



Dairy based Probiotic Beverages- Prospects, Challenges and Future Perspectives: A Review

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ABSTRACT

In recent years, there has been an increasing interest in health management through natural foods, driving novel innovations and it has fueled the development of new products around the world especially the probiotic foods. In the market of functional foods, the products targeting the gut health have been driving the efforts on research and development. Probiotics have increasingly been incorporated into foods and drinks in order to improve overall well being by maintaining the microbial gastrointestinal balance. The dairy products especially the beverages, offer a wide scope for the incorporation of the probiotics in an efficient and facile manner. Surging demand of probiotic dairy drinks from numerous end-user industries is contributing hugely to the market growth. At the same time in the probiotic selection process, the safety, functional, technological characteristics and safety issues need to be taken into consideration. Furthermore, it is necessary to update, reform and tighten the policies and regulations for the food manufacturers dealing with such functional foods in view of protect consumers protection and benefit. This review paper attempts to extensively provide insights into the various types, development, issues, challenges, safety and regulatory considerations and future perspectives for dairy based probiotic beverages.

Key words: Dairy beverages, Functional foods, Probiotics, Stability.

Over the last couple of decades, there has been a dramatic shift over the functionality of nutrients. Beyond providing basic nutrients, food is now viewed as a means to optimize good health (Granato *et al.*, 2010). Increased consumer awareness especially regarding health issues and accelerating economic growth has driven the usage of nutraceuticals /functional foods especially, in the dairy sector.

Functional dairy products occupy a predominant position within the functional foods segment, accounting for over 40% of this market. The dairy sector is the largest functional food market contributing to approximately 33% of the market. The dairy food industry is largely linked to probiotics and the use of probiotics has gained a huge momentum in recent past with considerable growth in functional food market.

Probiotics usually comprise bacteria, mainly *Lactobacillus*, *Bacillus* and *Bifidobacterium*, *Streptococcus* and *Enterococcus*, although some strains of yeast *Saccharomyces* genera have also been included in probiotic cultures. According to the International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus panel, the probiotic benefits can be delivered by only a few strains of a particular class of bacteria, for example, *Lactobacillus casei* or *Bifidobacterium bifidum*. Hence, the majority of probiotic products available in the marketplace contain most commonly *Lactobacillus* and *Bifidobacterium*, species are used in majority of the commercially marketed probiotic products (Hill *et al.*, 2014).

Probiotic microorganisms such as: *Lactobacillus acidophilus*, *L. reuteri*, *L. thermophiles*, *L. casei*, *L. johnsonii*, *L. rhamnosus*, *L. delbrueckii* subsp. *bulgaricus*, *Bifidobacterium bifidum*, *B. infantis*, *B. longum*, *B. brevis* and *B. Animalis*

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have been commonly used in the food industry (Sahrawat and Chaturvedi, 2023).

Probiotication is a process of inoculating beneficial microorganisms (mostly lactic acid bacteria) that confer health benefits, into a liquid substrate to manufacture functional beverages, which subsequently adds on to the market value of the final product.

Global dairy probiotic beverages market trends

The global functional dairy beverages market is a very dynamic segment of the dairy industry and with global dairy-based beverages market reaching a market value of 13.9 billion USD during 2021, which excludes traditional dairy beverages such as Kefir, Koumiss buttermilk, etc.

Indian dairy probiotic drinks market trends

India is fast emerging as a potential market for probiotics in food with the major players in the dairy sector. The India probiotic drinks market reached a value of INR 778 million in 2021. Looking forward, the market is expected to reach

INR 2,371 million by 2027, exhibiting a CAGR of 21.00% during 2022-2027. The escalating prevalence of gastrointestinal ailments due to changing dietary patterns and unhealthy food habits of the consumers is primarily driving the demand for probiotic drinks in India.

Physiological and health benefits of probiotics

Probiotic consumption confers several physiological benefits including: regulation of gastrointestinal tract motility (irritable bowel syndrome, constipation) (de Preter *et al.* 2007), enhancement in the absorption of minerals such as calcium and iron, prevention of osteoporosis, reduction in cholesterol, decrease in lactose intolerance (Suarez *et al.*, 2003), improved urogenital health, carcinogen detoxification, prevention of arteriosclerosis, enhanced bioavailability of nutrients such as riboflavin, folic acid, niacin, vitamins B₆ and B₁₂ and prevention of gut infections (Spanhaak *et al.*, 1998).

