

# Korean Traditional Fermented Foods - A Potential Resource of Beneficial Microorganisms and Their Applications

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This review describes the diversity of Korean fermented foods and their significance as potential sources of probiotic bacteria. Fermented foods consumed in Korea are categorized according to their base material. Fermented foods such as kimchi, meju, doenjang, kangjang, jeotgal, and makgeolli are reported to have significant medicinal properties. These fermented products, which are consumed regularly by local people, are rich sources of beneficial microbes represented by several genera, including *Weissella* spp., *Lactobacillus* spp., *Leuconostoc* spp., *Mucor*, *Penicillium*, *Scopulariopsis*, *Aspergillus*, *Rhodotorula*, *Candida*, *Saccharomyces*, and *Bacillus*, as well as lactic acid bacteria. Fermented foods are now taken beyond the boundaries of their use as mere side dishes and are used significantly as a functional as well as medicinal foods. Fermented foods are a rich source of potential natural substances with antioxidant, anticancer, anticholesteric, antiobesitic, and antiaging properties, so that traditional fermented foods used as food supplements can impart health benefits. Publication of scientific studies on the dietary benefits of various fermented foods and growing consciousness about the potential health benefits of traditional fermented food are reflected in the scores of reports currently available in this field. Food microbiologists now have abundant opportunities to explore Korean traditional fermented foods for the isolation of new bacterial strains and to evaluate the potential applications of these strains through microbiological research.

**Key words** : Doenjang, fermented foods, jeotgal, kimchi, lactic acid bacteria

## Introduction

The most intimate relationship between man, microbes and foods occurs through the process called fermentation [55]. During the Paleolithic period, our ancestors had lot of opportunity for food consumption which had been subjected to natural microbial fermentation. With lack of knowledge of microbes, our ancestors identified the palatability, preservative, analgesic and mind stimulating or sedating qualities of fermented foods and beverages [57]. It is difficult to say with certainty when intentional fermentation began in earnest; however, sophisticated measurements of the chemical content within ancient Neolithic vessels suggest intentional fermentation of fruit, rice, or honey beverages has been in common practice for close to 10,000 years [39]. Considering

many ancient records, preparation and consumptions of fermented foods in Korea since the 3<sup>rd</sup> or 4<sup>th</sup> century A.D [31] and fermented foods and beverages have heterogeneity of traditions and cultural preferences found in the different geographical areas, where they are produced. Fermentation has enabled our ancestors in temperate and cooler regions to survive during the winter season and those in the tropics to survive drought periods. Fermentation is a slow decomposition process of organic substances induced by microorganisms or enzymes that essentially convert carbohydrates to alcohols or organic acids [12]. In addition, it can increase the shelf-life of meat, fish, fruit and vegetables that are highly perishable due to their high water contents and nutritive values.

Fermentation was evolved as a preservation or prevention technique and during lean periods to counter spoilage of food products. It is one of the most economical methods for producing and preserving foods. It can be done in the household or in cottage industry using relatively simple techniques and equipments [2]. Besides preserving, fermentation also changes the organoleptic characteristics of foods through developing a wide diversity of flavors, aromas and textures.

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Moreover, fermentation may improve digestibility and nutritional quality through enrichment of food substrates with vitamins, proteins, essential amino acids and essential fatty acids [55]. It may also result in the detoxification and destruction of undesirable substances present in raw foods such as phytates, tannins and polyphenols [13].

World Health Organization (WHO) and Food and Agriculture Organization (FAO) recommended intake of a specific dose of vegetable and fruits in daily food to prevent chronic pathologies such as hypertension, coronary heart problems, and risk of strokes. Most fermented foods contain a complex mixture of carbohydrates, proteins, fats, and so on; undergoing modification simultaneously, or in some sequence, under the action of a variety of microorganisms and enzymes. Most of the end products of food fermentation, particularly acids and alcohols, are inhibitory to the common pathogenic microorganisms that may find their way into foods, e.g. inability of *Clostridium botulinum* to grow and produce toxin at pH values of  $\leq 4.6$ . When microorganisms ferment food constituents, they yield energy in the process and increase in numbers. To the extent that food constituents are oxidized, their remaining energy potential for human decreases [43].

Fermentation is primarily an anaerobic process converting sugars, such as glucose, to other compounds like alcohol, while producing energy for the microorganism or cell. Bacteria and yeast are microorganisms with the enzymatic capacity for fermentation, specifically, lactic acid fermentation in the former and ethanol fermentation in the latter. Many different products around the world are a result of fermentation, either occurring naturally or through addition

of a starter culture. Different bacterial and yeast species are present in each case, which contribute to the unique flavors and textures present in fermented foods (Table 1). These bacteria and yeasts are referred to as “probiotic” when they adhere to the following World Health Organization (WHO) definition: “live microorganisms which, when administered in adequate amounts, confer a health benefit on the host” [15].

