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Biopreservative: Bacteriocin its classification and applications in food

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Biopreservation is the method used for food preservation by using natural antimicrobials (biopreservative) and microbiotathereby increasing the storage life of food.There is increasing demand by consumers for chemical free food due to their reported harmful effects.Bacteriocins are proteins or peptides having bactericidal activity that can control the growth of food spoilage bacteria. These substances are produced by different types of gram positive and gram negative micro-organisms with variable molecular weights, biochemical properties and mode of action. Most bacteriocins are relatively specific to a single bacterial strain or species is targeted without disrupting other microbial populations. Use of bacteriocin is one of the alternatives to overcome this problem. A number of applications of bacteriocin have been reported in the areas of pharmaceuticals, livestock, agriculture, etc. but due to the non-toxicity and non- residence properties, the biopreservative potential of bacteriocins to control food pathogenic micro-organism and increase the shelf life of food products is of major focus.

Key Words : Biopreservation, Classification, Application in food

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INTRODUCTION

Biopreservative is the use of natural or controlled microflora or antimicrobials as a way of preserving food extending its shelf life (Baust and Baust, 2006). Modern technologies implemented in food processing and microbiological food-safety standards havediminished, but not altogether eliminated, the likelihood of food-related illness and product spoilage inindustrialized countries. The increasing consumption of precooked food, prone to temperature abuse, and the importation of raw foods from developing countries are among the main causes of this situation (Ananou *et al.,* 2007).Food spoilage refers to the damage of the original nutritional value, texture, flavour of the food that eventually render food harmful to people and unsuitable to eat. (Nath *et al.*,2014). Several bacterial pathogens including *Salmonella, Campylobacter jejuni, Escherichia coli 0157:H7, Listeria monocytogenes, Staphylococcus aureus* and *Clostridium botulinum*are found associated with such outbreaks. Food preservation is a continuous fight against micro-organisms spoiling the food or making it unsafe (Rasooli, 2007). In order to achieve improved food safety against such pathogens, food industry mostly relies on the application of chemical preservatives or more drastic physical treatments (e.g. high temperatures). These preservation techniques have many drawbacks which includes the proven toxicity of many of the

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commonest chemical preservatives (e.g. nitrites), the alteration of the organoleptic and nutritional properties of foods, and especially recent consumer demands for safe but minimally processed products without additives. To harmonize consumer demands with the necessary safety standards, traditional means of controlling microbial spoilage and safety hazards in foods are being replaced by combinations of innovative technologies that include biological antimicrobial systems such as lactic acid bacteria (LAB) and/or their metabolites.(Nath *et al.,* 2013; Hugas *et al.,* 2002 and Montville *et al.,* 1997).

Biopreservation :

Biopreservation, can be defined as the extension of shelf-life and food safety bythe use of natural or controlled microbiota and/or their antimicrobial compounds (Stiles, 1996). Fermentation is one of the mostcommon forms of food biopreservation, it is a process based on the growth of micro-organisms in foods, whether natural or added. These organisms mainly comprise lactic acidbacteria, which produce organic acids and other compounds that, in addition to antimicrobial properties,also confer unique flavours and textures to food products. Traditionally, a great number of foods have been protected against spoiling by natural processes of fermentation. Currently, fermented foods are increasing in popularity (60% of the diet in industrialized countries) (Holzapeel *et al.,* 1995).The starter cultures of fermented foods can be defined as preparations of one or several systems of micro-organisms that are applied to initiate the process of fermentation during food manufacture (Wigley *et al.,* 1999) fundamentally in the dairy industry and, currently, extended to other fermented foods such as meat,spirits, vegetable products, and juices. The bacteria used are selected depending on food type with the aim of positively affecting the physical, chemical, and biological composition of foods, providing attractive flavour properties for the consumer. To be used as starter cultures, micro-organisms must fulfil the standards of GRAS status (Generally Recognized As Safe by people and the scientific community) and at present no pathogenic nor toxigenic potentialobserved. In addition, use must be standardized and reproducible (Dass *et al.,* 1999). Food market globalization, the introduction of novel foods, new manufacturing processes and the growing demand for minimally processed, fresh-cut and ready-to-eat products may require a longer and more complex food chain, increasing the risk of microbiological contamination. Thus, novel and complementary food preservation technologies that comply with these demands from "farm to fork" are continuouslyseeked. Among alternative food preservation technologies, particular attention has been paid to biopreservation to extent the shelf-life and to enhance the hygienic quality, minimizing the impact on the nutritional and organoleptic properties of perishable food products. Biopreservation rationally exploits the antimicrobial potential of naturally occurring micro-organisms in food and/or their metabolites with a long history of safe use.

