EC NUTRITION
Review Article

Lactic Acid Bacteria of Camel Milk for Health Promotion

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Received: August 26, 2021; **Published:** May 31, 2023

Abstract

Lactic acid bacteria are the most important group of microorganisms in milk and most dairy products and are generally known as GRASS substances. Lactic acid-producing bacteria include *Lactobacillus, Bifidobacterium, Enterococcus, Streptococcus*, and *Bacillus*. Lactic acid bacteria in raw and fermented camel milk included *Enterococcus durans, Enterococcus faecalis, Enterococcus faecium, Lactobacillus casei, Lactobacillus kefir, and Lactococcus lacticus.* This microbial flora may have antitumor activity, lowering serum cholesterol, reducing and treating lactose intolerance, stimulating the immune system, and stabilizing the microbial flora of the gastrointestinal. Also, they have a positive effect on intestinal microbial balance and overall body health. *Lactobacillus* strains strengthen the intestinal mucosal barrier, which maintains and promotes immunity, reduces the movement of bacteria through the intestinal mucosa, and also reduces the rate of inflammatory bowel disease and irritable bowel syndrome. Starter media containing lactic acid bacteria can produce weak organic acids, diacetyl, ethanol, hydrogen peroxide, and antimicrobial peptides such as bacteriocins, which inhibit foodborne pathogens and bacterial spoilage. Lactic acid bacteria are the most important group of microorganisms in milk and most dairy products improve the immune system, prevent the growth of pathogenic bacteria, and promote health.

***Keywords**: Lactic Acid Bacteria; Camel Milk; Health*

Introduction

Fermentation of lactic acid bacteria reduces the impact of poor storage conditions by increasing food's shelf life and safety. Some LABs produce antimicrobials and bacteriocins that inhibit the growth of pathogenic microorganisms and spoilage. Lactic acid production leads to an acidic environment that suppresses undesirable pathogenic and spoilage bacteria [1]. It also plays a vital role in food preservation and is an effective tool for food safety applications. The microorganisms involved in fermentation included *Streptococcus lactis, Lactobacillus casei, Streptococcus diacetylactis, Lactobacillus lactis, Leuconostoc cremoris, Lactobacillus bulgaricus*, and *Lactobacillus acidophilus*. Microflora plays a vital role in producing the acid, texture, flavor, and aroma of dairy and other fermented products [2].

Lactic acid bacteria

The use of living microorganisms in food, especially lactic acid-producing bacteria to maintain human health has a long history [3]. Lactic acid bacteria are the most important group of microorganisms in most dairy products and there is a long history of their consumption by humans to produce and preserve food. These bacteria are commonly found in nutrient-rich environments such as milk, cheese, meat, beverages, and vegetables. They are also isolated from the soil, lakes, and intestines of animals and humans [4].

Lactic acid bacteria are desirable members of the body microflora and in addition, these bacteria are traditionally used in the production of fermented dairy products and have the property of being "Generally recognized as safe" [5]. Lactic acid bacteria are generally known as GRASS substances and many of them are even attributed probiotic and antibacterial properties. However, a variety of lactic acid bacteria found in human food, animal feed, and human and animal digestive tracts can act as a repository of antibiotic-resistant genes, which can be transmitted horizontally to pathogenic microorganisms [6]. Lactic acid bacteria are found in dairy foods, fermented foods, meat, plant-based foods, the gastrointestinal tract and urinary tract of humans and animals, as well as in soil and water [7]. Among lactic acid bacteria, lactobacilli play an important role in the fermentation process and can produce more lactic acid during fermentation than cocci lactic acid bacteria [8].

Types of lactic acid bacteria

Lactic acid-producing bacteria include *Lactobacillus, Bifidobacterium, Enterococcus, Streptococcus*, and *Bacillus*, and are physiologically divided into three distinct groups: Forced homogeneous fermenters: They convert hexoses almost completely to lactic acid but are unable to ferment pentoses and gluconates. Optional heterogeneous fermenters: They convert hexoses almost completely to lactic acid, and in addition can ferment pentoses to acetic acid and lactic acid. Forced heterogeneous fermenters: convert hexoses to lactic acid, acetic acid, ethanol, and carbon dioxide [9].

