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Functional Foods: Middle Eastern and Asian Studies

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Abstract Functional foods contain a specific ingredient that claims to improve health. Many studies have been done to prove the beneficial effects of these foods, which led to manufacturers' increased focus on the concept of functional food. In this review, we will discuss the concept of functional foods and their effects on health and distinguish the functional components, such as prebiotics and probiotics, in terms of their uses and special benefits. Moreover, we will provide background information on the global market for functional foods focusing on the Middle East and Asia, including the latest studies on probiotics, prebiotics, and their prospects.

Keywords: *Asia, functional foods, Middle East, prebiotics, probiotics*

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1. Introduction

Changes in lifestyle, diet, and increased consumption of junk food may cause many health problems, such as obesity, diabetes, cancer, and osteoporosis, in addition to many other diseases related to nutritional deficiencies [1,2]. Consumers have shown great interest in the active role of food in prolonging life via disease prevention. Hence, the term 'functional food' was suggested to describe food that may provide health benefits and prevent chronic diseases affected by diet [3,4,5]. Functional foods are significant in maintaining a healthy lifestyle; a healthy diet and physical exercise can confer many metabolic heart-protective benefits [6]. As the primary role of food is to sustain life, provide nutrients for the body, and produce energy, functional foods such as food fortified with probiotics, omega-3 fatty acids, antioxidants, minerals, and vitamins have expanded on this role [3,4,5]. Functional foods encourage scientists to investigate more in-depth, not just the food necessary for living and well-being but also the potential to prevent several chronic diseases and benefit human health [3,4,5].

The history of functional food began in the 1980s when a Japanese company started focusing on preventing lifestyle-related diseases by producing foods such as yogurt and *Lactobacillus acidophilus* milk [7]. Following this awareness, many food sector companies in the United States began to pay closer attention to the concept of functional foods for their consumers. An important aspect that requires attention is the safety and quality of food during the food production process, which needs to follow international standards [8]. Prebiotics, probiotics, carotenoids, and flavonoids are some examples of functional food components that have various beneficial effects; these include effects on the immune system, gastrointestinal tract, and gut microbiota composition [9]. In addition, probiotics can enhance non-pathogenic facultative anaerobes and gram-positive bacteria growth by stimulating B-group vitamin production and inhibiting pathogenic bacteria production by producing fatty acids and hydrogen peroxide (H_2O_2) [10,11]. When used in agriculture, probiotics can improve plant growth through increased photosynthesis rates and the production of growth hormones with other active substances [12,13]. Many studies have also shown that probiotics can increase plant performance, induce immunity, and ensure plant health [14]. For example, plant probiotics such as *B. animalis* and *L. acidophilus* have been commercially developed to control plant diseases and fertilization of plants; they have shown positive effects on rice, corn, and wheat [14]. Studies show that pseudomonads can benefit plants by increasing water, salt, and heavy metal stress tolerance, improving growth and nutrition, and reducing systemic resistance by colonizing plant roots [15]. Another study on strawberry plants shows that Phyllobacterium species can produce biofilms, colonize the plant roots, and increase plant quality and yield. Moreover, strawberries from the plant inoculated with the microorganism had a higher vitamin C content than plants not inoculated [16]. A better understanding of plant probiotics may help sustain agriculture's productivity and quality [17].

This review aims to highlight the health benefits of different functional foods and their uses, document studies on probiotics and prebiotics in the Middle East and Asia, and finally explore their prospects. The advantage of this review is that the beneficial effects of functional foods have been examined by type of food, highlighting the contribution of each food. The global market for functional foods is also included and can serve as a benchmark for the Middle Eastern and Asian markets, which can serve as an emerging source of revenue. Finally, we hope this review will provide collected information on aspects of functional foods from this region, as data is currently limited.

2. Functional Foods in Global vs Middle East Markets

The functional food market is growing due to factors impacting the sector, such as health claims. Japan is the provider of the functional foods market, followed by the US and Europe [18]. The Middle East and other developing countries show lower attraction of growth because of the high risk of potential investment; this could be due to the expensive price of functional foods in this region [18,19]. In 2022, according to the report published by The Business Research Company, the global functional food market size reached $203.64 billion and is expected to reach $229.7 billion in 2023 with a compound annual growth rate (CAGR) of 12.8%. The report stated that in 2027 the global functional foods market will grow from $354.96 at a CAGR of 11.5%, as shown in Figure 1. Demand for functional foods will increase, including carotenoids, dietary fibers, fatty acids, minerals, probiotics, prebiotics, and vitamins. The countries included in this report are Australia, Brazil, China, France, Germany, India, Indonesia, Japan, Russia, South Korea, the United Kingdom and the United States of America [20]. On the other hand, the growth of the functional foods market in the Middle East and Africa reached $12,148.25 million in 2021, and the market growth is expected to increase to $20,921.97 million by 2028 with a CAGR of 1.8% from 2021 to 2028. It is worth noting that in 2020, the functional food market in Saudi Arabia was the most growing [21].

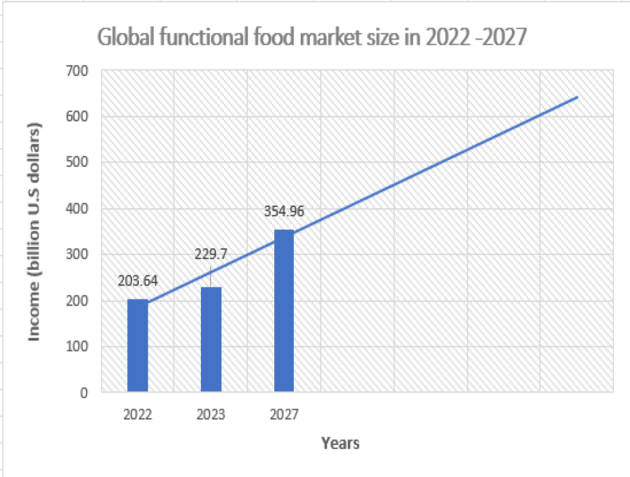

Figure 1. Global functional food market size 2022 and projected growth from 2023 - 2027 [20]

3. Types of functional foods components

Functional foods are rich in bioactive ingredients that help promote health and prevent disease. This is achieved when these foods are used in sufficient, specific, and non-toxic quantities. Because of the variety of nutritional benefits of functional foods, they have been divided into two main groups: conventional foods and modified foods, as shown in Figure 2 [22].

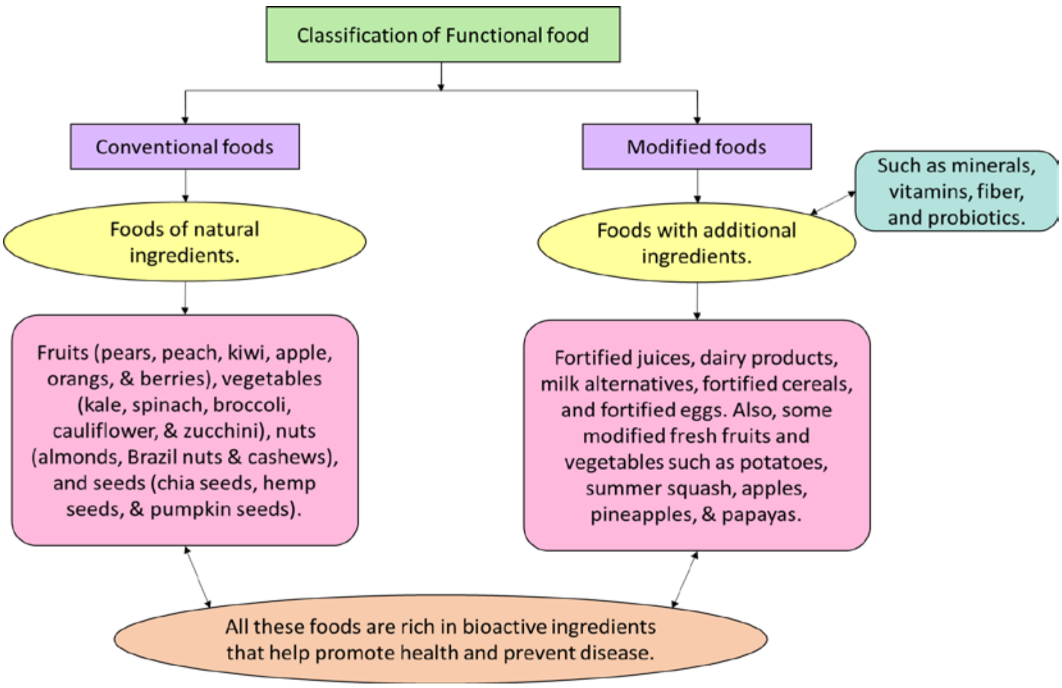

Figure 2. Classification of Functional Foods. This flow chart shows the two main classes of functional foods: conventional foods (Natural ingredients) and Modified Foods (Additional ingredients). Also, it shows examples of foods for each class

