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Review Paper

Nutraceuticals: Bridging Nutrition and Medicine for Healthcare

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ABSTRACT

Nutraceuticals have gained remarkable global attention as an emerging bridge between nutrition and therapeutic science. These naturally derived compounds—sourced from plants, foods, and traditional herbal systems—offer a complementary approach to maintaining health, preventing chronic illnesses, and supporting overall wellbeing. Over the past decade, India has witnessed rapid expansion in the nutraceutical sector, driven by increasing health awareness and the shifting preference toward natural alternatives to synthetic medicines. Nutraceuticals demonstrate promising roles in the management of several conditions, including cancer, cardiovascular disorders, diabetes, neurodegenerative diseases, pregnancy-related complications, and skin ageing, largely due to their antioxidant, anti-inflammatory, immunomodulatory, and metabolic regulatory properties. Advancements in extraction technologies, bioavailability enhancement, and scientific validation have further strengthened their therapeutic relevance. Despite their potential, challenges such as limited regulatory clarity, lack of standardized clinical evidence, and low public awareness continue to restrict their widespread adoption. This review provides a comprehensive overview of the history, categories, therapeutic applications, market trends, and future prospects of nutraceuticals, emphasizing their evolving role in modern healthcare

INTRODUCTION

There are a lot of opportunities for the term "Nutraceuticals" to grow and expand in terms of health benefits. It has demonstrated subsequent results in decreasing the need for conventional medicines and lowering the likelihood of negative

effects, depending on its nature and alternative use as modern medicines. Nutraceuticals have become popular health products that come from a variety of industries, including the food, herbal, and pharmaceutical manufacturing sectors. The importance of these products has been linked to the treatment of numerous conditions that require

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special attention, including cancer, metabolic issues, cold and cough, depression, coronary heart disease, delayed gastrointestinal emptying, and many more. For the last three years, the Indian nutraceutical market segment has grown at an annual rate of 20%, accounting for 2% of the global market. India is currently exhibiting a promising trend toward fast-moving health care goods, or nutraceuticals. The estimated market value of the nutraceutical industry in 2009 was INR 27 billion, and it is anticipated to reach INR 40.1 billion in 2011. With a market value of about US \$2 billion, India still accounts for 1.5% of the global nutraceutical market.¹A wide variety of bioactive substances, including lipids, phytochemicals, pharmaceuticals, flavors, fragrances, and pigments, are found in plants. The food, pharmaceutical, and cosmetics industries all make extensive use of plant extracts. In order to extract these valuable natural compounds from plants for commercialization, extraction techniques have been extensively studied. Conventional techniques that have been in use for many years, like Soxhlet extraction, take a long time and use a lot of solvents (Luque de Castro & Garcia-Ayuso, 1998). New extraction methods that reduce the amount of organic solvent used, shorten the extraction time, and improve pollution prevention are in greater demand. Some possible uses for the extraction of nutraceuticals from solid plant matrices have been documented, and the novel extraction techniques have reached a relatively mature state. The theoretical foundation for both the traditional Soxhlet extraction and a number of cutting-edge extraction methods, such as accelerated solvent extraction, supercritical fluid extraction, ultrasound-assisted extraction, and microwave-assisted extraction, is provided in this review. Each extraction method's practical considerations, including matrix properties, solvent selection, liquid-solid ratio, temperature, pressure, and extraction duration, are covered.

Lastly, possible uses for those extraction techniques are examined.²

Nutraceuticals may be used to improve health, delay the aging process, prevent chronic diseases, increase life expectancy, or support the structure or function of the body. Nutraceuticals, in contrast to pharmaceuticals, are substances that usually do not have patent protection. Both pharmaceutical and nutraceutical compounds might be used to cure or prevent diseases, but only pharmaceutical compounds have governmental sanction.

A dietary supplement is considered a product that bears or contains one or more of the following dietary ingredient: A mineral, a vitamin, an amino acid, a medical herb or other botanical, a dietary substance for use by man to supplement the diet by increasing the total daily intake, or a concentrate, metabolite, constituent, extract, or combination of these ingredients. Nutraceuticals are one of these nutritional supplements that are used for health purposes other than nutrition.

