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Use of Bacteria in the Dairy Industry: A Review

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Abstract

Bacteria are microorganisms that are widely distributed in nature. There are many types of bacteria, including pathogenic bacteria and beneficial bacteria. Beneficial bacteria are widely used in the food industry in general and in the dairy industry in particular, where they are mainly used in the production of yogurt and cheese of all kinds. They have many health benefits, as they aid digestion and strengthen the digestive and immune systems.

Keywords: Dairy Industry, Lactic Acid Bacteria, Probiotic Bacteria

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1. Introduction

Bacteria, as a large group of prokaryotic unicellular microorganisms, occur widely in the environment, and most of them do not cause diseases. Bacteria have been greatly exploited for their useful activities, and several studies indicate that such beneficial activities surpassing other microorganisms lead researchers to investigate the application of bacteria. At the same time, few have pathogenicity to humans and animals, and fast-growing bacteria or their metabolites cause spoilage of several food products. Bacterial waste products are processed for the production of various useful substances because of their ubiquitous nature (Gopal et al., 2015). Bacteria with beneficial activities on food in the dairy industry and fermented milk products, and their recent applications, are reviewed. Many products, such as antibiotics, enzymes, amino acids, organic acids, vitamins, and many polysaccharides, are processed by the action of bacteria. Bacteria are the most widely used microorganisms for the production of fermented foods and their products, and it has a great impact on our foods as well as health (Soemarie et al. 2021; Skowron et al. 2022).

Fermented milk products such as yogurt, cheese, kefir, and acidophilus milk are prepared by the action of bacteria. It has been known for several centuries that milk becomes sour due to the action of certain microorganisms like lactic acid bacteria, which aid in the formation of curd, products with distinctive flavour, texture, and aroma, and prolong stability (Girma & Aemiro, 2021). Milk is an excellent medium for the growth of bacteria due to its optimal biological activity. Products like yogurt are formed from milk by the action of streptococci, which convert lactose to lactic acid, thus causing curdling. Coagulated curd is further treated by rennin and enzyme casein to form cheese. Besides agents of spoilage, bacteria with specific useful activities both in the food industry and in biological membranes with high potential for biotechnological exploitation need to be addressed. Information is on the beneficial or useful activities of bacteria on food in the dairy industry (Taye et al.2021). This

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review aimed to identify the types and roles of bacteria used in the manufacture of dairy products.

2. Types of Bacteria in Dairy Production

With regards to the historical definition of bacteria, proposed that bacteria, as microorganisms of ubiquitous occurrence, are prokaryotic and have a simple cell structure (Uluçay2023). Bacteria, in the dairy industry, produce lactic acid through the fermentation of lactose or milk sugar. Principal genera contributing to the manufacture of dairy products either directly or indirectly are Streptococcus, Lactobacillus, Leuconostoc, Lactococcus, Propionibacterium, etc. Bacteria as non-starters are Streptococcus thermophilus, Lactobacillus pharmerium, Lactobacillus delbrueckii, etc. The yeast and mould species also used in the industry are naturally limited. Yeast generally belongs to the Saccharomyces species, whereas moulds belong to the Penicillium genus. The genus cogitativus is used for many cheeses having a blue texture. Most of the cultured dairy products have bacteria as starters, which are derived from milk and milk products. Many of the probiotic culture bacteria are also used in the dairy industry (Gopal et al., 2015).

E.g., bifido bacteria, lactic cultures of sphermoides, acidophilus, etc. There are positive impacts of these various cultured species and genera of bacteria on nutritional, keeping quality, flavour, safety, and other organoleptic characters of different fermented dairy foods. Fermented dairy products are in high demand in local as well as international markets. In this era of food safety and assurance, several scholarly works in microbiology and biotechnology are conducted for the safety assessment of yogurt, cheddar cheese, paneer, and Dahi incorporating probiotics. Thus, keeping in mind a growing demand for fermented dairy foods in calorie-deficient and developing countries, a review on the varied types of bacteria and their merits in the dairy industry was undertaken. Food products containing microorganisms, generally referred to as starter cultures, are one of the oldest biotechnology enterprises in the world (Rabah et al., 2017).