Conventional foods are unmodified foods with natural ingredients or complete biologically active ingredients with beneficial health effects [22,23]. Heart-healthy fats, antioxidants, minerals, and vitamins are all considered conventional foods. Modified foods are foods with added ingredients to increase the biological benefits and their positive effect. Additional ingredients may be minerals, vitamins, fiber, and probiotics. Fortified foods are examples of modified foods, such as fortified juices, dairy products, milk alternatives, fortified cereals, and fortified eggs, as shown in Figure 2. In addition, the development of genetic modification or genetic engineering technology has led to genetically modified functional foods that can achieve food security worldwide and reduce famine and malnutrition [22]. For example, agricultural plants benefit most from genetic modification, as it helps increase yield, lower the cost of production, reduce agricultural pesticides, and enhance disease resistance [24].

On the other hand, functional components in functional foods are classified based on several classes; these are prebiotics, probiotics, carotenoids, flavonoids, dietary fibers, fatty acids, minerals, vitamins, polyols, phenolic acids, plant stanols and sterols, phytoestrogens, soy protein, sulfides and isothiocyanates which will discuss below [25].

3.1. Prebiotics & Probiotics

Prebiotics such as inulin, fructo-oligosaccharides (FOS), and polydextrose are found in many sources, such as whole grains, onion, honey, leeks, and bananas. Prebiotics help human health by supporting digestive health and calcium absorption and have been known to stimulate the growth of probiotics [5,25]. Probiotic or beneficial microbes such as yeast, lactobacilli, Bifidobacteria, and other organisms are shown in Table 1, and these can be found in yogurts and dairy and non-dairy applications [26]. So, bacteria that positively impact human health when administered appropriately are called probiotics or beneficial bacteria [27,28]. The beneficial effects of probiotics differ between strains. They can directly interact with intestinal microbiota and enzyme activities. Also, they interact with the intestinal epithelium and mucosal layer, thus affecting the mucosal immune system and the function of the intestinal barrier [29,30].

3.2. Carotenoids

The carotenoids are a widely dispersed pigment group now available as supplements [42]. The most studied carotenoids are beta-carotene, lutein, zeaxanthin, and lycopene [43]. These carotenoids can be found in carrots, pumpkins, eggs, spinach, tomatoes, watermelon, corn, and grapefruit [44,45]. Some of the benefits of carotenoids are to neutralize radicals that can cause damage to cells and to maintain eye health and prostate health [46]. In a randomized controlled trial of 233 participants, whole grain corn with a high content of carotenoids has been found to lower blood pressure, thus reducing cardiovascular disease risk [47].

3.3. Flavonoids

Flavonoids are compounds derived from plants and labeled as one of the functional components as they possess biochemical properties that positively impact human health. These active compounds work as antioxidants and anti-cancer agents [44]. They support maintenance for healthy brain, heart, and urinary tract function and neutralizing free radicals [44]. Flavonols, flavanones, isoflavonoids, flavones, chalcones, and anthocyanins are the six subgroups of flavonoids [48]. Various epidemiological studies have reported that high flavonoid consumption reduces the risk of diabetes, cancers, and cardiovascular diseases [47].

3.4. Dietary Fiber

Dietary Fiber is a component of plants that can be found in the diet, and it is resistant to enzymatic digestion [49]. The two basic categories of dietary fiber are soluble and insoluble fibers, which can be found in wheat bran, corn bran, psyllium seed husk, peas, and beans [44,49]. Other types of dietary fiber are β-glucan and whole grains found in barley, oat bran, brown rice, and cereal grains. These dietary fibers are essential for maintaining digestive health, reducing the risk of coronary heart disease (CHD) and some types of cancer, and maintaining healthy glucose levels [50]. Another epidemiological study found a link between the incidence reduction of intestinal cancer and inflammatory diseases with consuming a rich diet in dietary fibers and refined carbohydrates [51].

Table 1. Examples of major probiotic species, the food source, and beneficial effects

Genus	Probiotic microorganism	Type of food added to	Probiotic effect	References
Lactobacillus	L. acidophilus L. gasseri L. reuteri L. johnsonii L. rhamnosus	Yogurt	-Prevent colonic hyperplasia in mice. -Immune response modulation in chicken.	[31,32,33,34]
Bifidobacterium	B. adolescentis B. animalis B. longum	Pickles, yogurt	-Antimicrobial substances production against pathogens in chicken.	[32,35,36,37]
Saccharomyces	S. boulardii S. cerevisiae	Bread	-Stimulate immune response in agriculture. -Inhibit pathogens by producing inhibitory substances.	[10,32,38]
Bacillus	B. subtilis B. coagulans	Yogurt, sauerkraut	-Bacteriocins production in agriculture. -Stimulate immune responses.	[10,32,38]
Streptococcus	S. pneumoniae S. thermophilus	Yogurt	-Mortality reduction in layer chickens.	[39,40]
Enterococcus	E. durans	Cheeses, milk	-Animal growth stimulation	[32,41]

3.5. Fatty Acids

The fatty acids include monounsaturated fatty acids, polyunsaturated fatty acids, omega-3 fatty acids, and conjugated linoleic acid [52]. These functional components are found in many sources, such as tree nuts, olive oil, walnuts, flaxseed oil, salmon, fish oils, beef and lamb [44,53]. Fatty acids significantly reduce the risk of CHD, helping maintain eye, heart, and mental health and support immunity [53]. In a study conducted to estimate the effect of fatty acids such as eicosapentaenoic and docosahexaenoic acid on CHD risk, the study results showed that intake of both fatty acids could affect the risk of CHD, especially amongst the higher-risk population [54].

3.6. Minerals

Minerals like calcium, magnesium, potassium, and iron benefit health when provided sufficiently [55]. They can be found in sardines, spinach, beans, almonds, potatoes, whole grain bread, bananas, fish, liver, and red meat [44,56]. Minerals support muscle and nerve functions, reduce osteoporosis, lower high blood pressure, minimize stroke risks, and maintain good immunity [57].

3.7. Vitamins

Vitamins are another class of functional components essential in supporting and improving human health [58]. These have antioxidant activity, so they prevent oxidation, which is linked to many conditions, such as cancer and arthritis [59]. Vitamins comprise many types, including vitamin A, thiamin (B1), riboflavin (B2), niacin (B3), pantothenic acid (B5), pyridoxine (B6), folic acid (B9), biotin, cobalamin (B12) and vitamin D [44,60]. A randomized controlled trial that reported the effect on schizophrenia symptoms by using vitamins and minerals revealed that some minerals and vitamins, such as vitamin B6, vitamin B8, and vitamin B12, may reduce the symptoms of schizophrenia [61].

3.8. Soy Protein and Sulfides

Soy protein can be found in soybeans and milk, yogurt, and cheese produced from soy [44]. Soybeans are an essential part of the Southeast Asia diet and a source of phytochemicals; they also contain other functional compounds that benefit human and animal health. Soy proteins can reduce the risk of CHD and breast and prostate cancers and improve skin health [62,63]. A meta-analysis that was done to evaluate the association between soy intake and type 2 diabetes reported that there might be an association of soy with type 2 diabetes mellitus, and further studies are needed to focus on the dose of intake and soy's actual mechanism [64]. Meanwhile, sulfides such as diallyl sulfide, the allyl group, methyl trisulfide, and dithiolthiones are functional compounds that enhance the removal of unwanted compounds and support human immune, digestive, and cardiac health [65]. The common sources of these functional compounds are garlic, cruciferous vegetables, onions, and scallions [44,66].