HISTORY OF NUTRACEUTICALS

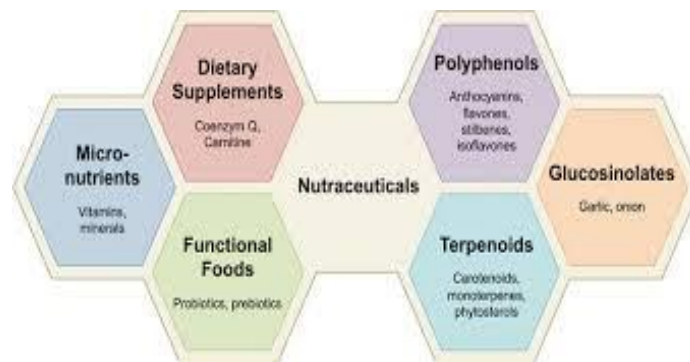
centuries old-proclaimed by our ancestors. The ancient writings and artworks of Egyptians, Romans and Greek civilizations depicted the medicinal and spiritual applications of plants. The idea arose 3000 Food may possess the ability to prevent diseases or treatment of ailment” this belief is couple of years ago when Hippocrates developed a relationship between food for health and therapeutic applications of it. The principal truth depicted in his statement that “Let food be thy medicine and medicine be thy food” is widely applied nowadays. Thus, from such finding, it could be believed that our nature and surroundings have much of the natural therapies to offer. One such finding presents the botanicals which are in use from ancient times for the treatment of cancer. Similarly, there are many plant derived chemotherapies which consists of Vinca and Taxus brevifolia species to treat cancer and related



problems.. It was from the time of Liang dynasty of China that the chemotherapy features of ginseng were discovered and applied even in today's time. From the documented history, Egyptians identified the medicinal importance of coriander, fennel,

juniper, cumin, garlic, turmeric, thyme, curry and dried mint found in pyramids.¹

CATEGORIES OF NUTRACEUTICALS



1. Traditional Nutraceuticals

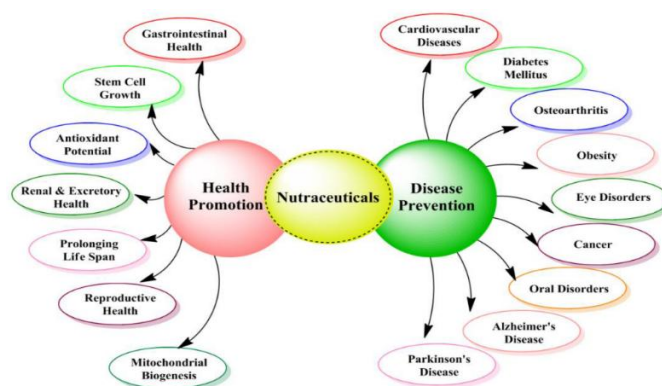
Under the category of traditional Nutraceuticals comes food in which no change to the food is made; It is simply natural, whole foods with new information about their potential health qualities. There has been no change to the actual foods, other than the way the consumer perceives them. Many fruits, vegetables, grains, fish; dairy and meat products contain several natural components that deliver benefits beyond basic nutrition, such as lycopene in tomatoes, omega-3 fatty acids in salmon or saponins in soy. Even tea and chocolate have been noted in some studies to contain health-benefiting attributes. Tomatoes and salmon are two types of food that researchers have found to contain benefits beyond basic nutrition - in this case, lycopene and omega-3 fatty acids, respectively.³ The components are natural and are having some potential which are actively involved in health benefits. E.g., Lycopene is obtained from tomatoes, pink grape fruit, guava, papaya, water melon are its potential benefits, and its anti-oxidant activity, protects against formation of

cancer mainly prostate, bladder, cervical, leukemia.⁴

2. Non-Traditional Nutraceuticals

This group of nutraceuticals is regarding enhancement of nutritional value by addition of nutrients and dietary ingredients for improvement of quality of nutrition. Eg: β -carotene derived from carrots, various fruits and vegetables Carrots, oranges, and tangerines are its potential benefits which possess antioxidant activity which neutralizes free radicals and protects the cornea against UV light, antioxidants, anti-carcinogenic, and anti-cancer properties.⁴ They are the result of agricultural breeding or added nutrients and/or ingredients, such as: orange juice fortified with calcium, cereals containing added vitamins or minerals, and flour with added folic acid, and are nontraditional nutraceuticals. Agricultural scientists have been able to develop methods to enhance the nutritional quality of certain crops.³

