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Health benefits of fermented foods

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ABSTRACT

In the past, the beneficial effects of fermented foods on health were unknown, and so people primarily used fermentation to preserve foods, enhance shelf life, and improve flavour. Fermented foods became an important part of the diet in many cultures, and over time fermentation has been associated with many health benefits. Because of this, the fermentation process and the resulting fermented products have recently attracted scientific interest. In addition, microorganisms contributing to the fermentation process have recently been associated with many health benefits, and so these microorganisms have become another focus of attention. Lactic acid bacteria (LAB) have been some of the most studied microorganisms. During fermentation, these bacteria synthesize vitamins and minerals, produce biologically active peptides with enzymes such as proteinase and peptidase, and remove some non-nutrients. Compounds known as biologically active peptides, which are produced by the bacteria responsible for fermentation, are also well known for their health benefits. Among these peptides, conjugated linoleic acids (CLA) have a blood pressure lowering effect, exopolysaccharides exhibit prebiotic properties, bacteriocins show anti-microbial effects, sphingolipids have anti-carcinogenic and anti-microbial properties, and bioactive peptides exhibit anti-oxidant, anti-microbial, opioid antagonist, anti-allergenic, and blood pressure lowering effects. As a result, fermented foods provide many health benefits such as anti-oxidant, anti-microbial, anti-fungal, anti-inflammatory, anti-diabetic and anti-atherosclerotic activity. However, some studies have shown no relationship between fermented foods and health benefits. Therefore, this paper aims to investigate the health effects of fermented foods.

KEYWORDS
Fermented food; bioactive peptides; cardiovascular disease; anti-carcinogenic; lactic acid bacteria

Introduction

Fermentation, one of the most ancient and economical methods of food preparation in the world, is defined as a technology in which the growth and metabolic activities of microorganisms are used to preserve foods (Nuraida 2015; Terefe 2016; Wilburn and Ryan 2017). It is an inexpensive process that requires comparatively little energy, and therefore it is the main strategy for food production in some cultures (Chaves−López et al. 2014). Food fermentation can be divided into two categories: aerobic fermentation, such as fungal and alkaline, and anaerobic fermentation, such as alcoholic and lactic acid (Nout 2014). During fermentation, microorganisms break down fermentable carbohydrates into end products such as organic acid, carbon dioxide, and alcohol (Ansorena and Astiasarán 2016; Kim et al. 2016), as well as anti-microbial metabolites such as bacteriocins that increase food safety by killing or inhibiting food-borne pathogens (Nout 2014). Fermentation also increases the shelf life of foods, especially highly perishable foods (Nuraida 2015; Terefe 2016), and enhances the organoleptic properties of food, the digestibility of proteins and carbohydrates, and the bioavailability of vitamins and minerals (Altay et al. 2013; Hwang et al. 2017). Because of these beneficial effects, fermented foods and beverages have been an indispensable part of the human diet since ancient times and they remain important in many developing countries where they are an integral part of local cultures and traditions (Ansorena and Astiasarán 2016; Borresen et al. 2012; Chilton, Burton, and Reid 2015; Narzary et al. 2016; Kanwar and Keshani 2016). Fermented foods exhibit beneficial effects on health by reducing blood cholesterol levels, increasing immunity, protecting against pathogens, fighting carcinogenesis, osteoporosis, diabetes, obesity, allergies, and atherosclerosis, and alleviating the symptoms of lactose intolerance (Tamang and Kailasapathy 2010). The health benefits associated with fermented foods are often attributed to the bioactive peptides that are synthesized in the microbial degradation of proteins by the bacteria involved in fermentation (Hebert, Saavedra, and Ferranti 2010; Martinez-Villaluenga, Peñas, and Frias 2017; Otağ and Hayta 2013; Walther and Sieber 2011). The most remarkable subgroup of bioactive peptides is the angiotensin-1-converting enzyme (ACE) inhibitor peptides that are formed during milk fermentation as milk proteins are degraded by proteinases in the cell wall of lactic acid bacteria. Due to the known anti-hypertensive effects of these peptides, especially valyl-prolyl-

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proline (VPP) and isoleucyl-prolyl-proline (IPP), fermented dairy products are recommended as a non-pharmacological strategy for the management of hypertension (Beltrán-Barrientos et al. 2016; Nejati et al. 2013; Usinger, Ibsen, and Jensen 2009). In light of this fact, VPP and IPP have been the most investigated bioactive peptides in both animal and human studies to date (Fekete, Givens, and Lovegrove 2015). Exopolysaccharides, another bioactive compound, are natural polymers of sugars that are produced biologically by various microorganisms during fermentation (Deepak et al. 2016). These polymers are composed of repeating mono- or oligosaccharide subunits bound by various glycosidic linkages (Fanning et al. 2012). Due to the potential health benefits from the anti-oxidant, anti-diabetic, anti-carcinogenesis, cholesterol lowering, and immunomodulatory properties of exopolysaccharides produced by certain strains of lactic acid bacteria, this bioactive compound has become a focus of interest (Nampoothiri et al. 2017; Patel and Prajapat 2013; Wu et al. 2010). The mechanism by which bacterial exopolysaccharides could reduce total serum cholesterol levels is similar to the mechanism used by dietary fibre, which involves binding cholesterol, reducing cholesterol absorption, and inducing the release of bile acids (Mumford et al. 2010; Nampoothiri et al. 2017; Tok and Aslim 2010). In addition to reducing cholesterol, exopolysaccharides play a crucial role in host-microbial interactions. They are involved in microbial colonization, attachment and immunomodulation, and they protect the bacterial wall against extreme conditions such as temperature fluctuations, osmotic stress, pH changes, or light intensity (Caggianiello, Kleerebezem, and Spano 2016; Fanning et al. 2012).

The vast majority of fermented products are formed by the natural fermentation process that includes pathogenic, non-functional and functional microorganisms (Tamang et al. 2016; Tamang et al. 2015). Functional microorganisms are involved in lipase, glucoamylase, protease and amylase. Along with enzymes, these microorganisms improve the nutritional value of anti-nutritive and inedible substrates, transforming them into edible products with many health benefits for consumers (Farhad, Kailasapathy, and Tamang 2010; Tamang 2010; Tamang, Watanabe, and Holzapfel 2016).

Fermented food groups

A wide variety of different foods can be fermented. For example, in Turkey, traditional fermented foods and beverages include fermented meat (sausage), fermented milk (ayran, cheese, koumiss, kefir, kurut, yoghurt, and torba yoghurt), fermented vegetables (mustard, pickles, and turnips), fermented fruits, non-alcoholic beverages (boza), and cereal-based fermented foods (tarhana) (Kabak and Dobson 2011).

Fermented milk and milk products

Because fermented milk products have beneficial hypotensive, hypo-cholesterolemic and antimicrobial effects (Ohsawa et al. 2015; Shiby and Mishra 2013), they constitute an important part of human nutrition (Adolfsson, Meydani and Russell 2004) and their functional and microbial properties have recently been extensively studied (Rhee, Lee, and Lee 2011). Studies on the potential benefits of milk fermented with lactic acid bacteria (LAB) have recently received special attention (Saikali et al. 2004). The great majority of milk-based fermented foods are produced from lactic acid bacteria (LAB) fermentation (Kim and Liu 2002; Żukiewicz-Sobczak et al. 2014), and the main reasons for using these bacteria are to protect the nutritional value of the resulting product and improve its shelf-life (Widyastuti and Febrisiantosa 2014). LAB provide acidification, which inhibits the proliferation of pathogens and microorganisms that cause spoilage while releasing anti-microbial bacteriocins (Beermann and Hartung 2013; Widyastuti and Febrisiantosa 2014). Some of the resulting beneficial effects on human health (Jeong, Lee, and Chung 2016) include the modification of gut microbiata and the prevention and treatment of inflammatory bowel disease (IBD) (Saez-Lara et al. 2015), in addition to anti-carcinogenic and hypo-cholesterolemic effects (Kapila, Sinha, and Singh 2007). Furthermore, the conversion of the milk sugar lactose into lactic acid is one of the major changes that occurs during lactic acid bacteria induced milk fermentation (Adam, Rubio-Texeira, and Polaina 2005; Ansorena and Astiasarán 2016), and this also provides health benefits by alleviating abdominal pain and diarrhoea in individuals with lactose intolerance (Ceapa et al. 2013). Fermented dairy foods, therefore, provide a variety of health benefits, such as modulating gut microbiota and immune response and lowering a person's risk of hypertension, diabetes, and high cholesterol (Linares et al. 2017).

