Review Article

Investigating Nutraceuticals: Recent Developments and Future Growth

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ABSTRACT

Background: Nutraceuticals are known as pharmaceutically formulated goods with both nutritional and therapeutic benefits. Such a product is intended to boost physical well-being, combat daily struggles such as stress, lengthen life, and so on. Due to their increased popularity, attention is being placed on herbs used as food and medicinal. Nutraceuticals have become more popular than medications and health supplements among both patients and healthcare professionals as a result of dynamic activity. Because of their alleged safety, nutritional supplements have attracted a lot of attention. Nutraceuticals are foods or dietary ingredients that offer health benefits, such as the capacity to cure or prevent disease. These nutraceuticals help combat some of the most significant health concerns of the 21st century, such as obesity, diabetes, oligoarthritis, cancer, cardiovascular disease, and elevated cholesterol.

Objectives: This review study provides a brief introduction on nutraceutical products and their uses in our daily life.

Methods: The required literature for the framing of the article was collected from various online sources, research papers, and also various journals.

Results: Because they eliminate side effects and contain natural dietary supplements, etc. nutraceuticals offer an edge over pharmaceuticals. Nutraceuticals are categorized into three main groups based on their natural source, chemical makeup, and form: Nutrients, herbal remedies, dietary supplements, and so on. Dietary supplements and natural/herbal goods were the industry categories that grew the fastest.

Conclusion: The present review article focused on providing recent developments in market value and the future of nutraceuticals.

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Introduction

Specially designed preparations, or nutraceuticals, are described as products made to fulfill certain dietary requirements and or offer preventative healthcare. Nutraceuticals are formulated nutrient(s) that help prevent and treat various ailments, in addition to a supplemented diet. Dr. Stephen De Felice developed the word "nutraceutical," combining the concepts "nutrition" and "pharmaceutical" in 1989. These are foods, or portions of foods, that can be used to treat or prevent illness, among other health benefits. Nutrition research has reached new heights, from predicting dietary shortfalls to concentrating on human health and the prevention and treatment of chronic disorders. Regulatory bodies fail to make a clear distinction between food supplements and nutraceuticals. A recent body of research has concentrated on redefining the word nutraceuticals, accounting for these drugs' toxicity, safety, and efficacy. Food items are nutritious substances that provide energy, maintain life, and promote development through oral, topical, or other applications [1].

Nutrient extraction from these foods is now commonly acknowledged and utilized. The choice of an epidemiological goal is the first stage in differentiating food/dietary supplements from nutraceuticals. Safety and efficacy studies that elucidate the mechanism of action come next. One approach to differentiate between these two types of formulations is the use of food supplements as agents to compensate for deficiencies in either macro or micronutrients. Furthermore, there has to be strong scientific evidence to justify the use of a nutraceutical in the treatment of a pathological ailment [1].

If there is enough clinical evidence, nutritional supplements ought to have a strong safety profile with fewer undesirable side effects and increased bioavailability. Even if the ingredients in two formulation types may have different uses as food supplements or nutraceuticals, they may still be distinguished based on their claims. Whereas food supplements include individual minerals, vitamins, protein, and vitamin supplements as well as herbal and functional foods, nutraceuticals consist of individual pro- and pre-biotic foods as well as food for certain therapeutic reasons. By prolonging or eliminating the need for pharmaceuticals in individuals who are qualified for an alternative nonpharmacological treatment for a pathological condition, the regular use of nutraceuticals may contribute to the prevention of pathological disorders. Certain foods, including herbs and spices, may reduce the risk of a variety of illnesses and improve quality of life (QoL) considerably, according to certain theories [2].

Numerous benefits are associated with nutraceuticals, one of which is their potential for treating and preventing complicated illnesses. However, nutraceuticals need to be prescribed, delivered, and constantly monitored to avoid excessive use and unfavorable side effects [3]. Numerous researchers have looked at drug compound-based nutraceuticals to improve their bioavailability and efficacy. Because statins are safe and effective, they have been used to prevent cardiovascular problems, even in pregnant women. Nutraceuticals with a good safety record and a proven impact on pregnancy may be a useful therapeutic option for the treatment of diabetes mellitus, and hypertension, or as a supplement to conventional medication therapy. Calcium, omega-3 polyunsaturated fatty acids, vitamin D, folic acid, resveratrol, alpha-lipoic acid, zinc, inositol, and probiotic supplements are among the potentially profitable opportunities for novel nutraceuticals [4].

