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# Fermented Functional Foods: A Treasure House of Health

Review Article

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## Abstract

Lifestyle and diet have been the most important components in determining one's health and well-being. Humans have fallen to a sedentary lifestyle as a result of technological improvements, and this has become the prime cause of significant lifestyle problems such as type 2 diabetes, obesity, hypertension, hypercholesterolemia, and cardiovascular diseases. Fermented functional foods have become increasingly popular in public health and wellness circles in recent years. Functional foods, also known as nutraceuticals, are highly nutritious and linked to a variety of potent health advantages. The understanding of these super-foods, as well as their incorporation with individual needs, can make these foods "a treasure house of health." Due to their immune-boosting properties, such health foods are in high demand in the current era of the COVID-19 pandemic, and hence have a lot of potential for the food industry. To alleviate its use, fresh studies and information about nutritious diets and biologically active dietary ingredients are needed. Here, we've discussed the fundamentals of fermented functional foods, as well as the various types of probiotics involved, the various phytochemicals as functional foods, and ultimately, the various health benefits of these health foods.

**Keywords:** Lifestyle, Diet, Nutraceuticals, COVID-19, Phytochemicals

## Introduction

It is commonly recognized that there is a direct link between the food we eat and our health. Foods are no longer solely intended to satisfy hunger and deliver essential nutrients. They provide extra health benefits to humans, such as avoiding diseases caused by poor nutrition and promoting physical and emotional well-being [1]. Fermented functional foods are abundant in nutrients and have been linked to a variety of health advantages [2]. The concept began in Japan in the 1980s, when government authorities began licensing foods with proven health advantages in an effort to improve the general public's health. They may, for example, guard against sickness, avoid vitamin deficiency, and support healthy growth and development of the people. This is clearly distinct from nutraceuticals, pharmafoods, and dietary supplements. "Superfood" and "miracle food" are marketing words, and using them to describe foods can create unreasonable expectations. Foods fortified with vitamins, minerals, probiotics are some examples. Fruits, vegetables, nuts, seeds, and grains are all nutrient-dense items that are frequently referred to as functional foods. Oats, for example, include beta glucan, a type of fibre that has been demonstrated to lower inflammation, boost immunological function, and improve cardiovascular health [3]. Antioxidants, which are beneficial molecules that help prevent diseases, are abundant in fruits and vegetables, which are fortified with extra components such as vitamins, minerals, probiotics, or fibre to boost a food's health benefits [4].

Fermentation was first documented in the Fertile Crescent around 6000 B.C., and practically every civilization since has had at least one fermented dish in its culinary legacy. Global cultures have created unique flavors and rituals surrounding fermentation, from Korean kimchi and Indian chutneys and pickles to the omnipresent sauerkraut, yoghurt, and cheese. Asian cultures, in particular, have a long history of fermenting a wide range of foods, including Chinese douchi (black beans), Japanese natto (soybeans), Korean banchan (side dishes), Lao pa daek (fish sauce), and Vietnamese mám (seafood), all of which are still staples in their daily diets. Fermented foods are also employed for therapeutic purposes in Eastern cultures, which registered dietitians who practice "food as medicine" may find particularly interesting. The link between fermented foods and health can

be traced all the way back to ancient Rome and China, and it's still a hot topic among researchers today [5]. Over 500 probiotic food products have been launched on the global market in the last few years, and the number of probiotic foods on the market is constantly expanding. Consumers and scientists are becoming more interested in probiotic foods made from fermented fruits and vegetables, grains, and animal products. Fruit juices, milk, sour milk, oat-based goods, and ice creams containing probiotics are commercially popular nowadays. Probiotic-containing foods include mayonnaise edible spreads, meat-based goods, cheese, and cheese-based dips. Asia, as a treasure-box of authentic fermented foods, has a diverse selection that includes: Bagoong (Philippines), Cahgem Pomba (India), Cheonggukjang/Doenjang (Korea), Chin Som Mok (Thailand), Dhokla (India), Douchi/ Doubanjiang/Mianchi (China), Idli (SriLanka/ India), Jalebi (Pakistan/Nepal/India), Kimchi (Korea), Kombucha (China/Russia/ Ukraine/Vietnam/Korea/Japan), Miso (Japan/Korea), Natto (Japan), Nem Chua (Vietnam), Puto (Philippines), and Tempeh (Indonesia). According to recent studies, COVID-19 fatality rates are lower in nations where traditional LAB fermented items are widely consumed. Fermented foods, for example, could be used as a preventative measure [6]. Other nutrients included in these products may help to boost their effectiveness (e.g., vitamin K125) [7].

