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# INNOVATIVE FOOD PRODUCTS - NUTRACEUTICALS AND FUNCTIONAL FOODS

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*Review Based Book Chapter*

**NUTRACEUTICALS AND DISEASE PREVENTION**

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**REVIEW BASED BOOK CHAPTER**

# NUTRACEUTICALS AND DISEASE PREVENTION

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## Abstract

Nutraceuticals, a fusion of "nutrition" and "pharmaceuticals," refer to products derived from food sources that offer health benefits beyond basic nutrition. They encompass dietary supplements, functional foods, medical foods, and pharmaceuticals, aiming to promote general well-being, prevent chronic diseases, and manage various health conditions. The expanding importance of nutraceuticals in illness prevention and health promotion is examined in this chapter. The potential of nutraceuticals—a broad category that includes dietary supplements, functional foods, and bioactive compounds—to prevent chronic illnesses and enhance general health is becoming more widely acknowledged. The chapter explores the scientific underpinnings of nutraceuticals; therapeutic benefits, emphasizing how they might alter biological pathways linked to oxidative stress, inflammation, and metabolic abnormalities. The impact of several nutraceuticals, including, minerals, vitamins, polyphenols, antioxidants, and omega-3 fatty acids, in lowering the risk of diseases like cancer, diabetes, cardiovascular disease, and neurodegenerative disorders is highlighted in this chapter through a review of recent research. It also discusses the difficulties of standardizing, regulating, and using these substances in clinical settings, highlighting the necessity of more research to validate their safety and effectiveness. This chapter concludes by highlighting the potential of nutraceuticals as a preventative measure in contemporary healthcare and providing information on how to incorporate them into dietary plans for illness prevention.

**Keywords**
Functional Foods, Dietary Supplements, Disease Prevention, Neurodegenerative Disorders, Metabolic Disorders

## 1. Introduction

Nutraceuticals are special preparations made with an aim to fulfill dietary requirements and often provide preventive therapy. These are the preparation of nutrients which helps disease prevention and treatment along with a supplementary diet. The term nutraceutical is derived from two terms "nutrition" and "pharmaceutical". These are

bioactive compounds derived from food that offer extra health benefits beyond basic nutrition, between food and medicine [1]. They are dietary supplements, functional foods, and botanicals that offer therapeutic benefits or prevention of disease. These compounds, such as vitamins, minerals, fatty acids, antioxidants, and phytochemicals from plants, sustain many body functions, such as immune function, cardiovascular function, cognitive function, and metabolic function [2]. Nutraceuticals are used in the management and prevention of long-term diseases including heart disease, diabetes, cancer, and neurodegenerative disorders. Nutraceuticals exist in a variety of formats including fortified food, supplements, or extracts but their effectiveness will depend on optimal dosing, purity, and patient health needs. Even though, nutraceuticals can be utilized to support a healthy way of life, they must not be utilized instead of conventional medical treatment and must be utilized with caution to avoid drug interactions or side effects [3]. Nutrition science has progressively developed from the eradication of nutritional deficiencies and management of chronic diseases. Contemporary literature has emphasized the need for redefining the definition of nutraceuticals considering their efficacy, safety and toxicity. Nourishing substances that are ingested, imbibed or otherwise introduced in the body to maintain one alive, aid in energy production, and sustain body development constitute food products. Nutrient isolation of food products has been achieved effectively and utilized today [4].

The history of nutraceuticals is traced back to ancient times, as food and herbs have been used for their medicinal values. Nature products such as ginseng and garlic were known to the ancient Greeks and Egyptians and to traditional Chinese medicine for their medicinal properties. In the Middle Ages, herbal medicine was advanced, and renaissance scientific studies laid the foundation for pharmacognosy. In the 20th century, the discovery of the vitamins and the function of disease-fighting elaborated further on food and health connection. The naming of the nutraceutical was established in 1989 by Dr. Stephen DeFelice. The industry developed strongly with an increase in diet foods and functional supplements during the 1990s. Nutraceuticals blend age-old, centuries-old tradition with state-of-the-art science to yield a final element of preventive medicine and overall well-being [5].

## 2. Types of Nutraceuticals

Nutraceuticals can be classified as functional foods are the normal foods with added nutrients or bioactive compounds, such as fortified breakfast cereals, probiotic milk, or omega-3-enriched foods [6]. Dietary supplements such as vitamin, mineral, herb, amino acid, or fatty acid concentrated products that are available, such as multivitamin, fish oil, or turmeric capsules. Herbal products like ginseng, garlic, or turmeric consumed for their pharmaceutical action. Probiotics and prebiotics including fiber and live healthy bacteria that promotes intestinal health. Animal-derived nutraceuticals extracted from bees, collagen, and fish oil that provide heart, skin, and joint health benefits. Marine-derived nutraceuticals including omega-3 concentrates from fish or algae, and krill oil to support brain and heart health. Functional beverages included healthy ingredients in energy drinks, sport drinks, and herbal teas. Cosmeceuticals are the products which contain pharmaceutical components with cosmetic importance i.e. wrinkle cream or vitamins for hair growth.