The aim of the present article is to examine the diversity of Korea’s fermented foods, their microbial diversity and health benefits for why they should be included in nutritional diets of different countries across the continents.

### Fermented foods and their origin

The ability to create tasty food using microbes reflects human culinary innovation at its best. The use of microbial fermenters has been instrumental in making a large range of foods, popular around the world. Examples of these are given in Table 1, illustrating its microbial diversity and place of origin.

These traditional foods have been consumed in some cases for thousands of years, with recipes being passed down through generations, as well-documented elsewhere [29]. Initially, many foods underwent fermentation naturally, but today, a number of them are made with the addition of a starter culture and the process has become automated and more reproducible and reliable. There are clearly types of fermented foods consumed across countries and continents, such as sauerkraut, kimchi and cortido, all products of fermented cabbage.

A trend in the past two decades has been made in the

Table 1. Examples of fermented foods and their countries of origin

Fermented food	Ingredients	Place of origin	Microorganisms	References
Yogurt	Milk	Greece, Turkey	<i>L. bulgaricus</i> , <i>S. thermophilus</i>	Ben-Yahia et al. (2012)
Kefir	Milk	Russia	<i>Saccharomyces cerevisiae</i> , <i>L. plantarum</i>	Steinkraus (1996)
Sauerkraut	Green Cabbage	North America and Germany	<i>L. plantarum</i>	Steinkraus (1983)
Sopressata	Pork ham and tongue	Italy	<i>Lactobacillus curvatus</i> , <i>L. plantarum</i> , <i>Penicillium chrysogenum</i>	Steinkraus (1996)
Sourdough	Rice or wheat flour	Egypt	<i>L. reuteri</i> , <i>Saccharomyces cerevisiae</i>	Gaenzle (1995)
Idli	Rice, Black gram	India	<i>L. mesenteroides</i> , <i>E. faecalis</i> , <i>P. cerevisiae</i>	Mukherjee et al. (1965)
Tepa	Stinkhead fish	USA	<i>Lactobacillus plantarum</i>	Doyle et al. (2001)
Pulque	Agave plant sap	Mexico	<i>Zymomonas mobilis</i>	Campbell-Platt (1987)
Ogi	Cereal	Africa	<i>Lactobacillus</i> sp., <i>Saccharomyces</i> sp., <i>Candida</i> sp.	Steinkraus (1996)
Miso	Soybean	Japan	<i>Aspergillus oryzae</i> , <i>Zygosaccharomyces</i> , <i>Pediococcus</i> sp.	Hesseltine (1986)

globalization of foods, aided by shipping and airline delivery, and a desire by consumers to gain access to products. Thus, in the depths of winter in temperate countries, consumers can still purchase “fresh” fruit and vegetables from countries in the southern hemisphere. However, for the most part, global distribution is not required for fermented foods. Instead, they tend to be made locally with outside temperature not being an issue. Often, immigrants will introduce these foods for their own use, then their popularity grows and consumption becomes widespread. The net result is that fermented foods are widely consumed across the globe [41].

The Korean foods that best represent the tradition of fermentation developed in Korea include, kimchi (fermented cabbage), doenjang (soybean paste), ganjang (soy sauce), gochujang (chili paste), jeotgal (fermented fish sauce) and Makgeolli (alcoholic beverage), whose fermentation can take anywhere from several months to several years. The degree of fermentation is a key factor in the taste and flavor of food cooked at home and in restaurants. Table 2 shows the major traditional fermented Korean foods along with their significant health benefits.

Kimchi is a general term used to represent a highly varied group of salted and fermented vegetable food items in Korea. Kimchi had very long history in the Korean cuisine, initially with radish and later extended with *Baechu* cabbage, cucumber, green onion, red pepper and other spices [47]. It's taste dependent mainly upon the ingredients, fermentation conditions and bacteria involved in the fermentation [8, 28, 29]. Previous studies have reported that kimchi has anti-

cancer, antioxidative, antiatherosclerotic, antidiabetic, anti-obesity effects [17, 22, 23, 48] as it is rich in vitamins, minerals, dietary fibers and other functional components. The classical identification of bacterial strains from kimchi found that *Leuconopstoc mesenteroides* and *Lactobacillus plantarum* were the predominant species [37] and majority of bacteria are culturable [24, 30]. Recent study on microbial communities of 13 different Korean commercial kimchis using molecular method found that *Weissella* with 44.4%, *Lactobacillus* with 38.1% and *Leuconostoc* with 17.3% at genus level [50]. Hence, kimchi is a rich source of probiotic LAB fermented vegetarian food.

