

SYNBIOTICS IN THE INDIAN DAIRY SECTOR: CURRENT STATUS, TECHNOLOGICAL ADVANCES, HEALTH BENEFITS AND FUTURE PROSPECTS – A REVIEW

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Abstract

The growing interest in functional foods has transformed the global dairy industry, leading to the development of products that provide health benefits beyond basic nutrition. Among these, synbiotics, which combine probiotics and prebiotics in a single formulation, have emerged as one of the most promising categories of functional foods. Synbiotics enhance survival and activity of beneficial microorganisms while simultaneously improving gastrointestinal health, immune function, nutrient utilization, and metabolic regulation. India, being the world's largest milk producer, offers immense opportunities for development and commercialization of synbiotic dairy products. Traditional fermented dairy products such as dahi, lassi, shrikhand, chakka, and probiotic beverages provide suitable matrices for incorporation of synbiotic ingredients. The present review critically examines the concept of synbiotics, mechanisms of action, health benefits, dairy applications, technological challenges, market opportunities, regulatory considerations, and future prospects in the Indian dairy sector. Particular emphasis is placed on recent developments in synbiotic dairy foods, indigenous dairy products, consumer acceptance, and emerging trends in personalized nutrition and microbiome-based functional foods.

Keywords: *Synbiotics, Probiotics, Prebiotics, Functional dairy foods, Indian dairy industry, Gut microbiota, Fermented milk products, Functional nutrition*

1. Introduction

The relationship between diet and health has received increasing scientific attention over the past three decades. Consumers are no longer satisfied with foods that merely satisfy hunger; instead, there is growing demand for products capable of improving health, preventing disease, and enhancing quality of life. This shift has led to rapid expansion of the functional food sector worldwide. The dairy industry has been at the forefront of functional food innovation because milk provides an ideal vehicle for delivery of bioactive compounds and beneficial microorganisms. Fermented dairy products have long been recognized for their nutritional and therapeutic benefits. In recent years, incorporation of probiotics, prebiotics, and synbiotics into dairy foods has further expanded the health-promoting potential of dairy products.

Synbiotics represent a significant advancement over conventional probiotic foods because they combine probiotics with specific substrates that selectively support microbial survival, colonization, and metabolic activity. According to the International Scientific Association for Probiotics and Prebiotics (ISAPP), synbiotics are defined as “a mixture comprising live microorganisms and substrate(s) selectively utilized by host microorganisms that confers a health benefit on the host.” India occupies a unique position in the global dairy landscape. The country contributes nearly

one-fourth of global milk production and possesses a rich tradition of fermented dairy foods. These characteristics provide exceptional opportunities for development of synbiotic dairy products tailored to Indian consumers.

2. Concept and Evolution of Synbiotics

The concept of synbiotics emerged from the recognition that probiotic efficacy can be enhanced through simultaneous administration of selective growth substrates. Early definitions described synbiotics as combinations of probiotics and prebiotics designed to improve survival and implantation of beneficial microorganisms within the gastrointestinal tract. Recent scientific advances have expanded this concept considerably. Contemporary definitions recognize two major categories:

Complementary Synbiotics: These consist of independently functioning probiotics and prebiotics administered together to provide health benefits.

Synergistic Synbiotics: These formulations are specifically designed so that the administered substrate selectively supports growth or activity of the co-administered microorganism, thereby producing enhanced health effects.

3. Components of Synbiotics

3.1 Probiotics: Probiotics are live microorganisms that confer health benefits when administered in adequate amounts. Common probiotic organisms

used in dairy products include *Lactobacillus acidophilus*, *Lactobacillus rhamnosus*, *Lactobacillus casei*, *Lactobacillus plantarum*, *Bifidobacterium bifidum*, *Bifidobacterium longum* and *Streptococcus salivarius* subsp. *Thermophilus*. These organisms contribute to maintenance of intestinal microbial balance, pathogen inhibition, and enhancement of host immunity.

3.2 Prebiotics: Prebiotics are selectively utilized substrates that promote growth and activity of beneficial microorganisms. Important prebiotics used in dairy applications include Inulin, Fructooligosaccharides (FOS), Galactooligosaccharides (GOS), Resistant starch, Lactulose, Dietary fibers and β -glucans.

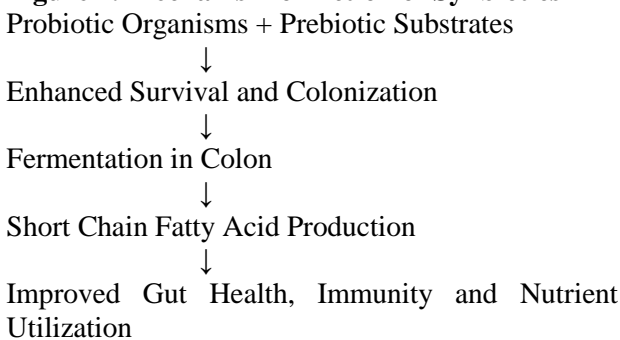
Table 1. Common Synbiotic Components Used in Dairy Products

Probiotic	Prebiotic	Dairy Application
<i>L. acidophilus</i>	Inulin	Yogurt
<i>B. bifidum</i>	FOS	Fermented milk
<i>L. casei</i>	GOS	Probiotic beverages
<i>L. plantarum</i>	Resistant starch	Functional dairy foods
<i>B. longum</i>	Lactulose	Synbiotic desserts

4. Mechanisms of Action of Synbiotics

Synbiotics exert beneficial effects through multiple mechanisms. The prebiotic component serves as a selective substrate for probiotic microorganisms, enhancing their survival during processing, storage, and gastrointestinal transit. Upon reaching the colon, these microorganisms ferment prebiotic substrates to produce short-chain fatty acids such as acetate, propionate, and butyrate. These metabolites contribute to reduction of intestinal pH, suppression of pathogenic microorganisms, improvement of intestinal barrier function, enhancement of mineral absorption, modulation of immune responses and regulation of lipid metabolism.

