REVIEW/DERLEME

KIMCHI: A TRADITIONAL FERMENTED FOOD WITH EMERGING HEALTH IMPLICATIONS

KİMCHİ: ORTAYA ÇIKAN SAĞLIK ETKİLERİYLE GELENEKSEL BİR FERMENTE GIDA

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ABSTRACT

Kimchi is a fermented food prepared from ingredients such as Chinese cabbage (*Brassica rapa subsp. pekinensis*-kimchi cabbage*)*, radish, cucumber, salt, red chilli powder, garlic, leek, and ginger, and is widely consumed in Korea and other East Asian countries. The production methods and composition of kimchi differ across regions. Recognized as a low-energy food, kimchi contains high amounts of dietary fiber, vitamins C and B, β-carotene, and minerals including sodium (Na), calcium (Ca), potassium (K), iron (Fe), and phosphorus (P), as well as various functional compounds and phytochemicals. Kimchi is microbiologically rich, containing lactic acid bacteria (LAB) at concentrations of approximately 1×10^7–10^9 colony forming units (CFU)/g. The genera *Weissella*, *Lactobacillus*, and *Leuconostoc* account for 44.4%, 38.1%, and 17.3% of the total bacterial content, respectively. Kimchi demonstrates diverse positive effects on human health, attributed to both its nutritional composition and the probiotic bacteria developed during fermentation. The literature highlights anticancer, antioxidant, anti-obesity, and hypolipidemic activities as primary benefits. Nevertheless, additional research is required to clarify the molecular mechanisms underlying these effects and to determine the full health potential of kimchi.

Keywords: kimchi; fermented foods; health promotion; antioxidants, anti-inflammatory agents

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Introduction

Kimchi is a traditional Korean food that has been consumed for more than 2,000 years (1). Kimchi, identified with Korea, is also widely produced and consumed in other East Asian countries, such as Japan and China (2). Kimchi is obtained by fermenting vegetables such as Chinese cabbage (*Brassica rapa subsp. pekinensis*- Kimchi cabbage), radish, and cucumber together with various ingredients including salt, red chilli powder, garlic, leek, and ginger. Depending on the main raw material and preparation methods, kimchi is classified into hundreds of varieties with distinct biochemical, nutritional, and organoleptic characteristics (1).

Kimchi is a low-energy food rich in vitamins, minerals, and dietary fiber. Classified as a fermented food, kimchi is suggested to have various potential health benefits, partly due to its diverse functional components (3). The proposed health-promoting effects mainly include anticancer, antioxidant, anti-inflammatory, anti-obesity, anti-aging, and lipid-lowering properties (4).

This review aims to examine the composition and production process of kimchi, a traditional Korean fermented food, and to evaluate its potential health benefits.

To conduct this review, a comprehensive literature search was performed using databases including PubMed, Web of Science, Scopus, and Google Scholar. The search strategy utilized keywords such as "kimchi", "fermented foods", "probiotics", "microbiota", "health benefits", "antioxidant", and "metabolic health", along with their combinations. To reflect the most current evidence, the search was primarily restricted to studies published within the last decade (2015–2025). Original research articles, systematic reviews, and meta-analyses published in English with full-text availability were included as the primary criteria.

Production and Composition of Kimchi

Kimchi is produced by mixing and fermenting various foods that contain functional components and have low energy content. Although the composition of kimchi varies according to region and production method, Park et al. (4) defined a commonly used “typical kimchi” composition to increase comparability among studies. According to this composition, kimchi cabbage (100%) is the main ingredient, to which approximately 13% radish, 3.5% red pepper powder, 1.4% garlic, 0.6% ginger, 2.2% fermented anchovy sauce, 1% sugar, and 2% green onion are added, with a final salt concentration of approximately 2.5%