For people at risk of elevated statin levels, which further contribute to cardiovascular illnesses, researchers have assessed the nutraceutical linked with the medicinal component ezetimibe. The use of a new nutraceutical in combination with non-steroidal anti-inflammatory medicines has the potential to treat osteoarthritis, enhancing its efficacy and safety for commercial usage. Nutraceuticals, including antioxidants, omega-3 fatty acids, algae, aloe vera, seaweed, wheatgrass, teas, and herbs like ginseng and echinacea continue to have a strong and expanding market. The worldwide nutraceutical market is projected to reach 722.49 billion USD by 2027, growing at a compound annual growth rate of 8.3%, reflecting the growing interest in these products for their possible nutritional, safety, and therapeutic impacts. Other notable regional markets, such as Japan and Canada, are expected to increase at corresponding rates of 3.4% and 5.7% from 2020 to 2027. In several clinical consequences, including diabetes, atherosclerosis, cardiovascular diseases, cancer, and neurological illnesses, recent investigations have demonstrated promising effects for these substances [5]. Numerous changes are brought about by these circumstances, including changes in the redox state. The majority of dietary supplements include antioxidant activity that can help to prevent this condition. They are regarded as beneficial sources of health promotion as a result, particularly for the avoidance of serious illnesses, including diabetes, infections, renal, and gastrointestinal problems.

Nutraceuticals have become more popular than medications among the general population and healthcare professionals due to their dynamic activity (nutritional and medicinal effects). The use of nutraceuticals in supportive and preventative therapy is covered in detail in the current study, which is followed by a collection of literature on related patents [6].

Historical perspective

The use of nutraceuticals dates back over 3000 years. Hippocrates (460–377 B.C.) once remarked, "Let food be the medicine and let medicine be the food." To prevent goiter, American food manufacturers started iodizing salt in small amounts at the beginning of the 20th century. The term nutraceuticals was initially coined in 1989 by Stephen De Felice, chairman and founder of the Foundation for Innovation in Medicine, located in Cranford, New Jersey [7]. According to De Felice, a nutraceutical is a food (or part of a meal) that provides health or medical benefits, such as the prevention and or treatment of an illness. Nonetheless, although being widely used in marketing, the term nutraceutical has no legal significance [5].

Dietary practices in Japan, England, and other countries are already being impacted by nutraceuticals. The first nations to consider eating to be more important for good health than exercise or hereditary features were Germany, France, and the United Kingdom. Canada defined them as products of foods but sold in pills, powders, and other medicinal forms not typically associated with food. In India, nutritional components made from herbal or botanical raw materials are known as nutraceuticals, and they are used to treat or prevent a variety of acute and chronic conditions [8].

Nutraceuticals are now one of the market categories with the fastest growth rates, with a predicted compound annual growth rate of 7.5%. According to estimates, the worldwide market for nutraceuticals will grow from $241 billion in 2019 to $373 billion in 2025. Nutraceuticals have been used with certainty to provide desired therapeutic results with fewer negative effects. Herbal nutraceuticals are effective tools for maintaining health and operate in opposition to acute and chronic illnesses brought on by poor dietary choices by fostering optimum health, longevity, and QoL [9].

Materials and Methods

A non-systematic review of the scientific literature on the development of nutraceuticals was done, with a focus on the importance of these products' function in the treatment of disease. To do this, a bibliographic search was carried out primarily within the last decade utilizing a variety of databases, such as ScienceDirect and PubMed; however, in certain cases, older references had to be checked. The search started with a combination of keywords like nutraceuticals and supplements or using nutraceuticals to treat various health issues. Out of all the publications found, those pertinent to the topic of the review were selected as an inclusion or exclusion criterion.