Lactic acid bacteria (LAB) :

LAB was realized as group of biopreservative bacteria in the beginning of the 1900's based on their interavtion with the food lab and plays an important role in food fermentation processes. LAB is widely used in food preservation, microbial stability and production of aroma compounds (Narayanapillai Udhayashree *et al.,* 2012). LAB are characterized as Gram-positive cocci or rods, non-aerobic (microaerophilic) but aerotolerant, able to ferment carbohydrates for energy and lactic acid production. The metabolic pathway from glucose may be homofermentative or heterofermentative. Lactic acid bacteria are also able to produce small organic substances that contribute with aroma and give specific organoleptic attributes to the products (Caplice and Fitzgerald, 1999). LAB have attractive physiological properties and technological applications such as resistance to bacteriophages (Wigley *et al.,* 1999), proteolytic activity, lactose and citrate fermentation, production of polysaccharides, high resistance to freezing and lyophilization, capacity for adhesion and colonization of the digestive mucosa, and production of antimicrobial substances.

These micro-organisms are found in milk, meat, fermented products, as well as in fermented vegetables and beverages inhibiting the growth of pathogenic and deteriorating micro-organisms, maintaining the nutritive quality and improving the shelf-life of foods. They have also been used as flavour and texture developers. Lactic acid bacteria include various major genera: *Lactobacillus, Lactococcus, Carnobacterium, Enterococcus, Lactosphaera, Leuconostoc, Melissococcus, Oenococcus, Pediococcus, Streptococcus,*

*Tet.ragenococcus, Vagococcus*and *Weissella*. Other genera are: *Aerococcus Microbacterium, Propionibacterium* and *Bifidobacterium* (Carr *et al.,* 2002). The most common species are *Lactobacillus acidophilus, L. plantarum, L. casei, L. caseirhamnosus, L. delbrueckiibulgaricus, L. fermentum, L. reuteri, Lactococcuslactislactis, Lactococcuslactiscremoris, Bifidobacteriumbifidum, B. infantis, B. adolecentis, B. longum, B. breve, Enterococcus faecalis, Enterococcus faecium* (Garrity, 1984), and some strains are recognized as probiotics (Fuller, 1989; Parada *et al.,* 2003). LAB are usually known as safe (GRAS), and have an important role in the preservation of foods and fermented products. They can be used as natural competitive microbiota or as specific starter cultures under controlled conditions (Cintas *et al.,* 2001). Some of these bacteria produce antagonistic substances, called bacteriocins, which in small amounts are very active against pathogens (Moreno *et al.,* 2000).

LAB bacteriocins :

Bacteriocins are proteinaceous toxins produced by bacteria to inhibit the growth of similar or closely related bacterial strain(s) (Kathir, 2005).The antimicrobial ribosomally synthesized peptides produced by bacteria, including members of the LAB, are called bacteriocins.Bacteriocins are peptides or complex proteins biologically active with antimicrobial action against other bacteria, principally closely related species. They are produced by bacteria and are normally not termed antibiotics in order to avoid confusion and concern with therapeutic antibiotics, which can potentially illicit allergic reactions in humans and other medical problems (Deraz *et al.,* 2005). Bacteriocins differ from most therapeutic antibiotics in being proteinaceous agents that are rapidly digested by proteases in the human digestive tract. Since, bacteriocins are ribosomally synthesized; there exists a possibility of improving their characteristics to enhance their intensity and spectra of action (Nath *et al.,* 2013;Saavedra *et al.,* 2004,). Colicine was the first bacteriocin, discovered in 1925 by André Gratia and his workgroup (Jacob *et al.,* 1953).

Attractive characteristics of the LAB bacteriocins whichmake them suitable candidates for use as food preservativesare as follows, (Nath *et al.,* 2014):

– Protein nature, inactivation by proteolytic enzymes of gastrointestinal tract

– Non-toxic to laboratory animals tested and generally non-immunogenic

– Inactive against eukaryotic cells

– Generally thermoresistant (can maintain antimicrobial activity after pasteurization and sterilization)

– Broad bactericidal activity affecting most of the Gram-positive bacteria and some, damaged,Gram-negative bacteria including various pathogens such as *L. monocytogenes, Bacillus cereus S. aureus,* and *Salmonella*

– Genetic determinants generally located in plasmid, which facilitates genetic manipulation toincrease the variety of natural peptide analogues with desirable characteristics.