Kimchi production is a complex process involving the biochemical transformation of cruciferous vegetables, primarily kimchi cabbage, through osmotic dehydration and lactic acid fermentation (5, 6). The production process begins with trimming, washing, and draining the kimchi cabbage (7). In the subsequent stage, the cabbage is treated with brine to remove water from the plant tissue. This step inhibits aerobic bacteria that may cause spoilage while creating a selective environment for facultative anaerobic lactic acid bacteria (LAB). Excess salt is then removed from the cabbage, which is subsequently combined with a rich seasoning mixture containing garlic, ginger, red pepper powder, radish, and fermented fish sauce (5, 8). The prepared mixture is then stored at low temperatures (generally 4–10 °C), allowing the proliferation of beneficial LAB naturally present in the environment, such as *Leuconostoc, Lactobacillus,* and *Weissella*. As a result of this microbial metabolism, glucose and fructose are converted into bioactive metabolites, including lactic acid, acetic acid, mannitol, carbon dioxide (CO_2), and gamma-aminobutyric acid (GABA), thereby establishing the characteristic organoleptic profile and microbiological stability of the product (5, 9).

The differentiation of this sensory and microbial structure from that of traditional vegetable pickles is primarily due to fermented fish sauce (jeotgal), which is a key component in many kimchi varieties. By using jeotgal, kimchi provides not only a plant-based but also an animal-protein–derived fermentation matrix (8, 10). This component provides an important nitrogen source for LAB, thereby promoting the dominance of specific species, such as *Lactobacillus sakei*, and increasing microbial diversity (8). In addition, amino acids (e.g., leucine, glycine) produced during fish protein hydrolysis impart a characteristic "umami" flavor to kimchi that is not found in other pickled products (11, 12).

Kimchi is a product with approximately 200 varieties prepared from a wide range of vegetables and regional recipes; therefore, its nutrient composition varies considerably depending on the raw materials used and the preparation techniques employed (8, 13). In general, kimchi is considered a low-energy food due to its low energy content. This product is characterized by a remarkably low caloric density, typically yielding less than 20 kcal per 100 g. This nutritional profile is inherently linked to its vegetable-based matrix, which furthermore contributes a substantial dietary fiber fraction, potentially representing up to 24% of its dry matter. In addition, it contains vitamins K, C, B_6, B_{12} and folate, β-carotene, and minerals such as sodium (Na), calcium (Ca), potassium (K), iron (Fe), and phosphorus (P). Beyond its macro and micronutrients, kimchi also contains various bioactive compounds. Capsaicin, allyl compounds, gingerol, isothiocyanates, and chlorophyll are the main components contributing to the sensory properties and biological activity of kimchi. Furthermore, benzyl isothiocyanate, indole derivatives, thiocyanates, and β-sitosterol are among the essential compounds that constitute the phytochemical profile of the product (13, 14).

In a study, Korus et al. (15) examined the nutrient profile of kimchi and the variability among different kimchi types in detail, demonstrating that the raw material used (Chinese cabbage, white radish, kohlrabi, or cucumber) is a determining factor influencing the composition of the product. The analyses conducted on 100 g of kimchi samples reported dry matter contents ranging from 5.80 to 11.01 g, total dietary fiber from 1.65 to 3.80 g, vitamin C from 19.40 to 50.64 mg, vitamin B_1 from 11 to 52 µg, and vitamin B_2 from 29 to 242 µg. Similarly, total polyphenol content varied by kimchi type, ranging from 67.4 to 193.7 mg/100 g, with the highest antioxidant activity observed in Chinese cabbage kimchi.

The microbial composition of kimchi has also been addressed in numerous studies, particularly in a study examining 13 different commercial baechu kimchi products, which demonstrated a characteristic LAB pattern during fermentation (4, 16). In the initial stages (pH ~5.6–4.3), heterofermentative species such as *Leuconostoc mesenteroides* are dominant, whereas as fermentation progresses and the environment becomes more acidic (pH ~4.1), the dominance of species such as *Lactobacillus sakei* becomes more pronounced. In these matured kimchi samples, the majority of LAB consists of the genera *Weissella* (44.4%), *Lactobacillus* (38.1%), and *Leuconostoc* (17.3%). At the species level, *Weissella koreensis* (27.2%), *Lactobacillus sakei* (14.7%), *Weissella cibaria* (8.7%), *Lactobacillus graminis* (13.8%), and *Leuconostoc mesenteroides* (7.8) were found to be predominant (4). Various studies have reported that the viable bacterial load in kimchi generally ranges from 10^7 to 10^9 colony forming units (CFU)/g, with LAB counts in particular reaching these levels (4, 16). In addition, recent regional analyses have revealed that the microbial profile of kimchi varies according to the region of production; for example, the relative abundances of genera such as *Weissella*, *Leuconostoc*, *Latilactobacillus*, *Bacillus*, and *Trichocoleus* show significant differences between northern–southern and eastern–western regions (12).

