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Review

A survey on the function of lactic acid bacteria in milk fermentation and preservation

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This review was conducted to find out the main function of lactic acid bacteria in milk fermentation and preservation. Lactic acid bacteria (LAB) are a group of Gram-positive, non-spore forming, cocci or rods, which produce lactic acid as the major end product during the fermentation of carbohydrates. LAB includes *Lactobacillus, Lactococus, Streptococcus* and *Leuconostoc* species. The presence of LAB in milk fermentation can be either as spontaneous or inoculated starter cultures. Both of them are promising cultures to be explored in fermented milk manufacture. LAB has a role in milk fermentation to produce acid which is important as preservative agents and generating flavour of the products. The main reasons for the fermentation practice using LAB are to increase milk palatability and improve the quality of milk by increasing the availability of proteins and vitamins. Furthermore, LAB confers preservative and detoxifying effects on milk as well. When it is used regularly, LAB fermented milks boost the immune system and strengthen the body in the fight against pathogenic bacterial infections. Thus, LAB fermentation is not only of a major economic importance, but it also promotes human health. Therefore, it was concluded that the lactic acid bacteria have a vital role in milk and milk products fermentation and preservation and this suggests the need for educating the communities about benefits of consuming fermented milk and milk products needs to be part of health education.

Key words: Fermentation, lactic acid bacteria, milk, preservation.

INTRODUCTION

Lactic acid bacteria (LABs) are industrially important organisms used for the production of milk and milk products like yoghurt, cheese, buttermilk and kefir. The species used for these applications typically belong to the group of gram-positive bacteria including the genera *Lactobacillus*, *Lactococcus*, *Leuconostoc*, *Pediococcus*, and *Streptococcus*. They are recognized for their fermentative ability and thus enhancing food safety, improving organoleptic attributes, enriching nutrients and increasing health benefits (Panesar, 2011; Liu et al., 2011; Sharma et al., 2012; Steele et al., 2013).

Due to the characteristics of milk that is highly perishable, the main purpose of milk fermentation using LAB is to prolong its shelf-life as well as to preserve the nutritious component of milk. It is also recognized that fermentation of milk using LAB will undoubtedly produce good quality of products with highly appreciated organoleptic attributes. Recently, there is a growing interest to develop a variety of fermented milk products for other beneficial purposes, particularly for health purposes and preventing of toxins produced by food-borne pathogens and spoilage bacteria that enter human body (Shah, 2007; Ali, 2010; Panesar, 2011; Sharma et al., 2012).

The presence of LAB in milk fermentation can be either spontaneous or inoculated starter cultures. Milk itself is known as one of the natural habitats of LAB (Delavenne et al., 2012; Wouters et al., 2002). In general, the technology of milk fermentation is relatively simple and cost-effective. On the other hand, standardized fermented milk products are produced and manufactured in large-scale production under controlled conditions and become an important industrial application of LAB as starter cultures. There are some important features of LAB starters in fermented milk products. A single potential starter culture will dominate and reduce the diversity of microorganisms in fermented milk products compared to that of products under natural fermentation.

Using lactic acid bacteria in milk fermentation and preservation is indispensable to improve milk palatability and quality. However, there is a limitation to reviewing these and other related information and thereby to delivering such synthesized and summarized data to the beneficiaries.

Therefore, reviewing sensible findings on lactic acid bacteria function in milk fermentation and preservation seems to be a milestone area to deliver combined information to the beneficiaries. Based on this outlined background, the objective of this paper was to review lactic acid bacteria function in milk fermentation and preservation and thereby to deliver combined information for beneficiaries.

Most of the related research findings of lactic acid bacteria (LAB) function in milk fermentation and preservation were reviewed. Related reports which focus on health promoting properties of LAB were also reviewed. Findings on antimicrobial and preservative property of LAB that have been reported by various scholars were also reviewed and combined.