Gochujang is Korea's traditional fermented condiment. It is a red hot paste made of steamed rice or barley, rice cake powder, or rice porridge mixed with fermented soybean powder, salt, and red pepper powder. Gochujang came into existence in the late 16th century and was widely used in Korean food in the late Joseon Dynasty. It is still being used today as the key ingredient to give Korean dishes that special taste that we all know and love. Gochujang contains abundant nutrients benefiting the human body: protein, fat, vitamin B2, vitamin C, carotenes, and more. Capsaicin is the naturally-occurring compound found in peppers: it's what gives gochujang its spicy taste. Capsaicin is believed to have anti-bacterial effects, prevent diseases and facilitate recovery by helping cleanse out body systems, reduce body fat, and prevent obesity. In addition, the beta-carotenes and vitamin C found in gochujang are believed to have anticarcinogenic and antimutagenic properties [54].

Table 2. Korean traditional fermented foods and their health benefits

Traditional fermented food	Microorganisms	Health benefits	References
Kimchi	<i>Leuconostoc mesenteroides</i> , <i>Lactobacillus plantarum</i>	Antimutagenic and anticancer effect, antioxidative and antiaging, antiobesity effects	Park et al., (2014)
Meju	<i>Aspergillus</i> sps., <i>Mucor</i> sps., <i>Penicillium</i> sps., <i>Rhizopus</i> sps., <i>Candida</i> sps., <i>Hansenula</i> sps., <i>Saccharomyces</i> sps., <i>Bacillus</i> sps.	Anticancer activity, antioxidant effects	Shin and Jeong, (2015)
Doenjang	<i>Bacillus siamensis</i> , <i>B. licheniformis</i> , <i>Enterococcus faecalis</i> and <i>E. faecium</i> , <i>Tetragenococcus halophilus</i>	Anti-inflammatory effect, antioxidant effects, antitumor activity, antiaging effects	Nam et al., (2015)
Jeotgal	<i>Staphylococcus</i> sps., <i>Bacillus</i> sps., <i>Halomonas</i> sps., and <i>Kocuria</i> sps.	Rich source of probiotic microbes, regulate intestinal movements, lower cholesterol, boost the immune system	Guan et al., (2011)
Makgeolli	<i>Saccharomyces cerevisiae</i> , <i>Lactobacillus</i> sps.	antioxidant, anti-hypertensive, anti-diabetes and anti-cancer activities.	Nile (2015)

Ganjang and doenjang, are the next important traditional Korean fermented food from soybean sauce and soybean paste respectively, are the essential flavors and nutritional bases of authentic Korean cuisine. Ganjang is used as an essential condiment to enhance saltiness and flavor. Doenjang can be eaten as a sauce for vegetables, fish and meats and as an ingredient in soups for additional protein and for flavor. These soybean products are prepared by mixing meju (fermented soybean block) with high salt brine (approximately 18%), followed by ripening in a porcelain pot. The liquid portion is separated and boiled after approximately two months, resulting in ganjang. Doenjang is the remaining solid portion, which is subsequently mashed and fermented for a month to 180 days in the porcelain pot [46]. A number of studies have examined several aspects of these food products, including determining the microorganisms responsible for the quality and flavors of fermented foods. In microbial studies, the presence of specific microorganisms has been determined, including fungal species of the genera *Mucor*, *Penicillium*, *Scopulariopsis*, and *Aspergillus*, yeasts in the genera *Rhodotorula*, *Candida* and *Saccharomyces* and bacterial species in the genus *Bacillus* and *lactic acid bacteria* (LAB) [10, 32].

Jeotgal, or jeot, is a salted and fermented food in Korean cuisine used as an important additive for improving the taste of foods or alone as a food in itself. It is made by adding 20-30%(w/w) salt to various types of seafood such as shrimp, oyster, shellfish, fish, fish eggs, and fish intestines and becomes palatable through subsequent preservation and fermentation. According to the major ingredients and the regional preparation methods, more than 160 kinds of jeotgal are known to exist in Korea, of which about 30 are sold commercially. The possible microbial source of jeotgal fermentation include organisms that occur naturally on or in marine animals, organisms associated with the animals' environment (e.g., seawater or marine mud), terrestrial organisms not normally associated with the marine environment, and organisms associated with the natural microflora of the marine salt used in preparing the seafood for fermentation. Hence, jeotgal is a large source of microorganisms, as indicated by the isolation of 19 novel species in this product since 2000 [3, 18, 26, 38]. Previous studies that have evaluated the microbial communities in jeotgal have isolated bacterial species in the genera *Acromobacter*, *Bacillus*, *Brevibacterium*, *Clostridium*, *Flavobacterium*, *Halobacterium*, *Leuconostoc*, *Micrococcus*, *Pediococcus*, *Pseudomonas*, *Sarcina*, and