2.1. Lactic Acid Bacteria

Lactic acid bacteria (LAB), a heterogeneous group of Gram-positive bacteria, are widely recognized for their essential role in the production of fermented foods of various origins. They dominate many ecosystems, including fermented dairy products, meats, vegetables, and plants (Wang et al.2023). There is increasing evidence that some strains of LAB originating from dairy products confer health and nutritional benefits on human consumers (Miranda et al.2021). Novel applications have been explored for the utilization of LAB in the food and biotechnological industries (Abedin et al.2024). However, the use of LAB in food biopreservation, primarily in meat and beverages (Kaveh et al., 2023). Bacteriocinogenic strains with novel bacteriocins that have yet to be identified are needed for development into food biopreservation cultures. New strains of LAB and bacteriocins produced by species not traditionally used in dairy products are needed for the development of probiotic cultures equipped with new metabolic traits (Palva, 1998). LAB research and development highlighted where new investment would be most fruitful and contribute to improving human health and welfare. Special emphasis on the historical evolution of research and development on LAB, and insight into the LAB community in Nordic countries. LAB are a great group of diverse, durable, and eco-friendly microorganisms, whose impact on mankind's health and welfare is immeasurable. Effective utilization of LAB is possible with their metabolic and technological diversity, profound understanding of their physiology and genetics, and a supporting infrastructure of technologies and know-how. Several of the continuing and emerging trends at a global, scientific, industrial, and regulatory scale are discussed, and societal implications of these trends are envisaged (Ayed et al., 2024).

2.2. Probiotic Bacteria

Health claims about the consumption of foods containing probiotic bacteria have gained increased attention in recent years, and more and more publications associate a specific health benefit with a particular bacterium (Liang et al.2024). However, the health claims for most organisms are in a very early development stage, and in most instances, evidence of health benefits is not yet fully convincing (Rabah et al., 2017).

With the rapid growth of an increasingly globalized market for probiotic dairy foods, strains are commercially available under a multitude of brand names, describing a blend of bacteria. These bacteria are protected by patents and/or secrecy. That complicates a sound assessment of the health claims with respect to the safety and efficacy of many organisms. However, Lactobacillus rhamnosus GR1 and Lactobacillus reuteri RC-14 strains remain very widely studied organisms to that particular end, with relatively favorable results (Gaucher et al., 2019). To date, Lactobacillus rhamnosus GR1 and Lactobacillus reuteri RC-14 strains are the only probiotics approved by the National Institute for Health to prevent urinary tract infection. Nevertheless, safety studies have started with a number of other organisms, and some encouraging results have been obtained (Sharpe et al.2021).

Probiotics are non-pathogenic microorganisms that confer health benefits to the host. Since then, they have moved on to a much-sought-after routine commercial product. Fate or fortune plays a large part in serendipitous discovery, which is often not reproducible (Gao et al.2021).

2.3. Spoilage Bacteria

A distinctly different class of spoilage bacteria is those forming spores that survive heat treatment and relatively low pH, and which are not generally pathogenic to humans (Gopal et al., 2015). Although Bacillus cereus was the first spore-forming species noted for spoilage of milk, a number of species from several genera now recognized as potential spoilage organisms have been shown as capable of cause significant spoilage during shelf-life. Major spoilage contaminants are anaerobic, but spoilage of milk, cream, and yogurt may occur in vacuum-sealed containers, and during incubation for solid-set yogurt, can lead to "puffing" (the rupture of the lid on containers) (Meng et al.2022).