Several health benefits are attributed to the consumption of probiotic containing foods *viz.*, beneficial effects on mineral metabolism, antimicrobial, antihypertension properties, anticarcinogenic properties, reduction in LDL-cholesterol levels (Fluegel *et al.* 2010) and reduction of food allergies symptoms (Isolauri *et al.*, 2000), inflammatory bowel symptoms and Crohn's syndrome. Probiotic bacteria strengthen the endogenous host defence mechanisms (de Vrese *et al.*, 2005) enhance humoral immune responses and thus strengthen the immunologic barrier in the intestine as well. Additionally, probiotic bacteria stimulate nonspecific host resistance to microbial pathogens and modulate the host's immune responses to potentially harmful antigens thus down-regulating the hypersensitivity reactions (Kumar *et al.*, 2015).

Classification of dairy based beverages

Food matrices have a vital role in the beneficial health effects of probiotics on the host. Dairy beverages offer an excellent delivery module for probiotics and they remain at the forefront of probiotic beverage development and market at present. Dairy-based beverages can be grouped into three distinct segments

Traditional dairy beverages

Kefir: Kefir is a fermented drink with low alcohol content, acidic and bubbly from the fermentation carbonation of kefir grains with milk or water. This drink originated in Caucasus mountains many centuries ago. Owing to its health benefits, its consumption has spread to other parts of the world over time. This drink has become popular in countries such as Japan, France, United States of America and Brazil. Kefir differs from other fermented products because of the specific property of its starter culture: the kefir grains (Otles and Cagindi, 2003; Subbalakshmi, 2024).

Koumiss: Koumiss is a dairy product made from fresh horse milk containing a small amount of alcohol and is naturally fermented using the original mix of ferments (lactic

acid bacteria and yeast). Koumiss is also a traditional drink of the nomadic people of Xinjiang and Inner Mongolia in northwest China. It enhances immunity and regulates gut homeostasis. Koumiss occupies a predominant place in Mongolian medicine as the first beverage used in food-based therapy (Güzel-Seydim *et al.*, 2010).

Value added dairy beverages: High protein beverages, Effervescent/carbonated beverages, Thirst-quenching beverages, Sports beverages/energy drinks, Milk fat globule membrane beverages and Consumer-specific nutrition solutions.

Functional dairy beverages

A. Probiotic dairy-based beverages

Drinkable Probiotic yoghurt (Yakult) (Aryana and Olson, 2017), Yakult Miru-Miru Mil-Mil, Acidophilus milk, Sweet acidophilus milk, Acidophilin, Acidophilus-yeast milk, Acidophilus-Bifidus milk (A/B milk) Bifidus milk, Bifihurt (Algeyer *et al.*, 2010)

Acidophilus milk is manufactured by subjecting milk to high temperature (95°C for 1 h or 125°C for 15 min). This process results in denaturation of milk serum proteins causing the release of peptides that are essential for the growth of *Lactobacillus acidophilus*. After the heat treatment, the milk is cooled to 37°C and kept for about 3 to 4 h so as to allow all the spores to germinate. The milk is then reheated to destroy the vegetative microorganisms (Vedamuthu, 2006). Then a pure culture of *Lactobacillus acidophilus* at the rate of 2-5% is added to the milk and incubated at a temperature of about 37.8°C. Fermentation (usually takes 18-20 h) is allowed to occur till pH 5.5 or 1% lactic acid (Kandylis *et al.*, 2016). To enhance the functionality of the acidophilus milk vitamins and minerals are also added (Ozer and Kirmaci, 2010). Additionally, to improve the overall sensory acceptability, flavouring and aroma compounds are also commonly added to acidophilus milk (Junaid *et al.*, 2013). Acidophilus milk has a peculiar distinctive tangy flavor, slightly thick texture and a short shelf-life (Goodarzi *et al.*, 2017). Acidophilus-yeast milk is produced from milk that is inoculated with *Lactobacillus acidophilus* and sucrose or lactose fermenting yeasts (*Saccharomyces lactis*). Acidophilin is used in treatment of intestinal ailments such as colitis, enterocolitis etc. and also available as a medicinal supplementary product.

