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Bacillus Augmented Food Fermentation And Functional Food: A Review

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Abstract

Bacillus species have been recognized as a significant microorganism associated with traditional fermented foods globally. Their ability to produce enzymes, antimicrobial compounds, and bioactive peptides during fermentation enhances the nutritional, sensory, and functional properties of these foods. The roles of *Bacillus* in producing functional foods and nutraceuticals have been increasingly gaining attention due to their ubiquitous and highly durable nature. The products, enriched with specific bioactive components, offer various health benefits beyond basic nutrition and the market of such products has been rapidly expanding. This review delves into the multifaceted role of *Bacillus* in food fermentation and explores its potential in developing functional foods and nutraceuticals.

Keywords: *Bacillus*, Antimicrobial, Bioactive, Sensory, Nutraceuticals

Introduction

Food fermentation, an ancient practice, utilizes microorganisms to transform raw ingredients into palatable and often preserved products. *Bacillus* species, ubiquitous in various environments, play a pivotal role in fermenting diverse food substrates (Jeyaram *et al.*, 2008). Their ability to produce various enzymes, including amylases, proteases, lipases, and cellulases, is crucial in breaking down complex food components into simpler, more digestible, and flavourful compounds (Kuligowski *et al.*, 2017). Furthermore, *Bacillus* species produce antimicrobial substances like bacteriocins, contributing to food preservation and safety (Mah *et al.*, 2019).

The rising consumer interest in functional foods has led to exploring the potential of *Bacillus* in developing these health-promoting products (Das *et al.*, 2020). These foods, enriched with bioactive components, provide benefits beyond basic nutrition. *Bacillus*-fermented products can be sources of probiotics, prebiotics, and bioactive peptides that exhibit antioxidant, antihypertensive, antidiabetic, and anticancer

activities (Oba *et al.,* 2021). This review focuses on the multifaceted role of *Bacillus* in food fermentation and its potential in developing functional foods.

Bacillus in Traditional Food Fermentation

Bacillus species are instrumental in producing various traditional fermented foods globally. Their diverse metabolic capabilities and adaptability to different environments have made them essential in fermenting various substrates, including soybeans, legumes, cereals, and vegetables. Some notable examples of *Bacillus*-fermented foods *natto, tempeh, douchi*, and various fermented soybean pastes are popular in Asian countries. These products benefit from the enzymatic activities of *Bacillus* species, enhancing their digestibility and producing characteristic flavors and textures (Nagata *et al.,* 2017; Adem *et al.,* 2020). Other Bacillus Fermented Cereals Several traditional fermented cereal products, such as idli (India) and uji (Kenya), rely on *Bacillus* species for fermentation. These bacteria produce lactic acid and other organic acids, contributing to the sour taste and improved shelf-life of these products (Jeyaram et *al.,* 2010).

The traditional use of *Bacillus* in food fermentation highlights its long-standing role in enhancing food quality, safety, and nutritional value.

Table 1. Bacillus fermented traditional food of the world

Sl. No.	Substrate	Name of the Fermented food	Place	References
1.	Soybean	*Kinema*	Sikkim	Tamang &Nikkuni,1996
		Hawaijar	Manipur	Jeyaram *et al.,* 2008
		Natto	Japan	Wang *et al.*,2023
		Douchi	China	Chen *et al.*,2006
		Chungkookjang	Korea	Joo *et al.,* 2007
		Tungrymbai	Meghalaya	Mishra *et al.,* 2019
2.	Locust bean, néré (*Parkia biglobosa)*	*Dawadawa/Iru*	West Africa	Ogbadu & Okagbue,1988
		Sumbala	Burkina Faso/West Africa	Somda *et al.*,2014
3.	Egg	*Pidan*	China	Mao *et al.,* 2018

4.	Roselle seed	*furundu*	Sudan/West Africa	Yagoub *et al.*,2004
		Dawadawa-botso	Niger	Ibrahim *et al.*, 2018
		Bi-kalga	Burkina Faso	Ouoba *et al.*, 2008
5.	Sesame seed	*Sithu*	Manipur	Singh *et al.*, 2023

Health Benefits of *Bacillus*-fermented Foods

Bacillus-fermented foods offer several health benefits beyond basic nutrition, contributing to their recognition as functional foods. Some notable health benefits include:

Improved Digestibility: The enzymatic activities of *Bacillus* species during fermentation break down complex carbohydrates, proteins, and lipids into simpler, more readily absorbed compounds (Kuligowski *et al.*, 2017; Florindo *et al.*, 2018).