OUTLINED DESCRIPTION OF LACTIC ACID BACTERIA FUNCTION IN MILK FERMENTATION

LAB are widespread in nature and predominate of microflora in milk and milk products; many species are involved in the daily manufacturing of dairy products (Ayad et al., 2004). The lactic acid bacteria used in the dairy fermentation can roughly be divided into two groups of the basis of their growth optimum. Mesophilic lactic acid bacteria have an optimum growth temperature between 20 and 30°C and the thermophilic have their optimum between 30 and 45°C. Traditional fermented products from sub-tropical countries harbor mainlythermo-philic lactic acid bacteria, whereas the products with mesophilic bacteria originated from western and northern European countries. The lactic acid bacteria can be mainly divided into two groups based on the end-products formed during the fermentation of glucose. Homofermentative lactic acid bacteria such as *Pediococcus, Streptococcus*, and *Lactococcus* produce lactic acid as the sole product of glucose fermentation. Heterofermentative lactic acid bacteria such as *Weissella* and *Leuconostoc* produce equimolar amounts of lactate, CO_2 and ethanol from glucose (Caplice and Fitzgerald, 1999; Jay, 2000; Kuipers et al., 2000).

LAB have been extensively used in food fermentation, including the production of milk products, and its proteolitic activity is very important in producing flavor compounds of end product (Moulay et al., 2013). Proteolytic system of LAB is important for the growth of microorganisms and it is involved in casein utilization within LAB cells and give contribution to the development of organoleptic properties of fermented milk products (Moulay et al., 2013; Yamina et al., 2013).

Milk fermentation process has relied on the activity of LAB, which play a crucial role in converting milk as raw material to fermented milk products. In milk fermentation industry, various industrial strains of LAB are used as starter cultures (Table 1). Starter cultures of LAB were obtained from a sequence activity and passed a process of isolation, selection and confirmation. Several behaviors as the characteristics of each individual selected strains of LAB has been established and used in the production of fermented milk products industrially. The most important properties of LAB are their ability to acidify milk and to generate flavour and texture, by converting milk protein due to their proteolytic activities (Mäyrä and Bigret, 2004). The mild acid taste and pleasant fresh are characteristics of fermented milk products such as yoghurt and cheese (Kongo, 2013; Griffiths and Tellez, 2013).

Health promoting property of lactic acid bacteria

The high demand of fermented milk products is due to the health property generated from consumption of fermented milk products (Table 2). Fermented milk products are reported to contribute to human health through several mechanisms (Sharma et al., 2012). Certain lactic acid bacteria strains of the genera Lactobacillus, are utilized as health promoting bacteria (Saxelin et al., 2005), while certain Lactobacillus strains like *L. helveticus* are believed to produce bioactive health beneficial peptides from casein protein of milk and showed effect of antihypertensive, immune modulator activity, anticancer and calcium binding ability. *L. helveticus* is known as one of LAB which has efficient (Nouaille et al., 2003).

Antimicrobial compounds produced by lactic acid bacteria

The preservative action of starter culture in food is

Table 1. The main lactic acid bacteria associated with milk and milk product fermentation.

Species/ subspecies	Their main uses in different milk products	References
Lactococcus		
Lc. Lactis subsp. Lactis	Mesophilic starter used for many cheese types, butter and butter milk.	Broome et al. (2003) and Wouters et al. (2002)
Lc. lactis subsp. Lactis biovar diacetylactis	Used in Gouda, Edam, sour cream and lactic butter and butter milk.	Wood (1997) and Leroy and De Vuyst (2004)
Lc. Lactis subsp. cremoris	Mesophilic starter used for many cheese types, butter and butter milk.	Weerkam et al. (1996)
Streptococcus		
Sc. thermophilus	Thermophilic starter used for yogurt and many cheese types' particularly hard and semihard high-cook cheeses.	Broome et al. (2003) and Beresford et al. (2001)
Lactobacillus		
Lb. acidophilus	Probiotic adjunct culture used in cheese and yogurt.	Briggiler-Marcó et al. (2007)
Lb. delbrueckii subsp. Bulgaricus	Thermophilic starter for yogurt and many cheese types, particularly hard and semihard high-cook cheeses.	Slaterry et al. (2010)
Lb. delbrueckii subsp.lactis	Used in fermented milks and high-cook cheese.	Broome et al.(2003) and Giraffa 2010
Lb. helveticus	Thermophilic starter for fermented milks and many cheese types particularly hard and semihard high-cook cheeses	Broome et al. (2003) and Griffiths and Tellez (2013)
Lb. casei	Probiotic milk and cheese ripening adjunct	Briggs (2003) and Kongo
Lb. plantarum	culture Cheese ripening adjunct culture.	(2013) Leroy and De Vuyst
Lb. rhamnosus	Probiotic adjunct culture used in cheese	(2004) Coppola et al. (2005)
Leuconostoc		
Ln. mesenteroides subsp. cremoris	Mesophilic culture used for Edam, Gouda, fresh cheese, lactic butter and sour cream.	Weerkam et al. (1996) and Slaterry et al. (2010)

