

## INDUSTRIAL PERSPECTIVES OF LACTIC ACID BACTERIA FOR BIOPRESERVATION AND FOOD SAFETY

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### ABSTRACT

Consumers are becoming more attentive towards the ingredients and preservation methods used for food preservation and pathogens control. The rapid globalization and use of chemical preservatives have changed the behaviors of foodborne pathogens. One of the most emerging problems is resistance to antibacterial compounds. Innovative and alternative approaches are getting appraisal to combat with the common and resistant foodborne pathogens in order to get maximum food safety in environment friendly manners. Amongst different alternative methods, one more interesting and widely acceptable method is the use of living probiotic bacteria or its acceptable metabolites for food biopreservation. The biopreservation phenomenon is the use of beneficial microbes and their products for food safety. Lactic acid bacteria have a potential to be used for food preservation due to their probiotic capabilities. They have been successfully used for the production and safety of foods including; meat, milk and vegetables. Lactic acid bacteria are amongst the beneficial microbes, which can also enhance the food taste and aroma, other than food safety against unwanted bacteria. The objective of this review is to cover and summarize the use of lactic acid bacteria for food safety and biopreservation.

**Keywords:** Food safety. Bio-control. Protective culture. Antimicrobials. Biopreservatives. Foodborne pathogens.

### INTRODUCTION

Quality and safety of food remains always the prime concern for consumers as well as food processing industries. Consumers are becoming more diverse in food selection for consumption (Henson and Northen, 2000; Akbar and Anal, 2014a). Food safety standards implementation in food production industries is important for safe and healthy food production (Banterle *et al.*, 2006). Improper hygiene and insufficient sanitation are the important issues in food industries (Borch and Arinder, 2002). Emergence of new pathogens and sources of foodborne illness have been identified recently by researchers (Akbar and Anal, 2013). Detection of pathogens with classical and molecular techniques is helpful for the identification of foodborne pathogens. Epidemiology of foodborne pathogens is not totally known for many of the existing potential foodborne pathogenic bacteria and newly emerging food related pathogens such as, *Escherichiacoli* O157, Enteric aggregative *Escherichiacoli*, *Vibriovulnificus*, *Campylobacterjejuni* and *Streptococcus parasanguinis* (Akbar and Anal 2015).

Thermal and non-thermal processing are common practices for the preservation of raw food and its final products. The aim of all technologies involved in food preservation processes is to prevent the spoilage and

pathogenic microorganisms and to extend the shelf life. It is important to know the physical and chemical stresses which can lead to the inactivation of microbes responsible for spoilage and foodborne diseases associated with the processing of food (Akbar and Anal, 2011). The uses of chemical additives in food production have raised concerns, leading the European Union to ban many antibiotics and growth promoters used in livestock industry (Atterbury, 2009). The adulteration caused by extensive use of chemicals and antibiotics in food preservation and the ban on them has provoked the researchers to search the natural procedures for food preservation (Paari *et al.*, 2011).

Lactic acid bacteria (LAB) are generally regarded as safe. It has been associated with production of fermented foods from centuries. This group of bacteria can be an attractive mean of naturally controlling the growth of spoilage and pathogenic organisms in different foods (Harris *et al.*, 1992). Bacteriocins obtained from LAB are antagonistic to other bacteria, most commonly to Gram-positive group (Cleveland *et al.*, 2001). The use of lactic acid bacteria as protective cultures or their antagonistic metabolites such as hydrogen peroxide, lactic acid and particularly bacteriocins are some of the examples of biopreservation (Akbar and Anal, 2014b).

Food protection and preservation can be achieved by using different biological means including medicinal plant materials and essential oils, all these

materials are repeatedly reported with antimicrobial activities and their uses in biopreservation. All these except lactic acid bacteria and its antimicrobial metabolites are beyond the scope of the current study. For continuous improvement, further research studies are needed to investigate the possible ways of biopreservation of different foods. This review covers the use of LAB for the welfare of mankind in terms of food safety.

