Fermented Foods: Their Health-Promoting Components and Potential Effects on Gut Microbiota

Aabid Manzoor Shah 1,†, Najeebul Tarfeen 2,†, Hassan Mohamed 1,3,* and Yuanda Song 1,*

1 Colin Ratledge Center for Microbial Lipids, School of Agricultural Engineering and Food Science, Shandong University of Technology, Zibo 255000, China
2 Centre of Research for Development, University of Kashmir, Hazratbal 190006, India
3 Department of Botany and Microbiology, Faculty of Science, Al-Azhar University, Assiut 71524, Egypt

* Correspondence: hassanmohamed85@azhar.edu.eg (H.M.); ysong@sdut.edu.cn (Y.S.);
Tel.: +86-15653301370 (H.M.); +86-13906174047 (Y.S.)
† These authors contributed equally to this work.

Abstract: Fermented foods play a significant role in the diets of many cultures, and fermentation has been recognized for its many health benefits. During fermentation, the physical and biochemical changes due to microorganisms are crucial to the long-term stability of fermented foods. Recently, fermented foods have attracted the attention of scientists all over the world. Some putative mechanisms that explain how fermented foods affect health are the potential probiotic effects of the microorganisms in fermented foods, bioactive peptides and biogenic amines produced as a result of fermentation, phenolic compounds transformed to bioactive substances, and decreased antinutrients. In addition, increased vitamin content, antioxidant, antihypertensive, and antidiabetic activities have associated with fermented products. The purpose of this paper is to present various types of fermented foods and the health-promoting components that emerge during the fermentation of major food matrices, as well as the affect of fermented foods on the gut microbiome once they are ingested.

Keywords: fermented foods; bioactives; health benefits; gut microbiota

1. Introduction

Since prehistoric times, humans have consumed foods that have undergone fermentation. One of the earliest examples of intentional usage of fermentation was the discovery of clay pots from 7000 BC that were employed to ferment rice, honey, and other foods in China [1]; however, it is possible that inadvertent production and consumption of fermented products may have significantly predated this, since meals would have spontaneously fermented while being stored [2]. Microorganisms, which were first identified by Antoni van Leeuwenhoek in the 1670s, first attracted attention as causes of food decay and illness; however, valuable applications have been reported, such as their capacity to generate antibiotics against harmful microbes and to improve the health of humans [3]. Nevertheless, the role of bacteria in the preservation of food through fermentation is arguably the most significant. Microorganisms use the process of fermentation to create types of alcohol, CO₂, and/or organic acids, mainly from sugars and mostly in anaerobic environments [4]. Foods with a longer shelf life are produced as a result of the build-up of organic acids and alcohols and the subsequent increase in the acidity of the food substrates that hinder the action of enzymes and other microbes from growing in the food system.

Almost all humans have applied the fermentation process to vegetative and non-vegetative plant materials (such as fruits, seeds, tubers, and other materials) and animal materials (such as eggs, fish, meat, and milk), which are the staple foods available in various regions [5]. There are two main techniques for fermenting foods. First, foods can be naturally fermented; this process is frequently referred to as "spontaneous fermentation," and it occurs due to microorganisms that are naturally found in raw food. Examples of such
foods include sauerkraut, kimchi, and some fermented soy products. Second, foods can be fermented by adding starter cultures to food, referred to as “culture-dependent ferments,” such as natto, kefir, and kombucha [6]. Backslopping is a culture-dependent fermentation technique in which a small quantity of a previously fermented batch is introduced to uncooked food, such as sourdough bread [7]. Backslopping acts as a starter that can be used to start the fermentation process. Selected commercial starters can also be used to standardize the organoleptic properties of the finished product.

Almost every cuisine in the world includes fermented foods in some form. In recent years, the popularity of fermented foods has increased in the Western world, largely due to claims that fermented foods provide health benefits and due to the growing interest in digestive health. Fermented foods may have positive impacts on health and disease via a number of processes. First, fermented foods contain microorganisms that may be probiotic, such as lactic acid-producing bacteria [7]. The majority of fermented items have been shown to have at least $10^6$ microbes per gram, with quantities changing depending on the area, age, and time of examination, and the product’s usage [6]. By buffering and protecting probiotic strains from intestinal damage, the associated food matrix seems to play a key role in their survival and protection against bile acids and pH in a gut environment [8]. Fermentation has the potential to transform some substances into bioactive metabolites. For instance, lactic acid bacteria can transform phenolic substances (such flavonoids) into bioactive metabolites [9]. In addition, prebiotics and vitamins, which are included in fermented foods, may have positive effects on health [10]. In this review, we provide a brief overview of fermented foods and their possible health advantages. This is followed by a discussion of how fermented foods affect the gut flora, since changes are typically observed as broad shifts in microbial populations which, in turn, affect the health status of a person.

2. Fermented Foods

Early evidence of fermentation processes comes from the Neolithic period, which began in China around 7000 BC, when agriculture was developing and there were seasons with plenty of food available, followed by periods of time when there was a relative lack of food. Around 8000 BC, agriculture began in the Fertile Crescent of Southwest Asia, and by 7000 BC, domesticated goats, sheep, and cattle were known to exist [11]. The domestication of animals enabled the production of raw milk and meat, both of which had a relatively short shelf life. However, by 6500 BC, simple methods were developed for turning milk into cheese by using fermentation. The main advantages of fermentation procedures were to increase shelf life and to preserve food at a time of relative scarcity. Fermented foods differ from the basic materials that they are produced from in terms of their taste, texture, appearance, and function. Many years ago and long before the development of nutritional sciences, fermented foods would have been purposefully produced as a stable supply of vitamins, minerals, calories, and other nutrients [2]. In the following paragraphs, different types of fermented foods are discussed.

2.1. Fermented Milks

Wherever fresh milk has been consumed, invariably, there are fermented versions that have been made. Although it is uncertain when and where dairy husbandry was originally practiced, the nutritional qualities of milk have been advantageous to humans as they have evolved. However, the same elements that provide milk with its nutritional benefits also make it quite perishable. As a result, fermentation emerged as the primary method for preserving milk’s nutrients. According to Carr et al. LAB consume lactose and produce lactic acid that mediates the random fermentation of milk; the majority of dairy LAB are species from the genera Lactococcus, Pediococcus, Lactobacillus, and Leuconostoc [12]. These bacteria produce lactic acid and alter other milk components, thus, increasing the nutrient bioavailability as well as improving the quality of milk [13]. The inhibition of spoilage and pathogenic microbes by LAB and their bioactive molecules is significant [14]. In many parts of the world, starter culture-mediated artificial fermentations have largely replaced milk’s
natural tendency to spontaneously ferment [2]. According to Bintsis (2018), dairy cultures are made up of carefully chosen and well-defined LAB species strains that are produced in concentrated and stable forms. Indeed, even in underdeveloped nations, they are widely used due to their widespread availability, simplicity of use, and constant qualities [15].

