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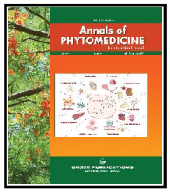

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Role of functional foods in health promotion and disease prevention: An overview

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Abstract

Good health is the primary concern of every individual and many developing countries are striving to achieve better nutrition by increased use of functional foods. Key elements in functional foods provide various health benefits, reducing the risk of chronic disease like cancer. To counter the challenges due to the changing scenarios such as demographic and epidemiological transition, urbanization, climate change, food insecurity, financial crisis, *etc*., health promotion has emerged as an important tool; nevertheless the need for newer, innovative approaches cannot be understated. Functional foods contain specific components that can help prevent diseases and promote wellness. These foods are consumed therapeutically since they have physiologically active components that provide several health benefits over and above nutrition. Herbal products or plant products rich in phenolic compounds, flavonoids, terpenoids, coumarins, and other constituents have shown multiple health benefits. In this review, a comprehensive and multifaceted approach is adapted to address stress management through the lens of nutrition. By highlighting the intricate connections between stress, eating patterns, and specific nutrients, this review provides a nuanced understanding of how dietary choices can contribute to a more resilient and balanced lifestyle. It emphasizes mindful eating practices further underscoring the importance of a holistic approach to well-being, where the nourishing power of food is harnessed to support both physical and emotional resilience. Incorporation of functional foods into daily diets is beneficial for their nutritional, healing, and pharmacological benefits. Therefore, increased consumption of diet-derived antioxidants may be particularly helpful by contributing to a better quality of life and world peace.

1. Introduction

It is a challenge of the modern era to serve and feed the ever-growing population with healthy and adequate nutritional food, which also does not harm the environment, it is produced in and corrects the problems of undernutrition, overnutrition, and inadequate nutrition. Starvation will put more pressure on the body plus other evils that are a threat to the lives of both the mind and physique. Consequently, the modern comforts have eradicated some issues and introduced new ones and the most famous are obesity and diabetes which go hand in hand with modern comforts available today in the developed countries. To address the challenges due to the shift in scenarios such as demographic and epidemiological transition, urbanization, climate change and insecurity, food crisis, financial crisis, *etc*., health promotion has come out as an effective approach (Rajeshwari *et al*., 2014). Foods containing a range of dietary bioactive compounds with notable health benefits are offering a significant chance to enhance public health and wellness (Gul *et al*., 2016).

On the other hand, health promotion has a much broader view, or rather a scope, and is supposed to respond to such occurrence which is either healthy or unhealthy in its impact on health, disparity, shift in the pattern of consumption, environment, and perception on culture. Most individuals look forward to eating foods that will be able to give their foods the highest nutrient density. Its future benefited from what could be scientifically described as functional foods, poised to halt ageing and diseases, apart from providing the essential nutritional requirements. Such strategies promote those who wish to have a slim body to improve their diet by taking whole and functional foods and increasing their physical activity (Benvenutti *et al*., 2021). Expanding this definition, functional foods with bioactive compounds have been defined and adopted for the prevention of chronic diseases and for maintaining systems in addition to essential nutrition. Thus, dietary nutraceutical supplements can help lower the risks associated with diseases. Functional foods and nutraceuticals highlighted in the recently advocated nutrition-based lifestyle studies could be effective in reducing various diseases. Overall, functional foods and nutraceuticals prescribed/tailored toward following dietary guidelines have significant potential for public health by addressing nutritional deficiency (Gul *et al*., 2016).

The relationship between nutrition and health has significantly grown in importance in recent years due to accumulating evidence that a balanced diet can decrease the risk of developing various degenerative diseases. Dietary compounds with functional attributes not only provide nutrients but may also offer additional health benefits that could enhance individuals' quality of life. They create an opportunity to reduce both the direct and indirect healthcare costs associated with multiple common chronic illnesses such as high blood sugar, heart diseases, uncontrolled cell growth, *etc*. In addition to supplying adequate nutrition, functional foods exert beneficial effects on one or

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more specific bodily functions that either promote overall health and wellness or decrease the chances of illness occurrence (Henson *et al*., 2008).

Broadening the concept, functional foods containing bioactive compounds have been recognized and implemented for preventing chronic diseases and maintaining systems beyond basic nutrition. There are two kinds of functional foods: traditional food produced from natural ingredients and modified food with supplementary health additives. They can come from plants, animals, microbial sources like probiotics, or even algae and mushrooms; these contain vital nutrients as well as non-nutrients like vitamins, minerals, and omega-3 fatty acids. Similarly, dietary nutraceutical supplements may help reduce disease risk. Green practices including functional foods and nutraceuticals emphasized in nutrition-based lifestyle approaches have the potential to mitigate a wide variety of health concerns. Overall, functional foods and nutraceuticals prescribed/tailored toward following dietary guidelines have significant potential for public health by addressing nutritional deficiency (Jha and Palta, 2011; Rajeshwari *et al*., 2013).

Health promotion is the process of enabling people to increase control over and to improve their health. To reach a state of complete physical, mental, and social well-being, an individual or group must be able to identify and realize aspirations, satisfy needs, and change or cope with the environment. Health is; therefore, seen as a resource for everyday life, not the objective of living. Health is a positive concept emphasizing social and personal resources, as well as physical capacities. Therefore, health promotion is not just the responsibility of the health sector but goes beyond healthy lifestyles to well-being (Tones, 2002).

Enhancement in health requires a secure foundation in these introductory prerequisites. Health creation as a term is associated with health education (Tones, 2002). Historically, there has been a shift from health education to health creation. The end of health education in its early days was to make people apprehensive of the health consequences. People were considered "empty vessels" that process information in a logical manner and latterly act consequently. Changes in individual opinion stations and behaviors were seen to affect the information and knowledge. The line of study was that if you give people with knowledge, they could make good opinions regarding their health. To be suitable to live a healthy life, individual provocation, chops, and the influence of the social terrain were honored as veritably important determinants as well. Just informing people is not enough. They also have to be encouraged, educated, trained, and eased to be suitable to ameliorate their health and change the terrain where they live (Koelen and van Ban, 2004). Living a healthy life depends on individual motivation, skills, and social influences. Informing people alone is not enough; they need education, training, and support to ameliorate their health and terrain. Health professionals have shifted from purely educational approaches to broader health creation (Tones, 2002).