Biological Activities of Kimchi

Antioxidant Effects

Kimchi contains numerous components with antioxidant properties. Chlorophyll, phenolic compounds, vitamin C, carotenoids, dietary fibers, LAB, and other phytochemicals derived from both raw materials and the fermentation process act as hydrogen donors and play a role in the neutralization of free radicals (15).

According to Kim et al. (17) kimchi exhibits significant scavenging activities against nitric oxide (NO), superoxide anion (O_2^-), and hydroxyl radical (·OH) under *in vitro* conditions. In addition, an increase in cell viability and a decrease in lipid peroxidation were reported. Several studies have also reported that various Lactobacillus strains isolated from kimchi exhibit high antioxidant activity in radical scavenging assays (18, 19).

Data from animal studies further support the antioxidant capacity of kimchi and show that both traditional kimchi and kimchi enriched with black raspberry reduce oxidative damage and lipid peroxidation by increasing hepatic antioxidant enzymes, including superoxide dismutase (SOD), catalase, and the glutathione system. These findings indicate that different forms of kimchi possess protective potential against oxidative stress (20, 21).

While clinical evidence is relatively limited compared to laboratory models, some human studies support these findings. For instance, a randomized trial showed that high kimchi consumption (210 g/day) can significantly reduce serum lipid peroxidation and enhance systemic antioxidant capacity in healthy adults (22). However, more large-scale clinical trials are needed to fully confirm these antioxidant benefits in diverse human populations.

Anti-Inflammatory Effects

Studies conducted in human cell models have demonstrated that kimchi and kimchi-derived LAB exhibit pronounced anti-inflammatory effects. It has been reported that fermented kimchi extracts and *Lactobacillus* species isolated from kimchi reduce nitric oxide production in macrophages activated by inflammatory stimuli and significantly suppress the expression of key pro-inflammatory markers such as inducible nitric oxide synthase (iNOS), cyclooxygenase-2 (COX-2), tumor necrosis factor-alpha (TNF-α), interleukin-1 beta (IL-1β), and interleukin-6 (IL-6) (18, 23). The anti-inflammatory effects of kimchi are thought to be attributed to both phenolic compounds enriched through fermentation and the immunomodulatory properties of LAB strains (23).

However, a 4-week randomized controlled clinical study involving 39 healthy participants found that kimchi consumption did not significantly alter systemic inflammatory markers. The insufficient sample size, limited intervention duration, and similar dietary patterns between groups were considered limitations of the study, and the need for more comprehensive clinical studies was emphasized (24).

Gastrointestinal Effects and Gut Microbiota

Kimchi consumption plays a central role in maintaining gut microbial homeostasis and alleviating functional disorders. In a randomized, double-blind, placebo-controlled clinical trial, daily consumption of 210 g of kimchi was found to significantly reduce symptoms of irritable bowel syndrome (IBS), including abdominal pain, bloating, and incomplete evacuation (25). This clinical improvement was associated with a decrease in serum pro-inflammatory cytokines (TNF-α, IL-12) and the inhibition of harmful fecal enzyme activities such as β -glucosidase and β -glucuronidase (25).

Carbohydrates in kimchi cabbage are reported to be converted into short-chain fatty acids (SCFAs) by probiotic bacteria during the fermentation process (26). These SCFAs support gut health by enhancing the integrity of the intestinal barrier (26). A recent clinical study identified that kimchi intake strengthens the gut ecosystem by significantly increasing the relative abundance of beneficial species such as *Akkermansia muciniphila* and *Bifidobacterium adolescentis* (25, 26). Conversely, it was concluded that regular consumption depletes pathogenic Escherichia populations and creates a protective foundation against local inflammation by optimizing the gut microbial balance (25, 26).