## Fermented Microorganisms as Probiotics

Probiotics are quickly becoming a popular type of nutritional supplement all over the world. Fermented foods are high in probiotic bacteria, so eating them adds healthy bacteria and enzymes to your total intestinal flora, improving the health of your gut microbiome and digestive system while also boosting your immune system [8] (Fig1). Fermented foods have unique functional features that provide consumers with health benefits due to the presence of functional microorganisms that have probiotic capabilities, antibacterial properties, antioxidant properties, peptide synthesis, and so on [9]. The purported health advantages of fermented functional foods are attributed to the interaction of ingested live microorganisms, bacteria, or yeast with the host (probiotic effect) or the intake of microbial metabolites created during the fermentation process (biogenic effect). Competitive exclusion, nutritional competitiveness, and/ or immune response stimulation have all been hypothesized as probiotic modes of action [10].

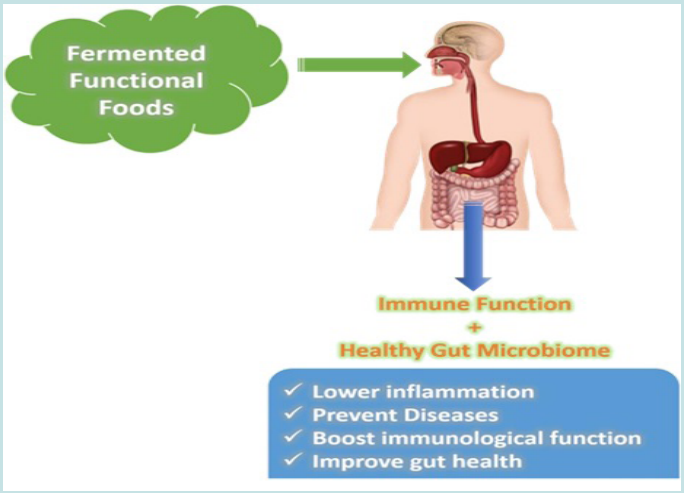


**Figure 1:** Effects of fermented functional foods on health.

During fermentation, bacteria produce bioactive metabolites such as bioactive peptides, fatty acids, organic acids, and vitamins, which give fermented functional foods their biogenic qualities [11].

## Types of Probiotics Involved

Probiotics significance to the modulation of respiratory, gastrointestinal, and immune systems has begun to be completely acknowledged and scientifically examined in recent decades. Lactic acid bacteria (LAB), particularly those of the genus *Lactobacillus*, but also *Bifidobacteria*, make up the majority of commercially available probiotics today. Probiotics are also made up of bacteria from the genera *Lactococcus*, *Leuconostoc*.

*Enterococcus*, *Pediococcus*, and *Streptococcus* [12]. LABs, primarily *Lactobacillus*, as well as *Bifidobacterium* and its fermentation products, have been demonstrated in numerous studies to boost innate and acquired immunity, reduce allergies, avoid lesions in the stomach mucosa, and generate an intestinal infection defense [13,14,15]. Furthermore, probiotic LABs are functional foods, which means they possess unique features that may help to prevent or treat a variety of disorders [14]. LABs have a generally accepted safe state. They play a crucial role in the dairy sector, as they are required for the manufacturing of a variety of innovative and classic dairy products. LABs (*Lactobacillus, Lactococcus, Leuconostoc, Enterococcus, Streptococcus* and *Pediococcus*) have been shown to have probiotic action, which helps to prevent gastrointestinal disorders [15]. In 2017, LeBlanc JG demonstrated that probiotics can produce a variety of physiologically active metabolites (lactic acid, aminobutyric acid, bioactive peptides, bacteriocin, reutericycline, conjugated linoleic acid and exopolysaccharides) in addition to probiotic activity [16]. Recently, De Bellis and his coworkers have also claimed that the carrier food along with its functional components influence the performance of probiotic bacterial strains by buffering the probiotic across the gastrointestinal tract, contributing to successful bacterial cell implantation, and regulating probiotic characteristics. Because of their high content of nutrients, fibres, vitamins, minerals, and dietary bioactive phytochemicals, plantbased matrices are particularly suitable for housing and distributing microbial communities. Henceforth, foods supplemented with LAB strains that have probiotic qualities (a variety of biological activities) are functional foods with undeniable health advantages [17].

