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Fermented food products for gastrointestinal health and related diseases

Abstract

The incidence of lifestyle diseases such as inflammatory bowel diseases is increasing due to unhealthy eating habits and modern lifestyles, resulting in a growing demand for fermented foods worldwide due to their scientifically proven functional and nutritional attributes. Fermented foods are obtained by controlled microbial growth and enzymatic degradation of food constituents. These foods have a good amount of probiotic bacteria and bioactive peptides that benefit human health. Bioactive peptides are formed by either fermentation or enzymatic hydrolysis of food proteins. Fermented foods and beverages *i.e.*, dahi, yogurt, kefir, kimchi, sourdough bread, pickles play a significant role in gut microbiota balance and mental health. Starter culture used in the fermentation of food products provide various health-promoting activities to fermented foods like anti-oxidant activity, anti-hypertensive activity, probiotic activity and improves protein digestibility. Several groups of lactic acid bacteria (LAB) strains produce Exopolysaccharides (EPS) such as α and β- glucans, galactans, fructans, and gluco- and fructo-oligosaccharides. EPS produced by LAB has a positive impact on gut health. In addition, probiotic bacteria have proven to be a beneficial ingredient for any gut disorder (inside or outside the GI tract). They regulate the level of immunoglobulins (IgA) and inflammatory cytokines and improve gut barrier activity. Symbiotic yogurt (made with bacterial strains of *Lactobacillus acidophilus* and *Bifidobacterium longum*) helps raise high-density lipoprotein (HDL) cholesterol and also changes the ratio of low-density lipoprotein (LDL) to HDL. Consumption of kefir inhibits the pathogen's action by the production of acids and bacteriocins. Isolation and pharmaceutical applications of health-promoting bioactive peptides from fermented foods have been emerging in dairy and food research areas.

Keywords: fermentation, high-density lipoprotein (hdl) cholesterol, gastrointestinal, health-benefits, probiotic bacteria, yoghurt, lactose intolerance

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Introduction

Fermented foods and beverages have been an integral part of the human diet, for centuries. Fermented foods or beverages are prepared through controlled microbial growth and enzymatic degradation of macro and micro constituents of food. The fermentation process of food can be categorized by the primary metabolites and micro-organisms such as yeast, *Acetobacter*, Lactic acid bacteria (i.e., *Leuconostoc, Lactobacillus, and Streptococcus*), propionic acid (produced by *Propionibacterium freudenreichii*), and ammonia and fatty acids. Fermentation is also defined based on food substrates viz. dairy, vegetables, fruits meat and fish, legumes crops (soybean), cereals, starchy roots, and fruits. Food that contains monosaccharides, disaccharides or oligosaccharides is fermented by yeast or lactic acid bacteria. Fermented milk and milk products have numerous health-promoting properties like hypertensive, hypocholesterolemic and anti-microbial effects[1] and their functional and microbial properties have recently been extensively studied.[2] Lactic acid bacteria retain the nutritional quality of dairy products and increase their shelf-life. Acidified conditions inhibit the proliferation of pathogens and microorganisms, which aids in preventing food spoilage by releasing anti-microbial bacteriocins.[3] It can also have beneficial effects on gut health, i.e., modulation of gut microbiota and in the prevention and treatment of inflammatory bowel disease (IBD)[4] in addition to anti-carcinogenic and hypo-cholesterolemic effects.[5] Furthermore, lactose conversion to lactic acid occurs during lactic acid bacteria-induced milk fermentation.[6] It also provides health benefits by alleviating abdominal pain and diarrhea in individuals with lactose intolerance.[7] Fermented dairy products provide several health benefits, such as modulating gut microbiota and immune response, and lowering a person's risk of hypertension, diabetes, and high cholesterol levels.[8] Fermented dairy products contain tri-peptides, *i.e.,* valyl-prolyl-proline (VPP) and isoleucyl-prolyl-proline (IPP) that are investigated for their possible health effects.[9] Fermented milk products containing *Lactobacillus sps.* assist in treating moderate hypertension by producing ACE-inhibitory peptides and GABA (g -amino butyric acid).[10] These tripeptides also exhibit anti-microbial, anti-inflammation, anti-mutagenic, anti-oxidant, and anti-haemolytic properties.[11]

Different fermented food products

Cheese

Cheese can be fermented or unfermented. It is energy-dense food that contains a good amount of nutrients such as proteins, fats, minerals (*i.e.,* Ca and Mg), and vitamins (*i.e.,* Vitamin A, B2, and B12).[6] During cheese production acidification of milk is done by starter culture that can be mesophilic or thermophilic bacteria. But nowadays several researchers are successfully using probiotic starter culture in cheese making. The enzyme used for cheese making, called rennet (obtained from calf stomach, or produced by microbial or plant source) is used for coagulation of milk protein (Casein, amino acid chain at 105 – 106 k-casein). Cheese has several bioactive peptides that exhibit different biological activities.[12] Biological active peptides, vitamins, and minerals together are responsible for the beneficial effects of cheese such as the management and treatment of several diseases.[13] Kim et al.,[14] reported that biometabolites produced in cheese from conjugated linoleic acids and sphingolipids played an important role in obesity management by modulating lipid and skeletal muscle metabolism.