The Bifidus milk was developed in Germany in 1948 and was the first infant product containing Bifidobacteria. Considering its health benefits it has been a market success since then. The milk is heat treated (80-120°C for 5-30 min) and inoculated with *Bifidobacterium bifidum* or *B. longum* at 10% level. The milk is then allowed for fermentation at 37°C until pH 4.6-4.7 is attained. Protein enrichment and fat standardization are commonly practiced in Bifidus milk production. Bifidus milk has a characteristic aroma and a slightly acidic flavor. Bifidus milk is easily

digested, used as a supplement for the treatment of GI tract ailments (Silva *et al.*, 1999) and hepatic disorders (Yerlikaya, 2014).

Enriched dairy based Probiotic beverages

Value-added beverages are gaining huge popularity in the Western countries. Especially, the sports beverages and high protein beverages are presently, dominating the dairy-based beverages market.

- Prebiotics included dairy probiotic beverages (Guimaraes *et al.*, 2018), Fruit extract / pulp (Singh *et al.*, 2014; Poorani *et al.*, 2020; Jayalalitha *et al.*, 2023) and Vegetable extract enriched dairy probiotic beverages (Arsic *et al.*, 2018; Subramonian *et al.*, 2018), Microalgae enriched dairy probiotic beverages, Adjuvant added dairy probiotic beverages, Carbonated dairy based synbiotic beverages, Composite dairy probiotic beverages, Chocolate flavoured dairy probiotic beverages, Honey enriched dairy probiotic beverages, Probiotic whey-based beverages (Pescuma *et al.*, 2010). Buttermilk whey-based probiotic beverages (Antunes *et al.*, 2009).

Non bovine milk based probiotic beverages

Global demand towards non-bovine milks have been increasing much faster than anticipated. The global bovine and non-bovine milk productions increased between 1983 and 2013 by 41% and 165%, respectively. Although majority of dairy based probiotic beverages use cow's milk, milk from non-bovine species including from goat, sheep, mare, camel, donkey, etc. are also being widely used as probiotic carrier dairy food bases (Ayyash *et al.*, 2018). The therapeutic properties of non-bovine milks advocates their use in the food products (Ranadheera *et al.*, 2018; Sharma *et al.*, 2022). The mono and polyunsaturated fatty acid profiles and mineral compositions of goat's and sheep's milks vary from that of cow's milk (Slaćanac *et al.*, 2010).

Furthermore, the goat's milk is more easily digested by humans and has a high buffering capacity (Bozanic *et al.*, 2004). Donkey milk has high lysozyme content and hence it exhibits antibacterial activity. Owing to its high total solids content, the dairy products manufactured from sheep's milk are considered as suitable to offer protection to the probiotic microorganisms during gastrointestinal passage (Balthazar, *et al.*, 2017). These properties of non-bovine milks make them potentially suitable for the development of functional dairy products (Turchi *et al.*, 2017).

In spite of having many functional and nutritional advantages compared with cow's milk, the usage of non bovine in the production of functional foods including probiotic or symbiotic products still remains challenging (Pinto *et al.*, 2017, Abduku and Eshetu, 2024).

Challenges in the usage of non bovine milk based probiotic beverages

1. Geographical heterogeneity and seasonal variation is commonly observed in the production of non-bovine milks.

2. The high antimicrobial activity exhibited by the milk from non-bovine species such as camel's and donkey is the major limiting factor in the manufacture of functional dairy products. Poor probiotic growth and viability are often observed in the milk from the non bovine species.
3. The volume of global non-bovine milks production is much lower than the bovine's milk, thus limiting the mass production of any functional food from these milk species.

Probiotic requisites and selection criteria

For a probiotic strain to be used in the food products, the most important criteria is that it must be generally regarded as safe (GRAS). Furthermore, it is essential that these probiotic bacteria must be present in a dairy food product to a minimum level of 10^6 CFU/g or the daily intake should be about 10^8 CFU/g. This takes into account the possible reduction in the probiotic count during the post production period such as transport, storage and passage through the gastrointestinal tract.

During the selection process of probiotics, the safety, functional and technological characteristics, have to be taken into consideration FAO/WHO (2002). The safety aspects include the specifications such as source and origin. The probiotic bacteria selected should be non toxic, must not be mutagenic, or carcinogenic to the host, must be antagonistic to pathogens and genetically stable and not exhibit plasmid transfer mechanism.

