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Review

Potential improvement in the safety and quality of traditional fermented soybean products: A narrative review

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Abstract

Soybeans are one of the most significant crops in the world due to their nutritionally valuable. It has been converted to produce a variety of fermented soybean products. During conventional soybean fermentation, microorganisms are involved, biochemical reactions occur, and bioactive components are produced. With the rise of people's living standards, customers are paying more attention not only to the flavor and nutrition of fermented soybean meals, but also to their safety and quality. Mycotoxins, biogenic amine production, and high salt content are among the public health concerns associated with fermented soybean foods. This paper reviews the prevalent concerns about the safety and quality of fermented soybean foods, as well as potential improvements. Attempts and methods have been proposed to ensure the safety of the fermentation process and food quality. Official regulations, the employment of suitable microbes, the use of high-quality cultivars, and the administration of chemicals are all viable options for improving safety and quality. We conclude that implementing international food standards, guidelines, and codes of practice such as the Codex Alimentarius for fermented soybean products and the application of scientific novel methods (e.g., starter combination, high-pressure processing, or low-dose gamma irradiation, additive usage, low salt fermentation technique) are the potential solutions to mitigate the issues and improve the safety and quality of the products.
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Keywords: Fermentation, soybean, safety, quality, food, nutrition

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Introduction

Soybean (*Glycine max* [L.] Merrill) is a low-cost major protein source for the human diet that can be utilized as a meat substitute (Xiang et al., 2019). Soy-based foods are known as non-fermented (soymilk, okara, tofu, yuba, soy nuts, etc.) and fermented (miso, tempe, sufu, natto, etc.) (Liu, 2008). Several studies have reported that fermenting soybeans results in numerous beneficial properties. The fermentation procedure can shorten cooking time, improve the nutritional quality of soybeans, boost bioactive components such as phytoestrogens, and make soybeans more digestible (Chen et al., 2016). Some fermented soybean products (FSPs) are often used as condiments to stimulate the appetite and improve food flavor (Xiang et al., 2019).

It is widely known that anti-nutritional substances included in whole soybeans have a deleterious impact on nutrient and micronutrient absorption. Whole soybeans contain anti-nutritional factors such as trypsin inhibitor, lectins, phytic acid, and oligosaccharides, raising concern for their consumption (Thakur et al., 2019). Briefly, it has a negative effect on nutrient absorption and utilization, as well as vitamin degradation (Thakur et al., 2019). This impact can trigger nutrient deficiencies, which can lead to a variety of health-related issues, particularly in animals. The trypsin inhibitor activity in unfermented soybean has a negative impact on the growth performance and pancreas weight of broiler chickens (Hoffman et al., 2019; Hemetsberger et al., 2021).

Studies have shown that microorganisms used in conventional fermentation are capable of producing toxins that contaminate FSPs (Chen et al., 2016). For example, *Rhizopus microspores,* a popular species employed as a soybean fermentation starter, can produce two types of mycotoxins, rhizoxins and rhizonins. These mycotoxins are present in tempe (an Indonesian fermented soybean cake) and fermented bean curd (a fermented soybean paste) (Rohm et al., 2010). *Aspergillus oryzae*, which is often employed in traditional soybean fermentation, also produces toxic secondary metabolites, such as cyclopiazonic acid, aspergillomarasmine, 3-nitropropionic acid, kojic acid, maltoryzine, and violacetin (Blumenthal, 2004).

Biogenic amines (BA), harmful substances generated during the fermentation process, are frequently identified in substantial concentrations in fermented soybean products from Korea, China, Japan, and Indonesia (Park et al., 2019). Certain fermented soybean products, such as fermented bean curd, soy sauce, douchi, and dajiang, are typically stored without being sterilized, but with a high salt content. This technique prevents spoilage and extends the shelf life of the food (Chen et al., 2016; Liu et al., 2020). However, an excessive intake of salt may result in an expansion in circulating volumes and lead to an increase in blood pressure in humans (Komnenov et al., 2019). As such, this narrative review will evaluate the issues associated with the safety and quality of commonly fermented soybean products and offer some potential solutions.