2. Malnutrition remains a deep challenge

Years ago, when food was scarce and daily life needed more physical activity, people did not worry about being overweight and were concerned about simply getting enough to eat. Comforts have eradicated and generated modern developed world woes like obesity and diabetes. On the other hand, new evidence-based approaches that are more of solution-focused are being developed and embraced more. By these changing nutritional policies, those aspiring to lose weight are encouraged to partake in whole, healthy foods and exercise. These wise practices relate food consumption with health and a healthy lifestyle more healthily or consciously (Rajeshwari *et al.*, 2013).

Poor diets are responsible for the early mortality of mothers, infants, and young children and poor and always irreparable physical body and brain growth in the young. This, in turn, results in poor health into adulthood, both for the well-being of an individual and for the social and economic development of nations (DFID, 2004). There are now several forms of malnutrition that affect some countries, communities, or households at once: undernutrition, overweight and obesity as well as micronutrient malnutrition. Stunting, which reflects chronic undernutrition during the early stages of life, causes children to fail to grow to their full genetic potential, both mentally and physically. Increasing rates of overweight and obesity globally have been associated with increases in non-communicable diseases including cancer, cardiovascular diseases, and diabetes-deadly diseases that are straining our health facilities (Ng *et al*., 2014). The essential vitamins and minerals deficiencies (micronutrient) are still prevalent and have detrimental impacts on children survival and development, adolescent girls and women (Black *et al*., 2013).

Nutrition is a vital prerequisite of health and growth. There is adequate literature evidence of the interconnection between infection and malnutrition. Improved nutrition levels for the children results to stronger immunity thus lesser sickness and improve health standards. Healthy citizens learn better and are ready to work more, generate working opportunities that will pave a way to step by step elimination of poverty and hunger. Improved nutrition is the first step towards eradicating poverty and a sign post to improving standards in the quality of life (Xia *et al*., 2020). The right diet along with exercise and non-smoking helps reduce the occurrence of over 80% of the cardiovascular diseases, 70% stroke and 90% of type-2 diabetes. National Institute of Health has published that lack of physical activity and improper diet can lead to the development of more than 20 different diseases and several psychological disorders. Particularly, unfavorable eating and physical inactivity were leading risk factors for cancer, heart diseases, and diabetes. Various kind of epidemiological both retrospective and prospective, case control and diet intervention studies have hints to or proved that concentrate on plant foods which are rich in antioxidants play a significant role in preventing chronic degenerative diseases. There is evidence that suggests that prevention is the most sustained and less expensive way to handle chronic diseases (Ng *et al*., 2014).

The eradication of hunger and malnutrition are primary goals of sound health policies. Such policy should ensure access to sufficient quantities of healthy foods across culturally diverse populations. This newly designed, food and nutrition policies have to care and adopted the means of production and distribution of food stuffs; both in private and public sectors. Using an agricultural food and nutrition policy as well as economic and environmental approaches that provide a positive health effect on nations and on the international level, is something governments should strive for. The first goal in such a policy would be nutrition and diet goals. The tax and subsidy approaches should favor easy access for all people to healthy foods and better diets (Rajeshwari *et al*., 2013).

3. Differences between nutraceutical and functional foods

According to Hippocrates, the father of modern medicine, "Let food be the medicine, and the medicine shall be the food." This has increased attention on the health benefits specific foodstuffs may provide and how consumers and food and nutrition scientists have become keener on these benefits of foods (El Sohaimy, 2012). Sometimes, both the terms nutraceutical and functional food are equated as being the same, but they are indeed different. Nutraceuticals derive from biologically active compounds that may provide health benefits, and are usually supplemented in addition to food, but functional foods provide their benefit only as food (Jalgaonkar *et al.,* 2019).

Foods that enhance health and nutrition can be classified as nutraceuticals or functional foods. Nutraceuticals are isolated, purified, and formulated products taken in the form of capsules or pills. Functional foods are a part of a regular diet, providing physiological benefits above basic nutrition. Nutraceuticals are connected with medical claims and may prevent and cure diseases; these include dietary supplements and other specialized foods. Functional foods, on the other hand, decrease the occurrence of diseases but do not prevent or cure them. The essential nutrients, which are considered functional foods necessary for healthy survival, include vitamins, proteins, fats, and carbohydrates. When a functional food is used for the prevention or treatment of diseases other than anemia, it is referred to as a nutraceutical. Nutraceuticals and functional foods play a vital role in ensuring a good quality of life (Kalra, 2003).

4. Functional foods and their bioactive components

Moment, the scientific community echoes Hippocrates' statement as it recognizes some foods as functional foods. The Academy of Nutrition and Dietetics defines functional foods as "whole foods and fortified, enriched, or enhanced foods that have a potentially beneficial effect on health when consumed as part of a varied diet on a regular basis, at effective levels." Traditional systems of drug, similar as Ayurveda, highlight the significance of including specific super foods in the diet to meet nutritive requirements and enhance overall well-being (Gul *et al.,* 2016).

Super foods are particularly gaining attention not only as sources of essential nutrients but also because they're rich in bioactive composites, known as phytochemicals or phytoceuticals. These composites have functional properties that go beyond basic nutrition. For this reason, super foods are honored as "Functional foods," emphasizing their significance in ultramodern diets and holistic health approaches (Bouayed and Bohn, 2012).

The medicinal value of plants lies in some chemical substances that produce a definite physiological action in the human body. The most important of these bioactive constituents of plants are phenolic compounds, *viz*., tannins, flavonoids which are responsible for their antioxidant activity. Phytochemicals/bioactive compounds are non-nutritive plant chemicals, naturally occurring biologically active compounds in plants. The prefix 'phyto' is from a Greek word meaning plant. In plants, phytochemicals act as a natural defense system for host plants and provide color, aroma and flavor. More than 4000 of these compounds have been discovered to date and it is expected that scientists will discover many more. In fact, some people claim that many of the diseases afflicting human beings are the result of lack of phytonutrients in their diet (Awoyinka *et al*., 2007).