- Functional aspects include persistence and viability in the gastrointestinal tract, Ensuring the viability of probiotics is highly essential for delivering the benefits of the probiotic products. They must survive during their passage through the GI tract, digestion and possess the ability to adhere and colonize the gut mucosa, confers benefits such as promote immuno-stimulation without inflammatory effects.
- Several technological aspects need to be essentially considered in probiotic selection and inclusion into the products, as the probiotics encounter several stress conditions during food processing, storage and gastrointestinal transit. Most probiotic strains are sensitive to oxygen and their viability is affected by the presence of oxygen in dairy products. Bifidobacterium species are anaerobic and the oxygen toxicity results in a significant decline in their numbers during storage. Several processing steps involved in the processing of dairy products (e.g., agitation and mixing) inevitably incorporate a high amount of oxygen in the product.
- Selection criteria of probiotics include:
 - ✓The culture type and form.
 - ✓Effect on viability during the production process and the ability to withstand the processing conditions of the food during manufacturing.
 - ✓Ease of application in the food products.
 - ✓The minimum count of bacteria required to obtain a beneficial effect.
 - ✓Stability during storage in the product.

- ✓ Possess acceptable sensory properties and have minimum changes in sensory properties of the food.

Production of probiotics for industrial use in the manufacturing of dairy beverages and the challenges encountered

Commercially available probiotic cultures may consist of a single strain or a mixture of several strains of bacteria. The strain or culture production process influences the properties of probiotics. Hence, a detailed information on strain specific properties should be available for the process optimisation.

A commercial probiotic supplement must have the maximum yield, high stability and show consistent performance for the intended application. The probiotic should be stable in the environmental conditions such as humidity, temperature and pressure. The probiotic should also exhibit rapid action without any significant delay.

Bioreactors are used for the commercial production of probiotic cells biomass. For industrial operations in food culture production, traditional batch and fed-batch fermentation are widely used. The density of the probiotic cells could be enhanced by modified continuous fermentation or fed-batch fermentation having the provision for cell recycling through a membrane to exclude lactic acid.

During the past liquid and frozen concentrates have been used extensively, but using freeze-dried and spray-dried preparations can save the transport and storage cost on a large scale in addition to offering the culture stability. As many LAB cannot tolerate the relatively high temperatures employed during spray-drying, for the production of dried LAB, freeze-drying is the most popular method despite that spray drying is more economical than freeze-drying, especially on a large scale. Even though, freeze-drying process causes less damage to microorganisms than spray-drying, stabilizers (cryoprotectants and lyoprotectants) protectants are usually added to the cultures to be dried in order to prevent, or mitigate, cell injury during drying and subsequent storage. The most commonly used protectants at industrial scale are lactose or sucrose, monosodium glutamate (MSG) and ascorbate in milk or in water base. Furthermore, the industrial production of probiotic bacteria should be economically viable to produce functional food incorporated with probiotics.

Challenges encountered during the biomass production of probiotics

During the probiotic cell mass production using a bioreactor, it is highly essential to important to maintain conditions such as optimum temperatures, pressures and pH levels inside the bioreactor, as these conditions are differ for the growth of different types of probiotics.

The cryoprotectants and lyoprotectants are used to prevent damage to the probiotic cells during the freezing or lyophilisation process and hence, the viability of the cells can be maintained. Cryoprotectants delay ice formation by

raising the viscosity of the solution and retain the amorphous structure of ice close to the cells thereby protecting the cells from injury during the process of freezing. Lyoprotectants work by stabilizing the cell membrane's lipid bilayer structure in the absence of water and thereby protect the cells during freeze drying. Rehydration of dried cells is also highly essential for maximum productivity. The cells face the risk of losing viability when the optimum conditions are not provided. Hence, in the production of biomass at large commercial levels, the rehydration conditions play a very important role.

• Nutrients requirements of probiotics

Probiotic bacteria especially, the lactobacilli are nutritionally fastidious organisms. Hence, factors such as medium formulations, pH and temperature influence the viability and growth activity of the culture.

• Interaction with starter culture

The interactions between starter culture and probiotic impose a great impact on the product quality. The fermented dairy products having good survival of the bacteria by using starter and probiotic organisms together with excellent sensory properties becoming quite popular. The most suitable and optimum combination of a starter and a specific probiotic bacteria needs to be determined by employing a screening process that evaluates the impact of different starters on the survival of the probiotic strain and on the sensory properties (Yerlikaya, 2014). During the selection of a suitable starter its negative impact on probiotic survival both *in vitro* and *in vivo* should also be taken into consideration. The survival of the probiotic bacteria could be influenced by the metabolites formed by the starter such as hydrogen peroxide, lactic acid and bacteriocins.