The compounds released from milk products during fermentation and their health benefits are shown in Table 1 (Fernández et al. 2015; Linares et al. 2017).

One of the most recent detailed studies of the health benefits of fermented dairy products investigated the biologically active tripeptides valyl-prolyl-proline (VPP) and isoleucyl-prolyl-proline (IPP) (Jauhiainen et al. 2009). (Kim, Park, and Choue 2010) have proposed these tripeptides as a dietary strategy for moderate hypertension (Kim, Park, and Choue 2010). Another study showed that milk fermented with *Lactobacillus spp.* may be a potential treatment against moderate hypertension by producing both ACE-inhibitory peptides and GABA (γ -aminobutyric acid) (Nejati et al. 2013). In the light of these studies, it has been proposed that during milk fermentation, lactic acid bacteria (LAB) exhibits proteolytic action on milk proteins and thus produces anti-hypertensive peptides (Hsieh et al. 2015). Milk fermented by *Lactobacillus spp.* can have positive effects in the management of cardiovascular diseases caused by hypertension (Rodríguez-Figueroa et al. 2013). In addition, these tripeptides have been found to have therapeutic potential in the prevention and treatment of metabolic syndrome and its complications by showing insulin-like adipogenic properties and modulating inflammatory response in adipocytes (Chakrabarti and Wu 2015). For example, (Nakamura et al. 2013) suggested that VPP and IPP peptides reduced arterial dysfunction and thus prevented cardiovascular disease (Nakamura et al. 2013). In addition to their anti-hypertensive effects, these tripeptides exhibit antimicrobial, anti-inflammation, anti-mutagenic, anti-oxidant and anti-haemolytic properties (Aguilar-Toalá et al. 2017).

Table 1. The compounds released from the fermented milk and milk products during fermentation and their health benefits (Fernández et al. 2015; Linares et al. 2017).

Microorganism involved in fermentation	End products which affected by fermentation and their health benefits
Lactobacillus spp. *Propionibacterium spp.* *Bifidobacterium spp.*	→ increase the levels of some organic acid such as propionic, lactic, acetic, orotic and citric acid (Urbienė and Leskauskaitė 2006; Penna et al. 2015) and produces lipolytic, glycolytic and proteolytic enzymes (Penna et al. 2015). → exhibit β-Galactosidase (lactase) activity and attenuates lactose intolerance symptoms (Parvez et al. 2006; Saqib et al. 2017). → exhibit lipolytic and proteolytic activities and produces free amino and fatty acids (Nespolo and Brandelli 2010). → exhibit better plasma lipid profile and cholesterol lowering activity by binding cholesterol and triglycerides in the small intestine (Banjoko et al. 2012; Chang et al. 2015). In addition, propionic acid exhibits hypocholesterolemic effect (Bourrie, Willing, and Cotter 2016) → produce lactic acid and thus facilitates lactose digestion and treatment diarrhea (Drouault and Corthier 2001) → show antimicrobial activity (Macuamule et al. 2016) by neutralizing toxins of pathogens and spoilage microorganism (Widyastuti and Febrisiantosa 2014) and by producing antimicrobial peptides (Mariam 2009). In addition, lactic acids exhibits antimicrobial activity by inhibiting the growth of pathogens and spoilage microorganism (Ao et al. 2012). → modulate the immune system (Chang et al. 2015). → maintain normal blood insulin levels (Masood et al. 2011).
Lactobacillus spp. *Bifidobacterium spp.* *Propionibacterium sp.* *Streptococcus sp.*	→ have the ability to synthesize water soluble vitamins such as thiamine (B1), riboflavin (B2), biotin (B7), cobalamin (B12), folic acids (B9) and enhance these vitamin content (LeBlanc et al. 2011; Capozzi et al. 2012; Patel et al. 2013).
Lactobacillus spp. *Streptococcus spp.*	→ synthesis GABA(γ-aminobutyric acid) and thus exhibits GABA's health effects such as anti-hypertensive (Kajimoto et al. 2004), anti-depressant (Wu and Shah 2016), diuretic (Li & Cao 2010), tranquilizer (Gobbetti, Cagno, and De Angelis 2010), anti-diabetic (Li et al. 2010) and main inhibitory neurotransmitter effect (Dhakal, Bajpai, and Baek 2012).
Lactobacillus spp. *Streptococcus sp.* *Bifidobacterium sp.*	→ synthesis bioactive peptides and these peptides exhibits health effect such as antihypertensive, anti-microbial, anti-thrombotic, opioid, mineral binding, anti-oxidative and immunumodulatory activities (Ferreira et al. 2007; Jäkälä and Vapaatalo 2010; Wakai and Yamamoto 2012; Shori and Baba 2015; Beltrán-Barrientos et al. 2016).
Lactococcus spp. *Lactobacillus spp.* *Pediococcus sp.* *Enterococcus sp.* *Streptococcus sp.* *Bifidobacterium sp.*	→ synthesis of bacteriocins producing peptides and these peptides exhibits health effect such as bactericidal (Batdorj et al. 2006; Nespolo and Brandelli 2010) and anti-microbial activity (Abbasiliasi et al. 2012) by the inhibiting cell wall biosynthesis of pathogenic microorganism (C Borresen et al. 2012) and by binding cell surface receptors (Todorov 2008).
Lactococcus sp. *Lactobacillus spp.* *Streptococcus spp.* *Bifidobacterium sp.*	→ synthesis conjugated linoleic acid (CLA) and CLA shows anti-carcinogenic (Larsson, Bergkvist, and Wolk 2005; Gutiérrez 2016), anti-atherosclerosis, anti-inflammatory activities (Van Nieuwenhove et al. 2007), anti-diabetic, anti-osteoporosis activities (Kuhl and De Dea Lindner 2016), anti-adipogenic and hypotensive activities (Liu et al. 2011; Song et al. 2016).
Lactobacillus spp. *Propionibacterium sp.* *Lactococcus sp.* *Bifidobacterium sp.* *Streptococcus spp.*	→ synthesis exopolysaccharides (EPS) and EPS improves the DNA repair, protect against UV-induced carcinogenesis (Morifuji et al. 2017), exhibit anti-tumor, anti-bacterial (Enikeev 2012), gastroprotective (Rodríguez et al. 2009), antioxidant, anti-microbial properties (Prado et al. 2015) and immunumodulatory functions (Patel, Majumder and Goyal 2012), alleviate influenza virus-induced infections (Nıshımura et al. 2013).

Cheese

Cheese is a generally high-quality fermented dairy product with high energy values and high fat, protein, calcium and vitamin B content (Ansorena and Astiasarán 2016). During cheese production, milk, rennet, starter culture, and proteases and peptidases from secondary microbial flora are used to break down casein and produce bioactive compounds that are responsible for a wide range of biological activities (López-Expósito et al. 2017). Cheese's vitamin and mineral content together with bioactive peptides (antihypertensive, antioxidant, opioid, anti-proliferative and antimicrobial peptides and conjugated linoleic acids (CLA)) are mainly responsible for its effects in preventing and treating diseases (Hur et al. 2016). Cheese's anti-carcinogenic characteristics originate from the conjugate linoleic acids (CLA) and sphingolipids it contains (Walther et al. 2008). CLA also helps to fight obesity by reducing energy intake, increasing energy expenditure, modulating lipid metabolism and changing skeletal muscle metabolism (Kim et al. 2016). In addition to its anti-carcinogenic and anti-obesity characteristics, one research study suggests that cheese enriched with CLA may have positive effects on many atherosclerotic biomarkers (Sofi et al. 2010).

