FSAR 1978

Food Science of Animal Resources

Food Sci. Anim. Resour. 2024 March 44(2):255~268
DOI https://doi.org/10.5851/kosfa.2023.e83

pISSN : 2636-0772 eISSN : 2636-0780
http://www.kosfaj.org

REVIEW

# Overview of Dairy-based Products with Probiotics: Fermented or Non-fermented Milk Drink

Hye Ji Jang, Na-Kyoung Lee, and Hyun-Dong Paik*

Department of Food Science and Biotechnology of Animal Resources, Konkuk University, Seoul 05029, Korea

OPEN ACCESS

**Received** November 13, 2023
**Revised** December 21, 2023
**Accepted** December 24, 2023

***Corresponding author** : Hyun-Dong Paik
Department of Food Science and Biotechnology of Animal Resources, Konkuk University, Seoul 05029, Korea
Tel: +82-2-2049-6011
Fax: +82-2-455-3082
E-mail: hdpaik@konkuk.ac.kr

***ORCID**
Hye Ji Jang
https://orcid.org/0000-0002-6814-7629
Na-Kyoung Lee
https://orcid.org/0000-0002-2395-550X
Hyun-Dong Paik
https://orcid.org/0000-0001-9891-7703

**Abstract** Probiotic products have long been recognized for their health benefits. Additionally, milk has held a longstanding reputation as a dairy product that offers high-quality proteins and essential micronutrients. As awareness of the impact of food on health grows, interest in functional products such as probiotic dairy products is on the rise. Fermentation, a time-honored technique used to enhance nutritional value and food preservation, has been used for centuries to increase nutritional value and is one of the oldest food processing methods. Historically, fermented dairy products have been used as convenient vehicle for the consumption of probiotics. However, addressing the potential drawbacks of fermentation has recently led to increase in research on probiotic dairy drinks prepared without fermentation. These non-fermented dairy drinks have the advantage of maintaining the original flavors of milk drinks, containing potential health functional probiotics, and being an alternative dairy product that is helpful for probiotics intake. Currently, research on plant-based dairy products is rapidly increasing in the market. These developments might suggest the potential for novel forms of non-fermented dairy beverages with substantial prospects in the food market. This review aims to provide an overview of milk-based dairy beverages, both fermented and non-fermented, and discuss the potential of non-fermented dairy products. This exploration paves the way for innovative approaches to deliver probiotics and nutrition to consumers.

**Keywords** probiotics, dairy product, milk drink, non-fermented milk drink

## Introduction

Owing to the rapidly changing environment, consumer have recently become interested in consumption of functional food to improve and maintain their health (Küster-Boluda and Vidal-Capilla, 2017; Lillo-Pérez et al., 2021). Functional foods are considered to promote health and well-being and reduce diseases. To provide these benefits, functional foods should also contain health-promoting components such as probiotic, prebiotics, vitamins, minerals, bioactive compounds, and antioxidants (Konstantinidi and Koutelidakis, 2019; Mantzourani et al., 2019). Probiotics and probiotic-based foods are consumed worldwide as functional health foods (Lee and Paik, 2021; Lillo-

Pérez et al., 2021).

Probiotics are defined as live microorganisms that confer health benefits to the host when administered at an adequate dose (FAO and WHO, 2002). Probiotics have been shown to exhibit antioxidant, antidiabetic, anticancer, anti-inflammatory, anticavity, neuroprotective, immune-enhancing, antihypertensive, and cholesterol-reducing properties (Cheon et al., 2020; Jang et al., 2018; Kim et al., 2021; Lewis-Mikhael et al., 2020; Lim et al., 2020; Song et al., 2019). Recently, one study reported that probiotics as prophylactics or adjuvant treatment, could help healing COVID-19 (Lee and Paik, 2021), and many people have become more concerned about their health since the outbreak of COVID-19. The interest in fermented foods has increased significantly since COVID-19, while fermented foods alone may not offer complete protection against viral diseases such as COVID-19. However, it is reported that they could have a potential role in supporting the immune system and aiding in its defense (Wan-Mohtar et al., 2022).

Fermentation is an age-old food processing technique known to enhance the value of food by breaking down complex organic compounds through biochemical transformations (Romulo and Surya, 2021). This technology has been utilized extensively in dairy product processing with various health benefits (Ilango and Antony, 2021). In addition, most probiotic vehicles are probiotic foods by fermented or non-fermented to improve for the host (Rodrigues et al., 2019). Several food products such as dairy, beverages, meats, and cereals have been used as delivery vehicles for probiotics (Aspri et al., 2020). Among these products, probiotic dairy products are the most common because of their convenience of consumption, nutritional, and physicochemical properties, intestinal regulation, and therapeutic effects (Yilmaz-Ersan et al., 2020). Nevertheless, research is being conducted to solve problem caused by the use of probiotics in dairy products due to various side effects by probiotics and taste aversion due to fermentation (Sotoudegan et al., 2019).

In general, fermented dairy products are well known for their health benefits; however, non-fermented dairy products have also been reported. Future trends in the food industry will continue to develop with the increasing interest in functional foods. In particular, new probiotic-containing dairy products can developed with various functionalities.

This review aims to provide the currents and prospects for fermented and non-fermented milk drinks. It includes an overview of probiotics, characteristics of fermentation and non-fermentation, and detailed discussion about milk-based drinks, which encompass both fermented and non-fermented varieties. Furthermore, we comprehensively explore the potential for non-fermented dairy products to become more widely used as functional foods in the future, owing to their health benefits and convenience.

## Probiotics and Its Applications

The concept of probiotics was introduced in 1908 by the Russian Nobel laureate Elie Metchnikoff (Zendeboodi et al., 2020). Metchnikoff observed that consuming fermented foods, particularly those containing lactic acid bacteria (LAB), had favorable effects on human health and contributed to longevity (Cremon et al., 2018). As the guideline by Food and Agriculture Organization (FAO) and the World Health Organization (WHO), probiotics are live microbial cultures that confer health benefits to the host when administered in adequate amounts (FAO and WHO, 2002; García-Burgos et al., 2020; Rasika et al., 2021). It is important that probiotics are considered safety issues when selecting probiotics strains (Shi et al., 2016). Examples include the identification of virulence factors related to pathogenicity and infectivity, virulence and metabolic activity of microorganisms (Shi et al., 2016). Probiotics promote the gastrointestinal microbes by competing with harmful bacteria (El-Saadony et al., 2021; Tripathi and Giri, 2014). In general, LAB are considered to be representative probiotics, and many studies have reported their roles in the prevention of antibiotics-related diarrhea, irritable bowel syndrome, and immune modulation (Kim et al., 2021). In addition, probiotics have been reported to have various bio-functional benefits such as antioxidant, anti-inflammatory, anticancer, anticavity, and antimicrobial effects, as well as improving intestinal function (Hyun et al., 2023; Kang et al., 2023; Kim et al., 2021; Wang et al., 2022).