• Effect of pH on probiotics

During the processing of dairy products, such as yogurts and fermented milk, the subjection of probiotics to the low pH values is also a matter of concern. The pH of the medium is a critical stress factor for the probiotics viability during processing and storage, although there are variations between species and strains with respect to the survival in acidic environments. F1 F0 AT Pase, biofilm formation, cell density, metabolic regulations, malolactic fermentation, protection and repair of cellular macromolecules are few of the mechanisms utilized by *Lactobacillus* in acid tolerance. The easiest technological solution to tackle the acid stress is to promote a previous strain exposure to lower pH values for a short period of time, thereby inducing a tolerance of the microorganism. Furthermore, acid-resistant strains exhibited a higher fermentation rate and enzymatic activity, such as of glucosidases, which favours its metabolic function and survival in the gut.

• Effect of exposure to oxygen on probiotics

During the dairy processing, especially for the manufacturing of certain types of yogurts and fermented

milks, the processes such as stirring and whipping are employed which create environments with a rich concentration of oxygen. The exposure of probiotic cultures to high concentrations of dissolved oxygen causes increased accumulation of toxic metabolites such as superoxide, hydroxyl radicals and hydrogen peroxide, which eventually lead to death of probiotic microorganisms. Differences in the impact of toxic effect of oxygen on probiotics can be observed, there are variations between different species. For *eg.*, *Bifidobacterium* spp., which is strictly anaerobic in nature, is more vulnerable to the toxic effects of oxygen than strains of *Lactobacillus acidophilus*.

• Effect of temperature on probiotics

The next vital issue concerning the viability and growth of probiotic strains into food is the temperature. During processing, the heating temperatures below 45°C are usually compatible with the probiotic cultures, although this depends on the duration of exposure and the specific strain. Processes that include heating steps above 45°C cause reduction in the probiotic population. On the other hand, lower temperatures are generally used to delay the chemical reactions and growth of microorganisms in foods, therefore a lower temperature confers increased bacterial growth inhibition. Because of their nature, dairy products, both the fermented and non fermented dairy products, require low storage temperature for preservation, which determines the survival and viability of probiotics in these products. Freezing the products might also lead to a considerable reduction in the number of viable microorganisms in food and this reduction would depend on the specific strain tolerance to low temperature, freezing rate and duration. Cold temperatures influence DNA/RNA functions related to the transcription and translation and reduce the membrane fluidity as well (Daneshi *et al.*, 2013). Additionally, the cold stress could cause reduction of enzymatic activity and increase sensitiveness toward sodium chloride, which may cause damage in the cell membrane.

• Effect of packing process and material used on probiotics

The packaging process and the material used for packing also influence the functionality of the probiotics in the dairy foods. Generally, the probiotic bacteria prefer microaerobic or anaerobic environment; hence, exposing these microorganisms to oxygen during packaging may result in lower viability. The presence of oxygen alone cannot cause a very significant damage in the bacterial cell (Endo *et al.*, 2014); however, in the presence of water, oxygen can be reduced and may form reactive oxygen species (ROS), which are toxic and harmful to the probiotic bacteria. These ROS such as superoxide (O_2^-) and hydroxide anion (OH^-) attack lipids, proteins, lipids and nucleic acids in the cell leading to cell death. The use of suitable packaging materials and appropriate packaging technology is essential to safeguard the full therapeutic potential of the probiotic properties throughout storage.

Moreover, the harvesting time also influences the functional properties of the cells. Finally, but more significantly, the challenge in the biomass production of probiotic cells includes its economic perspective which is the key factor and the backbone of any industrial or commercial production.

Strategies to address viability, stability, functionality and sensory issues

There are several ways to tackle the challenges related to probiotic functionalities through processing, biological, technological changes. For instance,