## Health Impact of Fermented Functional Foods

Fermented functional foods, as well as nutrient-dense whole foods including whole grains, fruits, vegetables, and legumes, should be included in a well-balanced, healthy diet. Fermented foods and beverages have grown in popularity as more people become aware of their nutritional and medicinal benefits. Fermented foods not only provide the vitamins and minerals your body need, but they also promote general wellness. In fact, they can help replace any dietary gaps in your diet and improve your health by increasing your consumption of vital elements including vitamins, minerals, fibre, heart-healthy fats and probiotics [18]. Following are some of the health benefits of these fermented functional foods from throughout the world: (i) nutrient synthesis, (ii) immunomodulation, (iii) illness prevention, (iv) allergy prevention and so on. Functional foods that have been modified, fermented or fortified can all be found in a well-balanced diet [11]. Nonetheless, probiotic bacteria belonging to Lactobacillus and

Bifidobacterium spp. have been shown to disrupt many aspects of COVID-19 infection, including receptor binding and metabolic pathways implicated in illness prognosis. The literature shows that bee honey has inhibitory effects against SARS-CoV-2 in silico and in vitro, as well as improved treatment outcomes in COVID-19 patients who are hospitalized. MKs are abundant in fermented milk, as are many other beneficial chemicals. It possesses a wide range of bioactivities, albeit none have been empirically examined in the context of COVID-19, with the exception of a few in silico studies. The bioactive form of vitamin K, bioactive peptides, antioxidants, probiotics, and antibacterial agents may be increased by fortifying fermented milk with natural honey (e.g., oligosaccharides). All of these chemicals have the ability to boost immunity and repair nutritional deficits, both of which are typical in COVID-19 infection [19].

Probiotic bacteria can create a wide range of metabolic compounds that are beneficial to human health. These bioactive compounds are responsible for such specific preventive as well as functional modulations. Bacteriocins, peptides, amino acids, metabolic enzymes, short chain fatty acids, antioxidants, vitamins, anti-inflammatory and immunomodulatory agents, and exopolysaccharides are only a few of the bioactive chemicals produced by probiotic bacteria. These chemicals work together to promote the gut's physiological function and overall health. The most crucial conditions for supplementing foods with probiotic bacteria are to keep the microbial cells alive during the food's manufacturing, packaging, and storage [20]. Jakubczyk and his coworkers studied the bioactive peptides produced by *Lactiplantibacillus plantarum* subsp. *plantarum* fermentation of Faba beans which revealed antihypertensive (ACE inhibitory) and anti-oxidative activities. After three days of fermentation, the sample demonstrated the highest level of action against metabolic disorders [21]. Microbes in fermented foods have been found to create antimicrobial peptides such bacteriocins, which have been linked to biosafety as certain bioactive peptides limit the growth of pathogenic microorganisms in fermented foods like sausages, boosting their stability and shelf life. Microbial enzymes like bile-salt hydrolase have been shown to have a therapeutic effect on systemic lipid and cholesterol metabolism, energy metabolism, immunological homeostasis, including intestinal electrolyte balance [22]. Microbes also produce exopolysaccharides in fermented foods which are reported to function as prebiotics, as well as having hypocholesterolemic, antioxidant, and antimicrobial properties [23]. The fermentation of dietary fibres by gut microbiota and probiotic microorganisms produces short-chain fatty acids (SCFAs), which include acetate, lactate, propionate, and butyrate. By limiting the growth of pathogenic bacteria, modifying cholesterol and lipid metabolism, and giving energy to the colonic epithelium, these SCFA extend their health benefits to protect against diseases including colon cancer and IBD [24]. Many fermented foods, such as kefir, buttermilk, koumiss, dahi, and kurut, have been studied using next-generation sequencing technology to decipher the diverse microbial diversity present [25]. Due to the presence of 63 amino acid degradation proteins, metaproteomics investigations in fermented fish demonstrated the role of bacteria groups like *Bacillus* sp., *Escherichia* sp., *Pseudoalteromonas* sp. and *Streptococcus* sp. in aroma generation [26].

Table 1 depicts various LAB strains isolated from different food matrices and their bioactive compounds conferring various therapeutic effects. In a study conducted by Gupta and Sharma, *Pediococcus acidilactici* (Ch-2) isolated from Chuli (dried apricot) was reported for many functional properties and novel compounds and found out to have safe status for further use in food and nutraceutical industry. Also, they reported 'Squalene' – for the first time, a rare and therapeutic anti-cancer chemical was recovered from probiotic bacteria extracted from fermented food products, and it was recommended for further exploration as a significant source of Squalene [29]. When VillarrealSoto et al. studied the impact of fermentation conditions on the production of bioactive compounds with anticancer, anti-inflammatory and antioxidant properties in kombucha tea extracts. Black tea fermentation with the kombucha consortium boosts its bioactive potential and also promotes synergy between fermentation byproducts and microbes, resulting in the creation of interesting metabolites [30]. Xu et al., for the very first time claimed that fermentation by plant- and animal-derived *Pediococcus pentosaceus* improves the composition of bioactive chemicals in broccoli juice, including GS, sulforaphane, and sulforaphane nitrile concentration, myrosinase activity, and organic acid, vitamin, and amino acid profiles. The findings reveal new information about the bioconversion pathways of many phytochemicals during the fermentation of broccoli juice, and they reflect a thorough examination of P. *pentosaceus's* potential in the production of functional fermented foods. They provide a theoretical foundation for P. *pentosaceus*' prospective applications in the manufacturing of vegetable-derived goods, as well as the properties that permit the use of cruciferous vegetables as remarkable carriers of probiotic bacterial strains [34]. Ivanov and his coworkers discovered the presence of "traditional" starter strains Lb. *delbrueckii* subsp. *bulgaricus* and Str. *thermophilus*, as well as various LAB and spoilage taxa, in a *metagenomic*

