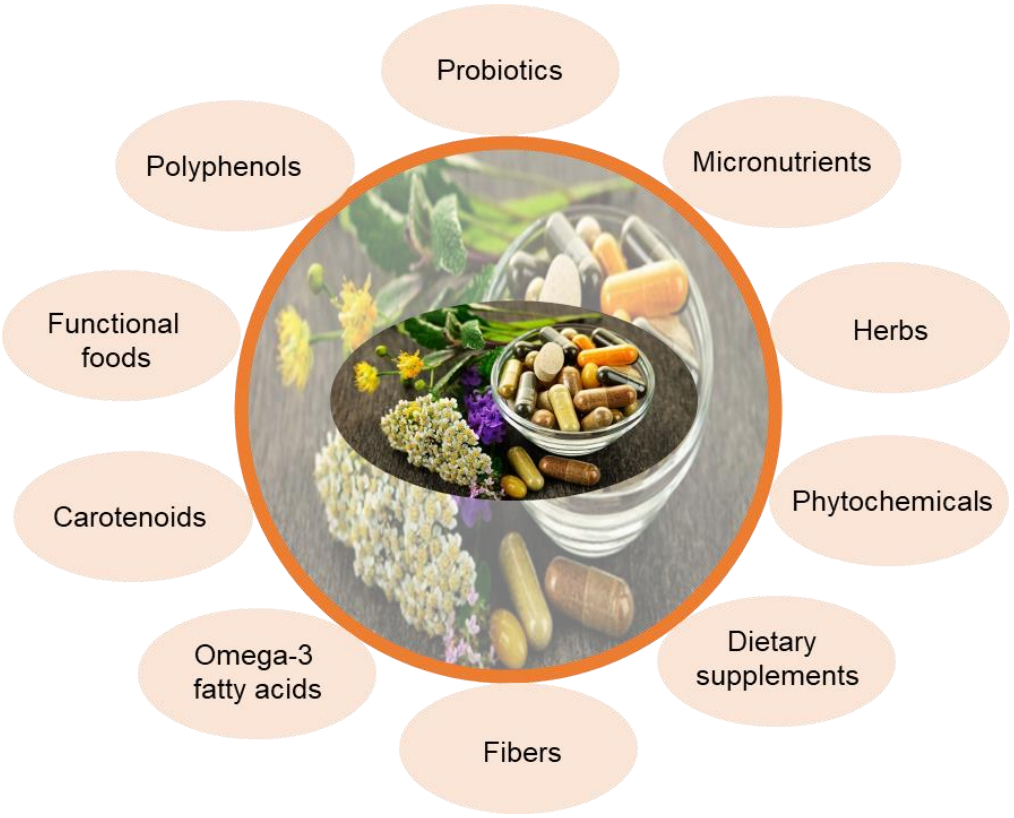

Figure 1. Types of nutraceuticals that available in different foods

Nutraceuticals, either isolated from foods or synthesized, provide concentrated health benefits.[13] This category includes dietary supplements, fortified foods, and herbal products designed for specific therapeutic effects.[12] They often contain higher bioactive compound concentrations than whole foods, targeting specific health concerns more effectively. The variety of functional foods and nutraceuticals highlights their role in supporting health and wellness.[14] As our understanding of bioactive compounds grows, so does the potential for developing innovative products to improve health outcomes.[15]

2.2 Overview of Key Functional Components of Nutraceuticals

Functional foods rich in antioxidants, like fruits, vegetables, and nuts, are vital for neutralizing harmful free radicals in the body.[16] These antioxidants significantly reduce oxidative stress and inflammation, contributing to the prevention of chronic diseases, particularly cardiovascular disorders.[17] By lowering oxidative stress, antioxidants help maintain vascular health and prevent certain cancers.[18] The inclusion of antioxidant-rich foods in a balanced diet is crucial for long-term health.[19] Examples of functional components in different nutraceutical foods are represented in Table 2.