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Inconsistency of quality improvement

Traditionally fermented soybean foods are typically prepared using traditional fermentation process. There are numerous methods for producing indigenous soy-based foods (Figure 1). Asian countries offer a variety of fermented soybean preparation products based on traditional customs (Table 1). Standard quality procedures are not followed properly throughout the typical fermentation process, resulting in varied outcomes for fermented soybean products. Numerous elements contribute to the consistency of quality for particular fermented soybean food. For instance, the quality of tempe (Indonesia's fermented soybean cake) might be influenced by soybeans, process water, yeast, fermentation time, and fermentation temperature (Novita & Abidin, 2020). In daily practice, fermentation is a complicated process, and the final product's quality is highly dependent on a variety of factors, including geographical location, the environment, weather, seasons, etc. (Liu et al., 2020). For instance, there is a possibility in Indonesia that the small-scale industry of fermented soybean business may fall short of achieving the government's national food quality and safety criteria due to environmental factors and raw materials (Anggriawan, 2018; Kadar et al., 2021).

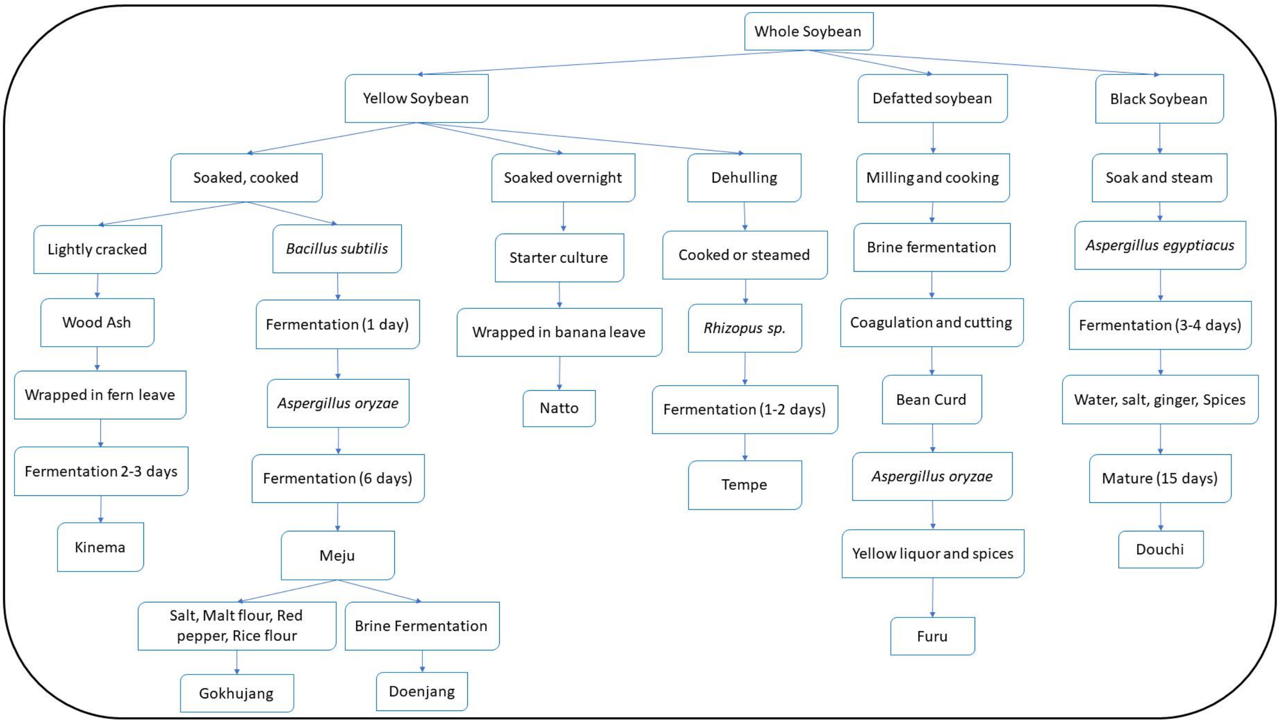

Figure 1. Different methods of soybean fermentation process

Table 1. Countries' distribution and variety of fermented soybean products

Country	Local name	Microorganism	References
India	Bekang	*B. subtilis, B. licheniformis, B. pumilus, Bacillus cereus, B.amyloliquefaciens*	Chettri & Tamang, (2014); Singh et al., (2014a, 2014b)
	Tungrymbai	*B. subtilis, B. pumilus, B. licheniformis, B. amyloliquefaciens, Lactobacillus brevis,*	
	Hawaijar	*B. subtilis, B. licheniformis, B. amyloliquefaciens, B. cereus,*	
Japan	Miso	*Bacillus subtilis, Pediococcus acidilactici, Leuconostoc mesenteroides, Micrococcus halobius, Aspergillus oryzae, Zygosaccharomyces rouxii and Torulopsis sp*	Tamang et al., (2016)
	Natto	*Bacillus subtilis, Aspergillus oryzae*	Liu, (2012)
Indonesia	Kecap	*Rhiz. oligosporus, Rhiz. oryzae, Asp. oryzae, Ped. halophilus, Staphylococcus sp., Candida sp., Debaromyces sp., Sterigmatomyces sp.*	Alexandraki et al., (2013)
