

The Impact of Nutraceuticals on Chronic Disease Prevention and Management: A Review

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Abstract—Nutraceuticals are considered bioactive food products that offer medical and health advantages, including disease prevention and management. Herbal medicine is becoming more and more necessary every day. Due to the current, competitive, and stressful environment, illnesses of all kinds are developing. Although allopathic treatments are available for the majority of diseases, they are not economical and come with a number of negative side effects. As a result, a lot of individuals are starting to utilize herbal products and modify their lifestyles. These products may process foods, dietary supplements, genetically modified foods, etc. Nutraceuticals have gained attention for their safety profile, medicinal efficacy, and nutritional advantages. Chronic ailments, such as cardiovascular disease, diabetes, cancer, and neurological problems, have a considerable impact on world health. The prevention and management of these diseases are essential for lowering morbidity, mortality, and healthcare expenditures. Nutraceuticals, or bioactive compounds derived from food and dietary supplements, have emerged as a promising strategy for reducing the risk of chronic disease. This review attempts to give a thorough summary of the available data regarding the role of nutraceuticals in managing and preventing chronic diseases. Nutraceuticals, including probiotics, omega-3 fatty acids, antioxidants, fortified foods, and polyphenols, have been shown to have anti-inflammatory, anti-oxidant, and anti-proliferative properties. These properties may help in the prevention and treatment of chronic illnesses. Overall, this review offers a thorough assessment of the existing data on the influence of nutraceuticals on chronic illness management, enlightening healthcare professionals, policymakers, and individuals on the potential role of nutraceuticals in preventing and treating chronic diseases.

Index Terms—Dietary supplements, Nutrient, Diseases, prevention probiotics.

I. INTRODUCTION

Any material regarded as food or a component of food that has health advantages beyond its typical nutritional value, such as illness prevention or health promotion, is referred to as a nutraceutical. Customers are choosing dietary supplements to enhance their health because of the negative impacts of medications. These products contain carbohydrates, lipids, proteins, vitamins, minerals, and other necessary nutrients. The term nutraceutical is encompassing nutrition and pharmaceutical and it was coined in 1989 by Dr. Stephen L. Defelice.[1]

The most common type of nutraceutical products are dietary supplements. A dietary supplement is a liquid or capsule version of nutrients found in foods and is taken as an additional supplement to the daily diet. Amino acids, vitamins, minerals, botanicals and herbs are all forms of dietary supplements. Amino acids help to build muscle and improve muscle function. Vitamin B6 and B12 along with folic acid plays an important role in prevention of cardiovascular disease. Vitamin D strengthens bones & prevents osteoporosis and reduces certain types of cancers. Minerals such as calcium also strengthen bones and helps in prevention of osteoporosis. Functional foods are another form of nutraceutical products. Instead of taking a dietary supplement, functional foods are enhanced with nutrients and eaten normally. The two categories of functional foods are processed food and fermented foods.[2]

Nutraceuticals are products, which other than nutrition are also used as medicine. A nutraceutical product may be defined as a substance, which has physiological benefit or provides protection against chronic disease. Nutraceuticals can be used to maintain the body's structure or function, prevent

chronic illnesses, prolong life, and promote health. Nowadays, nutraceuticals have received considerable interest due to potential nutritional, safety and therapeutic effects. Recent studies have shown promising results for these compounds in various complications.[3]

Chronic diseases, including type 2 diabetes mellitus (T2DM), cardiovascular disease (CVD) and inflammatory- based diseases such as rheumatoid arthritis, osteoarthritis and Crohn's disease, are life-long conditions that significantly impact on quality of life. Many of these conditions are becoming more common, especially those regarded as lifestyle illnesses (T2DM, CVD) and the risk factors that are linked to them (obesity, hyperglycemia, hypertension, and hypercholesterolemia). Currently, initial management strategies for these diseases include a combination of increased physical activity and dietary change aimed at ameliorating risk factors; pharmacological interventions are required as the condition progresses. When knowledge of dietary sources of nutrients and non-nutrients is limited and nutraceuticals offer a more convenient source, nutraceuticals with good safety profiles have grown in popularity as alternatives to reduce some of the risk factors and symptoms associated with these chronic conditions.[4]

This review aims to critically examine the current body of literature on the impact of nutraceuticals on health and disease prevention. By synthesizing findings from a diverse array of studies, we intend to provide a comprehensive overview of the potential benefits and limitations associated with the use of nutraceuticals. In order to do this, we will examine the ways in which nutraceuticals work, examine the clinical data that backs their application, and point out areas that need more research. Additionally, we will discuss considerations related to safety, regulatory frameworks, and the challenges of translating research findings into practical recommendations.