Dairy based and non-dairy based products that contain probiotics can provide these benefits. Most importantly, dairy-based products are widely consumed, consumer interest in health has increased worldwide increase in recent years, and global market trends show challenges following consumer needs (García-Burgos et al., 2020; Ozuna and Franco-Robles, 2022; Yilmaz-Ersan et al., 2020). The health functionality of fermented dairy products, as well as non-fermented dairy products, has shown potential for development (Jang et al., 2022; Oliveira et al., 2017). In addition, although dairy products with sugar and additives are the most common products for consuming probiotics, one study showed that the development of probiotic milk without sugar and food additives might address in intent of the government and consumers to reduce the consumption of highly processing foods (Oliveira et al., 2017).

In addition to dairy-based drinks, probiotic drinks are made from diverse raw materials, including cereals, fruits, and vegetables (Chavan et al., 2018). In recent, the development of non-fermented probiotic beverages as new functional product has also been reported without fermentation-induced changes (de Oliveira Ribeiro et al., 2020). Many consumers prefer not to consume dairy products such as milk, yogurt, cheeses, and ice cream because of lactose intolerance, allergies, restricted diets, and vegan diets (de Oliveira Ribeiro et al., 2020; Szparaga et al., 2019). Therefore, non-fermented beverages have been studied using plant-based milk, fruit, and other ingredients (Szparaga et al., 2019). Importantly, the food matrix should be carefully chosen to maintain probiotic viability, retain probiotic activity, and reach the intestine at sufficient levels (FAO and WHO, 2002). One study showed that fruits being used as vehicles for probiotics because they contain diverse minerals, vitamins, antioxidants, and dietary fibers (Santos et al., 2017). Non-dairy milks, such as soy bean, almond, and coconut milk are good alternative substances for the development of probiotic beverage owing to their suitable food matrices (Santos et al., 2017).

Future trends in the food industry will continue to develop with the increasing interest in functional foods. In particular, new probiotic-containing dairy products can be developed with various functionalities.

## Fermentation and Non-fermentation

Fermentation is one of the oldest technologies used to preserve and create value-added advantages. Therefore, fermentation is reported to be an economical technology (Agyei et al., 2020; García-Burgos et al., 2020; Ranadheera et al., 2017; Shori, 2016). There are two primary methods for fermenting foods. One method involves natural fermentation, known as “wild fermentation” or “spontaneous fermentation,” which takes place with microorganisms naturally present in the raw food or processing environment. The other technique is the addition of starter cultures, also termed “culture-dependent ferments,” to foods (Patel et al., 2023). Generally, fermentation enhances the nutritional value and sensory perceptions through microbial metabolic activities, thereby increasing the overall value of the food (Shori, 2016).

Fermentation is a biological process in which microorganisms break down complex organic compounds into simpler forms. Enzymatic or microbial actions on food constituents drive the fermentation process, inducing favorable biochemical alterations that substantially transform the food (Nkhata et al., 2018; Šikić-Pogačar et al., 2022). Fermentation is a natural means of enhancing the content of vitamins, essential amino acids, proteins; mitigating anti-nutrients; elevating the visual appeal of food; enriching flavors; and intensifying aromas (Šikić-Pogačar et al., 2022). Consequently, microbial activity plays a pivotal role in shaping the fermentation of edibles and precipitating shifts in their chemical and physical attributes. Various benefits of fermented foods made through fermentation have been reported (Şanlier et al., 2019).

Traditionally, probiotics have been widely used to ferment dairy products as starter cultures, and most commercial probiotics include *Lactobacillus* sp., *Bifidobacterium* sp., and *Streptococcus thermophilus* (García-Burgos et al., 2020; Ranadheera et al., 2017; Senok et al., 2005; Shori, 2016). Dairy products align with probiotics because they are traditionally associated with beneficial fermented bacteria and fermented dairy products. Consumers naturally relate fermented dairy products with living cultures and recognize the benefits of these cultures (Nagpal et al., 2012). Various health benefits of dairy product and fermented foods have been reported, including modulation of the intestinal microbiota and immune-enhancing, antibacterial, anticancer, anti-allergenic, and antioxidant effects (Abd Rahim et al., 2023; Garbacz, 2022; Jang et al., 2018; Kariyawasam et al., 2021; Marco et al., 2017; Tasdemir and Sanlier, 2020). However, the health benefits of dairy products vary depending on the microbial species (Widyastuti et al., 2021). For example, *Lactobacillus helveticus* potentially impacts human well-being through direct mechanisms, such as inhibiting pathogens, altering gut microbiota, and influencing the host immune system (Widyastuti et al., 2021).

Many studies have shown that probiotics grow stably in food and are known to have various advantages, such as physicochemical, stability-improving, nutritional, sensory, and functional properties (Ranadheera et al., 2017). Nevertheless, consumers strongly demand non-fermented products; therefore, the development and sales of non-fermented drinks are expected to increase (Ranadheera et al., 2017). Commonly, in fermented products, the viability of numerous probiotic strains could be compromised due to the antagonistic interplay between starter cultures and probiotics, alongside the acidification inherent to these cultured products. Consequently, a novel trend has surfaced: non-fermented dairy products have been developed and brought to the market, reflecting this evolving approach (Awaisheh, 2012).