**Food safety and foodborne pathogens:** Food safety and foodborne diseases are common issues related to everyone all around the world. It is related to all what we eat and drink. The word “food safety” covers every aspects of food contamination from chemical to biological (Akbar and Anal, 2011). The perishable foods such as meat are rich in water and nutrition, making them more prone to pathogens growth (Xiaoshuan *et al.*, 2009). Meats from healthy animals at the stage of slaughtering are thought to be free of any pathogens. Contamination occurs during processing and handling of meat due to unhygienic practices and use of contaminated utensils (Akbar and Anal, 2015). Bacteria from gut, hide and environment play important role in contaminating the internal meat tissues during cutting and processing, which can be handled easily by following the good hygiene practices (GHP) during slaughtering and processing (Sofos, 2008). Ready-to-eat (RTE) foods such as, red meat, poultry meat, sea foods and vegetable products have been recognized as potential foodborne pathogens vehicles (Borch and Arinder, 2002; Akbar and Anal, 2011). *Listeria monocytogenes* exhibits its survival in vacuum and gas packed RTE meat products stored at low temperature (Gibbons *et al.*, 2006). *Salmonella* has been confirmed in epidemics related to RTE foods (Reij and Den Aantrekker, 2004). Vaccines for foodborne pathogens particularly the newly emerging one is unavailable and the multidrug resistance makes its management harder (Tauxe, 1997; Akbar and Anal, 2011). Continuous monitoring of foodborne pathogens is needed as the detailed data regarding microbial risk assessment in food is limited (Marthi, 1999). Implementation of food safety systems such as, microbial risk assessments (MRA) and hazard analysis and critical control point (HACCP) is necessary to achieve microbial food safety from farm to fork (Perni *et al.*, 2009).

**Lactic acid bacteria:** It is a widespread microorganism and easily isolated from carbohydrates rich foods (Aureli *et al.*, 2011). *Lactobacillus* is the most common bacterium which is used for the human welfare. These bacteria help in the digestion of food, and produce active compounds like vitamin K and bacteriocins, and maintain the balances of normal intestinal flora. It is more frequently used for protective culture in foods to inhibit the unwanted microbial flora (Aureli *et al.*, 2011; Rodgers, 2003). The LAB is grouped in *Clostridium* branch of

Gram-positive bacteria. It is micro-aerophilic, non-spore forming and catalase negative bacteria. It is divided in cocci and rod shapes based on its morphology, such as *Bacillus*, *Lactococcus*, *Pediococcus* and *Enterococcus* (Khan *et al.*, 2010). It produces lactic acid from glucose. The G+C content is usually between 32 and 51 mol %. In homo-fermentation, it converts glucose to lactic acid, while in hetero-fermentation it produces CO<sub>2</sub>, ethanol and lactic acid. It contains approximately 125 species, including *L. casei*, *L. plantarum*, *L. rhamnosus* and *L. acidophilus* (Gomes and Malcata, 1999), predominantly mesophilic in nature and cannot usually resist high temperature (Messaoudi *et al.*, 2013).

**Lactic acid bacteria as probiotics:** Selection of LAB for its uses as a probiotics is based on its ability to survive in diverse and extreme conditions and its ability to produce bioactive compounds for host that also work against other bacteria (Akbar and Anal, 2014b; Galvez *et al.*, 2010). Tolerance to a wide range of pH is one of the desired properties in the probiotic bacteria, facilitating the survival of such probiotics in host gastrointestinal system (Dunne *et al.*, 2001). Thermostability in probiotic bacteria is another required property for its use in protective culture and bio-preservation of food and food safety (Gaggia *et al.*, 2011). Encapsulation technology can enhance the probiotics protection in drastic conditions for its better use. Studies on the control release of probiotics and protection from high temperature and low pH has been conducted and described in detail (Anal and Singh, 2007). In order to ensure the safe intestinal passage of any probiotic bacteria, it needs to show sufficient tolerance to bile salt, which can be measured *in-vitro* by simply plating the isolates on media supplemented with bile salts (Messaoudi *et al.*, 2013).

