Journal of Ethnic Foods

REVIEW ARTICLE

Open Access

Gochujang, a Korean traditional fermented soybean product: history, preparation and functionality

Su-Jin Jung[1,2†] and Dong-Hwa Shin[3,4*†]

Abstract

Korean food has garnered global interest, especially after COVID-19, with a significant increase in demand for K-Food staples like bulgogi, tteokbokki, bibimbap, kimchi, and galbi, as well as related YouTube content. A key ingredient that enhances the deliciousness of Korean cuisine is *Gochujang*. *Gochujang*, with its unique taste and aroma, is an unparalleled fermented spice seasoning, adding spiciness and a special flavor to a variety of dishes. Made from ingredients such as *Meju*, glutinous rice, red pepper powder, malt, and salt, *Gochujang* has a rich history spanning thousands of years and is celebrated for its spicy and sweet flavor. *Gochujang* is differentiated by commercial and traditional manufacturing methods. Traditional *Gochujang* is produced through natural fermentation using glutinous rice, malt, *Meju* powder, salt, and red pepper powder. Conversely, commercial production blends traditional methods with modern industrial techniques, utilizing pure microbial cultures like *Aspergillus oryzae* and *Bacillus subtilis* as starters to meet mass production demands. Beyond its culinary uses, *Gochujang* is recognized globally for its nutritional value and health benefits. Fermentation enhances its health functionality by creating new substances or converting fermentation metabolites. Notable compounds synthesized during fermentation include capsaicin from red pepper powder and non-glycoside isoflavones from *Meju*, which are linked to antiobesity, antidiabetic, antiatherosclerosis, and anticancer effects. *Gochujang* also helps restore intestinal microbial balance, promoting gut health. This review aims to explore the historical background of *Gochujang*, its production methods, flavor characteristics, nutritional composition, health benefits, and the expansion of culinary research involving *Gochujang*.

Keywords Korean fermented food, Meju, Gochujang, Microorganisms, Health functions

Introduction of *Gochujang* and production method

Application of fermentation technique to soybean as food stuffs in Korea

Fermented foods are a class of processed foods with human history, and when early carbohydrates or protein foods are left in their natural state, they are decomposed by enzymes produced by numerous types of microorganisms in the air or in themselves to create new products and new substances are beneficial or harmful to humans. A beneficial change is called fermentation, and harmful cases are classified as decay, making food impossible to eat.

†Su-Jin Jung and Dong-Hwa Shin contributed equally to this work.

*Correspondence:
Dong-Hwa Shin
dhshin@jbnu.ac.kr
[1] Clinical Trial Center for Functional Foods, Biomedical Research Institute, Jeonbuk National University Hospital, Jeonju 54907, Korea
[2] Research Institute of Clinical Medicine, Medical School, Jeonbuk National University, Jeonju 54907, Korea
[3] Shin Dong Hwa Food Research Institute, Seoul 06179, Korea
[4] Department of Food Science and Technology, Jeonbuk National University, Jeonju 54896, Korea

© The Author(s) 2024. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

Humans have consumed fermented foods for thousands of years. Although they were likely produced initially as a means of preservation, it would have been readily apparent that these foods possessed other desirable attributes [1]. Global fermented foods vary depending on the climate and the products produced. In the East, there are many products mainly utilizing grains and beans, which are agricultural products, and in the West, milk and meat fermented products produced in the livestock industry have become common, and this condition continues even now. In particular, in Eastern Asia, including Korea, China, and Japan, fermented products using soybeans have been in their diet widely since BC [2]. The origin of fermented soybeans was known as the Manchurian region, where fermented foods using soybeans have long been commonplace. Soybean fermented foods are still an important source of protein for these people and contribute greatly to maintaining health [3]. Korean traditional foods use agricultural products from a longstanding heritage of Korean society, and such agricultural products provided by nature have been largely used in practical life due to distinctive four seasons. In particular, the dietary life was determined based on the principle food of rice and then cultures with boiled rice (*Bab*) were already settled in B.C. Also, some side dishes were also introduced as the major elements in this dietary life. In addition, some subsidiary food materials that provide specific flavors to *Bab* which has no particular unique taste were required and then subsidiary foods were also developed. By introducing brining methods to agricultural raw materials in Korea, it was an occasion that the dietary life in Korea was changed to fermentation-based diets. Various fermented soybean products provide taste and flavor to all side dishes.

Introduction of *Gochujang* (fermented red pepper paste)

Globally, there are more than 5000 species of fermented foods, and they differ greatly depending on the region and ethnicity of folk [4]. *Gochujang* is a type of traditional Korean fermented food, and it basically uses soybeans and red pepper as basic ingredients, but it does not use only beans such as *Ganjang (*soy sauce), *Deonjang* (fermented soybean paste) and *Cheonggukjang* [5]. The characteristic of *Gochujang* is a fermented spice that uses beans as the main ingredient, but adds red pepper powder to it to create a unique spicy taste [6]. The basis of soybean paste manufacturing is *Mejub* (fermented soybean brick), which is immersed, boiled, grinded, molded into a certain shape (mostly donut type), and then naturally fermented for a considerable period of time, recently adjusted temperature and humidity to make *Meju*. Mold and bacteria (mainly Aspergillus and Bacillus) are involved in this fermented *Meju,* and the modified *Gochujang Meju* is different by inoculating selected isolate which is superior function to digest soybean protein and other ingredients into active compounds to final taste.

History of *Gochujang* preparation

The history of soybean-based side dishes in ordinary diet is estimated to be B.C., but the old literary basis relies on Chinese literature. The records of the first Korean literature show the queen in the third year of King Sinmun's reign (AD 683) [7]. From this, it is estimated that soy sauce was widely distributed to the general public long before this period [8]. Soybean-based sauces formed a culture of sauces in Southeast Asia, especially Korea, China, and Japan, and in these countries, soybean-based sauces were used as important condiments for diet and still occupy an important position in their table. Unlike soy sauce, soybean paste, and C*heonggukjang*, which are mainly based on beans, *Gochujang* uses a unique red pepper as one of main raw material which is a seasoning with a strong spicy taste. In order to estimate the history of Gochujang, we need to look at the date when red pepper was introduced into this country. Based on the existing literature, there are two main theories about the introduction of chili peppers: One claims that chili peppers were brought from Central and South America by Columbus in the late fifteenth century and spread to Asia via India within just 100 years. Another theory suggests that chili peppers were introduced to Korea through Japan during the Japanese invasions of Korea in 1592 [9]. However, these theories are challenged by the fact that the varieties cultivated in Korea are different from those in Central and South America and India. The Korean chili pepper is the result of evolutionary processes that occurred millions of years ago among species, making it difficult to determine the exact timeline of these events [10, 11]. This confusion is attributed to a lack of proper understanding of the characteristics, diversity, and evolutionary processes of chili pepper varieties, as well as their culinary and agricultural significance [12]. One scholar asserts that chili peppers were already being cultivated during the *Goguryeo* period [13, 14]. Ancient texts do mention chili peppers, but there is debate among scholars about whether the chili peppers mentioned in historical documents are the same as the ones we consume today [13, 15]. Advances in life sciences have now made it possible to analyze the origins and evolutionary processes of various chili pepper varieties on Earth. It has been found that Korea has two varieties: a mild variety and a slightly spicy variety that evolved around 500,000 years ago [12]. Further research is needed to determine whether these two varieties evolved on the Korean Peninsula or were introduced from elsewhere. However, I think the Korean

people have a factor that prefers spicy taste. In the myth of our people, it is said that *Woongnyeo*, a bear, ate garlic and turned into a woman and gave birth to *Dangun,* so you can find a factor in garlic that likes spicy taste. Before peppers became common, Korean food used garlic, green onions, zompi (*Zanthoxylum piperitum*. D.C.), and wild chives as ingredients for spicy taste, and these ingredients were used as seasoning in various dishes, and garlic, green onions, and wild chives are still added together when making kimchi. Mixing them like this to harmonize the spicy taste of peppers. Ingredients that make spicy taste, such as garlic, have different taste characteristics that make spicy taste with ingredients other than capsaicin, the cause of spicy taste of red peppers. With this combination, the wisdom of harmonizing the spicy taste was demonstrated. *Gochujang* has not been in our diet longer than other soybean sauces, but as the spicy taste craze has been blowing in recent years, *Gochujang,* including *Kimchi,* has been in the spotlight in the global market. Spicy taste is the cause, and research is underway to confirm that the molecular structure of capsaicin, a spicy ingredient, does change when *Gochujang* is fermented. There is a significant difference in the taste of *Gochujang* after mixing the raw ingredients at the first time and after long-term ripening. In other words, when sweet and savory taste are added, the spicy taste is greatly modified and refined. *Gochujang* has now become an indispensable spice for Korean dietary culture, but it is also a unique sauce enjoyed by people around the world. In the meat-oriented Western style, spicy and savory *Gochujang* is a good combination of all ingredients, and it is expected to become a spicy sauce that is welcomed at the table of the world in the future.