Results

Nutraceuticals in disease treatment

According to Figure 1, the pharmacological advantages of nutraceutical products include anti-aging, protection against certain chronic diseases, maintenance of body homeostasis, prevention of cardiovascular disease, neurodegenerative disease, metabolic disorders like diabetes, cancer, protein deficiencies, ocular complications, allergies, and Parkinsonism. Readers will have a better grasp of the potential applications of nutraceuticals in the treatment of various clinical conditions from this portion of the chapter [10].

Nutraceuticals in allergic disorder treatment

Allergies are common because of how sensitive the human immune system is. Clinical management is problematic since most allergy causes are either unknown or difficult to diagnose. Allergy responses can range in severity in the body from mild irritation to potentially fatal conditions including acute respiratory distress [11]. Increases in white blood cell and basophil counts are examples of hematological changes associated with allergic disorders. Plant bioactive quercetin is widely used in nutraceuticals to manage allergies because of its effect on low-density lipoprotein [12]. Eucalyptus essential oil is another plant product that is mostly used in nutraceuticals to manage allergies [13].

Nutraceuticals in cardiovascular disease treatment

According to the World Health Organization (WHO), cardiovascular conditions are the leading cause of death worldwide. This illness manifests itself in a variety of ways, including heart failure, vesicular obstruction, hypertension, stroke, etc. Any of these manifestations may cause mortality or necessitate urgent surgical intervention, such as angioplasty and bypass surgery. However, with prompt action, at least 50% of cardiovascular disease may be avoided. For the management of cardiovascular disease, vitamins, antioxidants, omega-3 fatty

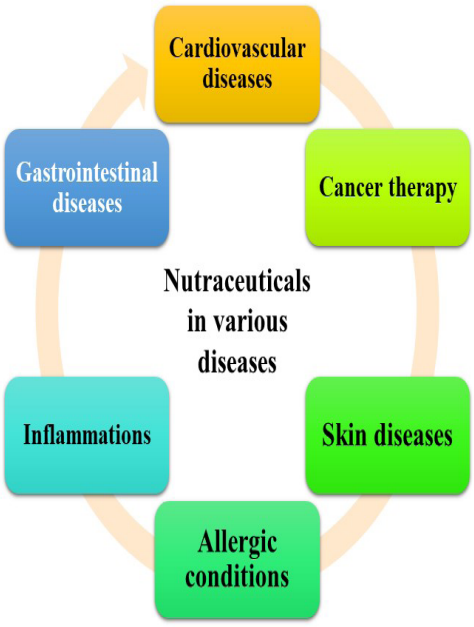

Figure 1. Nutraceuticals related to various disease treatment

acids, dietary fibers, and minerals are packaged as nutraceuticals supported by exercise [14].

The abundantly present flavonoid components in fruits and vegetables are frequently developed as nutraceuticals for cardiovascular issues. These plant bioactive inhibit the cyclooxygenase enzyme, which prevents platelet aggregation, as well as the angiotensin-converting enzyme, which causes hypertension. To reduce cardiovascular risk, other compounds, such as melatonin, serotonin, dietary indoleamines, tannis, etc. are being investigated as nutraceuticals. Omega 3 fatty acids from fish are utilized as nutraceuticals to treat cardiac arrhythmia because they reduce lipid and bad cholesterol levels. The idea that these products have no after-effects contributes to consumer adoption of nutraceuticals for cardiac disorders [15].

Nutraceuticals in cancer therapy

The development of medication resistance and the adverse effects of current treatments are the major causes of today's complex cancer therapy. According to a global poll, there will be 15 million additional cancer cases in 2020, which would result in a 50% increase in the overall cancer population. Chemotherapy, radiation therapy, and surgery have been the three main pillars of cancer treatment to date. However, the greatest preventative approach against cancer may be a healthy lifestyle that includes a diet high in antioxidants. As they have few side effects and are frequently loaded with substances or plant extracts that can dodge resistance, nutraceuticals may be the ideal candidates to close the current gap in cancer treatment [16].

According to recent studies, carotenoids like lycopene are effective against several malignancies and are thus a crucial part of the composition of many nutraceuticals. Nutraceuticals made from plant extracts that are high in biochanin, isoflavones, tannins, and plant bioactive including curcumin, gallic acid, and caffeine have impressive effectiveness against a variety of malignancies. Nutraceuticals with pectin and carotene are useful in treating prostate tumors due to their capacity to scavenge free radicals. Regular fruit consumption may provide the body with several nutraceuticals, such as cysteine, vitamin C, vitamin E, and lycopene as well as protect against many cancers. Some glucosinolate bio-transformed compounds are beneficial in treating liver, colon, and lung cancer. According to reports, a significant clinical trial using several potent nutraceuticals, particularly lycopene, green tea, vitamin D, and E, is being conducted to control prostate cancer [17].