	Tauco	*Rhiz. oryzae, Rhiz. ologosporus, Asp. oryzae, Zygosaccharomyces soyae, Bacillus sp., Ent. hermanniensis, Lb. agilis, Lb. brevis, Lb. buchneri, Lb. crispatus, Lb. curvatus, Lb. delbrueckii, Lb. farciminis, Lb. fermentum, Lb. pantheris, Lb. salivarius, Lb. vaccinostercus, Lc. lactis, Lactococcus sp., Leuc. camosum, Leuc. citreum, Leuc. fallax, Leuc. lactis, Leuc. mesenteroides, Leuc. pseudomesenteroides, Ped. acidilactici, Strep. bovis, Strep. macedonicus, W. cibaria, W. confusa, W. paramesenteroides, W. soli*	Kindossi et al., (2012); Winarno, (1973)
Korea	Chungkookjang	*Bacillus amyloliquefaciens, B. licheniformis, Bacillus megaterium, and B.subtilis, Leuconostoc, Lactobacillus, Pseudomonas, Pantoea and Weissella genera*	Hong et al. (2012)
	Doenjang	*B. subtilis, B. licheniformis, B. pumilus, Mucor plumbeus,*	Chang et al., (2013); Kim et al.,

		Aspergillus oryzae, Debaryomyces hansenii, Leuconostoc mesenteroides, Tor. halophilus, Lactobacillus sp.	(2016)
	Gochujang	*B. velegensis, B. amyloliquefacious, B. subtilis, B. licheniformis, Oceanobacillus spp. Zygosaccharomyces, Candida lactis, Zygorouxii, Aspergillus, Penicillium, Rhizopus*	Nam et al., (2012); Jang et al., (2019); Sanni et al., (1991)
	Meju	*Bacillus cereus, B. circulans, B. licheniformis, B. megaterium, B. mesentricus, B. subtilis, B. pumilus, Aspergillus spp, Botrytis cinerea Rhizopus oryzae, Rhodotorula flava, Zygosaccharomyces japonicus, Lactobacillus sp, Ped. acidilactici*	
	Kanjang	*Asp. oryzae, B. subtilis, B. pumillus, B. citreus, Sarcina mazima, Sacch. rouxii*	Shin, (2012)
China	Furu	*B. pumilus, B. megaterium, B. stearothermophilus, B. firmus, Staphylococcus hominis*	Lin et al., (2016)
	Yandou	*B. subtilis*	Qin, (2013); Ouoba, (2005); Rabie, (2009); Sanni, (2002)
Taiwan	Jiang-sun	*Lb. plantarum, Ent. faecium, Lc. lactis subsp. lactis*	Chen, (2010)
China, Taiwan	Douchi	*B. amyloliquefaciens, B. subtilis,*	Yang et al., (2019a, 2019b)
	Meitauza	*B. subtilis, Asp. oryzae, Rhiz. oligosporus, Mu. meitauza, Actinomucor elegans*	Zhu et al., (2008)
India, Nepal, Bhutan	Kinema	*B. subtilis, B. licheniformis, B. cereus, B. circulans, B. thuringiensis, B. sphaericus*	Chettri et al., (2016); Chettri & Tamang, (2015); Singh et al., (2014a, 2014b)
Japan, Korea, China	Shoyu	*Asp. oryzae or Asp. sojae, Z. rouxii, C. versatilis*	Sugawara, (2010).
Indonesia (Origin), Netherlands, Japan, USA	Tempe	*Bacillus pumilus and B.brevis, Rhizopus spp., Lactobacillus casei*	Frias et al., (2017)