Sesame seed oil is notable for its antioxidative properties, improving cardiovascular health, reducing inflammation, and lowering cancer risk.[34] Its antioxidants, such as sesamol, sesamin, and sesamolin, protect against oxidative stress and DNA damage.[35,36] Additionally, bioactive peptides from milk and antioxidants in honey further enhance their health benefits, providing protection against oxidative stress and supporting overall health.[37,38]

Table 2. Examples of nutraceutical food sources and potential health benefits; adopted from Vignesh et al. 2024[8]

Nutraceutical food	Nutrition component	Potential health benefits	Reference
Grape	• Resveratrol • Antioxidants	Help to prevent several diseases such as cancer, diabetes, and alzheimer's	[20]
Carrots, pumpkin	• β-carotene	Good for eye health, strong immune system, and healthy skin	[21]
Grapes, strawberries, raspberries	• Ellagic acid	Help as antioxidant, antimutagenic, and anticancer	[22]
Beef and Dairy	• Conjugated linoleic acid	➢ Several properties including anticarcinogenic, antiobesity, antidiabetic, and antihypertensive ➢ Prevent lifestyle diseases or metabolic syndromes	[23]
Yogurt, dairy	• Lactobacilli	Improve lactose intolerance, prevent and treat cancer, regulate immunity, and improve gastrointestinal diseases.	[24]
Tea, cocoa	• Catechins	Prevention and treatment of chronic diseases.	[20]
Garlic, onion	• Adenosine, lignan • Allyl sulfur	➢ Lowered risk of heart disease, menopausal symptoms, osteoporosis and breast cancer ➢ Reduce inflammation, improve digestion, and boost the immune system.	[25,26]
Turmeric	• Curcumin	Oxidative stress and inflammatory conditions, metabolic syndrome, arthritis, anxiety, and hyperlipidemia.	[27]
Tomato	• Lycopene	Anticancer, cardiovascular diseases, neurobiological antioxidant effects, anti-inflammatory, antihypertensive and antiaggregative Effects.	[28]
Fish oil	• EPA and DHA	Proper fetal development, including neuronal, retinal, and immune function, inflammation, peripheral artery disease, major coronary events, and anticoagulation.	[29,30]
Rosemary	• Carnosol	➢ Inhibits inflammation that promotes tumor growth, selectively induces cell death, reduces cell proliferation, and prevents tumor angiogenesis and invasion. ➢ Enhances detoxifying enzyme activity, inhibits inflammation that promotes tumor growth, selectively induces cell death, reduces cell proliferation, and prevents tumor angiogenesis and invasion.	[31,32]
Oat bran	• B-glucan	Improved immune health, and blood sugar levels, reduced heart disease risk and decreased cholesterol levels.	[33]

Prebiotics, found in foods like garlic, onions, bananas, and whole grains, promote the growth of beneficial gut microbes. These fibers, including inulin and FOS, enhance gut health and overall wellness.[12] Probiotics, present in yogurt and fermented products, balance the gut microbiome, improving digestion, immune function, and possibly mental health.[13,39] Maintaining a healthy gut microbiome through prebiotics and probiotics is crucial for comprehensive health.[40]

Omega-3 fatty acids, abundant in fatty fish, flaxseeds, and walnuts, are essential for cardiovascular and cognitive health.[14] Key components like ALA, EPA, and DHA reduce inflammation and support brain function.[41] These fatty acids help lower triglyceride levels, reduce heart disease risk, and improve cognitive performance, potentially protecting against

neurodegenerative diseases.[30,42,43] Including omega-3-rich foods in the diet supports overall health and cognitive function. By incorporating these nutrient-rich components, functional foods and nutraceuticals play a pivotal role in enhancing health and preventing diseases.

2.3 Mechanisms: How Nutraceuticals Work

Nutraceuticals can effectively reduce inflammation, a major contributor to various chronic diseases. For instance, curcumin, a compound in turmeric, inhibits enzymes like COX-2, lipoxygenase, and inducible nitric oxide synthase (iNOS). It also downregulates inflammatory cytokines such as TNF-α, IL, MCP, and migration inhibitory protein by inhibiting the activation of nuclear factor kappa B (NF-κB).[27,44] Similarly, green tea polyphenols, particularly catechins and EGCG, act as antioxidants and suppress inflammatory processes by inhibiting the IL-1β signaling pathway and the protein expression of p38 and NF-κB.[45,46] These actions help protect against diseases linked to chronic inflammation, such as rheumatoid arthritis and certain cancers.[8]