II. CATEGORY OF NUTRACEUTICALS

Wide variety of nutraceutical foods are available in the market which falls in the category of traditional foods and non-traditional foods.[5]

A. NON-TRADITIONAL NUTRACEUTICALS

Artificial foods made with biotechnology are known as non-traditional nutraceuticals. Bioactive components found in food samples are designed to create goods for human well-being. Scientists in agriculture have successfully developed methods to increase the nutritional value of specific crops. Research currently is being conducted to improve the nutritional quality of many other crops. They are arranged into fortified nutraceuticals and recombinant nutraceuticals.[6]

Fortified nutraceuticals

They are enriched with vitamins, minerals, usually at a range up to 100 percent of the Dietary intake for that nutrient. Fortified nutraceuticals are the food with agricultural breeding or with added nutrients. Some of the examples of fortified nutraceuticals are orange juice with calcium, cereals with added vitamins or minerals, flour with added folic acid, and milk with cholecalciferol commonly used for vitamin D deficiency.[7]

Recombinant Nutraceuticals

Biotechnology is used to produce probiotics and extract bioactive components using enzyme/fermentation and genetic engineering methods. Energy-providing foods, such as bread, alcohol, fermented starch, yogurt, cheese, vinegar, and others are produced with the help of biotechnology.[8]

B. TRADITIONAL FOODS

Under the category of traditional Nutraceuticals comes food in which no change to the food are made; It is simply natural, whole foods with new information about their potential health qualities. Apart from the consumer's perception, the meals themselves have not changed. Lycopene in tomatoes, omega-3 fatty acids in salmon, and saponins in soy are just a few examples of the natural components found in many fruits, vegetables, grains, fish, dairy, and meat products that provide advantages beyond basic nutrition. Even tea and chocolate have been noted in some studies to contain health-benefiting attributes.[9,10]

Probiotic Micro-organisms

Probiotics (for life) are live microorganisms that, when consumed with or without food, enhance the intestinal microbial balance and, as a result, the large intestine's health and functionality. The major sources

are the cultured dairy products such as natural cheese, yogurt, kefir and butter milk lactobacillus also in green foods such as wheat grain, spirulina and chlorella.

Lactobacillus acidophilus is one of the main components of the probiotic fighter among the more over 400 distinct bacteria that inhabit the human gastrointestinal system. The immune system is strengthened by it. Bacterial vaginosis and thrush are two vaginal illnesses that Lactobacillus acidophilus might lessen. Yogurt contains both Bifidobacteria and Streptococcus thermophilus, which helps cure rotavirus infection and prevent diarrhea in young children. Probiotics only have a temporary impact, and consistent daily use is required to improve health. Through altering the microflora, stopping pathogens from adhering to the intestinal epithelium, competing for nutrients required for pathogen survival, generating an antitoxin effect, and reversing some of the effects of infection on the intestinal epithelium, such as secretory changes and neutrophil migration, they have an antimicrobial effect. Probiotics can cure lactose intolerance by the production of the specific enzyme (β -galactosidase) that can hydrolyze the offending lactose into its component sugars. Examples are Yogurt is one of the best sources of probiotics, which are friendly bacteria that can improve your health. Kefir is a fermented probiotic milk drink.

Probiotics gaining importance against helicobacter pylori infection, colonic cancer, irritable bowel syndrome, pancreatitis, antibiotic induced diarrhea, Crohn's disease and pouchitis.[11]

Prebiotics

Prebiotics" are a more recent addition to our vocabulary and are substances which when consumed are not digested by us. Instead, they act as a nutrient source for the good probiotic bacteria. This encourages the probiotic bacteria to grow in a favorable environment, which in turn reduces the chances that harmful microorganisms may start to grow in our digestive tract. Example: Inulin is a prebiotic that has been widely used in processed foods. Essentially, it is a type of fiber obtained from the roots of plants such as chicory, Jerusalem artichoke, and even dandelions.[12]

Chemical Constituents

Nutrients: Nutrients are vitamins, minerals, amino acids, and fatty acids with established nutritional

functions. Most vegetables, wholegrain cereals, dairy products, fruits, and animal products such as meat, poultry, contain vitamins and help cure heart diseases, stroke, cataracts, osteoporosis, diabetes, and cancer. Minerals found in the plant, animal, and dairy products are useful in osteoporosis, anemia and build strong bones, teeth, muscles, improve nerve impulses and heart rhythm. Flaxseed and salmon contain fatty acids omega-3 PUFAS, and are potent controllers of the of the inflammatory processes, maintenance of brain function, and reduce cholesterol deposition.