Preparation process of traditional *Gochujang Meju*

The manufacturing method of *Gochujang* varies slightly depending on the region or the person who manufactures it, but the taste and characteristics vary as red pepper powder and various ingredients are added based on making *Gochujang Meju* [16]. In particular, the taste and flavor vary depending on the grains used to give sweetness, that is, rice or barley. *Gochujang Meju* is main ingredient for making *Gochujang* which has all deferent types of microbes and enzyme they produced. *Meju* for preparing *Gochujang* use soybean and grains like as rice or barley. Those carbohydrate source induce some microorganisms which produce amylase. During fermentation period, the amylase covert starch in grains into mono or disaccharide that are related to sweet taste of *Gochujang.* The method for making *Gochujang Meju* is as follows [16, 17]: Soybeans are soaked for about 3 h (if soaked for too long, it becomes difficult to mash the beans). Rice is soaked for about 6 h. Then, after grinding the beans and rice, mix them well. The mixture is steamed for more than 1 h and 30 min using a steamer. After steaming, the mixture is molded into donut shapes for fermentation or usually left in an unmolded state to ferment for about 3–4 days. After completely drying in the air, the mixture is ground and ready for use. The traditional method for making *Gochujang,* also known as *Gochujang*, follows a specific production period from the middle of the lunar winter solstice to the middle of the New Year. If necessary, the production can be extended from December to May of the following year. To prevent the paste from becoming sour when soaking time is delayed, an increased amount of salt is used.

The raw material mixing ratio for *Gochujang* consists of 25% red pepper powder, 22.2% glutinous rice, 5.5% *Meju* powder, 8% salt, with the remainder being malt and water [16]. To create the paste, glutinous rice is first soaked in water for 24 h to soften it. After soaking, the rice is drained and ground into a fine texture. Simultaneously, malt is soaked in water, using about 5% of the total volume of the *Gochujang*. The ground glutinous rice is then combined with the malt water, and this mixture undergoes a saccharification process, similar to the process used for making sikhye. The saccharification takes place at a temperature of 55–60 °C for approximately 1 h and 30 min. Once saccharification is complete, the mixture is heated for about 1 h and then allowed to cool. Following this, the remaining raw materials are added according to the predetermined mixing ratio: red pepper powder, *Meju* powder, and salt. All ingredients are thoroughly mixed to achieve a uniform consistency. The well-mixed *Gochujang* is then transferred into an earthenware pot. The *Gochujang* is left to ferment in a sunny location for at least 6 months. This prolonged fermentation period allows the flavors to develop and deepen, resulting in the rich and complex taste characteristic of traditional gochujang. In general, sauces like as *Gochujang* based on soybean need to be aged for at least 1–6 months, depending on the case, for a few years to have a subtle taste and aroma. In particular, just after mixing all ingredients *Gochujang* has a rough taste that does not match the first stage of fermentation, but it becomes characteristic spice as a complex flavor seasoning as it harmonizes and purifies through the time going. *Gochujang* has a variety of flavors and scents depending on the raw material used, and the varieties of microorganisms involved is also wide. *Gochujang* is a unique property that has viscosity and can be widely used in the form of sauce or in all foods. As consumers' preference for spicy taste has increased in recent years, the use of *Gochujang* is also expanding, and various new products

are coming out through various ingredients combinations like as fruits or fishes, and it is solidifying its value as a spice favored by people around the world.

Spicy component of red pepper and how to make Gochujang

The most distinctive taste of *Gochujang* comes from the spicy taste of red pepper, and these spicy flavors include capsaicin as the main ingredient, but other ingredients that produce complex taste and flavor. But main ingredient is capsainoid. The main characteristic of the spicy taste of peppers is capsainoid, which is a generic term for similar compounds. Capsainoid contains capsaicin, dihydrocapsaicinm nordihydrocapsaicinm homocapsaicin, homodihydrocapsaiein. Among these compounds, capsaicin and dihydrocapsaicion account for 90% of the total capsaicinoid. The content of capsaicin among various varieties of peppers produced in Korea is known to be around 0.2–0.4% [18]. The degree of spicy taste varies depending on each ingredient of capsainoid, and the content of red pepper also varies as given in Supplementary Table 1 [19]. The primary pungent components of red pepper are capsaicin (content 46–77%, pungency strength 100), dihydrocapsaicin (content 21–40%, pungency strength 100), and nordihydrocapsaicin (content 2–12%, pungency strength 57), with capsaicin and dihydrocapsaicin having the highest content and pungency, while nordihydrocapsaicin has relatively lower content and pungency, balancing the overall heat. Traditional *Gochujang* has been made using various ingredients and methods depending on the region for generations. In contrast, factory-made *Gochujang* is categorized into aged and saccharified types based on fermentation and the sequence of adding red pepper powder. The table below highlights the differences between traditional and factory-made *Gochujang* (Table 1) [16].

Microorganisms concerned

Gochujang uses various ingredients compared to that of *Doenjang* or *Ganjang*. The species and genus of microorganisms in the traditional *Gochujang*, which includes a large amount of red pepper powders, malts, grains, *Ganjang*, etc. As traditional *Gochujang* apply natural fermentation condition, so that many different microbes could be concerned but the modified *Gochujang* is processed using Koji. In traditional *Gochujang,* naturally occurring molds like *Aspergillus oryzae* and *Bacillus* species are used to ferment *Meju* powder. Factory-made *Gochujang*, however, utilizes pure cultured strains of *A. oryzae,* which are inoculated into starchy materials and cultivated in controlled facilities. Traditional *Gochujang* incorporates *Meju* powder, while factory-made versions may use a soybean-based *Meju* similar to that used for doenjang, although some companies may use it sparingly or not at all. The *Meju* helps enhance umami through amino acids and peptides derived from soybean protein breakdown.

The microbial load in *Gochujang* is about $10^7 \sim 10^8$/g and the frequency of presenting the microorganisms is determined as *Bacillus velegensis* > *B. amyloliquefaciens* > *B. subtilis* and the *Oceanobacillus* is also detected in addition to the halophilic microorganisms determined as *B. ligueformis* > *B. subtilis* > *B. velezensis* > *B. amyloliqueformis* [20]. Yeast revealed in *Gochujang* are *Zygosaccharomyces* and *Candida lactis*. Also, *Z. rouxii* shows the highest detection rate [21]. *Aspergillus* is the predominant strain, and *Penicillium* and *Rhizopus* are also detected. These would be usually proliferated on the surface of *Gochujang* instead of inside it. And also depending upon company, microbes are quite differ and fermentation period as given in Supplementary Table 2 [22]. As shown in Supplementary Table 2, microbes in *Gochujang* are quite universe during fermentation period and by manufacturers. *Bacillus* species are the dominant

Table 1 Differences between traditional Gochujang and factory-made Gochujang

Items		Traditional	Factory-made	Notes
Main ingredient	Starch material	Glutinous rice 20% or more (locally sourced)	Use of wheat, barley, rice (can be imported)	Traditional red pepper paste: Use of natural microorganisms Factory-made red pepper paste: use of isolated strains as seed
	Red pepper powder	More than 20%	More than 6% (typically around 10%)	Factory-made gochujang: used after seed *koji* (strain isolation)
	Preservatives	Not allowed	Possible within the standard range	
Fermentation	Method	Traditional vessel	Tank fermentation	Traditional gochujang: natural fermentation Factory-made gochujang: adjustment of fermentation conditions
	Period	Within 6 months	Within 15 days	
Sterilization		Unsterilized	Selective sterilization (targeting enzymes, yeast, etc.)	

microbes at all stages, but the dominant microbes gradually change during fermentation. In another case, the *Lactobacillus* group appears and contributes to the sour taste of *Gochujang* thereafter.

Functionality of *Gochujang*

Gochujang is a fermented Korean soybean and chill paste staple in Korean cuisine. *Gochujang* adds a spicy flavor to food and has various functional characteristics that enhance its popularity and adaptability in culinary applications. It possesses qualities beyond simply enhancing flavor, rendering it a significant component of multiple culinary practices in Korea. The fermentation process not only enhances the flavor but also significantly increases the physiological activity of *Gochujang* compared to unfermented *Gochujang* and plain red pepper powder containing capsaicin. Specifically, the health benefits of *Gochujang* are largely attributed to the synergistic effects of various fermentation metabolites [23], which differ based on the duration of fermentation and subsidiary ingredients used during preparation. The metabolites formed during fermentation could be transformed or newly formed compounds that give *Gochujang* its distinctive flavor and taste. For example, metabolites like lactic acid and acetic acid impart a tangy flavor to the paste, contributing to its overall taste profile. Further, capsaicin from red pepper powder acts as an antioxidant compound [24], potentially contributing to overall health and reducing the risk of chronic diseases [25, 26]. Interestingly, *Gochujang* serves as a symbiotic food, as it has characteristic properties of both probiotics and prebiotics, positively impacting gut health and helping to restore balance in microbiomes disrupted by disease. Comparative studies have shown that the physiological activities of traditional fermented *Gochujang* are significantly more pronounced than those of both unfermented *Gochujang* and red pepper powder. In line with the observations on physiological activities, recent investigations have unveiled discrepancies in the health benefits associated with traditional fermented *Gochujang* and commercially produced *Gochujang,* where *Gochujang* is manufactured with distinct techniques [27]. These discrepancies in the health benefits are influenced by the fermentation period and the ingredients used, as summarized in Table 2.