Worldwide, the majority of dairy-fermented foods are made from cow’s milk; however, historically, milk from other mammals, including sheep, goats, camels, mares, buffalo, and yaks, may have been more significant and may still be in some areas. Small ruminant farming, which includes raising ewes and goats, has had a long history in many Mediterranean nations as well as numerous African and Asian countries. For instance, the majority of milk from ewes and goats is utilized to create conventional dairy goods, primarily cheeses. In the Himalayas and nearby areas, milk and fermented milk products from domesticated animals such as yak are popular dairy products [16]. The chemical makeup of milk from different mammal species varies, with significant variances in things such as total solids, fat, lactose, protein, and mineral content. There is a wide range of traditional and commercial fermented milk products with more than 400 generic names globally [17], and there are at least 1000 additional types of cheese and cheese-related goods available [18]. The method of coagulation (enzyme, acid, or acid plus heat), the degree of whey separation (from none to complete), or the type of fermentation (lactic acid bacteria alone or lactic acid bacteria plus fungal or other adjunct cultures) can all be used to distinguish different types of fermented dairy foods.

Yogurt and yogurt related products are the most popular fermented milk products that are produced by the inoculation of starter culture. Despite the fact that commercial cultures are now widely accessible, the culture for many traditionally made items is drawn from a previous batch (i.e., backslopping). Traditionally, milk from cows, goats, sheep, and other animals is heated to a boil or just below it, allowed to cool, and then inoculated to create yogurt. The yogurt bacteria, Streptococcus thermophilus and Lactobacillus delbrueckii subsp. bulgaricus, are moderate thermophiles and require higher temperatures (from 40 to 45 °C) for fermentation, thus, the manufacturing conditions must accommodate this requirement [2].

Other common fermented milk products are Bulgarian buttermilk, “kefir,” “koumis,” and “viili” [2]. L. delbrueckii subsp. bulgaricus, a prolific acid generator (generating up to 4% lactic acid), ferments milk to generate Bulgarian buttermilk, which has a significantly higher acidity than yogurt. Kefir is a milk beverage made by spontaneously fermenting milk with kefir grains. It is thick, acidic, slightly fizzy, and faintly alcoholic [19]. Kefir grains are made up of lactic and acetic acid-producing bacteria, symbiotic lactose- and non-lactose-fermenting yeasts (such as Kluyveromyces marxianus, Saccharomyces unisporus, and S. cerevisiae), and a carbohydrate and protein matrix known as kefiran [20]. The by-products of fermentation, include lactic acids, acetaldehyde, ethanol, and carbon dioxide, all add to the organoleptic qualities of kefir [21]. Water kefir, a fermented beverage comprised of water kefir grains, water, and sugar that include bacteria and yeasts but differ from the classic kefir starting cultures, is a dairy-free alternative to kefir. Kefir grains have been found to contain a variety of microbial species, most frequently Streptococcus thermophilus, Leuconostoc sp., Lactobacillus paracasei, L. brevis, L. helveticus, Lactococcus lactis, Acetobacter orientalis, A. lovaniensis, Candida kefyr, S. cerevisiae, S. unisporus, and Kluyveromyces marxianus [22–24].

Another milk product from the Caucasian region that spontaneously ferments is called “koumis.” In Mongolia and northwest China, similar goods are made such as “chigee” and “airag” [25]. The mare’s milk that is used, which gives the final product a smooth, rich taste due to its reduced protein and higher fat content, is what defines “koumis.” A very well-known milk product from Finland called “viili”, naturally ferments milk and includes the lactic acid bacteria and filamentous yeast Geotrichum candidum. According to Tamime and Robinson (2007), comparable goods are also produced in Sweden, Iceland, Denmark, and Norway [26]. Due to the evolution of Lactococcus lactis strains that produce extracellular polysaccharides (EPSs), the majority of these products have a thick and gooey consistency [27].
2.2. Cheese

Fermented dairy foods are produced by a combination of events, i.e., the capacity of LAB to multiply in milk and to produce just enough acid to bring the pH down to the isoelectric point of the caseins. If left undisturbed, an acid-induced milk gel is quite stable, but if ruptured unintentionally or on purpose, the curd and whey separate. When whey is removed, cheese is produced, which can be eaten right away or kept fresh for a long time if properly salted and/or dried. About 25% of cheese consumption is made up of acid-coagulated cheeses like cream cheese, quark cheese, and cottage cheese, with a smaller fraction produced by combining acid with heat (ricotta) [28–30]. The remaining portion is produced by enzymatic coagulation using rennet, natural or synthetic chymosin, or other acid proteinases. Cheeses can be divided into three main categories based on the characteristic method of production, ripening type, or moisture content: soft-to-hard bacterially ripened, mold-ripened, and surface-ripened. Cheeses that have been internally bacterially matured include cheese with eyes (Emmental), Dutch types of cheese (Edam and Gouda), hard cheese (Cheddar) and very hard cheese (Parmesan). Although they are typically not matured, heavily salted cheeses such as feta and “pasta filata” variants of mozzarella may be categorized in this group. The Limburger Munster and Tilsit varieties of cheese are surface-ripened cheeses. Among the cultivars that have undergone mold ripening are those that have both external (Brie, Camembert) and interior (Roquefort, Gorgonzola, Stilton, Cabrales) fungi. Although the majority of these cheeses are now manufactured globally, they are sometimes linked to certain places or nations. Indeed, a number of these cheese names are also secured by country-of-origin labels, which also demand that they are produced in accordance with traditional methods [2].

2.3. Fermented Meat

Everywhere in the world, people eat animal flesh. Traditional methods of preserving meat from various domesticated animals include smoking, sun drying, and cutting it into whole chunks or slices. To manufacture sausages, some meat is put into an animal’s gut. Several of these products undergo fermentation to improve their organoleptic and storage qualities. In fact, one of the most common ways that processed meat products are ingested in the Western world is by putting minced, diced, or chopped meats into casing material (often animal intestines), followed by fermentation [2]. It is now known which groups of bacteria predominate during the fermentation of beef. The majority of the bacteria are lactic acid bacteria, which include strains of Lactobacillus sakei, L. plantarum, L. carnosum, L. curvatus, L. pseudomesenteroides, L. gelidum, Pediococcus pentosaceus, Enterococcus faecium, and Weissella [31,32]. The Micrococci, Kocuria, and Staphylococci (coagulase-negative) make up the other major bacterial group [2]. These bacteria, in particular, change nitrate into nitrite and add flavor to fermented sausages. The Enterobacteriaceae family may also be present occasionally. A variety of yeast and mold species also contribute significantly to the flavor and texture development of fermented meats as they ripen [33].

2.4. Fermented Fishes

Since fish and shellfish spoil quickly, several straightforward technologies have been used to preserve them and to give them a lengthy shelf life. These processes include smoking, seasoning, curing, drying, and fermentation. These products improve flavor and provide “deliciousness” in addition to their preservation abilities [34]. There are typically two varieties of fermented fish products. Fish sauces and fish pastes are among the most popular condiments and flavorings in many Asian countries. Fish can be combined with salt (15% to 25%) to make these products. The Philippines’ “burong isda” and Thailand’s “pla-ra” are examples of products made from a combination of fish, salt, and carbohydrates. Although fish sauces are used as a condiment throughout East Asia, they are mostly found to be linked with Malaysia, Thailand, Laos, Vietnam, Myanmar, Cambodia, and other South Asian countries. Over the past 30 years, researchers have examined the microbiology
of fermented fish sauces. Various species of bacteria, such as lactic acid bacteria and micrococci, and certain species of yeasts, have been documented [2].