The association of off-flavors (such as "bitty cream" and "sweet curdling") with milk powders. Other noted milk powder defects are bitterness, fruitiness, rancidity, and flat-sour spoilage. Major producers of spoilage are relatively rare-and this, at least partly for reasons of milk-source management, has been effective for a number of years. However, with the increased globalization of supply and the heat treatment of drinks, the presence of these organisms in the system has become a major problem not only for the processing but also for the avoidance of spoilage during the product's shelf life. (Akinsemolu & Onyeaka, 2024)

The presence of significant numbers of spore-forming bacteria in raw milk and interaction with their spores in crewed powder. Initial bacterial levels from the supply farm were investigated and indicated a very varied picture, but with generally low levels. The raw milk reception and processing in a DAF was shown to result in flow-through of spores via gravity, whilst still subjecting them to heat and/or choices with demonstrated effectiveness against spore-formers. (Gupta & Brightwell, 2023)

3. Role of Bacteria in Fermentation

Bacterial fermentation is a key process contributing to human food production and preparation. Spontaneous fermentations were likely exploited by early humans in prehistoric times, seeking food preservation through spoilage, such as intentionally standing of milk leading to souring, or leaving flower receptacles for beer production (González-González et al., 2022). The earliest tool dates back to 30,000–30,500 B.C., with the earliest food remnants dated to 17,700–15,000 B.C. Crafting vessels made from materials like stone, clay, or glass was likely to have occurred simultaneously with the discovery of fermentation. Eventually, one or more wild strains of bacteria, yeast, or molds became dominant, leading to repeated preservative production. Inspired by adaptation and specialization processes for different food matrices, human interaction with those "wild ferments" gradually refined knowledge about each food. These processes were controlled by humans over time to reach optimum processes, sustenance, and traditions. Nutritional, sensory, and other properties of fermented foodstuffs became invaluable; some strains were recognized, and others lost (Dunn et al.2021; Flachs & Orkin, 2021).

3.1. Cheese Production

Cheese is a food product made by coagulating milk proteins through means of fermentation. The need for cheese is both cultural and biological; its transformation into a more dry, storable product allows it to be safely eaten year-round. Cheese is a rich source of nutrients, including high-quality proteins, peptides, amino acids, fats, vitamins, and minerals. All the essential amino acids, essential fatty acids, and many bioactive peptides can be supplied from cheese. The widespread adoption of pasteurization to improve the safety of cheese and the stringency of this process are key factors in the control of pathogenic bacteria. However, some producers of cheese use traditional, non-heat treatment methods with unpasteurized milk. These methods allow for the development of distinct flavors and textures imparted through the fermentation and side reactions of the diverse indigenous microflora (Nitu et al.2021, Devi et al.2023, Mohsin et al.2024). Raw milk cheeses can develop a broader flavor profile and higher concentrations of aromatic compounds during manufacturing and ripening in comparison to their pasteurized counterparts. This broader flavor profile is a function of the local microflora of the raw milk used to manufacture the cheese. Along with moisture and pH, lactic acid bacteria are an essential component for cheese fermentation and production. These include both exogenous starter LAB and indigenous LAB. Cheese microflora can be broadly separated into two groups: starter lactic acid bacteria (SLAB) and non-starter lactic acid bacteria (NSLAB). The SLAB utilized in cheese manufacturing is commercially obtained strains of Lactococcus, Lactobacillus, and Streptococcus; these are responsible for the vast majority of acid production and are termed primary microbiota (Coelho et al., 2022; Psomas et al., 2023).