Probiotic Potential: Some *Bacillus* species, such as *Bacillus* coagulans, exhibit probiotic properties. These beneficial bacteria can survive the harsh conditions of the gastrointestinal tract and colonize the gut, contributing to a healthy gut microbiome (Elshaghabee *et al.*, 2017).

Production of Bioactive Peptides: During fermentation, *Bacillus* species release proteases that break down proteins into smaller peptides. Some of these peptides exhibit bioactive properties, including antioxidant, antihypertensive, antidiabetic, and anticancer activities (Sanjukta *et al.*, 2015; Kwon *et al.*,2010).

Anti-nutritional Factor Reduction: *Bacillus* fermentation helps reduce anti-nutritional factors naturally present in some food substrates, such as phytic acid in soybeans. These factors can interfere with nutrient absorption, but their reduction through fermentation enhances the bioavailability of essential minerals (Ashiuchi *et al.*, 1998).

The diverse health benefits associated with *Bacillus*-fermented foods underscore their potential in developing functional foods targeting specific health concerns.

Table2. Bioactive compounds present in Bacillus fermented foods and its health benefits.

Sl.No.	Bioactive Compound	Health Benefits	References
1	Fibrinolytic enzymes	Fibrinolytic activity	Singh *et al.*, 2014
2	Fibrinolytic enzymes	Fibrinolytic activity	Huy *et al.*, 2016
3	Nattokinase and serine protease subtilisin	Fibrinolytic activity and tissue plasminogen activator can be increased	Mohanasrinivasan *et al.*, 2017
4	Angiotensin I-converting enzyme (ACE) inhibitory peptides	anti-hypertensive effect	Handa *et al.*, 2020 Vallabha and Tiku 2014
5	Isoflavone	Improved glucose metabolism and lower incidence of gestational diabetes-mellitus	Jang *et al.*, 2020
6	Poly-γ-glutamic acid	Suppression in the elevation of post prandial blood glucose level	Chettri *et al.*, (2016)
7	Lipopeptide	Biosurfactant activity	Cao *et al.*, (2009)

Functional Food Development Using *Bacillus*

The increasing understanding of the health benefits associated with *Bacillus* fermentation has spurred research into its potential for developing functional foods. Major areas are discussed below.

Probiotic-enriched Foods: *Bacillus coagulans*, with its probiotic attributes, is incorporated into various food products, including dairy products, fermented beverages, and dietary supplements. Research focuses on optimizing the viability and stability of *B. coagulans* in these products to deliver effective probiotic doses (Elshaghabee *et al.*, 2017).

Bioactive Peptide Production: *Bacillus* strains capable of producing specific bioactive peptides with desired health benefits are screened and selected. Fermentation conditions are optimized to maximize peptide production, and downstream processing techniques are developed to purify and concentrate these bioactive components (Sanjukta *et al.*, 2015).

Targeted Health Applications: Research explores the use of *Bacillus*-fermented products for specific health applications, such as stress relief and diabetes management, leveraging their production of bioactive compounds like GABA (Nagata *et al.*, 2017).

Delivery Systems for Bioactive Compounds: Innovative delivery systems like encapsulation technologies are explored to protect bioactive compounds from degradation during processing and storage, ensuring their targeted delivery and bioavailability (Sagara *et al.*, 2017).

Conclusion

Bacillus species play a critical role in food fermentation, contributing to the production of diverse traditional fermented foods and offering various health benefits. The scientific understanding of their metabolic capabilities and the health-promoting properties of their fermentation products has opened new avenues for developing functional foods targeting specific health concerns. Continued research in this field holds immense potential for creating novel functional food products that contribute to improving human health and well-being.

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