2.5. Fermented Legumes

The main legume used to create fermented foods is soybeans. Fermented soy products have a significant role in Asian diet, culture, and cuisine. In Africa and the Indian subcontinent, respectively, locust beans and black grammes are more prevalent. In Asia, three main categories of fermented soybean dishes are developed according to the ethnic and gastronomic customs of the local or regional populations. The predominant kind produces pastes (such as “miso”) and salty sauces (such as soy sauce, “tamari”, and “shoyu,”) that are fermented by LAB, yeast, and filamentous fungus. Various fermented soy bean meals include tempeh, miso and natto [2].

Tempeh, a traditional Indonesian meal, is made by fermenting boiled, dehulled soybeans with a starting culture of the fungus *Rhizopus oligoporus* for 35–37 h at room temperature [35,36]. This results in a tender white cake with a flavor reminiscent of mushrooms and a chewy texture. Depending on changes in production, tempeh’s microbial composition changes [37]. *Escherichia coli*, *Enterococcus faecium*, lactic acid bacteria, and *Rhizopus* are all present in tempeh [38]. It has been demonstrated that fermenting soybeans lowers the levels of phytic acid, phenols, protease inhibitors, and antinutritional substances that are prevalent in raw soybeans and may be connected to the phytases expressed by *Rhizopus* species in tempeh [39]. Miso soup is made using miso, a traditional Japanese paste made from fermented soybeans. Miso is made by culturing soybeans with “koji,” a mold called *Aspergillus oryzae*, however other lactic acid bacteria and *S. cerevisiae* may also be employed.

Miso manufacturing differs substantially from other fermented soy foods in terms of the strain of *A. oryzae*, ingredients, salt content, and temperature. *Bacillus amyloliquefaciens, B. subtilis, Staphylococcus kloosii,* and *S. gallinarum,* can all be found in miso at various times after fermentation begins, but only the *Bacillus* species remains in the finished product. The presence of *Lactococcus sp.* GM005, which generates a bacteriocin with potent antibacterial activity that prevents the growth of a variety of bacteria, including *Lactobacillus plantarum, Pediococcus acidilactici,* and *B. subtilis,* has also been detected in a variety of miso samples [40,41].

Itohiki-natto is the most popular variety of natto, a traditional Japanese fermented soy food. The fermentation of fried yellow soya with *B. subtilis var. natto* results in natto [42]. As a result, a thick dish with a distinctive flavor and potent odor is produced [43]. The duration of soybean steaming, the humidity level, the temperature, and the fermentation period all affect the properties of natto. Several bioactive substances, including nattokinase, vitamin K2, dipicolinic acid, and bacillopeptidase F are produced during the fermentation of natto [36].

2.6. Fermented Vegetables

In both the Eastern and Western worlds, fermented vegetables are frequently eaten as sides or as ingredients in various meals. Sauerkraut and table olives are the two most popular fermented vegetables in the Western world. In contrast, every nation or region cultivates and enjoys its own distinctive fermented vegetables in the East. Since LAB is primarily used to ferment these products, they are frequently thought of as potential sources of bacteria that resemble probiotics. As a result, there has been an increase in the development and sale of fresh and unheated items due to consumer demand in fermented foods that contain living bacteria.

The majority of the Mediterranean nations have long valued table olives for their culinary traditions, economic importance, and nutritional value. Alkaline- and brine-treated raw olives are both used to make fermented olives. Spanish-style, Greek-style, and California-style olives are the three main varieties that are typically manufactured. For fermentation, all three varieties rely on the native microbiota, with yeasts and lactic acid bacteria (LAB) serving as the main organisms. *Pediococcus pentosaceus, Leuconostoc*
mesenteroides, Pichia membranaefaciens, P. fermentans, Lactobacillus plantarum, Candida oleophila, 
C. silvae, Saccharomyces cerevisiae, and Cystofilobasidium capitatum are the most common yeast 
species discovered in olives [2]. Olive pate, a traditional French food, is known to have 
many bioactive compounds and relies on Lactobacillus species for fermentation [44].

Another common vegetable consumed both in the Eastern and Western worlds is 
cabbage, with fermented varieties being popular in many areas. European or white cabbage 
(Brassica oleracea) is the primary ingredient in sauerkraut, a fermented cabbage dish popular 
in the Western world. Germany, as well as other Asian, and American nations, commonly 
consume sauerkraut. Shredded cabbage is combined with 2.3–3.0% salt to make sauerkraut, 
which is then allowed to ferment naturally, typically with Leuconostoc spp., Pediococcus spp., 
and Lactobacillus spp. [45]. A preserved cabbage results from the end product’s low pH. 
Through the use of culture-dependent techniques, it has been demonstrated that homemade 
and store-bought sauerkraut both contain Lactobacillus sakei, L. curvatus, L. delbrueckii, L. casei, 
L. plantarum, L. lactis, Enterobacteriaceae, Bifidobacterium dentium, Staphylococcus epidermidis, 
Lactococcus lactis and Weissella confusa. Lactobacillus and Leuconostoc spp. have also been 
found to predominately be present in sauerkraut [46–48]. Some Lactobacillus species 
that have been isolated from sauerkraut have probiotic potential due to their adhesion 
to Caco-2 cells [49]. It has been demonstrated that the common sauerkraut-causing L. paracasei HD1.7 produced a broad-spectrum bacteriocin that may aid in the preservation of 
sauerkraut [50].

In East Asian cuisine, napa cabbage (Brassica rapa), among other vegetables, is 
frequently used, particularly to make kimchi. The term “kimchi,” which has Korean origins, 
refers to a variety of salted and fermented greens. The main ingredients are Chinese cabbage 
and/or radishes; as well as a variety of seasonings, such as salt, sesame seed, and 
soybean sauce; various flavorings, such as chili, onion, garlic, pepper, and ginger; and other 
additional foods (e.g., shrimps, carrot, pear, apple) [51]. The cabbage is fermented and 
rinsed to make kimchi. Next, the remaining flavors, spices, and food items are added and 
combined with the cabbage. Finally, fermentation occurs. Even though starter cultures can 
be employed to produce kimchi commercially, the fermentation happens spontaneously 
thanks to the bacteria that are naturally present on the cabbage and other ingredients. 
Before fermentation, the kimchi mixture contains a variety of bacteria from the genera Pseu-
domonas, Leuconostoc, Weissella, Lactobacillus, and Pantoea [52]; however, once fermentation 
has begun to take place, the bacterial community is quickly dominated by the Leuconostoc 
spp. after just three days of fermentation [52]. Leuconostoc citreum is the most prevalent 
species in this genus before fermentation, but it only makes up a small fraction of the 
population after three days, when Leuconostoc gelidum and L. gascomitatum take over [52]. 
The kind and quantity of the foods contained affect the microbial composition of kimchi 
because it can contain a wide range of components. For instance, more garlic has been 
reported to increase Lactobacillus concentration in kimchi, while red pepper powder increases 
Weissella and decreases Lactobacillus and Leuconostoc proportions [53,54]. Several yeast such 
as Saccharomyces, Trichosporon, and Candida, and archaeal taxa including Halococcus and 
Natronococcus, have also been found in commercially sold kimchi [55].