NUTRACEUTICALS ON DISEASE PREVENTION



Nutraceuticals play an important role in the prevention of different disease onsets and minimization of the complication of the disease. It

provides protection against non-communicable diseases, delay ageing process, increases life expectancy, improves function of the body.⁵

	Nutraceuticals	Disease prevention
	Plant Polyphenols, Stilbenes, Soybean & Other Phytoestrogens, Vitamin C, Vitamin D, Vitamin E, Coenzyme Q 10, Unsaturated Fatty Acid, Brahmi and Inosine.	Parkinson's disease
	Soy Isoflavones, Omega 3 Fatty Acid, Lipoic Acid, Catechins, Spices Like Fenugreek and Cinnamon, Bitter Melon, Pomegranate	Diabetes mellitus
	Lutein, DHA, Green Tea, Carotenoids, Flavonoids, Vitamin E, Coenzyme Q10, Zeaxanthi, Melatonin, Spirullina, Flavonoids, Ascorbic Acid, Tocopherol, Carotenoids, Caffeine, Pyruvate	Eye Disorders
	Curcumin, Lutein, Lycopene, Lavandula, Beta Carotene, Folic Acid and Vit B12.	Alzheimer's disease
	Diacerin, Banana, Ginger, Green Tea, Pomegranate, Boswellia, Oxaceprol, Tipi, Willow Bark, Curcumin, Avocado, Soybean, Collagen Hydrolysate, Chondroitin Sulfate and Glucosamine	Osteoarthritis
	Ginseng, Beta Carotene, Sulfur Compounds in Garlic.	Cancer
	Odonto Nutraceuticals, Green Tea, Grapes, Cocoa Seed Extracts rich in Polyphenols, Flavonoids and Proanthocyanidins	Oral Disorders

1.Cancer

Nutraceutical rich bioactive dietary components have the ability to prevent cancer 24. Herbal nutraceuticals possess anti-mutagenic and anti-carcinogenic properties. Antioxidant activities of carotenoids, lycopene are effective for cancer. They are oxygen quencher and decreases oxidative stress. Nutraceutical controls DNA damaging factors in cells and prevents DNA transcription in

tumors 25. Ginseng is anti-inflammatory molecule that prevents chronic inflammation of cancer. Beta carotene from yellow and orange fruits has anti-cancer activity. Cruciferous vegetables lowers the chances of colorectal and lung cancer. They block enzymes that promote tumor growth. Sulfur compounds in garlic boosts immune system, reduces atherosclerosis and platelet aggregation 26. Recent research further reported herbal

nutraceuticals has the ability to alter metastatic spread of cancer

2. Cardiovascular Diseases

Cardiovascular diseases Nutraceuticals like flavonoids, flavones, flavonones, and quercetin in onions, cruciferous vegetables, blackberries, cherries, berries, apples, and other antioxidant vitamins and minerals may reduce the risk of death from CVDs. They inhibit the cyclooxygenase pathway and angiotensin-converting enzyme (ACE), which is responsible for high blood pressure. They also prevent platelet aggregation and stickiness. Flavonoid groups strengthen tiny capillaries, which carry oxygen and essential nutrients to all cells. Polyphenols present in grapes alter cellular metabolism and signaling, which reduces arterial diseases. A potent antioxidant, ginger, an anti-inflammatory agent, is recommended for the prevention of hypertension and palpitation. Allicin lowers blood pressure and cholesterol. The omega-3 series has lipid-lowering properties and is prescribed for the treatment of arrhythmias. CVD could be managed by the supplementation of different lipid-lowering nutraceuticals along with maintenance of proper lifestyle. Polyherbal products could affect synergistically to achieve a potential therapeutic target.⁵