To date, limited studies on non-fermented drinks have been reported. The characteristics of the advantages and disadvantages of non-fermented milk drink are shown in Table 1. The reasons for their benefit can be summarized as follows. 1) Incorporating probiotics into non-fermented dairy products allows individuals to access the potential health benefits associated with probiotics while retaining the original flavor and texture of the dairy products. 2) The addition of probiotic to non-fermented dairy products can target individuals who might prefer milder flavors or who may not be accustomed to the tangy notes often associated with traditional fermented dairy products. By introducing probiotics into non-fermented products, individuals can experience the advantages of probiotic consumption without altering their taste preferences. Furthermore, some consumers might have dietary or cultural considerations that lead them to opt for non-fermented dairy products. These individuals benefit from the nutritional potential of probiotics without compromising on their dietary choices or culture culinary practices. Ultimately, the inclination towards using probiotics in non-fermented dairy products underscores the evolving landscape of health-conscious consumer preferences. The reflects the desire to integrate wellness-promoting elements into a diverse range of foods catering to a spectrum of tastes, preferences, and dietary requirements.

**Table 1. Characteristics of the advantages and disadvantages of non-fermented milk drink compared to fermented milk**

| Advantages | Disadvantages |
|---|---|
| • Retaining the original flavors of milk drink<br>• Containing the potential health benefits of probiotics<br>• Alternative dairy products to help you consume probiotics | • Problems with storage stability due to microbial growth<br>• Difficulty obtaining nutritional benefits due to material decomposition, which is an advantage during fermentation |

## Dairy-based Milk Drink

Dairy-based milk drinks were divided into fermented and non-fermented products. Each has its own characteristics and related probiotics strains health properties have been reported (Table 2).

### Fermented milk drink

Fermented milk is an important part of the human diet worldwide because of its high nutritional value and enhancement of sensory factors through fermentation (Shori, 2016). Fermented milk is the most commonly used probiotic products delivering

**Table 2. Fermented and non-fermented dairy-based probiotic milk drinks and their health properties**

| Process type | Probiotic strain | Health properties | Reference |
|---|---|---|---|
| Fermented | | | |
| Acidophilus milk | *L. acidophilus* | Improvement of gastrointestinal conditions | Hati and Prajapati, 2022 |
| Bifidus milk | *B. longum*; *B. bifidum* | Treatment of gastrointestinal conditions and constipation | Yerlikaya, 2014 |
| Fermented milk | *L. acidophilus*; *L. rhamnosus*; *L. fermentum*; *L. plantarum*; *L. paracasei*; *L. casei*; *L. delbruekii*; *L. brevis*; *S. thermophilus*; *B. bifidum* | Antioxidant effect; antimicrobial effect; antihypertensive effect; reduction of LDL; anticholestrol effect; anticarcinogenic effect; and antiobesity effects | Beltrán-Barrientos et al., 2016; Hou et al., 2019; Mendez Utz et al., 2019; Oliveira et al., 2017; Wa et al., 2019 |
| Kefir | *L. casei*; *L. acidophilus*; *L. paracasei*; *L. fermentum*; *K. marxianus*; *S. unisporus*; *Sac. cerevisiae* | Antimutagenic effect; anticarcinogenic effect; cholesterol-lowering; reducing lactose intolerance; immune system modulation; antioxidant effect; and antimicrobial effects | Bengoa et al., 2019; Egea et al., 2022; Hong et al., 2019; Melo et al., 2018; Nielsen et al., 2014; Otles et al., 2003 |
| Kumys | *L. delbrueckii*; *K. marxianus* | Anti-asthma effect, supports the cardiovascular system, and inhibition of *Helicobacter pylori* | Arslan, 2015; García-Burgos et al., 2020; Marsh et al., 2014; Yerlikaya, 2014 |
| Yogurt | *L. acidophilus*; *L. bulgaricus*; *L. rhamnosus*; *L. plantarum*; *L. helveticus*; *L. casei*; *L. fermentum*; *S. thermophilus*; *B. lactis* | Improvement of gastrointestinal; antimicrobial effect; lowering the cholesterol; reducing lactose intolerance; anticancer effect; immune system modulation; improvement of inflammatory bowel disease effect; and antidiarrheal effects | Arain et al., 2023; García-Burgos et al., 2020; Ghasempour et al., 2020; Lim et al., 2020; Olson and Aryana, 2022; Shah, 2006; Tasdemir and Sanlier, 2020 |
| Non-fermented | | | |
| Milk drink | *L. plantarum*; *L. acidophilus*; *B. lactis*; *B. animalis* | Improvement of gastrointestinal conditions and antioxidant effects | Daneshi et al., 2013; Jang et al., 2022; Oliveira et al., 2017 |

*L.*, *Lactobacillus*; *Lacticaseibacillus*; *Lactiplantibacillus*; *S.*, *Streptococcus*; *B.*, *Bifidobacterium*; *K.*, *Kluyveromyces*; *Sac.*, *Saccharomyces*; LDL, low density lipoprotein.

probiotics (Ranadheera et al., 2017; Shori, 2016). The most common examples of fermented milk include yogurt, kefir, acidophilus milk, and any other products; however, there are many different products based on geography, historical practices, and diverse types of milk (Bagheripoor-Fallah et al., 2015; Savaiano and Hutkins, 2020).

Although several viable organisms are required in probiotic products, either to ferment or contain them, the most commonly used strains are *Lactobacillus* sp., *Lacticaseibacillus* sp., *Limosilactobacillus* sp., *Lactiplantibacillus* sp., *Ligilactobacillus* sp., *Lactococcus* sp., and *Bifidobacterium* sp. The most commonly used *L. acidophilus*, *L. gasseri*, *L. helveticus*, *L. delbrueckii* subsp. *bulgaricus*, *L. casei*, *L. paracasei*, *L. rhamnosus*, *L. fermentum*, *L. reuteri*, *L. plantarum*, *L. lactis*; *Bifidobacterium* sp. include *B. bifidum*, *B. longum*, *B. breve*, and *B. animalis* sp. *lactis* (Kandylis et al., 2016; Yerlikaya, 2014). However, milk is fermented by each special culture (García-Burgos et al., 2020). *L. plantarum* and *Bifidobacterium* sp. are frequently selected as probiotics and are well suited for the production of fermented milk products. Fermented milk by *L. plantarum* showed high antioxidant effects and 89% angiotensin-converting enzyme inhibitory effects (Chen et al., 2018; Li et al., 2020).