Improved intestinal health and bowel function

Gochujang has multiple health benefits, including intestinal health and bowel function. The natural fermentation process during preparation introduces probiotics, fostering a balanced gut microbiota. Ingredients like glutinous rice and fermented soybeans provide prebiotic fibers, supporting the growth of beneficial bacteria. The bioactive compounds in red peppers may offer anti-inflammatory and antioxidant properties, which contribute to a healthier gut environment. However, recent studies have underscored the significant impact of traditional *Gochujang* on enhancing intestinal health and alleviating constipation [31, 32]. The unique spicy flavor and color of *Gochujang*, along with its symbiotic properties, have been observed to alter intestinal microflora and improve bowel function in preclinical [31] and clinical [32] investigations. Specifically, a preclinical study with beneficial bacteria and lower microbial diversity (BMG) and harmful bacteria with higher microbial diversity (VMG) was conducted to evaluate the efficacy of *Gochujang* in improving bowel function. Here, *Gochujang* supplementation in the BMG group effectively enhanced intestinal motility and altered the composition of intestinal microorganisms by regulating enteric nervous system (ENS) [31]. Also, it improved the frequency of bowel movement and water content in stools via MAPK activation and enhanced the c-Kit/SCF signaling pathway. Notably, the ratio of *Bacteroidetes* and *Firmicutes* was reduced in both BMG and VMG groups. However, *Acetatifactor was reduced in BMG,* whereas *Caproiciproducens* and *Acutalibacter* were reduced in VMG. These preclinical findings were corroborated by a recent clinical study [32], which assessed the impact of commercial and traditional *Gochujang* on gastrointestinal movements and intestinal environment in patients with functional constipation. Here, observations strongly indicated improved bowel movement frequency and colon transit time across all groups supplemented with *Gochujang.* Interestingly, supplementation of *Gochujang* increased fecal butyric acid and reduced calprotectin levels, indicating reduced intestinal inflammation. In support, the previous investigations highlighted the role of butyric acid and calprotectin [48]. These findings suggest that traditional *Gochujang*, with its rich content of beneficial bacteria, can effectively improve constipation by altering the composition of intestinal microorganisms and enhancing gastrointestinal motility. Moreover, observations highlight the potential of traditional *Gochujang* in addressing clinical concerns related to bowel health and intestinal inflammation.

Protective effects of Gochujang against inflammation and its role in gut health

Gochujang has been shown to possess several health benefits, as its metabolites and active compounds contribute to the prevention of conditions such as obesity, oxidative stress, and inflammatory bowel disease (IBD). *Gochujang* has unique health-beneficial properties that compensate for its high salt content. High salt content is often linked to inflammation-related problems like atrophic gastritis [67]. Interestingly, the salt in *Gochujang* appears

Table 2 Reports demonstrating the relationship between Gochujang consumption and health benefits

Functionality	Study types	Consumption/Study description	Health effects of fermented foods	References
Cancer	In vitro	Traditional Gochujang with Garlic porridge	Reduced cancer cell viability Enhanced anticancer activity	[28]
Cancer & antimutagenic	In vitro	Traditional Gochujang	Reduced cancer cell viability Antibacterial effect	[29]
Cancer	In vitro	Traditional vs commercial Gochujang	*Meju* (fermented soybean) and glutenous rice powder significantly reduced the viable cancer cells	[27]
Cancer	In vitro	Gochujang prepared from different fermentation period [15 and 30 days]	Growth inhibitory effect on HT-29 human colon cancer cells and AGS human stomach cancer cells	[30]
Gastrointestinal & Microbiome	In vivo	Seven-week-old ICR mice, Traditional Gochujang	Alleviated constipation by increasing defecation frequency and water content in feces by reducing AQP3 mRNA expression Increased GI transit time and excitatory neurotransmitter levels and decreased inhibitory neurotransmitter levels Decreased the *Bacteroidete*s and *Firmicutes* ratio	[31]
Constipation & gut health environment	RCT	Functional constipation subjects (n = 50), High dose of beneficial microbes traditional Gochujang (HTK) Low dose of beneficial microbes traditional Gochujang (LTK) - Commercial Gochujang (CK): 25.3 g (powder pills 19 g)/day, 4 week	Reduced total colonic transit time and increased defecation frequency HTK: Increase in butyric acid, a short-chain fatty acid beneficial for gut health HTK: decrease in calprotectin (an intestinal inflammation marker	[32]
Hepatic Inflammation	In vivo	C57BL/6 mice [3 weeks-old], 13 weeks, 2 types of traditional Gochujang: High percentage of beneficial microbiota Gochujang (HBM) vs diverse beneficial microbiota Gochujang (DBM)	Regulated the gut microbiota-derived LPS production and Firmicutes/Bacteroidetes ratio Regulated the levels of gut microbiota such as *Bacteroides, Muribaculum, Lactobacillus*, and *Enterorhabdus* correlated with hepatic inflammation Antihepatic inflammation effects via reduced lipid accumulation, hepatic injury, and inflammatory response	[33]
Obesity	In vivo	Gochujang products prepared using rice *koji* (fermented grain) & soybean *meju*	Improved of lipid profiles: Lower TG Reduced expression of obesity-related genes, body weight gains, epididymis fat weights Inhibition of the lipogenic enzymes fatty acid synthase, malic enzyme, and lipoprotein lipase in epididymis adipose tissues Inhibition of glucose-6-phosphate dehydrogenase in the liver	[34]
Obesity	In vivo	4-week-old C57BL/6 J male mice, 14 weeks, traditional Gochujang	Lower body weight, blood leptin, and insulin levels with reduced Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) index Improved serum and liver lipid profiles	[35]
Obesity	In vitro	OP9 pre-adipocyte cells (fat cell), aqueous ethanol extracts of traditional Gochujang	α-glucosidase inhibitory activity and adipogenesis inhibitory activity were 29.6% and 20.8%, respectively Gochujang, p-coumaric acid, N6, N6, N6-trimethyllysine, threonine, and methionine positively correlated with inhibition of adipogenesis activity	[36]

Table 2 (continued)

Functionality	Study types	Consumption/Study description	Health effects of fermented foods	References
Obesity	In vivo	4-week-old C57BL/6 J male mice, 12 weeks, traditional Gochujang	Slightly reduces hyperlipidemia in HD-induced obese mice Gochujang capsaicin-independently activates brown adipose tissue (BAT) with and/or without cold exposure Gochujang activates white adipose tissue (WAT) browning under the cold treatment in HD-induced obese mice	[37]
Obesity	RCT, placebo	Overweight women (n = 53), Gochujang 32 g/day, 12 weeks	Decrease in visceral fat Decrease in serum TG and Apo B	[38]
Obesity	RCT, placebo	Overweight and obese adults (n = 60), High dose of beneficial microbes traditional kochujang (HTK) Low dose of beneficial microbes traditional kochujang (LTK) Commercial kochujang (CK) 25.3 g (powder pills 19 g)/day, 3 weeks	HTK, CK group: decreased of WC HTK, LTK group: decreased of TC, LDL-C, HDL-C, and TG HTK: decreased of visceral fat All group: increased of beneficial microorganisms	[39]
Obesity	RCT, placebo	Overweight women with the PPAR-γ2C1431T polymorphism (n = 53), 32 g/day, 12 weeks	Antiobesity effects	[40]
Diabetic	In vivo	90% pancreatectomies diabetic rats	Regulated blood glucose levels	[41]
Blood pressure	In vitro	Fermented gochujang for 45 days	Inhibited angiotensin-converting enzyme (ACE) activity	[42]
	In vitro	Seventy-three traditional made Gochujang (TMK) samples from different regions in Korea	The specific strains of *B. subtilis* and *B. velezensis* of Gochujang had antioxidant, fibrinolytic, and ACE inhibitory activity	[43]
Antiatherosclerosis	RCT, placebo	Adult with hyperlipidemia (n = 30), Gochujang 35 g/day, 12 weeks	Decreased of TC and LDL-C Increased of HDL-C	[44]
Immune	In vitro	Balb/c mice (RAW 264.7 cell) murine macrophage cell line RAW 264.7 (294 strains isolated from traditional and commercial Gochujang)	Improved of cytokines	[45]
Stress relief	RCT, placebo	Adult with hyperlipidemia (n = 30), 35 g/day, 12 weeks	Stabilized autonomic nervous function Reduced heart rate during breath	[46]
Inflammatory bowel disease (IBD)	In vivo	DSS-Induced Colitis Rat Model, 14 days, Traditional Gochujang	Decreased the serum levels of IL-1β and IL-6 and inhibited TNF-α, IL-6, and IL-1β mRNA expression in the colon Downregulated the expression of iNOS and COX-2 and decreased the activation of NF-κB in the colon Modulation in gut microbiota significantly increased the number of *Akkermansia muciniphila* while decreasing the numbers of *Enterococcus faecalis* and *Staphylococcus sciuri* Prevented DSS-induced colitis in rats by modulating inflammatory factors and the composition of gut microflora	[47]