3. Parkinson's Disease

In Parkinson's disease, the dopamine-releasing cells in the brain get damaged because of neurodegeneration. It is the second most common age-related disorder in the world. Plant Polyphenols, stilbenes, soybean and other phytoestrogens, vitamin C, vitamin D, vitamin E, coenzyme Q10 and unsaturated fatty acid revealed protective roles against progression of Parkinson's disease. Herbal nutraceutical (Brahmi) is a natural brain tonic that helps in mental peace and relaxation, migraine, headache, insomnia,

depression, anxiety, brain cell rejuvenation, blood circulation in the brain, improved memory function, and hormone secretion. Researchers also used the dietary supplement inosine, a precursor to urate, for slowing the progression of Parkinson's disease.¹ Several vitamins, including vitamin B3, vitamin B9 or folate, vitamin B12, vitamin B6, vitamin D, vitamin E, and vitamin C, can be used in Parkinson's disease. The anti-Parkinson drugs currently employed prevent disease progression by providing symptomatic relief only. The main challenge lies in recognizing the ideal lead molecule, which, besides targeting multiple pathways and curing disease, is also the least toxic to humans. With this as the principal, a wide number of herbal and natural products have been studied clinically for use in PD to evaluate and clarify if such herbal molecules can be implemented as an independent or adjunctive therapy in disease management. It is hard to retrospectively study the effect of an herbal drug, food product, or supplement in a large population due to the high levels of variance and unreliability of results based on patients' statements and contributing lifestyle patterns. Thus, these challenges during clinical trials on synthesized herbal products restrict the emergence of identified lead molecules in the market.⁶

4. Diabetes Mellitus

Herbal dietary supplements containing nutraceuticals have proven to offer therapeutic benefit on type 2 diabetes. Soy isoflavones, omega 3, fatty acid lowers mortality and incidence of diabetes, promote insulin sensitivity, reduce glucose tolerance and bring blood sugar normal.. Green tea and epicatechin 3 gallate reduces fasting and postprandial glucose and improves insulin resistance. Bitter melon, pomegranates are good for diabetes which regulates metabolism and transports glucose from the blood into cells.⁵ In recent years, many herbal dietary supplements and



herbal medicines have shown benefits for type 2 diabetes mellitus in preclinical studies. However, only a few have been validated in well-designed randomized clinical trials. Isoflavones are phytoestrogens that have structural and functional similarities to human estrogen. Soy isoflavones have been researched the most, and their consumption has been linked to a lower risk and death rate from type II diabetes, heart disease, osteoporosis, and some cancers. Omega-3 fatty acids may help improve glucose tolerance in people at risk of diabetes. Insulin is necessary for making long-chain n-3 fatty acids, so the heart might be especially vulnerable to their lack in diabetes. Ethyl esters of n-3 fatty acids could be beneficial for diabetic patients.⁷

5. Alzheimer's disease

Alzheimer's disease is also termed as senile dementia. Antioxidants seem to delay the progression of disease. Nutraceuticals such as beta carotene, lycopene, curcumin, lutein and lavender utilize their antioxidant action to counteract oxidative stress mediated neuronal injury. These dietary molecules have the ability to postpone the onset of dementia. Many reports suggest that supplementation of folic acid and B12 vitamins reduce homocysteine level which in turn prevent disease progression.⁵ Nutraceuticals that are useful in the management of AD include super essential antioxidants, which could be used in the treatment of all chronic diseases due to oxidative stress, which plays a pivotal role in neurological disorders, including AD. The process of aging and lack of intake of dietary antioxidants accelerates oxidative stress resulting in disease progression and stimulation. Several studies have documented the intake of higher amounts of dietary antioxidants with reduced risk in patients suffering from AD, which is highly imperative as disease prevention is significantly cooler than treating it. Further, researchers propose that the prevention of

AD is not as complicated as it was assumed to be. The intake of food products rich in polyunsaturated fatty acids and saturated and trans fatty acids has a tendency to suppress neurodegeneration while foods rich in trans-fat can enhance neurodegeneration. The use of antioxidants for treatment is a promising option for slowing the progress and advancement of diseases.⁶

NUTRACEUTICALS IN SKIN CARE

The skin is the largest organ of the human body and is continuously ageing due to both internal and external factors. Internal factors are part of the so-called natural aging process within cells, but it can be accelerated by external factors such as UV radiation, tobacco, inadequacy of nutrition, and hormonal imbalance. These factors cause the formation of free radicals and inflammation, which act to fragment and degrade the collagens and elastic fibers. Over time, these internal and external influences sum up to lead to increased skin roughness, wrinkling, pigmentation change, telangiectasias, loss of elasticity, and decreased firmness that give skin its aged appearance.⁸ According to the European Nutraceutical Association definition, nutraceuticals are naturally occurring, non-toxic, bioactive compounds from animal, microbial, and plant sources that have disease prevention, health promotion, or medicinal properties. Although nutraceuticals can be an alternative to synthetic pharmaceuticals, in addition to being components of nutritive, functional foods, nutraceuticals can be used as pharmaceutical formulations. Especially when nutraceuticals are taken as foods, bioavailability may be relatively low, and tissue distribution may be poor compared with that of pharmaceuticals. Optimal efficacy of nutraceuticals requires proper functioning of hepatic phase II detoxification metabolism and of the gastrointestinal microbiota. There are several categories of skin-protective



