Fermented Soybean Paste

Subjects: Nutrition & Dietetics
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Fermented soybean paste is an indigenous food for use in cooking in East and Southeast Asia. Korea developed and used its traditional fermented foods two thousand years ago. Chungkookjang has unique characteristics such as short-term fermentation (24–72 h) without salt, and fermentation mostly with Bacilli. Traditionally fermented chungkookjang (TFC) is whole cooked soybeans that are fermented predominantly by Bacillus species. However, Bacillus species are different in the environment according to the regions and seasons due to the specific bacteria. Bacillus species differently contribute to the bioactive components of chungkookjang, resulting in different functionalities.

Keywords: Fermented Soybean Paste ; chungkookjang

1. Introduction

Soybeans have been consumed as a primary source of protein in unfermented and fermented forms in East Asian countries, where rice is the main staple. Lysine and methionine are limited amino acids in rice and soybeans, respectively. Rice and soybeans are complementary protein sources and together make a complete protein source. Although dried soybeans have long storage durations, they need to be soaked and boiled before eating. Boiled soybeans were initially fermented to preserve them for longer periods. According to the fermentation conditions, the degradation of soybean components is varied and different types of fermented soybeans are produced. In Korea, soybeans are fermented with and without salt. The salt-added soybeans are fermented for several months to several years, while soybeans without salt have a short-term fermentation of 2–3 days. In Korea, short-term fermented soybean without salt is called chungkookjang (some studies spell it as cheonggukjang), while long-term fermented soybeans with salt are doenjang and kochujang with added red peppers. According to short- and long-long term fermentation, the microorganisms that ferment soybeans are different. The primary microorganisms are Aspergillus and Bacillus to make meju, the component of doenjang and kochujang [1]. They are fermented for more than six months, and salt concentrations influence the type and relative abundance of microorganisms, and the bioactive components are varied [2]. Their quality controls are more difficult. However, chungkookjang is made by 2–3 day fermentation, and the primary microorganisms are Bacillus species. The bacteria for chungkookjang can be easier to control than doenjang. Small differences in the bacteria can result in different bioactive compounds and flavors that contribute to their functionality for health and palatability. Furthermore, the microorganisms in the fermented soybeans can act as probiotics, and they also contain prebiotics such as dietary fibers and poly-γ-glutamic acid (γ-PGA) [3]. As a result, fermented soybeans act as synbiotics.

The fermented soybeans have been reported to have more beneficial functions than unfermented soybeans for type 2 diabetes when they are optimally made [4][5][6][7][8]. Soybeans contain proteins, isoflavone glycosides, soluble dietary fiber, and fats, and they are beneficial for glucose and lipid metabolism [9][10][11]. Traditionally made chungkookjang is known for better alleviating energy and glucose dysregulation, memory impairment, and immunity compared with unfermented soybeans in animal and human studies [4][6][7]. The differences are associated with bacterial-driven changes of soybean components and bacteria that modify their absorption in the gastrointestinal tracts and gut microbiota [4][7].

2. Improvement of the Gut–Liver–Brain Axis by Chungkookjang

2.1. Chungkookajng Effects on Gut Microbiota and SCFA as Synbiotics

The gut microbiota composition is highly variable among individuals. Its heterogeneity has an association with both intrinsic factors (genetics, genders, and age) and extrinsic factors (diet, herbs, polyphenols, age, antibiotics, lifestyle, and disease status) [12]. With aging, the diversity and amount of gut microbiota decrease. Many host diseases with aging are related to the composition of intestinal microbiota. However, the efficacies of gut microbiota modulations remain controversial. The intake of probiotics, prebiotics, and synbiotics contributes to the alteration of gut microbiota to reduce inflammation and insulin resistance, contributing to improved gastrointestinal and systemic health. Chungkookjang acts as a synbiotic to modulate gut microbiota [4]. In humans and animals, the gut microbiota is involved in gastrointestinal functions and other health-related functions, including energy, glucose, amino acid, and bone metabolism, as well as brain function [13][14]. These functions have bidirectional communications through the gut microbiota–liver and brain axis: SCFA production, inflammation, and immune response, and endocrine regulation including enteric hormones are the modulators from the gut to the liver and brain whereas the hypothalamic–pituitary–adrenal (HPA) axis, autonomous nervous system, and neurotransmitters deliver signals from the brain to the peripherals including the gut microbiota (Figure 1) [15]. These results suggest that brain function is involved in the gut microbiota–liver–brain axis in two-way communications.