Regulatory implications

Despite fermented soybean products are generally considered safe, there are still health risks associated with improperly fermented soybean products, which are produced under inadequate hygienic standards and uncontrolled conditions, especially in household industry settings. It has been claimed that traditional fermented soybean products marketed in Northeast India are contaminated with pathogens (*Bacillus cereus, Clostridium botulinum, Escherichia coli, Proteus mirabilis*) (Keisam et al., 2019). To improve hygienic standards and safeguard community health, various food safety assurance systems should be implemented, such as education and information, starting culture utilization, high-quality raw materials, and ideal fermentation conditions (Tamang et al., 2020). Standardization of the manufacturing process is necessary to provide consistent quality, particularly in small-scale industry settings (Anal, 2019).

There are a variety of certification schemes available, including Good Manufacturing Practices (GMP), Good Agricultural Practices (GAP), Good Hygienic Practices (GHP), Hazard Analysis Critical Control Points (HACCP), and International Organization for Standardization (ISO) standards. One or more of these certifications should be implemented and supported by government policies in order to eliminate public health concerns associated with fermented soy products, particularly in small scale industrial settings. Having Codex Alimentarius registration for fermented soybean products, such as kimchi, gochujang, and doenjang, will improve the quality standard, particularly in international trade and commerce (Lee et al., 2012). Food safety and quality audits are also commonly used to ensure the compliance and effectiveness of food safety initiatives. Audits are commonly used to evaluate management systems, check the state of premises and products, and certify that they meet specified food safety and quality requirements (Kotsanopoulos & Arvanitoyannis, 2017). There are specific fermented soybean product standards that can be followed, such as the Codex Alimentarius regional standard for fermented soybean paste (Asia) CODEX STAN 298R-2009 or Indonesian national standard SNI 3144:2009 for tempe. However, the goal of food safety and quality audits should be one of continuous development rather than one-time evaluation results or policing (Bradford-Knox, 2017).

Anti-nutritional factor

Numerous processing techniques, such as soaking, pressure cooking, blanching, germination, fermentation, autoclaving, genetic editing, and other methods, all assist in reducing the anti-nutrient effects (Thakur et al., 2019; ten Brink et al., 1990). It is feasible to reduce the antinutrient content of meals by utilizing any of these varied strategies alone or in combination (ten Brink et al., 1990). It has been suggested that autoclaving may be a more effective method than other processing methods for reducing levels of several anti-nutritional components (Samtiya et al., 2020). However, further study is still required to develop strategies for removing heat-stable anti-nutritional components found in a variety of foods without impairing their nutritional content. Phytic acid, tannins, alkaloids, saponins, and non-protein amino acids are examples of heat-stable antinutritional factors, whereas lectins, cynogenic glycosides, and protease inhibitors are examples of heat-labile antinutritional factors. These substances are found in a variety of grain legumes, including soybeans (Thakur et al., 2019). When present in trace amounts, several anti-nutritional agents and their metabolites may have beneficial health benefits such as decreased blood glucose and lipid levels, as well as a decreased risk of cancer. In contrast, a lack of understanding and information about their properties can lead to health issues (Gemede & Ratta, 2014).

Innovative fermentation techniques with specific microbes have been used to lower the level of anti-nutritional elements in fermented soybean products, such as soybean meal. Fermentation of soybean meal protein with *Bacillus siamensis* isolate JL8 resulted in a significant reduction of major antinutritional factors (ANFs) in soybean meal (SBM), specifically glycinin, beta-conglycinin, and trypsin inhibitor, which were reduced by 86.0%, 70.3%, and 95.01%, respectively (Zheng et al., 2017). After 24 hours, a comparable study using solid-state *Bacillus subtilis* fermentation was able to lower the quantities of beta-conglycinin subunits, glycinin subunits, and trypsin inhibitors in soybean meal by 70%, 50%, and 58%, respectively (Seo & Cho, 2016). Additionally, soybean meal fermentation at 35 °C with an appropriate proportion of *Bacillus subtilis*, *Bacillus lactis,* and *Saccharomyces cerevisiae* might increase the levels of free amino acids and short peptides while decreasing the activity of protease inhibitors (Zhang et al., 2017).