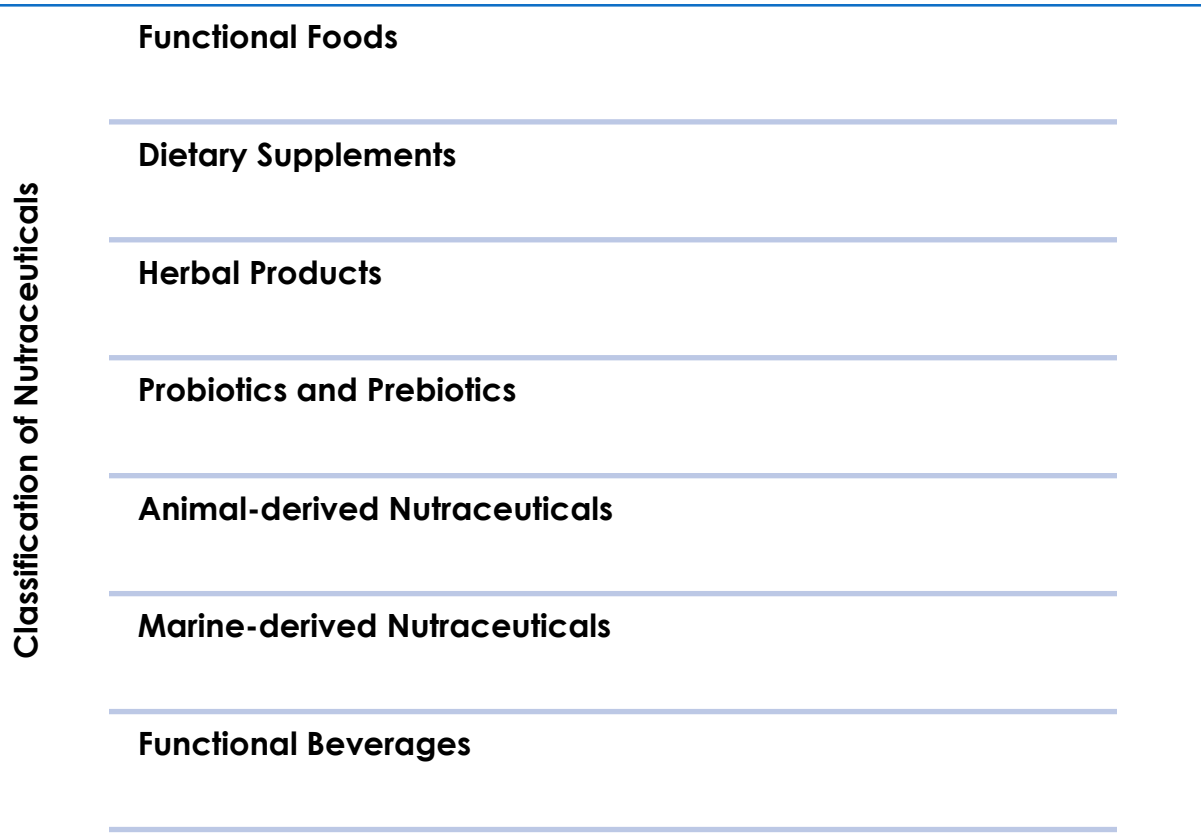


**Figure 1**. Classification of Nutraceuticals

## 3. Potential Health Benefits of Nutraceuticals

Nutraceuticals may play a very important role in preventing numerous chronic diseases through maintaining good overall health and eliminating certain risk factors [7]. Following are some diseases and conditions for which nutraceuticals may prevent CVS disorders, omega-3 fatty acids (fish oil or flaxseed) reduce triglycerides, lower blood pressure, and reduce inflammation, lowering the risk of heart disease and stroke. Plant sterols reduce LDL (bad) cholesterol, Coenzyme Q10 (CoQ10) supports cardiovascular health and reduces oxidative stress [8].