Dahi

Dahi has a significant place in the Indian diet and is equal to the Western fermented product, yogurt. Dahi is the product obtained from boiled or pasteurized milk (90°C/5-10 minutes) followed by fermentation using lactic acid bacteria (in form of previous dahi, concentrate culture or freeze-dried culture). During fermentation, several changes occur in dahi making that possess positive effects on milk constituents such as protein, lactose, vitamin, and minerals. Dahi is prepared by inoculation of lactic acid bacteria that play a vital role in the production of nutraceuticals compound in fermented foods. Nowadays probiotic dahi attracts the attention of consumers due to its well-proven health benefits, 'Probiotic' bacteria are good or gut-friendly bacteria that maintain gut microbiota balance in the human intestine. In addition, LAB possesses several other positive effects in fermented products such as improved nutritional quality by producing vitamin B12.[15]

Yogurt

Yoghurt is a fermented milk product that is prepared by using certain starter culture strains (*Streptococcus thermophilus* and *Lactobacillus delbrueckii subsp. Bulgaricus*). Yogurt is a product that contains a good amount of macro and micro-nutrients such as fat, protein, vitamin B_2 and $B_{12,}$ and milk minerals (Ca, Mg, Zn, and K).[16] During the fermentation of yogurt, several changes occur, such as the production of health-promoting peptides from milk proteins, along with the synthesis of vitamin B_9, production of conjugated linoleic acid (CLA), improvement in calcium absorption and thereby improving the shelf-life of yogurt.[17] Researchers reported that the human consumption of yogurt helps in the management of several intestinal and extra-intestinal diseases such as lactose intolerance, and infectious diarrhea. It also reduces the duration and incidence of respiratory infections and improves immune and anti-inflammatory responses.[18]

Koumiss

Koumiss or kumis is an ancient fermented milk drink also known as kumis, chige, airag and arrag (Mongolian language words). It is consumed in Central Asia and prepared by using raw mare's milk. Kumis is prepared by using the back-slopping method, in which 30% previous batch of kumis (fermented) is added as inoculum in 70% raw mare's milk.[19] Zhang et al.,[20] reported that raw milk (Mare's) kumis contains an abundant amount of LAB; *i.e., Lactobacillus (L.) plantarum, L. helveticus, L. kefiranofaciens, and Lactococcus (Lc.) lactis*. Kumis has a good amount of vitamins (*i.e.,* C, A, E, $B_{2,}$ $B_{12,}$ and Pantothenic acid) and minerals (*i.e.,* Ca and P). Kumis also contains essential fatty acids such as linolenic and linoleic acid. A higher amount of lactose in mare's milk is suitable for lactic acid fermentation. Kumis reported several health-promoting properties *i.e.,* regulates blood pressure, improves immune health, and has positive effects on the functioning of kidneys, liver, endocrine glands, gut system, nervous and vascular systems. Kumis is rich in microflora that plays a vital role in gut health and is helpful in the treatment of digestive diseases.[21]

Kefir

Kefir is a very popular acid-alcoholic fermented dairy product in Europe (eastern part), Russia and Southwest Asia. It is traditionally prepared from kefir grains and the portion that remains after the separation of kefir grains. But nowadays commercial production of kefir uses freeze-dried kefir starter culture.[22] Kefir has a slightly acidic taste and creamy consistency, and kefir grains used for kefir production are white to yellowish–white in colour, have a gelatinous texture, and size (diameter) of kefir grains varies from 0.3–3.5cm. Different microbial strains of kefir starter culture stick to a polysaccharide matrix of kefir grains, which contains LAB (10^8 colonies forming unit (CFU)/g), yeast (10^6–10^7CFU/g), and acetic acid bacteria (10^5CFU/g).[23] Kefir production can be done in three ways i.e, (1) the artisanal process, (2) the commercial process (by the Russian method), and (3) the commercial process (by using pure culture). Several researchers attempted kefir production by using non-animal milk such as soy milk, coconut milk, fruit juices, and sugar and molasses solutions.[24–26]

Rosa et al.,[27] summarized the different health-promoting properties of kefir and reported that regular kefir consumption helps in the management of various gastrointestinal and allergenic diseases and conditions. Kefir consumption alleviates lactose intolerance and improves digestion. In, addition kefir also had health-promoting properties such as anti-hypertensive, anti-microbial, anti-inflammatory, antioxidant, anti-carcinogenic, anti-allergenic, and hypocholesterolemic effects.