Range of activity :

They form a heterogeneous group considering the antimicrobial spectrum, producing species, molecular weight, stability, physical chemical properties and mode of action of bacteriocins.There is the classic type, which has a spectrum of activity only against homologous species, and a second type, less common, which shows action against a wide range of Gram-positive micro-organisms. One example of this second type is nisin, which is produced by certain strains of *Lactococcuslactis* subsp. *lactis* (De Vuyst and Vandamme, 1992; Rodriguez *et al.,* 2005; Moreno *et al.,* 2000). Other is pediocin, produced by *Pedicoccuspentosaceus* (Moreno *et al.,* 2000).

Nisin, produced by *L. lactis* subsp. *lactis,*which is active against Gram-negative bacteria, but only when used at high concentrations or when the target cells have been pre-treated with EDTA (Stevens *et al.,* 1991).Nisin is effective against food-borne pathogens such as *L. monocytogenes* and many other Gram-positive spoilage micro-organisms (Delves-Broughton, 1999 and Thomas and Delves-Broughton, 2001). Nisin is listed in Spain as E-234, and may also be cited as nisin preservative or natural preservative. In addition to the nisin, several authors have outlined issues involved in the approval of new bacteriocins for food use (Fields, 1996).

Bacteriocins are not frequently active against Gram-negative bacteria. The outer membrane of this class of bacteria acts as a permeability barrier for the cell. It is responsible for preventing molecules such as antibiotics, detergents and dyes from reaching the cytoplasmic

membrane (Stevens *et al.*, 1991). Some studies have alreadyreported bacteriocin activity against this group of bacteria. Examples are plantaricin 35d, produced by *Lactobacillus plantarum*and active against *Aeromonashydrophila* (Messi *et al.*, 2001); bacteriocin ST151BR, produced by *Lactobacillus pentosus* ST151BR (Torodov and Dicks, 2004) and a bacteriocin produced by *Lactobacillus paracasei*subsp. *paracasei*active against *Escherichia coli* (Caridi, 2002); thermophylin, produced by *Streptococcus thermophilus*active against *E. coli*, *Yersinia pseudotuberculosis* and *Yersinia enterocolitica* among the gram-negative species and against several *Bacillus* species, *Listeria monocytogenes* and *Salmonella typhimurium*among the gram-positives (Ivanova *et al.*, 1998). Torodov and Dicks, 2005 reported that bacteriocins ST28MS and ST26MS, produced by *Lactobacillus plantarum*isolated from molasses inhibited the growth of *Escherichia coli* and *Acinetobacter baumanii* along with some Grampositive bacteria. Lade *et al.* (2006) have isolated two *Lactobacillus* species (*L. plantarum* and *L. lactis*) from vegetable waste that produced a bacteriocin which inhibitted the growth of *E. coli*.

Classification of LAB bacteriocins :

Jeevaratnam *et al.*, 2005 have classified the LAB bacteriocins into four general classes of antimicrobial peptides or proteins (bacteriocins) and have characterized.

– Lantibiotics

– Small (≤13kDa) hydrophobic heat stable peptides

– Large (~30 kDa) heat-labile proteins

– Complex proteins that require additional carbohydrates or lipids moieties to attain antimicrobial activity

Class I (Lantibiotics) :

Lantibiotics are a family of membrane active peptides that contain the unusual thio-ether amino acids lanthionine and β-methyl lanthionine as well as other modified amino acids such gene-encoded serine and threonine are subjected to enzymatic dehydration to give rise to dehydroalanine and dehydrobutyrine, respectively (Jung, 1991). They are small (< 5 kDa) heat-stable peptides acting on membrane structures (Sahl and Bierbaum, 1998). A very well-known example of this group is nisin (Broadbent *et al.*, 1989).Their distinguishing feature is the presence of post-translationally modified amino acid residues. The best example in this class is nisin produced by *Lactococcus lactis* subsp. *lactis*. Class I is being further subdivided into Ia and Ib. Class Iabacteriocins, which include nisin, consist of cationic and hydrophobic peptides that form pores in the target membranes and have a flexible structure compared to class Ib. Class Ibbacteriocins, which are globular in nature, have no net negative charge (Altena *et al.*, 2000) and they exert their action by interfering with essential enzymatic reactions of sensitive bacteria (Deegan *et al.*, 2006).

Class II (small heat stable peptides):

Most of the new bacteriocins belong to the class II bacteriocins which are small (30–100 amino acids, < 10kDa), heat-stable and commonly unmodified. It has been shown that several LAB produce multiple bacteriocins (2–3 bacteriocins)while most bacteriocin producers synthesize only one bacteriocin,. The production of some class II bacteriocins (plantaricins of *Lactobacillus plantarum*C11 and sakacin P of *Lactobacillus sake*) have been shown to be transcriptionally regulated through a signal transduction system which consists of three components: an induction factor (IF), histidine protein kinase (HK) and a response regulator (RR)(Nath *et al.*, 2014).