nutraceuticals: probiotics, polyphenols, and vitamins. for aesthetic skin nutraceuticals contains several other categories including carotenoids, organosulfurs, polysaccharides, polyunsaturated fatty acids, quinones, and retinoids.⁹

NUTRACEUTICALS IN PREGNANCY

There is growing recognition that a mother's diet during pregnancy impacts the health of her offspring through epigenetic changes. Several studies have examined supplementation with micronutrients, such as omega-3 polyunsaturated fatty acids, minerals, and vitamins, including folic acid and vitamin D, during pregnancy to see whether they might help reduce the risk of conditions such as pre-eclampsia and prevent impaired fetal development, such as intrauterine growth restriction (IUGR). They are the leading cause of perinatal mortality and morbidity worldwide and appear to result from a failure of trophoblast invasion, with critical consequences for placental perfusion by maternal blood. These complications affect both pregnancy outcomes at delivery and the long-term cardiovascular health of affected women and their offspring. As well as micronutrient supplementation, a large number of pregnant women use many types of extracts for various purposes. The problem with the use of such products during pregnancy is that there are not sufficient studies to rule out possible effects on the correct development of the placenta and the foetus, so there is no regulation of their use. Many experimental studies have been carried out to analyze the effects of extracts of various herbs in animal models of mice or rats, but the results have often been contradictory. Many of these products affect the cytochrome P450 superfamily (CYP), which accounts for 65-80% of all CYP-mediated drug metabolism black elderberry, ginger and horsetail show potent inhibition of CYP1A2, while fennel and raspberry leaves inhibit CYP2D6 and CYP3A4.¹⁰

A low availability of dietary choline during pregnancy alters foetal brain biochemistry and hippocampal development. This induces behavioural changes which persist during the lifetime of the offspring. Humans having choline deficiency but with an otherwise balanced diet develop liver damage due to programmed cell death. Because de novo synthesis of choline is not enough to compensate this lack of choline (Zeisel, 2000).¹¹

Hypertensive disorders in pregnancy are among the most common medical complications, affecting 5% to 10% of pregnancies worldwide. These disorders include chronic hypertension, gestational hypertension, pre-eclampsia, and chronic hypertension with superimposed pre-eclampsia, being a major cause of maternal, fetal, and neonatal morbidity and mortality.

There is a lack of evidence-based data regarding the treatment of hypertension during pregnancy, with no evidence supporting what target blood pressure values should be reached. The management of hypertension in pregnancy depends on blood pressure levels, gestational age, and the presence of associated maternal and fetal risk factors. However, almost all drugs recommended by the latest international guidelines have a questionable safety profile for the fetus, so the risk-benefit ratio of this treatment should always be carefully considered in clinical practice for each individual.

Although non-pharmacological treatments have always been considered marginal in the management of hypertension in pregnancy, their role should be taken into account in light of the most recent evidence. As a matter of fact, randomized controlled clinical trials testing the efficacy and safety of dietary supplements in pregnancy are more numerous compared to conventional drugs, and their results seem to be promising.¹²



NUTRACEUTICALS IN LACTATION

Medical issues mothers encounter range from medication-related side effects of birth control and diuretics to hormonal endocrine disorders related to thyroid gland disorders and PCOS, including personal worries regarding their infant's weight, nutrition, and support within the home or workplace. The most specific concern of mothers with low milk supply is to increase lactation in order to prevent early breastfeeding termination. They may entertain options from friends and medical professionals based on perceived safety, ease, and affordability. The majority of them find success with nutraceutical and pharmaceutical interventions.¹³