Kimchi

Kimchi is a very popular ancient fermented food product, that originated in Korea. An ancient Korean book "Samkuksaki" (published in 1145 A.D.) and other ancient documents published literature about Kimchi and similar products. Presently kimchi is commonly consumed in the countries like China and Japan. As per ancient literature, kimchi is prepared by brine fermentation of vegetables in a stone jar. Raw materials needed for kimchi preparation are (1) Major raw materials (different types of vegetables such as Chinese cabbage, radish, cucumber, leaf mustard, sweet potato, etc.); (2) Spices such as black and red pepper, onion, mustard, cinnamon, garlic, and ginger; (3) Seasonings such includes salt, corn syrup, soybean sauce, sesame seed, and salt-pickled seafood; (4) Other optional ingredients varies according to geography, taste, and availability. These ingredients include mushrooms, seasonal vegetables, seafood, cereals, fruits, and meats.[28] During the fermentation of kimchi, several health-promoting compounds are generated such as phytochemicals, volatile compounds, organic acids, peptides, etc., which possess a wide range of functional properties. Scientific literature on kimchi shows that biological compounds generated during kimchi production had positive effects on immune health, and help in the management of cancers, metabolic syndrome, aging, and cardiovascular disease (CVD).[29] Kimchi has a high amount of salt content that will cause major health concerns of high blood pressure,[30] but studies show that raised sodium intake from kimchi consumption had no adverse health effects as higher potassium content of kimchi neutralized the effect on blood pressure.[14,31]

Sauerkraut

Sauerkraut is a traditional fermented cabbage-based food product that is prepared by a natural fermentation process for thousands of years. It has low calorific value and contains good amounts of nutrients and Vitamin C, β-carotene, and folic acid content. In addition, sauerkraut has very pleasant organoleptic qualities. Sauerkraut is commonly consumed with fruit salad and added in soups, stews, and Caesseroles in Asia, Europe, and the United States. Saurkraut is prepared from shredded cabbage (0.7-2 mm thick strip) and anaerobic conditions are created by the addition of salt (0.7-2.0% sodium chloride). Several other ingredients such as spices, carrots, herbs, and wine are also added during the fermentation of cabbage to improve the flavour of sauerkraut. Fermentation of cabbage is done in anaerobic conditions

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(fermented in a container/jar and covered with a lid) for one week to months. Several scientific studies reported the health-promoting effects of sauerkraut on human health such as anti-oxidant, anti-inflammatory, anti-carcinogenic, and immunity booster.[32]

Sourdough bread

Bread is a traditional food that is consumed since ancient times. Traditionally bread recipe contains flour (*i.e.,* wheat or rye), water, salt (optional), and leavening agents (*i.e.,* chemicals, baker's yeast, sourdough). Sourdough is considered the oldest, natural starter and an alternative leavening agent for baker's yeast and chemical. Sourdough bread's popularity and consumption increased due to multiple health-promoting properties.[33] Fermentation of sourdough is naturally done by LAB and yeast. Natural sourdough fermentation helps in the management of gastrointestinal disorders, i.e., irritable bowel syndrome (IBS), and celiac disease i.e., gluten intolerance syndrome by changing the molecular structure of proteins and carbohydrates. Consumption of sourdough bread improves digestion and gut health as sourdough bread contains prebiotic compounds. In addition, sourdough has quality mineral and vitamin content.[34] Starter cultures used for the fermentation of different traditional fermented foods and beverages shows in Table 1.

Table 1 Traditional fermented foods and beverages and the fermenting microorganisms used to make them

Products	Fermentation culture/micro-organisms	Reference
Fermented dairy products		
Dahi	Mixed culture (Lactococcus lactis ssp. lactis, L. lactis ssp. cremoris, L. lactis ssp. lactis biovar. Diacetylactis)	Vijayendra et al.[76]
Yogurt	Streptococcus thermophilus and Lactobacillus delbrueckii subsp. Bulgaricus	Chen et al.[56]
Cheese	Lactic acid bacteria strains (Lactococcus lactis ssp. lactis, L. lactis ssp. cremoris, L. lactis ssp. lactis biovar. Diacetylactis, Streptococcus thermophilus, Lactobacillus delbrueckii subsp. Bulgaricus, Propionibacterium freudenreichii)	Kongo,[64]
Kefir	**Bacterial species** Lactobacillus kefiranofaciens, Lactobacillus plantarum, Lactobacillus paracasei ssp. paracasei, Streptococcus thermophilus, Lactobacillus delbrueckii subsp. Bulgaricus. **Yeast** Saccharomyces cerevisiae, S. unisporus, Candida kefyr, and Kluyveromyces marxianus ssp. Marxianus	Zanirati et al.[77]; Prado et al.[70]
Kumiss	**Bacterial specices** Lactobacillus kefiranofaciens, Lactococcus lactis, Lactococcus raffinolactis, Lactobacillus helveticus, Citrobacter freundii **Yeast** Pichia sp. BZ159, Meyerozyma caribbica, Dekkera anomala, Kazachstania unispora, Kluyveromyces marxianus, and uncultured Guehomyces	Tang et al.[75]
Fermented food products		
Sourdough bread	**Bacterial species:** Lactiplantibacillus plantarum, Levilactobacillus brevis, Fructilactobacillus sanfranciscensis, Limosilactobacillus fermentum, Leuconostoc mesenteroides, Weissella cibaria, Weissella confuse, etc. **Yeast** Kazachstania exigua, Torulaspora delbrueckii, Wickerhamomyces anomalus, Pichia kudriavzevii, Saccharomyces cerevisiae, Kazachstania humilis, Candida krusei, etc.	Calvert et al.[55]
Sauerkraut	Lactobacillus plantarum, Leuconostoc mesenteroides ssp. mesenteroides/ dextranicum, Lactobacillus brevis, Lactobacillus rhamnosus GG	Beganović et al.[54]
Kimchi	Leuconostoc mesenteroides, Lactobacillus plantarum, Lactobacillus brevis and Pediococcus cerevisiae (Leu. citreum, Leu. gasicomitatum, Leu. carnosum, Leu. gelidum, Leu. mesenteroides, Lb. sakei, Weissella koreensis, and W. cibaria)	Lee et al.[30]