3.9. Polyols and Phytoestrogens

Polyols such as xylitol, sorbitol, mannitol, and lactitol are examples of sugar alcohols resulting from sugar reduction [67]. These can be found in fruits and vegetables like mushrooms [44]. Studies have shown that polyols can reduce dental caries risk [44,68]. On the other hand, phytoestrogens are compounds mainly found in soy and some vegetables [69]. Genistein and lignans are examples of phytoestrogens and have functional properties that enable them to protect bone and immune health and lower the risk of menopausal symptoms [70]. A meta-analysis performed showed that some phytoestrogens such as daidzein, genistein, and glycitein can reduce prostate cancer risk [71]

3.10. Phenolic Acids

Phenolic acids are compounds made by plants that have many functions and are essential for plant-microbe interactions [72]. Caffeic and ferulic acids are phenolic in all food groups but higher in cereals, oilseeds, herbs, fruits, vegetables, and legumes [73]. These compounds offer protection from CHD and stroke, reduce the risks of cancers, and support eye health [74].

3.11. Plants' Stanols and Sterols

Plants stanols and sterols are found naturally in food from plant sources and are cholesterol-like in structure [75]. Plant stanol and sterol compounds are called phytosterols and are found in seeds, wheat, nuts, vegetables, fruits, and legumes [44,75]. These compounds can be categorized into free stanols/sterols and stanol/sterol esters [76]. They are essential as they may reduce the risk of coronary heart disease [44,76]. Several studies have shown that plant sterols and stanols can lower the low-density lipoprotein cholesterol (LDL). For instance, an intake of 1.5 to 3 g/d successfully lowered the LDL by 7.5% - 12%, reducing the risk of coronary heart disease [77].

3.12. Isothiocyanates

The bioactive products of glucosinolate degradation are called isothiocyanates. This is a group of chemicals that have health-beneficial effects [78]. Sulforaphane is a type of dietary isothiocyanate that can be found in cruciferous vegetables (from the Brassica genus) such as broccoli, cauliflower, broccoli, sprouts, and cabbage [79]. Isothiocyanates also have an anti-bacterial effect and function as an insect deterrent. They also possess antibiotic properties, described first with Helicobacter pylori in humans. Isothiocyanates positively affect health by enhancing antioxidant defenses in cells and removing undesirable components by increasing detoxification [80]. It has been suggested that isothiocyanates show their effect via different signaling pathways to inhibit carcinogenesis by stimulating inflammation, apoptosis, and cell cycle arrest [80,81]. Moreover, a study showed that some isothiocyanates are effective against resistant and non-resistant pathogens [82].

4. Impact of Probiotics and Prebiotics on Human Health

Many studies have shown that functional food components such as probiotics, prebiotics, and single micronutrients enhance immunocompetence and positively impact gut microbiota composition and human health [5]. Due to their positive impact on health and many other factors, the probiotic market demand is increasing; this is also contributed to by the demand for non-diary probiotics due to vegetarianism amongst consumers [3]. Many of these consumers are becoming vegetarians due to increased cholesterol levels and lactose intolerance attributed to milk consumption [3].

Probiotic use for these consumers is good because it can help in affecting the composition of gut microbiota and health [3]. Changes in microbiota composition are associated with health problems, contributing to physiological processes such as obesity, blood pressure control, and glucose homeostasis [83]. A study was conducted to compare the gut microbiome between obese/healthy people from both Saudi Arabia and France in 2015 [84]. It showed a difference in the microbial biodiversity between French obese and normal cohorts, with Bacteroidetes higher in the obese cohort. Still, there was little difference between obese and normal Saudi people in terms of biodiversity of microbes, with no difference in Bacteroidetes but greater Firmicutes in the obese cohort [84]. This study showed that different eating habits will affect the fecal microbiota, as the Saudis' eating habits are other compared to European eating habits; the information from this study will be helpful to determine and study which foods can be more beneficial to having a healthy gut microbiota composition [84,85].

Another study that aimed to examine the Japanese population's gut microbiota composition and its relationship to obesity showed that non-obese people had lower ratios between Firmicutes to Bacteroidetes than the ratio found in obese people; moreover, the bacterial diversity was lower in non-obese people compared with obese people, these results indicated that changes in the gut microbiota composition are associated with obesity [86]. This study showed that obese people had different intestinal microbes profiles than non-obese people [86]. Additionally, a study on 8-week-old mice treated with Lactobacillus and Bifidobacterium probiotics has shown decreased Firmicutes, Actinobacteria, and Bacteroides compositions [87]. Meanwhile, other studies have reported that Bacteroidetes' proportion was increased while Firmicutes and Proteobacteria abundance was decreased when treated with S. cerevisiae and S. boulardii probiotics [88]. Hence, probiotic production and development are given priority in food design. However, the probiotics must be studied appropriately before reaching the market [3,89]. For instance, toxicity testing and survivability tests on probiotics during processing and storage, in addition to the overall costs for producing the probiotics, are required in advance [3,89].

In 2019, a study done in Pakistan revealed that most respondents lacked awareness of functional foods and their benefits to health [90]. In addition, the same study also showed the levels of awareness in people who live in rural areas are lower than those who live in urban areas; education levels and gender have an essential role in functional food acceptance in Pakistan [90]. The more educated participants were more willing and open to consuming functional foods and willing to bear the cost. At the same time, males were less prepared to accept functional foods than females [90]. Another study done in Canada in 2014, which aimed to identify the need for functional foods amongst people above 60 years old, showed that 85.5% of respondents agreed that awareness and knowledge are the most critical factors in promoting functional foods in the market and 63.5% stated that more information is needed in newspapers, magazines and food labeling [91].

For more than 100 years, the function of gut bacteria was unknown until a scientist named Tissier discovered that probiotics helped to maintain health [27,92]. Tissier discovered that when Bifidobacteria were found in the stools of breast-fed infants, these infants were healthier than infants for whom the same bacteria were absent in the stool and suffered diarrhea despite being breast-fed [27,92]. Probiotics have become more popular lately due to their proven positive impact on human health; they can improve immunity, increase calcium uptake, reduce cholesterol levels, prevent intestinal infections, enhance vitamin synthesis, avoid food-borne pathogens effects, and enhance lactose metabolism [27,93]. As a result, the food industry has promoted and studied these bacteria to incorporate them mainly in fermented dairy foods such as yogurt [27]. There are some challenges for probiotic production at the industry level, such as the selection of the probiotic organism and its percentage composition, probiotic safety and toxicity, the sensory criteria, and the ability of probiotics to survive in storage and processing conditions; these factors will affect the distribution and acceptability of the functional foods [32,94]. For probiotics to be beneficial, they must be able to survive and be effective until they reach the human gut and proliferate, as summarized in Figure 3.

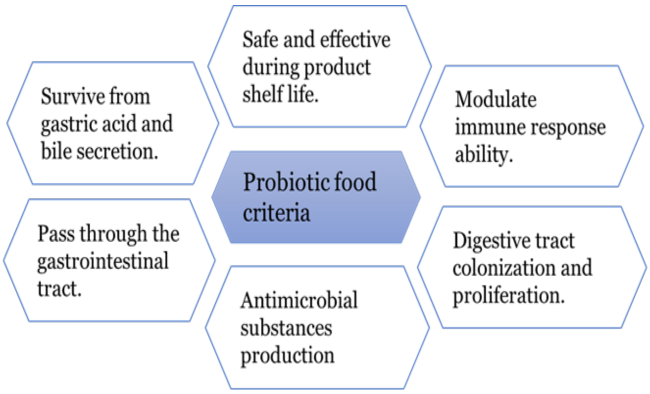

Figure 3. Criteria for developing food containing probiotics [27,28,92,93,95].

Probiotics act by certain mechanisms to provide health benefits: 1) by competing with pathogens in binding to a receptor or consuming a nutrient or colonizing the area, 2) by adhering to the intestinal interface, 3) through functional enhancement of the mucosal barrier, 4) to enhance immune responses, 5) to develop bacteriocins, and 6) to modify cell kinetics [95]. Some of the main probiotic groups are listed in Table 1.

Prebiotics stimulate the growth and metabolic activity of one or more colonic beneficial bacteria; prebiotics and probiotics help improve health [96]. Prebiotics can replace or give additional support for probiotics [97]. Studies have shown that prebiotics affect health positively by increasing resistance to gastrointestinal infections [9], modulating immune system activities [98], and causing significant changes in the composition of gut microbiota [99].