Cheese is a highly probable vehicle for enteropathogens, particularly because of the common practice in the production of these cheeses to utilize unpasteurized milk, which is a health risk (Willis et al.2022). There is a health risk because, aside from these potentially pathogenic microorganisms, the safety of the cheese product is also a concern, as it is impossible to ensure the absence of pathogenic microorganisms in the unpasteurized milk (Willis et al.2022). Fresh Mexican-style cheese (FMSC) produced in Mexico is typically made from unpasteurized milk, and in its production, no bacteria are inoculated; this cheese is not a fermented product. Due to its high moisture content, FMSC has a short shelf life and is, for the most part, consumed soon after it is made (E. Vera-Santander et al., 2024). Unfortunately, there have been many recorded cases of illness associated with the consumption of this cheese. This phenomenon can be attributed to the common production practice of using unpasteurized milk or to inadequate handling techniques during its production (Possas et al., 2021). For these reasons, this cheese is considered a highly probable vehicle for Salmonella, Listeria monocytogenes, Escherichia coli, and Staphylococcus aureus, among others (Olea-Rodríguez et al.2021). Bio-preservation is defined as the use of microorganisms or their metabolites, such as bacteriocins, to increase the shelf life and/or safety of food. Lactic acid bacteria (LAB) have emerged as one of the most promising natural biological antagonists due to their capacity to produce a wide variety of antimicrobial substances, making them a common (pre-), starter culture for the food industry, especially in the manufacture of fermented dairy products. Various studies have explored the potential application of non-traditional bacteriocin-producing LAB, especially lactobacilli and enterococci, to improve the safety and shelf-life of cheese. LAB are regarded as safe (GRAS) and with a qualified presumption of safety (QPS) status by the FAO and EFSA, respectively. Many strains of LAB have been studied as bio-preservation tools based on their ability to secrete antimicrobial compounds (Cirat et al.2024; Zapaśnik et al., 2022).

3.2. Yogurt Production

Yoghurt, a fermented milk product, is characterized by flavor, aroma, viscosity, and mouthfeel. It is rapidly consumed around the world and has health benefits due to the consumption of lactic acid bacteria, particularly probiotics. Health officials advocate active consumption of probiotic food due to their beneficial health properties (Hoxha et al., 2023). Probiotic cultures reduce the number of gut bacteria, decrease cholesterol levels, improve lactose tolerance, and lower the risk of colorectal cancer. Fermented products with probiotics can protect against pathogens, mutagenic or carcinogenic compounds, and cholesterol-solubilizing agents. Fermented products are an important part of the traditional diet in countries around the Black Sea, and the consumption of Bulgarian yoghurt is widespread due to the health benefits attributed to the probiotic lactobacilli commonly found in the Bulgarian culture. The research spanned seven years, and the scope of the project focused on species new to traditional dairy fermentation, but also on mesophilic aerobes, yeasts, and molds. A comprehensive study of yogurt and strains included microbiological, biochemical, physico-chemical, and molecular methods to explore species diversity, enzyme production, and bioactive potential as bioprotective cultures and probiotic strains (Pahumunto & Teanpaisan, 2023; Tripathy et al., 2021; Astawan et al., 2012).

3.3. Kefir Production

Kefir is a fermented dairy product that is produced by the addition of kefir grains to milk. The grains, which are made of a polysaccharide matrix and a complex community of microbes, mainly lactic acid bacteria (LAB), yeasts, and acetic acid bacteria, act as starter cultures for the fermentation process. Kefir grains are a heterogeneous matrix loosely held together with the polysaccharide kefiran, water, proteins, and polysaccharides, and they contain lactic acid bacteria (LAB), yeasts, and occasionally acetic acid bacteria in a complex symbiotic consortium. The process of fermentation involves two major metabolic processes: LAB ferment lactose into lactic acid, diacetyl, and other volatile compounds, and yeasts ferment sugars into carbon dioxide and alcohol, resulting in the carbonated product. During production, the quality of the milk base influences the sensory and microbiological properties of kefir. Kefir can be produced from cow's milk, sheep's milk, goat's milk, or non-dairy alternatives such as soy, coconut, almond, or rice milk. Some manufacturers provide a dairy-free variant for users who are allergic to lactose or casein. The most widely used milk for kefir production comes from cow (bovine) and goat (caprine) herds. The milk is consumed whole or fermented, partly skimmed, double or triple-cream, pasteurized, ultra-pasteurized, or any combination thereof. The process flows among kefir manufacturers in different ways, although most will include pasteurization, cooling, and transfer of the milk to holding tanks before fermentation. A quota of matured kefir cultures is added to the pasteurized and cooled milk, usually along with milk solids for fat-free or low-fat formulations. The temperature is reduced further to 21 to 24 °C, and fermenting is controlled until a pH of 4.6 is reached (McGovern et al.2024; Gökırmaklı and Güzel-Seydim2022; Virginia O\u27Brien, 2012).