Gastrointestinal health-promoting properties of different types of fermented food products

Hypocholesterolemic effects

Several scientific findings reported that regular consumption of selected probiotics (*Lactobacillus acidophilus, Lactobacillus fermentum, Lactobacillus casei subsp. Casei*, etc.) may help in the reduction of serum cholesterol (especially LD-L). Ali,[35] studied the Hypocholesterolemic effects of kishk (a fermented functional food product containing dried milk and whole wheat mixture) on a rat experimental model over a period of 8 months. Rats fed a diet supplemented with kishk significantly ($p \leq 0.05$) decreased the body weight and the liver/body weight ratio (maximum decrease was 18.78% at 30% supplementation level). Administration of kishk supplemented diet increased several other body parameters such as high-density and low-density lipoprotein (HDL and LDL) cholesterol, triglyceride concentration, serum cholesterol and atherogenic indices. In addition, parameters of kidney functioning and enzymatic activities of liver enzymes, also elevated positive group (supplemented with kishk and a high-cholesterol diet).

Kobayashi et al.[36] investigated the hypocholesterolemic effects of fermented soymilk in rats. Male rats (Sprague-Dawley; age: 7 weeks) were fed with 1% cholesterol (Control diet); 1% cholesterol + 11.7% fermented soymilk (F-5); 1% cholesterol + 23.4% fermented soymilk (F-10) over the period of 5 weeks. The hepatic triglyceride, cholesterol level, liver weight and fat mass were reduced in rats fed with the fermented soymilk diet. A cholesterol synthesis-related gene expression (SREBP-2) decreased significantly ($p<0.05$) in the liver of the rats fed with the F-5 diet, while a cholesterol catabolism-related gene expression (CYP7a1) increased significantly ($p<0.05$).

Effects of fermented foods on gut health

The potential probiotic effect of the fermentation microorganisms is widely reported in modern research, several groups of starter cultures used for the fermentation of food products reported probiotic properties such as it to preserve the milk by producing lactic acid and other antimicrobial compounds; adding flavour to fermented foods by the production of flavour compound (such as acetaldehyde and other extracellular polysaccharides); improved nutritional quality by synthesis of vitamins and free amino acids. In, addition probiotics bacteria were also reported with therapeutic and prophylactic properties against cancer and control serum cholesterol levels.[37] Bekar et al.[38] conducted a preliminary trial (Randomized, double-blind study) of probiotics on infection of *Helicobacter pylori* and improves its eradication rate by triple therapy (Used antibiotics: Lansoprazole (30 mg, dose), Amoxicillin (1000 mg, dose), and Clarithromycin (500 mg, dose) with kefir 250 ml twice a day). The study revealed that kefir addition to triple therapy increased the eradication rates of *H. pylori* and decreased the adverse effects of triple therapy. The consumption of soybean and bean tempeh to improves the human microbiota compositions, an in-vitro gut simulator model shows that consumption of tempeh boosts the abundance of *Bifidobacterium*, *Lactobacillus, Escherichia coli*, and *Enterococcus* in the gut.[39] Sourdough bread fermented for 8 hours can be a good source for probiotic bacteria, as Costabile et al.[40] reported that consumption of sourdough bread significantly increased the level of *bifidobacteria* in the gut compared to non-fermented bread. Gastrointestinal health-promoting properties of different types of fermented food products are shown in Figure 1.

Probiotics bacteria role in gut health

Probiotic bacteria maintained the gut microbiota balance and add beneficial functions to gut microbial communities that prevent inflammation in the gut and other intestinal or systemic disease phenotypes. Probiotics have been extensively researched for their role in maintaining the intestinal barrier, which is act as the primary barrier against infections and food allergies entering the intestinal tract. The food matrix of fermented foods provides resistance to probiotic microorganisms in the GI tract in severe conditions such as highly acidic, bile salts and enzymes.[41] Miqual et al.[42] evaluated the anti-nociceptive of bacterial strain *Faecalibacterium prausnitzii* in rodent model and observed that *F. prausnitzii* significantly decrease colonic hypersensitivity in rats that were kept under neonatal maternal separation stress and partial restraint stress. The study also revealed that experimented bacterial strain exhibits anti-nociceptive properties and can be used for the treatment of abdominal pain in Irritable Bowel Syndrome (IBS) patients

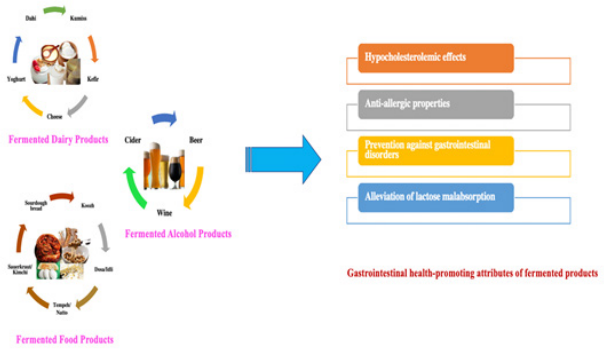

Figure 1 Gastrointestinal health-promoting properties of different types of fermented food products.