5. Categories of functional foods

Functional foods are classified according to their origin, which may be plant, animal, or microbial in nature, and sometimes also from algae and mushrooms. The primary and secondary metabolites from plants are the common source of functional foods. Examples include β-glucan, omega-3 and 6 fatty acids, phytoestrogens, and vitamins such as ascorbic acid and tocopherols (Figure 1). Plant proteins, amino acids, and compounds like soybean and flaxseed help reduce cholesterol levels and lower the risk of breast cancer and menopausal symptoms (Rajeshwari *et al*., 2013).

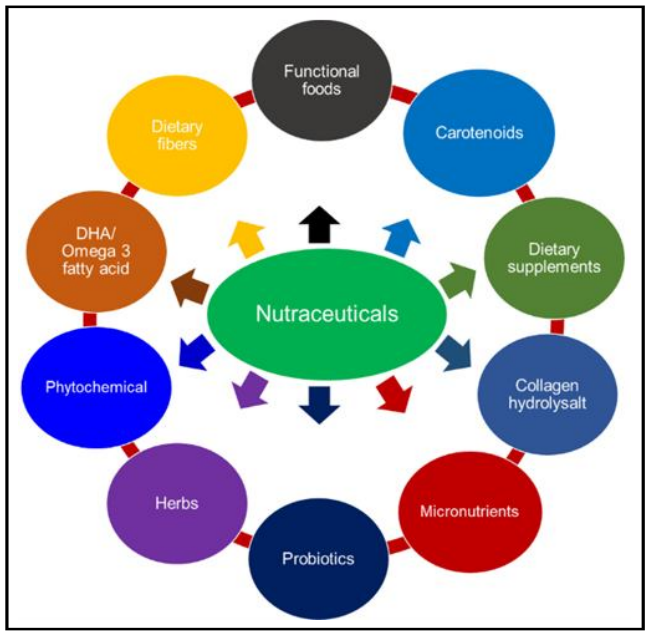

Figure 1: Types of nutraceuticals (Rajeshwari *et al*., 2014; Vighnesh *et al*., 2024).

Animal-derived functional foods rich in polyunsaturated fatty acids and milk proteins help improve immunity, reduce inflammation, and promote muscle mass. Fish like salmon contain EPA and DHA, while milk products like whey and casein are functional foods. Probiotics and prebiotics are the microorganisms that play a significant role in gut health. Probiotics found in the gastrointestinal tract are helpful in promoting beneficial microflora and regulating harmful bacteria. Prebiotics support the growth of probiotic bacteria, while synbiotics combine both probiotics and prebiotics for enhanced health benefits. Mixed functional foods may include ingredients like algae and mushrooms, which offer various health benefits. Algae, rich in PUFA, enhance the immune system and reduce inflammation, while mushrooms combat viruses and bacteria and reduce inflammation. Functional foods obtained from various sources offer an array of health benefits. These range from improving cardiovascular health to enhancing immunity and promoting gut health. Therefore, adding such foods to a balanced diet can help prevent various degenerative conditions and promote general wellness (Arshad *et al.,* 2021).

Dietary substances that possess functional characteristics have been divided into two categories, namely conventional or standard food and non-traditional or modified food, based on the extensive array of health advantages they offer. Such functional characteristics, which

are found in nearly all food types, should be formulated with the preferences of consumers considered. Prebiotics, probiotics, synbiotics, symbiotic foods, isoflavones, phytosterols, anthocyanins, antioxidants, and foods with reduced amounts of both fat and sugar are instances of functional food categories. While product preferences vary, their distribution among market segments is not consistent (Siro *et al*., 2008). In comparison to other food sectors, dietary substances with functional characteristics have predominantly been created in industries or facilities connected to milk, baby food, carbonated beverages, bakery goods, and sweets. Fortified foods are created using vitamins such as ascorbic acid and tocopherol, along with minerals like zinc, iron, and calcium, *etc*. Subsequently, focus shifted to foods containing various micronutrients along with soluble dietary fiber, phytosterols, and omega-3 fatty acids, to enhance well-being and protect against diseases such as cancer (Bigliardi and Galati, 2013).

6. Functional foods in disease prevention

Functional foods play a significant role in managing different diseases by providing bioactive compounds that support therapeutic outcomes. For diabetes patients, low-glycemic index foods such as whole grains and legumes regulate blood sugar levels, whereas ingredients like cinnamon and fenugreek improve insulin sensitivity. In cardiovascular health, omega-3-rich fish, nuts, and seeds lower cholesterol levels and improve vascular function. Functional foods also help in controlling hypertension by providing essential nutrients such as potassium and nitrate-rich foods to lower blood pressure (Habeeba and Mehta, 2022).

Inflammatory diseases like arthritis are treated with anti-inflammatory agents from turmeric and omega-3 fatty acids in fatty fish. Functional foods address the mechanisms that lie underneath, such as inflammation, oxidative stress, and hormonal imbalance, providing a complementary approach in disease management. They also play an important role in digestive disorders; probiotics and prebiotics keep the gut flora healthy. Antioxidant-rich foods protect against oxidative stress and may reduce cancer progression, while supporting bone density and brain health in age-related conditions (Rajeshwari *et al*., 2013).

Obesity and weight management can be benefited from high-fiber fruits and vegetables, which are satiety promoting, as well as compounds in green tea and chili peppers, which boost metabolism. Functional foods also support immune health by preventing infections, nutrient-dense ones that contain vitamins C, E, and zinc, and fermented foods improve gut health. Overall, functional foods represent a natural approach to disease management and complement conventional medical care for better health outcomes (Vighnesh *et al*., 2024).