Yogurt is an excellent source of nutrients, highly nutritive proteins, and bioactive peptides formed by fermentation. Fermentation of lactose by yogurt culture enhances digestibility for patients with lactose intolerance in comparison to milk (Meybodi et al., 2020). Generally, *Lactobacillus* sp. and *S. thermophilus* are used as starter cultures, and yogurt is manufactured containing various probiotic strains (Jang et al., 2018). Additionally, yogurt has been reported to various health benefits such as gastrointestinal effects, increased digestibility of lactose, heart health improvements, anti-cholesterol effects, anti-cancer effect, immune-enhancing effects, and reduction of type 2 diabetes (Daniel et al., 2022; Freitas, 2017; Gharibzahedi and Chronakis, 2018; Hazra et al., 2013).

Kefir is a naturally fermented milk product produced using kefir grains, or mother cultures prepared from kefir grains. Kefir grains are a good source of LAB, acetic acid bacteria, and various yeasts cells combined with a matrix of casein and complex sugars in a polysaccharide matrix (Ahmed et al., 2013). Kefir has reported to have numerous positive effects, such as wound healing, anti-carcinogenic, immunomodulatory, and antimicrobial effects, and has also been reported to inhibit *Helicobacter pylori* (Arslan, 2015; Bourrie et al., 2016).

Kumys is a fermented milk drink that is popular in Central Asia and Eastern Europe (Kim et al., 2017). Kumys is naturally fermented by LAB and yeast (Li et al., 2022). *Lactobacillus* strains derived from kumys have shown potential as probiotics (Wu et al., 2009). *L. fermentum* SM-7 in kumys reduced cholesterol levels in both *in vitro* and *in vivo* experiments (Pan et al., 2011). In addition, kumys has been suggested to be a therapeutic agent for asthma, cardiovascular disorder, and gynecological diseases (Yerlikaya, 2014).

Acidophilus milk is a type of fermented milk product that uses *L. acidophilus* as the starter culture. Acidophilus milk can be fermented or non-fermented (Aryana and Olson, 2017). One study reported that fermented milk with *L. acidophilus* LA-5 reduced the number of pathogenic bacteria and the beneficial bacteria protected against intestinal diseases (Meng et al., 2021).

## Non-fermented milk drink

Usually, milk is a well-known nutritious food containing bioactive compounds, such as immunoglobulin, antimicrobial peptides, enzymes, cytokine, and other substances, along with essential nutrients. It has played an important role in promoting health and well-being (Górska-Warsewicz et al., 2019; Jung et al., 2016; Khan et al., 2019). In addition, milk has been reported to have health benefits, such as bone health, enhanced immune system, improved intestinal health, reduced risk of stroke, cancer, and high blood pressure, and improved weight management (Chauhan et al., 2021; Jung et al., 2016).

In the food industry, various functional foods have been developed by applying probiotics to milk as food additives (Damián et al., 2022). However, in recent decades, the market for probiotic dairy products has mainly consisted of fermented products such as yogurt, fermented milk, and cheeses (de Oliveira Ribeiro et al., 2020). Generally, probiotic milk is a new product of fermentation that is based on a widely used food technology and enhances the availability of nutrients and bioactive compounds (García-Burgos et al., 2020; Vicenssuto and de Castro, 2020). Recently, the government and consumers interested in the development of probiotic milk have shown great interest with the aim to reduce the consumption of highly processed products (Oliveira et al., 2017). And as another type of probiotic milk for health-conscious people, non-fermented probiotic milk has become excitingly popular (Jang et al., 2022). The process of non-fermented milk drink is shown in Fig. 1.

Non-fermented milk refers to milk containing probiotics without fermentation process. Therefore, non-fermented milk drink has several advantages compared to fermented milk drink. Firstly, the original flavor of milk can be maintained, secondly, since probiotics containing potential functionality are added, the product itself can be expected to be functional, and lastly, it can be expected to be another alternative food for consuming probiotics (Table 1). Additionally, Table 1 shows the advantages as well as disadvantages of non-fermented milk drink.

Several research articles have been reported non-fermented milk and its potential effects, follow as: milk containing *L. acidophilus* maintains its physicochemical, microbiological, and sensory characteristics. Additionally, a study reported strain screening to develop non-fermented milk containing probiotics and the physicochemical, microbiological, sensory, and functional properties of non-fermented milk (Aboulfazli et al., 2016; Jang et al., 2022; Oliveira et al., 2017).

Jang et al. (2022) reported that non-fermented milk with probiotics showed antioxidant effects depending on the health functionality of the added probiotics compared with milk without probiotics. Nevertheless, these results will provide sufficient supplementary data for future research on non-fermented milk with probiotics. In addition, non-fermented milk