Nutraceuticals in skin disease treatment

The skin is the biggest organ in the body and provides defense against various pathogens, ultraviolet rays, and toxins as well as engaging in sensitivity. Skin plays a significant protective role for the body, but it may also experience changes including immunological dysfunction, photoaging, and inflammation that can be harmful

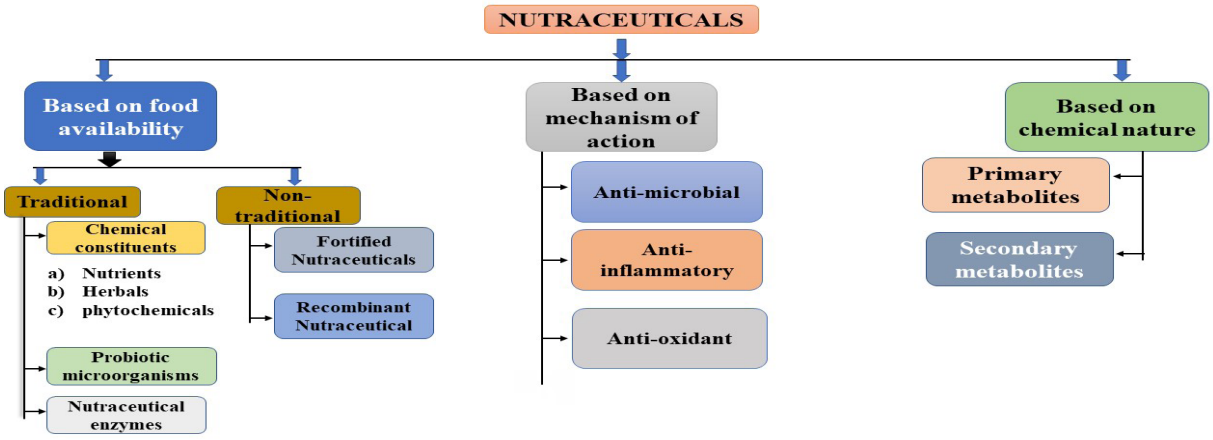

Figure 2. Classification of nutraceuticals

to human health. With the use of nutraceuticals, a feasible technique may be established to alleviate skin-related illnesses and postpone or reduce premature skin aging. These nutraceuticals may include carotenoids, bioactive peptides, bioactive polysaccharides, and plant extracts. In several human studies, supplementation with these compounds showed reduced aging symptoms as well as protection against ultraviolet-radiation aging [18].

Nutraceuticals in inflammation disease treatment [19]

The body's response to irritation or injury is called inflammation, and it is typified by swelling, pain, redness, and heat. The benefits of nutraceuticals in osteoarthritis have been investigated. These include ginger, soybean, unsaponifiable, glucosamine, chondroitin, and S-adenosylmethionine. Even if the trials are safe and well-tolerated, the results are hampered by their diversity and unequal results. Micronutrients, such as vitamins C and D are advantageous. Cat's claw has a potent anti-inflammatory effect. The efficacy of a cat's claw is attributed to its active components, known as oxindole alkaloids; however, preparations of the plant that are soluble in water and lack alkaloids do not have strong anti-inflammatory and antioxidant effects. *Vaccinium myrtillus*, *Vaccinium angustifolium*, *Vaccinium ashei*, and *Vaccinium* corymbosum fruits contain resveratrol, which has the greatest known sirtuin-like deacetylase activity of any phytochemical.

Positive results have been observed in the prevention and treatment of inflammation as a result of the phytochemicals included in nutraceuticals. They assist in reducing oxidative stress in chronic inflammatory illnesses, such as cancer, rheumatoid arthritis, asthma, osteoarthritis, and autoimmune disorders.

