Review Article

# Fermented Foods as Probiotics: A Review

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## Abstract

Fermented foods and drinks derived from animals as well as plants play an important role in diets. These foods usually contain lactic acid bacteria (LAB) grown during fermentation, and these naturally contain compounds, including organic acids, ethanol, or antimicrobial compounds with the ability to inhibit spoilage organisms and pathogenic bacteria in fermented foods. Furthermore, these bacteria are able to adapt well to the spontaneous fermentation process and play a role in human as well as animal health, especially in digestive tract, commonly known as probiotics. This study therefore aims to describe the microorganisms produced by fermented foods suitable for development as probiotics to improve human health, as these generally have the ability to improve the immune system against pathogenic bacteria. Several genera are used as probiotics, including *Lactobacillus, Bifidobacterium, Bacillus, Pediococcus,* and several yeasts. Therefore, LAB produced from fermented foods were concluded to be suitable potential candidates for probiotics, to replace antibiotics in overcoming pathogenic bacteria, and to possess the ability to improve the immune system and strengthen the body against pathogenic bacteria.

**Key words:** Fermented foods, lactic acid bacteria, probiotics

## INTRODUCTION

Fermented foods have been a major part of human diet for centuries.[1] Furthermore, fermented foods derived from meat, milk, and plant foods have a longer shelf-life, compared to fresh raw materials.[2] This is because fresh foods are very perishable due to their high water content and nutritional value. Fermented foods and drinks derived from animals and plants play an important dietary role in various parts of the world including Asia as well as western countries, and contain nutrients with great potential in maintaining health and preventing disease, but also undergo changes in taste, texture, decreased toxicity, and cooking time.[3,4] These foods naturally contain compounds, including organic acids, ethanol, or antimicrobial compounds, with the ability to inhibit any spoilage organisms and pathogenic bacteria present.[5]

LAB were initially isolated from fermented food but are the most suitable candidate for increasing fermentation, in terms of product safety, and also have the ability to spontaneously adapt well during the fermentation process.[6] Recently, the role of bacteria in human and animal health has begun to develop quite well, especially in terms of the digestive tract and protection against disease. Lactic acid bacteria (LAB) isolated from fermented foods with the ability to aid in digestive health are known as probiotics, and are generally used as microbe-containing dietary supplements, as well as considered as an important

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functional food group. Thus, consuming probiotics is useful for maintaining health against pathogenic bacteria in the gut microbiota, and maintaining the normal balance of gut microbiota helps to improve digestive health as well as the immune system.[7]

## FERMENTATION

Fermentation is known as one of the oldest food preservation methods in the world, and is also a food processing technique to reduce or even eliminate toxic compounds present. A previous study utilized various microorganism types to convert starch into protein by inserting inorganic nitrogen.[8] In general, fermentation generally occurs in the presence of fungi or bacteria, and in this process, microorganisms produce several compounds, including organic acids, gas (alcohol), carbon dioxide, diacetyl, hydrogen peroxide, phenylacetic acid, bacteriocins, and peptides. This process is aimed at extending the shelf life of fruits, vegetables, meat, and fish,[9] and also serves the main roles of food preservation through the formation of metabolites with the ability to inhibit pathogenic or spoilage bacteria, for instance, organic acids (lactic acid, acetic acid, formic acid, and propionic acid), ethanol, carbon dioxide, diacetyl, reuterin, bacteriocins, and others, often associated with water reduction due to the addition of a sufficiently large salt quantity.[10]

## MICROORGANISMS ROLE IN THE FERMENTATION PROCESS

The fermentation of food products utilizes LAB, and several other bacteria, for instance, pathogens, as well as yeast and mold. LAB occur naturally in food, especially fermented products, and play an important role in almost all food and beverage fermentation processes.[11] These bacteria also produce organic acids with the ability to extend the shelf life of fermentation products, and are naturally found in soil, water, manure, waste, and plants, as well as parts of the mucous membrane, including human and animal intestines, mouth, skin, urinary tract as well as genitals, and probably, have a beneficial effect on these organs. After discovery, LAB gained numerous benefits in various applications, for instance, as starters in food and feed fermentation, pharmaceuticals, probiotics, and biological control agents.[12] Taxonomically, these bacteria are divided into two different phyla, Firmicutes and Actinobacteria. Phylum Firmicutes comprises *Lactobacillus, Lactococcus, Leuconostoc, Oenococcus, Pediococcus, Streptococcus, Enterococcus, Tetragenococcus, Aerococcus, Carnobacterium, Weissella, Alloiococcus, Symbiobacterium* and *Vagococcus* genuses and Actinobacteria consist of *Atopobium* and *Bifidobacterium*.[13]