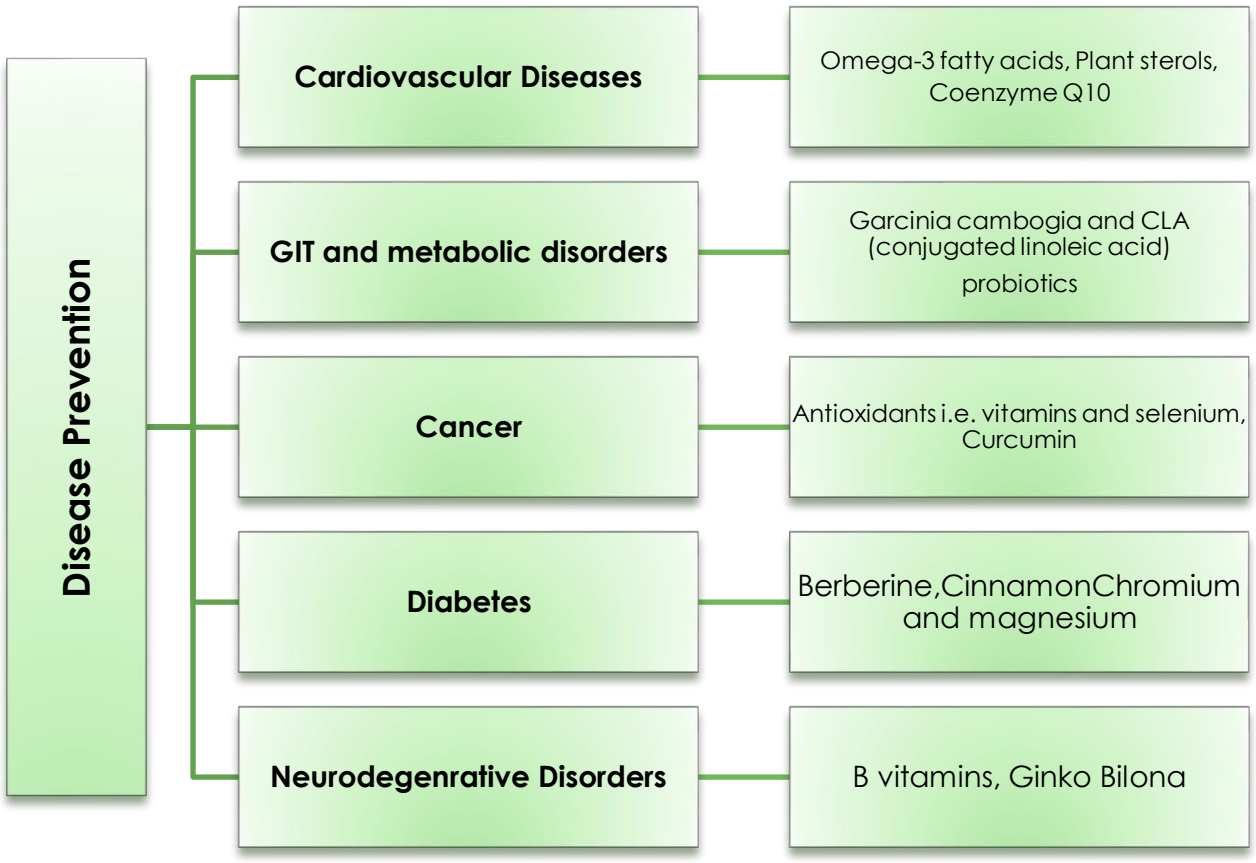


**Figure 2.** Disease Prevention from Various Types of Nutraceuticals

Chromium and magnesium improve insulin sensitivity and glucose control. Berberine reduces blood sugar and improves insulin action. Cinnamon extract can normalize blood sugar and improve insulin sensitivity [9]. Nutraceuticals also pay significant contribution in preventing cancers i.e. Antioxidants vitamin C, vitamin E, and selenium

inhibit free radicals that harm DNA and contribute to cancer formation. Curcumin (turmeric) has anti-inflammatory and anticancer activity that inhibits cancer cell proliferation. Flavonoids (fruits and vegetables) add to protection from oxidative damage related to cancer [10]. Nutraceuticals also helps improving bone density and osteoporosis, calcium and vitamin D support bone density and strength, magnesium plays a role in mineralization of bone and protects against osteoporosis [11]. DHA and EPA omega-3 fatty acids sustain brain function and are protective against cognitive decline. B vitamins (especially B6, B9, and B12) avoid accumulation of homocysteine, which is a risk for cognitive decline. Ginkgo biloba improves memory and shield against Alzheimer's [12]. Omega-3 fatty acids have anti-inflammatory action, reducing joint pain and inflammation. Turmeric (curcumin) and ginger are both known to have anti-inflammatory activity in alleviating symptoms of arthritis [13]. Green tea extract (high in catechins) may have the ability to increase fat oxidation and lead to weight loss. Garcinia cambogia and CLA (conjugated linoleic acid) may have the ability to reduce body fat and improve metabolic function [14]. Probiotics ensure a balanced gut microbiome, supporting digestion and preventing conditions such as irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), and constipation. Prebiotics stimulate the growth of friendly gut bacteria, enhancing digestive health [15]. Collagen supplements enhance skin elasticity and minimize wrinkles. Vitamin C and vitamin E facilitate skin repair, minimize sun damage, and possess antioxidant properties to protect skin cells from aging. Vitamin C, vitamin D, and zinc enhance immune function, preventing infection and autoimmune disease. Probiotics promote a healthy gut microbiome that is essential to immune function [16]. Stress and mood enhancement is an also a key role of nutraceuticals like ashwagandha known as an adaptogen, ashwagandha may help reduce stress, anxiety, and depression by balancing cortisol levels and supporting the body's stress response. St. John's Wort often used to manage mild to moderate depression, St. John's Wort may help boost mood and alleviate symptoms of depression [17]. Milk thistle known for its active compound silymarin, milk thistle has liver-protective properties and is commonly used to detoxify and support liver function [18].