They are also further subdivided into IIa and IIb, Class IIa includes pediocin PA-1 (Venema *et al.*, 1997) and sakacin P having anti-listerial activity with a conserved N-terminal sequence Tyr-Gly-Asn-Gly-Val and two cysteines forming S-S bridge in the N-terminal half of the peptide.

Class IIb:

Bacteriocins composed of two different and no sequence similarities between complementary peptides andare formed by a complex of two distinct peptides. These peptides have little or no activity. Examples arelactococcin G and plantaricins EF e JK.In this it needs both peptides to be fully active. The primary amino acid sequences of the peptides are different. Though each one is encoded by its own adjacent genes, only one immunity gene is needed (Cleveland *et al.*, 2001).

Class IIc:

Small peptides, heat-stable, which are transported by leader-peptides. It includes divergic in A and acidocin B.

Class III (Large heat labile bacteriocins):

These are big peptides, heat labile proteins with molecular weight over 30 kDa. It includeshelveticins J (Joerger and Klaenhammer, 1986) and helveticinsV (Vaugham *et al.,* 1992), acidofilicin A and lactacins A and B. Most of the low molecular weight bacteriocins are highly cationic at pH 7.0, and this seems to be a unifying feature of both the lantibiotics and nonlantibiotics (Cintas *et al.,* 2001).

Class IV (Circular peptides):

They include bacteriocins that form large complexes with other chemical moieties, carbohydrates or lipids required for activity. Presently, no such bacteriocins have been purified and it is believed that the reason is formation of complexes with other macromolecules in the crude extract due to their cationic and hydrophobic properties. The majority of bacteriocins produced by bacteria associated with food belong to classes I and II.

Mode of action of bacteriocin :

Different mechanisms of action have been proposed for bacteriocins such as: alteration of enzymatic activity, inhibition of spore germination and inactivation of anionic carriers through the formation of selective and non-selective pores (Abee, 1995; Martinez and De Martinis, 2006).

Bacteriocins, particularly lantibiotics, inhibit target cells by forming pores in the membrane, depleting the transmembrane potential ($\Delta\psi$) and /or the pH gradient, resulting in the leakage of cellular materials.In order to form pores by nisin, target cells require ($\Delta\psi$) (inside negative) and ΔpH (inside alkaline) has been suggested by the early studies. Bacteriocins are positively charged molecules with hydrophobic patches may be inefficient to inhibit Gram negative organisms because the outer membrane hinders the site for bacteriocin action, which is the cell membrane (De Martinis *et al.,* 2001 and Morisset *et al.,* 2004). Electrostatic interactions with negatively charged phosphate groups on target cell membranes are thought to contribute to the initial binding with the target membrane. It is likely that the hydrophobic portion inserts into the membrane, forming pores. There is debate over the types of pores formed by nisin, with most groups favoring the "barrel-stave" or "wedge" models. In the "barrel-stave" model, each nisin molecule orients itself perpendicular to the membrane, forming an ion channel that spans the membrane and the "wedge" model, after a critical number of nisin molecules associate with the membrane, they insert concurrently, forming a wedge (Cleveland *et al.,* 2001).

LAB bacteriocins can work via different mechanisms to exert an antimicrobial effect, butthe cell envelope is generally the target. The initialelectrostatic attraction between the target cellmembrane and the bacteriocin peptide is thoughtto be the driving force for subsequent events (Deegan *et al.,* 2006). Bacteriocins may possess a bactericidal orbacteriostatic mode of action on sensitive cells,this distinction being greatly influenced by severalfactors such as bacteriocin dose and degree of purification, physiological state of the indicatorcells and experimental conditions (Cintas *et al.,* 2001). According to Jack *et al.* (1995), at least for the nonlanthionine-containing bacteriocins, the increased antibacterial activity observed at low pH may bethe result of any one of a number of factors, including the following: (i) aggregation ofhydrophilic peptides is less likely to occur, and,thus, more molecules should be available tointeract with sensitive cells; (ii) fewer molecules will remain bound to the wall, making moremolecules available for bactericidal action; (iii) hydrophilic bacteriocins may have an enhanced capacity to pass through hydrophilic regions of thecell wall of the sensitive bacteria; and (iv)interaction of the non-lanthionine-containing bacteriocins with putative membrane receptors may be inhibited at higher pH values.

Several features of the mode of action of the non-lanthionine-containing bacteriocins of gram positive bacteria require further explanation: (i)the reason why, for two sensitive strains, one undergoes lysis following treatment with a particular bacteriocin while the other is not known; (ii) for a bacteriocin to come into contact with the cytoplasmatic membrane of sensitive cells, the molecules must firstly pass through the cell wall; the mechanism of this translocation remains to be understood; and, finally, (iii) there is evidence that non-lanthionine containing bacteriocin molecules may be adsorbed on the surface of most gram-positive bacterial cells, including sensitive, resistant, and producer strains;

the influence of this is not yet fully understood (Jack *et al.,* 1995).