SCFA, bile acids, trimethylamine-N-oxide, and immunoglobulin A produced by the gut microbiome act as metabolic modulators [16]. Gut microbiota directly activate the vagus nerve from the enteric nervous system to transmit the signals from the gut to the brain [17]. The activation of the HPA axis releases cortisol from the adrenal gland that influences gut microbiota composition and survival, which, in turn regulates the host immune response and other types of metabolism [17]. The enteric nervous system communicates with the central nervous system through the vagal nervous system, and gut microbiota are a modulator to control nutrient metabolism [18]. Gut microbiota modulate the secretion of gut hormones, including cholecystokinin, ghrelin, peptide YY, and glucagon-like peptide-1 (GLP-1). The gut hormones influence the vagal afferent pathway to modulate brain function and regulate intestinal metabolism [19]. These processes represent the gut microbiota–gut–brain bilateral communications that gut microbiota use to modulate brain function, including mood, emotions, neurodegeneration, and cognition (Figure 1) [18][20].

Figure 1. Potential action mechanism of chungkookjang in glucose metabolism and memory function. ANS, autonomous nervous system; HPA, hypothalamus–pituitary–adrenal; SCFA, short-chain fatty acids. Chungkookjang components directly influence glucose metabolism in the liver and brain, and they also indirectly affect them through the gut–microbiome–liver–brain axis. The improvement of glucose metabolism in the hippocampus reduces amyloid-b deposition, which decreases memory impairment. Thus, chungkookjang intake (about 20–30 g/day) protects against and partially alleviates type 2 diabetes, Alzheimer’s disease, and post-stroke symptoms.

2.2. Chungkookajng Effect on the Gut-Microbiome-Gut-Liver-Brain Axis

A few studies have investigated gut microbiota changes that occur when consuming chungkookjang. Intake of chungkookjang fermented with B. amyloliquefaciens and B. subtilis increased Bacillales, Lactobacillales, and Verrucomicrobiales (Akkermensia muciniphila) and decreased Enterobacteriales in the cecum of type 2 diabetic rats [4]. Consumption of chungkookjang made with B. amyloliquefaciens SRCM 100730 and SRCM 100731 changed the amounts of Bacteriodia and Clostridia in ischemia-induced gerbils, similar to non-ischemic gerbils [21]. Furthermore, oral γ-PGA administration changed the relative abundance of Lactobacillales and Clostridiales in the large intestines of experimental animals [3]. The sizes of γ-PGA differently influence gut microbiota: 2000 and 2 kDa γ-PGA intake dramatically increased the relative abundance of Lactobacillales from 8% to 42% and 38%, respectively, whereas they decreased Clostridiales from 43% to 15% and 8%, respectively [3]. In particular, L. intestinalis survival increased from 0.9% to 23% in response to 2000 kDa γ-PGA and from 0.3% to 30% in response to 2 kDa γ-PGA in vitro. These results suggest that chungkookjang-enriched γ-PGA can promote the survival of L. intestinalis that is reported to efficiently synthesize equol from daidzein, especially from chungkookjang [22]. Therefore, oral administration of γ-PGA, especially the small size, can help modulate the gut microbiota as a prebiotic.

Chungkookjang has insulinotropic activity, and it is associated with elevating the release of GLP-1 from L-cells to increase serum GLP-1 concentrations based on an animal study [23][24]. Chungkookjang intake also increased the production of SCFA and the integrity of intestinal tissues and decreased the production of proinflammatory cytokines in rodents [4]. The SCFA and cytokines enter to the bloodstream and are delivered into the liver and brain to modulate neuronal cell survival [25][26]. The modulation of the gut microbiome by chungkookjang induces changes that improved memory impairment in experimental animals [21]. Further studies need to research the mechanism of potentiating the axis by chungkookjang intake in humans.

3. Conclusions

Soybeans contain various bioactive compounds that contribute to health benefits, and chungkookjang fermented with B. amyloliquefaciens has an acceptable flavor to most people. After their short-term fermentation with Bacilli, the fermented soybeans improve the utilization of the bioactive compounds such as increased isoflavone aglycones, smaller sizes of dietary fibers, γ-PGA, and peptides. Chungkookjang has better efficacy for type 2 diabetes and dementia than unfermented soybeans, shown mostly in experimental animals. Chungkookjang elevates the relative abundance of Bacillales, Lactobacillales, and Verrucomicrobiales (Akkermensia muciniphila), while it reduces the relative abundance of Enterobacteriales in the cecum. Thus, chungkookjang is considered a synbiotic. Chungkookjang made by fermenting the soybeans with B. amyloliquefaciens and B. licheniformis produces high concentrations of γ-PGA. The γ-PGA-rich chungkookjang has better efficacy for preventing and alleviating neuronal cell survival by improving brain insulin sensitivity and neuroinflammation and modulating the brain–liver–gut microbiota axis. Since a few studies on chungkookjang with respect to dementia have been conducted in human studies, the conclusions are extrapolated mainly from animal studies. Further research is needed to characterize the health-promoting activity of chungkookjang, including diabetic symptoms and memory impairment in human studies.

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