AGS, a human gastric adenocarcinoma cell line; ICR, Institute of Cancer Research; TG, thyroglobulin; AQO, aquaporin; OP9, macrophage-derived cell line; LDL-C, low-density lipoprotein-cholesterol; HDL-C, High-density lipoprotein-cholesterol; TNF, tumor necrosis factor; IL, interleukin; COX, cyclooxygenase; iNOS, inducible nitric oxide synthase; DSS, dextran sulfate sodium; RCT, randomized controlled trials

to function differently compared to regular table salt. Reports have shown that despite its saltiness, *Gochujang* mitigates colitis symptoms, indicating an anti-inflammatory effect distinct from that of salt alone. In animal models of DSS-induced colitis, *Gochujang* administration effectively suppressed intestinal inflammation. This was evident through improvements in the disease activity index (DAI), colon weight/length ratio, and colon histomorphology [45]. These observations suggest that *Gochujang* can counteract large intestine inflammation despite its high salt concentration. Notably, key inflammation-related cytokines like TNF-α, IL-1β, and IL-6 were notably reduced in serum and colonic tissues after *Gochujang* consumption, indicating its potent anti-inflammatory properties [45]. These observed effects are attributed to the presence of bioactive components in *Gochujang*, particularly genistein and daidzein from fermented soybeans (*Meju*), which are known to reduce inflammatory cytokines [68–70]. Further, the relationship between gut microbiota and human diseases, including colonic inflammation, is gaining global attention [71]. Multiple reports suggest that the potential positive impact of *Gochujang* on gut microbial composition is significant. It not only increases the beneficial *Akkermansia muciniphila* but also decreases *Enterococcus faecalis* and *Staphylococcus sciuri*, enhancing intestinal microflora regulation [45]. However, these observations contradict the reports where high-salt diets are associated with reduced intestinal microbial diversity and exacerbate colitis (72). Additionally, *Gochujang*'s influence on the gut microbiota extends to maintaining diversity, unlike the same amount of salt in other forms. Specifically, *Gochujang* does not significantly increase *Bacteroidetes* associated with colitis risk. However, soy-derived isoflavones such as genistein and daidzein positively regulate the gut flora composition (73). Still, it is essential to note that protective effects against inflammation may vary depending on the ingredients used and preparation methods. Collectively, *Gochujang*'s role in managing colonic inflammation and enhancing gut health is multifaceted, and incorporating *Gochujang* as part of a balanced, anti-inflammatory diet potentially beneficial to individuals dealing with inflammatory conditions. The presence of unique bioactive compounds contributes to its anti-inflammatory properties and positive impact on gut microbiota.

The role of *Gochujang* in stress management and immune activation

Gochujang is a household name in Korean cuisine. Certain compounds of *Gochujang* have the potential to activate the immune system and facilitate stress management. Previously, Capsaicin has been investigated for its potential to alleviate stress [60, 61]. It can enhance the secretion of endorphins [62], which are considered body's innate hormones responsible for promoting positive emotions and reducing stress, consequently promoting a feeling of well-being. Furthermore, autonomic nervous system (ANS) in humans acts like a sophisticated computer, autonomously regulating various bodily processes. It is broadly divided into two components: the sympathetic nervous system, which is active during exercise, stress, or fear, and the parasympathetic nervous system, more prominent during sleep. These systems work in tandem to maintain homeostasis under normal conditions. However, when the ANS malfunctions, it impacts the body's response to external stimuli, often manifesting as altered heart rate variability. Clinical assessment of ANS health involves observing changes in heart rate, particularly during specific activities like the Valsalva maneuver, repetitive deep breathing exercises, and evaluating blood pressure variations in different postures. These tests are crucial in evaluating parasympathetic function [63]. Stress-induced activation of the sympathetic nervous system elevates levels of catecholamine, an oxidative stress hormone, which has been linked to promoting tumor cell growth [64]. In this context, a study observed the effects of consuming 35 g of *Gochujang* pills daily for 12 weeks in hyperlipidemic patients [44]. The findings indicated a positive impact on ANS function, attributed to the stress-regulating properties of *Gochujang*. Specifically, the paste was noted to stabilize breathing patterns by reducing the heart rate difference during inhalation and exhalation in repetitive deep breathing exercises [43]. This significant result implies that regular intake of *Gochujang* could aid in stress management and potentially lower the risk of coronary artery diseases. It regulates the concentration of immune cytokines in spleen cells and enhances the activity of natural killer cells, thereby contributing to an overall boost in immune function [43]. Moreover, emerging investigations suggest a strong connection between the gut and the brain. A balanced and diverse gut microbiota is linked to an enhanced ability to deal with stress and improved mental health [65]. Also, bioactive compounds produced during fermentation may contribute to immune activation [66]. Collectively, *Gochujang* and its metabolites facilitates immune activation and stress management.

Anticancer effect of *Gochujang*

The efficacy of *Gochujang* in preventing cancer and inhibiting the spread of tumors depends on the preparation methods. Anticancer effects are generally believed to be more potent with increasing fermentation time. Recent investigations have highlighted the significant role of fermentation in enhancing the anticancer properties of *Gochujang*

[29]. Notably, traditional *Gochujang* fermented for an extended period of fermentation and maturation showed higher anticancer activities than commercially fermented and non-fermented *Gochujang* [27–30, 49–51]. The fermentation process, during which wheat utilized in the initial stages is gradually substituted with fermented wheat utilized in the final stages, is crucial in enhancing the *Gochujang* antimutagenic and anticancer properties. This enhancement in anticancer properties is not solely attributed to the inherent compounds of *Gochujang*, such as capsaicin, vitamin C, and β-carotene, but also to the metabolites produced by microorganisms during fermentation. Further, pre-clinical studies have demonstrated that *Gochujang*, prepared by fermenting for extended periods [15–30 days], shows increased efficacy against various cancer cell lines, including stomach, colon, lung, cervical, and liver cancers [30]. The inhibition of tumor metastasis and formation was significantly higher in traditional *Gochujang* fermented for six months compared to industrially fermented or unfermented variants [51]. It is hypothesized that the heightened anticancer effect in traditional *Gochujang* is due to the interaction between the fermentation microorganisms and the ingredients of *Gochujang*, including starch substances and fermented soybean (*Meju*) [27, 31]. Therefore, the fermentation period and ingredients used to prepare *Gochujang* are crucial in defining its anticancer properties.

Influence of *Gochujang* on obesity and blood glucose levels

Traditionally, *Gochujang* is believed to have antiobesity and antidiabetic effects. Recent investigations offered evidence for these beliefs, shedding light on the substantial health benefits of *Gochujang*, particularly in managing obesity, metabolic syndrome, and diabetes. Capsaicin, a key component found in red peppers, stimulates the spinal cord and promotes the secretion of adrenal hormones [34, 52–54]. These adrenal hormones play a significant role in enhancing metabolic activity. Specifically, capsaicin in *Gochujang* aids in the breakdown of glycogen and fat cells stored in the liver for energy. Notably, capsaicin's ability to enhance beta-adrenergic activity in brown adipose tissue has been associated with reduced body fat [55]. Further, multiple studies suggest that traditionally produced *Gochujang* has a greater antiobesity and antidiabetic effects than commercial and non-fermented *Gochujang* [52, 56]. Here, activity against obesity could be due to the synergistic effect of the non-glycoside isoflavones of *Meju*, the capsaicinoid component of red pepper, and metabolites produced during fermentation [57]. Capsaicin potentially lowered body fat, while secondary metabolites of *Gochujang* may have influenced energy and glucose metabolism. Still, *Gochujang*'s auxiliary components might be crucial to obesity prevention. However, extended investigations are necessary to unwind the potential benefits of *Gochujang* and its auxiliary components.

Gochujang, produced with rice yeast, lowered obesity much more than *Gochujang* made with white yeast [58]. Also, *Gochujang* prepared with giant Baeami rice yeast, red pepper powder, and *Meju* fermented with yeast demonstrated a greater antiobesity effect than *Gochujang* made with Tabasco hot sauce [59]. These observations suggest the significance of ingredients used throughout the preparation of *Gochujang* in determining health benefits. The impact of *Gochujang* extends to combating metabolic syndrome, a condition often exacerbated by high-fat and high-salt diets. In support, HFD-induced obese mice showed that the administration of traditional fermented *Gochujang* for 14 weeks significantly improved antiobesity effects and metabolic syndrome factors [35]. The traditional *Gochujang* supplemented group exhibited lowered body weight, blood leptin, insulin levels, and improved serum and liver lipid profiles. Additionally, they showed decreased expression of mRNA associated with fat metabolism, an effect not observed in the high-salt (SALT) group, indicating the unique benefits of *Gochujang* over mere salt supplementation. Recent research has shown [37] that traditional *Gochujang,* activates brown adipose tissue (BAT) and increases proteins associated with BAT activation under normal conditions. It particularly activates BAT and promotes the conversion of white adipose tissue (WAT) to a brown fat-like state, significantly enhancing thermogenesis (heat production) in cold environments. In contrast, high doses of capsaicin (a compound found in chili peppers) moderately activate BAT but do not effectively convert WAT to brown fat in cold environments. Low doses of capsaicin do not affect the browning of WAT when exposed to cold and only increase proteins related to BAT activation. These findings suggest that the beneficial effects of *Gochujang* on BAT activation and WAT browning are independent of capsaicin. Moreover, a clinical trial involving obese adults demonstrated a reduced risk of cardiovascular disease following the consumption of 32 g of *Gochujang* daily for 12 weeks [38]. In addition, the consumption regimen reduced abdominal visceral fat and the ratio of visceral to subcutaneous fat more effectively than a placebo [38].