Yoghurt

Yoghurt, the most well-known food containing probiotics, is defined as a coagulated dairy product that is formed by lactic acid fermentation with *Lactobacillus bulgaricus* and *Streptococcus thermophiles* (Eales et al. 2015). While it has the same micronutrient composition as milk, yoghurt contains more protein, vitamin B_{12} and B_2, calcium, magnesium, potassium and zinc (Wang et al. 2013). During the fermentation of milk to produce yoghurt, folate is synthesized and protein and CLA content, shelf life, protein digestibility, and calcium absorption all increase (Adolfsson, Meydani, and Russell 2004). Biologically active peptides are also produced (Ivey et al. 2015).

Koumiss

Koumiss is slightly alcoholic fermented beverage traditionally made from unpasteurized mare's milk (Choi 2016; Rong et al. 2015; Ya et al. 2008; Yao et al. 2017). Koumiss originated with the nomads of Asia and it is still commonly consumed in west and central Asian nations such as Kazakhstan, Mongolia, Kyrgyzstan, and Russia (Abdel-Salam et al. 2010;

Uniacke-Lowe 2011). Its microflora contain lactic acid bacteria (*Lactobacillus delbrueckii subsp. bulgaricus* and *Lactobacillus acidophilus)*, lactose-fermenting yeast (*Saccharomyces spp. K. Marxianus var. Marxianus and Candida koumiss*), non-lactose-fermenting yeast (*Saccharomyces cartilaginous*), and non-carbohydrate-fermenting yeast (*Mycoderma spp*.) (Wszolek et al. 2006). The main microorganisms in koumiss are the lactic acid bacteria that transform lactose to lactic acid and the yeast that transform sugar to carbon dioxide and ethyl alcohol. Koumiss undergoes two main fermentations, namely lactic acid fermentation and alcohol fermentation (Chen et al. 2010), and these changes produce a distinctive sour, alcoholic flavour (Choi 2016; Lv and Wang 2009; Zhang and Zhang 2012). This beverage usually contains about 2% alcohol, 0.5–1.5% lactic acid, 2–4% lactose and 2% fat (Mu, Yang, and Yuan 2012; Sun et al. 2009). In addition to this content, it is rich in vitamins C, A, E, D, B_1, B_2, B_{12} and trace elements and antibiotics (Abdel-Salam et al. 2010; Dönmez et al. 2014). Koumiss was first used by the Mongolian people to treat diseases such as tuberculosis, ulcers, and hepatitis (Wu et al. 2009). Modern studies on koumiss have shown positive effects on the kidneys, liver, endocrine glands, blood-formation organs, and the digestive, nervous, immune and cardiovascular systems in addition to healing effects on disorders such as anemia, avitaminosis, gastric and intestinal diseases (Mu, Yang, and Yuan 2012; Rong et al. 2015; Sari et al. 2014). Consequently, koumiss is regarded as complete food with many health benefits (Zhang and Zhang 2012).

Kefir

Kefir is an ancient fermented milk drink with a sour, acidic, and mildly alcoholic taste and a creamy consistency. It originated in the Caucasus (Kabak and Dobson 2011; Prado et al. 2015; Rai, Sanjukta, and Jeyaram 2017; Sari et al. 2014) and is produced by the acid-alcoholic fermentation of milk by microorganisms found in kefir grains (Kesenkaş, Gürsoy, and Özbaş 2017). Acid-alcoholic fermentation is produced by a combination of various yeast, acetic acid, and lactic acid bacteria strains (Adam, Rubio-Texeira, and Polaina 2005). The potential health benefits of kefir are attributed to the complex microbiata created by these various microorganisms and fermentation metabolites (Bourrie, Willing, and Cotter 2016). Because kefir has pleasing organoleptic characteristics in addition to anti-hypertensive, anticarcinogenic, hypocholesterolemic, anti-inflammatory, antimutagenic, anti-allergenic, anti-bacterial, anti-diabetic, antioxidant, and probiotic effects, it has become a focus of interest in recent years (Guzel-Seydim et al. 2011; Leite et al. 2013; Nielsen, Gürakan, and Unlü 2014; Rosa et al. 2017). Regular consumption of kefir is also beneficial to intestinal health and the immune system. It alleviates symptoms of lactose intolerance by regulating serum glucose levels (Ahmed et al. 2013). A recent study by Gamba et al. has even shown that kefir has anti-fungal properties by inhibiting the growth of *Aspergillus flavus* (Gamba et al. 2016). In addition, the health benefits of bioactive compounds formed during the production of kefir have recently attracted attention (Adiloğlu et al. 2013; Kesenkaş, Gürsoy, and Özbaş 2017).

Fermented meat and meat products

The fermentation of meat is the most ancient and widely used form of fermentation (Kumar et al. 2017). Traditional fermented meat products are valuable and popular for a variety of reasons (Leroy, Scholliers, and Amilien 2015). The production of fermented meat comprises many biochemical, microbiological and chemical changes, and these changes provide fermented meat products with their characteristic taste, colour, aroma and odour (Karaçil and Acar Tek 2013). Lactic acid bacteria, which play an important role in the fermentation of meat, reduce pH and produce bacteriocins that prevent the growth of pathogenic and spoilage microorganisms, thus improving the safety, stability and shelf life of fermented meat products (Dincer and Kivanc 2012).

Sucuk (Turkish fermented dry sausage)

Sucuk, which is one of the most popular traditional Turkish fermented meat products, is produced by first chopping beef or mutton and adding fat, spices, preservatives, colouring materials, additives, and starter cultures including lactic acid bacteria and staphylococci (Akkaya et al. 2014; Eren et al. 2008; Guzin Kaban 2010; Karsloğlu et al. 2014). Nitrite or nitrate is added because of its antioxidant and antibacterial properties, and sucrose or glucose is included to act as the substrate for the fermentation of lactic acid bacteria (Güzin Kaban 2013; Yüceer and Özden Tuncer 2015). Lactic acid bacteria, the dominant microorganisms used in the fermentation of meat, limit the growth of spoilage and pathogenic microbes by producing bacteriocins and organic acids as well as acidifying sugars (Kabak and Dobson 2011; G Kaban and Kaya 2008; Sriphochanart and Skolpap 2010). Micrococci, another microorganism used in meat fermentation, degrade nitrites or nitrates to nitric oxide (Ordóñez et al. 1999). The use of different combinations of microorganisms in the production of sucuk provides the final product with a variety of beneficial biochemical, physicochemical, and microbial properties in addition to a desirable taste, texture, and colour (Kaban and Kaya 2008; Kundakci, Kayacier, and Ergonul 2007). Although many consumers enjoy sucuk because of these sensory properties and assume that it is a safe food, sucuk has been strongly criticized by nutritionists because of its high fat, salt, and biogenic amine content and the possibility of serious infection (Kjeldgaard et al. 2012; Papavergou, Savvaidis, and Ambrosiadis 2012).

Meat fermentation can be divided into natural (uncontrolled) fermentation and controlled fermentation, where a starter culture is added to achieve the desired effect (Mokoena, Mutanda, and Olaniran 2016). Although natural fermentation is superior to the controlled fermentation in terms of sensory properties, natural fermentation creates an opportunity for the formation of harmful bacteria, such as those that produce biogenic amines (Ojha et al. 2015). Due to increasing awareness of this, consumer demand has shifted over time from a focus on delicious food to one that emphasizes safe and healthy food. Therefore, there has recently been increased interest in the use of fermented meat products as probiotic starter culture carriers (Ertürkmen, Kiliç, and Kiliç 2016). Probiotic starter cultures added during the fermentation of meat have been shown to produce beneficial bioactive peptides such as the ACE-inhibitory peptide, inhibit proteolytic action and fatty acid oxidation, and prevent the growth of pathogenic microorganisms that produce biogenic amines (Neffe-Skocińska, Wójciak, and Zielińska 2016). However, one study found that microbial starter cultures added during fermentation increased the microbial safety of naturally fermented sucuk by reducing the level of biogenic amines (Talon et al. 2008).