Stability :

Some studies of characterization of bacteriocins show that these molecules can be active under certain ranges of temperature and pH. Sensibility to proteolytic enzymes evidences the proteinaceous characteristic of bacteriocins (De Martinis *et al.,* 2003). Torodov and Dicks, 2004, reported that complete inactivation or significant reduction in antimicrobial activity of the bacteriocins ST28MS and ST26MS produced by *Lactobacillus plantarum*isolated from molasses was observed after treatment with proteinase K, pronase, pepsin and trypsin. These bacteriocins remained stable after incubation for 2h at pH values between 2.0 and 12.0. No decrease in antibacterial activity was recorded after 90 min at 100ºC or 20 min at 121º C. The thermotolerance feature might be related to the molecular structure of the bacteriocin, usually composed by small peptides without tertiary structure.

Requirements and regulatory status for bacteriocins:

In general, the following features should be considered when selecting bacteriocin-producing strains for food applications (Ananou *et al.,* 2007):

– The producing strain should preferably have GRAS status.

– Depending on the application, the bacteriocin should have a broad spectrum of inhibition that includes pathogens or else high specific activity.

– Thermostability.

– Beneficial effects and improved safety.

– No adverse effect on quality and flavour.

It is critical in some countries to distinguish bacteriocins from antibiotics since regulations often prohibit antibiotics in food (Wessels *et al.,* 1998). The use of bacteriocin-producing starter cultures as ingredients may not require special consideration in many countries (e.g. USA) if the micro-organism is GRAS. However, if a purified bacteriocin is used as a food preservative, the substance must be approved as GRAS, and for approval to be granted, the bacteriocin must be genetically and chemically identified and characterised, and its use and efficacy must be shown; the manufacturing process must be described and assays used for quantification and standardization of the peptide must be shown as well. Toxicological data and the fate of the molecule after ingestion are also required.

Applying bacteriocins in food preservation :

The strategies for the application of LAB and/or bacteriocins in food are diverse:

– Inoculation of food with LAB (starter cultures or protective cultures) where bacteriocins are produced *in situ.*

– Use of food previously fermented with the bacteriocin-producing strains as an ingredient in the food processing (Nisaplin™, Microgard™, Alta™2341).

– Addition of purified or semipurifiedbacteriocins. The purified bacteriocins are consideredadditives and always require express authorization for their use (Fields, 1996).

To the date, the only commercially produced bacteriocins are the group of nisins produced by *Lactoccocuslactis,* and pediocin PA-1, produced by *Pediococcusacidilactici*(Schobitz *et al.,* 2006). Minimally processed refrigerated foods have been gaining consumer acceptance in the last years due to their natural appeal. However, the microbiological safety of these foods is of concern due to the possible presence of non-proteolytic toxic strains of *Clostridium botulinum,* able to grow at 4ºC, and the post-processing contamination with psychrothophic pathogens.

Food applications of bacteriocins :

Application of bacteriocins in dairy products :

Bacteriocins have wide applications in dairy industry especially during the fermentation of the products. Many researchers have demonstrated the effectiveness of nisin and/or nisin-producing strains against pathogenic bacteria such as *Clostridium butulinum*in cheese (Hirsch *et al.,* 1951) and against *L. monocytogenes*in cheeses such as Camembert (Sulzer, and Busse, 1991 andMaisnier-Patin *et al.,* 1992), Ricotta (Davies *et al.,* 1997), and Manchego (Nunez *et al.,* 1997). The lytic ability of bacteriocins like nisin and lacticin 3147 might be explored in the acceleration of cheddar cheese ripening. Cell lysis of the starter culture is advantageous for improved flavour development (Guinane *et al.,* 2005). The level of nisin used depends on food composition, spore load, required shelf-life and temperature during storage (Hirsch *et al.,* 1951). Other bacteriocins have been tested in milk and dairy products,

such as pediocinAcH in milk and Cheddar and Munster cheeses against *L. monocytogenes, S. aureus*, and *E. coli* O157:H7 (Buyong *et al.,* 1998 and Rodrígueze *et al.,* 1995), lacticin 3147 against undesirable LAB, *L. monocytogenes* and *B. cereus* in Cheddar, Cottage cheese and yogurt (Ross *et al.,* 2002; Ryan *et al.,* 1996; Mcauliffe *et al.,* 1999; Morgan *et al.,* 2001) and enterocin AS-48 against *B. cereus, S. aureus*and *L. monocytogenes* in milk and Manchego cheese (Muñoz *et al.,* 2004; Muñoz *et al.,* 2007). Zottola *et al.* (1994) used nisin-containing cheddar cheese that had been made with nisin-producing lactococci as an ingredient in pasteurized process cheese or cold pack cheese spreads. The shelf-life of the nisin-containing pasteurized process cheese (301 and 387 IU nisin/ g) was significantly greater than that of the control cheese spreads.