4. Bacterial Cultures in Dairy Products

Lactobacillus helveticus is used for the production of Swiss-type cheeses, primarily Emmental. These appetising cheeses are produced from thermised milk using both a mesophilic and thermophilic starter culture, as well as adjunct cultures of Lb. helveticus. The texture is important to the shelf life and appearance of these cheeses, and exemplifies how a simple change in cheesemaking conditions can lead to a major alteration in the cheese characteristics. Adjunct lactobacilli are of the heterofermentative type, typically Lb. helveticus. Proteolysis, aroma and flavour development, and eye formation have all been correlated with the composition of the Lactobacillus strains used in the adjunct culture. Mesophilic culture and cheddaring methods, together with lactobacilli adjunct cultures, are used for the manufacture of this product compressed for a longer shelf life (Gagnaire et al.2022; Gasser et al.2023).

4.1. Starter Cultures

Starter cultures are defined as a certain specific population of microorganisms that are deliberately added to the food for processing for desired fermentation, irrespective of their number. (Prema Latha et al., 2015). These selected microorganisms or starter cultures are required to produce or develop the desired end product/food product. The dairy industry utilizes different organisms like bacteria, yeast, and molds as starter cultures (García-Díez and Saraiva2021).

Mainly, two types of starter cultures are utilized in this industry. They are innoculative cultures and adjunctive cultures. Inoculative cultures are cultures which inoculated at large numbers at the beginning of the fermentation with a view to producing the desired food. The resulting food product from such a culture system will possess the traits of the starter culture organisms used like for example, the curd from a mesophilic culture would be firm with a distinct flavor profile, while that from a thermophilic culture is soft with a mild flavor profile. On the other hand, adjunctive cultures are those cultures that are added to the desired food in smaller numbers after the first fermentation in order to impart additional desired flavor or textural characteristics to the food, like the development of aroma and flavor in cheddar cheese and the nutty flavor and smooth body of Swiss cheese. The cultures are selected strains from the genera Streptococcus, Lactococcus, Leuconostoc, Lactobacillus, and Bifidobacteria (dependent on their substrates and resultant pH). These organisms perform important functions in fermented milk products. They synthesize milk sugar into lactic acid, which reduces the pH and leads to the coagulation of milk proteins. (García-Díez and Saraiva2021; Ziarno et al.2023)

Commercially prepared starter culture powders are now available in different compositions and formats, but still, several quality parameters, like viability, adherence, and phage resistance, are required to improve. Other avenues for developing new starter cultures, like genetic modification, consortia of different strains, and cell-free cultures, are being explored. (González-González et al., 2022) In other fermented foods, the successful incorporation of novel strains/new cultures has helped in the development of desirable and novel products. However, strict regulations for recommending every strain for a desirable and novel product have slowed this approach. Efforts are on to improve the strains/produce new strains with desirable traits via genetic methods that would benefit the industry. (Glonti & Pirnay, 2022)

4.2. Adjunct Cultures

Adjunct cultures, originating from dairy products or raw milk, are used to produce typical flavour compounds or modify the properties of dairy products. They are, however, not sorted by any specific typological differences due to their proven benefits in the flavour, aroma, or other aspects of dairy products. Besides those discussed above, these cheap, considered process candidates were isolated for their proteolytic properties to modify whey protein concentrates, which were used as emulsifying agents for the production and storage of low-fat cheese-like products (Garbowska et al., 2021). Meanwhile, adjuncts with apparent and unique post-acidifying properties were successfully selected, grown in pure culture, and applied in cheese-making to modify the textural attributes of cheddar-like cheese products to be widely commercialized in Beijing. Surface-ripened cheese produced with adjuncts of different species and genera did show significantly different flavour and aroma profiles, demonstrating the applicability of adjunct cultures under conditions of far stricter monitoring with concern over possible hurdles impacting food safety. Studies have also been performed on the search for dairy products or raw milk-derived organisms as possible adjunct cultures for some cheese varieties. A brand-new viscous yogurt, produced with adjunct cultures isolated from Kazakh traditional fermented milk products, has been demonstrated as a promising starter adjunct culture (Li et al., 2022). It seems that lactobacilli adjuncts identified with a cultivation-selection strategy will probably be an up-and-coming topic for both food diversity and related genetic studies. (Zhang et al., 2024; Massoud and Khosravi-Darani2023)