Mycotoxin contamination

The common microorganisms involved in FSPs, especially in the traditional fermentation process, have been described (Table 1). Mycotoxins are secondary metabolites of molds that may be harmful to humans or animals when consumed and may also have unfavorable effects on crops (Zain, 2011).When mycotoxins are inhaled, they can induce acute disease or persistent illness episodes known as mycotoxicosis. Due to mycotoxin's extreme toxicity, exposure should be limited to a minimum. Different countries have set their own maximum levels of aflatoxins in food for humans, which range from 5 to 50 g/kg (Wu, 2004) and 4 to 5 g/kg for beans (Wu, 2004) and 4 to 5 µg/kg for beans (Adejumo & Adejoro, 2014). The term "mycotoxin" originates from the Greek word "*mykes*", which means fungus, and the Latin word "*toxicum*" which means poison or toxin (Kirovska & Velickova, 2021). Mycotoxin is produced during fungal growth and is detected in the hyphae and spores of organisms. Numerous mycotoxins have been detected in fermented food products, including aflatoxins, ochratoxins, deoxynivalenol (DON), trichothecenes, zearalenone, and citrinin (Omotayo et al., 2019; Sivamaruthi et al., 2019). Although aflatoxin contamination is more prevalent in crops such as peanuts and maize, a prior study discovered that soybean seeds contained more than 20 aflatoxins (Roy et al., 2001). Some trichothecene mycotoxins, such as DON and T-2 toxins (a trichothecene produced by Fusarium spp.) can cause direct damage to mucosal tissues by disrupting the intestinal epithelial barrier, hence facilitating translocation of intestinal commensal microbiota, and pathogens. As a result, microorganism infection and inflammation may be increased (Nazhand et al., 2020). Aflatoxin (AF) is a prevalent mycotoxin produced by *Aspergillus flavus*, *A. parasiticus* and *A. nomius*. Aflatoxins are formed chemically from difuranocoumarins with bifuran-based coumarin nuclei groups and lactone rings (Aflatoxin Gs) or pentanone rings (Aflatoxin Bs and Aflatoxin Ms). During the biosynthesis of AF in plants by *A. flavus* and *A. parasiticus*, the main substrate of hexanoyl is converted to polyketide via a polyketide synthase and two fatty acid synthases (Nazhand et al., 2020).

It has been reported that 97.5% of tested samples of 40 domestic and imported (from Japan) soy sauces sold in China were contaminated with DON. Domestic soy sauces had a mean incidence rate of DON contamination of 97.1%, with concentrations ranging from 4.5 to 1245.6 g/l, whereas those imported from Japan had a mean incidence rate of 100%, with concentrations ranging from 30.5-238.3 g/l (Zhao et al., 2013). Meju prepared without additives may result in the isolation of *Aspergillus ruber,* which releases aflatoxin B_1 and ochratoxin A (Shukla et al., 2017). *Aspergillus oryzae* and *Aspergillus sojae* are frequently employed in the fermentation of soybeans to produce soy sauce and miso. These strains are closely related to the aflatoxigenic fungi *Aspergillus flavus* and *Aspergillus parasiticus*. While it has been demonstrated that these fermented soybean products do not create aflatoxin, they may contain homologs of numerous aflatoxin production pathway genes (Shukla et al., 2017). Aflatoxin is frequently found in doenjang, which is made through inoculation with a natural starter. The aflatoxigenic *Aspergillus flavus* is identified as the fungal community present throughout conventional manufacturing (Zain, 2011).