The main lactic acid bacteria are the genera *Lactobacillus, Enterococcus, Pediococcus, Streptococcus*, *Lactococcus, Melisococcus, Onococcus* and *Leucococcus* [10]. These bacteria are deficient in spores, catalase, oxidase, and indole and are not able to regenerate nitrate and belong to the family Lactobacillaceae. Lactic acid bacteria includes *Lactococcus, Leuconostoc, Pediococcus, Streptococcus*, and *Lactobacillus,* which are thermophilic and are naturally present in raw materials such as milk, meat, and even in the digestive tract of animals and humans [11]. They are also part of the normal flora of the mouth, intestines, and female reproductive system. The most common strain of lactic acid-producing bacteria is *Lactobacillus plantarum*, which is a lactobacillus with voluntary heterogeneous fermentation. The types of microbial additives available include *Lactobacillus acidophilus*, *Lactobacillus buchneri*, and *Lactobacillus plantarum*, which can be used due to their good ability to improve fermentation conditions [12].

Lactobacilli are a group of lactic acid bacteria that are the end product of lactic acid fermentation [13]. *Lactobacilli* have a fermentative metabolism and more than half of them produce lactate as their final product [14]. Different species of *Lactobacillus* including *Lactobacillus arizonensis, Lactobacillus kimchi, Lactobacillus carnis, Lactobacillus bulgaricus, Lactobacillus brevis, Lactobacillus durans* and *Lactobacillus kefirgranum*.

Camel milk composition

Camel milk contains 7 oligosaccharides, which have more oligosaccharides than cow's milk. These oligosaccharides have high biological activity and inhibit the binding of pathogenic microorganisms to the mucus of the colon. It also stimulates the growth of colon bifidobacteria as a prebiotic and acts as a nerve growth factor. Thus, milk of one hump camel is a source of oligosaccharides that are used on an industrial scale in functional feeds including infant foods [15,16]. In mature camel milk, the total concentration of oligosaccharides was 0.12 g/100 mL vs. 0.04 g/100 mL for cow milk, while this ratio was inverse in colostrum (0.20 and 0.29 g/100 mL in camels and cattle, respectively) [17].

Lactic acid bacteria in the camel milk

The predominant microbial flora of camel milk is lactic acid bacteria, which can be used in dairy processing technology. This microbial flora may have antitumor activity, lowering serum cholesterol, reducing and treating lactose intolerance, stimulating the immune system, and stabilizing the microbial flora of the gastrointestinal tract [18]. Lactic acid bacteria in 26 samples of raw and fermented camel milk from four regions of Kazakhstan, including *Enterococcus durans, Enterococcus faecalis, Enterococcus faecium, Lactobacillus* *casei, Lactobacillus kefiri, Lactobacillus subunit, Lactobacillus subacus Crotius, Lactococcus lacticus* [19]. *Bifidobacterium* and *Lactobacillus* classes are regularly used in the human diet. While *Bacillus, Enterococcus*, and yeast species are commonly used in animal feed [20].

Lactic acid bacteria must have several important physiological properties to survive in the intestine, including resistance to oral enzymes such as lysozyme, resistance to bile salts, and ability to attach to small intestinal epithelial cells. Probiotic lactobacilli isolated from 40 samples of Rafsanjan traditional yogurt were *Lactobacilli casei*, *ramensus*, *plantarum, acidophilus, bulgaricus, delbruki, fermentum*, and *brevis*. The highest antibacterial effect was observed from *Lactobacillus plantarum*. Isolated probiotic *Lactobacilli* showed a significant inhibitory effect on *Staphylococcus aureus, Escherichia coli, Streptococcus pyogenes*, and *Proteus vulgaris* in culture by producing antimicrobials [21].

In one study, 9 *Lactobacilli* were isolated from the milk of one hump camel in Golestan province and *Lactobacillus paraplantarum, Lactobacillus frintensis, Lactobacillus brevis, Lactobacillus pantris, Lactobacillus Johnson and Lactobacillus mali* were also identified in this milk [22]. Among 177 isolates of raw camel milk, 14 belonged to *Lactobacillus fermentum* and six to *Lactobacillus plantarum*. All strains had antibacterial activity against *Listeria monocytogenes*, *Staphylococcus aureus*, and *Escherichia coli* [23]. To identify lactic acid bacteria in camel milk of Golestan province, they were able to isolate 56 *Enterococcus facium*, *faecalis, duranse, and rhamnosus species* and 18 *Lactobacillus fermentum* and *plantarum*. *Enterococcus faecium* and *Lactobacillus fermentum* were the highest [24].