Fermented foods - Prevention against gastrointestinal disorders

Each year, gastrointestinal diseases account for a significant portion of morbidity and mortality worldwide. Since several decades ago, probiotics have been used to treat gastrointestinal diseases, but due to a lack of scientific evidence about safety and efficiency, this is not used for clinical procedures. There is a need to study the novel therapeutic attributes of these bacterial strains and fermented products. Improvements in cognitive function were seen in healthy older persons after receiving *L. helveticus*-fermented milk.[43] A probiotic preparation (VSL#3-6g/day) containing three *Bifidobacterium* species, four *Lactobacillus* strains, and one *Streptococcus* strain has shown promise in maintaining remission in ulcerative colitis and pouchitis, as well as preventing postoperative Crohn's disease recurrence.[44] An isolated yeast strain AKP1, that was added to the diet beforehand significantly reduced the cold-induced gastric lesion in the stomach.[45] *Lactobacillus* (*Lactobacillus rhamnosus* 19070-2 and *L. reuteri* DSM 12246) supplementation reduced the frequency of gastrointestinal symptoms significantly.[46]

Fermented foods for anti-allergic reactions

Starter culture strain i.e., *Lactobacillus* is widely used in food applications due to its therapeutic properties and anti-allergic effects in foods.[47] In line, Yang et al.[48] examined the effects of Lactobacillus on soybean allergy alleviation. Studies revealed that *Lactobacillus* strains (*Lactobacillus acidophilus, Lactobacillus plantarum subsp. Plantarum, Lactobacillus delbrueckii subsp. bulgaricus*) alleviated the allergic symptoms in mice model, and reduced the IgE, IgG, and IgG1 level in serum, also up-regulated and down-regulated the

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level of interleukin (IL-2), IL-10, interferon-γ, and IL-4, IL-6, IL-17A, respectively. In, addition, these bacterial strains promoted the proportion of regulatory T cells (Tregs) and suppressed the mast cell expressions. Similarly, studies by Won et al.[49] and Hong et al.[50] reported that probiotic starter culture strains (*e.g., Lactobacillus* and *Lactobacillus kefiranofaciens M1*) isolated from kimchi and kefir grains reported with anti-allergic properties.

Fermented foods alleviate lactose malabsorption

Lactose intolerance is a disease related to lactase deficiency in which a patient does not contain lactase (ß-D-galactosidase enzyme) for digestion of milk sugar (lactose), lactase deficiency leads to discomfort and abdominal pain, diarrhea, borborygmi and flatus on the consumption of lactose rich dairy products.[51] Lactose intolerance can be genetic, damage of intestinal mucosa due to medication, surgery, radiation or disease, or congenital (it is an extremely rare condition in which lactase enzyme is completely absent). Fermented foods and dietary supplement with prebiotics, probiotics and synbiotics helps in lactose digestion by altering the composition of foods and the metabolism of colonic microbiota.[52] Starter culture used in the manufacturing of yogurt, *Streptococcus thermophilus,* and *Lactobacillus delbrueckii subsp. bulgaricus* contain a limited amount of lactose degradation enzyme ß-D-galactosidase that helps in the malabsorption of lactose in lactose-intolerant peoples.[53–77]

Conclusion

The utilization of fermented food products increases rapidly as they possess various nutritional and health properties, in addition to their preservation and sensory attributes. During the production of fermented foods, there are multiple bioactive peptides formed that have lots of potential health benefits against various diseases, e.g., Hypertension, obesity, hypocholesterolemic, lactose intolerance, inflammatory bowel diseases (IBD), etc. Fermentation of foods increases the level of the vitamins in the fermented products, *i.e.,* vitamin B2 (Riboflavin), B9 (Folate), B12, and K. Fermented foods improve gastrointestinal health. There is a need for more studies, on the effects of different regional and traditional fermented foods on gut health and diseases and the identification and isolation of specific peptides for gut health for medical applications can be a new dimension of research.

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Conflicts of interest

Author declares there is no conflict of interest in publishing the article.

