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Role of Nutraceuticals in Prevention and Management of Chronic Diseases: A Comprehensive Review

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Abstract
Nutraceuticals have emerged as an important area of research because of their potential role in health promotion and disease risk reduction. These bioactive products, obtained from natural and food-based sources, are increasingly utilized as supportive agents in the management of various chronic and degenerative disorders. The growing consumer preference for preventive healthcare and safer therapeutic options has significantly expanded the scope of nutraceutical applications in modern healthcare systems. Nutraceutical compounds such as probiotics, polyphenols, flavonoids, carotenoids, dietary fibres, and plant-derived extracts exhibit a wide range of biological activities including antioxidant, anti-inflammatory, antimicrobial, anticancer, and immunomodulatory effects.

The present review highlights the classification, sources, mechanisms of action, therapeutic applications, and clinical significance of nutraceuticals in maintaining human health. Particular emphasis is given to their role in reducing oxidative stress, improving metabolic functions, enhancing immune responses, and supporting cardiovascular and neurological health. The paper also discusses current advancements in nutraceutical research, challenges associated with quality control and standardization, and the importance of scientific validation for their efficacy and safety. With increasing global interest in functional and natural healthcare products, nutraceuticals are expected to play a significant role in future nutritional and therapeutic strategies.

Keywords
'Nutraceuticals', 'Functional Foods', 'Chronic Diseases', 'Antioxidants', 'Omega-3 Fatty Acids', 'Cardiovascular Diseases', 'Diabetes; Obesity', 'Preventive Healthcare'.

1. Introduction

The term nutraceutical is derived from the combination of the words "nutrition" and "pharmaceutical." It was first coined in 1989 by Dr. Stephen DeFelice, founder and chairman of the Foundation for Innovation in Medicine (FIM), Cranford, New Jersey, to describe foods or food components that provide health benefits beyond basic nutrition, including disease prevention and management [1]. Nutraceuticals are broadly defined as substances that are foods or parts of foods and provide medical or health benefits, including the prevention and treatment of diseases [2].

In recent decades, the global nutraceutical industry has experienced rapid growth due to increasing health awareness and the rising prevalence of lifestyle-related disorders. Modern dietary habits, sedentary lifestyles, and excessive consumption of processed and junk foods have significantly contributed to chronic diseases such as obesity, cardiovascular diseases, cancer, diabetes, and metabolic syndromes [3]. As a result, consumers are increasingly shifting toward preventive healthcare approaches and natural therapeutic alternatives.

Nutraceuticals support normal physiological functions and overall well-being through their nutritional and therapeutic properties. They may help improve health, delay aging, prevent chronic diseases, enhance life expectancy, and support the structure and function of the body [4]. Nutraceuticals constitute a broad category of products derived from food sources that provide additional health benefits beyond their basic nutritional value [5]. These products are commonly regulated as food ingredients, dietary supplements, or pharmaceutical-related products depending on regional regulatory frameworks.

A dietary supplement is generally defined as a product containing one or more dietary ingredients such as vitamins, minerals, amino acids, herbs, botanicals, or other bioactive substances intended to supplement the diet. Common nutraceuticals include omega-3 fatty acids, glucosamine, green tea, ginseng, echinacea, lutein, folic acid, and cod liver oil, many of which possess multiple therapeutic properties [6]. In recent years, nutraceuticals have attracted considerable scientific and commercial interest because of their nutritional value, safety profile, and potential therapeutic applications [7]. Furthermore, the increasing cost of conventional medical treatments has accelerated interest in nutraceuticals as natural and cost-effective alternatives, thereby strengthening their role as an important link between nutrition and medicine [8].

2. Methodology

This review was conducted through a systematic collection and analysis of published scientific literature related to nutraceuticals and their role in health promotion and disease management. Relevant data were obtained from electronic databases including PubMed, Google Scholar, and ScienceDirect, along with reports from organizations such as the World Health Organization and Centers for Disease Control and Prevention. Keywords including nutraceuticals; functional foods; chronic diseases; antioxidants; omega-3 fatty acids; bioactive compounds; cardiovascular diseases; diabetes; obesity; neurodegenerative disorders; preventive healthcare and dietary supplements were used to identify relevant studies. Articles published mainly between 2000 and 2025 were considered to ensure updated scientific evidence. Studies focusing on the classification, sources, mechanisms of action, therapeutic applications, and health benefits of nutraceuticals were included, while duplicate and unrelated articles were excluded. The collected information was systematically reviewed and synthesized to provide a comprehensive understanding of the importance of nutraceuticals in modern healthcare.