The adherence ability of probiotic bacteria to the available human cell lines is desirable for its use as probiotics. The evidences from ecological studies of some environmental habitats suggest that, to compete and survive successfully in a natural ecosystem, such as human intestine, an effective adherence capability of bacterium is desirable to adhere itself to the available sites in the intestine (Duany *et al.*, 2011; Juntunen *et al.*, 2001). One of the main functions of probiotics is the ability of competitive exclusion of the target pathogens from intestinal epithelia. So the good adherence property is directly proportional to the better activity of probiotics. It has been observed in many studies that probiotic bacteria have the ability to attach itself to mucin efficiently. Adherence can be measured using hydrocarbons (xylene, toluene) or available cell lines such as colon adenocarcinoma cell line Caco-2, porcine epithelial cell line IPEC-J2 (Messaoudi *et al.*, 2013; Juntunen *et al.*, 2001). Probiotics bind the epithelial cells binding sites to compete with pathogenic bacteria by inhibiting the colonization of pathogenic bacteria such as,

*E. coli* and *Salmonella* (Mazahreh and Ershidat, 2009). The LAB (*Lactobacillus reuteri* 104R, *Lactobacillus rhamnosus* GG) possessing cell surface-localized mucus adhesion-promoting protein (MapA), SpaCBA pili on the cell surface and SpaB, SpaF pilin subunits, which exhibit substantial binding capacity to mucus (Ossowski, *et al.*,2010).

Bacteriocin production is an important property of lactic acid bacteria making it more attractive for its use as probiotics in animals and human as well as in food safety practices. These bacteria produce a variety of antimicrobial proteins collectively called bacteriocins (Galvez *et al.*, 2007) including metabolic products and short polypeptide with bacteriostatic and bacteriocidal activities. Bacteriocins are specific in their action against species and act through the process of adsorption to receptors on the surface of the target bacteria. The resulting, morphological, biological and metabolic changes lead to the destruction of targeted bacteria (Muhammad *et al.*, 2015; Messaoudi *et al.*,2013).

Strains having a diverse metabolic capability would be of greater advantage over the strains with limited potential. The ability of probiotics to metabolize those nutrients which have not been used by the host would be a useful property of the species (Rajput and Li, 2012). The non-digestible oligosaccharides of human's intestine are normally available for microbial growth. The bacteria *Bifido bacterium* and *Lactobacillus* are amongst the few microbes capable to metabolize these oligosaccharides. It provides them a significant advantage on other bacteria in the presence of these substrates. This concept leads the researcher to the phenomenon of prebiotic, where a specific nutrient supplement can be used for the enhancement of probiotics growth and activity (Gaggia *et al.*, 2011; Padma and Prabhasankar, 2014). The dietary carbohydrates which escape the digestion, can influence the microbial ecology of the gut. The fermentation of these compounds by *Bifido bacterium* and *Lactobacillus* results in the acidification of colon and formation of short chain fatty acid, facilitate the regulation of cellular processes (Blaut,2002). – galactosidase or phosphor- –galactosidase production by LAB can be exploited for lactose free milk production in food industries (Shah, 2007).

The higher ability of competition for limiting factors in probiotics bacteria can deprive the unwanted and pathogenic bacteria from available food in competitive environments (Malti and Amarouch, 2008). Some bacteria secrete siderophores, a low molecular weight compounds to respond the iron limitation in cell. Siderophores helps in transportation of environmental iron inside the cells. Such organisms dominate the environment by depriving iron to others with the help of their potential scavenging system (Verschuere *et al.*, 2000).

Bacteriophage resistance capabilities in lactic acid bacteria can be best alternative in phage prone starter cultures (Dalyet *et al.*, 1996). *Lactococcus lactis* strains bearing natural antiphage barriers and mechanisms to prevent phage infection. These mechanisms include blocking of phage adsorption, DNA entry, DNA replication and assembly. The antiphage system abortive infection mechanism (Abi) present in LAB inhibits phage multiplication and protein synthesis after DNA entry (Haaber *et al.*,2010). Most of these mechanisms are plasmid mediated and can transfer from one strain to another making the opportunity of phage resistance more prominent amongst different strains (Garneau and Moineau, 2011).

#### **Antimicrobial compounds and activity of lactic acid**

**bacteria:** Lactic acid bacteria often exhibit inhibition to other microbes, which is the basis of their ability to keep on improving the safety and quality in many food products. It produces bacteriocin, designated as natural or food grade protein and is widely acceptable for food preservations (Iyer *et al.*, 2013; Messaoudi *et al.*,2013). Lactic acid bacteria as a protective culture or fermentation microbes have already been used in production of food as one of an effective method for shelf-life extension by simple fermentation. *Pediococcus*, *Streptococcus*, *Carynebacterium*, *Lactococcus*, *Leuconostoc* and *Lactobacillus* are the most commonly used genera as a starter cultures in the fermentation processes of meat, milk, and vegetable products (Akbar and Anal, 2014b; Sobrino-Lopez and Martin-Belloso, 2008). One of the important roles of the LAB is to inhibit the natural flora, including spoilage bacteria and pathogens (Akbar and Anal, 2014b). There is a group of bioactive compounds produced by LAB responsible for its antimicrobial activity against other bacteria (Kumaree *et al.*, 2015; Schillinger and Lucke, 1989). Some of the prominent known antimicrobial compounds of LAB are in discussion below.