Effects of Kimchi on Health

The health effects of kimchi arise not only from the rich vitamin, mineral, and phytochemical content of its raw ingredients but also from bioactive metabolites produced during fermentation. Components such as Chinese cabbage, garlic, onion, red pepper, and ginger possess natural profiles of polyphenols, glucosinolates, organosulfur compounds, and carotenoids; together with the fermentation process, these components enhance the antioxidant, anti-inflammatory, and other functional properties of kimchi. These biological foundations suggest that kimchi consumption may be associated with various health outcomes through mechanisms such as probiotic activity, reduction of oxidative stress, and modulation of inflammation (27).

However, to maintain conceptual clarity, it is important to distinguish between a functional fermented food and a true probiotic. Although kimchi is microbiologically rich and contains high amounts of live lactic acid bacteria (LAB) with potential probiotic properties, strict scientific classification as a "probiotic" requires strain-level identification and proven clinical efficacy for those specific strains. Therefore, kimchi is more accurately defined as a functional fermented food with high probiotic potential rather than a standardized probiotic product.

Cancer

Numerous studies have demonstrated the anticancer effects of various ingredients used in kimchi production (28-30). These effects are mainly attributed to bioactive components such as glucosinolates in cabbage, organosulfur compounds (notably allicin and diallyl sulfides) in garlic, and capsaicin in red chili pepper. Several *in vitro* studies have shown that kimchi cabbage can induce apoptosis in colon carcinoma cells and may be particularly effective in preventing colorectal cancer (28, 29). Garlic has also been reported to exert anticancer effects due to its high content of organosulfur compounds (11–35 mg/g; 33 types). In addition, garlic's antimicrobial activity against *Helicobacter pylori*, a major risk factor for gastric cancer, is considered a possible cancer-preventive mechanism. Red chili pepper is thought to play a role in anticancer processes through its capsaicin content. Although this potential role remains controversial, capsaicin is believed to induce apoptosis in cancer cells by generating excessive reactive oxygen species. It has also been reported that capsaicin can inhibit the development of preneoplastic breast lesions by up to 80% (30).

Under *in vivo* conditions, kimchi extract fermented for three weeks inhibited the proliferation of human cancer cell lines, including gastric adenocarcinoma and acute promyelocytic leukemia. Leukemia cells treated with kimchi extract exhibited increased apoptosis and decreased mitochondrial transmembrane potential (31). Similarly, Han et al. (32) reported that consumption of fermented kimchi significantly reduced colitis and colitis-associated colorectal cancer in mice, whereas non-fermented kimchi showed no protective effect. This finding indicates that fermentation is a key determinant of anticancer activity. Moreover, other animal studies have shown that kimchi can markedly reduce tumor development in pancreatic, liver, and gastric cancers and may exert protective effects against cancer cachexia (33-35). However, well-designed human studies are required to validate these findings clinically.

Obesity

Animal studies have demonstrated that kimchi may play a role in regulating body weight in rats. Although this effect is thought to be partly attributable to capsaicin derived from red chili pepper, kimchi has been reported to exert a greater weight-reducing effect than red chili powder alone (36). Furthermore, a recent 2025 *in vitro* study highlighted that freeze-dried kimchi cabbage exhibits pronounced dual properties by significantly inhibiting lipid accumulation and adipogenesis in 3T3-L1 cells while simultaneously showing high antioxidant activity (37). To support findings from animal studies, Jung et al. (38) conducted an extensive cross-sectional study analyzing 115,726 participants and reported a J-shaped association between kimchi consumption and obesity. This trend suggests that while moderate intake (1-3 servings/day) reduces obesity risk-likely due to the probiotic and fiber content-excessive consumption (≥5 servings/day) may reverse these metabolic benefits. This threshold effect is potentially attributed to the high sodium concentration in kimchi and the increased total energy intake associated with high-consumption dietary patterns.