3. Classification

Nutraceuticals are broadly classified into level of processing, food source, chemical composition and mechanism of action.

Classification by Level of Processing:

- *Traditional nutraceuticals* – These are natural foods that inherently contain bioactive compounds with health-promoting properties. Fruits, vegetables, cereals, herbs, spices, fish oil, and soy products are common examples. These nutraceuticals are rich in antioxidants, vitamins, minerals, flavonoids, and other phytochemicals that help in disease prevention and health maintenance [9].

- Non-traditional nutraceuticals - These are developed through food fortification or biotechnology to enhance nutritional value and therapeutic benefits. Examples include vitamin-fortified cereals, calcium-enriched milk, and genetically modified crops. These products are designed to improve nutrient intake and reduce nutritional deficiencies [1].

Classification by Sources of Nutraceuticals [9],[10],[11]

Source Type	Description	Major Sources	Important Bioactive Compounds	Health Benefits
Plant Sources	Nutraceuticals obtained from fruits, vegetables, cereals, herbs, spices, and medicinal plants. These are rich in phytochemicals and antioxidants.	Turmeric, Garlic, Ginger, Green tea, Soybean, Tomato, Citrus fruits, Berries, Flaxseed	Polyphenols, Flavonoids, Carotenoids, Dietary fiber, Curcumin, Lycopene	Antioxidant, anti-inflammatory, anticancer, cardioprotective effects
Animal Sources	Nutraceuticals derived from animal products containing essential fatty acids, proteins, vitamins, and minerals.	Fish oil, Cod liver oil, Milk, Egg, Yogurt, Honey	Omega-3 fatty acids, CLA, Probiotics, Calcium, Peptides	Supports bone health, heart health, immunity, and brain function
Microbial Sources	Nutraceuticals produced from beneficial microorganisms or fermentation processes.	Probiotic bacteria, Yeast, Fermented milk products, Kefir, Kimchi	Probiotics, Prebiotics, Enzymes, Vitamins	Improves gut microbiota, digestion, immunity, and nutrient absorption

Classification by Chemical Composition [1],[4],[5],[10],[11]

- Isoprenoid derivatives (terpenoids) include carotenoids, tocopherols, and saponins, which possess antioxidant and cardioprotective properties.
- Phenolic compounds such as flavonoids, anthocyanins, resveratrol, and tannins exhibit antioxidant, anti-inflammatory, and anticancer activities.
- Carbohydrates and derivatives include prebiotics like inulin and fructooligosaccharides (FOS), dietary fibres, and resistant starch, which improve gut health and digestion.

- Lipids mainly consist of omega-3 polyunsaturated fatty acids (PUFAs) and conjugated linoleic acid (CLA), known for their cardiovascular and anti-inflammatory benefits.
- Amino acid-based compounds include peptides, proteins, and glucosamine that support tissue repair, metabolism, and joint health.
- Microbial nutraceuticals include probiotics such as *Lactobacillus* and *Bifidobacterium*, which help maintain intestinal microbial balance and immunity.
- Minerals such as calcium, selenium, and zinc are essential for bone health, antioxidant defense, and immune function.

Classification by Mechanism of Action of Nutraceuticals [1],[10],[11],[12]

Mechanism	**Description**	**Examples of Nutraceuticals**	**Health Benefits**
Antioxidant Activity	Neutralizes free radicals and reduces oxidative stress by enhancing antioxidant defense systems.	Vitamin C, Vitamin E, Flavonoids, Polyphenols, Carotenoids	Prevents cellular damage, aging, cancer, cardiovascular diseases
Anti-inflammatory Action	Inhibits inflammatory mediators such as cytokines, COX, LOX, and NF-κB pathways.	Curcumin, Resveratrol, Omega-3 fatty acids, Green-tea catechins	Reduces chronic inflammation, arthritis, obesity, metabolic disorders
Immunomodulatory Effect	Enhances immune cell activity and improves immune response.	Probiotics, Prebiotics, Zinc, Vitamin D, Herbal extracts	Strengthens immunity and protects against infections
Antimicrobial Activity	Inhibits the growth of pathogenic microorganisms including bacteria, fungi, and viruses.	Garlic, Ginger, Probiotics, Green tea extract	Improves gut health and prevents microbial infections
Cardioprotective Mechanism	Regulates lipid metabolism and improves blood circulation and endothelial function.	Omega-3 fatty acids, Phytosterols, Dietary fibres	Lowers cholesterol, hypertension, and risk of cardiovascular diseases
Antidiabetic Action	Improves insulin sensitivity and regulates glucose metabolism.	Fenugreek, Cinnamon, Flavonoids, Probiotics	Helps manage blood glucose levels and diabetes mellitus
Anticancer Activity	Induces apoptosis and inhibits tumor growth, angiogenesis, and metastasis.	Curcumin, Lycopene, Sulforaphane, EGCG	Reduces cancer progression and tumor development