2.7. Alcoholic Beverages

One of the most significant fermented food products, both economically and culturally, 
is alcohol-containing beverages. Their use is linked to a variety of acceptable cultural 
practices on a global scale, including rituals, conventions, religions, and entertainment. 
Every continent and region produces and consumes alcoholic beverages, including beers, 
wines, and distilled alcoholic beverages. In addition to being consumed socially or for fun, 
alcohol is also consumed during religious rituals. Additionally, drinking alcohol is deeply 
ingrained in Latin American, African, and Asian ritualistic cultures. In Europe and the 
Mediterranean, on the one hand, in particular, wine has a long history and sociocultural 
significance in the eating habits of people [2]. In Asia, on the other hand, grapes and other 
fruits are typically consumed unfermented, without tradition or culture supporting wine.
Alcoholic beverages are typically derived from foods such as cereals and potatoes, which have few fermentable carbohydrates, and therefore, dried amylolytic starters are necessary. As a result, a saccharification step mediated by enzymes is required, typically by fungus solid-state fermentation. In Asia, the malting procedure is not as common as it is in Europe and the United States. Instead, the conversion of starches to sugars is accomplished using conventionally prepared dry amylolytic starters [2,56]. Particularly, the country of Japan has emerged as a significant single-malt whisky manufacturer [57].

2.8. Other Fermented Foods

Sourdough starter is formed by fermenting flour with lactic acid bacteria and yeasts that are naturally present in the flour and environment. Sourdough starter is made over the course of seven days, replacing the microorganisms each day with new flour and water. When the starter is ready, a tiny amount is added to the components for the sourdough base to start the fermentation process; this procedure is known as “backslopping” [58,59]. Cereal proteins, lipids, carbohydrates, and phenolic substances undergo microbial and enzymatic-driven transformations during fermentation [58,60]. The activities of the microorganisms and the enzymes are interconnected, for instance, lactic acid bacteria cause a pH decrease that modifies the action of cereal enzymes and the solubility of substances (such as gluten), and the enzymes can then facilitate substrates for the growth of microorganisms [58]. Sourdough starters have been found to include a number of species from the genera Leuconostoc, Lactobacillus, Pediococcus, Weissella, and Streptococcus [60]. The majority of starters contain Lactobacillus species, with Lactobacillus sanfransiscensis being an important species [61]. The most prevalent yeast species are S. cerevisiae, S. exiguous, Candida humilis, C.milleri, and Issatchenkia orientalis [62].

A fermented tea beverage known as kombucha is thought to have developed in north-east China about 220 BC and was widely used throughout the Qin Dynasty. Later, similar fermented tea drinks gained popularity in Eastern Europe and Russia [63]. Traditional kombucha is made through the symbiotic culture of bacteria and yeast, which employs a blend of bacteria and yeast to aerobically ferment black tea (green tea may also be employed) and white sugar known as SCOBY. Along with organic acids and carbon dioxide, the yeast transforms sucrose to ethanol, which the acetic acid bacteria then use to create acetaldehyde and acetic acid [64]. The precise SCOBY composition, the kind and proportion of tea and sugar, fermentation time, oxygen concentrations, temperature, and storage duration all affect the microbial and metabolite makeup of kombucha [24]. Bacteria such as Lactobacillus, Lactococcus, Gluconobacter, and Acetobacter and yeasts such as Zygosaccharomyces and Saccharomyces are among the common bacterial and fungi species that make up SCOBY [63,65,66]. After fermentation, studies using high-throughput sequencing analysis have shown that the bacterial genera Lyngbya, Komagataeibacter, Lactobacilli, Gluconobacter, and Bifidobacteria are more prevalent than the yeast genera Candida and Zygosaccharomyces [65,67].

A bacterial cellulose finished product by Komagataeibacter xylinus is called nata (formerly, Acetobacter xylinum). It is a favorite among Filipino people and is typically locally manufactured in small batches. Nata is typically consumed as a treat or candy because of its mildly sweet flavor [68,69]. A fermented duck egg known as pidan (or century egg) is mostly eaten in China. Alkaline salts that give off an ammonia flavor are first used to cure the eggs. Several Bacillus and Staphylococcus species have been identified in pidan [2].

3. Health-Promoting Components of Fermented Foods

3.1. Antioxidant Components

Food antioxidant activity is regarded as a vital component of food because it protects the body against oxidative damage, which is a factor in the development of the majority of age- and diet-related chronic diseases [70]. The by-products of oxidation are free radicals that cause oxidative damage [71] to various bodily physiological functions, including the production of calories by breaking down lipids, and the release of catecholamines in response to stress and inflammatory processes. The human body can defend itself
against oxidative damage using non-enzymatic antioxidants such as vitamin C, tocopherols, carotenoids, and phenolic compounds, as well as enzymatic systems such as, glutathione peroxidase (GPx), superoxide dismutase (SOD), and catalase (CAT) [72]. Natural antioxidants, as in fermented foods, have drawn more attention as a result of rising concerns due to the intake of artificial antioxidants, and therefore may aid to safeguard human health [73,74].

Dairy products contain antioxidant capacity in vitro. Milk has a lower antioxidant activity than yogurt and other fermented milk products. Bioactive peptides are released in fermented milk, due to the proteolysis of milk proteins, particularly, casein, α-lactalbumin, and β-lactoglobulin [72]. The antioxidant activity of fermented kinds of milk can be influenced by factors such as milk origin, the fat content of milk, and microbe strains. Amino acids such as methionine, tryptophan, and tyrosine, as well as their positions in the peptides, are thought to be responsible for the antioxidant action of fermented milk [70]. Fermented milk products with strong antioxidant activity are frequently produced by some LAB species, including those in the Lactococcus, Lactobacillus, Leuconostoc, Streptococcus genera [70,75]. Studies have shown that the generation of antioxidative peptide was strain specific by evaluating the proteolytic activity of 19 chosen Lactobacillus strains from 10 distinct species [76]. Conjugated linoleic acid (CLA), one of the key antioxidants in milk fat along with vitamins A and E, carotene, and coenzyme Q10, may also boost the antioxidant activity of fermented milk [77]. Among other things, folic acid has antioxidant qualities, and according to the research, LAB species have the intriguing potential to substitute other functional microorganisms in fermented dairy products by accumulating folate in milk [78].

When Lactococcus hircilactis and Lactococcus laudensis were compared for their potential as starter cultures for the manufacture of fermented milk with significant antioxidant activity, it was discovered that L. hircilactis produced modest levels of folates [79].

The effects fermentation has on the antioxidant activity of grains and foods made from fermented grains have been studied extensively. In general, depending on the raw material, the fermenting agent, and the process circumstances, fermentation boosts the antioxidant activity of fermented foods by producing a variety of different molecules. Numerous grains, including cereals such as wheat and buckwheat, pseudocereals such as quinoa, and legumes such as lupin and lentil, have been researched. The impact of various fermentation processes has also been studied. Phenolic chemicals, GABA, and bioactive peptides are a few of the ingredients that give fermented grain-based diets high antioxidant activity. Because phenolic compounds are bio-converted during fermentation from their conjugated states to their free forms, it is possible to enhance the overall phenolic component content. Enzymes made by fermenting microorganisms break down grain cell walls structurally, increasing the bioavailability and bioaccessibility of bound phenolic substances [72,80]. In one study, quinoa and buckwheat were fermented with Lactobacillus paracasei and P. pentosaceus and an increase in phenolic content was observed, which was also observed in wheat germ, buckwheat, barley and rye, when treated with fermented Lactocaseibacillus rhamnosus and S. cerevisiae [72]. Quinoa fermented with Lactobacillus rossiae strain T0B10 and L. plantarum strain T6B10 showed twice times more antioxidant activity and increased total phenolic content than the control, according to studies by Lorusso et al. (2017) [81].