Applications in meat products :

When evaluating a bacteriocin-producing culture for sausage fermentation and/or biopreservation, onemust bear in mind that meat and meat products are complex systems with a number of factorsinfluencing microbial growth and metabolite production. Therefore, the influence of formula and fermentation technology on the performance of bacteriocin-producing cultures needs to be assayed.The most-studied bacteriocins in meat and meat products include nisin, enterocin AS-48, enterocins Aand B, sakacin, leucocin A, and especially pediocin PA-l/AcH, alone or in combination with several physico-chemical treatments, modified atmosphere packaging, high hydrostatic pressure, (HHP), heat,and chemical preservatives, as an additional hurdle to control the proliferation of *L. monocytogenes* and other pathogens (Cleveland *et al.,* 2001; Nielsen *et al.,* 1990; Cutter and Siragusa, 1994; Aymerich *et al.,* 2000; Garriga *et al.,* 2002; Ananou *et al.,* 2005a; Ananou *et al.,* 2005b). Furthermore, several bacteriocinogenic LAB have been used asbioprotective cultures for food manufacturing processes in attempts to control these pathogens (Cleveland *et al.,* 2001;Vandenbergh, 1993 and Campanini, 1993). The data available on the use of nisin in cured and fermented meat are equivocal. Compared todairy products, nisin use in meat products has not been very successful because of its low solubility,irregular distribution, and lack of stability. Pediocin PA-l/AcH is more suitable for use in meat and meatproducts than nisin; however, *P. acidilactici* is not an indigenous meat strain (Cleveland *et al.,* 2001).

Applications in vegetable products :

Tests of bacteriocins in vegetable products include nisin in tinned vegetables and fruit juices (Delves-Broughton, 1999; Alpas and Bozoglu, 2000 and Komitopuloue *et al.,* 1999), pediocin PA-1/AcHin salad and fruit juice (Cleveland *et al.,* 2001 ; Alpas and Bozoglu, 2000 andVedamuthu *et. al.,* 1992), and enterocin AS-48 against *B. cereus* in rice and vegetables (CoboMolinos *et al.,* 2005 and Grande *et al.,* 2006) and in fruit juices against other pathogens such as *E. coli* O157:H7, *S. aureus* and the spoilage bacterium *Alicyclobacillusacidoterrestris* (Ananou *et al.,* 2005c; Grande *et al.,* 2006 and Grande *et al.,* 2005).

Applications in fish :

The deterioration of fresh fish is generally caused by Gram-negative microorganisms; however, in vacuum-packed fresh fish and seafood, pathogenic organisms such as *Clostridium botulinum* and *L. monocytogenes* can also cause problems. The combination of nisin and Microgard reduced the total aerobic bacteria populations of fresh chilled salmon, increased its shelf-life, and also reduced the growth of innoculated *L. monocytogenes*in frozen thawed salmon (Zuckerman and Ben Avraham, 2002). Nykänen *et. al.,* 1989 demonstrated the synergistic effect of combination lactic acid, sodium chloride, and/or nisin in rainbow trout, and more recently (Vázquez *et al.*,2005) showed the effect of LAB cultures on pathogenic micro-organism control in fish. Listerial control was achieved in cold-smoked salmon using *Carnobacteriumdivergens* or *L. sakei.*

Canned food products :

Alcoholic beverages :

The insensitivity of yeasts to nisin allows its use to control spoilage LAB in beer or wine. It can maintain its activity during fermentation without any effect on growth and fermentative performance of brewing yeaststrains and with no deleterious effect on taste. It can therefore be used to reduce pasteurization time- temperature combination and can increase the shelf-life of beers (Bali *et al.,* 2012). Nisin can also be used to reduce the amount of sulphur dioxide used in wine making to control bacterial spoilage (Todorov *et al*., 2003).