5. Health Benefits of Probiotics

Probiotics are defined by the WHO as live microorganisms that, when administered in adequate amounts, confer a health benefit on the host and are specially formulated products that involve live microorganisms. The probiotics used in fermented dairy products are commonly lactic acid bacteria (LAB), which consist mainly of members of the genera Lactobacillus, Lactococcus, Streptococcus, Leuconostoc, Bifidobacterium, Enterococcus, Propionibacterium, and certain yeasts, fungi, molds, and Bacillus (Latif et al., 2023). The probiotic functions of LAB have been well documented because of their generally recognized as safe status (GRAS) for foods, and with the laboratory-scale fermented products also being commercialized in foods. Controlled pathogenic and spoilage microorganisms on food products are performed by LAB directly or through the metabolic by-products, viz., acid, hydrogen peroxide, diacetyl, and bacteriocins. These properties of LAB are commercially valuable for most sectors of the food industry (Rabah et al., 2017). The health-promoting effectiveness of probiotics is strain, dose, duration of intake, and food carrier matrix-dependent. Probiotic strains are predominantly species-specific, and the ability for health claims is closely linked with the probiotic strain's characteristics. The strain is represented with a Roman numeral and italic after the genus and species name. Besides the precious probiotic properties of LAB, there exist intrinsic limitations with respect to their commercial use in foods. Heat treatments during dairy product processing are particularly detrimental to LAB viability. Probiotics are also sensitive to gut-derived physicochemical stresses and transformed to a sub-lethal injury state, overwhelming fast-growing background microbiota. Another important yet often neglected aspect of probiotic viability is their potentially ill health effects, like enzymatic and non-specific cleavage of gastrointestinal proteins. (Gizachew et al.2023; Motey et al.2021)

Probiotics are marketed in dietary supplements and probiotic foods, which are fermented dairy and non-dairy products containing live beneficial bacteria or their byproducts. The first probiotic dietary and DD foods developed were yogurt drinks based on Lactobacillus bulgaricus and Streptococcus thermophilus. Commercial cheese and yogurt production is dominated by cultures of lactic acid bacteria and propionibacteria, which are probiotic microorganisms. yogurt, the most widely consumed fermented dairy food worldwide, continues to be an area of active research and new product development. Yogurt is produced by fermentation of pasteurized milk with metabolic activities of spirulina, fungus, molds, or yeasts to enrich the yogurt with bioactive compounds. Since gut health is associated with overall health, a variety of probiotics having gut health benefits are introduced in yogurt, and yogurt drinks tailored to consumer segments, such as diabetics, pregnant women, and growing infants. Concerns regarding fat and sugar added to yogurt and their detrimental health effects opened an opportunity for the development of fat-reduced and low-calorie yogurt products. The opportunities and challenges in the dairy industry were discussed regarding probiotic content improvement in the fortified probiotic cheese and fat-reduced cheese platforms for probiotic delivery. In addition to DD probiotics, on the lookout for non-dairy probiotic products like probiotic beers and soy beverages is also burgeoning. (Spacova et al.2023; Fusco et al.2022)