The ability of LAB to produce antimicrobials has been used to preserve different foods historically. Preservation of milk and milk products, meat and meat products such as sausage by fermentation are the best examples, the history of dairying can traced back to approximately 6000 B.C. Fermentation process reduces available carbohydrates and also produce some organic compounds that exerts antimicrobial activity (Ross *et al.*,2002), the most common being propionic acids and lactic acid. Furthermore, the production of these inhibitory primary metabolites and many other antimicrobial compounds can be produced by different LAB. Changing the environment, e.g., acidification, or production of toxins against competitors are some known ways of LAB to inhibit the competing bacteria (Akbar and Anal 2014b; Ross *et al.*,2002). Lactic acid is produced by the fermentation of hexoses by homo-

fermentation or equimolar amounts of lactic acid, acetic acid/ethanol, and carbon dioxide (CO<sub>2</sub>) produced by the process of hetero-fermentation (Ross *et al.*, 2002). It has been observed that weak acids have high antimicrobial activity at acidic pH than at neutral pH. Acetic acid is stronger inhibitor as compared to lactic acid and giving a broad range of inhibitory activity against microbes such as, bacteria, molds, and yeasts, whereas propionic acid has a high antimicrobial activity towards molds and yeasts (Malti and Amarouch, 2008; Eklund, 1983). In a mixture of acids produced by LAB, it is forecasted that lactic acid contributes to reduce the acidity, while the remaining acids such as, acetic acid and propionic acid, work as antimicrobial agents by interfering with its cell membrane maintenance potential (Ross *et al.*, 2002).

Some of the LAB (*Lactobacillus johnsonii* NCC 533, *Lactobacillus paracasei* subsp. *paracasei*) produce hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) in the presence of oxygen through the action of flavoprotein-containing oxidases, superoxide dismutase and NADH oxidases (Pridmore *et al.*, 2008; Marty-Teyssset *et al.*, 2000). The bactericidal effect of H<sub>2</sub>O<sub>2</sub> has been attributed to its strong oxidizing effect on the bacterial cell. Some of the H<sub>2</sub>O<sub>2</sub> producing reactions scavenge oxygen, thereby creating an anaerobic environment which is not suitable for certain organisms. Interestingly, the colonization of Lactobacilli strains in the urogenital tract has been found to decrease the chances of gonorrhoeal infection and other urinary tract infections (Condon, 1987).

The LAB produces carbon dioxide (CO<sub>2</sub>) mainly during hetero-fermentative process of hexoses to lactic acid-fermentation. There are some other metabolic pathways by which CO<sub>2</sub> generates during fermentation. The formation of CO<sub>2</sub> not only creates an anaerobic environment but can also act as a potential antimicrobial agent to other microbes in the environment (King and Nagel, 1975). The lower concentration of CO<sub>2</sub> can stimulate the growth of some organisms, but the presence of higher concentration prevents it (Borneman *et al.*, 2012). Carbon dioxide is a common source of microbial growth inhibition in modified atmosphere packaging and hurdle technology. Gram-negative bacteria are more sensitive to the carbon dioxide as compared to gram-positive bacteria (Akbar and Anal, 2011).

Diacetyl is a major flavouring and aroma component in cheese, butter and cream. Some lactic acid bacteria such as, *Streptococcus*, *Pediococcus*, *Leuconostoc*, *Lactobacillus* and *Lactococcus* can produce it in high quantities in citrate metabolism (Malti and Amarouch, 2008; Ross *et al.*, 2002). Its activity has been reported against Gram-negative bacteria, molds and yeast. It interferes with the amino acid utilization in Gram-negative bacteria by reacting with arginine utilization (Malti and Amarouch, 2008; Pakdeeto *et al.*, 2003).