**Table 1.** Summarizing the Potential Health Benefits of Various Nutraceuticals

| Nutraceutical | Health Benefits | Examples/Source | Reference |
|---|---|---|---|
| **Immune System Support** | Boosts immunity, protects against infections | Vitamin C, Zinc, Echinacea, Probiotics | [19] |
| **Anti-inflammatory Effects** | Reduces inflammation, supports joint and heart health | Omega-3 Fatty Acids, Curcumin (Turmeric) | [5] |
| **Cardiovascular Health** | Improves heart function, lowers cholesterol, and regulates blood pressure | CoQ10, Garlic Extract, Flavonoids (Fruits) | [5] |
| **Brain and Cognitive Function** | Enhances memory, reduces cognitive decline, and improves mental clarity | Ginkgo Biloba, Omega-3 (DHA & EPA), Phosphatidylserine | [10] |
| **Digestive Health** | Improves gut health, supports digestion, and reduces symptoms of IBS | Probiotics, Fiber (Psyllium) | [15] |
| **Weight Management** | Aids in fat loss, boosts metabolism, promotes lean body mass | Green Tea Extract, Conjugated Linoleic Acid (CLA) | [5, 14] |
| **Antioxidant & Anti-aging** | Fights oxidative stress, reduces aging signs, and protects against age-related diseases | Resveratrol, Vitamin E | [5] |
| **Bone Health** | Maintains bone density, supports bone mineralization and strength | Calcium, Vitamin D, Magnesium | [11] |

## 4. Role of Nutraceuticals in Preventing Various Diseases

Now-a-days, there is growing interest in the role of nutraceuticals to enhance health and as remedies to certain diseases. Nutraceuticals are derived with the combination of "nutrition" and "pharmaceuticals" which means bioactive compounds that exist in foods and have potential health or medical benefits in addition to the nutritional

benefits. These substances include vitamins, minerals, antioxidants, polyphenols, probiotics as well as herbs which have been clinically proven to boost human immunities, reduce inflammation and modulate metabolism [20].

Due to the increased incidence of chronic and infectious diseases it is necessary to search for safer ways of treatment instead of conventional chemotherapy and pharmacological effects. Therefore, nutraceuticals provide natural solutions to diseases through enhancing body functions without exposing the patients to other serious side effects of synthetically manufactured drugs. Hence, the utilization of nutraceuticals in preventive medicine has been emphasized, due to their proven benefits by science. They can also lower the risk of viral diseases, allergy, inflammatory response, and metabolic diseases which are prevalent in the modern society [21].

It is possible to build up the human body immunity against diseases through the consumption of functional foods and nutraceuticals. Moreover, systematic diseases, including diabetes, obesity and cardiovascular diseases became major threats to people's health, and nutraceuticals are considered as complementary remedies to traditional medications. Here, an attempt has been made to understand the place of nutraceuticals in the prophylaxis of viral diseases, allergy, inflammation, and metabolic disorders [22].

A benefit accrued from the intake of nutraceuticals is that it cures disease instead of masking symptoms as it deals with the origin of diseases. Most diseases are of a chronic nature, and many of them have their roots in, for instance, oxidative stress, chronic inflammation, compromised immune response, and metabolic disturbances. For this reason, including nutrients or food substances containing compounds that facilitate these processes in nutraceuticals maintains a healthy balance in the body for a decreased chance of diseases [2].

The relation between nutrition and the well-being of an individual has gained the center stage thus creating a great market for nutraceutical products across the developed as well as developing nations. There's awareness on what people take every day thus leading to consumption of foods and supplements that has more than nutritional value. Consumers are being provided with functional foods which contain

bioactive compounds, extracts of herbal products and the dietary supplements thus introducing nutraceuticals to the consumers' meal plans [23].

In the subsequent sections, the discussion has been made regarding the importance of nutraceuticals as an antiviral agent, as an antiallergic, as an anti-inflammatory, and as an anti-metabolic disease agent. It is to understand the workings of such mechanisms and the value that attaches them in enhancing health and human wellbeing [1].

