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 microorganisms 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 3rd or 4th 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.
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 ≤ 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  | _L. bulgaricus, S. thermophilus_ | Ben-Yahia et al. (2012) |
| Kefir          | Milk        | Russia          | _Saccharomyces cerevisiae, L. plantarum_ | Steinkraus (1996) |
| Suerkraut      | Green Cabbage | North America and Germany | _L. plantarum_ | Steinkraus (1983) |
| Sopresattta    | Pork ham and tongue | Italy | _Lactobacillus curvatus, L. plantarum, Penicillium chrysogenum_ | Steinkraus (1996) |
| Sourdough      | Rice or wheat flour | Egypt | _L. reuteri, Saccharomyces cerevisiae_ | Gaenzle (1995) |
| Idli           | Rice, Black gram | India | _L. mesenteroides, E. faecalis, P. cerevisiae_ | Mukherjee et al. (1965) |
| Tepa           | Stinkhead fish | USA | _Lactobacillus plantarum_ | Doyle et al. (2001) |
| Pulque         | Agave plant sap | Mexico | _Zymomonas mobilis_ | Campbell-Platt (1987) |
| Ogi            | Cereal      | Africa          | _Lactobacillus sp., Saccharomyces sp., Candida sp._ | Steinkraus (1996) |
| Miso           | Soybean     | Japan           | _Aspergillus oryzae, Zygosaccharomyces, Pediococcus 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 antitumor activity, antioxidant effects, anticancer activity, antioxidative effects, antioxidants, and antimutagenic properties [54].

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 benefitting the human body: protein, fat, vitamin B2, vitamin C, carotenoids, 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-carotenoids and vitamin C found in gochujang are believed to have anticarcinogenic and antimutagenic properties [54].

| Traditional fermented food | Microorganisms                                                                 | Health benefits                                                                                      | References               |
|----------------------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|--------------------------|
| Kimchi                     | Leuconostoc mesenteroides, Lactobacillus plantarum                            | Antimutagenic and anticancer effect, antioxidative and antiaging, antibesity effects                  | Park et al., (2014)      |
| Meju                       | Aspergillus ssp., Mucor ssp., Penicillium ssp., Rhizopus ssp., Candida ssp., Hansenula ssp., Saccharomyces ssp., Bacillus ssp. | Anticancer activity, antioxidant effects                                                            | Shin and Jeong, (2015)   |
| Doenjang                   | Bacillus siamensis, B. licheniformis, Enterococcus faecalis and E. faecium, Tetragenococcus halophilus | Anti-inflammatory effect, antioxidant effects, antitumor activity, antiaging effects                 | Nam et al., (2015)       |
| Jeotgal                    | Staphylococcus ssp., Bacillus ssp., Halomonas ssp., and Kocuria sps.         | Rich source of probiotic microbes, regulate intestinal movements, lower cholesterol, boost the immune system | Guan et al., (2011)      |
| Makgeolli                  | Saccharomyces cerevisiae, Lactobacillus ssp.                                  | 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 es-
sential 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 li-
quid portion is separated and boiled after approximately two 
months, resulting in ganjang. Doenjang is the remaining sol-
id 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 pro-
ducts, 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 gen-
era Rhodotorula, Candida and Saccharomyces and bacterial spe-
cies 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 re-
gional preparation methods, more than 100 kinds of jeotgal 
are known to exist in Korea, of which about 30 are sold 
commercially. The possible microbial source of jeotgal fer-
m entation include organisms that occur naturally on or in 
marine animals, organisms associated with the animals’ en-
v ironment (e.g., seawater or marine mud), terrestrial organ-
isms 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 in-
dicated by the isolation of 19 novel species in this product 
since 2000 [3, 18, 26, 38]. Previous studies that have eval-
uated the microbial communities in jeotgal have isolated 
bacterial species in the genera Acromobacter, Bacillus, Brevi-
bacterium, Clostridium, Flavobacterium, Halobacterium, Leuco-
nostoc, 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 ar-
chaeon [1], and several halophilic and halotolerant bacteria 
in the Halomonas genus [19] were also isolated from jeotgal.

Makgeoli is a popular traditional Korean rice wine con-
sumed by Koreans for many centuries, as it contains 6 - 8% 
 alcohol and the makgeolli fermentation is accomplished us-
ing 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 dis-
mutase-like activity, and antibacterial and antioxidant prop-
erties [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 hist-
amine 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, 매주, 된장, 간장, 찹쌀과 같은 발효식품은 중요한 약리적인 성질을 가지 것으로 보고되고 있다. 이러한 발효식품들은 지역 주민들에게 규칙적으로 소비되고 있으며, 이들 발효식품들은 Weissella spp., Lactobacillus spp., Leuconostoc spp., Mucor, Penicillium, Scopulariopsis, Aspergillus, Rhodotorula, Candida, Saccharomyces, Bacillus와 유산균을 포함한 다양한 유익미생물을 기반으로 만들어 진다. 발효식품들은 음식으로서의 이용가치의 경계를 넘어서 약리적인 식품으로써 뿐만 아니라 기능적인 면에서까지 높여지고 있다. 이러한 발효식품은 잠재적 항산화, 항암, 항콜레스테롤, 항당뇨, 항노화의 물질이 풍부한 기원으로 여기고 있다. 전반적으로 전통발효식품은 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.