PROBIOTICS IN THE INDIAN FOOD SECTOR: CURRENT STATUS, TECHNOLOGICAL ADVANCES, REGULATORY FRAMEWORK AND FUTURE PROSPECTS: A REVIEW

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Abstract
The increasing consumer demand for functional foods has accelerated the growth of probiotic products worldwide. Probiotics, defined as "live microorganisms that, when administered in adequate amounts, confer a health benefit on the host," have emerged as one of the most extensively studied functional ingredients in food systems. India, being the world's largest milk producer and possessing a rich heritage of fermented foods, presents significant opportunities for probiotic food development. Traditional Indian foods such as dahi, lassi, buttermilk, fermented cereals, pickles, and ethnic beverages serve as promising vehicles for probiotic delivery. The Indian food industry has witnessed substantial expansion in probiotic dairy products, including yogurt, fermented milk beverages, ice cream, cheese, and infant nutrition products. However, challenges related to strain selection, product stability, consumer awareness, regulatory compliance, and substantiation of health claims continue to influence market growth. This review critically examines the concept of probiotics, indigenous fermented foods as probiotic carriers, technological developments, health benefits, regulatory frameworks, market trends, and future prospects of probiotics in the Indian food sector.

Keywords: *Probiotics, Functional foods, Fermented dairy products, Indian food sector, Gut microbiota, Dahi, Functional dairy foods, FSSAI*

1. Introduction

The relationship between diet and health has evolved from the traditional concept of adequate nutrition to the development of foods capable of promoting health and reducing disease risk. Functional foods represent one of the fastest-growing segments of the global food industry, with probiotics occupying a prominent position within this category (Pandey et al., 2015).

The International Scientific Association for Probiotics and Prebiotics (ISAPP) defines probiotics as "live microorganisms that, when administered in adequate amounts, confer a health benefit on the host" (Hill et al., 2014). To qualify as a probiotic, a microorganism must be taxonomically identified, demonstrate safety for intended use, remain viable in adequate numbers during shelf life, and provide clinically validated health benefits. India offers a unique ecosystem for probiotic food development due to its extensive dairy infrastructure, traditional fermented food culture, and growing health-conscious consumer base. The country contributes approximately one-fourth of global milk production and has a long history of consuming fermented foods such as dahi, lassi, chaas, shrikhand, idli, dosa, kanji, and pickles (Narula, 2022).

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2. Evolution of Probiotic Research: The concept of probiotics originated from the observations of Élie Metchnikoff, who proposed that consumption of fermented milk products containing lactic acid bacteria contributed to longevity. Scientific understanding of probiotics has evolved substantially over the past three decades with advances in microbiome science, genomics, metabolomics, and systems biology. Current research emphasizes strain-specific effects, host-microbe interactions, and personalized nutrition approaches (Guarner et al., 2023).

3. Major Probiotic Microorganisms Used in Foods: Common probiotic microorganisms used in the food industry include species of *Lactobacillus* (recently reclassified into multiple genera), *Bifidobacterium*, *Lactococcus*, *Streptococcus*, *Saccharomyces*, and *Bacillus*.

Table 1. Common Probiotic Microorganisms Used in Foods

Genus	Representative Species	Major Applications
Lactobacillus	*L. acidophilus*, *L. rhamnosus*, *L. plantarum*	Yogurt, fermented milk
Bifidobacterium	*B. bifidum*, *B. longum*	Infant foods, dairy products
Streptococcus	*S. thermophilus*	Yogurt, dahi
Lactococcus	*L. lactis*	Cheese, cultured milk
Saccharomyces	*S. boulardii*	Functional beverages
Bacillus	*B. coagulans*	Heat-stable foods

4. Traditional Indian Fermented Foods as Probiotic Carriers

India possesses a rich diversity of naturally fermented foods that provide excellent matrices for probiotic incorporation.

4.1 Dairy-Based Foods: Traditional dairy products such as dahi, lassi, chaas, shrikhand, misti dahi, and fermented buttermilk contain lactic acid bacteria that contribute to desirable sensory and functional properties. However, conventional starter cultures used in dahi production should not automatically be considered probiotics unless specific strains have demonstrated clinically proven health benefits.

4.2 Cereal-Based Foods: Fermented cereal products such as idli, dosa, dhokla, and ambali contain diverse microbial populations that may serve as potential sources of novel probiotic strains.

4.3 Fermented Vegetable Products: Traditional fermented products including kanji, gundruk, sinki, and pickles contain beneficial microorganisms with probiotic potential.