Nutraceuticals in gastrointestinal disease treatment [20]

Numerous nutraceuticals, including probiotics, prebiotics, flavonoids, aloe vera, resveratrol, omega-3, and omega-6 fatty acids, can repair and increase the growth of healthy bacteria in the gut while decreasing the impact of harmful bacteria.

Discussion

Types of nutraceuticals

Various types of nutraceuticals have been given based on different circumstances as shown in Figure 2.

Food bioavailability

Traditional nutraceuticals

Some components are accessible and can be taken for distinct health advantages; examples of these are lycopene found in tomatoes, omega-3 fatty acids found in salmon, and saponins found in soy. The following are further categories of conventional nutraceuticals [21].

Chemical constituents

Nutrients: A variety of vitamins, fatty acids, and amino acids were examples of primary metabolites with distinct functions in various metabolic pathways. Plant and animal products, in addition to vitamins, provide a host of health benefits and help cure ailments related to the heart, kidneys, lungs, and other organs. Plant-based nat-

ural chemicals can be used to cure several ailments, such as low hemoglobin levels and brittle bones. They also support neuron transmission, give strength to bones and muscles, and keep the cardiac muscles in rhythm. Salmon contains omega-3 polyunsaturated fatty acids, which are beneficial to the brain, the inflammatory response in general, and the levels of cholesterol in the arteries.

Herbals: Nutraceuticals and herbs combined effectively to lower the risk of several chronic diseases and enhance people's QoL. Salicin, found in willow bark (*Salix nigra*), has been shown in clinical investigations to have anti-inflammatory, analgesic, antipyretic, astringent, and antiarthritic properties. Parsley (*Petroselinum crispum*) contains a flavonoid called psoralen, which has antipyretic, diuretic, and carminative properties. Colds and the flu can be treated with peppermint (*Mentha piperita*) terpenoids, especially the bioactive component menthol. The tannins in lavender, or lavender (*Lavandula angustifolia*), help relieve tension and blood pressure, and they are good for respiratory ailments like asthma [22].

Phytochemicals: The main basis on which their categorization is based is phytochemicals. Carotenoids, also known as isoprenoids, are found in vegetables and are known to bolster the immune system, especially the killer cells that mount an anticancer defense. Legumes (such as soybeans and chickpeas), cereals, and palm oil contain noncarotenoids. These compounds fight cancer and decrease cholesterol. Flavonoids are a family of secondary metabolites that are present in most plants and include over 4000 distinct species. They have been demonstrated in clinical trials to prevent many illnesses, such as diabetes, renal difficulties, cancer, and heart disease due to their bioactive components and antioxidant qualities [23]. The biggest family of secondary metabolites, phenolic acids are mostly found in citrus fruits and red wine. They have the antioxidant capacity to scavenge free radicals generated by a variety of metabolic pathways, including protein carbohydrate, and fat metabolism. They also have anti-cancer and anti-tumor activity. One of the classical examples is curcumin (turmeric), used as phytochemicals in most the kitchen.

Probiotic microorganisms: Probiotic was first used by Metchnikoff. Due to its capacity to make the gut more hospitable for activities like absorption and metabolism, its utilization in modern medicine has seen significant growth. The removal of the intestine's poisonous flora and maintenance of a friendly environment is made possible by probiotics, such as *Bacillus bulgaricus*, which is an excellent example of a probiotic [24]. To cure a variety of human body illnesses, there are currently a variety of probiotic supplements with the necessary nutrients to combat various infections. The antibacterial property often had a changing effect on the microbiota, causing the epithelial tissues to become more grounded and creating an opportunity for the supplements to have greater retention, which the body requires. Probiotics are also highly helpful in treating lactose intolerance since they produce similar enzymes (such as ß-galactosidase) and hydrolyze lactose into its component sugars [25].

Nutraceutical enzymes: The enzymes are created by the cell, have a proteinaceous structure, and function as a biocatalyst. It speeds up the life process and lowers metabolic rate. Enzyme supplements can be used to treat medical conditions that are mostly gastrointestinal tract related-related, such as gastroesophageal reflux disease, constipation, diarrhea, and ulcerative colitis. For people with diabetes, the enzyme could be a better alternative. Many uncommon disorders, including Gaucher disease, Hunter syndrome, Fabry disease, and Pompe disease, are now treated using enzyme treatments. Microbial sources are chosen over plant and animal sources because they are more affordable, despite that enzymes are created by their cells [21].