The effects of kimchi on body weight have also been investigated in several clinical studies (39-41). In a double-blind, placebo-controlled, randomized trial using *Lactobacillus sakei,* the second most abundant microorganism in kimchi, 114 adults with a body mass index (BMI) ≥25 kg/m^2 were enrolled. Participants received either 5×10^9 units of *Lactobacillus sakei* or a placebo twice daily for 12 weeks. At the end of the study, fat mass and waist circumference were significantly lower in the intervention group, whereas no significant differences were observed in BMI or body weight (39). In a crossover study conducted by Kim et al. (40) involving 22 overweight or obese participants, the effects of fermented and fresh kimchi consumption were compared. Two 4-week intervention periods, separated by a 2-week washout period, were implemented, during which participants consumed 300 g of kimchi per day (100 g per meal) prepared according to a standard recipe, alongside dietitian-controlled meals. Although both groups showed significant reductions in body weight, BMI, and body fat, significant decreases in waist-to-hip ratio, fasting blood glucose, and insulin levels were observed only in the fermented kimchi group.

Similarly, in another crossover study involving 21 prediabetic participants, individuals consumed either fresh (1-day-old) or fermented (10-day-old) kimchi for the first 8 weeks, followed by a 4-week washout period and subsequent consumption of the alternate kimchi type for another 8 weeks (41). Anthropometric measurements and blood parameters were assessed at baseline and at weeks 8, 12, and 20. The results indicated that both fermented and fresh kimchi consumption led to favorable changes in body weight, waist circumference, fat mass, and fat-free mass. Furthermore, while both types significantly improved markers such as HbA1c and homeostatic model assessment for insulin resistance (HOMA-IR), the study authors emphasized (41) that certain indices (specifically insulin sensitivity and beta cell function) reached statistical significance only in the fermented kimchi group. The authors interpreted these findings cautiously; while they anticipated a more pronounced metabolic superiority for the fermented form, they acknowledged that they could not statistically prove a distinct advantage over fresh kimchi regarding general glycemic control in this population. They suggested that the observed benefits in both groups were likely driven by the baseline dietary fiber content, with fermentation providing additional, albeit specific, physiological potential (41).

Cardiovascular Health

Various animal studies have shown that kimchi consumption is associated with decreases in very low-density lipoprotein (VLDL), low-density lipoprotein (LDL), and triglyceride (TG) levels, along with increases in high-density lipoprotein (HDL) levels (4, 42). The high dietary fiber content of kimchi is thought to contribute to its hypolipidemic effect (4). In addition, LAB have been reported to exert hypolipidemic effects by participating in the metabolism of dietary cholesterol and reducing bile salt absorption (42). It has also been reported that fermented kimchi exhibits a greater hypolipidemic effect than fresh kimchi (40).

In a randomized controlled study involving 100 participants, individuals were provided with 15 g or 210 g of kimchi daily for 7 days in addition to a standard diet. As a result, fasting blood glucose, total cholesterol, and LDL concentrations decreased significantly in both groups after 7 days of kimchi intake, with the magnitude of the effect being dose-dependent. Moreover, participants with baseline total cholesterol and LDL levels above 190 mg/dL and 130 mg/dL, respectively, exhibited more pronounced lipid-lowering effects of kimchi (22). In another Mendelian randomization study conducted among middle-aged Korean adults, higher kimchi consumption was found to be associated with a small but significant reduction in the risk of low high-density lipoprotein cholesterol (HDL-C) levels in men, whereas no such association was observed in women. Although the magnitude of the effect was limited, kimchi was suggested to have a modest protective role in HDL metabolism in men (43).

The effects of kimchi on lipid metabolism have also been investigated in a pathological model. In this context, kimchi was shown to suppress endoplasmic reticulum stress–induced hepatic steatosis in mice, reduce TG accumulation in the liver, improve serum and tissue lipid profiles, and regulate the expression of genes related to lipid metabolism. In addition, these effects were reported to be associated with the suppression of oxidative stress and inflammatory responses (5).

Other Health Effects of Kimchi

Although a large proportion of studies (28-43) on kimchi have focused on the biological activities and health effects described above, several additional functional properties of kimchi have been investigated to a limited extent in the literature.

In addition, a recent meta-analysis based on a limited number of studies demonstrated that fermented kimchi consumption may be associated with small but significant improvements in fasting glucose and blood pressure (44).