*Serratia* as well as the yeasts *Saccharomyces* and *Torulopsis* from several kinds of jeotgal [7, 33, 34, 53]. Among these, species in the genera *Bacillus*, *Micrococcus*, *Pediococcus*, and *Pseudomonas* were detected in all four studies; bacteria in the genera *Brevibacterium* and *Flavobacterium* were the next most frequently isolated. *Halobacterium*, an extreme halophilic archaeon [1], and several halophilic and halotolerant bacteria in the *Halomonas* genus [19] were also isolated from jeotgal.

Makgeolli is a popular traditional Korean rice wine consumed by Koreans for many centuries, as it contains 6 - 8% alcohol and the makgeolli fermentation is accomplished using nuruk, which is a mixture of various microorganisms and prepared using cooked rice, medicinal plants and herb extracts [27, 36]. Nuruk is a traditional starter culture made from wheat, rice or grits, which allows for the growth of various natural types of microorganisms such as *Aspergillus* sp., *Rhizopus* sp. and *Mucor* sp., as well as yeasts such as *Saccharomyces cerevisiae* and also *Bacillus subtilis*, and various lactic acid bacteria during the fermentation of rice wines which are useful in the saccharification of the rice starch during fermentation [4, 49]. Moreover, some microorganisms from nuruk remain alive in the final product after bottling and during distribution [1, 35]. Makgeolli has nutritional characteristics that are different from those of other alcoholic beverages as it contains vitamin B, essential amino acids, glutathione and live yeast [19, 35]. It has been reported that makgeolli has various biological properties including anti-cancer properties, positive effects on blood circulation and lipids, antihypertensive, fibrinolytic and superoxide dismutase-like activity, and antibacterial and antioxidant properties [20, 25, 52].

### Negative Effects of Fermented Foods

Korean fermented foods are very delicious and till to date no side effects have been reported. However, in the Chaosh-an area of China, showed an increased risk of squamous cell carcinoma of the esophagus in habitual consumers of fermented fish sauce [21]. Another Chinese study showed that *N*-nitroso compounds and genotoxins present before and after nitrosation, appear to be responsible for the cancer risk [9]. An Egyptian study also found high levels of histamine in fermented fish [51].

### Conclusions and Recommendations

The expansive use and benefits gained from, fermented foods signify its need for the present and future human race.

They have long been a part of the human diet, and with further supplementation of probiotic microbes in some cases, they offer nutritional and health attributes worthy of recommendation of regular consumption. It is hoped that this review contributes to policy changes and increases the inclusion of fermented foods in regular diets.

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## 초록 : 한국전통발효식품 - 유익미생물의 잠재적인 자원과 응용

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본 논문은 프로바이오틱 세균의 잠재적 기원으로서의 중요성으로 한국 발효식품의 다양성을 살펴보았다. 한국에서 소비되고 있는 발효식품들은 여러 물질들을 기반으로 나눌 수 있다. 김치, 메주, 된장, 간장, 젓갈, 막걸리와 같은 발효식품은 중요한 약리적인 성질들을 가진 것으로 보고되고 있다. 이러한 발효 식품들은 지역 주민들에게 규칙적으로 소비되고 있으며, 이들 발효식품들은 *Weissella* spp., *Lactobacillus* spp., *Leuconostoc* spp., *Mucor*, *Penicillium*, *Scopulariopsis*, *Aspergillus*, *Rhodotorula*, *Candida*, *Saccharomyces*, *Bacillus*와 유산균을 포함한 다양한 유익 미생물을 기반으로 만들어 진다. 발효식품들은 음식으로서의 이용가치의 경계를 넘어서 약리적인 식품으로써 뿐만 아니라 기능적인 면에서까지 높아지고 있다. 이러한 발효식품은 잠재적 항산화, 항암, 항콜레스테롤, 항당뇨, 항노화의 물질이 풍부한 기원으로 여기고 있다. 전반적으로 전통발효 식품은 식품공급원뿐만 아니라 인간 건강을 높여주는 특성을 가지고 있다. 여러 다양한 발효식품이 식이에 대한 효과가 과학적 보고들이 많이 출판되었고 전통발효식품이 건강에 유익하다는 것에 대한 인식이 증가되고 있다. 이러한 영역에서 현재 많은 보고서가 있다. 식품미생물학자가 이용할 수 있는 충분한 기회를 제공할 뿐만 아니라 발효식품의 탐험과 신종균주의 분리, 미생물연구에 잠재적 응용가치를 높일 수 있다.