Herbals: Nutraceuticals along with herbs had an excellent impact on prevention of various chronic diseases to make life better. Salicin present in the willow bark (*Salix nigra*) had been proved for anti-inflammatory, analgesic, antipyretic, astringent, and antiarthritic response clinically.

Peppermint (*Mentha piperita*) contains various terpenoids especially menthol, a bioactive constituent, and cures cold and flu. Tannin contents of lavender (*Lavandula angustifolia*) help releasing stress and blood pressure and are useful for lung disorders such as asthma.[13]

Phytochemicals: Phytochemicals are one class of nutraceuticals. Based on their phytochemical characteristics, they are categorized by the chemical name assigned to them. For instance, carotenoids (isoprenoids), which are present in a variety of fruits, vegetables, and egg yolks, have anti-carcinogenic properties, increase natural killer immune cells, and shield the cornea from ultraviolet radiation. Non-carotenoids found in grains, palm oil, and legumes (such soybeans and chickpeas) lower cholesterol and prevent cancer. Berries, fruits, vegetables, and legumes contain flavonoid polyphenolics, which are powerful antioxidants and phytoestrogens that protect prostate and breast cancer and manage diabetes. Dark grapes, raisins, berries, and peanuts all contain non-flavonoid polyphenolics. Turmeric roots lower cholesterol and have potent anti-inflammatory, anti-oxidant, and anti-clotting properties. Blueberries, tomatoes, and bell peppers contain phenolic acids, which have antioxidant properties and lessen the mutagenicity of polycyclic aromatic hydrocarbons. One of the classical examples is curcumin (turmeric), used as phytochemicals in most of the kitchen.[14]

Nutraceutical Enzymes

The cell produces enzymes, which have a proteinous structure and function as biocatalysts. It speeds up life and lowers metabolic rate. Enzyme supplements may be used to treat GERD (gastroesophageal reflux disease), constipation, diarrhea, or ulcerative colitis, among other GIT-related conditions. For those with diabetes, the enzyme could be a better choice. Enzyme treatments are now utilized to treat a number of uncommon disorders, including Pompe disease, Fabry disease, Hunter syndrome, and Gaucher disease. Although enzymes are produced by their own cells, microbial sources are preferred more over plant and animal sources as they are more economical.[15]

III. BURDEN OF CHRONIC DISEASES AND LIMITATIONS OF CONVENTIONAL THERAPIES

Chronic diseases exact significant socioeconomic costs, with CVDs alone costing the global economy an estimated \$1.5 trillion annually [16]. Conventional therapies, including pharmacotherapy and lifestyle modifications, often face challenges such as adverse effects, non-compliance, and high costs [17]. For instance, metformin, a first-line drug for type 2 diabetes (T2DM), may cause gastrointestinal distress, while statins for hyperlipidemia are associated with myopathy risks [18]. These limitations highlight the need for adjunctive strategies, including nutraceuticals, to enhance therapeutic outcomes with minimal toxicity.

Chronic Disease Overview

Chronic diseases are non-communicable conditions characterized by prolonged duration and slow progression. Major categories include:

- Cardiovascular diseases (CVD): Hypertension, atherosclerosis, coronary artery disease.
- Metabolic disorders: Type 2 diabetes (T2D), obesity.
- Neurodegenerative diseases: Alzheimer's, Parkinson's.
- Autoimmune and inflammatory conditions: Rheumatoid arthritis.
- Cancers: Colorectal, breast, prostate.

IV. NUTRACEUTICALS IN CARDIOVASCULAR DISEASE PREVENTION AND MANAGEMENT

A. Omega-3 Fatty Acids

Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), derived from fish oil, reduce triglyceride levels by inhibiting peroxisome proliferator-activated receptor (PPAR) activation [19]. A meta-analysis of 29 trials found that omega-3 supplementation lowered the risk of major cardiovascular events by 8% [20]. However, their efficacy in CVD prevention remains debated due to inconsistent study designs [21].

B. Plant Sterols and Stanols

Dietary phytosterols, found in fortified dairy products and plant oils, competitively inhibit cholesterol absorption in the intestine. Clinical trials have reported a 10–15% reduction in LDL cholesterol levels with daily supplementation of 2 g phytosterols [22].

C. Garlic and Flavonoids

Garlic compounds (e.g., allicin) exhibit antihypertensive and antiplatelet properties, while flavonoids in berries and dark chocolate improve endothelial function via nitric oxide (NO) synthesis [23]. A randomized controlled trial (RCT) demonstrated that garlic supplementation reduced systolic blood pressure by 5.1 mmHg in hyperlipidemic individuals [24]

V. NUTRACEUTICALS IN DIABETES MELLITUS

T2DM and type 1 diabetes (T1DM) are characterized by insulin resistance and β -cell dysfunction, respectively. Nutraceuticals modulate glucose metabolism through mechanisms such as enhancing insulin sensitivity and inhibiting α -glucosidase [25].