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References

1. Ohsawa K, Nakamura F, Uchida N, et al. *Lactobacillus helveticus*-fermented milk containing lactononadecapeptide (NIPPLTQTPVVVPPFLQPE) improves cognitive function in healthy middle-aged adults: a randomized, double-blind, placebo-controlled trial. *Int J Food Sci Nutr.* 2018;69(3):369–376.
2. Rhee SJ, Lee JE, Lee CH. Importance of lactic acid bacteria in Asian fermented foods. *Microbial Cell Factories*. 2011;10(1):1–13.
3. Widyastuti Y, Febrisiantosa A. The role of lactic acid bacteria in milk fermentation. *Food and Nutrition Sciences*. 2014;5(4):435–442.
4. Sáez-Lara MJ, Robles-Sanchez C, Ruiz-Ojeda FJ, et al. Effects of probiotics and synbiotics on obesity, insulin resistance syndrome, type 2 diabetes and non-alcoholic fatty liver disease: a review of human clinical trials. *Int J Mol Sci.* 2016;17(6):928.
5. Kapila S, Sinha VP. Antioxidative and hypocholesterolemic effect of Lactobacillus casei ssp casei (biodefensive properties of lactobacilli). *Ind J Med Sci.* 2006;60(9):361–370.
6. Ansorena D, Astiasarán I. Fermented foods: Composition and health effects. 2016.
7. Ceapa C, Wopereis H, Rezaïki L, et al. Influence of fermented milk products, prebiotics and probiotics on microbiota composition and health. *Best Pract Res Clin Gastroenterol*. 2013;27(1):139–155.
8. Linares DM, Gómez C, Renes E, et al. Lactic acid bacteria and B*ifidobacteria* with potential to design natural biofunctional health-promoting dairy foods. *Front Microbol.* 2017;8:846.
9. Kim SM, Park S, Choue R. Effects of fermented milk peptides supplement on blood pressure and vascular function in spontaneously hypertensive rats. *IJBFS*. 2010;19(5):1409–1413.
10. Nejati F, Rizzello CG, Di Cagno R, et al. Manufacture of a functional fermented milk enriched of Angiotensin-I Converting Enzyme (ACE)-inhibitory peptides and γ-amino butyric acid (GABA). *Lwt-Food Sci Technol*. 2013;51(1):183–189.
11. Aguilar-Toalá JE, Santiago-López L, Peres CM, et al. Assessment of multifunctional activity of bioactive peptides derived from fermented milk by specific *Lactobacillus plantarum* strains. *JDS*. 2017;100(1):65–75.
12. López-Expósito I, Miralles B, Amigo L, et al. Health effects of cheese components with a focus on bioactive peptides. *Fermented foods in health and disease prevention*. 2017:239–273.
13. Hur SJ, Kim HS, Bahk YY et al. Overview of conjugated linoleic acid formation and accumulation in animal products. *Livestock Science*. 2017;195:105–111.
14. Kim B, Hong VM, Yang J, et al. A review of fermented foods with beneficial effects on brain and cognitive function. *PNF*. 2016;21(4):297–309.
15. Balamurugan R, Chandragunasekaran AS, Chellappan G, et al. Probiotic potential of lactic acid bacteria present in homemade curd in southern India. *Indian J Med Res.* 2014;140(3):345–355.
16. Wang H, Livingston KA, Fox CS, et al. Yogurt consumption is associated with better diet quality and metabolic profile in American men and women. *Nutr Res.* 2013;33(1):18–26.
17. Ivey KL, Hodgson JM, Kerr DA, et al. The effect of yogurt and its probiotics on blood pressure and serum lipid profile; a randomized controlled trial. *NMCD*. 2015;25(1):46–51.
18. Kok CR, Hutkins R. Yogurt and other fermented foods as sources of health-promoting bacteria. *Nutr Rev.* 2018;76(Suppl 1):4–15.
19. Mulyawati AI, Jatmiko YD, Mustafa I, et al. Diversity of lactic acid bacteria isolated from fermented mare's milk products based on PCR-RFLP analysis. In *IOP Conference Series: Earth and Environmental Science*. 2019;230(1):012104.
20. Zhang M, Dang N, Ren D, et al. Comparison of bacterial microbiota in raw mare's milk and koumiss using PacBio single-molecule real-time sequencing technology. *Front Microbiol*. 2020;11:58161.
21. Afzaal M, Saeed F, Anjum F, et al. Nutritional and ethnomedicinal scenario of koumiss: A concurrent review. *Food Sci Nutr.* 2021;9(11):6421–6428.

22. Bensmira M, Nsabimana C, Jiang B. Effects of fermentation conditions and homogenization pressure on the rheological properties of Kefir. *Lwt – Food Sci Technol.* 2010;43(8):1180–1184.

23. Chen Z, Shi J, Yang X, et al. Chemical and physical characteristics and antioxidant activities of the exopolysaccharide produced by Tibetan kefir grains during milk fermentation. *Int l Dairy J*. 2015;43:15–21.

24. Magalhães KT, Pereira GVM, Dias DR, et al. Microbial communities and chemical changes during fermentation of sugary Brazilian kefir. *World J Microbiol Biotechnol.* 2010;26(7):1241–1250.

25. Öner Z, Karahan AG, Çakmakçi MLE. Effects of different milk types and starter cultures on kefir. *Gida*. 2010;35:177–182.

26. Rattray FP, O'Connell MJ. Fermented milks kefir. In: Fukay JW, editor. Encyclopedia of dairy sciences. 2nd edn. San Diego, USA: Academic Press; 2011:518–524.