Most prebiotics identified are carbohydrates; their physiological properties determine their health benefits [100]. To consider the non-digestible carbohydrate as a prebiotic, it should be resistant to gastric acidity processing, stable during the shelf-life of food, resistant to mammalian enzymes, and be able to be fermented by the gut bacteria to enhance activity and the viability of probiotics further [5]. The difference between probiotics and prebiotics is that probiotics are beneficial living organisms, while prebiotics are an indigestible food ingredient, as shown in Table 2.

Table 2. Differences between prebiotics and probiotics

	Prebiotics	Probiotics	References
Definition:	Indigestible food ingredients like trans-galacto-oligosaccharides (TOS) and inulin.	Living organism that is good for health, such as Bifidobacterium and Lactobacillus spp.	[101,102]
Advantages:	i) Provide food for probiotics ii) Enhance immunity.	i) Balance gut microbiota composition ii) Reduce pathogenic bacteria iii) Prevent colon cancer.	[101,103,104]
Disadvantages:	iii) A high intake amount will increase fermentation, producing more gas and causing bloating.	i) Have short shelf-life in products ii) Instability to processing iii) Damaged by stomach acidity	[101,103]

The most common prebiotics are trans-galacto-oligosaccharides (TOS), fructo-oligosaccharides (FOS), and galacto-oligosaccharides (GOS), which have been shown to change gut microbiota composition in volunteer trials in Europe [101,105]. The FOS are most commonly used worldwide as they have no calories and are a soluble dietary fiber with various health benefits [34,106]. Some prebiotics are naturally found in specific foods like artichokes, onion, wheat, and asparagus [107,108]. Although these foods contain small amounts of prebiotics, with recent developments, it has been possible to isolate the active ingredients from these foods and add those to the most frequently consumed products, such as cereals, infant feeds, and yogurts [106].

Prebiotics can be used in various food products due to their helpful effect on health, either as an alternative to probiotics or by stimulating probiotic growth. They enhance human health (gastrointestinal, immunity), increase calcium (Ca) and magnesium (Mg) uptake, regulate enzymatic actions, modulate the production of mucin, and maintain body glucose levels [5]. Therefore, it is crucial to evaluate the prebiotic benefit in humans via long-term clinical trials to determine the optimum uptake levels of functional foods; more efforts must be directed toward achieving the functional diet goal [5].

5. Middle Eastern and Asian Studies on Probiotics & Prebiotics

5.1. Middle Eastern Studies on Probiotics and Prebiotics

Asia Pacific is the major functional food market worldwide. The increasing market trend indicates countries such as Malaysia, South Korea, and China; statistics show that their revenue accounts for approximately 34% of the global revenue of functional foods. The Middle East, Africa, and Eastern Europe account for around 6% of the whole revenue of functional food [18].

A paper published in 2015 showed that organic food consumption is increasing in the United Arab Emirates (UAE) [109]. Of 300 respondents, most responded "yes" in willingness to pay for healthy foods; this could result from increased awareness of healthy foods in addition to the diverse population and the relatively high income per capita [109]. Moreover, the study also showed the factors that affected the consumer’s ability to pay for these higher-priced foods are family size, income, age, and education; this information is significant for the food industry to promote the marketing of healthy foods in the United Arab Emirates [109,110]. However, in Arabian Gulf countries such as the UAE, there has been a lack of data on probiotics and functional foods and no guidelines on their labeling [12,111]. A study conducted in the UAE found that the non-dairy product labels contained all the information about the probiotic inside (strain and number). Still, only one dairy product provided the same label information [12,111]. The most common strain identified was L. acidophilus, but Enterococcus faecalis has also been used as one component in one of the probiotic products [111]. This study showed that the Arabian Gulf countries have various probiotic products and should address health claims in all products [111]. Design and packaging would also need to be considered since there is an increase in the level of health awareness, indicating that the functional food market has expanded [111].

A cross-sectional study in Oman 2020 investigated diary and non-diary probiotics in three different Middle Eastern countries; the results showed that multistrain probiotics were 61.8% as opposed to single strain, and 32.1% of probiotics were from dairy sources [112]. Moreover, the probiotics market is continuously developing in the Middle East, and the quality of the products should always be inspected to ensure consumer satisfaction and safety [112]. Functional food companies should understand the unique market characteristics of each country. For example, in 2015, the UAE had approximately 8.6 million expatriate workers, mostly classified under the low-income laborer group. In contrast, a smaller group of professionals were classified under the high-income laborer group [113]. In 2015, the sales values of functional packaged foods were around 284.6 million U.S. dollars; the dairy functional foods were the category that attracted the high-income laborer group [113]. Consumers' purchasing decisions are based on the design and packaging modernity and are not limited to health benefits [113]. Functional packaged foods sales increased more than functional foods beverages by 4.2%, possibly due to increased awareness of healthy foods and busy lifestyles in young adults [113].

The probiotic market in India achieved 12 million U.S. dollars in 2011, increasing to 448.456 million U.S. dollars in 2019; it is expected to increase further by 13.56% in 2025 and reach a market size of 961.856 million U.S. dollars [114,115,116]. It accounts for >1% of the global functional foods market under the probiotic segment. Moreover, the most common probiotic products in India is the Indian yogurt (dahi) and fermented milk [114,115].

5.2. Asian Studies on Probiotics and Prebiotics

Asians commonly consume a large amount of functional food, which has increased over the past five years [117]. A healthy plant-based diet with no meat products is the current trend, but this may have a negative effect because people with this diet will have a greater risk of developing vitamin B12 deficiency, which can lead to hematological and neurological consequences [117]. In 2015, a pilot study was carried out to examine the willingness to buy functional foods in both Germany (n=502) and China (n=443). It showed that German consumers were less willing to buy these functional foods, and Chinese consumers were more willing to [118]. Statistics show that the functional food market in the Asia Pacific region is predicted to reach 5.04 billion U.S. dollars by 2026, and the probiotic segment accounts for 23.5% of the total Asia Pacific functional food market [119]. As noticed in many studies, probiotics and prebiotics have a beneficial effect on health. In 2010, a study investigated the effect of *B. lactis* HN019 and fortified milk containing prebiotics on Asian children's growth, iron status, and anemia [120]. The baseline parameters (hematological, height, and weight) were measured at the beginning (very similar results), at the middle of the study period, and the end of the year; results showed that children who consume B. lactis HN019 and prebiotic-fortified milk have a lower risk of developing iron deficiency by 45% and gained more weight by 0.13 kg/year [120]. Another randomized, double-blind, placebo-controlled study done in Indonesia in 2011 explored the effect of Enterococcus faecium IS-27526 in milk on humoral immunity and children's body weight; sandwich ELISA results showed that the salivary IgA and body weight increased in the probiotic group whereas in the other group, no significant increase happened [121]. Salivary IgA increased more in underweight children, and body weight increased more in normal children [121]. This result showed that *E. faecium* IS-27526 positively affects immunity, especially in underweight children, and body weight gain in normal body weight children [121].

6. Future Prospects of Functional Foods

As functional foods gain interest in the food health and technological innovations field, some factors influence the future of the functional food market, as shown in Figure 4. Consumer acceptance is the most important factor in the rise of the functional food market in the last decade. Many studies have investigated the factors influencing consumer acceptance of functional foods [122,123,124]. Product characteristics, social and democratic characteristics, psychological characteristics, physical characteristics, and behavioral characteristics have been identified as potential determinants of consumer acceptance of functional foods. Therefore, these determinants must be considered to develop successful functional foods [122]. Consumer acceptance of functional foods was expressed by measuring overall acceptance, willingness to pay, willingness to purchase, perceptions of functional foods, and functional food choices [122]. In addition, it would be desirable for the development of a functional food if there were clear guidelines for labeling, and production costs could be reduced. This would allow consumers to use the products more frequently, increase market share, and reap the benefits [125].

While research on functional foods has increased over the past decade, a few studies have addressed functional foods' clinical effects and outcomes on the host [126]. It is worth noting that the 2019 meeting of the International Scientific Association for Probiotics and Prebiotics-Student and Fellows Association (ISAPP-SFA) discussed future insights and new techniques for collecting and analyzing data on how probiotics and prebiotics affect microorganisms and their interactions with the host. Proposed strategies included genetic characterization, strain modification, and modern techniques in vitro, in vivo, and in silico to detect the effect of probiotics and prebiotics on microorganisms. In addition, metabolomic tools were used to identify molecules of interest and benefit to the host. The outcomes from correlating between the determination of microbial structure and co-dependencies at body sites and discovering the effect of probiotic strains and prebiotic substances on the host can then be applied [127].