A. Berberine and Chromium

Berberine, an alkaloid from *Berberis* species, activates adenosine monophosphate-activated protein kinase (AMPK), improving glucose uptake in skeletal muscle [26]. A meta-analysis of 27 RCTs found that berberine reduced HbA1c levels by 0.87% in T2DM patients [27]. Chromium supplementation enhances

insulin receptor activity, though clinical efficacy remains inconclusive [28]

B. Cinnamon and Ginseng

Cinnamon polyphenols mimic insulin action and reduce hepatic gluconeogenesis. A meta-analysis of 12 studies reported a 0.99% decrease in fasting blood glucose after 12 weeks of cinnamon supplementation [29]. While ginseng (*Panax ginseng*) improves glycemic control, its impact on long-term complications requires further investigation [30].

VI. NUTRACEUTICALS IN CANCER PREVENTION AND MANAGEMENT

Cancer arises from genetic and epigenetic alterations driven by oxidative stress and chronic inflammation. Nutraceuticals exhibit anti-carcinogenic properties through antioxidant, anti-inflammatory, and anti-angiogenic mechanisms [31].

A. Curcumin and Sulforaphane

Curcumin, a polyphenol from turmeric, inhibits nuclear factor-kappa B (NF- κ B) signaling and tumor cell proliferation. Preclinical studies show its efficacy in colon, breast, and prostate cancers, though poor bioavailability limits clinical application [32]. Sulforaphane, found in cruciferous vegetables, induces phase II detoxification enzymes and apoptosis [33].

B. Resveratrol and Green Tea Catechins

Resveratrol (in grapes and red wine) activates sirtuins, promoting genomic stability and autophagy [34]. Green tea epigallocatechin gallate (EGCG) suppresses COX-2 expression and angiogenesis [35]. Despite promising *in vitro* evidence, human trials are limited by low potency and variability in absorption [36].

VII. NUTRACEUTICALS IN NEURODEGENERATIVE DISORDERS

Neurodegenerative diseases, such as Alzheimer's and Parkinson's, are linked to oxidative stress, mitochondrial dysfunction, and neuroinflammation. Nutraceuticals with neuroprotective potential include:

A. Omega-3 Fatty Acids and *Bacopa Monnieri*

DHA, a key structural component of neuronal membranes, enhances synaptic plasticity and reduces

amyloid-beta accumulation in Alzheimer's models [37]. *Bacopa monnieri* (Brahmi), an Ayurvedic herb, improves cognitive function by modulating acetylcholine levels [38].

B. Ginkgo Biloba and Probiotics

Ginkgo biloba extracts ameliorate cerebral blood flow and free radical damage, with mixed evidence for Alzheimer's efficacy [39]. Probiotics may influence the gut-brain axis, potentially slowing Parkinson's progression [40]

VIII. OTHER CHRONIC DISEASES

Autoimmune Disorders: Probiotics modulate gut immunity in rheumatoid arthritis and inflammatory bowel disease [41].

Fibromyalgia: Magnesium and vitamin D supplementation alleviate fatigue and pain symptoms [42].

CONFLICT OF INTEREST

The authors have no conflicts of interest

IX. CONCLUSION

The food and pharmaceutical sectors make extensive use of nutraceuticals. The majority of nutraceuticals, such as gamma terpenes, beta carotene, curcumins, limonene, eugenol, pinene, safranal, geraniol, aloine, caryophyllene, lycopene, and silymarin, are derived from minerals, animals, or vegetables. Pharmaceuticals are rapidly being replaced by nutraceuticals in the treatment and prevention of both acute and long-term health issues. As medicinal agents with both curative and preventative qualities, nutraceuticals have a lot of potential to grow in the future. Health experts, nutritionists, and toxicologists should strategically collaborate to fully study the potential of nutraceuticals, even if they appear to be a promising method for promoting health and preventing numerous diseases. Consumer perception of the connection between diet and illness will determine future demand for nutraceuticals. Health professionals, nutritionists, and regulatory toxicologists should strategically collaborate to plan appropriate regulations to provide the greatest health and therapeutic benefit to humanity, even though nutraceuticals hold great promise in promoting human health and preventing disease. It is crucial that the well-established health advantages are caused by

the nutrients included in a variety of meals, fruits, and vegetables.

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