**Table-1:** Therapeutic effects of various bioactive compounds obtained from different foods.

| Name of food | LAB involved | Bioactive compound | Therapeutic effects | References |
|---|---|---|---|---|
| Red ginseng beverage | L. fermentum | p-coumaric acid | Antidiabetic effect | [27] |
| Goat casein | L. lactis<br>L. bulgaricus<br>L. plantarum<br>L. rhamnosus | isracidin | Antibacterial<br>Anti-inflammatory | [28] |
| Chulli | P. acidilactici | squalene pyrrolo[1,2a] pyrazine1,4dione, hexahydro3 (2methylpropyl) n-Hexadecanoic acid | Anticancerous<br>Antioxidant<br>Anti-inflammatory | [29] |
| Kombucha tea extracts | LAB | - | Anticancer<br>Antioxidant<br>Anti-inflammatory | [30] |
| Yogurt Pickle | P. acidilactici L. plantarum | - | Antidiabetic<br>Hyperglycaemic<br>Antioxidant | [31] |
| Whey protein isolate | LAB | κ-casein f(106–109) | Satiety regulation,<br>Anti-carcinogenic<br>Antimicrobial<br>Anti-thrombotic<br>BPs | [32] |
| Blueberry pomace | LAB | chalcone-3-O-galactoside kaempferol | Antioxidant | [33] |
| Broccoli juice | Pediococcus pentosaceus | 4-hydroxyglucobrassicin<br>Glucobrassicin<br>4-methoxyglucobrassicin<br>Neoglucobrassicin | Antioxidant<br>Antimicrobial<br>Stress relief | [34] |
| Yoghurt | Lactobacillus delbrueckii subsp. bulgaricusStreptococcus thermophilus | indole-3-propionic acid (IPA) cyclo(phenylalanyl-prolyl) and cyclo(leucyloprolyl). | Neuroprotector<br>Antimicrobial | [35] |

analysis of authentic Bulgarian yoghurts. They identified that Lb. *delbrueckii* subsp. *bulgaricus* strains in homemade yoghurts are separate, authentic, and do not participate in commercial starters, according to RAPD, MLST, and PFGE investigations. The creation of new metabolites belonging to the amino acid class was the key innovation of this study. In addition, the metabolic properties of the adjacent microflora accumulate arginine, lysine, and histidine, which can be helpful not only for the proliferation of the starter cultures, but also for the yoghurt consumer. Human health-promoting metabolites such as indole-3-propionic acid and L-citrulline were also discovered. This discovery could help to explain the positive impacts of Bulgarian yoghurt on the aged, who have bright minds and sexual activity well into their senior years. Their results revealed that homemade yoghurts, produced in small farms of Bulgarian mountainous areas, are a source of LAB with health-promoting benefits, according to a detailed analysis of the current status of authentic Bulgarian yoghurt microbial diversity [35]. In a nutshell, fermented functional foods can help you get more of the nutrients you need, address nutritional gaps and improve your overall health.

## Conclusion

It is true that highly processed foodstuffs were favored for a long time, increasing the risk of chronic diseases like diabetes, cancer, coronary heart disease, obesity and premature mortality. Conversely, consumers' preferences have shifted to alternate, healthier foods. Fermented functional foods, interestingly, have been highlighted as a relevant segment in the functional food market, which has exhibited a steady development in recent years. There is a rising interest in recovering under-utilized health-beneficial bioactive compounds from various food matrices, which might be employed in diets or as nutraceuticals. Simultaneously, attempts to develop novel drinks and added-value products are still needed, particularly with under-utilized and unexplored food matrices. Finally, when the nutritional qualities of foods and the by-products are combined with the varied enzymatic machinery of rationally selected LAB, this makes great raw materials for the production of innovative functional foods products. So, it will not be wrong to say that the current public understanding of the health benefits of a well-balanced diet encourages people to eat healthier and stay healthier.

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