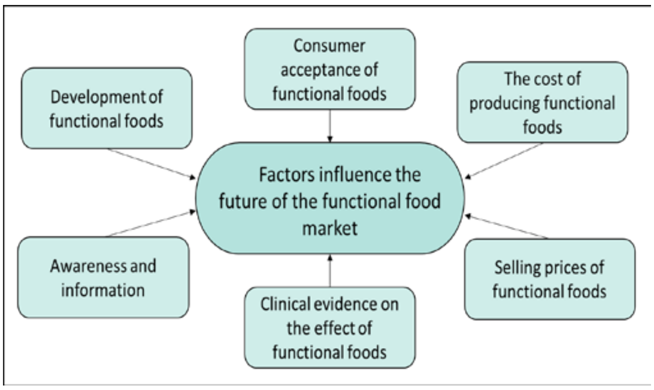

Figure 4. Factors influencing the future of the functional food market [122]

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References

[1] D.P. Monjiote, E.E.M. Leo, M.R.S. Campos, Functional and Biological Potential of Bioactive Compounds in Foods for the Dietary Treatment of Type 2 Diabetes Mellitus, Funct. Food - Improve Health Adequate Food. (2017).

[2] A. Mie, H.R. Andersen, S. Gunnarsson, J. Kahl, E. Kesse-Guyot, E. Rembiałkowska, G. Quaglio, P. Grandjean, Human health implications of organic food and organic agriculture: a comprehensive review, Environ. Health. 16 (2017) 111.

[3] D. Granato, G.F. Branco, F. Nazzaro, A.G. Cruz, J.A.F. Faria, Functional Foods and Nondairy Probiotic Food Development: Trends, Concepts, and Products, Compr. Rev. Food Sci. Food Saf. 9 (2010) 292–302.

[4] M.N. McGloughlin, Prospects for Increased Food Production and Poverty Alleviation: What Plant Biotechnology can Practically Deliver and What It Cannot - ScienceDirect, Acad. Press. (2012) 551–561.

[5] S.H. Al-Sheraji, A. Ismail, M.Y. Manap, S. Mustafa, R.M. Yusof, F.A. Hassan, Prebiotics as Functional Foods: A review, J Funct Foods. 5 (2013) 1542–1553.

[6] A. Alkhatib, C. Tsang, A. Tiss, T. Bahorun, H. Arefanian, R. Barake, A. Khadir, J. Tuomilehto, Functional Foods and Lifestyle Approaches for Diabetes Prevention and Management, MDPI AG Basel Switz. 9 (2017) 1310.

[7] M. Vella, Exploration of the Consumption, Awareness, Understanding and Motivating Factors Related to Functional Foods in Older Adults, Thesis, University of Guelph, 2013. http://hdl.handle.net/10214/5200.

[8] A. Panghal, N. Chhikara, N. Sindhu, S. Jaglan, Role of Food Safety Management Systems in safe food production: A review, J. Food Saf. 38 (2018) e12464..

[9] A. Anadón, M.R. Martínez-Larrañaga, I. Ares, M.A. Martínez, Chapter 54 - Prebiotics: Safety and Toxicity Considerations, in: R.C. Gupta (Ed.), Nutraceuticals, Academic Press, Boston, 2016: pp. 757–775.

[10] S.M. Cutting, Bacillus Probiotics, Food Microbiol. 28 (2011) 214–220.

[11] Y.C. Kim, A.J. Anderson, Rhizosphere Pseudomonads As Probiotics Improving Plant Health, Mol. Plant Pathol. 19 (2018) 2349–2359.

[12] A. Cencic, W. Chingwaru, The Role of Functional Foods, Nutraceuticals, and Food Supplements in Intestinal Health, Nutrients. 2 (2010) 611–625.

[13] R. Prasad, M. Kumar, A. Varma, Role of PGPR in Soil Fertility and Plant Health, in: D. Egamberdieva, S. Shrivastava, A. Varma (Eds.), Plant-Growth-Promot. Rhizobacteria PGPR Med. Plants, Springer International Publishing, Cham, 2015: pp. 247–260.

[14] J.D. Flores-Félix, L.R. Silva, L.P. Rivera, M. Marcos-García, P. García-Fraile, E. Martínez-Molina, P.F. Mateos, E. Velázquez, P. Andrade, R. Rivas, Plants Probiotics as a Tool to Produce Highly Functional Fruits: The Case of Phyllobacterium and Vitamin C in Strawberries, PLOS ONE. 10 (2015) e0122281.

[15] M.G. Dominguez-Bello, F. Godoy-Vitorino, R. Knight, M.J. Blaser, Role of the Microbiome in Human Development, Gut. 68 (2019) 1108–1114.

[16] M. Yasir, E. Angelakis, F. Bibi, E.I. Azhar, D. Bachar, J.-C. Lagier, B. Gaborit, A.M. Hassan, A.A. Jiman-Fatani, K.Z. Alshali, C. Robert, A. Dutour, D. Raoult, Comparison of the Gut Microbiota of People in France and Saudi Arabia, Nutr. Diabetes. 5 (2015) e153.

[17] B. Senghor, C. Sokhna, R. Ruimy, J.-C. Lagier, Gut Microbiota Diversity According to Dietary Habits and Geographical Provenance, Hum. Microbiome J. 7–8 (2018) 1–9.

[18] A. Vicentini, L. Liberatore, D. Mastrocola, Functional Foods: Trends And Development Of The Global Market, Ital. J. Food Sci. 28 (2016) 338–351.

[19] T.-C. Lau, M.-W. Chan, H.-P. Tan, C.-L. Kwek, Functional Food: A Growing Trend among the Health Conscious, Asian Soc. Sci. 9 (2012) p198.

[20] Functional Foods Market Size, Trends and Global Forecast To 2032, Bus. Res. Co. (2023). https:// www. thebusinessresearchcompany.com/report/functional-foods-global-market-report (accessed January 11, 2023).

[21] Middle East and Africa Functional Foods Market to 2028 - By Size, Share, Growth by End User and Forecast| Business Market Insights, Bus. Mark. Insights. (2022). https:// www.businessmarketinsights.com/ reports/middle-east-and-africa-functional-foods-market (accessed January 11, 2023).

[22] M.S. Arshad, W. Khalid, R.S. Ahmad, M.K. Khan, M.H. Ahmad, S. Safdar, S. Kousar, H. Munir, U. Shabbir, M. Zafarullah, M. Nadeem, Z. Asghar, H.A.R. Suleria, M.S. Arshad, W. Khalid, R.S. Ahmad, M.K. Khan, M.H. Ahmad, S. Safdar, S. Kousar, H. Munir, U. Shabbir, M. Zafarullah, M. Nadeem, Z. Asghar, H.A.R. Suleria, Functional Foods and Human Health: An Overview, IntechOpen, 2021.

[23] R. Choudhary, T. Rv, CONSUMPTION OF FUNCTIONAL FOOD AND OUR HEALTH CONCERNS, Pak. J. Physiol. 5 (2009). http://www.pjp.pps.org.pk/index.php/PJP/article/view/713 (accessed January 16, 2023).

[24] N. Sat, Genetically ModifiedOrganisms (GMOs): Transgenic Crops and Recombinant DNA Technology, J. Mol. Genet. Med. 5 (2021).

[25] R.R. Watson, S. Zibadi, V.R. Preedy, Dietary Components and Immune Function - Google Books, illustrated ed., Springer Science & Business Media, 2010, 2010. https:// books.google.ae/ books?id=hxPRdlnn85oC&lpg= (accessed June 12, 2019).

[26] C.S. Ranadheera, J.K. Vidanarachchi, R.S. Rocha, A.G. Cruz, S. Ajlouni, Probiotic Delivery through Fermentation: Dairy vs. Non-Dairy Beverages, MDPI AG Basel Switz. 3 (2017) 67.

[27] M. Kechagia, D. Basoulis, S. Konstantopoulou, D. Dimitriadi, K. Gyftopoulou, N. Skarmoutsou, E.M. Fakiri, Health Benefits of Probiotics: A Review, ISRN Nutr. 2013 (2013).