6.1 Mechanism of action of functional foods in disease prevention

Optimal nutrition plays a pivotal part in supporting physiological processes essential for health. Several functional plant foods have been known for their traditional uses and many of the traditional preparations/prescriptions usually include extracts. This is mainly due to the concept that medicine would be highly effective if it is used in its natural state containing all the constituents rather than a single entity. Functional foods have more health benefits than mere nutrition. They improve gut health, heart and brain function, and immunity. Phytonutrients have various health benefits, for example, they may have antimicrobial, anti-inflammatory, cancer preventive, antidiabetic, and antihypertensive effects to mention but a few. The phytochemical constituent of a plant will often determine the physiological action on the human body (Awoyinka *et al*., 2007).

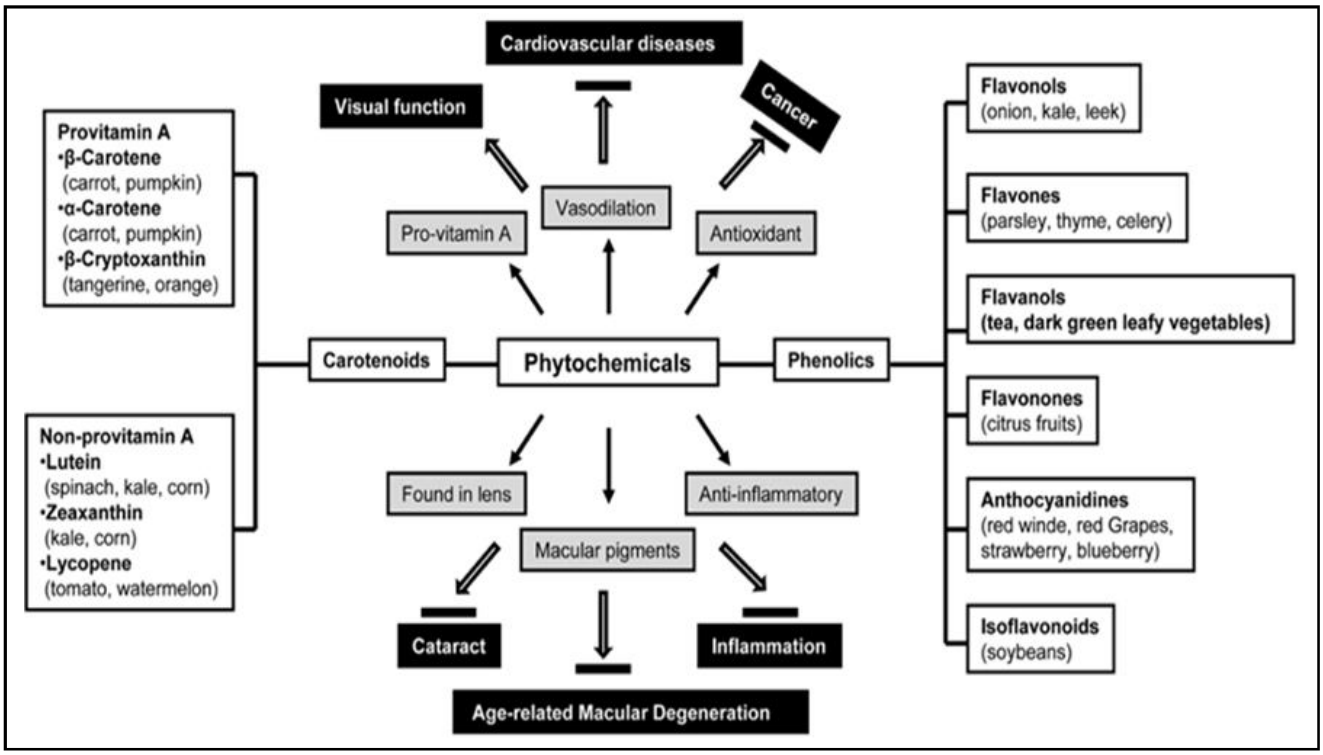

Figure 2: Multiple health benefits of phytochemicals (Rajeshwari *et al*., 2014).

Overwhelming evidence from epidemiological studies indicates that diets rich in phytoconstituents are associated with a lower risk of several degenerative diseases. Phytochemicals protect against stress-induced diseases as they adopt a multimodal therapeutic approach against multifactorial pathogenicity of diseases, *viz*., diabetes, (controlling blood glucose and lipids), cancer (inhibition of one or more of the stages of cancer process) and inflammatory diseases [inhibition of pro-inflammatory enzymes such as lipoxygenase (LPO), cyclo-oxygenases (COX-1 and COX-2)] (Rajeshwari *et al*., 2013a) (Figures 2 and 3), targets and drugs for effective disease management. Herbal products or plant products rich in phenolic compounds, flavonoids, terpenoids, coumarins, and other constituents show a reduction in blood glucose levels. Therefore, to combat the ever-increasing oxidative stress-induced diseases, increased consumption of diet-derived antioxidants may be particularly helpful as antioxidants, in diminishing cumulative oxidative damage (Rajeshwari *et al*., 2013). In contrast to current combination therapies; however, plant-based drugs contain a mixture of multiple components thereby saving considerable time and expense (Aggarwal *et al*., 2009).