Interestingly, supplementation with traditional *Gochujang* significantly reduced waist circumference, cholesterol, and triglyceride levels than commercial *Gochujang* in clinical trials [39]. Additionally, a notable reduction in visceral fat and an increase in beneficial gut microorganisms was observed with traditional *Gochujang* supplementation. Furthermore, administration of *Gochujang*

(5% *Gochujang* powder) improved insulin sensitivity and blood glucose tolerance in diabetic animal models showing insulin resistance [41]. Obese adults with mutations in the proliferator activator receptor-γ (PPARγ2) gene showed improved insulin sensitivity and better regulation of blood glucose levels upon consuming *Gochujang* [40]. Together, *Gochujang* significantly regulates obesity and blood glucose levels, but its efficiency depends on the ingredients used during preparation and reparation methods.

Antihypertensive, antithrombotic, blood lipid improvement effects of *Gochujang*

The specific investigations associated with *Gochujang* and antihypertensive effects are limited. However, the consumption of *Gochujang* known to inhibit the angiotensin-converting enzyme (ACE) involved in regulation of blood pressure [42]. In addition, *Gochujang* intake demonstrated improved thrombolysis and inhibited platelet aggregation [42, 45]. These observations validate the critical role of *Gochujang* in management of hypertension. Similar to its effect on other functions, traditionally prepared *Gochujang* has a greater influence on lipid metabolism than non-fermented *Gochujang*. It is believed that capsaicin in *Gochujang* positively influence energy and lipid metabolism by increasing catecholamine secretion from the adrenal medulla through activation of the sympathetic nervous system (SNS) [60]. Clinically, *Gochujang* intake effectively reduced obesity [61], hyperlipidemia [44], and blood TC and LDL-C concentrations. Together, the consumption of *Gochujang* over a long period potentially prevents and manages cardiovascular diseases.

Role of *Gochujang* in liver health

Traditional fermented *Gochujang*, is increasingly recognized for its positive impact on liver inflammation and associated intestinal microbiome dysbiosis, especially with fatty inflammation. Recently, a study investigated the preventative effects of *Gochujang* on hepatic inflammation and related gut microbiota using a high content of beneficial bacteria (HBM) and a diverse group of microorganisms (DBM). Here, the study demonstrated that *Gochujang* suppresses fat accumulation, alleviates hyperlipidemia, and reduces liver inflammatory parameters by inhibiting the JNK/IκB/NF-κB pathway, a critical pathway in inflammation and stress responses [33]. Further, the imbalance in gut microbiota induced by a high-fat diet is closely linked with hepatic inflammation [62]. Interestingly, *Gochujang* positively influences microbiome dysbiosis caused by a high-fat diet [33]. Besides, intestinal microbiome dysbiosis potentially leads to abnormal fat accumulation, increasing lipopolysaccharide (LPS), and inflammatory cytokines, which in turn cause liver inflammation. However, study observations indicated reduced LPS production and favorably adjusted the *Bacteroidetes*-to-*Firmicutes* ratio. Together, the study suggested that the changes in the intestinal microorganisms brought by *Gochujang* consumption correlate significantly with the improvement in liver inflammation [33]. In addition, these results suggest that the salt content in *Gochujang* does not detract from its anti-inflammatory effects.

The probiotic and prebiotic functions of *Gochujang*

As interest in health increases, research and commercialization of probiotics, prebiotics, and synbiotics are actively progressing. Probiotics primarily maintain gut health by inhibiting harmful bacteria and promoting beneficial ones, preventing conditions like diarrhea and constipation. They also offer health benefits such as antidiabetic, antiobesity, anti-inflammatory, anticancer, and antiallergy effects [63]. Prebiotics, non-digestible food ingredients, selectively ferment to alter gut microbiota composition and activity, producing short-chain fatty acids (SCFAs) like lactic acid, butyric acid, and propionic acid [64]. These SCFAs can circulate throughout the body, impacting various organs and tissues [65]. Synbiotics combine probiotics and prebiotics, where the prebiotics selectively promote the growth of the probiotics within the same product. Traditional *Gochujang* offers significant health benefits due to its synbiotic properties, combining prebiotics and probiotics that enhance gut health. The carbohydrates in glutinous rice break down into simple sugars during fermentation, feeding beneficial gut bacteria. *Meju* powder, rich in oligosaccharides like raffinose and stachyose, promotes the growth of these bacteria and aids in protein breakdown into peptides and amino acids, improving nutrient absorption and gut health. Capsaicin in chili peppers has anti-inflammatory properties and positively influences gut microbiota, contributing to a healthier digestive system. The fermentation process of *Gochujang* promotes the growth of various probiotics like lactic acid bacteria (LAB) and molds. *Lactobacillus spp*., commonly found in fermented foods, play a crucial role in maintaining gut health by producing lactic acid, which lowers gut pH and inhibits harmful bacteria. These bacteria also aid digestion and strengthen the immune system [45]. *Bifidobacterium* species further enhance digestive health and immunity by breaking down complex carbohydrates and fibers into beneficial SCFAs that support gut health. The synbiotic properties of *Gochujang* stem from its rich blend of prebiotic ingredients and probiotic microorganisms, which enhance gut health. The carbohydrates from glutinous rice and oligosaccharides from fermented soybeans serve as food for beneficial bacteria. Meanwhile, the fermentation process

of *Gochujang* promotes the growth of probiotics like *Lactobacillus* and *Bifidobacterium*. This combination fosters a healthy gut microbiome, improves nutrient absorption, reduces inflammation, and strengthens the immune system, making *Gochujang* not only a flavorful addition to meals but also a functional food with significant health benefits.

Type of cuisine using *Gochujang*

Gochujang is a unique fermented spice seasoning that is unprecedented in the world and can be used in a variety of foods to impart spicy taste and special flavor. *Gochujang,* with its unique taste and aroma, is one of the key ingredients that differentiates Korean cuisine and makes it more delicious. Korean food has captivated many, including foreigners. Post-COVID-19, there has been a significant rise in YouTube content and demand for K-Food like bulgogi, tteokbokki, kimchi, and galbi [66]. *Gochujnag* is a type of sauce and has similar physical properties and appearance to mayonnaise and ketchup, but its color, taste, and aroma are quite different, and in particular, the umami taste created during the fermentation process of *Gochujang* based on soybean. Popular K-Foods using gochujang sauce include bibimbap, tteokbokki, dakdoritang, dakgalbi, bulgogi, maeuntang, and ssam dishes (Fig. 1). The global popularity of K-Food, driven by its health benefits and social media exposure, has particularly boosted consumption of dishes like bibimbap. While bibimbap's health benefits are known, tteokbokki's are still being explored. Representative Korean cuisine and cooking methods using *Gochujang* are as follows.

Bibimbap

It is a representative Korean cuisine. *Bibimbap* is made by mixing well-boiled rice (*Bab*) with a variety of spices and vegetables, including *Gochujang*, adding cooked meat (mainly beef), eggs, sesame oil, and sesame seeds, then mixing them evenly and rub by spoon [67]. The combination can vary depending on preference taste, but *Gochujang* is an essential seasoning.

Several studies have shown bibimbap's health benefits, including improved immunity in animal experiments compared to a hamburger diet. In humans, those at risk of metabolic diseases who consumed a Korean diet including bibimbap and kimbap showed lower blood glucose and insulin levels, and significantly reduced postmeal triglycerides compared to those on a Western diet [68]. The differences were more pronounced in at-risk individuals, suggesting bibimbap as a recommended meal for both healthy individuals and those at risk of metabolic diseases. Recent studies on five types of bibimbap with various vegetables show significant health benefits [69]. Sanchae bibimbap increased B, T, and TH lymphocytes, IFN-γ secretion, and erythrocyte agglutination. For systemic anaphylaxis, mushroom bulgogi and Jeonju bibimbap reduced mortality rates by 50% and 25%, respectively, and extended survival time. Sanchae bibimbap inhibited footpad swelling by over 50%, indicating strong antiallergic effects. These findings highlight bibimbap's potential in boosting immunity and reducing allergic reactions.