Neuroprotective Effect	Protects neurons from oxidative damage and supports neurotransmitter function.	Omega-3 fatty acids, Ginkgo biloba, Polyphenols	Supports brain health and reduces neurodegenerative disorders
Gut Microbiota Modulation	Maintains healthy intestinal microbial balance and improves digestion.	Probiotics, Prebiotics, Dietary fibres	Enhances digestive health and nutrient absorption

4. Role of Nutraceuticals in Disease Management

Worldwide, the burden of chronic diseases such as cardiovascular diseases, cancer, diabetes mellitus, obesity, and neurodegenerative disorders is increasing rapidly. In 2001, chronic diseases accounted for approximately 59% of the 56.5 million total deaths worldwide and contributed nearly 46% of the global burden of disease [13]. Growing awareness regarding the relationship between nutrition and health has increased interest in nutraceuticals as supportive agents in disease prevention and management.

Cardiovascular Diseases

Cardiovascular diseases (CVDs) include disorders affecting the heart and blood vessels, such as coronary heart disease, hypertension, stroke, heart failure, and peripheral vascular disease. Poor dietary habits, obesity, inflammation, dyslipidemia, and sedentary lifestyles are major risk factors associated with CVDs. Nutraceuticals have gained significant attention because of their cardioprotective effects and ability to improve cardiovascular health. Bioactive compounds such as omega-3 fatty acids, garlic, soy proteins, dietary fibres, plant sterols, antioxidants, flavonoids, polyphenols, prebiotics, and probiotics help reduce LDL-cholesterol levels, improve lipid profiles, decrease inflammation, and maintain vascular function. These nutraceuticals may serve as complementary approaches alongside conventional therapies for the prevention and management of cardiovascular diseases [14],[15],[16],[17].

Cancer

Nutraceuticals play an important role in cancer prevention and management due to their antioxidant, anti-inflammatory, and chemopreventive properties. Flavonoids inhibit enzymes involved in estrogen biosynthesis, thereby reducing the risk of hormone-related cancers such as breast and prostate cancer. Phytoestrogens, especially soy isoflavones, have also demonstrated protective effects against certain cancers. Curcumin obtained from *Curcuma longa* exhibits strong anti-carcinogenic and antioxidative activities. Lycopene, predominantly found in tomatoes, protects cells from oxidative damage and reduces cancer risk. In addition, saponins and several plant-based foods such as beetroot, spinach, cucumber, and turmeric possess antitumor and antimutagenic properties that inhibit cancer cell proliferation [18],[19],[20].

Diabetes Mellitus

Nutraceuticals have shown beneficial effects in the management of diabetes mellitus by improving glucose metabolism and insulin sensitivity. Omega-3 fatty acids help regulate lipid profiles and reduce insulin resistance. Docosahexaenoic acid (DHA) contributes to neurovisual development and metabolic

regulation. Alpha-lipoic acid acts as a potent antioxidant and is widely used in diabetic neuropathy management due to its ability to reduce oxidative stress. Dietary fibres such as psyllium also help control blood glucose levels and lower serum cholesterol concentrations in diabetic individuals [18],[21],[22].

Obesity

Obesity is a major metabolic disorder associated with increased risks of diabetes, hypertension, and cardiovascular diseases. Nutraceuticals such as omega-3 fatty acids help reduce inflammation and improve lipid metabolism. DHA supports adipocyte regulation and insulin sensitivity, while alpha-lipoic acid promotes weight reduction by enhancing mitochondrial activity and decreasing oxidative stress. Dietary fibres including psyllium increase satiety, reduce caloric intake, and improve lipid profiles, thereby contributing to obesity management [23],[24],[25].

Alzheimer's Disease

Alzheimer's disease (AD) is a progressive neurodegenerative disorder characterized by memory loss, cognitive decline, and impaired daily functioning. Oxidative stress, neuroinflammation, mitochondrial dysfunction, and amyloid-beta plaque accumulation are major factors involved in AD pathogenesis. Nutraceuticals have demonstrated neuroprotective effects in slowing disease progression and supporting cognitive health. Omega-3 fatty acids, particularly DHA, are essential for neuronal membrane integrity and synaptic function. Antioxidants such as vitamin E, vitamin C, and polyphenols reduce oxidative neuronal damage. Curcumin inhibits amyloid plaque formation and suppresses neuroinflammatory pathways, while flavonoids and resveratrol improve cerebral blood flow and cognitive performance [26],[27],[28].