Non-traditional nutraceuticals: These are crops or foods that have been biotechnologically modified to boost their nutrient content. For example, broccoli and rice contain high levels of beta-carotene and vitamins, respectively. Bioactive components found in food samples have been created to offer benefits for human welfare. These are in the following order [26].

Fortified nutraceuticals: Nutraceuticals refer to the process of breeding agricultural products or adding additional nutrients to the main ingredients. Examples of this include adding minerals to cereals, fortifying flour with calcium, iron, and folic acid, and fortifying milk with cholecalciferol, which is commonly used to treat vitamin D deficiency.

Recombinant nutraceuticals: Biotechnology techniques have been successfully used in a range of food items, such as bread and cheese, to extract the enzyme required for adequately delivering essential nutrients through a fermentation process.

Mechanism of action [21]

To account for particular therapeutic capabilities, such as antibacterial, anti-inflammatory, and antioxidant properties, nutritional supplements have been further divided into categories.

Chemical nature [21]

Depending on the main and secondary metabolite sources, such as isoprenoid derivatives, phenolic compounds, fatty acids, carbohydrates, and amino acid-based materials, these categories are categorized.

Various reasons to select nutraceuticals [19]

Nutraceuticals cover most therapeutic areas, such as arthritis, cold and flu, digestive problems, insomnia, protection of certain cancers, osteoporosis, blood pressure, cholesterol control, analgesics, depression, and diabetes.

To improve their well-being and prevent chronic illness, people who are unsatisfied with the efficacy of medications in promoting health are turning to nutraceuticals.

Healthcare experts agree that crops produced with chemical fertilizers, insecticides, herbicides, and often genetically altered seeds are the source of our heavily processed food supply. These foods do not provide the nutrients needed for optimal wellness.

Nutritional supplements have a promising future as therapeutic agents that possess both curative and preventive qualities.

People with chronic conditions for whom allopathic therapy has proven ineffective.

Nutritional supplements are quickly taking the role of pharmaceuticals in the treatment and prevention of acute and chronic health problems.

Patients who are struggling financially and those who place more value on prevention than treatment.

The present article focused on reviewing present achievements in nutraceuticals and also depicting prospects of it. As of high public compliance it has become a very acceptable method of preventing or curing many diseases.

Challenges in the formulation of nutraceuticals and dietary supplements

The insufficient water solubility, high melting point, and chemical instability of the active ingredients provide challenges for creating nutraceuticals. For instance, curcumin, carotenoids, and omega-3 fatty acids have great nutritional value but are not well-soluble. As a result, one strategy is to define these as innovative delivery systems. They are pricey due to their innovative delivery methods. Therefore, efforts are required to make these formulations economical [27].

The high melting point of nutraceuticals presents another formulation issue. For example, carotenoids, fatty alcohols, and phytosterols all have high melting points that might make a formulation unstable. As a result, one strategy is to make a solid dispersion or dissolve it in an appropriate grade solvent before adding it to meals as suspended nanocrystals. The problem is that it results in decreased stability and shelf life, an unpleasant look, an offensive odor, and an unpleasant mouthfeel, all of which have an impact on market value and consumer demand. Thus, cost-effective technologies must be developed [28, 29].

Another difficulty is the volatility of chemicals. For instance, oils rich in omega-3 fatty acids, such as those derived from fish, flaxseed, or cod liver, as well as carotenoids, lycopene, or curcumin, all have stability concerns. The bioactive product's composition, environmental factors like temperature, pH, pressure, etc. or the presence of metals or other oxidation-promoting substances all have a significant impact on how much chemical degradation occurs [30, 31].

The development of dosage forms for nutraceuticals and dietary supplements that are appropriate for various segments of the aging population, particularly older individuals and children, is a problem. This is due to this population's limits on solid doses due to dysphagia, which prevents them from swallowing pills or capsules. As a result, the administration of nutraceuticals and dietary supplements must take into account the usage of sophisticated dosage forms, such as orodispersible pills, fast-dissolving films, and easy-swallowing gels, which are often employed in pharmaceutical applications [32].