Tteokbokki

Tteokbokki, made with sauces based on traditional Korean *Gochujang*, uses rice or wheat starch as the main ingredient for its rice cakes [70]. Garaetteok (thick noodles made from rice) and various seasonings, including *Gochujang*, are mixed together, boiled over mild heat, and various seasonings can be added as needed. It is a unique delicacy cuisine in Korea. Known for its simple preparation, it is accessible to all age groups and supports increased rice consumption and the globalization of Korean cuisine. The growing interest and demand for tteokbokki have led to diverse products based on ingredients, sauces, shapes, and cooking methods. Concurrently, consumer purchases of tteokbokki sauces and various Korean sauces and dressings are rising, meeting the demand for convenient meals.

Dakdoritang

Dakdoritang, also known as spicy chicken stew, is a traditional Korean dish featuring chicken pieces braised with vegetables in a spicy sauce. The key ingredients include chicken pieces, potatoes, carrots, and onions, all simmered in a sauce made from *Gochujang* (Korean red chili paste), pepper powder, soy sauce, garlic, and ginger. This dish is known for its rich, bold flavors and is often enjoyed as a hearty, warming meal. The spicy and slightly sweet sauce is absorbed by the tender chicken and vegetables, making it a favorite in Korean cuisine.

Dakgalbi

Dakgalbi is a popular Korean dish consisting of spicy stir-fried chicken marinated in a sauce made from *Gochujang*, garlic, soy sauce, and various spices. The chicken is usually combined with vegetables such as cabbage, sweet potatoes, carrots, and onions, along with rice cakes (tteok) and sometimes cheese. It's cooked on a large, flat griddle or pan and often enjoyed communally, directly from the cooking vessel. Dakgalbi is known for its bold, savory, and spicy flavors, making it a favorite in Korean cuisine.

Maeuntang

Maeuntang is a traditional Korean spicy fish stew known for its bold and flavorful broth. It typically features a

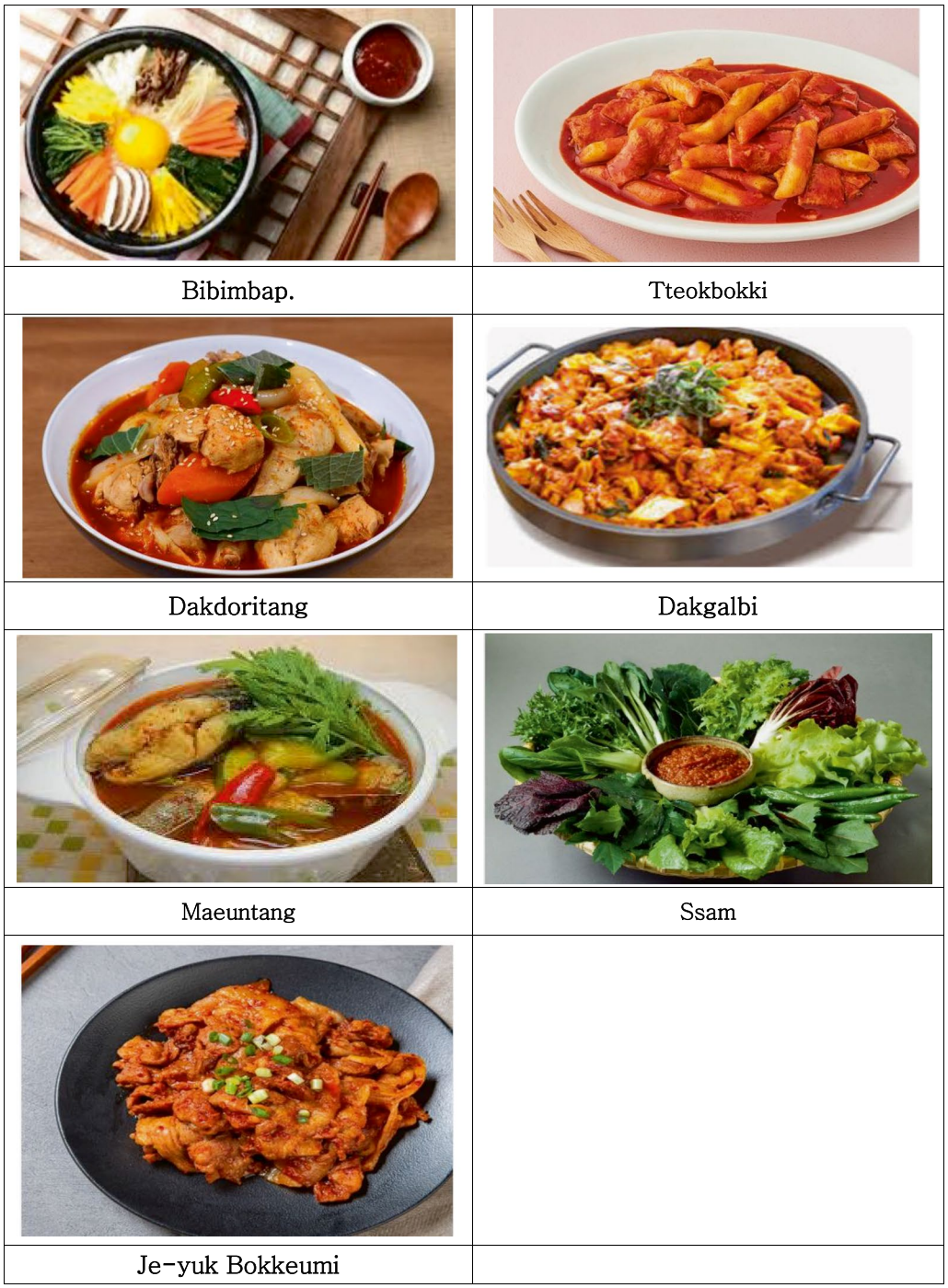

Fig. 1 Dishes made with Gochujang

variety of fresh fish, such as cod, pollock, or sea bass, cooked with vegetables like radish, napa cabbage, and bean sprouts. The broth is seasoned with *Gochujang*, pepper powder, garlic, and soy sauce, creating a rich and spicy flavor. Maeuntang is often garnished with green onions, mushrooms, and tofu, and is commonly enjoyed with rice. It's a popular dish in Korean cuisine, especially during colder months.

Je-yuk Bokkeum

Je-yuk Bokkeum is a popular Korean dish made from thinly sliced pork stir-fried in a spicy sauce. The sauce

typically includes *Gochujang*, soy sauce, garlic, ginger, sugar, and sesame oil. Vegetables such as onions, carrots, and bell peppers are often added to the dish. Je-yuk Bokkeum is known for its bold, spicy, and slightly sweet flavors. It is usually served with steamed rice and various side dishes (banchan), making it a hearty and flavorful meal.

Bulgogi

Bulgogi is a Korean dish featuring thinly sliced pork(beef) marinated in a sauce made from *Gochujang*, soy sauce, sugar, garlic, and sesame oil. The pork(beef) is typically stir-fried with vegetables like onions, carrots, and bell peppers. This dish combines savory, sweet, and spicy flavors, creating a deliciously balanced taste. *Gochujang* bulgogi is often served with rice, making it a popular and satisfying meal in Korean cuisine.

Ssam

Ssam [66] is a traditional Korean dish where leafy vegetables, typically lettuce or perilla leaves, are used to wrap various fillings. The fillings often include grilled meats such as bulgogi (marinated beef) or pork, rice, kimchi, and condiments like ssamjang (a thick, spicy paste made from *Doenjang* and *Gochujang*). The wrap is folded into a bite-sized bundle and eaten whole. Ssam is popular for its customizable nature and the combination of flavors and textures, making it a staple in Korean barbecue meals. Ssamjang is a sauce used for wrapping vegetables (ssam). It is a mixture of *Doenjang* (soybean paste) and *Gochujang* (red chili paste). Factory-made ssamjang combines sweeteners, garlic, salt, flour, and sesame oil, while traditional ssamjang blends doenjang or makjang with *Gochujang*, garlic, ginger, pepper, and sesame oil.

Chojang and Wasabi sauce

Chojang (*Gochujang*) mixed with vinegar, chopped garlic, sugar, and other seasonings [16]. This spicy yet sweet and sour sauce is usually served with sliced raw fish, but it is also used in spicy noodle dishes and vegetable salads. Wasabi sauce is a creamy condiment made from wasabi root, providing a sharp, pungent heat. It is commonly used to enhance the flavor of sushi, sashimi, and seafood dishes, adding a spicy kick. The sauce is also popular in dressings, dips, and as a flavoring for various Japanese and fusion dishes. The characteristics and differences between Chojang and Wasabi sauce are compared and presented in Table 3. Chojang and Wasabi sauce are distinct in their origins, ingredients, flavors, textures, and culinary applications, offering unique tastes and experiences in Korean and Japanese cuisines, respectively.