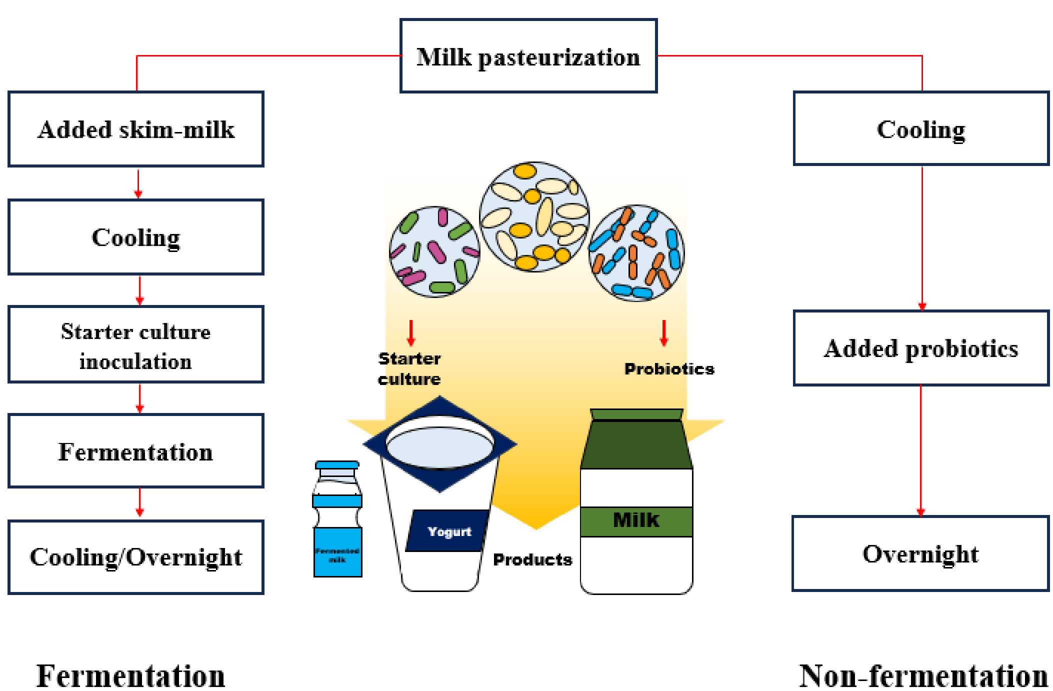


**Fig. 1. Manufacturing processes of fermented and non-fermented dairy products.**

might be a new dairy product that could conveniently deliver probiotics to the host. Furthermore, the development of various non-fermented milk products with added sugar or food additives is expected to complement the benefits of fermented milk (Jang et al., 2022; Oliveira et al., 2017). In addition, the use of ultrasound could lead to the production of functional non-fermented milk with health benefits by reducing the particle size, enzymatic activities, and modification of proteins (Kaveh et al., 2023).

## Conclusion and Prospect

The probiotic product industry is growing globally owing to various reported health functionalities. In particular, the dairy industry has been reported to be a top trend in the food industry. Generally, dairy products undergo a fermentation process to protect against contaminants and maintain viability and functionality during their shelf life. In addition to traditional probiotics, the integration of new functional ingredients such as prebiotics, postbiotics, and synbiotics is gradually gaining attention. This combination may further enhance the health-promoting potential of fermented dairy products. Fermentation process is one of the oldest technologies used to improve sensory properties and nutritional benefits. However, in addition to dairy-based fermented products, plant-based fermented products, such as soy- and cereal-based products, will be developed. Products that develop similar flavors or emphasize the natural flavor of plants will continue to be perceived as part of animal dairy products.

Although dairy-based fermented products are considered the most common products that deliver probiotics to the host for health purposes, dairy-based non-fermented products could be developed and commercialized in the coming future. Previous studies have reported the physicochemical, microbiological, sensory, and health benefits of non-fermented milk. For non-fermented dairy products to be commercialized, probiotic viability and safety during storage period, intestinal survival rates, and various health functional studies must be further conducted. Non-fermented dairy products can be fortified with probiotics to provide health benefits without altering their original characteristics. Similar to fermented dairy products, the rise in plant-based milk alternatives such as oat, pea, and rice milk, is driving the creation of non-fermented dairy products. Non-fermented products are enriched with probiotics and functional ingredients, such as vitamins, minerals, omega-3 fatty acids, and antioxidants, to offer enhanced nutritional value. Lastly, with growing health consciousness, non-fermented dairy products are adapting to consumer preferences by offering reduced sugar and low-fat additives while maintaining flavor and texture.

Taken together, fermented and non-fermented dairy product could be used as important foods that provide probiotics to humans. Research on the functionality and benefits of non-fermented dairy products is limited; however, the benefits and functional aspects of these products render them a potentially successful new type of product in the dairy industry and provide exciting developments that cater to diverse tastes, dietary needs, and wellness aspirations.

## Conflicts of Interest

The authors declare no potential conflicts of interest.

## Author Contributions

Conceptualization: Jang HJ, Lee NK, Paik HD. Investigation: Jang HJ, Lee NK. Writing - original draft: Jang HJ. Writing -

review & editing: Jang HJ, Lee NK, Paik HD.

## Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

## References


Abd Rahim MH, Hazrin-Chong NH, Harith HH, Wan-Mohtar WAAQI, Sukor R. 2023. Roles of fermented plant-, dairy- and meat-based foods in the modulation of allergic responses. Food Sci Hum Wellness 12:691-701.

Aboulfazli F, Shori AB, Baba AS. 2016. Effects of the replacement of cow milk with vegetable milk on probiotics and nutritional profile of fermented ice cream. LWT-Food Sci Technol 70:261-270.

Agyei D, Owusu-Kwarteng J, Akabanda F, Akomea-Frempong S. 2020. Indigenous African fermented dairy products: Processing technology, microbiology and health benefits. Crit Rev Food Sci Nutr 60:991-1006.

Ahmed Z, Wang Y, Ahmad A, Khan ST, Nisa M, Ahmad H, Afreen A. 2013. Kefir and health: A contemporary perspective. Crit Rev Food Sci Nutr 53:422-434.

Arain MA, Rasheed S, Jaweria A, Khaskheli GB, Barham GS, Ahmed S. 2023. A review on processing opportunities for the development of camel dairy products. Food Sci Anim Resour 43:383-401.

Arslan S. 2015. A review: Chemical, microbiological and nutritional characteristics of kefir. CyTA J Food 13:340-345.

Aryana KJ, Olson DW. 2017. *A 100-year review:* Yogurt and other cultured dairy products. J Dairy Sci 12:9987-10013.

Aspri M, Papademas P, Tsaltas D. 2020. Review on non-dairy probiotics and their use in non-dairy based products. Fermentation 6:30.

Awaisheh SS. 2012. Probiotic food products classes, types, and processing. In Probiotics. 3rd ed. Rigobelo EC (ed). IntechOpen, London, UK. pp 551-582.

Bagheripoor-Fallah N, Mortazavian A, Hosseini H, Khoshgozaran-Abras S, Rad AH. 2015. Comparison of molecular techniques with other methods for identification and enumeration of probiotics in fermented milk products. Crit Rev Food Sci Nutr 55:396-413.

Beltrán-Barrientos LM, Hernández-Mendoza A, Torres-Llanez MJ, González-Córdova AF, Vallejo-Córdoba B. 2016. *Invited review*: Fermented milk as antihypertensive functional food. J Dairy Sci 99:4099-4110.

Bengoa AA, Iraporda C, Garrote GL, Abraham AG. 2019. Kefir micro-organisms: Their role in grain assembly and health properties of fermented milk. J Appl Microbiol 126:686-700.

Bourrie BCT, Willing BP, Cotter PD. 2016. The microbiota and health promoting characteristics of the fermented beverage kefir. Front Microbiol 7:647.

Chauhan S, Powar P, Mehra R. 2021. A review on nutritional advantages and nutraceutical properties of cow and goat milk. Int J Appl Res 7:101-105.