Mycotoxin mitigation

Official regulation and policy are critical in reducing mycotoxin levels in foods in many countries. In 2003, the FAO reported that at least 99 nations regulated mycotoxins in food and/or feed. The number of countries has increased by around 30% compared to 1995. These countries collectively account for around 87% of the world's population ("Worldwide Regulations for Mycotoxins in Food and Feed in 2003" n.d.). Additionally, novel approaches for reducing mycotoxin levels in fermented soybean products should be studied. For instance, fermentation of Meju with plant extracts (*Nelumbo nucifera* leaves, *Ginkgo biloba* leaves, and *Allium sativum* cloves) has a substantial effect on the fungal microflora, resulting in an enhancement in the product's quality. This outcome could be explained by the extracts' diminished activity against toxin-producing fungal infections (Shukla et al., 2017).

Biogenic amines

Biogenic amines (Bas) are low molecular weight, non-volatile nitrogenous bases with an aliphatic, aromatic, or heterocyclic structure that have been identified in fermented foods, such as miso, chunjang, jajang, and sufu (Komprda et al., 2007; Pachlová et al., 2012; Renes et al. 2014; Alvarez & Moreno-Arribas 2014; Bai et al., 2013; Lee et al., 2019; Shukla et al., 2010; Guan et al., 2013; Byun & Mah, 2012). The biogenic amine is named for the amino acid from which it is produced. For instance, histamine is created when histidine is decarboxylated, while tyramine is formed when tyrosine is decarboxylated (Santos, 1996). Biogenic amines are formed in foods as a result of the presence of bacteria capable of decarboxylation of specific amino acids (Renes et al., 2014; Bover-Cid et al., 2003; Buňková et al., 2013). The bacteria with amino acid-decarboxylase activity are *Pseudomonas,* *Clostridium, Bacillus, Photobacterium, Enterobacteriaceae* family (*Escherichia, Klebsiella, Citrobacter, Proteus, Shigella,* and *Salmonella*), *Micrococcaceae* family (*Staphylococcus*, and *Micrococcus*), *Enterococcus, Lactobacillus, Carnobacterium, Pediococcus, Lactococcus,* and *Leuconostoc* (Santos, 1996; Stadnik & Dolatowski, 2010).

BA is generally not harmful to human health in small doses since it can be detoxified by amine oxidase enzymes found in the intestine. The recommended BA values include a maximum of 100 mg/kg histamine in food and 2 mg histamine per liter of alcoholic beverage, a maximum of 100 to 800 mg/ kg tyramine in food, and a hazardous dose of 30 mg/kg -phenylethylamine in food (ten Brink, 1990). Enzymes, such as monoamine oxidase (MAO), diamine oxidase (DAO), and histamine N-methyltransferase (HNMT), can metabolize dietary BA in a healthy human being (Fogel et al., 2007). However, BA can turn into toxic metabolites that might threaten human health when consumed in excess or when humans' detoxifying capacity is limited or damaged (Anderson, 2008; Ruiz-Capillas & Herrero, 2019). Because accumulation of biogenic amines is possible in the presence of uncontrolled microbial enzymatic reactions (Halász et al., 1994), the presence of BA in food is always undesirable, as it can cause headaches, respiratory distress, palpitation, hypo or hypertension, and allergic reactions when absorbed at high concentrations (Restuccia et al., 2015).

Biogenic amine mitigation

The formation of BA in fermented soybean products is a complex process that is influenced by a number of parameters, including the BA-producing strain or species, salt concentration, and high temperatures (Bai et al. 2013; Chun et al. 2020). Salt concentrations may have an effect on the production of BA. This occurs as a result of elevated salt levels, which restrict the growth of microorganisms that make biogenic amino acids, resulting in a decrease in the production of decarboxylase enzymes (Chun et al., 2020; Chin & Koehler, 1986). For example, during fermentation, the amounts of key biogenic amines such as cadaverine and putrescine that were detected from doenjang were higher at 9% salt than at 12%, 15%, and 18% salt (Chun et al. 2020). Thermal breakdown of BA has been demonstrated to occur under high-temperature treatment, such as boiling in Chunjang (black soybean paste). After 10 min of frying at 200 °C, tryptamine and b-phenylethylamine levels are approximately 40% lower. While other BAs, such as cadaverine, histamine, tyramine, spermidine, and spermine, exhibit declines of approximately 10% to 20% (Bai et al., 2013).