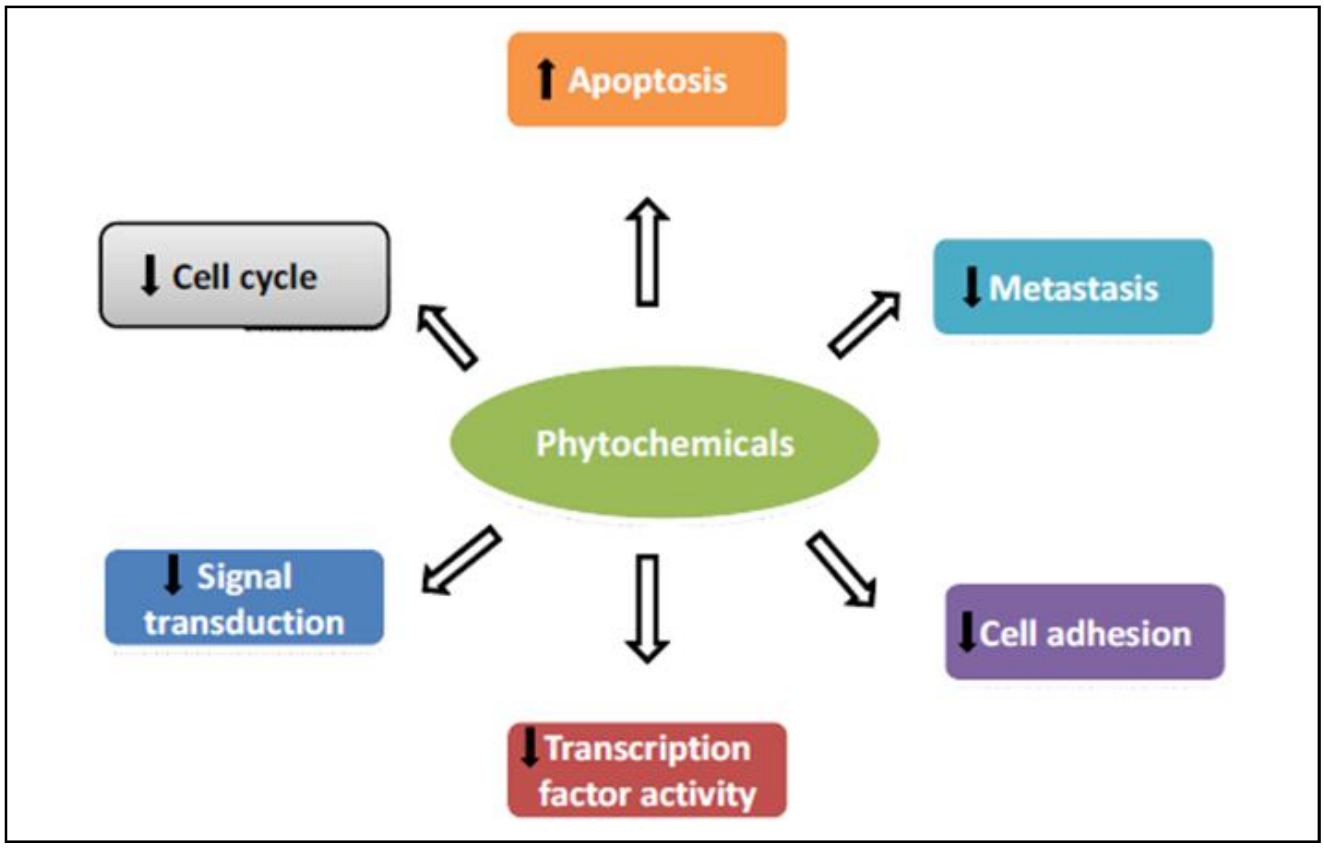

Figure 3: Therapeutic role of phytochemicals (Rajeshwari *et al*., 2014).

Some of the practical ways to introduce these foods into our daily diet include consuming probiotics such as yogurt and kefir for gut health, prebiotics like garlic, onions, and whole grains for the support of the microbiome, and omega-3-rich foods such as fatty fish and flaxseeds for cardiovascular and brain health. Other foods which can promote general well-being include antioxidant-rich fruits, fiber-rich vegetables, plant-based proteins, and sources of vitamin D. Anti-inflammatory and antioxidant effects can also be derived from the bioactive compounds turmeric and polyphenols. To achieve optimal benefits, diversify your food intake, introduce functional foods gradually, and maintain a balanced lifestyle with regular exercise and proper hydration (Rajeshwari *et al*., 2014).

7. Role of functional foods in mitigating stress

Stress is a challenge to the natural homeostasis of an organism, which can lead to physiological responses to regain equilibrium. Stress is a widespread issue where individuals experience significant emotional tension and find it difficult to manage specific pressures in life. These pressures manifest in various ways, ranging from traumatic incidents to daily obligations such as work and relationships (Rajeshwari *et al*., 2014).

7.1 The role of stress in diseases

Stress is a significant contributor to a wide range of diseases, from cardiovascular and metabolic disorders to mental health conditions and gastrointestinal issues. While stress cannot always be avoided, its impact on health can be mitigated through effective management strategies. Stress activates the hypothalamic-pituitary-adrenal (HPA) axis and the autonomic nervous system, leading to the release of hormones like cortisol and adrenaline. While these responses are beneficial in acute situations, chronic stress causes prolonged hormone exposure, resulting in negative health effects. It suppresses the immune system, reduces cytokine production, and impairs natural killer cell activity, thus increasing susceptibility to infections, slowing wound healing, and contributing to autoimmune diseases. Chronic

stress also increases blood pressure and heart rate, promoting inflammation and endothelial dysfunction, which increase the risk of cardiovascular problems, such as hypertension, atherosclerosis, and heart attacks (Rajeshwari *et al*., 2014). Stress in the brain impairs neurogenesis and synaptic plasticity in the Hippocampus, being associated with depression, anxiety, and post-traumatic stress disorder, and has been used to exacerbate neurodegenerative disorders such as Alzheimer's disease. It disrupts glucose metabolism and insulin function leading to obesity and type 2 diabetes, and worse, habits of eating to alleviate it. It also impacts gut health by altering motility, increasing intestinal permeability, and affecting the microbiota, which contributes to disorders like irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), and peptic ulcers. Although, stress does not directly cause cancer, it can influence tumor progression and metastasis by promoting angiogenesis and suppressing apoptosis in cancer cells (Benzie and Wachtel-Galor, 2009).

The pathological pathways of stress are associated with a complex interaction of molecular and physiological responses, leading to the body being in a state of disease. Stress triggers mechanisms like persistent low-grade inflammation, altered ion secretion, heightened epithelial permeability, and dysfunction of the stress system. Corticosteroid hormones, through mineralocorticoid and glucocorticoid receptors in the brain, are required to manage adaptation and recovery but impair these same processes under chronic stress and cause homeostatic failure (Khan *et al*., 2024). This impairment contributes to the development of diseases such as atherosclerosis, non-alcoholic fatty liver disease, depression, irritable bowel syndrome, and inflammatory bowel disease. Chronic stress fosters pathways like mild inflammation and signaling networks, which are significant in the pathogenesis of these diseases. Understanding these common pathological mechanisms is essential for developing a more effective treatment approach for stress-related disorders. The researchers believe that they can decrease the potential effects of chronic stress on their patients by identifying and attacking these pathways and enhance health maintenance and homeostatic intervention (Panickar and Anderson, 2011).