Future trends :

Bacteriocins represent one of the best-studied microbial defence systems. Foods preserved with biopreservative is getting popular due to greater consumer awareness and concern regarding synthetic chemical additives, this has leadscientists forthe isolation of new bacteriocins from food products and the various fermented products like milk products, vegetables, fruits, cereals, meat are few of the examples. There is a need to explore more micro-organisms producing novel bacteriocins with unique preservation characters, bacteriocin modifications with protein engineering, construction of food grade vectors, regulation and expression of heterologous proteins, modification and control of organoleptic properties of food items is also the thrust area of research. The isolation of novel bacteriocins from different strains and their combination with some suitable physical preservation techniques like low temperature, hurdle technology and mild thermal treatment, etc. can be proven by promising to provide safer and healthier food products by food processing industry.

LITERATURE CITED

Abee, T. (1995). Pore-forming bacteriocins of Grampositive bacteria and selfprotection mechanisms of producer organisms.FEMS Microbiology letters.129, 1- 10.

Alpas, H. and Bozoglu, F. (2000). The combined effect of high hydrostatic pressure, heat and bacteriocins on inactivation of foodborne pathogens in milk and orange juice. *World J. Microbiol. & Biotechnol.*,**16** : 387-392.

Altena, K., Guder, A., Cramer, C. and Bierbaum, G. (2000). Biosynthesis of the Lantibiotic Mersacidin: organization of a type b Lantibiotic gene cluster. *Appl. & Environmen. Microbiol.,* **66** (6) : 2565-2571.

Ananou, S. Garriga, M., Hugas, M., Maqueda, M., Martinez-Bueno, M., Galvez, A. and Valdivia, E. (2005a). Control of Listeria monocytogenes in model sausages by enterocin.AS-48. *Internat. J. Food Microbiol.,* **103** : 179-190.

Ananou, S. Garriga, M., Hugas, M., Maqueda, M., Martinez-Bueno, M., Galvez, A. and Valdivia, E. (2005b)..Control of *Staphylococcus aureus* in sausages by enterocin AS-48. *Meat Sci.,* **71**: 549-556.

Ananou, S. Garriga, M., Hugas, M., Maqueda, M., Martinez-Bueno, M., Galvez, A. and Valdivia, E. (2005c)..Control of *Staphylococcus aureus* in sausages by enterocin AS-48. *J. Appl. Microbiol.,* **99** : 1364-1372.

Ananou, S., Maqueda, M., Martinez-Bueno, M. and Valdivia, E. (2007). Biopreservation, an ecological approach to the safety and shelf-life of foods. *Communicating Current Research and Educational Topics and Trends in Applied Microbiology.* A. Mendez-Vilas (Ed.): 475.

Aymerich, T., Garriga, M., Ylla, J., Vallier, J., Monfort, J.M. and Hugas, M. (2000). Efficacy of organic acids against Escherichia coli O157: H7 attached to beef carcass tissue using a pilot scale model carcass washer.*J. Food Protect*., **63** :721-726.

Bali, V., Panesar, P.S. and Bera, M.B. (2012). Biopreservation: an emerging technique in Food processing industry. *Beverage & Food World*, **8** : 50-53.

Baust, J.C. and Baust, J.M. (2006). *Advances in biopreservation, CRC/Taylor and francis.* ISBN 978-0-8493-2772-8.

Buyong, N., Kok, J. and Luchansky, J.B. (1998). Use of a genetically enhanced, pediocin-producing starter culture, *Lactococcuslactis subsp. lactis*MM217, to control Listeria monocytogenes in Cheddar cheese. *Applied & Environmen. Microbiol.,* **64** : 4842- 4845.

Campanini, M., Pedrazzoni, I., Barbuti, S. and Baldini, P. (1993). Behaviour of *Listeria monocytogenes* during maturation of naturally and artificially contaminated salami: effect of lactic acid bacteria starter culture. *Internat. J. Food Microbiol.,* **20** : 169-175.

Caplice, E. and Fitzgerald, G.F. (1999). Food fermentations: role of microorganisms in food production and preservation. *Internat. J. Food Microbiol.,* **50**(1-2) : 131-149.

Caridi, A. (2002). Selection of *Escherichia coli* inhibiting strains of *Lactobacillus paracasei subsp. paracasei. J. Industrial Microbiol. & Biotechnol.,* **29** : 303- 308.

Carr, F.J., Hill, D. and Maida, N. (2002). The lactic acid bacteria: A literature survey. *Critical Rev. Microbiol.,* **28** : 281-370.

Cintas, L.M., Herranz, C., Hernandez, P.E., Casaus, M.P. and Nes, L.F. (2001). Review: Bacteriocins of lactic acid bacteria. *Food Sci. & Technol. Internat.,* **7** : 281-305.

Cleveland, J., Montville, T.J., Nes, I.F. and Chikindas, M.L. (2001). Bacteriocins: safe, natural antimicrobials for food preservation. *Internat. J. Food Microbiol.,* **71** : 1-20.