[28] C. Hill, F. Guarner, G. Reid, G.R. Gibson, D.J. Merenstein, B. Pot, L. Morelli, R.B. Canani, H.J. Flint, S. Salminen, P.C. Calder, M.E. Sanders, Expert consensus document. The International Scientific Association for Probiotics and Prebiotics consensus statement on the scope and appropriate use of the term probiotic, Nat. Rev. Gastroenterol. Hepatol. 11 (2014) 506–514.

[29] M. Fernández, J.A. Hudson, R. Korpela, C.G. de los Reyes-Gavilán, Impact on Human Health of Microorganisms Present in Fermented Dairy Products: An Overview, Biomed Res Int. 2015 (2015) 412714.

[30] T.R. Klaenhammer, M. Kleerebezem, M.V. Kopp, M. Rescigno, The impact of probiotics and prebiotics on the immune system, Nat. Rev. Immunol. 12 (2012) 728–734.

[31] Q. Mu, V.J. Tavella, X.M. Luo, Role of Lactobacillus reuteri in Human Health and Diseases, Front. Microbiol. 9 (2018) 757.

[32] M.J. Davoren, J. Liu, J. Castellanos, N.I. Rodríguez-Malavé, R.H. Schiestl, A Novel Probiotic, Lactobacillus johnsonii 456, Resists Acid and can Persist in the Human Gut Beyond the Initial Ingestion Period, Gut Microbes. 22 (2018) 1–23.

[33] Probiotics Basics - California Dairy Research Foundation, Calif. Dairy Res. Found. (2011). http:// cdrf.org/home/checkoff-investments/usprobiotics/ probiotics-basics/ (accessed June 11, 2019).

[34] S. Fijan, Microorganisms with Claimed Probiotic Properties: An Overview of Recent Literature, Int. J. Environ. Res. Public. Health. 11 (2014) 4745–4767.

[35] M. Messaoudi, R. Lalonde, N. Violle, H. Javelot, D. Desor, A. Nejdi, J.-F. Bisson, C. Rougeot, M. Pichelin, M. Cazaubiel, J.-M. Cazaubiel, Assessment of Psychotropic-like Properties of a Probiotic Formulation (Lactobacillus helveticus R0052 and Bifidobacterium longum R0175) in Rats and Human Subjects, Br. J. Nutr. 105 (2011) 755–764.

[36] T. Kelesidis, C. Pothoulakis, Efficacy and Safety of the Probiotic Saccharomyces boulardii for the Prevention and Therapy of Gastrointestinal Disorders, Ther. Adv. Gastroenterol. 5 (2012) 111–125.

[37] M. Fadhel, S. Patel, E. Liu, M. Levitt, A. Asif, Saccharomyces cerevisiae fungemia in a Critically Ill Patient with Acute Cholangitis and Long Term Probiotic Use, Med. Mycol. Case Rep. 23 (2019) 23–25.

[38] D. Chauhan, Y. Patel, J. A. Doshi, R. D. Doshi, A. Bose, Draft Genome Sequence of Bacillus coagulans ZB29, a Commercial Probiotic Strain | Microbiology Resource Announcements, (n.d.).

[39] H. Hanchi, W. Mottawea, K. Sebei, R. Hammami, The Genus Enterococcus: Between Probiotic Potential and Safety Concerns—

An Update, Front. Microbiol. 9 (2018) 1791.

[40] M. Roberfroid, G.R. Gibson, L. Hoyles, A.L. McCartney, R. Rastall, I. Rowland, D. Wolvers, B. Watzl, H. Szajewska, B. Stahl, F. Guarner, F. Respondek, K. Whelan, V. Coxam, M.-J. Davicco, L. Léotoing, Y. Wittrant, N.M. Delzenne, P.D. Cani, A.M. Neyrinck, A. Meheust, Prebiotic Effects: Metabolic and Health Benefits, Br. J. Nutr. 104 (2010) S1–S63.

[41] P. Markowiak, K. Śliżewska, Effects of Probiotics, Prebiotics, and Synbiotics on Human Health, Nutrients. 9 (2017) 1021.

[42] C. Galasso, C. Corinaldesi, C. Sansone, Carotenoids from Marine Organisms: Biological Functions and Industrial Applications, NCBI. 6 (2017) 96.

[43] K.R. Patel, F.D. Chahwala, U.C.S. Yadav, Flavonoids as Functional Food, in: V. Rani, U.C.S. Yadav (Eds.), Funct. Food Hum. Health, Springer Singapore, Singapore, 2018: pp. 83–106.

[44] S. Raghuwanshi, S. Misra, R. Sharma, P. Bisen, Indian Perspective for Probiotics: A Review, Indian J. Dairy Sci. 68 (2015) 195–205.

[45] A.N. Panche, A.D. Diwan, S.R. Chandra, Flavonoids: An Overview, J. Nutr. Sci. 5 (2016) 47.

[46] M. Hossain, A. Morsy, J. Han, Y. Yingfu, K. Kim, S. Saha, G.-M. Yang, H. Yeon Choi, S.-G. Cho, Molecular Mechanisms of the Anti-Obesity and Anti-Diabetic Properties of Flavonoids, International Journal of Molecular Sciences, 2016.

[47] S. Siyuan, L. Tong, R. Liu, Corn phytochemicals and their health benefits, Food Sci. Hum. Wellness. 7 (2018) 185–195.

[48] S. Ötles, S. Ozgoz, Health Effects of Dietary Fiber, 13 (2014) 191–202.

[49] N. Kaur, V. Chugh, A.K. Gupta, Essential Fatty Acids as Functional Components of Foods- A Review, J Food Sci Technol. 51 (2012) 2289–2303.

[50] S.R. Drago, Chapter 5 - Minerals, in: C.M. Galanakis (Ed.), Nutraceutical Funct. Food Compon., Academic Press, 2017: pp. 129–157.

[51] S. Sivaprakasam, P.D. Prasad, N. Singh, Benefits of short-chain fatty acids and their receptors in inflammation and carcinogenesis, Pharmacol. Ther. 164 (2016) 144–151.

[52] E. Ward, Addressing Nutritional Gaps with Multivitamin and Mineral Supplements, Nutr. J. 13 (2014) 72.

[53] U. Gröber, J. Schmidt, K. Kisters, Magnesium in Prevention and Therapy, Nutrients. 7 (2015) 8199–8226.

[54] D.D. Alexander, P.E. Miller, M.E. Van Elswyk, C.N. Kuratko, L.C. Bylsma, A Meta-Analysis of Randomized Controlled Trials and Prospective Cohort Studies of Eicosapentaenoic and Docosahexaenoic Long-Chain Omega-3 Fatty Acids and Coronary Heart Disease Risk, Mayo Clin. Proc. 92 (2017) 15–29.

[55] W. Willett, H. Sesso, E. Rimm, Demystifying Nutrition: The Value of Food, Vitamins and Supplements, Thesis, Harvard Medical School, 2013. https:// hms.harvard.edu/ sites/default/ files/assets/Sites/Longwood_Seminars/Nutrition_3_5_13.pdf.

[56] S. Rizvi, S.T. Raza, F. Ahmed, A. Ahmad, S. Abbas, F. Mahdi, The role of vitamin e in human health and some diseases, Sultan Qaboos Univ. Med. J. 14 (2014) e157-165.

[57] R. Nair, A. Maseeh, Vitamin D: The “Sunshine” Vitamin, J Pharmacol Pharmacother. 3 (2012) 118–126.

[58] D.O. Kennedy, B Vitamins and the Brain: Mechanisms, Dose and Efficacy—A Review, Nutrients. 8 (2016) 68.

[59] M.G. Soni, T.S. Thurmond, E.R. Miller, T. Spriggs, A. Bendich, S.T. Omaye, Safety of Vitamins and Minerals: Controversies and Perspective, Toxicol. Sci. 118 (2010) 348–355.

[60] M. Messina, Soy and Health Update: Evaluation of the Clinical and Epidemiologic Literature, 8 (2016) 754.

[61] J. Firth, B. Stubbs, J. Sarris, S. Rosenbaum, S. Teasdale, M. Berk, A.R. Yung, The effects of vitamin and mineral supplementation on symptoms of schizophrenia: a systematic review and meta-analysis, Psychol. Med. 47 (2017) 1515–1527.

[62] M. Iciek, A. Bilska-Wilkosz, M. Górny, M. Sokołowska-Jeżewicz, D. Kowalczyk-Pachel, The Effects of Different Garlic-Derived Allyl Sulfides on Anaerobic Sulfur Metabolism in the Mouse Kidney, Antioxidants. 5 (2016).