Chavan M, Gat Y, Harmalkar M, Waghmare R. 2018. Development of non-dairy fermented probiotic drink based on germinated and ungerminated cereals and legume. LWT-Food Sci Technol 91:339-344.

Chen L, Zhang Q, Ji Z, Shu G, Chen H. 2018. Production and fermentation characteristics of angiotensin-I-converting enzyme inhibitory peptides of goat milk fermented by a novel wild *Lactobacillus plantarum* 69. LWT-Food Sci Technol 91:532-540.

Cheon MJ, Lim SM, Lee NK, Paik HD. 2020. Probiotic properties and neuroprotective effects of *Lactobacillus buchneri* KU200793 isolated from Korean fermented foods. Int J Mol Sci 21:1227.

Cremon C, Barbaro MR, Ventura M, Barbara G. 2018. Pre- and probiotic overview. Curr Opin Pharmacol 43:87-92.

Damián MR, Cortes-Perez NG, Quintana ET, Ortiz-Moreno A, Noguez CG, Cruceño-Casarrubias CE, Pardo MES, Bermudez-Humarán LG. 2022. Functional foods, nutraceuticals and probiotics: A focus on human health. Microorganisms 10:1065.

Daneshi M, Ehsani MR, Razavi SH, Labbafi M. 2013. Effect of refrigerated storage on the probiotic survival and sensory properties of milk/carrot juice mix drink. Electron J Biotechnol 16:1-12.

Daniel N, Nachbar RT, Tran TTT, Ouellette A, Varin TV, Cotillard A, Quinquis L, Gagné A, St-Pierre P, Trottier J, Marcotte B, Poirel M, Saccareau M, Dubois MJ, Joubert P, Barbier O, Koutnikova H, Marette A. 2022. Gut microbiota and fermentation-derived branched chain hydroxy acids mediate health benefits of yogurt consumption in obese mice. Nat Commun 13:1343.

de Oliveira Ribeiro AP, dos Santos Gomes FS, dos Santos KMO, da Matta VM, de Grandi Castro Freitas de Sá D, de Araujo Santiago MCP, Conte C, de Oliveira Costa SD, de Oliveira Ribeiro L, de Oliveira Godoy RL, Walter EHM. 2020. Development of a probiotic non-fermented blend beverage with jucara fruit: Effect of the matrix on probiotic viability and survival to the gastrointestinal tract. LWT-Food Sci Technol 118:108756.

Egea MB, Santos DC, Filho JGO, Ores JC, Takeuchi KP, Lemes AC. 2022. A review of nondairy kefir products: Their characteristics and potential human health benefits. Crit Rev Food Sci Nutr 62:1536-1552.

El-Saadony MT, Alagawany M, Patra AK, Kar I, Tiwari R, Dawood MAO, Dhama K, Abdel-Latif HMR. 2021. The functionality of probiotics in aquaculture: An overview. Fish Shellfish Immunol 117:36-52.

Food and Agricultural Organization of the United Nations [FAO], World Health Organization [WHO]. 2002. Guidelines for the evaluation of probiotics in food. Available from: https://www.foodinprogress.com/wp-content/uploads/2019/04/Guidelines-for-the-Evaluation-of-Probiotics-in-Food.pdf. Accessed at Oct 15, 2023.

Freitas M. 2017. The benefits of yogurt, cultures, and fermentation. In The microbiota in gastrointestinal pathophysiology. Floch MH, Ringel Y, Walker WA (ed). Academic Press, Cambridge, MA, USA. pp 209-223.

Garbacz K. 2022. Anticancer activity of lactic acid bacteria. Semin Cancer Biol 86:356-366.

García-Burgos M, Moreno-Fernández J, Alférez MJM, Díaz-Castro J, López-Aliaga I. 2020. New perspectives in fermented dairy products and their health relevance. J Funct Foods 72:104059.

Gharibzahedi SMT, Chronakis IS. 2018. Crosslinking of milk proteins by microbial transglutaminase: Utilization in functional yogurt products. Food Chem 245:620-632.

Ghasempour Z, Javanmard N, Langroodi AM, Alizadeh-Sani M, Ehsani A, Kia EM. 2020. Development of probiotic yogurt containing red beet extract and basil seed gum; techno-functional, microbial and sensorial characterization. Biocatal Agric Biotechnol 29:101785.

Górska-Warsewicz H, Rejman K, Laskowski W, Czeczotko M. 2019. Milk and dairy products and their nutritional contribution to the average polish diet. Nutrients 11:1771.

Hati S, Prajapati JB. 2022. Use of probiotics for nutritional enrichment of dairy products. Funct Foods Health Dis 12:713-733.

Hazra T, Gandhi K, Das A. 2013. Nutritive value and health benefit of fermented milks. Res Rev J Dairy Sci Technol 2013:25-28.

Hong JY, Lee NK, Yi SH, Hong SP, Paik HD. 2019. *Short communication*: Physicochemical features and microbial community of milk kefir using a potential probiotic *Saccharomyces cerevisiae* KU200284. J Dairy Sci 102:10845-10849.

Hou Q, Li C, Liu Y, Li W, Chen Y, Siqinbateer, Bao Y, Saqila W, Zhang H, Menghe B, Sun Z. 2019. Koumiss consumption modulates gut microbiota, increases plasma high density cholesterol, decreases immunoglobulin G and albumin. J Funct Foods 52:469-478.

Hyun JH, Yu HS, Woo IK, Lee GW, Lee NK, Paik HD. 2023. Anti-inflammatory activities of *Levilactobacillus brevis* KU15147 in RAW 264.7 cells stimulated with lipopolysaccharide on attenuating NF-$\kappa$B, AP-1, and MAPK signaling pathways. Food Sci Biotechnol 32:2105-2115.

Ilango S, Antony U. 2021. Probiotic microorganisms from non-dairy traditional fermented foods. Trends Food Sci Technol 118:617-638.

Jang HJ, Jung J, Yu HS, Lee NK, Paik HD. 2018. Evaluation of the quality of yogurt using ginseng extract powder and probiotic *Lactobacillus plantarum* NK181. Korean J Food Sci Anim Resour 38:1160-1167.