Lb. =Lactobacillus; Lc. =Lactococcus; Ln.=Leuconostoc; Sc.=Streptococcus, subsp.= subspecies.

Table 2. Health benefits when milk is fermented.

Effect of fermentation	Changes in milk	Effect on health
Increase in lactic acid bacteria levels	Reduced lactose content in milk Reduced content of bad bacteria	No diarrhea and bloating Improved gut health Prevention of protection from bacterial vaginosis and fungal infections in women Ability to digest remaining lactose in the fermented milk and use as energy source
Breakdown to shorter chain proteins	Identification of casein peptides and whey peptides with functional properties	Easier digestion Some with antihypertensive effects Some with pain relief effects Some with immune enhancing properties Some with calcium binding bone building properties
Increased acidity	Sharpness of taste	Prevents harmful bacterial growth in milk

Source: http://whqlibdoc.who.int/publications/2003/9241591196.pdf and ftp://ftp.fao.org/docrep/fao/007/y5686e/y5686e00.pdf

proteolytic system (Korhonen and Pihlanto, 2003; Griffiths and Tellez, 2013). Another promising contribution of lactic acid bacteria is to use them as delivery vehicles for molecules with therapeutic value attributed to the combined action of antimicrobial metabolites produced during the fermentation process. These include many organic acids such as lactic, acetic and propionic acids produced as end products which provide an acidic environment unfavourable for the growth of many pathogenic and spoilage microorganisms. Acids are generally thought to exert their antimicrobial effect by interfering with the maintenance of cell membrane potential, inhibiting active transport, reducing intracellular pH and inhibiting a variety of metabolic functions (Rattanachaikunsopon and Phumkhachorn, 2010).

Some of the inhibitory compounds against other bacteria include hydrogen peroxide and bacteriocins (Oyewole, 1997). One of the arguments supporting the use of LAB fermentation is to prevent diarrheal diseases because they modify the composition of intestinal microorganisms and by this, act as deterrents for pathogenic enteric bacteria. LAB bacteria also produce fungal inhibitory metabolites. These are mainly organic acids, which include propionic, acetic and lactic acids ((Schnürer and Magnusson, 2005; Sauer et al., 2008). Thus, LAB is applied as a hurdle against non-acid tolerant bacteria, which are ecologically eliminated from the medium due to their sensitivity to acidic environment (Ananou et al., 2007). Also, fermentation has been demonstrated to be more effective in the removal of Gram-negative than the Gram-positive bacteria, which are more resistant to fermentation processing (Mensah, 1997). As such, fermented food can control diarrhoeal diseases in children (Guandalini, 2006 and Szajewska et al., 2006).

Moreover, LABs are also known to produce protein antimicrobial agents such as bacteriocins (Carolissen-Mackay et al., 1997; Aymerich et al., 2000). Bacteriocins are peptides that elicit antimicrobial activity against milk spoilage organisms and food borne pathogens, but do not affect the producing organisms. LAB also synthesizes other anti-microbial compounds such as, hydrogen peroxide, reuterin, and reutericyclin (Leroy and Vuyst, 2004). Other applications of LAB include their use as probiotics that restore the gut flora in patients suffering from diarrhea, following usage of antibiotics that destroy the normal flora (Aderiye and Laleye, 2003). In this manner, fermented food is used to prevent and to alleviate diarrhea. In addition, the consumption of food products rich in LAB helps to alleviate constipation and abdominal cramps.