Parkinson's Disease

Parkinson's disease (PD) is a chronic neurodegenerative disorder characterized by tremors, rigidity, bradykinesia, and postural instability. The disease is associated with degeneration of dopaminergic neurons, oxidative stress, mitochondrial dysfunction, and neuroinflammation. Several nutraceuticals have shown potential neuroprotective effects in PD management. Omega-3 fatty acids help maintain neuronal membrane stability and reduce inflammation. Antioxidants such as vitamin E, vitamin C, and polyphenols protect dopaminergic neurons from oxidative damage. Coenzyme Q10 supports mitochondrial energy production and may slow disease progression. Curcumin and flavonoids also exhibit neuroprotective activities by modulating inflammatory pathways and inhibiting neuronal apoptosis. Additionally, probiotics and dietary fibres may improve gut-brain interactions associated with Parkinson's disease pathophysiology [29],[30],[31].

Various Nutraceuticals Used Against different diseases

Disease	Examples (Nutraceutical)
Cardiovascular	Flavonoids (onion, black grapes)
Obesity	Chitosan, Fenugreek, Vitamin C
Diabetes	Calcium, Vitamin D, Emblica officinalis
Alzheimer	Vitamin E & C, Alpha-lipoic acid
Parkinson	Vitamin E
Vision improving	Carrot, Mango, Spinach, Kiwi, Egg yolk

Osteoarthritis	Glucosamine, Chondroitin, Sulfate
Hyperlipidemia	Emblica officinalis
Hypertension	Curry leaf, Green tea
Constipation	Buck Wheat

5. Benefits of Nutraceuticals

Nutraceuticals offer a wide range of health benefits beyond basic nutrition due to their bioactive compounds such as vitamins, minerals, antioxidants, polyphenols, and fatty acids. The common health benefits of nutraceuticals are as follows:

Health Promotion and Well-Being

Nutraceuticals contribute to improved general health by supporting essential physiological functions and enhancing overall well-being. They can complement a balanced diet and help individuals maintain optimal health through their nutrient-dense bioactive components [32].

Prevention and Risk Reduction of Chronic Diseases

Bioactive compounds found in nutraceuticals possess antioxidant and anti-inflammatory properties that can reduce oxidative stress, modulate metabolic pathways, and help lower the risk of chronic diseases including cardiovascular disorders, diabetes, and certain cancers [33].

Immune System Support

Several nutraceuticals, such as vitamins C and D, zinc, and probiotics, have been associated with enhanced immune function and improved resistance to infections by supporting immune cell activity and reducing pro-inflammatory mediators [34].

Anti-Aging and Cellular Protection

Research has shown that certain nutraceuticals may mitigate mechanisms of cellular aging by reducing oxidative stress, supporting mitochondrial function, and modulating gene expression related to senescence, which may contribute to healthy aging and the prevention of neurodegenerative disorders [35].

Support of Specific Organ Health

Nutraceuticals such as omega-3 fatty acids and antioxidants are reported to promote cardiovascular health by lowering LDL cholesterol and reducing inflammation, while other compounds support eye health, bone health, and cognitive function [36].

Enhanced Quality of Life and Functional Support

By helping regulate physiological processes and counteracting nutrient deficiencies, nutraceuticals can contribute to better physical performance, improved digestive health, and enhanced life quality, particularly in populations with special nutritional needs (e.g., the elderly) [37].

Nutraceuticals are available in various forms such as capsules, tablets, powders, and liquid extracts, either as single ingredients or in combination preparations. Their increasing use reflects a growing preference for preventive, natural, and cost-effective strategies in health maintenance and disease prevention [32].

Nutraceuticals and Functional Foods

Nutraceuticals and functional foods have gained considerable importance in modern healthcare because of their role in promoting health and reducing the risk of chronic diseases. Although the terms are often used interchangeably, functional foods are generally defined as foods that provide physiological benefits beyond basic nutrition when consumed as part of a regular diet, whereas nutraceuticals are bioactive compounds or products derived from food sources that possess therapeutic and disease-preventive properties [9].

Functional foods may include naturally enriched foods or fortified products containing vitamins, minerals, probiotics, prebiotics, dietary fibres, antioxidants, and phytochemicals. Common examples include probiotic yogurt, oat bran, green tea, fortified cereals, soy products, and omega-3 enriched foods. These foods contribute to improved digestive health, enhanced immunity, better cardiovascular function, and reduced oxidative stress [10].