Pastrami or pastırma

Pastırma, the most popular traditional dry-cured semi-fermented meat product, is made from whole muscle, and due to its sensory properties it is widely consumed and enjoyed by the Turkish people (Aksu, Erdemir, and Çakıcı 2016; Ceylan and Aksu 2011; Güzin Kaban 2013). The production of pastırma involves drying, curing, and pressing the meat and then adding cemen, a combination of red pepper, paprika, ground fenugreek, and garlic (Akköse et al. 2016; Gök, Obuz, and Akkaya 2008). In the curing process, nitrite or nitrate is added to provide a desirable taste and colour and to inhibit some pathogens and spoilage microorganisms, which increases the shelf life of the pastırma (Büyükünal et al. 2016). Many physical, microbial, biochemical, and organoleptic changes occur during the production of pastırma (Aksu, Dogan, and Sirkecioglu 2017; Gök, Obuz, and Akkaya 2008). Biochemical changes such as proteolysis increase the levels of free amino acids, and alongside these changes the addition of cemen provides pastirma's characteristic taste (Deniz et al. 2016; Gök, Obuz, and Akkaya 2008). One study showed that pastırma exhibited anti-oxidant and ACE-inhibitory properties, which was attributed to the cemen that was added and to the process of proteolysis that occurred during production (Deniz et al. 2016).

Fermented fish products

Because there are many microorganisms that contribute to fish spoilage (Heising et al. 2014; Jahncke 2016), fresh fish are generally considered a perishable product (Chintagari et al. 2017) and for this reason fermentation, which is one of the most widely used methods to preserve fish, has recently been focus of people's attention (Adjou et al. 2017). Fermentation of fish produces desirable organoleptic properties such as a desirable aroma, texture, and taste (Giyatmi and Irianto 2017), but apart from these characteristics, fermented fish products have also been shown to have good nutritional value (Adjou et al. 2017; Majumdar et al. 2015; Özyurt et al. 2016). For example, Loh and colleagues showed that feeding chickens with fermented fish results in a decrease in cholesterol concentration, a increase in DHA concentration and a favourable n-6/n-3 ratio in the eggs produced by chickens (Loh et al. 2009). Another study showed that fermented fish oil has significantly higher levels of DHA (docosahexaenoic acid) and EPA (eicosapentaenoic acid) than natural fish oil (Han et al. 2012). Besides having good nutritional and sensory properties, during fish fermentation bioactive peptides are produced by enzymatic reactions, and these peptides have beneficial anti-oxidative, anti-microbial, anti-thrombotic, anti-hypertensive and anti-hypocholesterolemic effects (Majumdar et al. 2015; Majumdar et al. 2016). For example, Ichimura and colleagues suggested that fermented fish sauce may reduce hypertension by producing ACE-inhibitory peptides and combat diabetes by stimulating insulin secretion (Ichimura et al. 2003). Another study showed that fermented fish oil's high levels of DHA (docosahexaenoic acid) may alleviate the symptoms of atopic dermatitis (Han et al. 2012).

Fermented fruit and vegetable products

Because untreated fruits and vegetables spoil easily, fermentation, the oldest method of preserving fruits and vegetables, is very popular. Fermented fruits and vegetables such as fermented olives, sauerkraut, kimchi, and pickled cucumbers an indispensable part of human nutrition around the world (Nguyen et al. 2013; Shah and Singhal 2017). The fermentation of fruits and vegetables is mainly lactic acid fermentation that occurs spontaneously when conditions are suitable for lactic acid bacteria (LAB), the dominant microorganism in this type of fermentation (Di Cagno, Filannino, and Gobbetti 2016; Gupta and Abu-Ghannam 2012; Nguyen et al. 2013). Lactic acid bacteria fermentation involves the oxidation of carbohydrates to carbon dioxide, alcohol, and organic acids that inhibit pathogen and spoilage microorganisms (Medina et al. 2015). The probiotics in fermented fruits and vegetables with lactic acid bacteria can help to prevent certain diseases such as cirrhosis and diarrhoea, while antioxidants in fermented fruits and vegetables can help to clear harmful free radicals that play a role in formation of degenerative diseases (Swain et al. 2014).

Fermented (table) olives

Table olives are the most common traditional fermented vegetables, and demand for them continues to increase around the world (Karovičová 2007; Tufariello et al. 2015). Olive fermentation, an ancient method used for the preservation of olives, is essential to produce a high-quality final product (Heperkan 2013; Iorizzo et al. 2016). Lactic acid bacteria and yeast are used for the fermentation of olives (Hurtado et al. 2012). The yeasts involved in olive fermentation improve the sensory properties of the end product, produce favourable volatile products, promote the growth of lactic acid bacteria, protect against pathogenic microorganisms, and reduce phenolic compounds (Bleve et al. 2014; Nisiotou et al. 2010). In addition, the lactic acid bacteria involved in olive fermentation have been shown to protect against cancer, constipation, high cholesterol, intestinal infections, and allergic reactions, modulate immune response, and aid digestion (Rodríguez-Gómez et al. 2014). Table olives also have anti-oxidant and anti-atherogenic properties and high levels of many vitamins and minerals (Tataridou and Kotzekidou 2015). They are also rich in oleic acid, which has a protective effect against breast, prostate, and colon cancer (Corsetti et al. 2012; Peres, Peres, and Xavier Malcata 2017; Sales-Campos et al. 2013). Table olives contain high levels of oleocanthal, a natural COX-inhibitor that also protects against certain cancers and neurodegenerative disorders (Parkinson and Keast 2014; Peres,

Peres, and Xavier Malcata 2017). Furthermore, olives inhibit the growth of many pathogenic and spoilage microorganisms (Malheiro et al. 2014). (Peres, Peres, and Xavier Malcata 2017) even suggest that fermented olives are a potential source of undiscovered healthy microbial strains and bioactive compounds.

Kimchi

Kimchi, an integral part of the Korean diet, is a traditional lactic acid fermented vegetable product prepared by adding a variety of ingredients such as radishes, spices, and fish sauce to the main ingredient, Chinese cabbage. The mixture is then fermented with a variety of microorganisms and consumed raw worldwide (Baick and Kim 2015; Kang et al. 2015; S.-H. Kim et al. 2017; H. Lee et al. 2014; M.-E. Lee et al. 2015; Park et al. 2014; S. Park et al. 2016; Shin, Kang, and Jang 2016). Functional phytochemicals, free amino acids, volatile compounds, and organic acids are produced by various microorganisms during the production of kimchi. Because of the health benefits of these compounds, kimchi was named one of the five healthiest foods in the world and has been receiving increased attention worldwide (Cui et al. 2015; Hong et al. 2016; Hong et al. 2016; Jung et al. 2011; Kim et al. 2016; Kim et al. 2011; Kim et al. 2017). Kimchi can lower the risk of carcinogenesis, atherogenesis, oxidation, tumours, bacterial infections, obesity, inflammation, mutagenesis, and cancer, in addition to slowing aging, lowering cholesterol, stimulating the immune system, and containing probiotics (Choi et al. 2013; Kwak et al. 2014; Lee et al. 2014; Park et al. 2014; Park, Kim, and Jeong 2017; Patra et al. 2016). In addition, An et al. (2013) showed that kimchi may have beneficial effects on people with prediabetes by inducing insulin sensitivity and by decreasing insulin resistance (An et al. 2013). High kimchi consumption has recently been a cause of concern because of its high salt content (Lee et al. 2012). However, one study showed that although there was an increase in sodium intake in individuals who consumed large amounts of kimchi, no adverse effects on blood pressure were observed (Kim et al. 2012). Another study showed no association between high kimchi consumption and increased risk of hypertension, suggesting that the high potassium levels in kimchi have a neutralizing effect on blood pressure (Song and Lee 2014).