## FERMENTED FOODS IN DIFFERENT COUNTRIES AS A SOURCE OF LACTIC ACID BACTERIA

### Brem (Bali, Indonesia)

This is a traditional food made of white glutinous rice originating from Indonesia,[14] produced precisely from glutinous rice extract, with a sweet and sour taste, starchy texture, and is usually consumed as a snack. Furthermore, the food has two variants, solid white and yellowish-white, as well as liquid brem produced from rice wine.[15] The production of solid brem involves fermentation of glutinous rice using yeast, while the liquid counterpart does not involve yeast.[16] Furthermore, the food is believed to be good for skin health, warming the body as well as increasing appetite.[17]

### Rusip (Indonesia)

This is a fermented product originating from Indonesia, especially Bangka and Lampung, usually produced by adding a lot of salt (10%–25% composition), as well as sugar or rice (10%), to fermented fish, followed by anaerobic fermentation for about 14 days.[18] The addition of over 10% salt prevents the growth of pathogenic bacteria, with the ability to accelerate putrefaction and cause a sour taste.[19] In addition, the final product of rusip contains *Streptococcus, Lactobacillus,* and *Leuconostoc* LAB.[20]

### Kimchi (Korea)

This is a traditional fermented vegetable originating from Korea, fermented at 15°C for ± 1 week, or at 25°C for ± 3 days. However, the lowest possible temperature is preferred for manufacture because this prevents the food from being overcooked, having an overly sour taste, and also keeps the taste optimal during a long shelf life.[21] Kimchi is made from a combination of Chinese cabbage (baechu), onions, radishes, chili powder, and garlic[22] as well as several other foods, for instance, carrots, apples, pears, or shrimp.[23] The food also contains several bacteria groups, including LAB (*Lactobacillus, Leuconostoc,* and *Weissella*) and pathogenic bacteria (*Pseudomonas and Pantoea*).[24]

### Gochujang (Korea)

Gochujang is made using chili powder, glutinous rice powder, soy porridge with salt, flavorings, for instance, shallots and garlic, as well as sweetener in the form of sugar syrup, and the mixture fermented for a long time.[25] Subsequently, the microorganisms formed during the fermentation process including, Zygosaccharomyces and Candida, *Bacillus velezencis* as well as *Oceanobacillus*[26] obtain protein and carbohydrate intake from the glutinous rice powder and soybean porridge present.

### Kefir (Russia)

Kefir is produced by nonspontaneous fermentation because a starter culture in the form of lactose symbiotic fermented yeast, for instance, *Kluyveromyces marxianus* and or non-lactose fermented yeast, for instance, *Saccharomyces*

*cerevisiae*,[27] must be added prior to the process. In addition, several studies on Kefir showed various species of LAB, pathogenic bacteria, and yeast, including *Lactococcus lactis subsp. lactis, Streptococcus thermophilus, Lactobacillus delbureckii* subsp. *bulgaricus, Lactobacillus helveticus, Lactobacillus casei* subsp. *pseudoplantarum, Lactobacillus brevis*,[26] *Lactobacillus paracasei, Lactobacillus kefiranofaciens, Lactobacillus plantarum, Lactobacillus kefiri, Acetobacter lovaniensis, Acetobacter orientalis, S. cerevisiae, S. unisporus, Candida kefyr, K. marxianus,* and *Leuconostoc mesenteroide*.[28-30]

### Gundruk (India)

Gundruk is produced from fresh local vegetables, for instance, rayosag (*Brassica rapa* subsp. *Campestris* var. *Cuneifolia*), cabbage (*Brassica* sp.), mustard leaves (*Brassica juncea* (L.) Czern), and cauliflower leaves (*Brassica oleracea* L. var. *botrytis* L.). The vegetables are withered for 1–2 days, finely crushed, pressed in an airtight container, fermented naturally for about 15–22 days, then sun-dried for 2–4 days.[31] Several LAB including *Pediococcus pentosaceus, Lactobacillus fermentum, L. plantarum, L. casei,* and *L. casei subsp. pseudoplantarum*[32] have been found in Gundruk.