Nutrition is the best way to handle stress as it brings the body into a state of optimum health balance. Functional foods derived from plants such as adaptogens, mushrooms offer a wealth of benefits for stress relief. Customizing one's diet to include functional foods can significantly enhance stress management leveraging the natural therapeutic properties of plants. The antioxidants and phytonutrients such as B vitamins, omega-3 fatty acids, magnesium, vitamin C, and probiotics found in functional foods play a crucial role in stress reduction and also help improve body's response to stress and fight stress-related free radicals. Some studies indicate that certain foods such as polyunsaturated fats like omega-3 fats and vegetables may play a role in managing cortisol levels. The energy production and neurotransmitter synthesis that B vitamins-rich food like legumes and dairy help with also aid in mood regulation. Amino acids, especially tryptophan, are known to be present in egg and turkey, which increase serotonin and hence emotional well-being (Martirosyan and Singharaj, 2016).

7.2 Functional foods as stress busters

"Functional Food" operates in the body in a targeted manner that assists in lowering the risk of various diseases by producing physiological effects beyond just nutritional benefits. As a result, research on the effectiveness and safety of medicinal plants with such functional components would provide the most essential information regarding herbal medicines to the pharmacologist. The primary function of functional foods is the support of the body's response to stress through provision of crucial nutrients, enhancing both the mental and physical condition. These foods are helpful in modulating hormone levels, diminishing inflammation, and even promoting improved brain functioning in dealing with the harmful impacts of chronic stress. The consumption of nutrients, such as omega-3 fatty acids from fish and nuts, may lead to reduced symptoms of depression and stress, owing to their anti-inflammatory and supporting effects on brain functioning. Magnesium, which is present in leafy greens and whole grains, is said to balance the stress-response system and reduce anxiety (Benzie and Wachtel-Galor, 2009).

Antioxidant-rich fruits and vegetables combat oxidative stress caused by chronic stress, protecting cellular health. Furthermore, foods supporting the gut-brain axis, such as probiotics (yogurt, kefir) and prebiotics (bananas, garlic), enhance gut health, which is closely linked to mental well-being (Benzie and Wachtel-Galor, 2010). By including these functional foods in their diet, individuals can improve their management of stress and its physiological effects (Ciferri and Giffard, 2020). Mindful eating can also help to recognize true physiological hunger, but due to psychological distress one may eat more as a way of coping (Rajeshwari *et al*., 2014).

The analysis of nutraceutical therapeutics reveals promising approaches for managing stress, offering a thorough strategy to modulate oxidative stress, inflammation, and neuroplasticity. With growing recognition of the mind-body relationship, integrating nutraceutical interventions into clinical practice presents substantial potential for enhancing resilience and fostering mental well-being. Nutraceuticals, and polyphenols especially, are considered to target the stress management process through oxidative stress and inflammation. Polyphenols are abundant in plant-based food components and have well-documented antioxidant properties that may help attenuate cellular damage and provide protection against stress. Polyphenols regulate key biological pathways to improve mitochondrial functions and enhance antioxidant defenses. Therefore, the overall influence on stress reduction is generated by these molecules (Khan *et al*., 2024). Certain polyphenols, like resveratrol and epigallocatechin gallate (EGCG), have distinct ways to counteract stress. Resveratrol, which is found in grapes and berries, promotes mitochondrial biogenesis and reduces oxidative damage to enhance cellular stress resistance as well as improve energy production. EGCG, one of the major catechins in green tea, decreases inflammation by modulating the NF-ºB pathway and enhances the body's antioxidant response via the Nrf2 pathway, which shows neuroprotective benefits (Eugeny and Natalia, 2019). Other types of polyphenols are flavonoids, which further contribute to stress management through their antioxidant and anti-inflammatory effects. These widely distributed phytonutrients in fruits and vegetables protect cells from damage and support a balanced inflammatory response. Polyphenols and flavonoids constitute powerful nutraceuticals for the support of resilience against physical and mental stress (Goldstein and Kopin, 2010).

7.3 Functional foods in weight management

The effectiveness and practicality of using functional foods to suppress appetite are key elements in weight management. Functional foods are formulated to increase satiety and suppress appetite, which leads to weight loss. Such foods should have limited flavors and tastes to make them less palatable, thus reducing the chances of overeating. Incorporation of fibers into low-calorie products can alter the texture and taste while reducing palatability (Sander *et al*., 2020). Regular intake of functional foods helps mitigate metabolic syndromes, such as obesity and gastrointestinal disorders, by causing fullness and reducing appetite. The various functional components include fibers, polyphenols, carotenoids, and ginger, which act through multiple mechanisms to facilitate weight control. For instance, dietary fibers cause feelings of fullness, whereas polyphenols activate AMP-activated protein kinase (AMPK) to regulate metabolism. Moreover, carotenoids improve metabolic parameters, and ginger may influence obesity through various mechanisms. Overall, functional components in food play a positive role in weight loss (Deighton *et al*., 2016).

7.4 Role of exercise in augmenting effects of functional food

The role of exercise and physical activity in enhancing effects of functional foods is important to prevent diseases like obesity, diabetes, and cardiovascular disease. Exercise along with the ingestion of functional foods may decrease lipid peroxidation and inflammation. Strength training is recommended primarily for weight loss. Adding strength training to functional foods enhances compliance and long-term compliance in obese subjects. Also, strength training is proven to be effective in lessening postmenopausal-related vascular risks (Suchomel *et al*., 2016).The pathological pathways of stress are associated with a complex interaction of molecular and physiological responses, leading to the body being in a state of disease. Stress triggers mechanisms like persistent low-grade inflammation, altered ion secretion, heightened epithelial permeability, and dysfunction of the stress system (Klonizakis *et al.,* 2013).