Nutraceuticals and functional foods exert beneficial effects through antioxidant, anti-inflammatory, antimicrobial, and immunomodulatory mechanisms. Regular consumption of these products has been associated with reduced risks of cardiovascular diseases, diabetes mellitus, obesity, cancer, osteoporosis, and neurodegenerative disorders [11]. Probiotics and prebiotics present in functional foods also help maintain healthy gut microbiota and improve nutrient absorption [38].

With increasing consumer awareness regarding preventive healthcare and healthy lifestyles, the demand for nutraceuticals and functional foods has grown rapidly worldwide. These products are increasingly recognized as important components of dietary management and complementary healthcare strategies [7].

6. Limitation of Nutraceuticals

Despite their growing popularity and potential health benefits, nutraceuticals are associated with several important limitations:

Limited Clinical Evidence

A significant number of nutraceutical products lack robust scientific validation through large-scale, randomized controlled trials. Most evidence is derived from in vitro or animal studies, which may not reliably translate to human outcomes.

Regulatory and Classification Challenges

Nutraceuticals occupy a grey area between foods and pharmaceuticals, leading to inconsistencies in regulatory frameworks, approval processes, and enforcement across different countries.

Risk of Toxicity and Overconsumption

Excessive intake of bioactive compounds, including fat-soluble vitamins and herbal extracts, may result in toxicity, adverse physiological effects, or nutrient imbalances when consumed without proper guidance.

Lack of Standardization and Quality Control

Variability in raw materials, extraction methods, and manufacturing processes often leads to inconsistencies in product composition, potency, and bioavailability, raising concerns about reliability and reproducibility.

Misleading Health Claims and Marketing Practices

Some nutraceuticals are marketed with exaggerated or unverified claims regarding disease prevention or treatment, which may mislead consumers and promote inappropriate usage.

Potential Drug–Nutrient Interactions

Certain nutraceuticals, particularly herbal supplements, can interact with prescription medications, altering pharmacokinetics and pharmacodynamics, thereby compromising safety and therapeutic outcomes.

Safety Concerns and Contamination Risks

Instances of contamination, adulteration, and presence of undeclared substances have been reported, largely due to inadequate quality assurance and monitoring mechanisms in some markets [1],[39],[40],[41],[42]

7. Future of Nutraceuticals

The future of nutraceuticals holds significant promise in the prevention and management of chronic diseases due to growing consumer awareness, advancements in food technology, and increasing scientific validation of bioactive compounds. Emerging research is focusing on personalized nutrition, novel delivery systems, and enhanced bioavailability to improve the therapeutic effectiveness of nutraceutical formulations. The integration of nutrigenomics and metabolomics is expected to enable targeted dietary interventions based on individual genetic profiles, thereby optimizing health outcomes. Furthermore, the development of functional foods fortified with bioactive ingredients may bridge the gap between nutrition and medicine. As clinical evidence continues to expand, nutraceuticals are likely to become an essential component of preventive healthcare strategies, complementing conventional therapies while promoting long-term wellness.

8. Conclusion

Nutraceuticals have emerged as a promising link between nutrition and medicine due to their significant role in health promotion, disease prevention, and supportive therapy. Bioactive compounds such as polyphenols, flavonoids, omega-3 fatty acids, probiotics, dietary fibres, vitamins, and plant-derived extracts possess antioxidant, anti-inflammatory, immunomodulatory, cardioprotective, anticancer, and neuroprotective properties that contribute to improved human health. Growing scientific evidence indicates that nutraceuticals may help in the prevention and management of chronic disorders including cardiovascular diseases, diabetes mellitus, obesity, cancer, and neurodegenerative diseases such as Alzheimer’s and Parkinson’s disease.

In addition to their therapeutic potential, nutraceuticals and functional foods are increasingly recognized as important components of preventive healthcare strategies because of their natural origin, relative safety, and ability to improve quality of life. However, challenges related to standardization, quality control, regulatory frameworks, clinical validation, and safety assessment still remain significant concerns. Therefore, extensive clinical research and strict regulatory monitoring are essential to establish the efficacy, safety, and appropriate therapeutic use of nutraceutical products.

With advancements in food science, biotechnology, nutrigenomics, and personalized nutrition, nutraceuticals are expected to play an increasingly important role in future healthcare systems. Their integration into modern dietary and therapeutic approaches may contribute substantially to the development of safer, cost-effective, and preventive healthcare solutions for global populations.

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