Certain nutraceuticals significantly impact metabolic processes, aiding in weight management and overall metabolic health. Green tea catechins, especially EGCG, enhance fat oxidation and thermogenesis, leading to increased calorie expenditure and potentially aiding in weight loss and maintenance.[47] Additionally, green tea consumption has been linked to reduced plasma serum amyloid alpha (SAA), which is involved in lipid transport and metabolism, suggesting a role in reducing adiponectin levels and supporting metabolic health.[48] Capsaicin, found in chili peppers, increases energy expenditure and promotes fat oxidation, contributing to weight loss and metabolic regulation.[18] Incorporating these functional foods into the diet can complement lifestyle efforts aimed at achieving and maintaining a healthy weight.[49]

Nutraceuticals such as resveratrol, found in red grapes and wine, offer significant cellular protection and repair benefits. Resveratrol activates sirtuin proteins, particularly SIRT1, which regulate processes like DNA repair, inflammation control, and energy metabolism, enhancing cellular resilience and mitigating aging effects.[50] This compound is being studied for its potential to protect against age-related diseases like Alzheimer's and cardiovascular disorders.[51] Berberine, derived from the Berberis genus, induces oxidative DNA damage selectively in cancer cells without affecting normal cells, making them more sensitive to treatments.[52] Genistein, an isoflavonoid from soy products, increases BRCA1 expression, reducing tumor development and impairing DNA repair mechanisms in cancer cells.[53]

In chronic diseases like type-2 diabetes and obesity, nutraceuticals modulate inflammation and metabolism through various pathways. Metabolic dysregulation can lead to metaflammation, where the NLRP3 inflammasome plays a crucial role by detecting metabolic imbalances and releasing pro-inflammatory cytokines like IL-1β.[54] Functional foods rich in anti-inflammatory agents, such as curcumin and polyphenols from green tea, help reduce elevated levels of inflammatory markers like CRP and IL-6.[55] Capsaicin and catechins also show potential in regulating markers like TNF-α and IL-17, which are associated with obesity-related inflammation.[56] Additionally, omega-3 fatty acids from fatty fish can reduce LBP levels, contributing to inflammation modulation in renal diseases.[43] Resveratrol's ability to dampen IL-1β-mediated inflammation offers a novel approach to managing chronic diseases.[55]

3. HEALTH BENEFITS OF NUTRACEUTICALS DERIVED FROM LOCAL FOODS

Nutraceuticals are increasingly recognized for their role in disease prevention and health promotion (Figure 2). These bioactive compounds, such as polyphenols in berries and tea, omega-3 fatty acids in fish oils, and curcumin in turmeric, offer significant benefits. Polyphenols exhibit strong antioxidant properties, reducing the risk of chronic diseases like cardiovascular disease and certain cancers. Omega-3 fatty acids help lower inflammation and improve heart health by reducing triglyceride levels and blood pressure. Additionally, curcumin and resveratrol provide anti-inflammatory and anti-cancer benefits, respectively, aiding in overall disease prevention and health maintenance. Incorporating these nutraceuticals into the diet supports a natural approach to enhancing well-being and longevity.