Sauerkraut

Sauerkraut is one of the most ancient and well-liked traditional fermented vegetables, and it has been commonly eaten for its health benefits in China for centuries (Palani et al. 2016; Elena Peñas et al. 2010; Xiong et al. 2012; Xiong et al. 2016). Sauerkraut is produced by spontaneous fermentation, which triggers many microbial, chemical, and physical changes that can affect the safety and quality of the final product (Beganović et al. 2011; Plengvidhya et al. 2007). This fermentation mainly depends on lactic acid bacteria found naturally in raw cabbage. These bacteria produce lactic acid when conditions are appropriate (Barrangou et al. 2002; Jin et al. 2016; Viander, Mäki, and Palva 2003). In addition to lactic acid bacteria, sauerkraut also contains yeast and fungi (Beganović et al. 2014). Because sauerkraut has high levels of vitamins C and B, minerals like calcium, iron, potassium, and phosphorus, and phenolic compounds (Elena Peñas et al. 2010; Xiong et al. 2014), it provides many health benefits. It contains probiotics and anti-oxidants, counteracts the effects of carcinogens, and acts as an anti-inflammatory (Peñas, Martinez-Villaluenga, and Frias 2017; Raak et al. 2014).

Fermented legume based foods

Legume based fermented products are widely consumed worldwide (S. Todorov and Holzapfel 2014). With fermentation, the taste, appearance, nutrient digestibility, nutritional value, texture, and shelf life of legumes are all improved, while protease inhibitors, lectins, oligosaccharides and phytates, non-nutritive compounds present in the seeds of legume, decrease (Frias, Peñas, and Martinez-Villaluenga 2017). In addition, the fermentation of legumes causes an increase in phenolic compounds in the legume seeds (Ademiluyi et al. 2015). One study showed that fermented legumes exhibited anti-diabetic properties by acting as anti-oxidants and modulating some enzymes such as acetylcholinesterase, glucosidase, and amylase (Ademiluyi et al. 2015).

Fermented mung bean

Because the non-nutritive compounds in the mung bean are reduced and the nutritional value is improved with fermentation, mung bean fermentation has been common for many years (John and Olusegun 2016; Onwurafor, Onweluzo, and Ezeoke 2014). Fermented mung beans have anti-diabetic and anti-oxidant properties due to their free amino acid and GABA content (Yeap et al. 2012). In addition, they have been shown to have potential chemopreventive (Yeap et al. 2013), hypolipidemic (Yeap et al. 2015), anti-stress (Yeap et al. 2014), hepatoprotective, and anti-inflammatory effects (Mohd Ali et al. 2012), Because of these health benefits, mung beans fermented with lactic acid bacteria have recently emerged as a novel functional food with many health benefits (Ali et al. 2015; Wu et al. 2015).

Fermented soybean products

Fermented soybeans are an important source of nutrition in the diet of China, Korea and Japan (Puri, Mir, and Panda 2015). Miso, a fermented soybean paste, is a mixture of soybeans that contains significant amounts of vitamins, minerals, fat, salt, carbohydrates, vegetable protein and microorganisms (Watanabe 2013). In humans, miso acts as a scavenger reactive oxygen species, an estrogen-like substance and an ACE-inhibitor (Yoshinaga et al. 2012). In addition, miso provides protection against radiation, stroke, hypertension, and some types of cancer (Ohara et al. 2002; Ohuchi et al. 2005; Watanabe 2013; Watanabe et al. 2006). Natto, another traditional fermented soybean product, is a traditional non-salted fermented food mainly consumed in

Japan and produced from the fermentation of soybeans by *Bacillus subtilis natto* which produces proteases that degrade proteins into peptides and amino acids (Kitagawa et al. 2017; Nagai and Tamang 2015). *Bacillus subtilis natto* is widely used in industrial production of an important vitamin called menaquinone-7 (Hu et al. 2017). In addition to producing menaquinone-7, *Bacillus subtilis natto* generates nattokinase during fermentation (Hsu et al. 2008). Nattokinase, a serine fibrinolytic enzyme, has anti-coagulant, anti-thrombotic and fibrinolytic properties and may play a role in the prevention of cardiovascular disease and hypertension (Dabbagh et al. 2014; Kurosawa et al. 2015; Lee, Lai, and Wu 2015; Shirole, Sharma, and Jagtap 2013). Consequently, natto is considered a very healthy snack and meal option (Hitosugi, Hamada, and Misaka 2015; Park et al. 2012).

Fermented cereal based foods

Although grains are inadequate for nutrition because they lack some basic compounds such as essential amino acids, fermentation of cereals is a simple way to improve their nutritional value as well as their sensory and functional qualities (Ozdemir, Gocmen, and Yildirim Kumral 2007). Fermentation decreases the level of carbohydrates and non-digestible polysaccharides and oligosaccharides in cereals and increases the synthesis of certain amino acids and the bioavailability of the vitamins of group B (Blandino et al. 2003). In addition, fermentation significantly reduces the content of non-nutrients, such as polyphenols, phytates and tannins, and increases the content of nutrients like free amino acids and their derivatives. For example, when cereals are fermented with lactic acid bacteria, the level of tannin and phytic acid decreases, resulting in increased iron absorption and removal of non-nutritive compounds which negatively affect the binding capacity, digestibility, absorption, and solubility of minerals. The activity of amylase, phytase, hemicellulose, and protease increases, which results in improved shelf life, digestibility, and nutritional value (Blandino et al. 2003; Ciesarová et al. 2017; Karovičová 2007; Magala, Kohajdová, and Karovičová 2015; Poutanen, Flander, and Katina 2009). It has also been noted that during fermentation, cereals have increased anti-oxidant activity (Đorđević, Šiler-Marinković, and Dimitrijević-Branković 2010).

Fermented rice bran

ce bran provides many health benefits due to its high levels of peptides, fatty acids, phenolic acids and bioactive compounds (A. Kumar et al. 2012). Although rice bran also has some nutritional limitations, such as its high dietary fibre and low protein and non-nutritive phytic acid content, fermentation has positive effects on these limitations (Supriyati, Susanti, and Susana 2015). Ferulic acid, a potent antioxidant responsible for rice bran's bioactivity, is the most abundant of the phenolic acids in rice bran, and fermentation increases the amount to make it even more abundant (Kim and Han 2014). It has recently been suggested that rice bran improves health and prevents some diseases related to oxidative stress, such as cardiovascular diseases, cancer, impaired glucose metabolism, insulin resistance, and neurodegenerative diseases, by neutralizing free radicals (Ciesarová et al. 2017; Jung et al. 2017; Kim and Han 2011). In addition, one study showed that fermented rice bran has a beneficial effect on hypertension and metabolic syndrome, and may prevent some lifestyle diseases (Alauddin et al. 2016). Another study showed that fermented rice bran reduces fatigue and stress (K. Kim et al. 2002), and fermented red brown rice protects against oxidative stress induced DNA damage (Kong et al. 2015). Also, fermented brown rice helps to lower cholesterol and protects the liver against the free radicals produced by copper accumulation (Baek, Park, and Lee 2005; Shibata et al. 2006). Brown rice fermented with *Aspergillus oryzae* is one of the most studied fermented cereals, and the results of these studies showed that fermented brown rice has anti-colitis, anti-cancer, prebiotic, chemopreventive, and anti-inflammatory properties and suggested that it is a promising dietary agent for the management of many types of cancer and may be a functional food (Ilowefah et al. 2015; Kataoka et al. 2008; Katyama et al. 2002; Kuno et al. 2004; Kuno et al. 2015; Nemoto et al. 2011; Onuma et al. 2015; Phutthaphadoong et al. 2010; Tomita et al. 2008).