5.1. Digestive Health

Probiotics are live microorganisms that, upon ingestion in the right numbers, confer health benefits beyond inherent basic nutrition (Gaucher et al., 2019). After the discovery and isolation of probiotics, their integration into the diet to prevent some disorders was quite intuitive and started a long way of research and validation with both specific and general aspects. Probiotics such as bifidobacteria or Lactobacillus are part of the gut microbiota, have health-beneficial effects for the host, such as reduction of gastrointestinal stress or protection against its inflammation, and are used in the dairy industry in fermented products such as pre-climacteric cheese or yogurt (Corcionivoschi et al., 2010). Through the work of researchers, it appears that probiotics must survive and withstand stresses occurring during their technological processing to undergo strict conditions in the gastrointestinal environment and still stay alive. One aspect is a special sensitivity regarding the combination of acid and bile exposure encountered in the gastrointestinal tract, with cells usually being adapted either to pH and osmotic shocks or bile stress exposure, but unable to withstand the threefold application of those stresses. (Gao et al.2021; Jena & Choudhury, 2025)

This stress response and the adaptation of probiotics are due to both cell wall modifications allowing better membrane leakage control and mechanisms such as osmoregulation through amino-acid and potassium-tertrazolylyadenosine 5-triphosphate-based systems or improvement of acid tolerance allowing cell survival during mesophilic production and at the large scale of manufacturing. Bifidobacteria and Lactobacillus have a high impact on maintaining gut health by fermenting dietary residue to liberate bioactive molecules such as short-chain fatty acids, and are easily able to survive the stress-challenging conditions of the stomach, having been isolated on different substrates and bile exposure or isolated after certain biopreservative preparation. They are a very heterogeneous group of bacteria whose common trait is the colonization of the intestinal tract. Bioacquisition of carbohydrates from host-inaccessible substrates, respectively, has health-promoting and anti-carcinoma properties and is used to treat inflammatory bowel diseases such as covert illness due to their inhibitory effect against enterotoxigenic strains of E. coli. (Averina et al.2021; Kaźmierczak-Siedlecka et al.2021)

5.2. Immune System Support

Immune System Support refers to the natural methods that assist in the body's immune response to fight antigens and diseases. Probiotics appear to be vital in keeping the immune system healthy. The recent probiotics and gut health studies have progressed from observing correlations to in-depth study of causative factors, and now studies related to in vitro screening of probiotic potential are gaining momentum. Probiotics and beneficial bacteria have been accepted in food production and gut health. These are the microbes that have several positive health effects when administered in adequate amounts (M. Linares et al., 2017). In shelf-stable dairy microbiota, Lactobacillus acidophilus and Bifidobacterium lactis are the most studied starters to confer health benefits. Infection of the gut may result from the temporary overgrowth of pathogens. Some LAB strains isolated from fermented dairy products show antimicrobial activity. These microorganisms may exert an antimicrobial activity, preventing pathogens' growth both in dairy products and in the intestinal tract. (Paszczyk & Tońska, 2022)

Several studies suggest that probiotic strains and metabolites, produced by LAB fermented dairy products, may be capable of influencing innate and/or adaptive immune function, modulating gut function, especially in infants delivered by Cesarian section who lost the birth canal microbiota and consequently Bifidobacterium. Encouragement of Bifidobacteria proliferation is exceptionally supportive for the gut health of infants born by Cesarian delivery. Non-studied Lactococci species from fermented dairy products exhibit potential immunomodulatory effects in a naïve gut microbiota, supporting the understanding of mechanisms that underlie the safety and efficacy of lactic starters (Shang et al., 2020).