### 4.1. Viral Diseases

In this case, viral infections still pose a significant threat to the global health of people with contagious diseases like Influenza, COVID-19, and other respiratory infections affect millions of people every year. These infections can be as simple as the flu to as severe as pneumonia and viral hepatitis and other severe diseases. This is so especially because viruses can mutate thus causing the long-term pharmaceutical solutions to be difficult, hence increased importance of preventive measures. As a result, immune systems are the initial line of defense against viral pathogens, and compounds that boost the immune reactions collectively called nutraceuticals are significantly vital constituents of disease precaution procedures [24].

Some of the most popular vitamins that are widely suggested to boost the human immune system include vitamin C and vitamin D. Vitamin C has antiviral effects as it boosts the production and activity of the body's white blood cells – the cells charge with the responsibility of detecting the presence of virus in the body. Also, Vitamin C work against inflammation and oxidative stress, which are other factors that make severe complications in viral infections. Vitamin D that is also called the sunshine vitamin is responsible for the modulation of T cells as well as macrophages that participate in antiviral responses. It looks like excessive intake of vitamin D is associated with increased prevalence of respiratory infections; thereby, beneficial to persons with poor levels of vitamin D [19].

Zinc is a trace element that can be involved in immune signaling and has an effect of peracute and chronic viral disease to decrease its severity and duration. It reduces the chances of viruses getting into host cells, stops the replication process of a virus, and promotes the effectiveness of immune system cells. Most of the reports suggest that Zinc taken as a supplement can helpful in decreasing the frequency of R.T.I, and in addition

it reduces the time taken to cure infections like the flu. Zinc has been therefore considered as an effective remedy as it has antiviral capabilities, which is why it is encouraged in the consumption of immune-booster nutraceutical products [22].

Polyphenols and flavonoids are natural constituents known to possess antiviral activity against various viruses. Such bioactive compounds present in the list of fruits, vegetables, and plant-derived food have a positive influence on antioxidant and anti-inflammatory properties. It is obvious that echinacea, elderberry and garlic are some of the herbs that have been widely used to fight viral infections. This herb is efficient in modulating the immune system and passions and increases the white blood cells number in the body and the capability of fighting infection. In this article, the author was able to explain how elderberry works to prevent virus to enter the host cell thus lower the chances of getting infected when taken early when the symptom starts to appear. Garlic has bioactive compounds such as allicins that possess antimicrobial substances that may combat human viruses with efficacy [25].

Moreover, omega-3 fatty acids, which present in fish oil and flaxseeds, moderates immune and inflammations, which are adverse to the outcome of viral illnesses. This is because inflammation is likely to occur in cases of chronic viral illness, and managing inflammation decreases the risk of developing conditions like ARDS. Curcumin that is found in turmeric also has the anti-inflammatory properties that may affect the body's immune response and suppress the replication of the virus [26].

The substances enriched with bioactive compounds, augmented through proper diet or foods supplements, help in improving the immune system and decrease the chances of viral diseases. Nutraceuticals therefore help prevent viral diseases hence serve as an adjunct to orthodox medicines which have many side effects on the human body. It is only now that the possibility of using nutraceuticals in ASH and antiviral defense is being explored, and thus the subject is an important area of public health interest and disease prevention [27].

### 4.2. Allergies

Allergies are a condition whereby the body's immune system acts abnormally and reacts to harmless matters like pollen, dust, animal fur, fungus, and some types of food. These allergens are harmless substances which if the immune system perceives them as

a threat, it deploys histamine and other irritant substances. This results to characteristic symptoms like sneezing, nasal issues such as a congested nose, an itching sensation, skin rashes, and breathing problems. Anaphylaxis, which is a life-threatening form of allergy, tends to have severe effects on human beings depending on the cause of the allergy. The symptoms involving allergies can be treated with antihistamines and other drugs, but dietary products may be used to help control allergic reactions and restore immunity [28].

Quercetin for instance is a flavonoid which is an excellent antihistamine found in onions, apples, berries – and citrus fruits. Among the herbs that can alleviate allergic reactions to histamine there are those that directly act as histamine antagonists and those that have indirect antihistamine effects. This helps in stabilizing mast cells so that they cannot release histamine, which is the leading compound to allergic reactions. Specifically, quercetin has been found to have some benefit in improving such conditions as seasonal allergies and asthma due to the regulation of inflammation. Bromelain which is an enzyme obtained from pineapples is also a useful compound in the body since it has anti-inflammatory effects and helps in the treatment of inflammation of nasal passages that result from allergy [29].