A recent *in vitro* study also reported that kimchi extract exerted strong antioxidant effects in skin cells and protected them against oxidative damage (45). Furthermore, it enhanced the production of collagen, elastin, and hyaluronic acid in fibroblasts, thereby supporting skin structure and moisture balance. Based on these findings, kimchi was highlighted as a potential “beauty food,” with a possible role in supporting skin health through dietary intake (45).

In addition, kimchi at an optimal ripening stage was shown to protect cells against oxidative stress and to reduce early cellular aging by extending the proliferative lifespan of fibroblasts. Accordingly, kimchi was suggested to possess potential anti-aging effects (46). In a randomized controlled study involving 13 adults, consumption of freeze-dried kimchi capsules equivalent to 30 g of fresh kimchi per day for 12 weeks increased the expression of genes associated with antigen presentation, particularly those related to the major histocompatibility complex class-II (MHC-II) pathway, enhanced intercellular signaling among immune cells, and supported the functional differentiation of cluster of differentiation 4-positive (CD4+) T cells; these findings were stated to demonstrate the immunomodulatory potential of kimchi (47).

Moreover, LAB isolated from kimchi were shown to strongly inhibit various foodborne pathogens, with this effect being attributed to low pH and the presence of organic acids. Therefore, kimchi-derived LAB were reported to have potential applications as natural antimicrobial preservatives for reducing biological hazards in foods (48).

Limitations and Safety Considerations

The sodium content of kimchi is a critical consideration, particularly for individuals at risk of hypertension. In an animal study conducted on spontaneously hypertensive rats, consumption of high-sodium kimchi-with salt levels of 2.4% (commonly found in commercial products) and 3.0% (typical of homemade varieties)-was found to significantly increase systolic blood pressure (48). However, the same study observed that low-sodium versions containing 1.4% salt did not exert an adverse effect on blood pressure, even under hypertensive conditions (49).

In contrast, epidemiological data have not identified a significant association between kimchi consumption and hypertension prevalence in the general population; this is attributed to the high potassium intake from vegetables, which may neutralize the effects of sodium (50). Nevertheless, a 12-year follow-up study reported that the consumption of "watery kimchi" was associated with an increased risk of hypertension specifically in obese men (51). Therefore, it is recommended that individuals, particularly those with sodium sensitivity or hypertension, be more cautious with kimchi consumption and opt for low-sodium kimchi variants when they do consume it (49, 51).

Furthermore, while some epidemiological studies have suggested a potential positive association between high consumption of salted fermented vegetables and gastric cancer incidence, this remains a highly controversial topic (52, 53). The varying types of kimchi, fermentation periods, and individual dietary habits make it difficult to draw definitive conclusions, highlighting the need for more nuanced, large-scale epidemiological studies.

Conclusion and Recommendations

Kimchi, a traditional food widely consumed in Korea and other East Asian countries for many years, exerts multiple beneficial effects on human health through its nutrient content and the bacterial communities that develop during fermentation. Kimchi demonstrates antioxidant, anti-inflammatory, antitumor, antimutagenic, anti-obesity, anti-atherogenic, and lipid profile–improving properties. It has also been reported to support health through antimicrobial and anti-aging potential. Based on these findings, regular consumption of kimchi at an appropriate frequency and amount within a balanced and adequate diet may contribute to health promotion in several respects. However, a large proportion of the existing evidence is derived from *in vitro* and animal studies. Consequently, well-designed, large-scale clinical studies are necessary to clarify the effects of kimchi on human health and to elucidate the underlying mechanisms of action.

Abbreviations

BMI: Body mass index

CD4+: Cluster of differentiation 4–positive

CFU: Colony-forming units

COX-2: Cyclooxygenase-2

GABA: Gamma-aminobutyric acid

HDL: High-density lipoprotein

HDL-C: High-density lipoprotein cholesterol

HOMA-IR: Homeostatic model assessment for insulin resistance

IBS: Irritable bowel syndrome

IL-1β: Interleukin-1 beta

IL-6: Interleukin-6

LAB: Lactic acid bacteria

LDL: Low-density lipoprotein

MHC-II: Major histocompatibility complex class-II

SCFAs: Short-chain fatty acids

SOD: Superoxide dismutase

TG: Triglyceride

TNF-α: Tumor necrosis factor alpha

VLDL: Very low-density lipoprotein

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