Bioactive compounds produced by lactic starters and particularly in LAB biocheese, show beneficial functional properties. Yogurt is a suitable carrier of probiotic lactic acid bacteria (LAB), playing an essential role in health promotion. Yogurt consumption positively affects stomach and gut health, preventing disorders like chronic constipation, diarrhea, mucosal inflammatory bowel symptoms, and gut cancer. Preferential growth of probiotic strains and potential inhibition of pathogens are associated with yogurt digestion, enhancement of gut mucosal immunity, affecting gut microbiota, and reducing lipopolysaccharide's deleterious effects. Bacteriocins produced by LAB, bacterially synthesized polypeptides with bactericidal effect on other bacteria, have attracted attention in several areas, including the food industry as natural antimicrobials for food preservation. Bacteriocins are safe and considered GRAS. Use of bacteriocins and other antimicrobial substitutes gives an alternative method to reduce or eliminate dosages of antibiotics and the development of drug-resistant bacteria. Bacteriocin-producing LAB have been selected for many biocheese varieties. Possible amino acids for Mannin131 are validated for biocheese, and novel amino acids are revealed. LAB from home-made fermented milk was selected as a probiotic starter culture for biocheese production. LAB can synthesize essential nutrients for humans, like B-group vitamins such as folate. (Ayivi and Ibrahim2022; Hussein et al., 2021; Mahmoodi et al.2022)

5.3. Nutritional Enhancements

Consumers are increasingly conscious of the nutritional value of food products, necessitating innovation in food technology to improve their healthfulness. This has led to interest in dairy products containing ingredients considered as functional components or possessing health benefits. These functional properties can be naturally produced or added to the food matrix. At the probiotic bacterial strain level, dairy products can be fortified with bioactive compounds that are not naturally produced, and various fermentation technologies have been developed. Fermentation could be employed to develop functional dairy products as probiotic strains have been shown to fortify fermented dairy products by the natural production of bioactive components that can promote human health (M. Linares et al., 2017).

Bioactive components might play a role in the health-promoting activity of fermented dairy products. Dairy products fermented by non-starter lactic acid bacteria, primarily by Lactobacillus helveticus, have been attributed to healthcare benefits such as the antihypertensive effects believed to be due to naturally released bioactive peptides from milk proteins during fermentation. Absorption of large bioactive peptides in the gut and their therapeutic effects have been shown in animal model studies. To adjust the levels of bioactive compounds by fermentation, factors impacting bioactive metabolites have been addressed. These include milk composition, strains, inoculation levels, and fermentation system. In general, specific commercial probiotic cultures, such as Lactobacillus helveticus, Lactococcus lactis subsp. lactis, Lactococcus lactis subsp. Cremoris and Bifidobacterium bifidum have been used to ferment milk for protein recovery as homemade, functional products. (Grujović et al.2022; Sharma et al.2023)

Most milk has a complicated matrix consisting of various components, including casein and whey proteins, minor components, fat globules, salts, and fluid phases. Diversity in proteins produces various bioactive peptides displaying differing bioactivities that are influenced by the types of bacteria involved in bioprocessing. Bacteria may access different substrates, producing a series of enzymes adaptable to the substrate or vice versa. Availability of low molecular weight protein substrates is linked to the fermentation temperature. Defining how substrate competition, proteolytic pathways follow each other, processing parameters, etc., dictate bioactive peptide excretion under both bioreactor and simulated gut conditions is challenging and needed for a better understanding of the mechanism of bioactive peptide development. (Wijesekara et al., 2024)

6. Conclusion

Bacteria are widely used in the dairy industry for the production of first and second-fermentation dairy products such as yogurt, cheese, butter, etc. Bulk milk and fermented dairy products are generally tested for bacterial counts as total bacteria count (TBC) or standard plate count (SPC). The existing methods for the detection of TBC have many limitations; thus, rapid methods such as new culture media, different types of testing conditions have been developed to enhance the growth of slow-growing bacteria. The enteric bacteria, coliforms, and related genera are problematic as their presence may denote faecal contamination, which leads to health hazards. Several traditional methods for their detection are available, but they are time-consuming, laborious, require skilled manpower, and sophisticated instrumentation. Rapid methods such as immunology and molecular methods are available, but they are expensive and not fully validated for milk products. Thus, the present paper reviews the conventional and rapid methods available for the detection of spoilage, pathogenic, and faecal bacteria in the dairy industry, along with their merits and demerits. Gaps in the existing methods are also highlighted for future research.

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