Generally, bacteriocins are antimicrobial proteinaceous compounds that are inhibitory towards sensitive strains and are produced by both Gram-positive and Gram-negative bacteria (Tagg et al., 1976).

Lactic acid bacteria as functional starter culture

Definitely, the most important application of lactic acid bacteria is their use as starter strains in the manufacture of various fermented dairy products. In particular, *Streptococcus thermophilus*, *L. lactis*, *L. helveticus*, and *L. delbrueckii subsp. Bulgaricus* are widely used as milk starter cultures. *S. thermophilus* and *L. bulgaricus* are the two bacteria required to make yoghurt and *Lactobacillus casei* is frequently found in cheeses. The proper selection and balance of lactic acid bacteria used for starter culture is critical for the manufacture of milk fermented food products with their desirable texture and flavor. Mankind exploited these bacteria for thousands of years for the production of fermented products because of ability to produce desirable changes in taste, flavor, and texture (Derek et al., 2009).

Starter cultures of LAB can be either mesophilic from the genera of *Lactococcus* and *Leuconostoc* or thermophilic from the genera of *Streptococcus* and *Lactobacillus* (Fox et al., 2004). Among species, *L. lactis, S. thermophilus* and *L. helveticus* are intensively studied. *L. helveticus* is specialized milk species and belong to the member of dairy niche species. Several cheese products are based on *L. helveticus* as starter (Slaterry et al., 2010).

Preservative property of lactic acid bacteria

Milk is a highly perishable food raw material. Its transformation into stable milk products provides an ideal vehicle to preserve its valuable nutrients, and making them available throughout the year. It is known that while unprocessed milk can be stored for only a few hours at room temperatures, cheeses may reach a shelf-live up to 5 years (depending on variety). Fermentation with LAB is a cheap and effective milk preservation method that can be applied even in more rural/remote places, and leads to improvement in texture, flavor and nutritional value of many milk products. LAB have a long and safe history of application and consumption namely in cheese processing (Aquilanti et al., 2006; Giraffa et al., 2010).

Fermentation makes the milk palatable by enhancing its aroma and flavor. These organoleptic properties make fermented food more popular than the unfermented one in terms of consumer acceptance. The lowering the pH to below 4°C through acid production, inhibits the growth of pathogenic microorganisms which can cause food spoilage, food poisoning and disease (Ananou et al., 2007). For example, LAB bacteria have antifungal activities (Schnürer and Magnusson, 2005). By doing this, the shelf life of fermented food is prolonged. This is because the sheer overgrowth of desirable edible bacteria in food outcompetes the other non-desirable food spoilage bacteria. Thus, LAB fermented foods have lactic acid as the main preservative since lactic acid bacterial growth is accompanied by the production of lactic and acetic acids with decrease in pH and increase in titratable acidity. Using LAB fermentation for detoxi-fication is more advantageous in that it is a milder method which preserves the nutritive value and flavor of deconta-minated food (Bata and Lásztity, 1999).

CONCLUSION

Lactic acid bacteria are a broad group of Gram-positive organism and are mainly used as a starter strains, particularly, *S. thermophilus, L. lactis, L. helveticus*, and *L. delbrueckii subsp. bulgaricus* which are widely used as milk starter cultures. They are also widespread in nature and predominate microflora in milk and milk products. Lactic acid bacteria have an essential role in milk fermentation and preservation since lactic acid bacteria display numerous antimicrobial activities in fermented foods. This is mainly due to the production of organic acids. Therefore, lactic acid bacteria exert strong antagonistic activity against many microorganisms, including milk spoilage organisms and pathogens. In addition, some strains may contribute to the preservation of fermented milk by producing bacteriocins. Milk fermentation is profitable in terms of improving milk quality, preservation and decontamination of toxins, often found in food. Together with food safety, the nutritional and flavour profile of the products need to meet the expectations of modern consumers. Fermentation with LAB is a cheap and effective milk preservation method that can be applied even in more rural/remote places, and leads to improvement in texture, flavor and nutritional value of many milk products. Education of communities about benefits of consuming fermented milk and milk products needs to be part of health education. This technology needs to be further developed to enhance safety and ease of application in a rural poor-resource setting.

Conflict of interests

The authors did not declare any conflict of interest.

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