27. Rosa DD, Dias MM, Grześkowiak LM. Milk kefir: nutritional, microbiological and health benefits. *Nutrition research reviews*. 2017;30(1):82–96.

28. Patra JK, Das G, Paramithiotis S, et al. Kimchi and other widely consumed traditional fermented foods of Korea: a review. *Front Microbiol.* 2016;7:1493.

29. Kim SH, Kim SH, Kang KH, et al. Kimchi probiotic bacteria contribute to reduced amounts of N-nitroso dimethylamine in lactic acid bacteria-fortified kimchi. *LWT*. 2017;84:196–203.

30. Lee ME, Jang JY, Lee JH, et al. Starter cultures for kimchi fermentation. *J Microbol Biotechnol.* 2015;25(5):559–568.

31. Song HJ, Lee HJ. Consumption of kimchi, a salt fermented vegetable, is not associated with hypertension prevalence. *J Ethn Foods*. 2014;1(1):8–12.

32. Peñas E, Martinez-Villaluenga C, Frias J. Chapter 24 – Sauerkraut: Production, Composition, and Health benefits fermented foods in Health and disease prevention. Boston: Academic Press; 2017:557–576.

33. Plessas S. Innovations in sourdough bread making. *Fermentation*. 2021;7(1):29.

34. Arora K, Ameur H, Polo A, et al. Thirty years of knowledge on sourdough fermentation: A systematic review. *Trends Food Sci Technol.* 2021;108:71–83.

35. Ali RF. Hypocholesterolemic effects of diets containing different levels of kishk as dried fermented milk–whole wheat mixture in experimental rats. *J Ethn Foods*. 2016;3(2):117–123.

36. Kobayashi M, Hirahata R, Egusa S, et al. Hypocholesterolemic effects of lactic acid-fermented soymilk on rats fed a high cholesterol diet. *Nutrients*. 2012;4(9):1304–1316.

37. Parvez S, Malik KA, Ah Kang S, et al. Probiotics and their fermented food products are beneficial for health. *Journal of applied microbiology*. 2006;100(6):1171–1185.

38. Bekar O, Yilmaz Y, Gulten M. Kefir improves the efficacy and tolerability of triple therapy in eradicating Helicobacter pylori. *J Med Food.* 2011;14(4):344–347.

39. Kuligowski M, Jasińska-Kuligowska I, Nowak J. Evaluation of bean and soy tempeh influence on intestinal bacteria and estimation of antibacterial properties of bean tempeh. *Pol J Microbol.* 2013;62(2):189–194.

40. Costabile A, Santarelli S, Claus SP, et al. Effect of breadmaking process on in vitro gut microbiota parameters in irritable bowel syndrome. *PLoS One*. 2014;9(10):e111225.

41. da Cruz AG, Buriti FC, de Souza CH, et al. Probiotic cheese: health benefits, technological and stability aspects. *Trends in Food Science & Technology*. 2009;20(8):344–354.

42. Miquel S, Martín R, Lashermes A, et al. Anti-nociceptive effect of Faecalibacterium prausnitzii in non-inflammatory IBS-like models. *Scientific reports*. 2016;6:19399.

43. Chung YC, Jin HM, Cui Y, et al. Fermented milk of Lactobacillus helveticus IDCC3801 improves cognitive functioning during cognitive fatigue tests in healthy older adults. *J Funct Foods*. 2014;10:465–474.

44. Madsen K, Cornish A, Soper P, et al. Probiotic bacteria enhance murine and human intestinal epithelial barrier function. *Gastroenterology*. 2001;121(3):580–591.

45. Banik A, Mondal J, Rakshit S, et al. Amelioration of cold-induced gastric injury by a yeast probiotic isolated from traditional fermented foods. *JFF*. 2019;59:164–173.

46. Rosenfeldt V, Benfeldt E, Valerius NH, et al. Effect of probiotics on gastrointestinal symptoms and small intestinal permeability in children with atopic dermatitis. *The Journal of Pediatrics*. 2004;145(5):612–616.

47. Vitheejongjaroen P, Kanthawang P, Loison F, et al. Antioxidant activity of Bifidobacterium animalis MSMC83 and its application in set-style probiotic yogurt. *Food Bioscience*. 2021;43:101259.

48. Yang A, Liao Y, Zhu J, et al. Screening of anti-allergy Lactobacillus and its effect on allergic reactions in BALB/c mice sensitized by soybean protein. *JFF*. 2021;87:104858.

49. Won TJ, Kim B, Song DS, et al. Modulation of Th1/Th2 balance by *Lactobacillus* strains isolated from kimchi via stimulation of macrophage cell line J774A. 1 *In vitro*. *J Food Sci.* 2011;76(2):H55–H61.

50. Hong WS, Chen YP, Chen MJ. The antiallergic effect of kefir Lactobacilli. *J. Food Sci.* 2010;75(8):H244–H253.

51. Shah NP. Functional properties of fermented milk. Health benefits of fermented foods. In: Tamang JP, editor. New York, NY: CRC Press; 2015:261–274.

52. Ibrahim SA, Gyawali R, Awaisheh SS, et al. Fermented foods and probiotics: An approach to lactose intolerance. *J Dairy Res*. 2021;88(3):357–365.