Bacteriocin as antimicrobials is active against bacteria and has been found non-toxic to animals and

humans, does not change the nutritional properties, effective at low concentration, have been found active under refrigerated storage and can also be used for food preservations. It has been extensively studied by the researcher for its use against unwanted bacteria and still need more attention due to its environmental and consumer friendly nature for its uses in the biopreservation of food products (Messaoudi *et al.*, 2013; Gaggia *et al.*, 2011). There are several reports on the production of bacteriocins or bacteriocin-like substances by Lactobacilli such as Lactacin B, Lactocin 27, Plantaricin A, Plantacin B and Helveticin J. It can affect the bacteria by inhibiting cell wall synthesis, increasing the cell membrane permeability of the target cells, or by inhibiting RNase or DNase activity (Galvez *et al.*, 2007). Fig. 1. illustrates the possible uses of lactic acid bacteria in food safety.

Production of antioxidants compounds from LAB has been reported in milk and other fermented products (Parrella *et al.*, 2012). The presence of LAB increased the antioxidant activity of soybean-yoghurt, fermented milk (Shori, 2013; Parrella *et al.*, 2012) and sourdough fermentation of cereal flours (Coda *et al.*, 2012).

In hurdle technology the LAB and its products in combination with other preservation methods can be effectively used. The anaerobic, microaerophilic nature of LAB and its growth in the presence of CO<sub>2</sub> are an effective combination with modified atmosphere packaging for food preservation (Borneman *et al.*, 2012). Bacteriocins in combination with metal chelators (EDTA, sodium tripolyphosphate) and other physical methods such as high hydrostatic pressure and heat can be effectively used against *Salmonella* and *E. coli* for its control (Ananou *et al.*, 2010; Ananou *et al.*, 2005). Enterocin AS-48 in combination with NaCl and low temperature has been found effective against *Staphylococcus aureus* (Ananou *et al.*, 2004). Synergistic effect of LAB in combination with organic acid has been reported against *E. coli* O157:H7 and *S. Typhimurium* (Seo *et al.*, 2013). Bacteriocins (Nisin, Pediocin, Enterocin) in combination with other hurdles (low and high temperature, hydrostatic pressure, Pulsed electric fields and salts) has been found active against pathogenic bacteria such as *S. aureus*, *L. monocytogenes*, *S. carnosus*, *B. subtilis*, *L. innocua* and *Arcobacter butzleri* (Ananou *et al.*, 2007).

**Biopreservation and Bio-control :** The term biopreservation refers to food safety and shelf life extension by using living microbes (LAB) and their metabolites. The term bio-control is specified for the use of one living species against another for its control (Galvez *et al.*, 2007). It has been reported that the food preservation ability of LAB is due to the production of hydrogen peroxide, diacetyl, organic acids, carbon

dioxide, ethanol, antifungal compounds such as phenyllactic acid or fatty acids, bacteriocins and antibiotics such as Reutericyclin (Settanni and Corsetti, 2008). Selective growth promotion of LAB utilizing its antagonistic ability to control meat-borne pathogens would minimise the spoilage bacteria and its spoilage effects (Akbar and Anal, 2014b). It has been reported that *Enterococcus faecium* and *Lactococcus lactis* responsible for producing a number of bacteriocins have potential to be used as biopreservative agent for fresh foods especially vegetable products, ready-to-eat fruit and meat products due to its low minimum inhibitory concentration against *Listeria* spp. and *S. aureus* (Settanni and Corsetti, 2008). The Reuterin from *Lactobacillus reuteri* in a combination with other bacteriocin such as enterocin AS-48, Nisin, or Lacticin 481 have strong synergistic effects on the growth of *Listeria monocytogenes*. Higher antimicrobial activity of Nisin combined with Reuterin against *S. aureus* has also been reported (Arques *et al.*, 2008). The application of Reuterin to control Gram-negative and Gram-positive pathogens has been investigated in dairy (Arques *et al.*, 2008; El-Ziney and Devere, 1998) and meat products (El-Ziney *et al.*, 1999).

Salami manufacturing provides a good example of bio-control approaches where addition of LAB to meat does not only impart desirable organoleptic qualities but also inhibit the spoilage and pathogenic bacteria (Khan *et al.*, 2010; Pakdeeto *et al.*, 2003). Nisin is an approved bio-control product of lactic acid bacteria for food application. Microbes with potential to inhibit mycotoxin producing fungi and to neutralize mycotoxin, has been successfully studied (Schillinger *et al.*, 1996).