Quinoa fermented with Lactobacillus rossiae strain T0B10 and L. plantarum strain T6B10 showed twice times more antioxidant activity and increased total phenolic content than the control, according to studies by Lorusso et al. (2017) [81]. Ripari et al. analyzed the metabolization of phenolic acids by LAB and discovered that co-fermentation of L. plantarum and L. hamnesii allowed for the release of bound ferulic acid and the conversion of the unbound ferulic acid to dihydroferulic acid and other volatile intermediates [72]. Therefore, by specifically converting phenolic compounds during sourdough fermentation, bread quality could be enhanced. Peas et al. demonstrated that bread made with wheat sourdough fermented by using L. brevis CECT 8183 and an industrial protease had a higher overall antioxidant activity because of the presence of GABA and short peptides (3 kDa) after fermentation [82]. During the fermentation of Kombucha tea, the concentrations of polyphenol and flavonoid increase. Additionally, during kombucha fermentation, in vitro superoxide radical scavenging and total phenolic component concentration increases [65,83]. Sauerkraut is known to breakdown glucosinolate into many
products including kaempferol. However, kaempferol has been demonstrated to have antiviral activity [84], radical scavenging action to protect against oxidative damage, and reduced cytokine-induced reactive oxygen species in vitro [85]. The fact that unfermented soybeans are less effective at scavenging free radicals and superoxide in vitro than tempeh may be related to changes in the polyphenol content and digestibility of fermented soybeans [86].

Regarding fruit, numerous publications have discussed how Lactobacillus fermentation affects antioxidant activity and phenolic concentration in fruit juices. Following fermentation by two strains of L. plantarum, Yang et al. investigated the antioxidant activity of a beverage comprising carrots, apples, and pears, and found increased antioxidant activity, reaching a peak after 4–8 days of fermentation [87]. When cashew-apple juice was fermented by L. plantarum, Kaprasob et al. examined the changes in antioxidant activity, physicochemical qualities, and volatile compounds. They discovered a positive correlation between the radical scavenging activity and vitamin C and condensed tannins but not hydrolysable tannins [88]. After fermentation with L. paracasei strain HI101, Sirilun et al. noted an increase in the antioxidant activity of Syzygium cumini L. fruit juice [89]. According to Bujna et al., fermentation of apricot juice by cultures of Bifidobacterium and Lactobacillus strains increased the antioxidant activity of the juice [90].

3.2. Vitamin Content

A sufficient intake of vitamins through diet is essential to prevent vitamin deficiencies because the majority of vitamins cannot be manufactured by the human body or can only be done so in insufficient amounts. Alternative approaches must be taken because food processing and heating remove some of the vitamins that are typically found in raw materials, and since the diet of the population is increasingly made up of processed foods. In fact, fermentation increases the amounts of several vitamins in food. For instance, microbial fermentation has received more attention in recent years as a worthwhile option for producing natural folate (vitamin B9) and as a sustainable technique based on renewable resources [91]. The utilization of LAB that produce folate has been seen as an intriguing method of bio-fortifying dairy and fermented meals [92]. Certain Bifidobacteria spp. and LAB can synthesize folates (vitamin B9) in fermented milk. A significant number of bacilli, including species of the genera Lactobacillus, Carnobacterium, and Enterococcus, and species of cocci of genera Lactococcus, Oenococcus, Pediococcus, Tetragnococcus, Vagococcus, and Streptococcus, specialize in the production of vitamin K2 [93]. Vitamin B12, which is essential for the production of blood cells and the health of the nervous system, is found in large quantities in dairy products. Fermentation has the potential to boost its content by up to 10 times [94].

Recent research has demonstrated that fermentation makes it possible to supplement foods made from plants with vitamin B12. For instance, vegans may be particularly interested in tempeh, a traditional Indonesian dish that is fermented by a fungus and typically prepared from soybeans since it is high in vitamin B12. The use of lupin as a substitute substrate and a co-culture of Rhizopus oryzae and Propionibacterium freudenreichii, however, have been found to enable the production of B12-enriched lupin tempeh. Signorini et al. suggested that the interaction between Propionibacterium and Rhizopus increased the amount of vitamin B12 in food by approximately 1230 ng/g dry weight [95]. Using three strains of P. freudenreichii, active vitamin B12 was produced in situ in a blend of aqueous cereal-based matrices (wheat aleurone, barley flour, and malted barley flour), demonstrating that cereal foods can be naturally enhanced with active B12 to a level that is nutritionally significant [96].

3.3. Antihypertensive Properties

In intervention studies, fermented milks have been discovered to lower blood pressure [97]. The activity is a result of the breakdown of milk proteins by digestive enzymes released by lactobacilli during fermentation, which results in the formation of antihyper-
tensive peptide. Antihypertensive peptides inhibit the angiotensin-converting enzyme (ACE) that is essential for the renin-angiotensin system, which controls blood pressure. Milk fermented with the *L. lactis* strain NRRL B-50571 contained ACE inhibitory peptides, and the antihypertensive effects of these peptides were examined in rats with spontaneous hypertension or in individuals who were pre-hypertensive [98]. Studies have demonstrated the capacity of seven LAB strains to release ACE-inhibitory peptides and synthesize GABA, and have discovered that milk fermented with *L. lactis* DIBCA2 had the highest ACE-inhibitory activity, while *L. plantarum* PU11 was discovered as the most effective producer of γ-aminobutyric acid (GABA) [99]. Utilizing the *Streptococcus salivarius* sp. fmb5 strain to make functional yogurt that is high in GABA, Chen et al. recently worked to optimize the culture conditions. The findings demonstrated that culture temperature, culture duration, and monosodium glutamate concentration had the greatest effects on GABA yield [100].

A promising technique for the creation of baked foods with antihypertensive effects is sourdough fermentation [101]. By producing flavored free amino acids and other amino acid equivalents that give bread flavor, it actually makes it possible to hide the reduced salt level while also enhancing bakery products with useful antihypertensive substances. The proteolytic activity of LAB converts cereal matrix proteins into peptides that provide fermented grains with their antihypertensive actions. The impact of a 21% addition of whole grain wheat sourdough (made by *L. brevis* CECT 8183) on ACE inhibitory substances was investigated by Penas et al. [82].

### 3.4. Antidiabetic Properties

Diabetes is known to have a high prevalence globally, and 90% of diabetes cases are T2DM cases [102]. Studies conducted in vitro and in vivo have shown that fermented foods have antidiabetic characteristics, although the precise mechanisms behind this activity are unknown. Phenolic chemicals, GABA, and antioxidants, have all been proposed to be potential culprits for the antidiabetic effects [103]. Due to the creation of organic acids, using sourdough fermentation to make bread results in bread with a low glycemic index (GI) and limited carbohydrate digestibility. Lactic acid from sourdough fermentation encourages interactions between gluten and starch during the heat treatment, which lowers starch bioavailability and, as a result, the GI of baked goods. In research on animals, kombucha has been demonstrated to have benefits on blood sugar levels and diabetes-related weight loss [72].