Probiotics are one of the essential factors that contribute towards the health of the colon which is directly associated with the immune system. A healthy gut flora ensures immunological tolerance minimalizes and does not allow the immune system to send antibodies against substances that do not pose harm to the organism. Research has indicated that *Lactobacillus* and *Bifidobacterium* tend to alleviate the allergic symptoms mainly among those with hay fever and eczema. Thus, by improving the condition of the guts, the effect of probiotics positively influences the body's immunity and reduces the sensitivity to allergens [30].

Vitamin C and polyphenols have an impact on allergic inflammation since oxidative stress affects cells and tissues. It is also noted that vitamin C helps fight the allergy by lowering histamine concentration in the blood stream. Anti-inflammatory compounds also present in green tea, berries, dark chocolate also modulates allergy responses in body [31].

Omega-3 fatty acids that are present in fatty fishes, flax seeds as well as walnut help decrease inflammation in allergic diseases such as asthma and eczema. Omega-3 reduces the activity of the immune cells and lowers the levels of cytokines – inflammatory molecules that may lead to worsening of the allergenic crisis and decreased respiratory performance [20].

Therefore, these nutraceuticals are beneficial as they help the allergy affected persons develop better immune systems that can handle the allergens. Unlike other anti-allergic medicine that are likely to lead to side effects such as dizziness, sleepiness and other related effects, nutraceuticals are a natural and long-term measure of dealing with allergic diseases. Day by day, knowledge about nutraceutical products as an effective antiallergic agent with hope for those who are interested on natural products is widening.

### 4.3. Inflammatory Disorders

Inflammation can become a chronic disease and one that is related to many diseases such as arthritis, asthma, and autoimmune diseases. Nutraceuticals also have the potential of being anti-inflammatory, thus being of value in decreasing inflammation and managing both the conditions that result from it. Curcumin is its active constituent derived from turmeric which has anti-inflammatory properties because it prevents certain activities which trigger inflammation and thus reduces pain. One such compound is resveratrol found in grapes and berries makes every effort to shield the cells from any harm that free radicals meaning chronic inflammation may cause [20].

The epidermal growth factor feeder-size is also reduced and omega-3 fatty acids available in fish oil decrease inflammation through cytokines. Glucosamine and chondroitin sulfate are two nutritional supplements widely used for joint relieve and treatment of osteoarthritis. Vitamin E and selenium also help in offering protection to the carbon body structure against the cause of oxidative stress and prevent inflammation-related damage. They are useful in the treatment of inflammatory diseases and enhancing health standards and wellbeing [5].

Glucosamine and chondroitin sulfate help in improving joint health and joint pain related to osteoarthritis as they were said to have the ability to repair damaged cartilage and decrease inflammation or swelling of the joint. As well, there are such

elements as vitamin E and selenium that can protect cells from oxidative stress, hence, refraining the heart from inflammation related hurt. It also has the effect of lowering the inflammatory markers and helps in giving relief in autoimmune diseases, due to the presence of catechins in the green tea extract. Thus, to help consumers suffering from inflammatory diseases or condition, it is possible through medication via functional food or supplements containing the bioactive compounds mentioned earlier. Apart from playing a role of reducing inflammation, nutraceuticals also play the role of preventing further stress on tissues and diseases that might be caused [32].

### 4.4. Metabolic Disorders

Pathologies of metabolism such as diabetes, obesity and cardiovascular diseases have become frequent due to inappropriate diet and lack of physical activities. It must be noted that these conditions can be managed through nutraceuticals on basis of glycemic control, lipid panel and weight management. Chromium, alpha-lipoic acid, and berberine are classified to improves insulin and glucose metabolism and hence can be used by diabetic patients. Psyllium and oat beta-glucans help in reduction of cholesterol levels and enhance cardiovascular health. The plant sterols and omega-3 fatty acid help in the prevention of the bad cholesterol also known as LDL while at the same time promoting the good cholesterol, the HDL [5].

To manage weight, green tea extract, congealed linoleic acid, and fibers are useful in the digestion of fats and in appetite regulation which are valuable tools in preventing complications arising out of obesity. Therefore, it can be concluded that addition of these nutraceuticals to their diets would help metabolic disorders subjects to minimize other related health complications [15].

Psyllium and oat beta-glucans are a dietary fiber that has many health benefits on cardiac health through the regulation of cholesterol levels and additionally acts as a prebiotic promoting optimal digestion. Carbohydrate strands also known as fibers help in minimizing level of LDLP (low density lipoprotein) cholesterol on the other hand enhancing level of HDLP (high density lipoprotein) cholesterol decreasing chances of atherosclerosis and heart diseases. Plant steryl esters which can also be obtained from nuts seeds and vegetable oils, lower cholesterol levels by inhibiting cholesterol reabsorption in the small intestine [33].