Fermentation of food is widely used and is a common form of biopreservation. The process is usually dependent on the growth of microorganisms in foods from nature or added during the process. Lactic acid bacteria can provide better physiological properties, from taste/color to consistency (Rodgers, 2003). Antimicrobial metabolites production by LAB during fermentation is an additional quality, which can help in food safety and product shelf life extension. Enterocin AS-48, Enterocins A and B, Leucocin A, Nisin, Sakacin and Pediocin PA-1/AcH are amongst the most-studied bacteriocins in meat and meat products. Various LAB have been used as bioprotective cultures in food processing in order to control the pathogenic bacteria (Ananou *et al.*, 2007; Rodgers, 2003).

**Protective culture approaches:** Protective culture is the addition of antagonistic LAB to food products for the competitive exclusion or inhibition of unwanted bacteria and extension of shelf life (Malti and Amarouch, 2008). The starter culture of *Lactobacillus plantarum*, *Lactobacillus curvatus* and *Micrococcus* sp. were found active against *Listeria monocytogenes* in the production

of Ostrich meat salami (Akbar *et al.*, 2014c; Dicks *et al.*, 2004). Probiotic bacteria (*Lactococcus*, *Lactobacillus* and *Pediococcus*) from fermented food have been successfully used for the extension of shelf life in cheese and ready-to-eat poultry meat (Paari *et al.*, 2011; Akbar and Anal, 2014b). These bacteria enhance the physical features of the meat such as, color and aroma by releasing aromatic substances during protective culture (Malti and Amarouch, 2008). The LAB used for fermented products as starter culture can grow during storage time, producing acidic compounds making the food environment hostile for pathogen growth (Rubio *et al.*, 2013). Protective culture is not limited to the use of bacteriocin only; it is a broad phenomenon where even the LAB itself is acceptable to consumer as a functional food component (Wessels *et al.*, 2004).

Meat products are prone to bacterial contamination as it contains best growth enhancing compounds for microbes. The foodborne pathogens such as *Listeria monocytogenes* and other psychrophilic bacteria (*Pseudomonas* spp. and *Brochothrix thermosphacta*) can grow on refrigerated foods (Katikouet *et al.*, 2005). Use of protective culture against the target pathogens in refrigerated food was found to be promising (Maragkoudakis *et al.*, 2009; Akbar and Anal, 2014b). Vatanyoopaisarn *et al.*, (2011) reported *Pediococcus acidilactici* (CP7-3) and *Lactobacillus plantarum* (CP1-15 and CP2-11) as starter cultures in Thai fermented sausage against *S. aureus*. In protective culture studies, it was found that the LAB usually suppresses unwanted microbes as a co-culture. *Streptococcus phocae* has been found active against *Vibriopara haemolyticus*, *Listeria monocytogenes* and coliforms in a protective culture in seafood products (Paari *et al.*, 2011). Maragkoudakis *et al.*, (2009) applied *Enterococcus faecium* PCD71 and *Lactobacillus fermentum* ACA-DC179 in raw chicken meat and found reduced growth of *L. monocytogenes* and *Salmonella enteritidis*. Hu *et al.*, (2008) reported the suppressed growth of spoilage bacteria in vacuum packed cooked ham in presence of *Lactobacillus sakei* as a protective culture. Adesokan *et al.*, (2008) reported the biopreservative activity of *Lactobacillus plantarum* against coliform and *S. aureus* in suya produced from poultry meat.

*Lactobacillus curvatus* CRL705 was used for the control of spoilage bacteria growth in vacuum-packaged refrigerated meat (Castellano *et al.*, 2010). Matamoros *et al.*, (2009) reported the bio-preservation potential of *Leuconostoc gelidum* EU2247 and *Lactococcus piscium* EU2441 applied on sea food. Protective culture activity of *L. mesenteroides* strains were reported in Iceberg lettuce leaf cuts and wounded Golden Delicious apples against *E. coli*, *S. typhimurium* and *L. monocytogenes* (Trias *et al.*, 2008). Vermeiren *et al.*, (2006) reported protective culture activity of *L. sakei* 10A against spoilage bacteria in cooked meat products. Protective

culture activities of different lactic acid bacteria in foods such as, meat (*L. curvatus* CRL 705 and *E. faecium* PCD 71 against *B. thermosphacta*, *Listeria spp.* *S. enteritidis* and *L. monocytogenes*) (Castellano *et al.*, 2010; Maragkoudakis *et al.*, 2009), seafood (*Streptococcus phocae* against *V. parahemolyticus*, coliform and *L. monocytogenes*) (Paari *et al.*, 2011) have been repeatedly reported. Table 1 show few examples of LAB as protective culture in different foods.