In a study, after collecting samples of camel milk in the Semnan, *Enterococcus gallinarum and Enterococcus kseli flavus* were identified, and it was reported that the identified bacteria are strong candidates for food and pharmaceutical industries [25]. The probiotic potential of *Lactobacillus paracasei* isolated from Xinjiang camel milk yogurt was also investigated and it was reported that this strain is a promising probiotic candidate for the preparation of antioxidant foods and supplements [26].

The effect of *Lactobacillus brevis* and *Enterococcus faecium* isolated from the chal (fermented camel milk) showed that these bacteria have a strong inhibitory effect against the yeast and these two bacteria were able to increase the amount of this yeast in 15 days and reduce shelf life compared to samples without these bacteria. Therefore, it was suggested that these isolated lactic acid bacteria shall be used as a biological and safe preservative to prevent fungal spoilage of food susceptible to spoilage with yeast, especially in the dough [27]. Probiotics may prevent attaching *Escherichia coli* to the intestinal wall, which has the potential for pathogenesis, by increasing intestinal mucosa [28].

In the analysis of physicochemical properties and lactic acid bacteria of fresh camel milk collected in Mongolia, camel milk microbiota was very diverse. The main orders were *Proteobacteria, Bacteroids*, *Deinococcus thermus*, *Firmicutes*, and *Actinobacteria*. A small number of lactic acid bacteria sequences were identified, representing *Streptococcus thermophilus, Lactobacillus lactis, Lactobacillus helveticus*, and *Leuconostoc mesanthroidus*. Also, *Lactobacillus paracasei, Enterococcus durans, Lactococcus lactis, Enterococcus italicus* and *Enterococcus faescium* isolated and identified. These results confirm that fresh camel milk has a high bacterial diversity and is a valuable natural source for the isolation of new lactic acid bacteria [8]. The presence of *Enterococcus faecium, Enterococcus faecalis*, and *Enterococcus durans* in raw milk and cheese made from raw milk is common. *Enterococcus faecium* and *Enterococcus durans* have been identified from Mexican fresh cheese and Egyptian cheese that *Enterococcus faecium* being the predominant species among *Enterococcus* isolates.

The beneficial effects of lactic acid bacteria

Among healthy foods, foods containing probiotics have particular importance. Because probiotics have a positive effect on intestinal microbial balance and overall body health. Probiotics are living organisms that exert beneficial effects on host health by modulating the intestinal microbial flora. These living microorganisms have beneficial effects such as improving the immune system, preventing the establishment and growth of pathogenic bacteria, reducing cholesterol absorption, and reducing the risk of colon cancer [3].

Probiotics are also living microorganisms that enter food with a certain number and able to produce beneficial health and nutrients for the consumer. They are dietary supplements that have beneficial effects on the digestive and immune systems. In the gastrointestinal tract, probiotics facilitate digestion, absorption of nutrients, lower cholesterol, and prevent the growth of undesirable microorganisms in the gastrointestinal tract. The immune system is also modulated by probiotics as well as they control allergic reactions [29].

Lactic acid bacteria in the stomach and intestines due to the intestinal absorption capacity can be used as potential probiotics for further development [30]. These microorganisms are well known for their ability to produce lactic acid as the end product of anaerobic metabolism and the synthesis of a large number of metabolites that have beneficial nutrition. For this reason, lactic acid is used as a starter culture, probiotics, and food supplements. The use of lactic acid bacteria improve the shelf life, taste, smell, composition, and structure of foods. Lactic acid bacteria are the most abundant human-related bacteria that are present in the mucosal and gastrointestinal tract [31]. Most species of this group are non-pathogenic and play an important role in the process of food fermentation in industrial and traditional ways. Lactic acid bacteria need an external source of amino acids or peptides, which can be provided through casein proteolysis [32].

Lactobacilli are the probiotic microorganisms and prevent the establishment of many harmful bacteria by producing organic compounds such as lactic acid, hydrogen peroxide, and acetic acid and increasing intestinal acidity [33]. *Lactobacillus* strains strengthen the intestinal mucosal barrier, which maintains and promotes immunity, reduces the movement of bacteria through the intestinal mucosa, and also reduces the rate of inflammatory bowel disease and irritable bowel syndrome [34]. Lactic acid produced by lactobacilli is the cause of the initial acidic taste in unripe cheese and is also important in the formation of curd tissue and whey excretion [35].