Conclusion

Traditional fermented foods are historically associated with the seasons, geographical locations, and locally produced ingredients of particular regions. While numerous fermented foods exist worldwide, only a few are traditionally known for their health benefits. *Gochujang*, a traditional Korean fermented food primarily made from soybeans, exhibits a complex and distinctive microbial

Table 3 Comparison of Chojang and Wasabi Sauce

Characteristic	Chojang	Wasabi Sauce
Image		
Origin	Korea	Japan
Main ingredients	Gochujang (red chili paste), vinegar, sugar, garlic	Wasabi root, sometimes with horseradish, vinegar, and mustard
Flavor profile (Spicy)	Capsaicin (Spicy, sweet, tangy)	Sinigrin (Sharp, pungent, quick heat)
Texture	Thick, paste-like	Smooth, creamy
Common uses	Dipping sauce for raw fish, vegetables, bibimbap	Accompaniment to sushi, sashimi, seafood, dressings
Making method	Depending on preference and method It is made by mixing main ingredients with auxiliary ingredients	Fresh wasabi rhizome is grated to form a paste, or horseradish is ground and mixed with mustard powder and other ingredients

profile. These microbial changes often positively influence well-being. In addition to its nutritious value, *Gochujang* offers a harmonious blend of spicy, sweet, and salty flavors, embodying both probiotic and prebiotic properties. Thus, *Gochujang* can be considered a symbiotic food, combining the characteristics of probiotics and prebiotics. Research has increasingly shown that *Gochujang* provides a range of health benefits, primarily due to its ability to modify gut microbiota composition and address microbiome dysbiosis related to diseases. Comprehensive investigations and comparative studies have demonstrated that the physiological activities of traditionally prepared *Gochujang* greatly exceed those of unfermented *Gochujang* and red pepper powder. However, there are inconsistencies in health functions between traditionally fermented *Gochujang* and commercially manufactured *Gochujang*, attributable to differences in fermentation periods and the compounds used in their preparation. To strengthen the identified health benefits, future research must delve deeper into the functionality of *Gochujang*. Further scientific investigations by the global community can enhance understanding and appreciation of traditional foods like *Gochujang*, along with their culinary applications. Modern science and technology should be utilized to disseminate information and experiences regarding the benefits of traditional cuisine more effectively. Preserving the cultural heritage of *Gochujang* is our responsibility, ensuring its legacy and benefits are passed down to future generations.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42779-024-00258-y.

Additional file 1.

Acknowledgements
Not applicable.

Author contributions
SJJ collected data and prepared, reviewed, and edited the manuscript. DHS provided the main concept, reviewed and edited the manuscript, and supervised. All authors read and approved the final manuscript. These authors contributed equally to this work.

Funding
This research was funded by 'Functional identification of Korean traditional soybean products (safety monitoring) project' under the Ministry of Agriculture, Food and Rural Affairs and partly Korea Agro-Fisheries and Food trade corporation in 2023.

Availability of data and materials
Not applicable on 'Gochujang, A Korean traditional fermented soybean product: History, preparation and functionality.'

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
The authors have agreed to the publication of this manuscript.

Competing interests
The authors declare no competing interests.

Received: 31 December 2023 Accepted: 10 September 2024
Published online: 24 October 2024

References

1. Tamang JP, Cotter PD, Endo A, Han NS, Kort R, Liu SQ, et al. Fermented foods in a global age: east meets west. Comprehens Rev Food Sci Food Safety. 2020;19(1):184–217.
2. Shin DH, Kim YM, Park WS, Kim JH. Ethnic fermented foods and beverages of Korea. In: Tamang JP, editor. Ethnic fermented foods and alcoholic beverages of Asia. New Delhi: Springer; 2016. p. 263–308. https://doi.org/10.1007/978-81-322-2800-4_11.
3. Lee C-H. A history of Korean Food Seoul: Sikanyeon; 2021.
4. Tamang JP, Holzapfel WH, Shin DH, Felis GE. Editorial: microbiology of ethnic fermented foods and alcoholic beverages of the world. Front Microbiol. 2017. https://doi.org/10.3389/fmicb.2017.01377.
5. Shin DH, Jung SJ. 16 Korean Traditional Fermented Soybean Foods and Their Functionalities. Phytochemicals in Soybeans: Bioactivity and Health Benefits; 2022:359.
6. Kim S-H, Ko J, Kwon DY. Jang, Korean fermented soybean product, the result of endeavors of ancients for the best taste of Korean diet. J Ethnic Foods. 2023;10(1):33.
7. Shin DH, Kwon DY, Kim YS, Jeong DY. Seicence and technology of Gochujang. Seoul: Public Healthy Edu; 2012.
8. Lee C-H. Soybean Sauce Culture on the Korean Peninsula. Korean food and foodways: the root of health functional food. Berlin: Springer; 2022. p. 139–55.
9. Bae M, Lee S. Study on history and quality evaluation of various hot peppers. J Kor Living Sci. 1984;1:187–202.
10. Kim S, Park J, Yeom S-I, Kim Y-M, Seo E, Kim K-T, et al. Multiple reference genome sequences of hot pepper reveal the massive evolution of plant disease resistance genes by retroduplication. bioRxiv. 2017:115410.
11. Carrizo García C, Barfuss MH, Sehr EM, Barboza GE, Samuel R, Moscone EA, et al. Phylogenetic relationships, diversification and expansion of chili peppers (Capsicum, Solanaceae). Ann Bot. 2016;118(1):35–51.
12. Tripodi P, Rabanus-Wallace MT, Barchi L, Kale S, Esposito S, Acquadro A, et al. Global range expansion history of pepper (Capsicum spp.) revealed by over 10,000 genebank accessions. Proceedings of the National Academy of Sciences. 2021;118(34):e2104315118.
13. Kwon DY. Story of red pepper. Seoul: Hyoll Korea; 2011.
14. Kwon DY, Soon-Hee K, Chung KR, Daily JW, Park S. Science and philosophy of Korea traditional foods (K-food). J Ethnic Foods. 2023;10(1):26.
15. Park J. Red pepper and Kimchi in Korea. Chile Pepper Inst Newsl. 1999;8:1–8.
16. Shin DH, Kwon DY, Nam YK, DY J. Overview of Korean Jang(Fermented soybean products) manufacturing Seoul: Korea Jang Cooperative; 2023.
17. Shin DH. Utilization of soybean as food stuffs in Korea. Soybean and Nutrition London: IntechOpen. 2011:81–110.
18. Kim DH. Food chemistry (9th Revised). Seoul: Tamgudang; 1994.
19. C.H C. Science of Pungency. Food Journal. 2001:38–40.
20. Nam YD, Sl P, Lim SI. Microbial composition of the Korean traditional food "kochujang" analyzed by a massive sequencing technique. J Food Sci. 2012;77(4):M250–6.
21. Park KY. Science and functionality of fermented soybean products, Korea Jang Cooperation (pp. 105–130). Korea: CRC Press. 2009.