- Selection of oxygen-resistant probiotic strains,
- The use of oxygen impermeable containers
- Removing molecular oxygen through oxygen-scavenging
- Electroreduction of milk
- Inclusion of nutrients and prebiotics (non-digestible components such as lactulose, inulin and a range of oligosaccharides) in dairy products also have been added to enhance the viability of probiotics (Yerlikaya *et al.*, 2012) Prebiotics are non-digestible dietary components that pass through the gastrointestinal tract and selectively stimulate the proliferation and/or activity of populations of desirable bacteria in the gut. Due to the synergy between probiotics and prebiotics, prebiotics influence the survival and growth of the probiotics (Champagne *et al.*, 2018).
- Addition of adjuvants such as tryptone (Shobharani and Agrawal, 2009) and antioxidants such as ascorbate, ascorbic acid, glucose oxidase and L-Cysteine.
- Addition of resistant starch. Resistant starch serves as an ideal surface for adherence of the probiotic cells to the starch granule during manufacturing, processing, storage and passage through the gastrointestinal tract. This provides protection to the probiotic cells in the adverse environmental stress conditions and thus offers enhanced delivery of metabolically active and viable probiotics to the intestinal tract.
- Microencapsulation using materials such as alginate, lipids and prebiotics. Microencapsulation technology is a recently employed technique employed in the food industry. Probiotics that are included in the food products are microencapsulated to safeguard the cells and ensure stability of probiotic cells against undesirable environmental conditions during processing and storage (Verruck *et al.*, 2017). Although this technique is used for the production of probiotic yogurt and cheese, its use in the beverage formulations needs still more attention as the microbeads might cause sensory defects in the beverages.
- Pre-adaptation of cells to stress /prior exposure to sub-lethal levels of the given stress (temperature, pH or bile salts). For *eg.*, exposing to chemical solution for the oxidative stress and the acid stress in dairy probiotic products containing *L. acidophilus* and *B. bifidum*, can be used to bring about the "destressing effect." For the former, the addition of sodium citrate or calcium carbonate

neutralizes the lactic acid produced during the fermentation process. For the latter, the addition of antioxidant substances such as sodium ascorbate or D-ascorbate (4 g/kg) would be used to react with ROS thereby eliminating the stress caused by exposure to oxygen.

- Addition of the probiotics after pasteurization
- Adopting novel thermal/nonthermal technologies
Emerging food processing technologies such as non-thermal and other novel technologies are becoming more and more popular as the present day consumer have high preference towards minimally processed foods. In the recent years, several of these technologies are being used at industrial scale in food industry.
- As compared to the standard pasteurization treatment at 72°C for 15 s application of 600W ultrasonic power enhanced the kinetic stability of the beverages with reduced phase separation (Guimaraes *et al.*, 2018). Non-thermal treatment of whey based beverages offered decreased rate of whey protein denaturation and particle size and gelation tendency of inulin and gellan.
- High hydrostatic processing (HHP) is another non-thermal food processing technology which is used in the beverage industries across many countries. HHP is a technology that immerses a product under water and exposes it to a hydrostatic pressure of several 100 megapascal in a HP vessel. The product is commonly packed in a high-pressure-suitable packaging and held under pressure for certain time, until decompression. HP treatment employs pressure range from 100 to 800 MPa and temperatures ranging from 20 to 60°. HHP is effective in extending the shelf-life and preserving the flavour and texture attributes of fermented whey beverage upto 45 days in cold storage (Pega *et al.*, 2018).
- Ohmic heating (OH) is another recently emerging food processing technology that minimizes changes in food components as compared to the conventional heat treatment and thereby prevents the formation of off-flavours in food products to a large extent (Cappato, *et al.*, 2017). Ohmic heating generates a uniform and fast heating and effectively ensures microbiological safety in foods.
- Supercritical carbon dioxide (SC-CO₂) is yet another non thermal emerging technology that has a large potential of being used in food processing industry. The SC-CO₂ treatment does not cause any harmful effect on physico-chemical, nutritional and sensory properties of food products (Amaral, *et al.*, 2017).
- Cold-plasma is an emerging food processing technology that is used for decontamination of the food products including the dairy products. Cold plasma technology employment inactivates microorganisms of various types in dairy products at temperatures below 50°C and extends the storage shelf-life of products with minimum harm to the probiotics and the food matrix. Use of Cold plasma technology has several advantages that include reduced preservative use, having no residual formation, being

energy efficient and also is easily compatible with commonly used packaging materials (Misra *et al.*, 2016). However, the application of this technology might cause issues with colour in the processed products and might enhance the lipid peroxidation in high fat products.

Hence, it is necessary to optimize various technological and economical aspects in the manufacturing process of these products, including the development of suitable packaging process and materials which offer adequate protection and preserve the therapeutic efficacy of probiotics.