Current status of nutraceuticals

Herbal or botanical raw materials are used to create nutraceutical foods or dietary components that aid in the treatment and prevention of illnesses. More than millions of individuals use these natural products worldwide, and this market is expanding quickly (7% to 12% annually). By the end of 2025, the global market for nutraceuticals is predicted to grow from USD 4 billion to USD 18 billion. The worldwide market for health and wellness was estimated by Euro Monitor to be worth US$4.92 trillion in 2023. It is anticipated to grow at a compound annual growth rate of 10.93% from 2024 to 2032 to reach

Table 1. List of some nutraceuticals with their therapeutic benefits [34]

Name of Nutraceuticals	Therapeutic Benefits
Natural purified lutein esters	Dietary supplement Functional foods antioxidants
Green tea	Cancer prevention Weight management Lowering cholesterol
Ginkgo biloba	Allergy relief
Ginseng	Immunomodulator
Glucosamine	Arthritis treatment
Garlic	Cholesterol lowering Cardiac diseases Diabetic support
Natural lycopene	Reducing the risk of prostate and cervical cancers; Supporting cardiovascular health
Quercetin	Allergy

US$13.89 trillion, driven by functional/fortified goods created to provide certain health benefits.

While there is a serious lack of consumer understanding of traditional nutraceutical components in India, manufacturers of these goods must take up the cause and educate Indians about their products. The past ten years have witnessed the greatest increase in the global nutraceutical business. Over the next five years, India is anticipated to have substantially greater growth rates for drinks and functional food compared to dietary supplements [33].

Japan is the biggest consumer of nutraceutical products in the Asia Pacific region, followed by China. The market for functional foods in India is anticipated to develop moderately, and by 2025, functional foods and beverages are anticipated to make up over 71% of the market for dietary supplements. With a compound annual growth rate of 9.7%, the Middle East and African functional foods market will increase from US$25.07 million in 2021 to US$47.88 million in 2028. Non-herbals had the quickest rate of growth, whereas proteins and peptides had the highest market revenue in 2011. The rise of the functional food and dietary supplement markets in Eastern Europe is driving the market for nutraceutical goods. The biggest user of dietary supplements in the area is Russia.

The nutraceutical market is anticipated to be held by Hungary and Russia in 2017 in proportions of just under 20% and just under 24.5%, respectively. While current nutraceuticals are accessible as forms of food or as ingredients in foods or as full foods themselves, such as probiotic drinks and yogurt, they originally came in medical formats, such as capsules, pills, or powder in a prescribed quantity. More studies are under observation to make nutraceuticals a favorable way of drug delivery hence in the treatment of many diseases [34]. Some nutraceutical products with their therapeutic benefits are given below in Table 1.

Recent developments in nutraceuticals [35]

The nutraceutical sector is currently compliant with traditional food or pharmaceutical technologies. However, the cutting-edge research methodologies used in the creation of nutraceuticals are being driven by recent developments in the realm of nanotechnology. Currently, nano-systems structures or molecules having at least one dimension and a size between 1 and 100 nm are used in a wide range of food and health sciences applications. For example, nanoengineered materials have been used in the following ways: a) For food packaging and sensory enhancement; b) For smart delivery and nanofortification of functional and fortified goods; and c) For individualized care in nanomedicine. The term nanonutraceuticals refers to the use of nanoscale materials for the encapsulation and delivery of nutraceuticals.

The favorable biological features of nano-nutraceuticals are mostly attributed to the biological activity of the loaded bioactive substances, despite that the mechanism of action of nanoparticles is not yet fully understood and may vary depending on the chosen nano-system. For instance, nano-nutraceuticals can work by chelating

Table 2. List of some commercially marketed nutraceuticals [17]