In weight loss, green tea extract has been also investigated for its impact on fat burning and appetite suppressant effects organs TW, CLA and fiber supplements. Catechins and caffeine present in green tea extract also help in increasing basal metabolic rate and the later enhances fatty oxidation rate for weight reduction. CLA enables the body to have a slimmer look by assisting the loss of body fat particularly the abdominal kind without the loss of lean body mass; it is therefore appropriate for any person with a desire to have a better shape. They also create fullness so that it is easy to avoid over indulgence, thus cutting down on the number of calories consumed [34].

Consuming the mentioned nutraceuticals in their daily diet will enhance an individual's capacity to manage metabolic diseases and thus, the likelihood of other related conditions including hypertension, cardiovascular disease and type-2 diabetes. It is the plausible therefore, that this study re-affirms that dietary intervention, physical activity and nutraceutical intervention, all factors that work synergistically will bring forth a vast improvement on metabolism health [5].

### 4.5. Cancer

Cancer is a complex disease characterized by uncontrolled cell growth, and nutraceuticals play a role in its prevention by modulating oxidative stress, inflammation, apoptosis, and gene expression. Curcumin, one of the most extensively studied nutraceuticals, has been shown to induce apoptosis (programmed cell death), inhibit the nuclear factor-kappa B (NF-kB) inflammatory pathway, and suppress tumor growth. Resveratrol, found in red grapes, wine, and berries, influences gene expression, inhibits angiogenesis (the formation of new blood vessels in tumors), and triggers apoptosis in cancer cells. Sulforaphane, a bioactive compound in cruciferous vegetables like broccoli, enhances the detoxification of carcinogens and promotes the death of malignant cells [3].

Green tea is rich in epigallocatechin gallate (EGCG), which inhibits cancer cell proliferation, reduces oxidative stress, and prevents DNA damage. Lycopene, a powerful antioxidant found in tomatoes and watermelon, has been associated with a reduced risk of prostate cancer by lowering oxidative stress and inhibiting tumor growth. Additionally, omega-3 fatty acids, known for their strong anti-inflammatory

properties, have been shown to suppress tumor progression and metastasis, making them valuable in cancer prevention strategies.

### 4.6. Hypertension

Hypertension is one of the causes of cardiovascular disease, and these nutraceuticals play their vital role in the management of hypertension by enhancing the elasticity of the blood vessel walls and thereby decreasing the stiffness of arteries. There are omega-3 fatty acids found in fish oil and flaxseed which has been proved to have properties such as reducing inflammation, enhance endothelial function and decreased blood pressure levels. Other beneficial compound includes CoQ10; is also involved in antioxidant and energy producing works in the mitochondria; also helps in the release of NO, which causes dilation of blood vessels and therefore better circulation [1].

Catechins, found in green tea, flavonoids found in dark chocolate and berries, sabrosol, brings positive effects on endothelial mechanics and has anti-oxidative effects, which helps in better blood vessels health. One of the most important minerals in our body, magnesium assists the patients by acting like a natural calcium blocker so as to make arteries dilation and reducing the blood pressure. L-arginine which is an antecedent of NO, also enhances the dilation process for increased blood circulation and decreased vascular tone. All the above nutraceuticals are useful in managing hypertension thus lowering the risks of heart diseases and stroke.

### 4.7. Diabetes Mellitus

Diabetes mellitus is a metabolic disorder, which results from the body's inability to produce enough insulin or the tissues refusing to accept the insulin that is produced. Nutraceuticals have positive effects on glucose control through promoting both insulin sensitivity and decreasing the oxidative stress and carbohydrate digestion and absorption rate. The use of cinnamon has been established to enhance insulin receptor sensitivity which results to increased glucose uptake and low fasting blood glucose level.

Berberine is an active compound derived from plants and has the capacity to straighten the glycolysis pathway by increasing AMPK or the insulin sensitive enzyme which helps to reduce blood glucose level. Alpha-lipoic acid (ALA), an antioxidant,

works to combat the oxidation process and enhanced the glucose transport in the sensitive tissues to insulin. The constituent of curcumin in turmeric works as an anti-inflammatory agent that helps to tackle the problem of insulin resistance [2].

Also, the food also contains soluble fiber which reduces post-meal glycemic index because fenugreek seeds delay release of glucose into the bloodstream. Chromium picolinate as a trace mineral is useful in the regulation of insulin activity, stimulation of glucose uses and control of insulin tolerance. The benefits of the below nutraceuticals include the improvement of blood sugar levels with regard to diabetes and the prevention of complications that may be associated with the disease.

