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Leading the Way: Innovative Starter Cultures for Value-Added Dairy Fermentation

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Throughout human history, fermented foods have played a crucial role in both tradition and nutrition. The traditional methods used to make these goods have integrated them into the fabric of culture and greatly improved human health and wellbeing. Fermented foods, well-known for their abundant nutritional content and medicinal advantages, owe a great deal of their qualities to starting cultures. These cultures are microbial preparations that are given to raw materials to improve and direct the fermentation process. They contain vast amounts of one or more microorganisms. Lactic acid bacteria (LAB), which have a long history of safe use in the production of fermented foods and beverages, are essential to these processes. They produce organic acids, mainly lactic acid, which quickly acidify raw materials. Furthermore, LAB are involved in the synthesis of ethanol, acetic acid, fragrance compounds, bacteriocins, exopolysaccharides etc. Dairy starters primarily function by digesting lactose to produce lactic acid. The acid contributes to the overall flavour of the products, improves preservation, and gives fermented milk products their distinctive body and texture. The final product's flavour and aroma are enhanced by the lactic starter cultures' production of acetic acid, dialdehyde, and diethyl. Some hetero-fermentative lactic acid bacteria create carbon dioxide, which is involved in the texturization of certain fermented dairy products, such as the production of cheese "eyes"(Vuyst *et al.*, 2000)

The need and growing market awareness of safe dairy products have made manufacturers obligated to create them. Dairy starter cultures enhance the flavour, taste, texture, colour, and consistency of dairy products. The market for dairy starting culture is expected to expand significantly as a result of the rising demand for premium dairy products. The market for dairy starting cultures is predicted to expand due to the health advantages of adding starter microorganisms to dairy products, which include strengthening and enhancing the immune system and preventing gastrointestinal illnesses. The global dairy starter cultures market is projected to grow at a compound annual growth rate (CAGR) of 6.83 percent from 2022 to 2030, when it is valued at USD 2.73 billion. The leading suppliers in the global dairy starter cultures market include Dalton, BDF Ingredients, Chr. Hansen, DANISCO A/S, DSM, CSK, Lallemand, Sacco System, and Lactina. The market for dairy product starters is expanding quickly as a result of recent advancements. As people increasingly turn to dairy substitutes for their daily nutritional needs, more businesses are joining this sector. Companies of all kinds can now give reasonably priced, nutrient-dense plant-based dairy substitutes to their customers (Bhat *et al.*, 2011).

Fig 1: Product varieties in India

Innovative Dairy Starters and Their Applicability

Milk is a great source of nutrients that are good for you, such as peptides, bioactive fatty acids, and immunoglobulins. Dairy products have seen tremendous diversification as a result of its wholesome reputation, giving consumers access to a wide range of options such cheeses, yogurts, flavoured milk drinks, and dairy sweets. The health benefits of milk extend beyond its inherent ingredients and are associated with fermented and probiotic dairy products. Lactose is converted into lactic acid and other organic acids during the fermentation process

used to preserve milk, which is mostly carried out by lactic acid bacteria (LAB). By lowering the pH, this method prolongs the shelf life and safety of dairy products by preventing the growth of harmful and spoiling microorganisms. The biodiversity of traditional fermented foods and spontaneous fermentation processes is analysed to develop cultures of LAB that produce antimicrobial substances like bacteriocins to assure food safety, sugar polymers to improve texture, desirable aromatic compounds to enhance taste properties, or strains that display probiotic effects (Sinha *et al*., 2009).

EPS Generation and Texture Enhancement

In the formulation of food items, long-chain, high-molecular-mass polymers that dissolve or disperse in water to provide thickening or gelling qualities are essential ingredients. These polymers are also employed for secondary effects, such as controlling crystallization, inhibiting syneresis, encapsulation, and film formation in food, and emulsifying, stabilizing, and suspending particles. Interest in exopolysaccharides from LAB has increased as a result of the search for dietary ingredients with beneficial bioactive characteristics. The food business is starting to place more and more importance on functional food products, which provide health and sensory benefits in addition to their nutritional value (Bhat *et al*., 2011).