Tarhana

Tarhana, a traditional and popular cereal-based food fermented with lactic acid bacteria, is commonly prepared as a soup and is typically consumed in cold weather in Turkey (Bayrakçı and Bilgiçli 2015; Sengun et al. 2009). Tarhana contains 10.2% moisture, 6.2% ash, 16% protein, 3.8% salt, 60.9% carbohydrate, 1% crude fibre, and 5.4% fat (Erbaş et al. 2006). It is manufactured by combining yoghurt, wheat flour, salt, spices, bread yeast, and a variety of vegetables (Özel et al. 2015; Settanni et al. 2011). Lactic acid and alcohol fermentation take place due to various microorganisms that exist in the yoghurt and bread yeast used in the production of tarhana (Kumral 2015). Lactic acid bacteria and yeast create a low moisture content and pH, which are unfavourable conditions for harmful bacteria, spoilage, and pathogenic microorganisms (Colak et al. 2012). During fermentation, organic acids, a variety of vitamins including C, B_3, B_5 and B_9, minerals, and high-quality protein are synthesized. Because of these beneficial compounds, tarhana's prolonged fermentation time gives it a higher nutritional value and digestibility than the raw product. For all these reasons, it is considered as a good source of nutrition for children and the elderly (Bayrakçı and Bilgiçli 2015; Turantaş and Kemahlıoğlu 2012).

Fermented drinks

Fermented drinks, an integral part of nutrition in many societies, have recently received worldwide attention due to the health benefits attributed to them (Baschali et al. 2017; Marsh et al. 2014). These beverages are produced by a variety of microorganisms and raw material, just as in fermented foods (Basinskiene et al. 2016). The most commonly consumed traditional fermented beverages in

Turkey include non-alcoholic beverages such as kefir, ayran, shalgam juice, boza, and hardaliye (Altay et al. 2013).

Boza

Boza is a traditional Turkish non-alcoholic beverage obtained from the fermentation of a variety of cereals such as rice, barley, corn, oats, and millet and is generally consumed in winter and autumn (Altay et al. 2013; Botes et al. 2007; Heperkan, Daskaya-Dikmen, and Bayram 2014; Osimani et al. 2015). Boza is fermented using a variety of microorganisms such as yeast and lactic acid bacteria, which produce bacteriocins (Altay et al. 2013; Botes et al. 2007; Kabadjova et al. 2000; S. Todorov and Dicks 2006). These microorganisms produce many different types of boza with varying levels of stability and quality (Genç, Zorba, and Ova 2002; Zorba et al. 2003). Boza fermentation includes both lactic acid fermentation, which produces lactic acid and makes the drink more acidic, and alcohol fermentation, which produces carbon dioxide and increases the volume (LeBlanc and Todorov 2011). Lactic acid bacteria also increase the levels of free fatty acids, which gives boza its desirable taste and inhibits the activity of pathogenic microorganisms (Caputo et al. 2012). In addition to these beneficial effects, boza contains vitamins, minerals, carbohydrates, fibre, and protein, and is therefore considered a nourishing and functional beverage (Todorov 2008, 2010). One study also suggested that boza is a good source of ACE-inhibitory peptides (Kancabaş and Karakaya 2013).

Shalgam juice

Shalgam juice, a traditional fermented non-alcoholic beverage, is generally produced in Turkey by lactic acid fermentation and has a red colour, a blurry appearance, and a sour taste (Altay et al. 2013; Caputo et al. 2012). Bulgur flour, black carrots, salt, and sourdough are the basic materials used in the production of shalgam juice (Üçok and Tosun 2012). Its fermentation occurs in two stages. The first stage, called sourdough fermentation, provides the lactic acid bacteria and yeast that are essential for the second stage, called main fermentation (Erten, Tanguler, and Canbaş 2008). The fermentation of shalgam juice primarily involves lactic acid bacteria, which degrade sugars into lactic acid and other components that provide acidification and shalgam juice's characteristic taste (Swain et al. 2014; Tanguler and Erten 2012). Shalgam juice is beneficial for health due to its high vitamin and mineral content and its antioxidant properties (Baser et al. 2012; Okcu et al. 2016; Özdestan and Üren 2010). One study showed that shalgam juice has a protective effect against the development of colon cancer (Ozcan et al. 2012). Another study showed that it has anti-oxidant, probiotic, and anti-proliferative properties (Ekinci et al. 2016).

Beer

Beer is one of the most oldest and commonly consumed fermented alcoholic beverages (Ahn, Kim, and Kim 2017). Since ancient times it has been believed, without any scientific evidence, that moderate consumption of fermented drinks such as beer and wine is beneficial for health (Arranz et al. 2012). Beer has a high antioxidant capacity because of its high phenol, vitamin, and melanoidin content, and therefore it plays an important role in the prevention of many diseases (González-SanJosé, Rodríguez, and Valls-Bellés 2017). One study suggested that while excessive beer consumption has harmful effects on human health, moderate beer consumption (one to two alcoholic beverages per day) can have a beneficial effect on cardiovascular diseases by increasing plasma HDL cholesterol levels and reducing plasma LDL cholesterol and plasma fibrinogen levels (Bamforth 2009; de Gaetano et al. 2016). Moderate beer consumption also has a beneficial effect on the gastrointestinal system by inhibiting *Helicobacter pylori*-induced infections, and lowering the risk of diabetes. Its benefits to the neurological

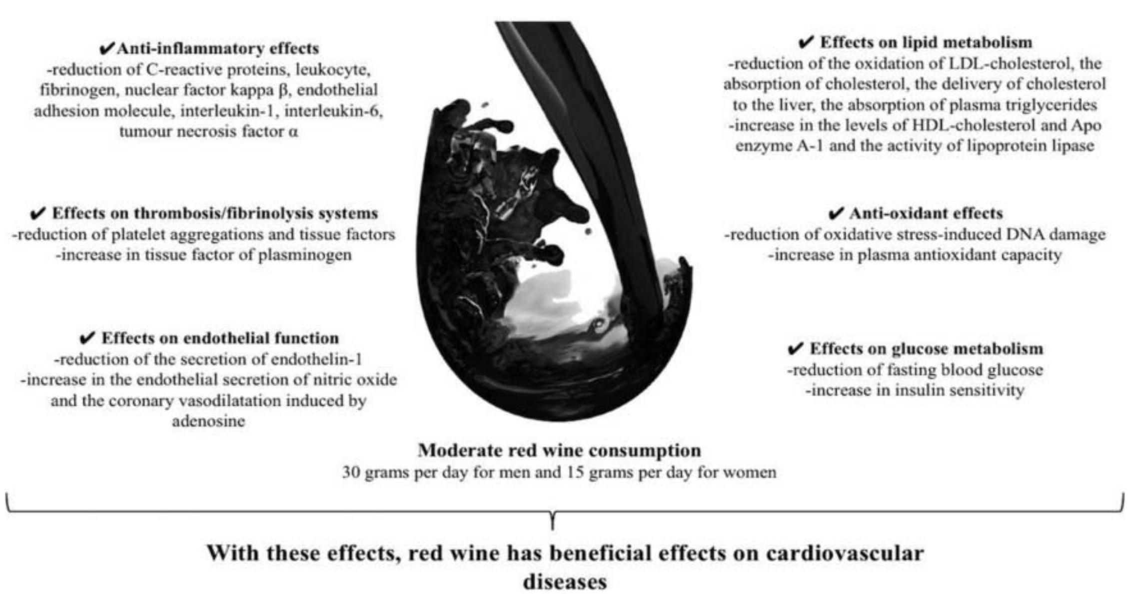

Figure 1. Influence on red wine and cardiovascular diseases (Chiva-Blanch, Arranz, Lamuela-Raventos, and Estruch, 2013).

Table 2. Studies showing the relationship between fermented foods and health benefits.