No.	Marketed Product	Manufacturing Company	Group	Content
1.	Consevel capsules	Sun Pharma Pvt. Ltd., India	Amino acid supplements	Antioxidants, calcium, and lactobacillus
2.	BrainFocus	Healthyhey Foods LLP, India	Vitamin supplements	Calcium and vitamins
3.	Calcirol D-3®	Cadilla Healthcare Limited, India	Calcium supplements	Calcium and vitamins
4.	Biovinca™	Cyvex Nutrition, Irvine, CA, USA	Neurotonic	Vinpocetine
5.	GRD	ZydusCadila Ltd. Ahmedabad, India	Nutritional supplements	Proteins, vitamins, minerals and carbohydrates
6.	PNerplus™	NeuroHelp, San Antonio, Texas, USA	Neuropathic pain supplement	Vitamin and other natural supplement
7.	Omega woman	Wassen, Surrey, U.K.	Immune supplement	Antioxidants, vitamins and phytochemicals
8.	CogniSure	Metagenics Inc	Amino acid supplement	Proline-rich polypeptide complex
9.	Coral calcium	Nature's Answer, Hauppauge, NY, USA	Calcium supplement	Calcium and trace minerals
10.	Daytime restoration and nighttime repose	Xigo Health	Restful sleep	Ginseng, *Ginkgo biloba*

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transition metals, improving antioxidant potential, and scavenging free radicals. Nuclear factor kappa-light-chain-enhancer of activated B cells, interleukin 6 and 1, tumor necrosis factor, and other molecular pathways, as well as enzymatic activities like acetylcholinesterase, inducible nitric oxide synthase, superoxide dismutase, nicotinamide adenine dinucleotide phosphate oxidase, and others, are all impacted. Additionally, these nanoformulations shield the beneficial compounds they have encapsulated from oxidation or digestion system enzyme activity. As a result, they enable their delayed and controlled release, prolong their activity, and improve their bio-efficacy through targeted delivery. Some marketed formulations of nutraceutical products are given below in Table 2.

Regulatory aspects of nutraceuticals

The primary set of laws governing the nutraceutical industry was created in 1994 and is known as the dietary supplement health and education act [36]. The food safety and standard rule for 2011 is now available. The food safety and standard authority has also released regulations about food industry license and registration, manufacturing, packaging, labeling, standards for food products, etc. The food safety and standard rules and regulations went into effect in August 2011. Manufacturers will be encouraged by this law to do clinical research, develop reliable processes, and enhance their goods.

The foreign direct investment act of 2012, which was just adopted, gives international companies more opportunities to produce and market nutritional supplements in India. Thus, one regulatory agency oversees the production, marketing, and distribution of nutraceuticals in India [37].

Future prospects of nutraceuticals [11]

The world is changing and becoming increasingly intriguing. Foods are becoming increasingly attractive, tasty, and nutritious to meet the increasing need for healthful nutrition. With the development of living modified organisms and genetically modified foods, the objective of feeding everyone will soon be accomplished, or, to put it another way, malnutrition will soon be eradicated, even though new challenges may arise. With pills that may be taken as nutrients to provide the body with the full recommended dietary allowance, including fiber to guarantee intestine or bowel emptying, the applications for nutraceuticals are virtually limitless.

Nutraceuticals have the potential to help food and nutrition societies realize their vision of a world free from hunger. The core of the value-added market performance is the increasing openness of consumers to how nutraceuticals may enhance great health. Soon, consumers are expected to consider supplementing as an effective way to improve health in addition to adopting supplement

goods to raise overall food intake, given the reported rise in consumer demand for nutraceuticals.

Conclusion

A growing understanding of the value of health and well-being, along with developments in scientific research and technology, are driving the global nutraceutical business to unprecedented growth and demand. Due to their potential health advantages and disease-prevention abilities, nutraceutical products, which connect diet and pharmaceuticals, have become more popular.

Nutraceutical products are in greater demand as a result of consumers' increased health awareness and proactivity. With the help of these products, people may easily and conveniently add necessary nutrients, anti-oxidants, and other bioactive substances to their meals. Further stoking the market demand are novel products developed in response to various health demands as a result of continuing research and development in the nutraceuticals sector. The current market for using nutraceutical products is characterized by a wide range of items, including herbal and natural goods, dietary supplements, functional meals, and drinks. Consumers are increasingly looking for goods that are not only efficient but also sustainable and ecologically beneficial, placing a focus on organic and natural components.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered for this article.

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Authors' contributions

All authors equally contribute to preparing all parts of the research.

Conflict of interest

The authors declared no conflict of interest.

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