### 3.5. Reducing Lactose Intolerance

It is widely recognized that persons with insufficient levels of lactase in the small intestine may experience bloating, gas, diarrhea, and abdominal pain when consuming lactose [104]. As a result, people who lack the enzyme lactase typically avoid milk. Contrarily, since the LAB used to manufacture yogurt produce lactase that can achieve lactose breakdown, and therefore, lessen symptoms, it is possible to ingest fermented dairy foods such as yogurt with fewer or no symptoms [72]. The functional characteristics of a probiotic yogurt made with donkey milk, *L. casei* and *L. acidophilus*, were studied by Perna et al. They discovered that the experimental yogurt had less lactose than regular yogurt [105]. Kefir contains bacteria (such as *Kluyveromyces marxianus*) that express the β-galactosidase enzyme which hydrolyzes lactose and lowers lactose concentrations in the beverage; it has been hypothesized that patients with lactose malabsorption can effectively handle kefir. Kefir has been reported to have a 30% lower lactose level than unfermented milk while having 60% more β-galactosidase than plain yogurt. A small cross-over randomized controlled trial (RCT) in 15 people with lactose malabsorption found that kefir produced considerably lower levels of breath hydrogen as compared with milk and breath hydrogen levels were similar immediately after drinking kefir and plain yogurt, suggesting that kefir and plain yogurt improved lactose digestion to a similar degree. This was despite reportedly higher β-galactosidase concentrations in kefir than yogurt [106].
3.6. Probiotic Effect

The health advantages of fermented foods may result from a probiotic action in addition to a biogenic effect, or from interactions between ingested living microorganisms and the host [107]. For live microorganisms to have a positive impact on the host’s health, they must be given in sufficient doses. Given that they promote the development and/or survival of LAB, primarily *S. thermophilus* and *Lactobacillus* spp., fermented milks and yogurt are among the most appealing food matrices for supplying healthy live bacteria [108]. The digestive tract (GIT) contains metabolically active cells that generate effector chemicals such as butyrate and short-chain fatty acids. It is difficult to get healthy cells into the GIT and to express cell metabolic pathways genetically. Champagne et al. employed fermented milk as a carrier for *Lactobacillus reuteri*, a probiotic bacterium. Probiotic starter cultures and the prebiotic fiber glucan have been created with a symbiotic effect for oat-based dairy fermented beverages [109].

However, plant-based fermented foods may serve as non-dairy replacements of probiotics, to meet the demands and trends for lower cholesterol, lactose-free, dairy-free, vegetarian, and vegan products. Probiotics are primarily ingested in dairy-based food items. Probiotic goods frequently contain probiotic microorganisms, primarily LAB and *bifidobacteria*. Recent research on the “probiotication” of fruit juice is scarce. The quality of *Punica granatum* L. juice probioticated with *Lactobacillus casei*, *L. plantarum*, *L. bulgaricus*, and *L. salivarius* was examined by Mustafa et al. in relation to fermentation temperature and pH. At 37 °C and a pH range of 3.5–4.0, they discovered that *P. granatum* L. juice cultivated with *L. casei* had a superior growth profile and a greater biomass density. Additionally, probiotication preserved the juice’s ability to scavenge free radicals [110]. *Lactobacillus* cultures (probiotic) have been studied in table olive fermentation; certain LAB strains could bind to the olive surface despite the comparatively high acidity and salinity of fermented vegetables [111].

Probiotics may improve both specific and nonspecific immune responses, as per evidence from in vitro systems, animal models, and human studies. These effects are thought to be mediated by activating macrophages, boosting cytokine levels, enhancing the activity of natural killer cells, and/or increasing immunoglobulin levels. Additional evidence of boosted immunity and greater infection resistance has been shown both in animals and in people. *Lactobacillus sp.* and *Bifidobacteria* lowered the spread of systemic *Candida albicans* in an immunodeficient euthymic mouse model [112]. Additionally, when *Lactobacillus GG* was given to children with cystic fibrosis, the severity of their pneumonia was found to be less severe in a placebo-controlled trial [113]. Surono et al. [114] assessed how *E. faecium IS-27526* in milk affected the humoral immune response as well as body weight of young children between the ages of 15 and 54 months. The findings demonstrated that *E. faecium IS-27526* significantly improved the humoral immune response, salivary IgA levels, and weight gain of underweight young children. Another human investigation [70] examined the impact of zinc supplementation and the probiotic *L. plantarum IS-10506* on the humoral immune response and zinc levels of Indonesian infants between the ages of 12 and 24 months. A considerable boost in the humoral immune response and an improvement in zinc status were both reported associated with probiotic and zinc supplementation. According to some theories, the effects of probiotics on the humoral immune response are the result of colonization, adherence to epithelial cells, and synthesis of SlgA triggered by probiotic cell wall components such as lipoteichoic acids and peptidoglycan [115].

3.7. Protein Digestibility Enhancement

By lowering the amounts of non-nutritive substances that encourage protein crosslinking (such as tannin and phenolic compounds) and enzyme inhibition needed for digestion (such as chymotrypsin and trypsin inhibitors), fermentation can increase the digestibility of nutrients of grains, such as pulses added to oat-based dairy fermented beverages to create a symbiotic effect. Despite the fact that protein digestibility improves during fermentation, when the concentration of sulphur amino acids changes, a general decrease in protein qual-
ity can be seen. Cabuk et al. explored how fermentation affected the amino acid makeup and in vitro digestibility of pea protein extracts [116]. They found that fermentation was an effective way to get rid of some non-nutritive substances in cereal matrices, but that using strains with strong proteolytic activity that extensively degrade sulphur amino acids, such as *L. plantarum* NRRL B-4496, may have a negative impact on the protein quality.

The health benefits of fermented foods like antioxidant, Antihypertensive, Antidiabetic, Reduce lactose intolerance, Enhancement of protein digestibility-Probiotic properties and their corresponding microbiology have been summarized in table (Table 1).

**Table 1.** Fermented foods and their health promoting properties.

<table>
<thead>
<tr>
<th>Health Promoting Property</th>
<th>Food to Be Fermented</th>
<th>Fermenting Microbes</th>
<th>References</th>
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<tr>
<td></td>
<td></td>
<td><em>L. acidophilus</em></td>
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<td></td>
<td></td>
<td><em>Lactobacillus delbrueckii</em> spp. bulgaricus strain LB340</td>
<td>[119]</td>
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<td></td>
<td></td>
<td><em>L. casei</em> strain AG</td>
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<tr>
<td></td>
<td><strong>Quinoa and buckwheat</strong></td>
<td><em>Lactobacillus casei</em> strain PRA205</td>
<td>[120]</td>
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<td></td>
<td></td>
<td><em>Lactobacillus plantarum</em> strain AFI</td>
<td>[121]</td>
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<tr>
<td></td>
<td></td>
<td><em>Pedicoccus pentosaceus</em></td>
<td>[75]</td>
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<tr>
<td></td>
<td></td>
<td><em>Lactobacillus rhamnosus</em> strain PTCC 1637</td>
<td>[70]</td>
</tr>
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<td></td>
<td><strong>Quinoa fermented</strong></td>
<td><em>P. pentosaceus</em> and <em>Lactobacillus paracasei</em></td>
<td>[122]</td>
</tr>
<tr>
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<td></td>
<td><em>L. plantarum</em> strain T6B10 and <em>Lactobacillus rossiae</em> strain T0B10</td>
<td>[81]</td>
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<tr>
<td></td>
<td></td>
<td><em>L. rhamnosus</em> and <em>S. cerevisiae</em></td>
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<td></td>
<td><strong>Bread supplemented with bioprocessed bran</strong></td>
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<td></td>
<td></td>
<td><em>Streptococcus salivarius</em> subsp. <em>thermophilus</em> strain fmb5</td>
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<td></td>
<td></td>
<td><em>Lactobacillus</em> spp.</td>
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<td></td>
<td></td>
<td><em>Pediococcus acidilactici, L. lactis</em> and <em>Pediococcus pentoseus</em></td>
<td>[125]</td>
</tr>
<tr>
<td></td>
<td><strong>Rice bran</strong></td>
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<td><strong>Rice bran</strong></td>
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<td></td>
<td><strong>Sourdough</strong></td>
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<td></td>
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<td></td>
<td><em><em>Syzygium cumini</em> L fruit juice</em>*</td>
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<td></td>
<td><strong>Tomato</strong></td>
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<tr>
<td></td>
<td><strong>Apple juice</strong></td>
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<td>[129]</td>
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<tr>
<td></td>
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</tr>
<tr>
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<td></td>
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<td></td>
<td></td>
<td><em>Lactobacillus</em> spp.</td>
<td>[99]</td>
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<td></td>
<td><strong>Sourdough</strong></td>
<td><em>L. brevis</em> CECT 8138 and protease</td>
<td>[82]</td>
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</tbody>
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Table 1. Cont.