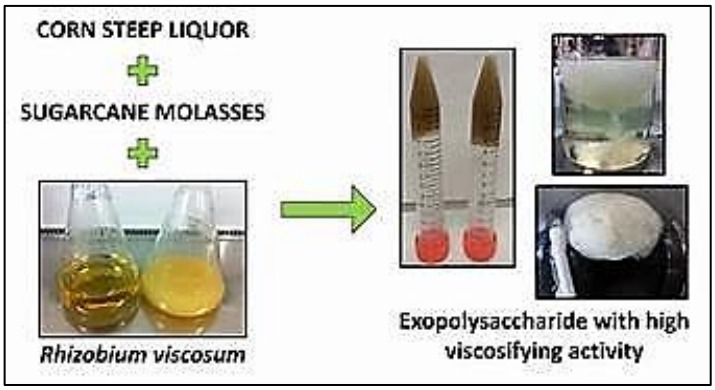

Fig 2: Application of exopolysaccharides in dairy industry

Aroma and flavour production

Lactic acid bacteria (LAB) significantly enhance the aroma and flavour of fermented products. They acidify foods, imparting a tangy lactic acid taste, and frequently perform proteolytic and lipolytic activities, which contribute to the production of aromatic compounds. Wild strain starter cultures and non-starter LAB (NSLAB) are particularly important in flavour development due to their high biosynthetic capacity. The inclusion of NSLAB as adjunct cultures in cheese manufacturing boosts the levels of free amino acids, peptides, and free fatty acids, intensifying flavour and accelerating ripening. Homofermentative LAB convert sugars almost entirely into lactic acid through pyruvate, maintaining redox balance and producing energy. However, pyruvate can also generate various metabolites such as acetate, ethanol, diacetyl, and acetaldehyde, which contribute to the distinct flavours of different fermented products. For instance, sourdough's flavour is influenced by the lactate/acetate ratio, kefir and koumiss have ethanol notes, butter and buttermilk owe their characteristic taste to diacetyl, and yoghurt's flavour is marked by acetaldehyde (Bhattacharya *et al*., 2010).

Metabolites produced by LAB

The primary source of carbohydrates for lactic acid bacteria (LAB) is lactose, and they have a somewhat straightforward homo- or hetero-fermentative metabolism. Genera like *Leuconostoc, Lactobacillus, Lactococcus* and *Streptococcus* are important dairy LAB. Food products must be preserved in order for the main fermentation product, lactic acid, to remain active. Fermented foods have a better texture and flavour thanks to LAB metabolism. For example, the viscosity and texture of fermented dairy products are greatly enhanced by the polysaccharide formation by LAB, and flavour development is facilitated by the chemical's diacetyl, ethanol, and acetaldehyde. LAB also use their proteolytic activity to create molecules that have nutritional value, like different B-vitamins and bioactive peptides from milk proteins. A few strains of LAB and bifidobacteria additionally generate conjugated linoleic acid (CLA) from linoleic acid in addition to other metabolites that support and promote human health (Sinha *et al*., 2009).

Bacteriocins production

Broad-spectrum antibacterial bacteriocins, which are produced by a variety of lactic acid bacteria, have a lot of potential applications in food preservation. Foods that are naturally maintained and keep their organoleptic and nutritional properties can

be produced by the food industry by using bacteriocins instead of harsh heat treatments and chemical preservatives. By adding live bacteriocin-producing LAB to food, bio preservation is automatically provided, encouraging a more organic approach to increasing food safety and shelf life. But there might be problems with bacteriocin-producing strains getting along with other fermentation-related organisms. For example, microorganisms that produce nisin can suppress the starting cultures needed to make cheese. There are several advantages to using bacteriocin-producing microorganisms in food. All things considered, the production of items with an innate preservation system result from the customization of these cultures to the unique microenvironment of various foods. By extending shelf life and improving food safety, this natural bio preservation method eliminates the need for harsh processing techniques and chemical additives (Bhat *et al.*, 2011).