The use of LAB for protective culture has some advantages on bacteriocin and its other antimicrobial metabolites, as the living LAB can adopt itself to the changing environment and conditions of foods during processing and storage, producing antimicrobials and other metabolites constantly (Settanni and Corsetti, 2008).

**Conclusion and future perspectives:** Prevention of foodborne infections and the assurance of food safety in food products need proper attention to satisfy the consumer and to reduce the economic and health losses.

Concerns over the use of chemicals/antibiotics coupled with the awareness and demands of consumers for natural food preservatives have increased the provision to use the probiotic LAB and its antimicrobial metabolites for food safety and functionality. The promising use of bacteriocin and other metabolites from LAB has proved itself as a good natural preservative. The use of probiotics can effectively reduce the application of chemical preservatives. Currently only limited data is available describing the use of LAB against pathogens. Its use can effectively be exploited as protective culture in perishable foods to be stored in refrigerators. There is an acute need to identify effective probiotics as a protective culture against specific target pathogens such as, *Campylobacter* and *Helicobacter*. Studies for the isolation of psychrophilic and thermophilic probiotic bacteria capable of antimicrobials production against varieties of bacteria and its uses for food safety purposes is needed for the safe production of quality foods.

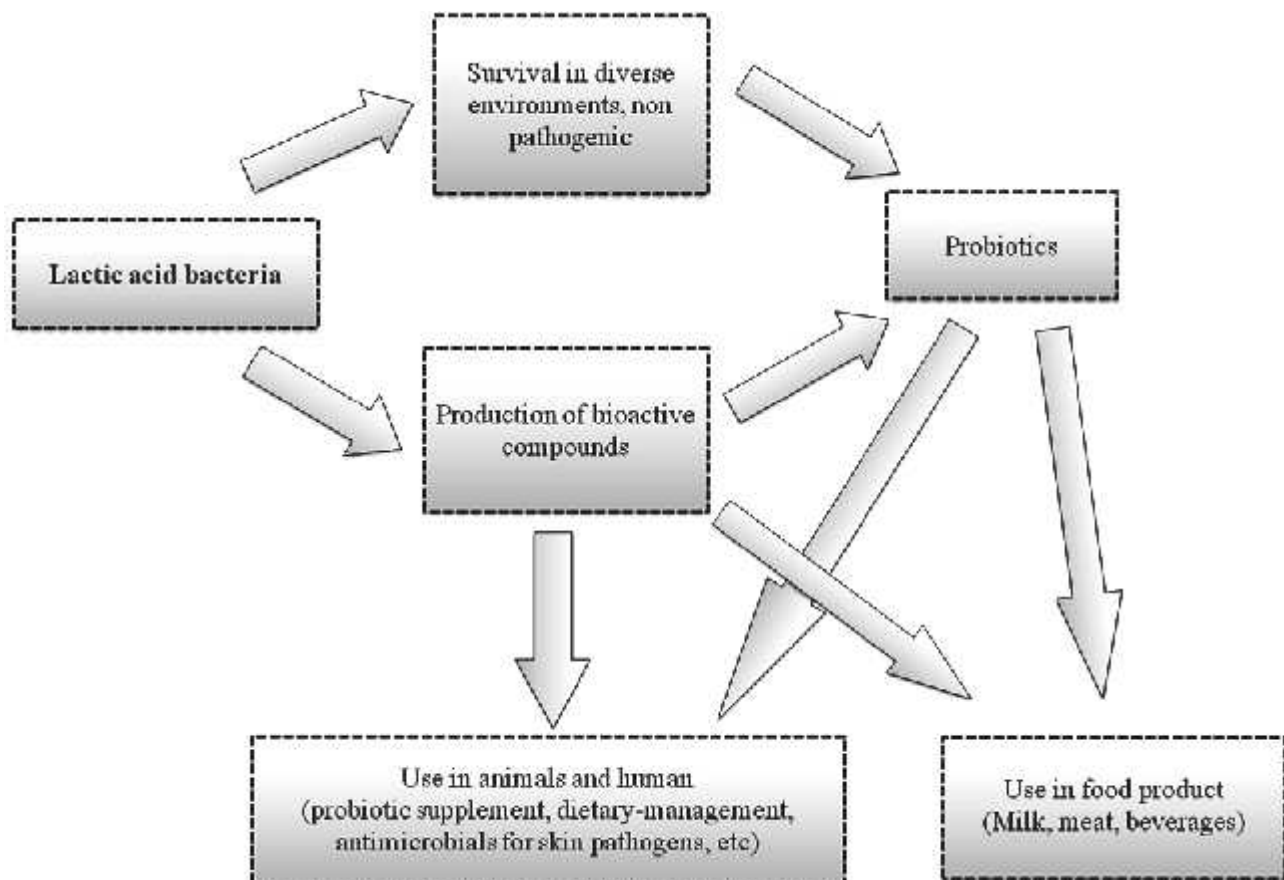


Fig. 1 Uses of lactic acid bacteria and its products for the welfare of human beings

**Table 1. Protective culture of lactic acid bacteria in foods.**

Lactic acid bacteria (LAB)	Target bacteria	Food materials	Reference
<i>L. lactis</i> subsp. <i>lactis</i>	<i>S. aureus</i>	Poultry meat sausage	Akbar and Anal (2013)