Jang HJ, Kim JH, Lee HS, Paik HD. 2022. Physicochemical analysis of non-fermented probiotic milk with probiotic *Lactobacillus plantarum* Ln1 isolated from Korea traditional fermented food. Food Sci Biotechnol 31:731-737.

Jung J, Paik HD, Yoon HJ, Jang HJ, Jeewanthi RKC, Jee HS, Li X, Lee NK, Lee SK. 2016. Physicochemical characteristics and antioxidant capacity in yogurt fortified with red ginseng extract. Korean J Food Sci Anim Resour 36:412-420.

Kandylis P, Pissaridi K, Bekatorou A, Kanellaki M, Koutinas AA. 2016. Dairy and non-dairy probiotic beverages. Curr Opin Food Sci 7:58-63.

Kang CE, Park YJ, Kim JH, Lee NK, Paik HD. 2023. Probiotic *Weissella cibaria* displays antibacterial and anti-biofilm effect against cavity-causing *Streptococcus mutans*. Microb Pathog 180:106151.

Kariyawasam KMGMM, Lee NK, Paik HD. 2021. Fermented dairy products as delivery vehicles of novel probiotic strains isolated from traditional fermented Asian foods. J Food Sci Technol 58:2467-2478.

Kaveh S, Gholamhosseinpour A, Hashemi SMB, Jafarpour D, Castagnini JM, Phimolsiripol Y, Barba FJ. 2023. Recent advances in ultrasound application in fermented and non-fermented dairy products: Antibacterial and bioactive properties. Int J Food Sci Technol 58:3591-3607.

Khan IT, Nadeem M, Imran M, Ullah R, Ajmal M, Jaspal MH. 2019. Antioxidant properties of milk and dairy products: A comprehensive review of the current knowledge. Lipids Health Dis 18:41.

Kim DH, Jeong D, Song KY, Chon JW, Kim H, Seo KH. 2017. Sensory profiles of koumiss with added crude ingredients extracted from flaxseed (*Linum usitatissimum* L.). J Milk Sci Biotechnol 35:169-175.

Kim KT, Yang SJ, Paik HD. 2021. Probiotic properties of novel probiotic *Levilactobacillus brevis* KU15147 isolated from radish kimchi and its antioxidant and immune-enhancing activities. Food Sci Biotechnol 30:257-265.

Konstantinidi M, Koutelidakis AE. 2019. Functional foods and bioactive compounds: A review of its possible role on weight management and obesity's metabolic consequences. Medicines 6:94.

Küster-Boluda I, Vidal-Capilla I. 2017. Consumer attitudes in the election of functional foods. Span J Mark ESIC 21:65-79.

Lee NK, Paik HD. 2021. Prophylactic effects of probiotics on respiratory viruses including COVID-19: A review. Food Sci Biotechnol 30:773-781.

Lewis-Mikhael AM, Davoodvandi A, Jafarnejad S. 2020. Effect of *Lactobacillus plantarum* containing probiotics on blood pressure: A systematic review and meta-analysis. Pharmacol Res 153:104663.

Li Q, Zhang C, Xilin T, Ji M, Meng X, Zhao Y, Siqin B, Zhang N, Li M. 2022. Effects of koumiss on intestinal immune modulation in immunosuppressed rats. Front Nutr 9:765499.

Li SN, Tang SH, He Q, Hu JX, Zheng J. 2020. *In vitro* antioxidant and angiotensin-converting enzyme inhibitory activity of fermented milk with different culture combination. J Dairy Sci 103:1120-1130.

Lillo-Pérez S, Guerra-Valle M, Orellana-Palma P, Petzold G. 2021. Probiotics in fruit and vegetable matrices: Opportunities for nondairy consumers. LWT-Food Sci Technol 151:112106.

Lim SM, Lee NK, Kim KT, Paik HD. 2020. Probiotic *Lactobacillus fermentum* KU200060 isolated from watery kimchi and its application in probiotic yogurt for oral health. Microb Pathog 147:104430.

Mantzourani I, Kazakos S, Terpou A, Alexopoulos A, Bezirtzoglou E, Bekatorou A, Plessas S. 2019. Potential of the probiotic *Lactobacillus plantarum* ATCC 14917 strain to produce functional fermented pomegranate juice. Foods 8:4.

Marco ML, Heeney D, Binda S, Cifelli CJ, Cotter PD, Foligné B, Gänzle M, Kort R, Pasin G, Pihlanto A, Smid EJ, Hutkins R. 2017. Health benefits of fermented foods: Microbiota and beyond. Curr Opin Biotechnol 44:94-102.

Marsh AJ, Hill C, Paul Ross R, Cotter PD. 2014. Fermented beverages with health-promoting potential: Past and future perspectives. Trends Food Sci Technol 38:113-124.

Melo AFP, Mendonça MCP, Rosa-Castro RM. 2018. The protective effects of fermented kefir milk on azoxymethane-induced aberrant crypt formation in mice colon. Tissue Cell 52:51-56.

Mendez Utz VE, Perdigón G, de Moreno de LeBlanc A. 2019. Oral administration of milk fermented by *Lactobacillus casei* CRL431 was able to decrease metastasis from breast cancer in a murine model by modulating immune response locally in the lungs. J Funct Foods 54:263-270.

Meng L, Li S, Liu G, Fan X, Qiao Y, Zhang A, Lin Y, Zhao X, Huang K, Feng Z. 2021. The nutrient requirements of *Lactobacillus acidophilus* LA-5 and their application to fermented milk. J Dairy Sci 104:138-150.

Meybodi NM, Mortazavian AM, Arab M, Nematollahi A. 2020. Probiotic viability in yoghurt: A review of influential factors. Int Dairy J 109:104793.

Nagpal R, Behare PV, Kumar M, Mohania D, Yadav M, Jain S. 2012. Milk, milk products, and disease free health: An updated overview. Crit Rev Food Sci Nutr 52:321-333.

Nielsen B, Candan Gürakan G, Ünlü G. 2014. Kefir: A multifaceted fermented dairy product. Probiotics Antimicrob Proteins 6:123-135.

Nkhata SG, Ayua E, Kamau EH, Shingiro JB. 2018. Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. Food Sci Nutr 6:2446-2458.