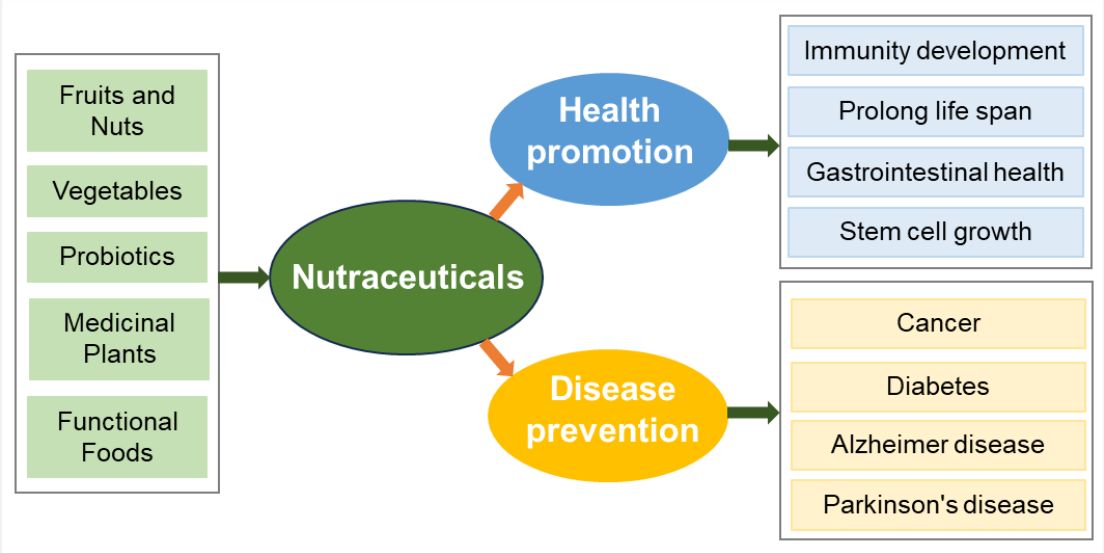

Figure 2. Potential benefits of nutraceuticals for good health

3.1 Contribution to Preventing Noncommunicable Diseases

Nutraceuticals have shown significant potential in preventing noncommunicable diseases (NCDs) such as cardiovascular diseases, diabetes, obesity, and certain types of cancer, primarily due to their rich bioactive compounds. These compounds, including polyphenols, flavonoids, vitamins, and minerals, play a crucial role in modulating metabolic pathways, reducing oxidative stress, and enhancing immune function. Polyphenols, for example, found in foods like berries, tea, and red wine, possess strong antioxidant properties that help neutralize free radicals, thereby preventing cellular damage and reducing the risk of chronic inflammation and associated diseases. Flavonoids, another important group of bioactives present in a variety of fruits and vegetables, have been linked to improved cardiovascular health through their ability to enhance endothelial function and reduce blood pressure. Moreover, omega-3 fatty acids, typically found in fish oils, are well-documented for their anti-inflammatory effects, contributing to lower risks of heart disease and improved lipid profiles. Vitamins and minerals also play indispensable roles in disease prevention. For instance, vitamin D has been associated with a lower risk of multiple sclerosis, diabetes, and some cancers due to its immune-modulating effects. Magnesium, on the other hand, is essential for glucose metabolism and has been linked to a reduced risk of type 2 diabetes.[57]

3.2 Potential Benefits for Oxidative Stress Management

Nutraceuticals have shown significant promise in managing oxidative stress, a condition characterized by an imbalance between free radicals and antioxidants in the body, leading to cellular damage and various chronic diseases. These bioactive compounds, found in foods, herbs, and dietary supplements, possess potent antioxidant properties that can neutralize free radicals, thereby reducing oxidative stress and its associated risks. Polyphenols, flavonoids, vitamins, and minerals are among the most effective nutraceuticals in combating oxidative stress. For instance, polyphenols, abundant in fruits and vegetables, have been demonstrated to enhance antioxidant defenses and modulate oxidative stress pathways. Flavonoids, found in tea, cocoa, and berries, exhibit strong free radical scavenging activities, which help in protecting cells from oxidative damage. Moreover, vitamins C and E are critical in maintaining the body's antioxidant defenses. Vitamin C, a water-soluble antioxidant, directly neutralizes free radicals and regenerates other antioxidants, including vitamin E, which protects cell membranes from oxidative damage. Additionally, minerals like selenium and zinc play crucial roles in the functioning of antioxidant enzymes, further bolstering the body's defense against oxidative stress. The integration of these nutraceuticals into the diet can significantly mitigate the effects of oxidative stress, thereby reducing the risk of chronic diseases such as cardiovascular diseases, diabetes, and

neurodegenerative disorders, highlighting the importance of dietary interventions and the potential of nutraceuticals in promoting health and preventing disease through oxidative stress management.[58]