[63] J.N. BeMiller, 19 - Carbohydrate and Noncarbohydrate Sweeteners, in: J.N. BeMiller (Ed.), Carbohydr. Chem. Food Sci. Third Ed., AACC International Press, 2019: pp. 371–399.

[64] W. Li, W. Ruan, Y. Peng, D. Wang, Soy and the risk of type 2 diabetes mellitus: A systematic review and meta-analysis of observational studies, Diabetes Res. Clin. Pract. 137 (2018) 190–199.

[65] M. Grembecka, Sugar Alcohols—Their Role in The Modern World of Sweeteners: A Review, Eur. Food Res. Technol. 241 (2015) 1–14.

[66] H.B. Patisaul, W. Jefferson, The Pros and Cons of Phytoestrogens, Front. Neuroendocrinol. 31 (2010) 400–419.

[67] I.M.C.M. Rietjens, J. Louisse, K. Beekmann, The Potential Health Effects of Dietary Phytoestrogens, Br. J. Pharmacol. 174 (2017) 1263–1280.

[68] T. Rice, E. Zannini, E.K. Arendt, A. Coffey, A review of polyols – biotechnological production, food applications, regulation, labeling and health effects, Crit. Rev. Food Sci. Nutr. 60 (2020) 2034–2051.

[69] A. Chandrasekara, Phenolic Acids, in: L. Melton, F. Shahidi, P. Varelis (Eds.), Encycl. Food Chem., Academic Press, Oxford, 2019: pp. 535–545.

[70] K.G. Ramawat, J.-M. Mérillon, eds., Natural Products: Phytochemistry, Botany and Metabolism of Alkaloids, Phenolics and Terpenes, Springer-Verlag, Berlin Heidelberg, 2013. https://www.springer.com/gp/book/9783642221439 (accessed June 11, 2020).

[71] Q. Zhang, H. Feng, B. Qluwakemi, J. Wang, S. Yao, G. Cheng, H. Xu, H. Qiu, L. Zhu, M. Yuan, Phytoestrogens and risk of prostate cancer: an updated meta-analysis of epidemiologic studies, Int. J. Food Sci. Nutr. 68 (2017) 28–42.

[72] E.A. Trautwein, M.A. Vermeer, H. Hiemstra, R.T. Ras, LDL-Cholesterol Lowering of Plant Sterols and Stanols—Which Factors Influence Their Efficacy?, Nutrients. 10 (2018).

[73] S.A. Doggrell, Lowering LDL Cholesterol with Margarine Containing Plant Stanol/Sterol Esters: Is it Still Relevant in 2011?, Complement. Ther. Med. 19 (2011) 37–46.

[74] J. Paluszczak, W. Baer-Dubowska, Chapter 105 - DNA Methylation as a Target of Cancer Chemoprevention by Dietary Polyphenols, in: R.R. Watson, V.R. Preedy, S. Zibadi (Eds.), Polyphenols Hum. Health Dis., Academic Press, San Diego, 2014: pp. 1385–1392.

[75] P. Boffetta, 1 - Classic Epidemiology of Lung Cancer, in: H.I. Pass, D. Ball, G.V. Scagliotti (Eds.), IASLC Thorac. Oncol. Second Ed., Content Repository Only!, Philadelphia, 2018: pp. 1-8.e3.

[76] Y. Wang, X. Miao, J. Sun, L. Cai, Chapter 6 - Oxidative Stress in Diabetes: Molecular Basis for Diet Supplementation, in: D. Mauricio (Ed.), Mol. Nutr. Diabetes, Academic Press, San Diego, 2016: pp. 65–72.

[77] P.J.H. Jones, M. Shamloo, D.S. MacKay, T.C. Rideout, S.B. Myrie, J. Plat, J.-B. Roullet, D.J. Baer, K.L. Calkins, H.R. Davis, P. Barton Duell, H. Ginsberg, H. Gylling, D. Jenkins, D. Lütjohann, M. Moghadasian, R.A. Moreau, D. Mymin, R.E. Ostlund, R.T. Ras, J. Ochoa Reparaz, E.A. Trautwein, S. Turley, T. Vanmierlo, O. Weingärtner, Progress and perspectives in plant sterol and plant stanol research, Nutr. Rev. 76 (2018) 725–746.

[78] S.L. Navarro, F. Li, J.W. Lampe, Mechanisms of Action of Isothiocyanates in Cancer Chemoprevention: An Update, Food Funct. 2 (2011) 579–587.

[79] B. Troesch, H.K. Biesalski, R. Bos, E. Buskens, P.C. Calder, W.H.M. Saris, J. Spieldenner, H.J. Verkade, P. Weber, M. Eggersdorfer, Increased Intake of Foods with High Nutrient Density Can Help to Break the Intergenerational Cycle of Malnutrition and Obesity, Nutrients. 7 (2015) 6016–6037.

[80] R.K. Srivastava, Need of Nutraceuticals / Functional Food Products For Health Benefits To World-wide People, J. Biotechnol. Biomed. Sci. 1 (2018). https:// openaccesspub.org/jbbs/article/885 (accessed June 13, 2019).

[81] D. Song, S. Ibrahim, S. Hayek, Recent Application of Probiotics in Food and Agricultural Science, Probiotics. (2012).

[82] L. Romeo, R. Iori, P. Rollin, P. Bramanti, E. Mazzon, Isothiocyanates: An Overview of Their Antimicrobial Activity against Human Infections, Molecules. 23 (2018) 624.

[83] C. Kasai, K. Sugimoto, I. Moritani, J. Tanaka, Y. Oya, H. Inoue, M. Tameda, K. Shiraki, M. Ito, Y. Takei, K. Takase, Comparison of the Gut Microbiota Composition Between Obese and Non-Obese Individuals in a Japanese Population, as Analyzed by Terminal Restriction Fragment Length Polymorphism and Next-Generation Sequencing, BMC Gastroenterol. 15 (2015) 100.

[84] O. Castaner, A. Goday, Y.-M. Park, S.-H. Lee, F. Magkos, S.-A.T.E. Shiow, H. Schröder, The Gut Microbiome Profile in Obesity: A Systematic Review, Int. J. Endocrinol. 2018 (2018).

[85] A. Ignacio, M.R. Fernandes, V. a. A. Rodrigues, F.C. Groppo, A.L. Cardoso, M.J. Avila-Campos, V. Nakano, Correlation Between Body Mass Index and Faecal Microbiota from Children, Clin. Microbiol. Infect. Off. Publ. Eur. Soc. Clin. Microbiol. Infect. Dis. 22 (2016) 258.e1–8.

[86] S. Muhammad, E. Fathelrahman, R.U.T. Ullah, Factors Affecting Consumers' Willingness to Pay for Certififed Organic Food Products in United Arab Emirates, J. Food Distrib. Res. (2015). https://ageconsearch.umn.edu/record/199045 (accessed June 18, 2019).

[87] R.A. Bagarolli, N. Tobar, A.G. Oliveira, T.G. Araújo, B.M. Carvalho, G.Z. Rocha, J.F. Vecina, K. Calisto, D. Guadagnini, P.O. Prada, A. Santos, S.T.O. Saad, M.J.A. Saad, Probiotics modulate gut microbiota and improve insulin sensitivity in DIO mice, J. Nutr. Biochem. 50 (2017) 16–25.

[88] L. Yu, X. Zhao, M. Cheng, G. Yang, B. Wang, H. Liu, Y. Hu, L. Zhu, S. Zhang, Z. Xiao, Y. Liu, B. Zhang, M. Mu, Saccharomyces boulardii Administration Changes Gut Microbiota and Attenuates D-Galactosamine-Induced Liver Injury, Sci. Rep. 7 (2017) 1359.

[89] M.K. Tripathi, S.K. Giri, Probiotic Functional Foods: Survival of Probiotics During Processing and Storage, J. Funct. Foods. 9 (2014) 225–241.

[90] A. Ali, D.B. Rahut, Healthy Foods as Proxy for Functional Foods: Consumers' Awareness, Perception, and Demand for Natural Functional Foods in Pakistan, Int. J. Food Sci. 2019 (2019) 12.

[91] M.N. Vella, L.M. Stratton, J. Sheeshka, A.M. Duncan, Functional Food Awareness and Perceptions in Relation to Information Sources in Older Adults, Nutr. J. 13 (2014) 44.