Corticosteroid hormones, through mineralocorticoid and glucocorticoid receptors in the brain, are required to manage adaptation and recovery but impair these same processes under chronic stress and cause homeostatic failure. This impairment contributes to the development of diseases such as atherosclerosis, non-alcoholic fatty liver disease, depression, irritable bowel syndrome, and inflammatory bowel disease. Chronic stress fosters pathways like mild inflammation and signaling networks, which are significant in the pathogenesis of these diseases. Understanding these common pathological mechanisms is essential for developing a more effective treatment approach for stress-related disorders. The researchers believe that they can decrease the potential effects of chronic stress on their patients by identifying and attacking these pathways and enhance health maintenance and homeostatic intervention (Khan *et al*., 2024).

8. Nutraceuticals and their therapeutic value

Epidemiological studies suggest that phytochemicals which are plant derived bioactive compounds have a protective effect towards diseases such as cancer, heart disease, hypertension and stroke (Figure 4) (Rajeshwari *et al*.,2014). It is well known that a number of key groups such as polyphenols and vitamins C and E are major contributors towards the antioxidant properties of plants. It is these phytochemicals that are able to counter reactive oxygen species and therefore help in combating degenerative diseases. These compounds are however present in vegetables, fruits, leaves, flowers, and roots as part of the plant. Phytochemicals are broadly classified as primary components which are sugars and proteins, and secondary components which are alkaloids flavonoids and tannins these compounds are the main bioactive agents which aid in the disease prevention properties (Krisnaiah *et al*., 2009; Vighnesh *et al*., 2024).

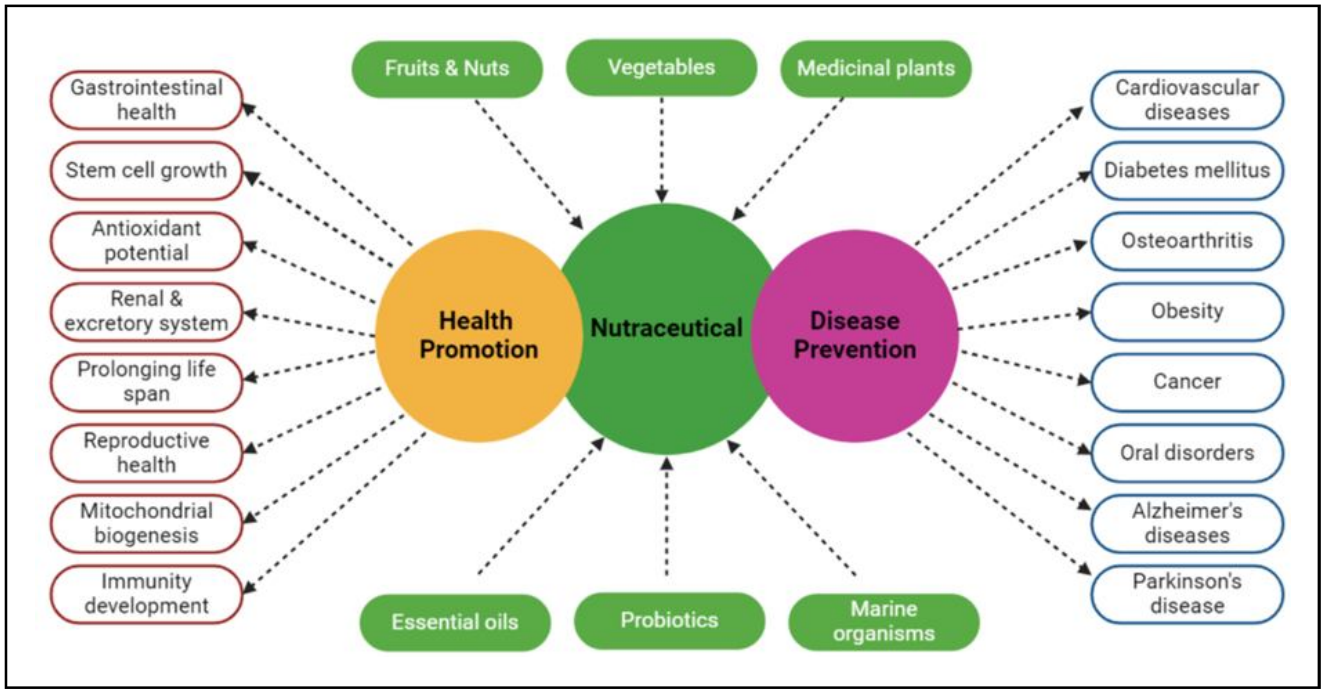

Figure 4: Health benefits of various nutraceuticals (Rajeshwari *et al*., 2014; Vighnesh *et al*., 2024).

Secondary metabolites are a group of compounds in the plants that do not get involved in primary metabolism and are known to be involved in adaptational and survival mechanism. Studies on the dynamics of secondary metabolism indicated that there is a definite turnover of these compounds evidenced by diurnal variation, seasonal variation and different stages of development. Alkaloids, terpenoids and phenolics are the three major classes of secondary metabolites. Phenolics act as antioxidants and protect cellular membranes and tissues containing lipids against oxidation, anthocyanins and flavonoids act as pollinator guide for insects as they are responsible for attractive coloration in flowers, all sulphur containing compounds are antimicrobial in nature and cardiac glycosides, used by plants to protect from herbivore, can be used in the treatment of heart diseases (Daniel, 2006).

Drugs of plant origin have failed to gain their importance in the pharmaceutical industry due to the lack of coordination between pharmacologist, chemist, botanist and clinicians. Research on some of the experimental animals has raised ethical problems and has laid emphasis on alternative methods which are advanced. Therefore, many non-animal approaches have been used to overcome the limitations (*viz*., discomfort, pain, fear, stress and suffering) of animal studies (Tweats *et al.,* 2007; Wood *et al.,* 2008). Many new advanced methods (using tissues, cells, physicochemical techniques and computer modelling) are being used to overcome the limitations of animal studies. Some of the antioxidant potential assays used for food stuffs are also used for plasma and tissues. But these *in vitro* methods do not indicate the response of these antioxidants in the human body during metabolism and absorption (Langley *et al*., 2007).