3.3 Health Benefits of Nutraceuticals in Gout Patients

Nutraceuticals, encompassing natural dietary supplements (NPS) such as nuts, vegetables, fruits, legumes, and whole grains, play a pivotal role in the management and treatment of gout, an inflammatory arthritis condition precipitated by the deposition of monosodium urate (MSU) crystals in joints due to elevated uric acid levels. The genesis of gout is intricately linked to purine catabolism by xanthine oxidase, an enzyme that facilitates the oxidative hydroxylation of hypoxanthine to xanthine and subsequently to uric acid, culminating in painful inflammation. The therapeutic landscape for gout has been enriched by the exploration of non-purine xanthine oxidase inhibitors, which are associated with fewer side effects compared to their purine analogs and are under active investigation for their efficacy in treating not only gout but also hyperuricemia, ulcers, cancer, and oxidative damage. Moreover, the acute attacks of gout are conventionally treated with colchicine, corticosteroids, nonsteroidal anti-inflammatory medications (NSAIDs), and IL-1 inhibitors. However, the comprehensive knowledge regarding the utilization of these agents remains fragmented and not well-organized, underscoring the need for continued research and education in this domain. The burgeoning interest in nutraceuticals is evidenced by the increasing volume of articles and patents, highlighting their potential as a mainstay in the prophylaxis and treatment of gout, thereby mitigating the onset of hyperuricemia and its associated complications.[59]

4. CHALLENGES RELATED TO NUTRACEUTICALS

Nutraceuticals have gained prominence due to their potential health benefits. However, several challenges accompany the use of these functional foods and dietary supplements. Ensuring consistent product quality remains a critical challenge in the nutraceutical industry. Manufacturers must adhere to rigorous quality control processes to maintain uniformity across batches. Standardization of ingredients and formulations is essential for reliable efficacy and safety.[60] Without strict quality control measures, the effectiveness and safety of nutraceuticals can vary significantly, potentially undermining consumer trust and product credibility.

Regulatory compliance presents another significant challenge. The classification and regulation of nutraceuticals vary globally, leading to inconsistencies in oversight and labeling standards. This lack of harmonization can cause confusion among consumers and complicate international trade. Establishing uniform regulations across regions would enhance consumer confidence, streamline market operations, and facilitate the growth of the nutraceutical industry.

Sourcing high-quality raw materials can be complex for nutraceutical companies. Establishing robust supply chains is crucial to maintaining ingredient integrity, traceability, and sustainability. Effective supply chain management ensures that products are not only safe and effective but also ethically sourced and environmentally friendly. This is particularly important as consumers become more conscious of the origins and environmental impact of the products they consume. The stability and shelf life of nutraceutical products are critical for maintaining their efficacy. Many nutraceuticals contain sensitive compounds like vitamins, probiotics, and herbal extracts that can degrade under certain conditions. Ensuring these products remain stable during storage and transportation is crucial. Formulations must be designed to withstand environmental factors such as temperature, light, and humidity to maintain their potency over time.[61]

Consumer education and safety concerns are also pivotal in the nutraceutical sector. Educating consumers about the benefits, proper usage, and potential interactions of nutraceuticals with medications is essential for their safe and effective use. Safety precautions, dosage guidelines, and awareness campaigns play a crucial role in informing consumers and preventing misuse or adverse effects. Proper education ensures that consumers can make informed choices and use nutraceuticals safely and effectively.

5. CONCLUSION

The exploration of local foods as sources for nutraceuticals offers a promising, sustainable approach

to enhancing public health. This review highlights the rich potential of local foods, abundant in bioactive compounds like polyphenols, flavonoids, vitamins, and minerals. Advanced processing techniques—ranging from drying and fermentation to encapsulation and nanoencapsulation—enhance the bioavailability and efficacy of these compounds. Local foods such as moringa, turmeric, and amaranth show promise in preventing and managing chronic diseases due to their antioxidant, anti-inflammatory, and immune-modulating properties. Despite challenges like variability in bioactive content and the need for standardized processing and comprehensive clinical studies, integrating local foods into the nutraceutical industry supports local agriculture, preserves biodiversity, and promotes sustainable development, fostering economic growth in rural and indigenous communities. In conclusion, leveraging the nutraceutical value of local foods with advanced processing methods presents a transformative opportunity for creating effective, natural health products that support public health and local economies, underscoring the need for ongoing research and innovation.

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Conflict of Interest

The authors declare no conflict of interest.

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