Currently, the majority of efforts to develop worldwide regulatory standards for biogenic amines are concentrated on fish and seafood products rather than fermented soybean foods (Park, Lee & Mah, 2019). The suggested toxic limit of BA content in fermented soybean products is 1000 mg/kg (Santos 1996), while the indicated harmful limit of β-phenylethylamine is 30 mg/kg, 100 mg/kg for histamine, and 100 mg/kg for tyramine (ten Brink et al., 1990). Attempts have been made to minimize the formation of BA in foods through sanitary handling and processing, the use of biogenic amine-degrading starter cultures (e.g. *B. subtilis* and *B. amyloliquefaciens* strains), the addition of some probiotic bacterial strains alone or in combination with the starter cultures, high-pressure processing, and low-dose gamma irradiation (Oh et al., 2014; Kim et al., 2005a; Mendes et al., 2005; Zhang et al., 2013). High pressures of 400 MPa for 5 min or 400 MPa for 5 min + 50 MPa for 72 h were able to considerably reduce BA levels to levels comparable to or less than control (Novella-Rodríguez et al., 2002). Gamma-irradiation of raw materials at dosages of 5, 10, and 15 kGy considerably decreased the amounts of histamine, putrescine, tryptamine, and spermidine by approximately 20–50% in the final fermented soybean products (Kim et al., 2003).

To reduce the concentration of BA in fermented soybean foods, one typical method is to employ a starting culture containing bacteria with lower decarboxylase activity (Alvarez & Moreno-Arribas, 2014). The application of *Bacillus subtilis* and *Bacillus amyloliquefaciens* strains can reduce histamine levels in vitro by 27-46% and 70%, and tyramine contents by 42-59% and 71%, respectively (Kim et al., 2012). Additionally, the use of *Lactobacillus plantarum* as a starter culture can reduce histamine and total BA content by 58-100% and 27%, respectively (Lee et al., 2016; Kung et al., 2017). Apart from using BA-deficient bacteria for fermentation, the use of additives has been recommended as an alternative strategy. When ethanol is added to the dressing mixture (red kojic rice, alcoholic beverage, salt, sugar, bean paste, and spices) during sufu fermentation, the BA content reduction decreases. This could be because ethanol inhibits the decomposition of water-soluble proteins during the ripening fermentation process (Qiu et al., 2018). Another addition, such as nicotinic acid, may inhibit the activity of *Enterococcus faecium* isolated from cheonggukjang's tyrosine decarboxylase. It implies that nicotinic acid could be employed as a tyrosine decarboxylase inhibitor to reduce tyramine content in vitro and in situ (Kang et al., 2018). Additionally, the application of gamma irradiation may help lower not just salt consumption but also biogenic amine levels during soybean fermentation (Kim et al., 2005). Though numerous strategies for reducing BA concentration in vitro and in situ have been published, practical implementation is still necessary to ensure the safety of fermented food items (Park et al., 2019).

High salt content

Numerous traditional fermented soybean products are manufactured utilizing salt-intensive processes. Sufu, aving, miso, dajiang, doenjang, and soy sauce are examples of traditional salt-fermented soybean foods; natto, tempe, and kinema are examples of non-salt-fermented soybean products. In general, sufu has a salt content of 5 to 11%, doenjang has a salt concentration of 9 to 18%, soy sauce has a salt concentration of more than 18%, douchi has a salt concentration of 10 to 15%, and dajiang has a salt concentration of more than 10% (Han et al., 2004; Jeong et al., 2014; Chun et al., 2019; Liu et al., 2020). Due to the fact that salt is used to regulate the content of water, it has an effect on microbial growth and fermentation pace. Additionally, salt enhances the sensory quality of fermented soybean products and prolongs their shelf life (Han et al., 2003; Jeon et al., 2016; Shim et al., 2016; Liu et al., 2020).