Computational (*in silico*) methods are being used for generating pharmacology hypothesis and testing. Computer-assisted drug design (CADD) aims to discover, enhance and study the biologically active molecules to develop in to a drug. It actually predicts whether a given molecule binds to a target strongly. Such methods have seen frequent use in the discovery and optimization of novel molecules with affinity to a target, the clarification of absorption, distribution, metabolism, excretion and toxicity properties as well as physicochemical characterization (Ekins *et al*., 2007).

Reverse pharmacology approach can be the best method which integrates documented clinical and experimental hits into leads that are further developed into drug candidates or formulations through more systematic and precisely designed preclinical and clinical research (Patwardhan and Mashelkar, 2009). Due to lack of clinical and scientific data there is no amalgamation of herbal medicine into medical practices which can be done by testing traditional and new herbal products. Therefore, search for many crude drugs of plant origin with antioxidant activity has become a central focus of research. Phytochemicals present in functional foods have a defensive role against disorders, which helps in lowering the threat of oxidative stress-induced diseases, thus enhancing a better quality of life (Rajeshwari *et al*., 2014).

Functional foods have more health benefits than mere nutrition. They improve gut health, heart and brain function, and immunity. Some of the practical ways to introduce these foods into your daily diet include consuming probiotics such as yogurt and kefir for gut health, prebiotics like garlic, onions, and whole grains for the support of the microbiome, and omega-3-rich foods such as fatty fish and flaxseeds for cardiovascular and brain health. Other foods which can promote general well-being include antioxidant-rich fruits, fiber-rich vegetables, plant-based proteins, and sources of vitamin D. Anti-inflammatory and antioxidant effects can also be derived from the bioactive compounds. To achieve optimal benefits, diversify the food intake, introduce functional foods gradually, and maintain a balanced lifestyle with regular exercise and proper hydration (Rajeshwari *et al*., 2013a).

9. Future research and challenges in functional foods

Future research on functional foods will include the biological pathways through which they act, including gut microbiome interactions and molecular targets. Future research on functional foods also focuses on personalizing nutrition, tailoring foods to individual genetics and lifestyles. The clinical trials will study their potential role in managing chronic diseases, such as cardiovascular conditions, diabetes, and neurodegenerative disorders. The mental health studies will be related to the effect of nutraceuticals on mood, stress, and cognitive functions. Nutraceutical research will further focus on optimizing bioavailability, examining synergistic effects, and finding sustainable and novel ingredients. Efforts will be made to establish regulatory standards, integrate new technologies and study consumer behaviour to improve the accessibility and impact of functional foods on public health (Falk *et al*., 2002).

Interdisciplinary research envisages the integration of fields such as genomics, microbiology, nutrition science, and food technology is essential in overcoming these challenges to fully bring about the potential of functional foods into the consumer world. Developing nutraceuticals and functional foods is a complex and costly process, with regulatory challenges, the need for health claim proof, and the risk of innovation (Ciferri and Giffard, 2020). Food companies traditionally fund research for new products, but in the case of functional foods, the risks are higher for both companies and consumers. Exclusive ingredients may be patented, but many products use common ingredients that can easily be copied, thus reducing the competitive advantage for the inventor. Moreover, proving health benefits through scientific evidence is hard because it is hard to identify biological markers, conduct long clinical studies, and find effective doses. Despite these challenges, the functional food and nutraceuticals market continues to grow, with some stand-alone products, such as Nestle and Benecol, that have already shown health benefits. The focus of most food companies has been on "functionalizing" conventional products, mainly by adding vitamins, minerals, or herbal extracts to them rather than designing new products. The complexity of natural bioactive compounds and their mechanisms of action can make it difficult to identify those with the most significant health benefits. Furthermore, ensuring their stability and bioavailability in food matrices is a challenge (Leroy and Rybowski, 2021).

There is growing interest in functional foods because they have the potential to offer benefits beyond basic nutrition, like improving immunity, reducing the risks of chronic diseases, and improving overall well-being. However, there is a need for more clinical trials and research on specific functional foods for safety, efficacy, and long-term impact. Many functional foods, such as probiotics, fortified foods, and bioactive compounds, have been preliminarily proven to be useful, but rigorous, large-scale clinical trials are needed to verify these claims. Clinical trials can give adequate evidence on optimal dosages, mechanisms of action, as well as interactions with medicines

or other dietary components. Some studies should be conducted by focusing on specific populations, such as children, the elderly, or those with chronic illnesses, to assess the advantages or risks for different groups. Such research helps build a solid scientific base, guiding public health policy, and ensuring that the consumer can make informed choices about adding functional foods into their diet.The literature is growing with regard to functional foods but remains limited due to the methodological approach and biased issues, including study design, funding conflict, small sample size, and lack of standardization (Alpert and Zhai, 2019).

There is a need for more robust, long-term, and large-scale studies that take into consideration diverse populations and complex interactions between diet and health. Moreover, the funding sources of the industries must be considered for their possible biasing effects, and the use of standardized definitions and methodologies must be encouraged for meaningful cross-study comparisons to be made. Only then can a clearer and more accurate picture of the potential benefits and risks of functional foods be established (Prakash, 2015).

10. Conclusion

In conclusion, the role of functional foods in promoting health and preventing diseases has been crucial due to their supply of bioactive compounds that would enhance bodily functions and mitigate the risk of chronic diseases. Their capability to facilitate cardiovascular health, manage blood sugar levels, improve gut health, and strengthen immune function makes them important elements in a well-balanced diet. There are promising areas for functional foods, particularly in the management of stress. These include compounds like omega-3 fatty acids, adaptogens, and polyphenols, which affect mood, cognitive function, and the body's response to stress. As the specific mechanisms and benefits of these foods continue to emerge, they are likely to be an integral part of strategies for preventive healthcare, offering natural and accessible ways to better well-being and to soften the blow of stress and disease. Thus, a holistic approach towards healthy well-being, would help us to cope with stress whether physical or emotional in nature. Therefore, increased consumption of functional foods may be particularly helpful by contributing to a better quality of life and to world peace. However, further research is encouraged to fully understand the potential of these 'Functional foods' and to explore new ways to leverage their benefits for human health.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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