The use of lactic acid bacteria with probiotic potential is the best choice, not only to increase the number of beneficial microbes in food products but also as microbes compatible with the intestinal environment [36]. In one study, the benefits of the *Lactobacillus plantarum* strain isolated from camel milk in producing low-fat cheese were presented as much more appropriate than commercial types [37]. Studies have also shown the therapeutic effects of probiotic lactic acid bacteria against vaginal, urinary tract, skin, and wound infections. Lactic acid bacteria have the effects of preventing and treating diarrhea caused by antibiotics, traveler's diarrhea, and other forms of diarrhea [38]. Reports have shown that bacteriocins produced by lactic acid-producing bacteria can reduce methane production. Increased milk production without changes in its composition has been observed as a result of supplementation with *Lactobacillus acidophilus*.

In investigating the effect of lactic acid bacteria in the form of cocci isolated from camel milk samples on reducing the sensitivity of milk casein proteins, proteolytic systems of lactic acid bacteria isolated from raw milk, especially camel milk can hydrolyze allergenic epitopes. Therefore, it reduces the allergenicity of cow's milk proteins, including caseins. The results indicate that proteinase enzymes produced by lactic acid bacteria isolated from camel milk have strong proteolytic activity against bovine milk caseins. Hydrolyzed alpha casein was also detected to a lesser extent by the serum IgE of patients with allergies to cow's milk than the normal type, which indicates a reduction in the allergenicity of this protein [39].

Starter media can produce weak organic acids, diacetyl, ethanol, hydrogen peroxide, and antimicrobial peptides such as bacteriocins, which inhibit foodborne pathogens and bacterial spoilage. Thus, the storage period will improve. The most common bacteriocin as a biological preservative in food is nisin [40]. It is produced by *Lactococcus lactis* and is the only known bacteriocin safe for use in dairy products [41]. Probiotics can produce bacteriocins that act as natural agents in inhibiting foodborne pathogens by enhancing fermented milk products' quality and safety. Inhibitory substances produced during lactic acid fermentation vary depending on the pathogenic reference markers. Gram-positive bacteria are more sensitive to bacteriocin than gram-negative bacteria. The specific nature of gram-negative bacteria makes them resistant to bacteriocin compared to gram-positive bacteria [42,43].

Lactic acid bacteria, which are gram-positive bacteria, produce bacteriocins with various activities. The effectiveness of bacteriocin against certain bacteria also depends on the pressure of microorganisms. The potential of bacteriocin production has been extensively studied in *Lactococci, Enterococci*, and *Lactobacilli* [44]. Bacteriocins have been successfully used in dairy products such as cheddar cheese using *Lactococcus* as a starter culture (nisin production) to control *Listeria monocytogenes, Clostridium sporogenesis* and *Staphylococcus aureus* [45].

Exopolysaccharide (EPS) plays a vital role in milk concentration or viscosity. Some EPS produced by LABs have been proven to have the potential to be used as food viscosifiers, thickeners, emulsifiers, or stabilizers [46]. This leads to viscosity or roughness, texture, improved mouthfeel, and reduced syneresis in dairy products. However, many additives have been suggested to increase stability and prevent the fermentation of camel milk [47]. *Lactococcus lactis* is one of the most common bacteria used in probiotic drugs in dairy products. According to a previous study, the subgroup of *Lactococcus lactis subsp cremoris* shows good inhibition of the angiotensin-converting enzyme (ACE) *in vitro* [48] that improves cardiac fibrosis [49]. Fermented camel milk by *Lactococcus lactis subgroup cremoris* has been shown to have a preventive effect against cardiac lesions caused by carbon tetrachloride with oxidative damage to the heart and histological changes [50]. Proteolytic and antioxidant activity was higher in camel milk than in cow milk. The LrK772 strain showed the highest inhibition of the angiotensin-converting enzyme (ACE) - more than 80%. This study also showed that the anti-cancer activity of the water-soluble extract of camel milk is higher than cow's milk. This means that peptides derived from camel milk fermentation have biological activity [51]. A possible explanation for the role of peptides is their ability as a result of other cancer-stimulating factors for cancer cell membrane receptors. A second explanation is that peptides from camel milk fermentation may have sufficient specific anticancer toxicity to target and induce cancer cell death [52].

Conclusion

Lactic acid bacteria are the most important group of microorganisms in milk and most dairy products improve the immune system, prevent the growth of pathogenic bacteria, and promote health. Starter media containing lactic acid bacteria can produce weak organic acids, diacetyl, hydrogen peroxide, and bacteriocins, which inhibit foodborne pathogens and bacterial spoilage.

Conflict of Interest

No conflict of interest.

Source of Funding

No source of funding.

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Volume 18 Issue 9 September 2023