<i>Streptococcus phocae</i>	<i>V. parahemolyticus</i> , coliform, <i>L. monocytogenes</i>	Seafood	Paari <i>et al.</i> , (2011)
<i>Pediococcus acidilactici</i> (CP7-3), <i>Lactobacillus plantarum</i> (CP1-15, CP2-11)	<i>S. aureus</i>	Thai fermented sausage (Sai-Krok-Prew)	Vatanyoopaisarn <i>et al.</i> , (2011)
<i>Lactobacillus curvatus</i> CRL705	Spoilage LAB, <i>B. thermosphacta</i> , <i>Listeria spp.</i>	Beef meat	Castellano <i>et al.</i> (2010)
<i>E. faecium</i> PCD71	<i>S. enteritidis</i> , <i>L. monocytogenes</i>	Chicken meat	Maragkoudakis <i>et al.</i> (2009)
<i>Leuconostoc gelidum</i> EU2247, <i>Lactococcus piscium</i> EU2441	<i>Vibrio spp.</i> , <i>S. aureus</i> , <i>L. monocytogenes</i>	Cooked and fresh peeled shrimp	Matamoros <i>et al.</i> (2009)
<i>Lactobacillus sakei</i> B-2	Spoilage bacteria	Vacuum packed cooked ham	Hu <i>et al.</i> , (2008)
<i>Lactobacillus plantarum</i>	Coliform, <i>S. aureus</i>	Poultry meat products	Adesokan <i>et al.</i> , (2008)
<i>Leuconostoc mesenteroides</i> CM135, CM160, PM249	<i>S. enteritidis</i> , <i>S. typhimurium</i> , <i>E. coli</i> , <i>L. monocytogenes</i>	Iceberg lettuce / Golden delicious apples	Trias <i>et al.</i> (2008)
<i>Lactobacillus sakei</i> 10A	Spoilage bacteria	Ham	Vermeiren <i>et al.</i> (2006)
<i>Lactobacillus casei</i> T3, <i>Lb. plantarum</i> Pe2, <i>Carnobacterium piscicola</i> Sal3	<i>L. innocua</i>	Cold-smoked salmon	Vescovo <i>et al.</i> (2006)
<i>Lactobacillus sakei</i> CETC 4808	Enterobacteriaceae, <i>Pseudomonas spp.</i> , <i>B. thermosphacta</i>	Beef meat	Katikou <i>et al.</i> (2005)
<i>Carnobacterium divergens</i> V41	<i>L. monocytogenes</i>	Cold-smoked salmon	Brillet <i>et al.</i> (2005)
<i>Lactobacillus curvatus</i> (LR55)	<i>L. monocytogenes</i> B164 (serotype 4b)	Non-acidified deli-type pickles	Reina <i>et al.</i> , (2005)
<i>Lactobacillus plantarum</i> , <i>curvatus</i> , <i>Micrococcus sp.</i>	<i>Lb. L. monocytogenes</i>	Ostrich meat salami	Dicks <i>et al.</i> , (2004)

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