Fermented products	Study types	Consumption	Health effects of fermented foods	References
Fermented milk	Randomized controlled	Milk with and without lactotripeptide	50 mg lactotripeptide intake $\Rightarrow$ systolic and diastolic blood pressure $\downarrow$ (significantly)	T Jauhiainen et al. 2012
Fermented milk	Randomized controlled	Milk with fermented *L.lactis NRRL B-50571* and *B-50572*	Milk with fermented *L.lactis NRRL B-50571* and *B-50572* $\Rightarrow$ systolic and diastolic blood pressure $\downarrow$ heart rate $\downarrow$ (significantly)	Rodríguez-Figueroa et al. 2013
Fermented milk	In vitro	—	VPP and IPP peptides $\Rightarrow$ exhibits insulin-like actions on adipocytes and suppresses inflammatory response	Chakrabarti and Wu 2015
Fermented milk	Preliminary	Fermented milk with VPP and IPP	VPP and IPP peptides $\Rightarrow$ prevents hypercholesterolemia induced atherosclerotic	Nakamura et al. 2013
Fermented milk	Placebo controlled	—	VPP and IPP peptides $\Rightarrow$ improves endothelial dysfunction and prevent against cardiovascular disease in mildly hypertension human	Hirota et al. 2007
Fermented milk	Review	—	Consumption of fermented milk products $\Rightarrow$ exhibits anti-hypocholesterolemic activity	Anandharaj, Sivasankari, and Parveen Rani 2014
Fermented milk	Randomized controlled	Fermented milk with L. helveticus LBK-16H	Fermented milk with L. helveticus LBK-16H $\Rightarrow$ exhibits blood pressure-lowering effects in hypertensive humans	Seppo et al. 2003
Fermented milk	Review	—	There are no relationship between fermented milk and blood pressure	Usinger, Reimer, and Ibsen 2009
Fermented milk	Randomized controlled	Fermented milk with L. helveticus LBK-16H	Fermented milk with L. helveticus LBK-16H $\Rightarrow$ shown as a potential for dietary strategy of hypertension	Tiina Jauhiainen et al. 2005
Fermented milk	Randomized placebo controlled	Fermented milk with L. helveticus	Fermented milk with L. helveticus $\Rightarrow$ reduce sympathetic activity, but shown any ACE-inhibitor activity	Usinger et al. 2010
Fermented milk	Rat	Fermented milk with L. helveticus	Fermented milk with L. helveticus $\Rightarrow$ shown as a functional food for the management of hypertension	Yongfu Chen et al. 2014
Fermented milk	Rat	Fermented skim milk with starter culture produced folate	Fermented skim milk with starter culture produced folate $\Rightarrow$ shown as protective effect against folate deficiency	Laiño et al. 2015
Fermented milk	Placebo controlled crossover	Fermented milk	Fermented milk $\Rightarrow$ reduces the levels of LDL-cholesterol in hypocholesterolemic adults	Andrade and Borges 2009
Cheese	Placebo controlled	Cheddar cheese fermented starter culture produced GABA	Cheddar cheese fermented starter culture produced GABA $\Rightarrow$ reduces systolic blood pressure (significantly)	Pouliot-Mathieu et al. 2013
Cheese	Dietary intervention	Control groups consumed 200 g/week enriched cheese with CLA and placebo cheese	Case group feed enriched cheese with CLA $\Rightarrow$ reduction in anti-inflammatory parameters (IL-6, IL-8 and TNF-α) and platelet aggregation Control group feed placebo cheese $\Rightarrow$ no significant change has been observed.	Sofi et al. 2010
Yoghurt	Randomized controlled	Case groups consumed 15 ml/kg/day yoghurt and placebo groups	With compared control group, in the case groups $\Rightarrow$ a significant decrease in the length of hospital stay and a significant increase in body weight gain	Pashapour and Iou 2006
Koumiss	In vitro	—	Koumiss $\Rightarrow$ rich in ACE inhibitory peptide and provide the protection against cardiovascular disease	Chen et al. 2010
Kefir	Randomized controlled	—	Kefir $\Rightarrow$ reduces the levels of fasting plasma glucose and HbA1C	Ostadrahimi et al. 2015
Kefir	Randomized controlled	Case group: 2 service/day skimmed milk + 2 service/day kefir Control group: 2 service/day skimmed milk	Compared with the control group; case group $\Rightarrow$ a significant reduction in the levels of plasma lipoprotein	Fathi et al. 2017
Kefir	In vitro	—	Anti-microbial peptide F1 isolated from kefir $\Rightarrow$ protective effect against E.coli infections	Miao et al. 2016
Natto	Rat		Natto $\Rightarrow$ exhibits inhibitory effect on adenosine 5′diphosphate induced platelet aggregation and fibrinolytic activity in hypocholesterolemic rats and a significant reduction in serum total cholesterol levels	Park et al. 2012
Natto	Population-based	—	Natto consumption $\Rightarrow$ prevent postmenopausal bone loss through the effects of menaquinone 7 or isoflavones	Ikeda et al. 2006
Natto	—	—	Higher natto consumption $\Rightarrow$ a significant in the levels of serum decarboxylase-free osteocalcin due to their vitamin K content Regular natto consumption $\Rightarrow$ associated with beneficial effect on bone health in elderly man	Fujita et al. 2012

(*Continued on next page*)

Table 2. (Continued).

Fermented products	Study types	Consumption	Health effects of fermented foods	References
Natto	Randomized controlled	No consumption 3 times a week	Compared with the consumption natto once a week, natto consumption three times per week have higher bone-specific alkaline phosphatase and lower decarboxylated osteocalcin Natto consumption ⇒ contribute to bone health	Katsuyama et al. 2004
Miso	Rat	—	Miso soup consumption ⇒ decreases blood pressure and this decrease is almost similar to the effect obtained from hypertensive drugs	Yoshinaga et al. 2012
Fermented rice bran	Rat	—	Fermented brown rice bran ⇒ have protective effects against hepatitis	Shibata et al. 2006
Fermented rice bran	Rat	—	Fermented brown rice bran fermented with LAB ⇒ have higher excretion of fecal triglyceride, total cholesterol and bile acids	Baek et al., 2005
Fermented rice bran	In vitro	—	Fermented rice bran ⇒ increases strongly the expression of adiponectin and PPAR-γ, prevents production of reactive oxygen species, increases GLUT 4 associated with glucose transport and insulin sensitivity	Kim & Han 2011
Fermented buckwheat	In vitro	—	Fermented buckwheat with LAB ⇒ have blood pressure lowering effects	Nakamura, Naramoto, & Koyama 2013
Fermented soybeans	In vitro	—	Fermented soybeans with *Bacillus subtilis* ⇒ produce small peptides that induced insulinotropic action in pancreatic beta cells of type 2 diabetic rats	Kwon et al. 2007
Fermented soybeans	In vitro	—	Fermented soybeans with *Bacillus subtilis* ⇒ exhibits better hepatic insulin sensitivity by improving hepatic insulin signaling cascade in diabetic rats	Kwon et al. 2006
Fermented soybeans	Rat	—	Fermented soybeans with *B. licheniformis*-67 ⇒ exhibits beneficial effects on biomarkers associated with metabolic syndrome and may alleviate the obesity related symptoms such as fatty liver disease and insulin resistance	Choi et al. 2016
Fermented mung bean	Rat	—	Fermented mung bean ⇒ a significantly reduction in the levels of plasma fasting glucose, cholesterol, triglycerides, LDL-cholesterol and a significantly increase in measured antioxidant levels in hyperglycemic mice, but not hypoglycemic mice	Yeap et al. 2012
Fermented mung bean	In vitro	—	Fermented mung bean milk added sucrose ⇒ a significantly increase in ACE-inhibitor activity by 67.5%	Wu et al. 2015
Fermented mung bean	In vivo	—	Compared with non-fermented mung bean, in fermented mung bean ⇒ GABA is increased 7.3-fold and the quality of aminoacids is increase 13.2-fold	Mohd Ali et al. 2012
Fermented legumes	Rat	—	A diet based on fermented legumes ⇒ have modulatory effects on liver tissue damage and oxidative stress in diabetic rat due to the high phenolic antioxidant content	Ademiluyi and Oboh 2012
Vinegar	Observational	A bread served with vinegar (18, 23 or 28 g)	A bread served with vinegar ⇒ improve postprandial blood glucose, insulin profile and feeling of satiety after meal in healthy individuals	Östman et al. 2005
Vinegar	Randomized crossover	10–20 grams vinegar	Compared with control groups, in the case group consuming vinegar ⇒ the postprandial glycaemia decreased approximately 23%	Johnston et al. 2010
Vinegar	Rat	—	Compared with control group fed high-fat diet that doesn't contain vinegar, in the case group given tomato vinegar ⇒ a significant improvement in glucose tolerance, hyperinsulinemia and the levels of HOMA-IR	Seo et al. 2014
Vinegar	Review	—	Vinegar consumption ⇒ a significant reduction in the levels of postprandial glucose and insulin responses in healthy individuals and individuals with glucose disorder	Shishehbor, Mansoori, and Shirani 2017
Vinegar	In vivo	—	Black vinegar ⇒ exhibits anti-oxidant and cholesterol-lowering effects	Chou et al. 2015
Vinegar	Rat		Compared with control group fed high-fat diet that doesn't contain vinegar, in the case group given tomato vinegar ⇒ a significant reduction in the levels plasma LDL-cholesterol and lipid and visceral fat accumulation in adipocytes	Lee et al. 2013