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<thead>
<tr>
<th>Health Promoting Property</th>
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<th>Fermenting Microbes</th>
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<td>Lupin—tempeh</td>
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<td></td>
<td>Cereal-based matrices (wheat aleurone, malted barley flour, barley flour)</td>
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<td>[96]</td>
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<tr>
<td></td>
<td>Kimchi</td>
<td>5 probiotic strains (<em>L. acidophilus, L. mesenteroides L. plantarum, L. casei and B. longum</em>)</td>
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<tr>
<td></td>
<td>Cashew apple juice</td>
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<tr>
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<td><em>L. casei</em> and <em>L. acidophilus</em></td>
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<td>[133]</td>
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<tr>
<td>Probiotic properties</td>
<td>Milk</td>
<td><em>Lactobacillus reuteri</em></td>
<td>[109]</td>
</tr>
<tr>
<td></td>
<td>Oat-based dairy-fermented beverages</td>
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<td>[134]</td>
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</tbody>
</table>

4. Fermented Foods and the Impact on Gut Microbiome

As already discussed, the health benefits of fermented foods have been linked to scientific research (Table 1). Several teams have reported, with varied degrees of success, that fermented meals can modify gut flora. Changes are typically observed as broad shifts in microbial populations and may not always correspond to the microbial makeup of the relevant fermented foods. Beta diversity has been shown to be significantly different between consumers and non-consumers in a recent study that assessed the impact of general fermented plant intake on microbial and metabolomic variations in consumers versus non-consumers [135]. People who consume these fermented goods have been found to contain a variety of bacteria in their microbiomes, including *Bacteroides* spp., *Pseudomonas* spp., *Oscillospira* spp., *Dorea* spp., *Lachnospiraceae*, *Enterobacteriaceae*, *Faecalibacterium praunitzii*, *Fusobacterium* spp., *Alistipes putredinis*, *Actinomyces* species, *Prevotella* spp., *Delfta species*, *Clostridium clostridioforme*, *Bacteroides uniformis*, *Achromobacter* species, and *Clostridiales* [135]. Despite differences in study conditions, some groups have found alterations in gut microbial populations after consuming fermented milk [136–138]. When given to individuals with irritable bowel syndrome (IBS), a fermented milk product with specified starters had the potential to substantially raise the SCFA levels in vitro, particularly butyrate, and it also caused a decline in *Bilophila wadsworthia* and an increase in *Clostridiales* isolates (such as MGS126 and MGS203), which are known for production of butyrate [136]. The effects of yogurt intake on the gut microbiome of healthy adults were found to cause shifts in overall diversity and composition after 42 days, albeit, this varied between people and no significant variations were seen [139]. Fermented dairy products are just one example of how diets can affect the bacteria communities in the gut. It was investigated in [140] how kimchi, both fresh and fermented, affected the gut flora of obese people. Despite the fact that both types of kimchi led to changes in the microbial population, specifically an increase in *Proteobacteria* and *Actinobacteria*. Some alterations
were limited to only one population, for example, an increase in *Actinobacteria* was seen in a group that received fermented kimchi, which was inversely associated with fat content in the body [140]. Population of *Lactobacilli* and *Bifidobacteria* in fecal samples increased substantially along with Clostridium fecal populations during two separate studies that examined the impact of fermented soy milk on normal healthy populations. These shifts were partly attributed to *Bifidobacteria*’s ability and not Clostridium’s to utilize specific soybean oligosaccharides [141,142]. It has been established that fermented foods can alter the microbial population in the gut, albeit, it is frequently unclear how these changes occur. Therefore, more thorough human feeding experiments must be carried out in order to give verifiable evidence that reveals whether or not fermented foods can alter the microbiome of the human gut.

Fermented foods have health benefits for the host, but some of the compounds they contain can also have an immediate impact on the gut microbiome of the host. In particular, the creation of polyphenols and dietary fiber, the latter of which results in in vivo production of short chain fatty acids, have drawn attention due to their known impact on microbial communities [143]. The bioavailability of polyphenols in fermented foods increase as a result of fermentation. Foods derived from plants contain a variety of phytochemicals called polyphenols, including flavonoids and non-flavonoids. The bulk of dietary polyphenols in the human diet are flavonoids and phenolic acids, which are valued for their antioxidant effects and have been shown to have a direct effect on gut flora [144]. A recent study looked at how fermentation affected the number of polyphenols in a variety of eight legumes that are popular in China. After 48 h of incubation, natural fermentation took place in beans (without the addition of microbial diversity) or with the addition of lactobacilli, and it was determined that both bound as well as soluble TPC (total phenolic content) [145]. Although the two fermentation techniques that were utilized had different antioxidant capacities, both techniques showed considerable increases in soluble TPC correlated to the non-fermented samples, and different increases in the levels were also detected in the bound TPC portion [145]. There have been reports of similar research involving different vegetables. Unfermented maize and corn fermented by using different strains of fungi (*Agaricus* sp.) were shown to have higher free polyphenol contents (FPP) than the non-fermented control, which included one of the strains that exhibited an FPP concentration that was 88 times higher than the control. Unsurprisingly, not all fermented plant items seem to benefit from this [146]. In a study conducted in 1994, the amount of polyphenols in de-hulled black gram dhal slurry was examined. It was discovered that the brewed product had substantially lower amounts of polyphenols than its raw counterpart; fermentation for 18 h caused a loss of nearly 50% of the TPC [147]. Therefore, research should be done on each fermented plant product before claims about its polyphenol concentration are made.