5. Probiotic Dairy Products in India: The dairy sector accounts for the majority of probiotic food products in India due to the favorable composition and buffering capacity of milk.The major Product Categories include Probiotic dahi, Yogurt, Fermented milk drinks, Lassi, Cultured buttermilk, Cheese, Ice cream, Infant formula. Milk provides proteins, lactose, minerals, and fat that support probiotic viability during processing and storage (Jang et al., 2024).

Table 2. Advantages of Dairy Foods as Probiotic Carriers

Property	Significance
High buffering capacity	Protects probiotics during gastric transit
Rich nutrient content	Supports microbial growth
Consumer acceptance	Enhances market potential
Refrigerated storage	Maintains viability
Established processing systems	Facilitates commercialization

6. Health Benefits of Probiotics: Probiotics exert beneficial effects through modulation of gut microbiota, enhancement of intestinal barrier function, immune regulation, and production of bioactive metabolites. Reported health benefits include Improved digestive health, Prevention of antibiotic-associated diarrhea, Reduction in lactose intolerance symptoms, Enhancement of immune function, Modulation of inflammatory responses, Improvement of metabolic health, Enhanced nutrient absorption and probiotic effects are strain-specific and must be supported by clinical evidence.

7. Technological Challenges in Probiotic Food Development: Despite increasing interest, several challenges limit commercialization of probiotic foods.

7.1 Survival During Processing: Heat, oxygen, acidity, and moisture can adversely affect probiotic viability.

7.2 Shelf-Life Stability: Maintaining adequate viable counts throughout storage remains a major challenge.

7.3 Gastrointestinal Survival: Probiotics must survive gastric acidity and bile salts to reach the intestine.

7.4 Sensory Acceptance: Incorporation of probiotics should not negatively affect flavor, texture, or appearance. Microencapsulation, immobilization, and protective carrier systems are emerging technologies for enhancing probiotic survival.

8. Regulatory Framework in India: Probiotic foods in India are regulated by the Food Safety and Standards Authority of India (FSSAI) under the Food Safety and Standards Act, 2006. Specific provisions governing probiotic foods are included in the Food Safety and Standards (Health Supplements, Nutraceuticals, Food for Special Dietary Use, Food for Special Medical Purpose, Functional Food and Novel Food) Regulations, 2022.

According to Indian regulations only approved probiotic strains may be used, Products must contain scientifically validated viable counts, Labels must specify genus, species, and strain designation, Health claims require scientific substantiation and Viable counts must be maintained until the end of shelf life. Indian guidelines recommend adherence to ICMR-DBT protocols for evaluation of probiotic foods.

9. Market Trends and Consumer Perspectives: The global probiotics market is projected to exhibit robust growth due to increasing consumer awareness regarding gut health and preventive nutrition. India has emerged as a rapidly expanding market for probiotic dairy products, driven by Urbanization, Rising disposable incomes, Increased health awareness, Growth of organized retail, Expansion of cold-chain infrastructure and Flavored probiotic beverages currently dominate the Indian market owing to superior consumer acceptance.

10. Emerging Trends: Recent developments in probiotic research include Synbiotic foods, Postbiotic ingredients, Precision probiotics, Personalized nutrition, Microbiome-targeted interventions, Non-dairy probiotic foods and Artificial intelligence-assisted strain selection, Integration of omics technologies and microbiome science is expected to accelerate development of next-generation probiotic foods.

11. Future Research Priorities: Future research in the Indian context should focus on:

- Isolation of indigenous probiotic strains from traditional foods.
- Clinical validation of health benefits.
- Development of region-specific probiotic products.
- Exploration of non-dairy probiotic matrices.
- Enhancement of probiotic stability.
- Consumer awareness and education.
- Personalized probiotic interventions.
- Commercialization of traditional fermented foods.

12. Conclusion

India possesses exceptional opportunities for development and commercialization of probiotic foods owing to its extensive dairy sector, rich tradition of fermented foods, and rapidly growing functional food market. Dairy products continue to dominate the probiotic landscape due to their favorable physicochemical properties and high consumer acceptance. However, sustained growth of the sector requires robust regulatory frameworks, scientific substantiation of health claims, improved processing technologies, and enhanced consumer awareness.

Future advances in microbiome science, biotechnology, and precision nutrition are expected to transform the probiotic food sector from generalized health promotion to personalized dietary interventions. Strategic collaboration among academia, industry, and regulatory agencies will be essential to fully realize the potential of probiotics in improving public health and enhancing the competitiveness of the Indian food industry.

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