53. Shah NP, da Cruz AG, Faria JDAF. Probiotics and probiotic foods: technology, stability and benefits to human health. New York: Nova Science Publishers; 2013.

54. Beganović J, Kos B, Pavunc AL, et al. Traditionally produced sauerkraut as a source of autochthonous functional starter cultures. *Micro Res.* 2014;169(7-8):623–632.

55. Calvert MD, Madden AA, Nichols LM, et al. A review of sourdough starters: ecology, practices, and sensory quality with applications for baking and recommendations for future research. *Peer J*. 2021;9:e11389.

56. Chen C, Zhao S, Hao G, et al. Role of lactic acid bacteria on the yogurt flavour: A review. *Int J Food Prop.* 2017;20:S316–S330.

57. Chen Y, Wang Z, Chen X, et al. Identification of angiotensin I-converting enzyme inhibitory peptides from koumiss, a traditional fermented mare's milk. *JDS*. 2010;93(3):884–892.

58. Devagaopalan H, Krishnaswamy I. Study on nutritional changes in ragi koozh under controlled fermentation with probiotics. *RJPP*. 2018;7(5):3089–3092.

59. Garofalo C, Arena MP, Laddomada B, et al. Starter cultures for sparkling wine. *Fermentation*. 2016;2(4):21.

60. Hutkins RW. Microbiology and technology of fermented foods. *John Wiley and Sons*; 2008.

61. Jung MY, Kim TW, Lee C, et al. Role of jeotgal, a Korean traditional fermented fish sauce, in microbial dynamics and metabolite profiles during kimchi fermentation. *Food Chem.* 2018;265:135–143.

62. Kang KH, Kim SH, Lee S, et al. Lactic acid bacteria directly degrade N-nitroso dimethylamine and increase the nitrite-scavenging ability in kimchi. *Food Control*. 2017;71:101–109.

63. Koebnick C, Wagner I, Leitzmann P, et al. Probiotic beverage containing Lactobacillus casei Shirota improves gastrointestinal symptoms in patients with chronic constipation. *Can J Gastroenterol*. 2003;17(11):655–659.

64. Kongo JM. Lactic acid bacteria as starter-cultures for cheese processing: past, present and future developments. Lactic acid bacteria-R and D for food, health, and livestock purposes. *InTechopen.* 2013:1–22.

65. Leite AMDO, Miguel MAL, Peixoto RS, et al. Microbiological, technological and therapeutic properties of kefir: a natural probiotic beverage. *Braz J Microbol.* 2013;44(2):341–349.

66. Lenoir M, del Carmen S, Cortes-Perez NG, et al. Lactobacillus casei BL23 regulates Treg and Th17 T-cell populations and reduces DMH-associated colorectal cancer. *J Gastroenterol.* 2016;51(9):862–873.

67. Martins FS, Silva AA, Vieira AT, et al. Comparative study of Bifidobacterium animalis, Escherichia coli, Lactobacillus casei and Saccharomyces boulardii probiotic properties. *Arch Microbiol*. 2009;191(8):623–630.

68. Parker KD, Maurya, AK, Ibrahim H, et al. Dietary rice bran-modified human gut microbial consortia confers protection against colon carcinogenesis following fecal transformation. *Biomedicines*. 2021;9(2):144.

69. Pradhananga M. Effect of processing and soybean cultivar on natto quality using response surface methodology. *Food Sci Nutr.* 2019;7(1):173–182.

70. Prado MR, Blandón LM, Vandenberghe LP, et al. Milk kefir: composition, microbial cultures, biological activities, and related products. *Frontiers in microbiology*. 2015;6:1177.

71. Rezac S, Kok CR, Heermann M, et al. Fermented foods as a dietary source of live organisms. *Front Microbiol.* 2018;9:1785.

72. Sjamsuridzal W, Khasanah M, Febriani R, et al. The effect of the use of commercial tempeh starter on the diversity of Rhizopus tempeh in Indonesia. *Sci Rep.* 2021;11:23932.

73. Song HS, Whon TW, Kim J, et al. Microbial niches in raw ingredients determine microbial community assembly during kimchi fermentation. *Food Chem*. 2020;318:126481.

74. Sridevi J, Halami PM, Vijayendra SV. Selection of starter cultures for idli batter fermentation and their effect on the quality of idlis. *J Food Sci Technol*. 2010;47(5):557–563.

75. Tang H, Ma H, Hou Q, et al. Profiling of koumiss microbiota and organic acids and their effects on koumiss taste. *BMC Microbiol.* 2020;20(1):85.

76. Vijayendra SVN, Gupta RC. Associative growth behavior of dahi and yogurt starter cultures with Bifidobacterium bifidum and Lactobacillus acidophilus in buffalo skim milk. *Ann Microbiol*. 2013;63:461–469.

77. Zanirati DF, Abatemarco M, Cicco Sandesb SH. Selection of lactic acid bacteria from Brazilian kefir grains for potential use as a starter or probiotic cultures. *Anarobe*. 2015;32:70–76.

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