Sensory properties of probiotic dairy beverages

A probiotic based dairy product must offer not only the minimum cell count to confer health benefits but also have sensory acceptance by the consumers. Hence, the sensory evaluation of these products must be carried over throughout processing to prevent eventual problems during marketing. In general, all the probiotic foods must be safe to the consumers and have good sensory properties. They must also include specific probiotic strains at an optimal level during storage (usually 10⁶-10⁷ CFU/g), which must be incorporated into foods without producing any off flavors. For example, bifidobacteria produce acetic and lactic acids and the taste and aroma of acetic acid confer extremely undesirable off-flavors to the dairy products. Thus to mask or minimise this defect "probiotic flavor", flavouring agents are commonly used. The addition of microencapsulated probiotic cultures to dairy food products offers as a good effective alternative to overcome this undesired flavour due to the presence of these probiotic culture strains.

Consumers find products that are fermented with *L. delbrueckii* spp. *bulgaricus* to be considerably acidic having a too heavy acetaldehyde flavor. Therefore, probiotic cultures have been developed to offer the preferred flavors in the products in which they are used. Examples of such cultures are the ABT cultures (ABT standing for *L. acidophilus*, *Bifidobacterium* and *S. thermophilus*). In fermented probiotic products, it is important that the probiotic culture used contributes to good sensory properties.

To achieve main goals of success in the probiotic beverages production, apart from the growth and survivability during the processing and storage, the sensory evaluation is very important which has a direct association with product quality, processing characteristics and consumer acceptability. Therefore, sensory properties and consumer acceptance must be thoroughly studied and evaluated before launching new products into the food market. The focus on sensory acceptability is still the prime factor for researchers and manufacturers worldwide.

Future perspectives

Functional probiotic dairy beverages provide additional benefits beyond basic nutritional supplementations and stand out as a special type of matrix to facilitate probiotic health benefits. But delivering an optimal final product with

probiotic effect remains a challenge. Intensive efforts have been made to redesign dairy-based beverages to ensure optimal probiotic effects and maintain the sensory properties.

Currently, the industrial demand for technologies which ensure probiotic stability in foods remains strong. The encapsulation technology for probiotics provides promising prospects for enhanced performance, however this technique is still in the research phase and has to be commercially up scaled to a large scale. Valid feasible technologies that optimum fermentation also ensuring probiotic stability are important. Furthermore, pilot and commercial-scale production of new anaerobic probiotic cultures will have to be researched. The stress factors influencing the viability and functionality of organisms need to be explored and controlled.

Research towards quality assurance of probiotic strains needs to be further strengthened and would be huge step in the probiotic based food product development. Similarly, controlled human studies are essential for the further promoting the probiotic functional foods and their ultimate success. The probiotics should be customised for specific target population groups such as the geriatric and babies. Future research on probiotic bacteria should centre on selecting new and target consumer specific strains for the host (age groups, gender and disease specific). Additionally, the scientific and technological research trends in future have to be targeted towards:

- Research on the mechanisms of action of probiotics in the gastrointestinal tract and develop diagnostic tools and biomarkers for their assessment. Promote research into the areas such as GI-tract biome, GI immunology, biomarkers and the functionality of probiotics in these aspects needs to be focussed.
- Evaluation of the effects of probiotics on GI-diseases and allergies.
- Ensure the stability and viability of probiotic products by developing low cost facile technologies (e.g. material development and process standardisation for microencapsulation). Novel polysaccharides capable of enhancing the bacterial adhesion needs exploration
- Develop facile and economically viable technology for bulk production of probiotics involving minimal cost and processing inputs and minimal steps.
- Develop suitable packaging material keeping in view of the probiotic viability and sensory aspects.
- Improve the techniques to enhance the sensory qualities of the beverages.
- Evaluate the role of probiotics in healthy consumer groups and to address consumer preference.

CONCLUSION

The dairy beverages marketplace is a competitive and growing category in the dairy industry. Fermented and non-fermented milk-based functional products including probiotics have a well-established market success.

Probiotic beverages are being widely promoted and popularized by functional drink manufacturers due to their health benefits and the ease of availability of these drinks in a variety of flavors especially the traditional or regional dairy-based drinks, which are becoming widely popular globally. For example, Kefir and Koumiss are gaining immense attraction across the globe. Moreover, the need for vital supplements and drinks among the older population and increased health consciousness among the younger generation is opening up vast opportunities and is driving the functional food market. Hence, the probiotic dairy beverage market is sure to witness an exponential growth in the coming years.

Conflict of interest

All authors declare that they have no conflict of interest.

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