[92] C.R. Soccol, L.P. de S. Vandenberghe, M.R. Spier, A.B.P. Medeiros, C.T. Yamaguishi, J.D.D. Lindner, A. Pandey, V. Thomaz-Soccol, The Potential of Probiotics: A Review, 48 (2010) 413–434.

[93] A. Panghal, S. Janghu, K. Virkar, Y. Gat, V. Kumar, N. Chhikara, Potential Non-Dairy Probiotic Products – A Healthy Approach, Food Biosci. 21 (2017) 80–89.

[94] Insel, D. Ross, M. Bernstein, Discovering Nutrition, Sixth Edition, Jones & Bartlett Learning, 2018. https:// books.google.ae/ books?id=G39KDwAAQBAJ&pg=PA251&lpg=PA251&dq= (accessed June 12, 2019).

[95] G.S. Howarth, H. Wang, Role of Endogenous Microbiota, Probiotics and Their Biological Products in Human Health, Nutrients. 5 (2013) 58–81.

[96] J.L. Carlson, J.M. Erickson, B.B. Lloyd, J.L. Slavin, Health Effects and Sources of Prebiotic Dietary Fiber, Curr. Dev. Nutr. 2 (2018).

[97] F. Indrio, Prebiotics and Probiotics, MDPI, 2018. https:// books.google.ae/books?isbn=3038971685.

[98] L.B. Bindels, N.M. Delzenne, P.D. Cani, J. Walter, Towards A More Comprehensive Concept For Prebiotics, Nat. Rev. Gastroenterol. Hepatol. 12 (2015) 303–310.

[99] D. Davani-Davari, M. Negahdaripour, I. Karimzadeh, M. Seifan, M. Mohkam, S.J. Masoumi, A. Berenjian, Y. Ghasemi, Prebiotics: Definition, Types, Sources, Mechanisms, and Clinical Applications, Foods. 8 (2019).

[100] G.E. Walton, J.R. Swann, G.R. Gibson, Prebiotics, in: E. Rosenberg, E.F. DeLong, S. Lory, E. Stackebrandt, F. Thompson (Eds.), Prokaryotes Hum. Microbiol., Springer Berlin Heidelberg, Berlin, Heidelberg, 2013: pp. 25–43.

[101] Yashoda, Difference Between Prebiotics and Probiotics, Pediaa. (2016). https://pediaa.com/difference-between-prebiotics-and-probiotics/ (accessed June 30, 2019).

[102] J. Slavin, Fiber and Prebiotics: Mechanisms and Health Benefits, Nutrients. 5 (2013) 1417–1435.

[103] K.R. Pandey, S.R. Naik, B.V. Vakil, Probiotics, Prebiotics and Synbiotics- A Review, J. Food Sci. Technol. 52 (2015) 7577–7587.

[104] V.R. Alonso, F. Guarner, Linking the Gut Microbiota to Human Health, Br. J. Nutr. 109 (2013) S21–S26.

[105] J. Levy, Prebiotics Benefits for the Body, Plus Best Prebiotic Sources, Dr Axe Food Med. (2018). https://draxe.com/prebiotics/ (accessed June 11, 2019).

[106] Q. Chaudhry, L. Castle, Food Applications of Nanotechnologies: An Overview of Opportunities and Challenges for Developing Countries, Trends Food Sci. Technol. 22 (2011) 595–603.

[107] O. Merhan, The Biochemistry and Antioxidant Properties of Carotenoids, IntechOpen. (2017).

[108] K.S. Cho, M. Shin, S. Kim, S.B. Lee, Recent Advances in Studies on the Therapeutic Potential of Dietary Carotenoids in Neurodegenerative Diseases, 2018 (2018).

[109] Health and Wellness Series - Functional Foods and Beverages in the United Arab Emirates, Agriculture and Agri-Food Canada;Government of, Canada, 2017. http:// www.agr.gc.ca/ eng/international-trade/market-intelligence/reports/health-and-wellness-series-functional-foods-and-beverages-in-the-united-arab-emirates/?id=1490111775171#c (accessed June 11, 2020).

[110] Sharma S, M. Arora, A. Baldi, Probiotics in India: Current Status and Future Prospects, PharmAspire. 4 (2014) 68.

[111] Middle East Feed Probiotics Market - Growth, Trends and Forecasts (2016 - 2021), 2019. https:// www. mordorintelligence.com/ industry-reports/ middle-east-feed-probiotics-market (accessed June 19, 2019).

[112] L. Al-Qysi, M. Mohammad, A. Al-iedani, M.M. AbuKhader, Investigating the characteristics of probiotics marketed in the Middle East and pharmacists' perception of use in Muscat, Oman, PharmaNutrition. 13 (2020) 100202.

[113] O. Chumphukam, W. Chaiwangyen, B. Sivamaruthi, S. Sirilun, S. Natakankitkul, N. Kangwan, K. Singsai, M. Suttajit, The Innovation of Functional Foods in Asia: IFFA 2018, Asia Pac. J. Clin. Nutr. 28 (2019).

[114] Global revenue of the Functional Food Market 2022 | Statistic, Statista. (2019). https://www.statista.com/statistics/252803/global-functional-food-sales/ (accessed June 19, 2019).

[115] Functional Foods Market in Asia: Opportunities and Challenges, Funct. Foods Mark. Asia Oppor. Chall. (2016). https:// www.futuremarketinsights.com/blogs/details/functional-foods-market (accessed August 5, 2019).

[116] India Probiotics Market Growth, Size, Share & Report | 2020 - 2025, Knowl. Sourc. Intell. LLP. (n.d.). https://www.knowledge-sourcing.com/report/india-probiotics-market (accessed August 3, 2020).

[117] APAC Functional Food Ingredients Market Analysis and Review 2019 - 2029 | Future Market Insights (FMI), (n.d.). https://www.futuremarketinsights.com/reports/asia-pacific-functional-food-ingredients-market (accessed June 11, 2020).

[118] I.S. Surono, F.P. Koestomo, N. Novitasari, F.R. Zakaria, Yulianasari, Koesnandar, Novel probiotic Enterococcus faecium IS-27526 Supplementation Increased Total Salivary sIgA Level and Bodyweight of Pre-school Children: A Pilot Study, Anaerobe. 17 (2011) 496–500.

[119] O.J. Onubi, A.S. Poobalan, B. Dineen, D. Marais, G. McNeill, Effects of Probiotics on Child Growth: A Systematic Review, J. Health Popul. Nutr. 34 (2015) 8.

[120] S. Bornkessel, S. Bröring, O. Omta, Consumer Acceptance of Functional Foods and Their Ingredients: Positioning Options for Innovations at the Borderline Between Foods and Drugs, Int. Food Agribus. Manag. Assoc. (2011) 15.

[121] I.A. Castro, A. Majmundar, C.B. Williams, B. Baquero, Customer Purchase Intentions and Choice in Food Retail Environments: A Scoping Review, Int. J. Environ. Res. Public. Health. 15 (2018).

[122] M.T. Baker, P. Lu, J.A. Parrella, H.R. Leggette, Consumer Acceptance toward Functional Foods: A Scoping Review, Int. J. Environ. Res. Public. Health. 19 (2022) 1217.

[123] V. Bruschi, R. Teuber, I. Dolgopolova, Acceptance and willingness to pay for health-enhancing bakery products – Empirical evidence for young urban Russian consumers, Food Qual. Prefer. 46 (2015) 79–91.

[124] F. Verneau, F. La Barbera, M. Furno, The Role of Health Information in Consumers' Willingness to Pay for Canned Crushed Tomatoes Enriched with Lycopene, Nutrients. 11 (2019) 2173.

[125] E.M. Perfetto, L. Burke, E.M. Oehrlein, M. Gaballah, FDAMA Section 114: Why the Renewed Interest?, J. Manag. Care Spec. Pharm. 21 (2015) 368–374.

[126] C.S. Birch, G.A. Bonwick, Ensuring the future of functional foods, Int. J. Food Sci. Technol. 54 (2019) 1467–1485.

[127] I. Spacova, H. Dodiya, A.-U. Happel, C. Strain, D. Vandenheuvel, X. Wang, G. Reid, Future of Probiotics and Prebiotics and the Implications for Early Career Researchers, Front. Microbiol. (2020).