However, excessive salt consumption can be detrimental to human health and the majority of epidemiological research has demonstrated that salt consumption is dose-dependently linked with blood pressure in participants with normotension and hypertension (Mohan et al., 2009; Graudal et al., 2019). Hypertension is a significant risk factor for heart disease and stroke (He et al., 2009; Komnenov et al., 2019). According to a previous study, hypertension is responsible for 62% of strokes and 49% of coronary heart disease (He et al., 2010). Increased sodium intake has also been linked to a number of adverse health effects, including worsening chronic kidney disease (Borrelli et al., 2021), an increased risk of gastric cancer (Tsugane et al., 2004; Peleteiro et al. 2011; D'Elia et al., 2014), decreased bone density (Teucher et al., 2008; Caudarella et al., 2009) and possible obesity (He et al. 2009; Grimes et al., 2013; Ma et al., 2015). According to the guidelines issued by the World Health Organization, adults should consume less than 2000 mg of sodium or 5 g of salt every day (Härtl 2013). Several organizations, including the European Society of Hypertension, the European Society of Cardiology, the American Heart Association, and the American Academy of Physician Assistants, recommend reducing salt consumption (Mancia et al., 2013; Welton et al., 2018). Salt-fermented soybean products are a substantial source of sodium in various nations, including Japan and Korea, and their consumption is positively connected with daily salt consumption (Anderson et al., 2010; Jeong et al., 2014).

A major difficulty in reducing the use of NaCl content in meals has been observed to be a loss in consumer approval (Liem et al., 2011). Efforts have been made to lower sodium concentration while maintaining the physicochemical features and sensory quality of fermented soybean products (Park et al. 2015; Lin et al., 2021). Several novel methods have been developed to produce low salt, or no salt fermented soybean products, such as natto, tempe, and kinema (Wang et al., 2007). In terms of physical strategies, the combination of high pressure and ultrasonic technology appears promising; chemical strategies include the right use of salt substitutes, flavor enhancers, and quality improvers. Biological techniques include functional microbial augmentation and microbial enzymatic technology. Cell fusion techniques and genetic engineering technology could be used in the future to improve the quality and safety of low-sodium fermented meals (Lin et al., 2021).

Potential quality improvement through soybean cultivar selection

Food-grade soybeans are the raw material for fermented and non-fermented soy food products, including tofu, soymilk, miso, natto, soy sprouts, and tempeh. Food-grade soybeans contain greater protein concentrations than feed-grade soybeans, ranging from 40 to 45% (Jegadeesan et al., 2020). Aside from high protein content, most food-grade cultivars share common characteristics such as low oil content, high seed quality with no mottling or cracking, and rapid water uptake, because most soy food products require a soaking step, thus rapid water uptake is essential (Mullin et al., 2001; Zhang et al., 2010; Anderson et al., 2019). Aside from these characteristics, advancements in soybean breeding and cropping systems provide not only improved chemical composition but also yield preservation through weed, pathogen, insect pest, and abiotic stress resistance (Anderson et al., 2019). The use of cadmium (Cd) safe soybean cultivars for fermentation may help to minimize unwanted metal deposition in the human body caused by Cd-contaminated soil (Zhi et al., 2020; 2015). Accumulation of Cd can occur in soybeans when they are grown on Cd-polluted soil (Arao et al. 2003; Sugiyama et al., 2011). A specific soybean cultivar may be more suitable for various fermented soybean products; for example, the Saedanbaek cultivar delivers higher quality standards than other cultivars (Jinpung, Daepung 2, Pyeongwon, Cheonga, and Saeolkong) during the soy paste fermentation process (Shin et al., 2019). This cultivar has demonstrated the ability to produce greater amylase and protease activities, viscous material amounts, and amino-type nitrogen content (Shin et al., 2019).

Conclusion

Fermented soybean products (FSPs) have piqued the interest of scientists and consumers due to their nutritional values, bioactive components, and flavor profiles and texture. Despite the fact that FSPs are considered safe foods, with the establishment of soybean fermented product standards, people have grown more conscious of the possibility of food-borne illness. Improving the safety and quality of fermented soybean products is critical in order to avoid future public health issues. Antinutritional factors, pathogenic microorganisms and mycotoxins, the formation of biogenic amines, the use of excessive salt concentrations during the fermentation process, and other safety dangers are still major concerns in fermented soybean production. The following characteristics are critical and should be considered in order to promote nutritional quality and safe fermented soybean foods. First and foremost, food regulation policies and standards must be enforced, particularly on industrial soybean fermentation products. Second, using appropriate microorganism strains in a controlled setting will result in a superior conventional soybean fermentation process.

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