Fenugreek (*Trigonella foenum-graecum*), native to India and Northern Africa, is one of the oldest known medicinal herbs. It is widely available and is often considered a natural solution for various conditions. Fenugreek contains compounds like diosgenin which it is believed act as precursors in the synthesis of steroid hormones, although such conversion typically takes place in-vitro and not via proteolytic cleavage within the human body. The galactagogue effect of fenugreek is said to be explained through its action on inducing perspiration, with the breast being a special form of "sweat gland". For lactation induction, it is said to be more effective if used within two weeks of delivery. As far as its use on humans is concerned, a survey conducted in the U.S. regarding 1,294 breastfeeding mothers consuming fenugreek, which were recruited through social media, reported 43% increase in supply, 12% maintenance, 24% no effect, 16% unsure, and 5% decrease. These results indicated that fenugreek may increase maternal milk production in the experimental group. Fenugreek has also been documented to raise serum prolactin and oxytocin levels in women, which was further reflected by infant weight gain, improvement in the

composition of breast milk, and increased milk volume.¹³

FUTURE PROSPECTS OF NUTRACEUTICALS

After virtually ignoring nutrition for the past century, even labeling anyone claiming benefits from vitamins or health foods as a food faddist or quack, now scientists and nutritionists are claiming that the connection between nutrition and disease is a new discovery. A new discovery it may be for those scientists who, for the past half century, have been scoffing at the first hand experiences and positive anecdotal reports of millions of consumers around the world, but for the food faddist whose ideas about nutrition have traditionally been much more consistent than those of scientists, there is little that is really new. Natural foods are best. Vitamins and other nutrients protect against disease. Nothing new here for food faddists. Science is however to be congratulated for finally listening to the food faddists.¹⁴ On the contrary, nutrition is only appraised to be a product for healthy living. In the forthcoming years, it is anticipated that work will be performed, as they both interact and complement each other. The implementation of newer technologies, such as the application of genetically modified technology in the food industry, nanotechnology-based nutraceuticals, etc., leads to better medical treatment and health care benefits, which further extended the increase in the nutraceuticals revenue market. The scientific research ratifies that the improved safety and potential effects of newly developed nutraceutical products will further stimulate the investments in newer technologies, such as nutrigenomics, converging techniques, varied imaging technologies, and their applications in nutrition development and healthcare.¹⁵



MARKET AND DEMAND

The growth in demand for bioactive ingredients for nutraceuticals and functional foods is explosive due to health concerns frequently cited: cardiovascular disease; breast, skin, colorectal, and brain cancers; female health concerns; CNS disorders; metabolism management; gastrointestinal disorders; and immunomodulation. A major problem found with the use of nutraceuticals in treating various diseases is that serious studies are not published with clear clinical evidence. Development, production, packaging, marketing, and sale have come a long way and are evolving.⁴

Nutraceuticals is a subject which is not so known to the people and it still needs awareness in common people regarding its use and ability for its potential. The lack of recognition in the market paired with the deficit marketing and distribution leads to the shortfall in the investments in the food research, and this is creating a huge challenge to the growth of nutraceutical industries in India. Due to this insufficient awareness in nutraceuticals, the manufacturing processes in several firms give negligible consideration to product extraction, enhancement of the shelf life, storage of the crude and prepared materials, meeting the quality standards of the ingredients and prevention from the contaminations. The negligence of the functional foods and nutraceuticals is not limited to social level but has reached out to the judicial level as well. There are many federal regulations which are not applicable to the food products or are still in progress which could restrain the natural products from getting supplied for the commercial purposes.¹

CONCLUSION

Nutraceuticals continue to evolve from traditional wisdom to scientifically supported therapeutic agents, offering safer and more holistic approaches

for maintaining health and preventing disease. Evidence from recent studies highlights their ability to combat oxidative stress, modulate inflammation, support metabolic functions, and enhance overall physiological balance. Their role in managing chronic disorders such as diabetes, cardiovascular diseases, neurodegenerative conditions, and complications related to pregnancy and lactation demonstrates their growing relevance in contemporary healthcare. However, despite their vast potential, the nutraceutical field faces challenges—particularly inadequate clinical validation, inconsistent manufacturing standards, and limited regulatory oversight. Strengthening research efforts, improving public awareness, and developing robust quality-control frameworks are essential for realizing their full therapeutic value. With continuous advancements in biotechnology, nanotechnology, and personalized nutrition, nutraceuticals are poised to become an integral component of preventive medicine and future health-care systems, supporting a shift toward safer, natural, and patient-centric therapeutic strategies.

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