Figure 1. Mechanism of Action of Synbiotics



5. Synbiotic Dairy Products

Milk provides an ideal environment for synbiotic formulation because of its nutrient richness, buffering capacity, and consumer acceptance.

5.1 Synbiotic Yogurt: Synbiotic yogurt represents one of the most extensively studied functional dairy products. Addition of inulin and fructooligosaccharides improves probiotic viability and sensory quality.

5.2 Synbiotic Dahi: Traditional Indian dahi offers excellent potential as a synbiotic carrier. Incorporation of probiotic cultures and dietary fibers can substantially enhance functional value.

5.3 Synbiotic Lassi: Lassi possesses high consumer acceptance and can serve as a convenient vehicle for delivery of synbiotic ingredients.

5.4 Synbiotic Shrikhand : Fortification of shrikhand with probiotic cultures and prebiotic fibers can create high-value functional dessert products.

5.5 Synbiotic Whey Beverages: Utilization of whey for preparation of synbiotic beverages represents a sustainable approach for dairy waste valorization.

Table 2. Potential Synbiotic Dairy Products in India

Product	Current Status	Commercial Potential
Yogurt	High	Very High
Dahi	Moderate	Very High
Lassi	Moderate	High
Shrikhand	Emerging	High
Whey beverages	Emerging	Very High
Ice cream	Emerging	High
Cheese spreads	Limited	Moderate

6. Health Benefits of Synbiotics

Numerous clinical and experimental studies have demonstrated beneficial effects of synbiotics.

Gastrointestinal Health: Synbiotics improve microbial balance, reduce intestinal infections, alleviate constipation, and enhance digestive health.

Immune Modulation: Several studies indicate improved immune function and reduced incidence of respiratory and gastrointestinal infections.

Metabolic Health: Synbiotics contribute to regulation of blood glucose, serum lipids, and body weight.

Mineral Bioavailability: Enhanced absorption of calcium, magnesium, and iron has been reported following synbiotic consumption.

Anti-inflammatory Effects: Short-chain fatty acids produced through fermentation exert anti-

inflammatory activity and contribute to maintenance of intestinal homeostasis. These benefits are largely mediated through modulation of the gut microbiota and production of beneficial microbial metabolites.

7. Synbiotics in the Indian Dairy Sector

The Indian dairy industry presents unique opportunities for synbiotic product development. Factors favoring growth include expanding middle-class population, increasing health awareness, growth of organized dairy sector, rising demand for functional foods and strong tradition of fermented dairy consumption. Major dairy cooperatives and private dairy companies have already introduced probiotic products, creating a favorable foundation for future synbiotic innovations.

Table 3. SWOT Analysis of Synbiotic Dairy Products in India

Strengths	Weaknesses
Large milk production	Limited consumer awareness
Strong dairy infrastructure	Higher production cost
Traditional fermented products	Stability challenges

Opportunities	Threats
Functional food market growth	Regulatory uncertainty
Personalized nutrition	Competition from supplements
Export potential	Consumer misconceptions

8. Technological Challenges

Despite considerable promise, several technological challenges remain. Maintaining probiotic viability throughout processing and storage remains a major concern. Exposure to heat, oxygen, acidity, and moisture can reduce microbial survival. Additional challenges include Compatibility of probiotic and prebiotic ingredients, Sensory alterations, Shelf-life limitations, Packaging requirements, Standardization of health claims and Microencapsulation and advanced delivery systems are emerging as effective solutions to these challenges.

9. Regulatory Perspectives

India currently regulates functional foods through the Food Safety and Standards Authority of India (FSSAI). Development of specific guidelines for synbiotic foods is essential to ensure consumer protection and facilitate commercialization. Future regulatory frameworks should address the minimum viable probiotic counts, approved prebiotic ingredients, labeling requirements, health

claim substantiation and safety assessment protocols.

10. Emerging Trends

Future developments in synbiotic dairy foods are expected to focus on precision synbiotics, personalized nutrition, microbiome-targeted foods, synbiotic infant formulas, synbiotic dairy alternatives, encapsulation technologies and Artificial intelligence-assisted formulation. Recent research is increasingly emphasizing rational design of synergistic synbiotics tailored to specific health outcomes and host microbiome profiles.

11. Future Research Priorities for India

Future research efforts should focus on development of indigenous synbiotic cultures, utilization of traditional Indian prebiotic ingredients, clinical validation of health benefits, development of synbiotic dairy beverages, shelf-life enhancement technologies, personalized synbiotic formulations, commercial scale-up studies and consumer acceptance research.

12. Conclusion

Synbiotics represent one of the most promising frontiers in functional dairy foods. Their ability to combine the benefits of probiotics and prebiotics offers significant opportunities for improving human health through dietary intervention. The Indian dairy sector, with its enormous milk production base, established dairy infrastructure, and rich tradition of fermented milk products, is uniquely positioned to become a global leader in synbiotic dairy innovations.

Continued advances in microbiome science, food technology, biotechnology, and personalized nutrition are expected to accelerate development of next-generation synbiotic dairy products. Strategic collaboration among researchers, industry, policymakers, and regulatory agencies will be essential for realizing the full potential of synbiotics in improving public health and enhancing competitiveness of the Indian dairy industry.

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