**Table 2.** Nutraceuticals Source and Mechanism of Action

| Key Role | Nutraceuticals | Source | Mechanism of Action | Reference |
|---|---|---|---|---|
| Modulating Inflammation | **Omega-3 Fatty Acids (e.g., EPA, DHA)** | fish oil and certain plant sources | Reduce inflammation by inhibiting the production of pro-inflammatory molecules like eicosanoids | [35] |
| | **Curcumin** | from Turmeric | Curcumin inhibits inflammatory pathways by targeting molecules like NF-κB, a key regulator of inflammation | [35] |
| | **Resveratrol** | found in grapes and red wine | Resveratrol has anti-inflammatory properties by activating SIRT1, a protein that plays a role in cellular protection and longevity | [36] |
| Antioxidant Activity | **Vitamin C and E** | citrus fruit, strawberries, sunflower, olive, nuts like almond, peanuts | These vitamins neutralize free radicals, unstable molecules that can damage cells and contribute to disease | [37] |
| | **Quercetin** | found in fruits and vegetables | Quercetin is a flavonoid with potent antioxidant properties, helping to protect cells from oxidative stress | [38] |
| | **Epigallocatechin-3-** | green tea | Performs its antioxidant activity by scavenging | [39] |

| | | | | |
|---|---|---|---|---|
| | **gallate (EGCG)** | | free radicals through hydrogen atom transfer (HAT) and single electron transfer (SET) mechanisms, and by chelating metal ions | |
| Supporting Gut Health | **Probiotics (beneficial bacteria)** | found in yogurt and fermented foods | Help maintain a healthy gut microbiome, which is crucial for digestion, immunity, and overall health | [40] |
| | **Prebiotics (food for probiotics)** | fruits, vegetables, and whole grains | Prebiotics, like fiber, are indigestible foods that serve as fuel for beneficial bacteria in the gut | [41] |
| Modulating Metabolic Pathways | **Chromium** | Brewer's yeast, lean meats, whole grains, some spices, and certain fruits and vegetables as well as nuts and seeds | Chromium helps regulate blood sugar levels and improve insulin sensitivity | [42] |
| | **Magnesium** | soy products (milk, flour, tofu) Legumes and seeds Fruit (bananas, dried apricots, etc.) | Magnesium plays a role in energy production, nerve function, and muscle function | [43] |
| | **L-Carnitine** | red meat, poultry, fish and dairy | L-Carnitine is involved in fatty acid metabolism and energy production | [44] |

## 5. Toxicity Evaluation of Nutraceuticals

While some nutraceuticals are safe, some may be harmful. Due to a dearth of pharmacological and toxicological research, toxicity and safety information are unavailable for a significant proportion of nutraceuticals. The pharmacological and

toxicological assessment of nutraceuticals is more complicated than that of pure synthetic pharmaceuticals because of the following factors: (1) the presence of multiple phytochemicals in a single plant; (2) the variability of phytochemical constituents due to climate, geography, and soil properties; (3) the use of pesticides and fertilizers; (4) harvesting variations throughout the day; (5) stress; and (6) quality control standards. The usage of nutraceuticals for both humans and animals has grown worldwide, and with it, so have the health hazards associated with the supplements' active ingredients and harmful contaminants. Safety is still a major concern because these nutraceuticals have not undergone the same thorough testing as medications and no extensive clinical trials have been conducted. Additionally, because the majority of nutraceuticals are plant extracts, it is highly probable that they contain metals (such as arsenic, cadmium, lead, and mercury), pesticides, mycotoxins, and other plant alkaloids (such as pyrrolizidine alkaloids). Another major worry is the adulteration of nutraceuticals with illegal substances.

## 6. Regulatory Considerations

The Food and Drug Administration (FDA) does not have a formal definition for the term "nutraceutical". Rather, goods with alleged health advantages fall under the category of dietary supplements. The Dietary Supplement Health and Education Act (DSHEA) of 1994 govern these supplements and require manufacturers to guarantee product safety and correct labeling prior to release. Nevertheless, the FDA does not have to approve them prior to marketing. Standards like ISO 21149, which are relevant to dietary supplements and nutraceuticals, are provided by the International Organization for Standardization (ISO) to guarantee uniformity and quality in production procedures.

## 7. Conclusion

There exist significant evidences that link nutraceuticals to disease prevention and health enhancement. The substances which are important for the immune function, decreasing inflammation, and regulating metabolism, are crucial for utilizing in the nutrition and diet. From emergence of different bioactive compounds in natural foods, nutraceuticals are increasingly being considered as an effective supplement to pharmaceuticals.

Through incorporating of these food supplements and products into the general dietary systems, persons will be able to boost their health, reduce diseases and have longer and healthy lives. As awareness with improvement in the functionality food products, nutraceutical continues to have a bright future in improving the quality of people's lives and minimizing the impacts of chronic as well as infectious diseases.

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All authors contributed equally in writing, drafting and conceptualization.

**Conflict of Interest**
The authors declare that there is no conflict of interest.

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