Oliveira D, Vidal L, Ares G, Walter EHM, Rosenthal A, Deliza R. 2017. Sensory, microbiological and physicochemical screening of probiotic cultures for the development of non-fermented probiotic milk. LWT-Food Sci Technol 79:234-241.

Olson DW, Aryana KJ. 2022. Probiotic incorporation into yogurt and various novel yogurt-based products. Appl Sci 12:12607.

Otles S, Cagindi O, Akcicek E. 2003. Probiotics and health. Asian Pac J Cancer Prev 4:369-372.

Ozuna C, Franco-Robles E. 2022. Agave syrup: An alternative to conventional sweeteners? A review of its current technological applications and health effects. LWT-Food Sci Technol 162:113434.

Pan DD, Zeng XQ, Yan YT. 2011. Characterisation of *Lactobacillus fermentum* SM-7 isolated from koumiss, a potential probiotic bacterium with cholesterol-lowering effects. J Sci Food Agric 91:512-518.

Patel P, Butani K, Kumar A, Singh S, Prajapati BG. 2023. Effects of fermented food consumption on non-communicable diseases. Foods 12:687.

Ranadheera CS, Vidanarachchi JK, Rocha RS, Cruz AG, Ajlouni S. 2017. Probiotic delivery through fermentation: Dairy vs. non-dairy beverages. Fermentation 3:67.

Rasika DMD, Vidanarachchi JK, Luiz SF, Azeredo DRP, Cruz AG, Ranadheera CS. 2021. Probiotic delivery through non-dairy plant-based food matrices. Agriculture 11:599.

Rodrigues VCC, Silva LGS, Simabuco FM, Venema K, Antunes AEC. 2019. Survival, metabolic status and cellular morphology of probiotics in dairy products and dietary supplement after simulated digestion. J Funct Foods 55:126-134.

Romulo A, Surya R. 2021. Tempe: A traditional fermented food of Indonesia and its health benefits. Int J Gastron Food Sci 26:100413.

Şanlier N, Gökcen BB, Sezgin AC. 2019. Health benefits of fermented foods. Crit Rev Food Sci Nutr 59:506-527.

Santos E, Andrade R, Gouveia E. 2017. Utilization of the pectin and pulp of the passion fruit from caatinga as probiotic food carriers. Food Biosci 20:56-61.

Savaiano DA, Hutkins RW. 2020. Yogurt, cultured fermented milk, and health: A systematic review. Nutr Rev 79:599-614.

Senok AC, Ismaeel AY, Botta GA. 2005. Probiotics: Facts and myths. Clin Microbiol Infect 11:958-966.

Shah NP. 2006. Health benefits of yogurt and fermented milks. In Manufacturing yogurt and fermented milks. Chandan RC (ed). Blackwell, Hoboken, NJ, USA. pp 327-351.

Shi LH, Balakrishnan K, Thiagarajah K, Ismail NIM, Yin OS. 2016. Beneficial properties of probiotics. Trop Life Sci Res 27:73-90.

Shori AB. 2016. Influence of food matrix on the viability of probiotic bacteria: A review based on dairy and non-dairy beverages. Food Biosci 13:1-8.

Šikić-Pogačar M, Turk DM, Fijan S. 2022. Knowledge of fermentation and health benefits among general population in North-eastern Slovenia. BMC Public Health 22:1695.

Song MW, Jang HJ, Kim KT, Paik HD. 2019. Probiotic and antioxidant properties of novel *Lactobacillus brevis* KCCM 12203P isolated from kimchi and evaluation of immune-stimulating activities of its heat-killed cells in RAW 264.7 cells. J Microbiol Biotechnol 29:1894-1903.

Sotoudegan F, Daniali M, Hassani S, Nikfar S, Abdollahi M. 2019. Reappraisal of probiotics' safety in human. Food Chem Toxicol 129:22-29.

Szparaga A, Tabor S, Kocira S, Czerwińska E, Kuboń M, Płóciennik B, Findura P. 2019. Survivability of probiotic bacteria in model systems of non-fermented and fermented coconut and hemp milk. Sustainability 11:6093.

Tasdemir SS, Sanlier N. 2020. An insight into the anticancer effects of fermented foods: A review. J Funct Foods 75:104281.

Tripathi MK, Giri SK. 2014. Probiotic functional foods: Survival of probiotics during processing and storage. J Funct Foods 9:225-241.

Vicenssuto GM, de Castro RJS. 2020. Development of a novel probiotic milk product with enhanced antioxidant properties using mango peel as a fermentation substrate. Biocatal Agric Biotechnol 24:101564.

Wa Y, Yin B, He Y, Xi W, Huang Y, Wang C. 2019. Effects of single probiotic- and combined probiotic-fermented milk on lipid metabolism in hyperlipidemic rats. Front Microbiol 10:1312.

Wan-Mohtar WAAQI, Ilham Z, Jamaludin AA, David W, Zaini NAM. 2022. Fermented foods as alternative functional foods during post-pandemic in Asia. Front Food Sci Technol 2:1047970.

Wang X, Zhang N, Li D, Wang M, Li C, Tian H. 2022. Mechanism of gastrointestinal adaptability and antioxidant function of infant-derived *Lactobacillus plantarum* BF_15 through genomics. Food Sci Biotechnol 31:1451-1462.

Widyastuti Y, Febrisiantosa A, Tidona F. 2021. Health-promoting properties of *Lactobacilli* in fermented dairy products. Front Microbiol 12:673890.

Wu R, Wang W, Yu D, Zhang W, Li Y, Sun Z, Wu J, Meng H, Zhang H. 2009. Proteomics analysis of *Lactobacillus casei* Zhang, a new probiotic *bacterium* isolated from traditional home-made koumiss in inner mongolia of China. Mol Cell Proteomics 8:2321-2338.

Yerlikaya O. 2014. Starter cultures used in probiotic dairy product preparation and popular probiotic dairy drinks. Food Sci Technol 34:221-229.

Yilmaz-Ersan L, Ozcan T, Akpinar-Bayizit A. 2020. Assessment of socio-demographic factors, health status and the knowledge on probiotic dairy products. Food Sci Hum Wellness 9:272-279.

Zendeboodi F, Khorshidian N, Mortazavian AM, Cruz AG. 2020. Probiotic: Conceptualization from a new approach. Curr Opin Food Sci 32:103-123.