Even though most of these investigations concentrate on pathogen inhibition, numerous studies have demonstrated that polyphenols can affect gut flora [148–150]. In most nations, tea is a popular beverage that is advantageously rich in flavonoids, which makes it a convenient supplier of polyphenols [151]. A 2006 study confirmed the capacity of tea polyphenols to suppress pathogens by investigating the impact of tea-extracted flavonoids on the microbiome in vitro and finding that the bulk of harmful bacteria was inhibited. Contrarily, the potential of polyphenols to suppress ostensibly helpful bacteria (such as commensal gut bacteria, *Bifidobacteria*, and *Lactobacilli*) has been investigated, with many studies coming to the conclusion that these microbes are generally not inhibited [152,153]. The specific characteristics of each group of bacteria have been emphasized as potential reasons, even if the processes by which polyphenols, in particular, boost good gut microbes and suppress pathogens are unclear. For instance, because they can transform polyphenols into less hazardous compounds, gut microorganisms can tolerate them whereas pathogens cannot. Some gut microbes, such as lactobacilli, can even use polyphenols as a dietary substrate. Contrarily, polyphenols have demonstrated inhibitory effects on pathogenic bacterial virulence factors, such as the reduction of the *H. pylori* urease enzyme necessary for its capacity to neutralize stomach acid [154]. Through bacterial enzymes such as esterase and
demethylases, the microbiota affect the accessibility of consumed polyphenols by converting them into forms that can be absorbed through the intestinal lining. Wine is a plentiful supplier of polyphenols, and manipulating a number of variables during the development and processing of the grapes can boost the overall polyphenol concentration [155]. Red wine polyphenols have been demonstrated to considerably modify the gut microbiota, including a rise in the overall microbial population, and to drastically reduced total cholesterol and blood pressure [156]. While Queipo-Ortuo and co-workers (2012) observed a substantial increase in Bifidobacterium, Prevotella, Enterococcus, Eggerthella lenta, Bacteroides, and Blautia coccoides-Eubacterium rectale groups in healthy persons who consumed alcohol once daily, the dominant groups changed over the course of the study. Barroso et al. (2017) revealed an increase in heterogeneity and could not recognize a consensus between healthy alcohol-consuming persons [157,158].

Clemente-Postigo et al. (2013) reported a significant reduction in lipopolysaccharide (LPS) or bacteria producing LPS, and therefore, this may be a possible advantage of wine polyphenol consumption [159]. Drinking beverages was associated with an increase in the bacterial number of Prevotella and Bifidobacterium that was inversely connected with LPS [159]. Similarly, Moreno-Indias and co-workers, in 2016, found that red wine intake increased levels of good bacteria such as Bifidobacterium and Lactobacillaceae, increased levels of bacteria such as Roseburia and Faecalibacterium prausnitzii which produce butyrate, and decreased levels of bacteria such as E. coli and Enterobacter cloacae, which produce LPS [160]. Red wine contains the polyphenols quercetin and resveratrol, which have been studied separately for their effects on intestinal dysbiosis in rats on high-fat diets [161,162]. Although Etxeberria et al. discovered that only quercetin had a tendency to lower the microbial levels connected with DIO, i.e., diet-induced obesity, Zhao et al. came to the same conclusion that a quercetin and resveratrol mixture also had a similar effect [161,162]; both investigations indicated that polyphenols were capable of reducing the ratio of Firmicutes/Bacteroidetes linked with high-fat diets. Consuming fermented foods with high polyphenol content may affect gut flora since polyphenols have the ability to suppress harmful bacteria and to possibly enhance favorable bacteria.

Short-chain fatty acids (SCFAs) are produced when microorganisms break down the fibers in carbohydrates. The formation of SCFAs is advantageous to a human host because it allows energy to be extracted from a complex carbohydrate that would otherwise be indigestible. This is significant in human nutrition because the microbes of the colon are proficient in this fermentative process, and thus, the SCFAs produced are used as a source of energy by colon cells [7,163]. Acetate, propionate, and butyrate are well-known examples of SCFAs; Lactobacillaceae and Bifidobacterium are well-known in vitro makers of these beneficial substances [163,164]. While SCFAs are known to have significant effects on the host’s metabolism and CNS, they also have profound impacts on the gut microbiota [163,165]. As previously mentioned, the synthesis of acetate by bacteria in any environment increases the degree of environmental acidity, and prevents the growth of less acid-tolerant bacteria. This is favorable in the intestine because LAB typically inhibit pathogen growth by this mechanism [166]. Acetate has been demonstrated to partially repair gut dysbiosis and to modify gut microbiota [167]. More significantly, SCFAs have been shown to promote host epithelial goblet cell production of mucus, which is predominantly made up of mucin proteins [168]. The intestinal epithelium is covered in mucus, with the colon having the thickest mucosal layer. This layer contains the majority of intestinal flora, and the mucus serves as a source of energy for these organisms [169,170]. A study, in 2003, in a tissue culture model suggested that SCFAs prompted mucin-2 protein expression via synthesis of prostaglandin; an investigation in rats, conducted in 2000, provided the proof that levels of specific SCFAs (acetate, propionate, and butyrate) accelerated secretion of mucus in the colon [171,172].

Therefore, SCFAs impact the pH and mucus content of gut flora. It has been demonstrated that some fermented foods contain significant amounts of easily absorbed SC-FAs [173]. Although most people find it difficult to directly consume vinegar due to its
strong flavor, it does contain significant amounts of acetate, which has the ability to affect the host gut flora [174]. The amount of SCFAs in cheeses varies and is frequently expressed as FFAs, which are crucial for the cheese’s organoleptic qualities and include fatty acids of different lengths [175]. The amounts of appropriate FFAs vary from cheese to cheese, and high levels can give some cheese varieties, including Cheddar and Gouda, a rancid off-flavor [176]. Italian hard cheeses are considered to be excellent sources of SCFAs, with Parmigiano Reggiano and Grana Padano having short- and medium-chain fatty acids making up 25% or more of the total TG content [176]. Since Propionibacteria are present in Swiss-type cheeses, the lactose is fermented into acetate and propionate SCFAs, resulting in products that are high in these substances [177]. In a 2007 study, the ability of Propionibacterium freudenreichii, a type of bacteria frequently used to make Swiss-style cheeses, to create SCFAs in rats was investigated [143]. One strain was observed to dramatically increase the level of these substances in the caecum. This means that by altering the quantities of specific molecules in food, fermented foods have the ability to affect gut flora. While SCFAs can promote more conducive surroundings for the development of advantageous gut microorganisms or can affect mucus levels, which serves as both an active domain as well as a source of energy for microbes present in the gut, polyphenols have been demonstrated to affect the microbiome of the gut in a direct manner.

5. Conclusions

In the history of humans fermented foods have played a significant role. Initially, the primary purpose of fermented foods was to extend the shelf life of seasonal foods. It has long been understood that consuming fermented foods has health benefits. Fermentation can be applied to nearly all the principal foods consumed by humans. Many of these are derived from regional dishes that are popular in various regions. The variety of fermented foods has significantly increased thanks to localization and adaptation of the fermentation process. Fermented foods have been studied for their potential to have health advantages were first noted by Metchnikoff. The health advantages of fermented foods are supported by a growing body of scientific data, including information that shows that fermented foods can be easier to digest because of the partial protein breakdown during fermentation and evidence that indicates that they may be higher in some vitamins and antioxidants. Frequent intake of fermented foods should be recommended and included in the international dietary recommendations due to the presence of beneficial components and the activity of those components. The human gut microbiome has drawn a lot of attention in recent years due to mounting evidence that it affects physical health and that disruptions to the gut microbiota are linked to several metabolic illnesses. The gut microbiota can be impacted by lifestyle factors, including nutrition, and there is growing interest in the possibility of using foods to favorably modify gut microbiota. The information in this review should help to make it possible to determine which microbe strains work best for producing beneficial components in various food matrices. Therefore, this information could serve as a starting point when developing new fermented foods.

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