Fig 3: Application of Bacteriocins in fermented pickles

Reduction of antinutritional factors

Food safety and nutritional quality can be improved by the fermentative action of some LAB strains, which can remove harmful or antinutritive ingredients. To alleviate lactose sensitivity and prevent galactose accumulation, for example, LAB can extract lactose and galactose from fermented milks. The removal of verbascose, stachyose, and raffinose from soy can also lessen intestinal cramps and gas. Additionally, it can improve digestion by breaking down proteinase inhibitors found in grains and legumes. LAB also detoxify natural toxins such as biogenic amines in traditional fermented foods and cyanogenic glucosides in cassava, boosting mineral bioavailability by reducing phytic acid and tannins in cereals and legumes (Vuyst *et al.*, 2000).

Low calorie sugar production

A polyol presents in many different organisms, mannitol has a number of health advantages. It improves the nutritional value of food by acting as a non-metabolizable sweetener and antioxidant, making it a healthier option. Fermented foods have a higher nutritional profile when lactic acid bacteria that produce mannitol are directly incorporated into food manufacturing. Mannitol does not cause hyperglycaemia due to its mild sweetness and non-toxic properties. Mannitol's uses in food processing are expanded by the fact that some strains of lactic acid bacteria, such as *Leuconostoc mesenteroides* and *Lactobacillus plantarum*, can produce it. There are logistical benefits to producing mannitol with food-grade microbes since there is no need for lengthy product-microorganism separation. Mannitol-enriched meals are further enhanced by the known advantages of specific lactic acid bacteria for gastrointestinal health (Bhattacharya *et al.*, 2010).

Probiotics for functional food

Prebiotics are non-digestible carbohydrates that are given to the large intestine in food and act as fermentable substrates for certain bacteria. Probiotics are items made to introduce live, potentially helpful bacterial cells into the gut environment of humans and other animals. Probiotics are strains of lactic acid bacteria (LAB), of which *Lactobacillus* and *Bifidobacterium* are the best studied genera. Most probiotic strains belong to the *Lactobacillus* species. Probiotics' effectiveness has been widely evaluated in both human and animal studies for a variety of illnesses, including diarrhoea brought on by antibiotics, traveller's diarrhoea, diarrhoea in children, inflammatory bowel disease, and irritable bowel syndrome (Sinha *et al.*, 2009).

List of innovative starter cultures used to ferment dairy products

Using strains with unique characteristics as innovative, functional starter cultures has the potential to improve the fermentation process and boost the quality of the finished product. However, as bacteriocin-producing LAB has shown, the strain used has a major impact on how well functional starting cultures work with particular meals. As such, careful selection of appropriate strains is essential. In light of

market and regulatory requirements, the industrial application of carefully selected natural food isolates with functional characteristics seems especially desirable (Sinha *et al.*, 2009).

Table 1: List of novel starters used in dairy fermentation

Probiotic Strater culture	Characteristics	Value added product
EXACT®	Mainly mesophilic cultures	Buttermilk, kefir, sour cream, quark, cream cheese
NU-TRISH®	Single strains or convenient culture blends	Probiotic dairy products
FRESHQ®	Bioprotective cultures reduce the risk of spoilage caused by yeast and mold contamination	Probiotic dairy products
SWEETY®	convert the naturally occurring sugars in milk, using more of the lactose and leaving glucose.	Fermented dairy products
YOFLEX®	mixed, single-strain cultures	Yoghurt

Conclusions

Recent developments in our knowledge of lactic acid bacteria's (LAB) metabolism offer potential for the introduction of a fresh batch of creative starting cultures. Functional LAB starters have the potential to open a multitude of benefits related to technology, marketing, and wellness (Sinha *et al.*, 2009). However, in order to fully realize their potential, research efforts both fundamental and applied are needed to obtain quantitative insights and to seamlessly integrate functional starting cultures into current production procedures. The dynamics of functional starting cultures can be analysed using mathematical modelling, which can provide important insights into the complex interactions between the food environment and bacterial activity (Bhattacharya *et al.*, 2010). This analytical method makes it easier to choose the best strain and design processes, which opens the door to improved process control, higher standards for food safety and quality, and a reduction in financial losses along the production chain.

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