### Khalpi (Nepal)

This is a pickled cucumber (*Cucumis sativus* L.) snack originating from Nepal, usually processed with a combination of salt, mustard, and chili powder, then fermented at room temperature, for approximately 7 days. Khalpi is produced using cucumber alone or combined with bacteria, for instance, *L. plantarum, L. brevis, Leuconoctoc fallax,* and *S. cerevisiae*.[32] The cucumber is cut, dried for 2 days, then placed in an airtight container, and fermented for 3–5 days.[33]

### Wine (America)

This is an alcoholic beverage produced by the fermentation of grape juice. The word "wine" is derived from a type of fruit often fermented to produce this drink.[34] The beverage's stability is greatly influenced by the pH factor, a value approaching neutral (pH 7) that makes all microbes and yeast types more active for fermentation and even decay. Meanwhile, a value below 3.5 inhibits the growth of most microbes; thus, only a few microbes are able to participate in fermentation.[35] Furthermore, the fermentation of grapes to produce wine usually requires the aid of bacterial culture, including *Staphylococcus cerevisiae*, used for the process of converting sugars present in grape juice into alcohol compounds and organic acids. These, in turn, form aldehydes, esters, and other chemical compounds, to extend shelf-life.[36]

### Garris (Sudan)

Garris is produced by mixing camel milk with some black cumin seeds (*Nigella Sativa*) and an onion,[37] and is fermented with the help of organisms, including *Lactobacillus* and yeast.[38] Compared to cow milk, camel milk has a longer shelf-life, and does not rot quickly, even in hot conditions.[39] Furthermore, majority (about 50%) of the identified LAB present in Garris are *Streptococcus Lactis* subsp. *Diacetylactis*, while the other bacteria identified are *Lactobacillus* sp. (*L. plantarum, L. casei, L. brevis, Lactobacillus leichmannii, L. fermentum,* and *Lactobacillus acidophilus*).[40]

### Ergo (Ethiopia)

This is fermented milk, similar to yogurt, originating from Ethiopia, and produced by spontaneous fermentation or without the addition of a starter culture. Ergo is milky white, thick, with great smell and taste, as well as a 15–20 day shelf-life.[41] Several microbes including aerobic mesophilic bacteria, LAB, *Staphylococcus* and yeast[42] have been identified in this food. Furthermore, several studies have shown Ergo fermentation produces several genera of LAB including, *Lactobacillus, Leuconostoc, Enterococcus, Lactococcus,* and *Streptococcus*.[43] Micrococcus, coliform, and spore species are also present in this fermentation process. A reduction in pH leads to the formation of antimicrobial compounds in the food, and consequently, a reduction in the number of microbes present.[44] *Lactococcus* sp. is the most dominant species in the Ergo fermentation process, having up to $10^9$ cfu/ml colonies until the process' end. Meanwhile, mesophilic bacteria also showed a similar value, and yeast showed an increase in colony number of up to $10^5$ cfu/ml, for 24 h.[45]

## ROLE OF MICROORGANISMS AS PROBIOTICS

The term "probiotics" refers to microorganisms providing benefits to humans as well as animals, with a role in the intestinal microbe balance and an important role in health maintenance. These microorganisms often come from the genus *Lactobacillus* and *Bifidobacterium* but also come from the genus *Bacillus*, *Pediococcus* as well as some yeasts.[46] The genus *Lactobacillus* is a heterogeneous group of LAB as well as the most widely used bacteria in food and feed fermentation, in addition to being widely used in the manufacture of probiotics. Furthermore, *Lactobacillus* are Gram-positive bacteria producing the final product in the form of lactic acid, during fermentation.[47]

Analyses on probiotic microbial strains are conducted *in vitro* and *in vivo*. Several *in vitro* analyses include testing for antibiotic resistance profiles, bacteria's origin, and safety evaluation in terms of virulence associated with pathogenic bacteria. Furthermore, probiotic microbial strains ought to be tested in relation to strain adherence to intestinal epithelial cells, intestinal mucosal permeability, and immunomodulatory effects.[1,48] In this study, *in vivo* analysis was performed out using experimental animals, for example, Rattus norvegicus or albino strains.

Probiotic bacterial strains are applicable to several food products, for instance, yogurt with *Lactobacillus reuteri*

and *Lactobacillus rhamnosus*[49] bacteria, fermented milk complete with inulin from strains of *Bifidobacterium animalis* and *L. acidophilus*,[50] chocolate products with strains of *L. paracasei*[51] and condensed milk with *L. acidophilus*.[52] In addition, these strains are also utilized in improving the health of the human body both directly and indirectly, including defense against the mucosa, repair of normal microflora, preventing infection, defense against food allergies, lowering blood cholesterol levels,[53] cariogenic activity,[54] modulating the mucosal immune system, enhancing the system digestion, as well as maintaining the intestinal microflora balance.[46]

## CONCLUSION

LAB have an important role in food fermentation due to the ability to produce compounds good for improving human and animal health. Furthermore, LAB produced from single or mixed cultures derived from fermented foods are suitable probiotics for improving digestive tract by maintaining the balance of gut microbiota. These microorganisms also have the capacity to improve the immune system against pathogenic bacteria. Several genera are used as probiotics, including *Lactobacillus*, *Bifidobacterium*, *Bacillus*, *Pediococcus*, and several yeasts.

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### Conflicts of interest
There are no conflicts of interest.

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