22. Ryu MS, Shin M-J, Yang H-J, Jeong D-Y, Uhm T-B. Changes in bacterial communities during the aging of traditional Gochujang, a Korean fermented red pepper paste. 미생물학회지. 2022;58(3):169–78.
23. Kwon DY, Chung KR, Yang H-J, Jang D-J. Gochujang (Korean red pepper paste): a Korean ethnic sauce, its role and history. J Ethnic Foods. 2015;2(1):29–35.
24. Hamed M, Kalita D, Bartolo ME, Jayanty SS. Capsaicinoids, polyphenols and antioxidant activities of capsicum annuum: comparative study of the effect of ripening stage and cooking methods. Antioxidants. 2019;8(9):364. https://doi.org/10.3390/antiox8090364.
25. Chen L, Kang Y-H. Anti-inflammatory and antioxidant activities of red pepper (Capsicum annuum L.) stalk extracts: comparison of pericarp and placenta extracts. J Funct Foods. 2013;5(4):1724–31.
26. Szallasi A. Capsaicin and cancer: guilty as charged or innocent until proven guilty? Temperature. 2023;10(1):35–49. https://doi.org/10.1080/23328940.2021.2017735.
27. Kim S-J, Jung K-O. In vitro anticancer effect of kochujang (Korean red pepper soybean paste) and its ingredients in AGS human gastric cancer cells. 2004.
28. Song H-S, Kim Y-M, Lee K-T. Antioxidant and anticancer activities of traditional Kochujang added with garlic porridge. J Life Sci. 2008;18(8):1140–6.
29. Chung K, Yoon K, Kwon D, Hong S, Choi S. Cytotoxicity testing of fermented soybean products with various tumour cells using MTT assay. Kor J Appl Microbiol Biotechnol. 1997;28:239–41.
30. Kim J-Y, Liu F-F, Lim Y-I, Park K-Y. Fermentation process increased antimutagenic and in vitro anticancer effects during Kochujang manufacturing. Kor J Food Preserv. 2014;21(6):878–84.
31. Kim N-Y, Kim K-A, Yang H-J, Jeong S-J, Han A, Cha Y-S. Comparison of the laxative effects of Korean Gochujang containing different microbiota on loperamide-induced constipation in ICR mice. Food Funct. 2023;14(16):7615–30.
32. Jung SJ, Jang HY, Lee SO, Chae SW. 4-week, randomized, double-blind human application trial to evaluate the effectiveness and safety of fermented red pepper (red pepper paste powder) in improving intestinal flora and bowel movements. Jeonju, Republic of Korea: Clinical Trial Center for Functional Food, Jeonbuk National University Hospital; 2023. p. 1–94.
33. Lee E-J, Edward OC, Seo E-B, Mun E-G, Jeong S-J, Ha G, et al. Gochujang ameliorates hepatic inflammation by improving dysbiosis of gut microbiota in high-fat diet-induced obese mice. Microorganisms. 2023;11(4):911.
34. Shin H, Jang E, Moon B, Lee J, Lee D, Lee C, et al. Anti-obesity effects of gochujang products prepared using rice koji and soybean meju in rats. J Food Sci Technol. 2016;53:1004–13.
35. Edward OC, Lee EJ, Han A, Mun E-G, Yang H-J, Kim J-W, et al. Gochujang consumption prevents metabolic syndrome in a high-fat diet induced obese mouse model. J Med Food. 2023;26(4):244–54.
36. Yang HJ, Kim MJ, Kim KS, Lee JE, Hong SP. In vitro antidiabetic and antiobesity activities of traditional kochujang and doenjang and their components. Preventive Nutrition Food Sci. 2019;24(3):274.
37. Lee H, Song J, Chung S, Cha Y-S, Han A. Gochujang elicits anti-obesity effects by increasing capsaicin-independent brown adipogenesis and thermogenesis in high-fat diet induced obese mice. J Funct Foods. 2023;111: 105886.
38. Cha Y-S, Kim S-R, Yang J-A, Back H-I, Kim M-G, Jung S-J, et al. Kochujang, fermented soybean-based red pepper paste, decreases visceral fat and improves blood lipid profiles in overweight adults. Nutr Metab. 2013;10:1–8.
39. Han AL, Jeong S-J, Ryu M-S, Yang H-J, Jeong D-Y, Park D-S, et al. Anti-obesity effects of traditional and commercial Kochujang in overweight and obese adults: a randomized controlled trial. Nutrients. 2022;14(14):2783.
40. Lee Y, Cha Y-S, Park Y, Lee M. PPARγ2 C1431T polymorphism interacts with the antiobesogenic effects of Kochujang, a Korean fermented, soybean-based red pepper paste, in overweight/obese subjects: a 12-week, double-blind randomized clinical trial. J Med Food. 2017;20(6):610–7.
41. Kwon DY, Hong SM, Ahn IS, Kim YS, Shin DW, Park S. Kochujang, a Korean fermented red pepper plus soybean paste, improves glucose homeostasis in 90% pancreatectomized diabetic rats. Nutrition. 2009;25(7–8):790–9.
42. Choi S-Y, Cho G-H, Lim S-I. Effects of functional ingredients addition on quality characteristics of Kochujang. Kor J Food Sci Technol. 2006;38(6):779–84.
43. Ha G, Yang H-J, Ryu M-S, Jeong S-J, Jeong D-Y, Park S. Bacterial community and anti-cerebrovascular disease-related bacillus species isolated from traditionally made Kochujang from different provinces of Korea. Microorganisms. 2021;9(11):2238.
44. Lim J-H, Jung E-S, Choi E-K, Jeong D-Y, Jo S-W, Jin J-H, et al. Supplementation with Aspergillus oryzae-fermented kochujang lowers serum cholesterol in subjects with hyperlipidemia. Clin Nutr. 2015;34(3):383–7.
45. Seo M-Y, Kim S-H, Lee C-H, Cha S-K. Fibrinolytic, immunostimulating, and cytotoxic activities of microbial strains isolated from Kochujang. Kor J Food Sci Technol. 2007;39(3):315–22.
46. Im J. The effect of Kochujang pills on blood lipids profiles in hyperlipidemia subjects: a 12 weeks, randomized, double-blind, placebo-controlled clinical trial. Master's thesis, Jeonju, Chonbuk National University[Google Scholar]. 2013.
47. Mahoro P, Moon H-J, Yang H-J, Kim K-A, Cha Y-S. Protective effect of gochujang on inflammation in a DSS-induced colitis rat model. Foods. 2021;10(5):1072.
48. Li G, Lin J, Zhang C, Gao H, Lu H, Gao X, et al. Microbiota metabolite butyrate constrains neutrophil functions and ameliorates mucosal inflammation in inflammatory bowel disease. Gut microbes. 2021;13(1):1968257.
49. Oh Y-S, Baek J-W, Park K-Y, Hwang J-H, Lim S-B. Physicochemical and functional properties of Kochujang with broccoli leaf powder. J Kor Soc Food Sci Nutrit. 2013;42(5):675–81.
50. Cui C-B, Oh S-W, Lee D-S, Ham S. Effects of the biological activities of ethanol extract from Korean traditional Kochujang added with sea tangle (Laminaria longissima). Kor J Food Preserv. 2002;9(1):1–7.
51. Park K-Y, Kong K-R, Jung K-O, Rhee S-H. Inhibitory effects of Kochujang extracts on the tumor formation and lung metastasis in mice. J Food Sci Nutrit. 2001;6(3):187–91.
52. Choo J. Body-fat suppressive effects of capsaicin through β-adrenergic stimulation in rats fed a high-fat diet. Kor J Nutr. 1999;32:533–9.
53. Choo J. Anti-obesity effects of Kochujang in rats fed on a high-fat diet. Korean J Nutr. 2000;33(33):787–93.
54. Koo B-S, Seong S-H, Kown D-Y, Sohn H-S, Cha Y-S. Fermented Kochujang supplement shows anti-obesity effects by controlling lipid metabolism in C57BL/6J mice fed high fat diet. Food Sci Biotechnol. 2008;17(2):336–42.
55. Koh J-B. Effects of cheonggukjang added Phellinus linteus on lipid metabolism in hyperlipidemic rats. J Kor Soc Food Sci Nutr. 2006;35(4):410–5.
56. Rhee S, Kong K, Jung K, Park K. Decreasing effect of kochujang on body weight and lipid levels of adipose tissues and serum in rats fed a high-fat diet. Journal of the Korean Soceity of Food Science and Nutrition. 2003.
57. Kim J. Antiobestic and cancer preventive effects of Kochujang: Pusan National University Busan, Republic of Korea; 2004.
58. Son HK, Shin HW, Jang ES, Moon BS, Lee CH, Lee JJ. Gochujang prepared using rice and wheat koji partially alleviates high-fat diet-induced obesity in rats. Food Sci Nutr. 2020;8(3):1562–74.
59. Son H-K, Shin H-W, Jang E-S, Moon B-S, Lee C-H, Lee J-J. Comparison of Antiobesity effects between Gochujangs produced using different Koji products and Tabasco hot sauce in rats fed a high-fat diet. J Med Food. 2018;21(3):233–43.
60. Diepvens K, Westerterp KR, Westerterp-Plantenga MS. Obesity and thermogenesis related to the consumption of caffeine, ephedrine, capsaicin, and green tea. American journal of physiology-Regulatory, integrative and comparative physiology. 2007.
61. Kim Y, Park Y-J, Yang S-O, Kim S-H, Hyun S-H, Cho S, et al. Hypoxanthine levels in human urine serve as a screening indicator for the plasma total cholesterol and low-density lipoprotein modulation activities of fermented red pepper paste. Nutr Res. 2010;30(7):455–61.
62. Caussy C, Hsu C, Lo MT, Liu A, Bettencourt R, Ajmera VH, et al. Link between gut-microbiome derived metabolite and shared gene-effects with hepatic steatosis and fibrosis in NAFLD. 2018;68(3):918-32.
63. Kerry RG, Patra JK, Gouda S, Park Y, Shin H-S, Das G. Benefaction of probiotics for human health: a review. J Food Drug Anal. 2018;26(3):927–39.
64. Gibson GR, Scott KP, Rastall RA, Tuohy KM, Hotchkiss A, Dubert-Ferrandon A, et al. Dietary prebiotics: current status and new definition. Food Sci Technol Bull Funct Foods. 2010;7(1):1–19.
65. Den Besten G, Van Eunen K, Groen AK, Venema K, Reijngoud D-J, Bakker BM. The role of short-chain fatty acids in the interplay between diet, gut microbiota, and host energy metabolism. J Lipid Res. 2013;54(9):2325–40.

66. Moon H-J, Cha Y-S. Sustainability of K-food: focused on the change in the health values of K-Food. J Ethnic Foods. 2023;10(1):23.
67. Mun E-G, Lee Y-E, Cha Y-S. The globalization of bibimbap: focusing on the diversity of modernization of bibimbap. J Ethnic Foods. 2023;10(1):39.
68. Jung S-J, Kim M-G, Park T-S, Kim Y-G, Song WO, Chae S-W. Rice-based Korean meals (bibimbap and kimbap) have lower glycemic responses and postprandial-triglyceride effects than energy-matched Western meals. J Ethnic Foods. 2015;2(4):154–61.
69. Oh S-H, Yu J-J, Kim S-G, Cho M-K, Choi D-S, Oh C-H, et al. Excellency and functionality of bibimbap. Food Ind Nutr. 2013;18(1):29–36.
70. Cheon HS, Cho W-I, Lee SJ, Chung M-S, Choi J-B. Acidic and steaming treatments of tteokbokki rice cake to improve its microbial and textural properties. Kor J Food Sci Technol. 2017;49(5):502–6.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.