system include improving cognitive function and lowering the risk of depression (Bamforth 2009). In addition, beer has been shown to reduce the incidence of obesity and carcinogenesis as well as having anti-oxidative, anti-mutagenic, vasodilatory, prebiotic and probiotic properties (Neto et al. 2017; Nogueira et al. 2017; Rodrigues et al. 2016).

Hardaliye

Hardaliye, a traditional fermented beverage fermented with lactic acid bacteria, is produced from red grape or ground mustard seeds (Coskun and Arici 2006; Çoşkun & Tirpanci-Sivri 2013). Due to the lactic acid bacteria flora of hardaliye, it is classified as a non-dairy probiotic beverage (Kılıç et al. 2016). Hardaliye has been produced and consumed in Trakya region of Turkey since ancient times, although this tradition is disappearing day by day (Gucer, Aydogdu, and Durgun 2009). Hardaliye, with its antioxidant properties, has been shown to reduce the levels of plasma malondialdehyde, dienoconjugate and homocysteine (Amoutzopoulos et al. 2013).

Red wine

The history of wine begins with the discovery of alcohol fermentation, the degradation of sugar into carbon dioxide and ethanol, by humankind. In the past, many health benefits were attributed to regular and moderate wine consumption without any scientific evidence (Arranz et al. 2012). However, moderate wine consumption (1–2 glasses a day) has recently been associated with many health benefits, such as reduced risk of atherosclerosis, diabetes, hypertension, hyperlipidemia, and cancer, due to the antioxidants in wine (Rosenzweig et al. 2017). In addition, Chiva-Blanch and colleagues showed that the phenolic content of red wine modulates leukocyte adhesion molecules and that ethanol and non-alcoholic compounds in red wine have an anti-inflammatory effect (Chiva-Blanch et al. 2012). The effect of red wine on cardiovascular diseases is shown in Figure 1 (Apostolidou et al. 2015; Arranz et al. 2014; Chiva-Blanch et al. 2013; Iriti and Varoni 2015).

Other fermented products

Sourdough bread

In order to improve taste, nutritional value and shelf-life, the use of sourdough in the production of bread is well known (Novotni et al. 2012). Sourdough fermentation is accompanied by the formation of taste compounds such as lactic and acetic acid (Lukšič et al. 2016). Peptides such as ACE-inhibitory peptides are also produced by proteolysis (Zhao et al. 2013), reducing the glycemic index of bread and improving the mineral bioavailability (Novotni et al. 2012).

Vinegar

Vinegar is a fermented product produced by double fermentation (alcoholic and acetic fermentation) of fruits and vegetables containing sugar and starch (Mas et al. 2016; Ozturk et al. 2015). Alcoholic fermentation consists of the degradation of fermentable sugar into carbon dioxide and ethanol under anaerobic conditions by yeast, whereas acetic fermentation is the degradation of the ethanol produced in alcoholic fermentation into acetic acid and water under aerobic conditions by acetic acid bacteria (Ozturk et al. 2015). In addition to its use for food preservation and flavour, vinegar has been used to fight infection, clear ulcers, and heal wounds since the time of Hippocrates (Johnston 2011). Vinegar consumption has recently been associated with many health benefits such as a reduced risk of obesity, cancer, diabetes, and atherosclerosis (Garcia-Parrilla et al. 2017). Upon consumption, the acetic acid in vinegar is metabolized to acetyl-coA, the AMP/ATP ratio increases, the phosphorylation of AMP-kinase is stimulated, and the synthesis of fatty acids is inhibited. Some transcription factors are reduced, such as those of acetyl coa carboxylase (ACC) and fatty acid synthase (FAS), while the transcription factors others are increased, such as those of acetyl coa oxidase (ACO) and carnitine palmitoyltransferase-1 (CPT-1) (Kim et al. 2013). It has been suggested that this is the mechanism by which vinegar lowers the risk of obesity (Park et al. 2014). Kondo et al. (2009) found that the administration of acetic acid inhibited hepatic lipid and body fat accumulation without altering skeletal muscle weight and food consumption. Vinegar's anti-hyperlipidemic effects have been investigated in animals, but there are only a limited number of human studies on these effects (Petsiou et al. 2014). Fushimi et al. (2006) found a significant decrease in serum total cholesterol and triacylglycerol levels in rats fed both cholesterol and acetic acid, the active compound in vinegar, when compared with cholesterol-fed rats. In addition, vinegar or acetic acid has also been used in the treatment of ulcerative colitis because of its ability to inhibit inflammation by suppressing T helper 17 and mitogen-activated protein kinase (Samad, Azlan, and Ismail 2016). The beneficial effect of vinegar on diabetes is attributed to the fact that it slows gastric emptying by inhibiting disaccharide activity in the small intestine and by promoting glucose uptake of muscles (Johnston, White, & Kent 2009). One study showed that vinegar consumption significantly improved postprandial insulin sensitivity in insulin-resistant individuals by inhibiting disaccharide activity in the small intestine and by increasing glucose-6-phosphate levels in skeletal muscle. In the same study, vinegar was suggested to have similar physiological effects with metformin and acarbose (Johnston, Kim, and Buller 2004). Another health benefit of vinegar is increased calcium ion absorption, caused by the binding calcium ion of acetic acid, an active compound in vinegar, in the small intestines (Garcia-Parrilla et al. 2017).

Studies showing the relationship between fermented foods and health benefits are given Table 2.

Conclusions

Fermented foods and beverages have historically been an integral part of the human diet and have long been thought to provide health benefits. Potential health benefits of fermented foods include a reduced risk of hypertension, diabetes, obesity, high cholesterol, diarrhoea, thrombosis, and so on. One explanation for the health benefits provided by fermented foods relates to the bioactive compounds formed during fermentation. With fermentation, the levels of many vitamins such as vitamin B_2 (riboflavin), vitamin B_9 (folate), vitamin B_{12}, and vitamin K in foods are increased. Melatonin is synthesized, as well as GABA, which regulates blood pressure and protects against cardiovascular disease and cancer. Exopolysaccharides, which have cholesterol-lowering, immunomodulator, antioxidant and anti-cancer properties, are generated, and a variety of bioactive peptides such as anti-hypertensive, anti-cancer, anti-inflammatory, anti-diabetic, ACE-inhibitory, anti-microbial, anti-adipogenic, anti-mutagenic, anti-thrombotic, and anti-atherogenic peptides are produced. The most well-known of these peptides are VPP and IPP, lactotripeptides produced during fermentation of milk that have anti-hypertensive and ACE-inhibitory effects. According to the European Food Safety Authority (EFSA), the recommended daily consumption of these lactotripeptides is at least 3 mg to keep blood pressure at normal levels (EFSA, 2011). In summary, many potential health benefits are attributed to fermented foods and beverages due to the biologically active peptides, vitamins, and other compounds produced by the bacteria responsible for fermentation. However, there is a need for further studies on the level of consumption necessary to see these health benefits.

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