Cobo Molinos, A., Abriouel, H., Ben Omar, N., Valdivia, E., Lucas, R., Maqueda, M., Martinez-Canamero, M.

and Galvez, A. (2005). Effect of Immersion Solutions Containing Enterocin AS-48 on *Listeria monocytogenes* in Vegetable.*Foods Appl. & Environmen. Microbiol*., **71** : 7781-7787.

Cutter, C.N. and Siragusa, G.R. (1994). Efficacy of organic acids against Escherichia coli O157: H7 attached to beef carcass tissue using a pilot scale model carcass washer. *J. Food Protection*, **57** : 97-103.

Dass, C.R. (1999). In : R.K, Robinson, C.A., Batt, P.D., Patel, (Eds).1999. Encyclopedia of Food Microbiology. pp. 2095-2100. Academic Press, Oxford, U.K.,.

Davies, E.A., Bevis, H.E. and Delvers-Broughton, J. (1997). Inhibition of Listeria monocytogenes in Camembert cheese made with nisin-producing starter. *Letters Applied Microbiology*., **24** : 343-346.

Deegan, L.H., Cotter, P.D., Hill, C. and Ross, P. (2006). Bacteriocins: Biological tools for biopreservation and shelf-life extension. *Internat. Dairy J.,* **16** :1058-1071.

Delves-Broughton, J. (1999). Nisin and its uses as a food preservative. *Food Technol.,* **44** : 100-117.

De Martinis, E.C.P., Publio, M.R.P., Santarosa, P.R. and Freitas, F.Z. (2001). Antilisterial activity of lactic acid bacteria isolated from vacuum-packaged Brazilian meat and meat products. *Brazilian J. Microbiol.,* **32** : 32-37.

De Martinis, E.C.P., Satarosa, P.R. and Freitas, F.Z. (2003). Preliminary characterization of bacteriocins produced by six lactic acid bacteria strains isolated from vacuum-packaged meat products. *Ciênc.Tecnol.Aliment.,* **23** : 195-199.

De Vuyst, L. and Vandamme, E.J. (1992). Influence of the carbon source on nisin production in *Lactococcuslactis* subsp. *Lactis*batch fermentations. *J. General Microbiol.,* **138** : 571–578.

Deraz, S.F., Karlsson, E.N., Hedstrom, M., Andersson, N.M. and Mattiasson, B. (2005). Purification and characterisation of acidocin D20079, a bacteriocin produced by *Lactobacillus acidophilus* DSM 20079. *J. Biotechnol.,***117**(4): 343-354.

Fields, F.O.(1996). Use of bacteriocins in food: regulatory considerations.*J. Food Protection*, **59**(3) : 72-77.

Fuller, R. (1989). Probiotics in man and animals. *J. Applied Bacteriology,* **66** : 365-378.

Garriga, M., Aymerich, M.T., Costa, S., Monfort, J.M. and Hugas, M. (2002). Bactericidal synergism through bacteriocins and high pressure in meat model system during storage. *Food Microbiol.,* **19** : 509-518.

Garrity, G.M. (1984). Bergey's manual of systematic bacteriology, vol. 2: the proteobacteria, Williams and Wilkins, New York.

Grande, M.J., Lucas, R., Abriouel, H., Ben Omar, N., Maqueda, M., Martinez-Bueno, M., Martinez-Canamero, M., Valdivia, E. and Galvez, A. (2005). Control of Alicyclobacillusacidoterrestris in fruit juices by enterocin AS-48. *Internat. J. Food Microbiol.,* **104** : 289-297.

Grande, M.J., Lucas, R., Abriouel, H., Valdivia, E., Ben Omar, N., Maqueda, M., Martinez-Bueno, M. Martinez-Canamero M. and Galvez, A. (2006). Inhibition of toxicogenic Bacillus cereus in rice-based foods by enterocin AS-48. *Internat. J. Food Microbiol.,* **106** :185-194.

Guinane, C.M., Cotter, P.D., Hill, C. and Ross, R.P. (2005). Microbial solutions to microbial problems; lactococcalbacteriocins for the control of undesirable biota in food. *J. Appl. Microbiol*., **8** :1316-1323.

Hirsch, A., Grimstead, E., Chapman, H.R. and Mattic, A.T.R. (1951). A note on the inhibition of an anaerobic sporeformer in swiss cheese by a nisin producing streptococcus. *J. Dairy Sci.,* **18** : 205-206.

Holzapeel, W.H., Geisen, R. and Schillinger, U. (1995). Appropriate starter culture technology on food safety in developing countries. Internat. J. Food Microbiol., **24** : 343-362.

Hugas, M., Garriga, M., Pascual, M., Aymerich, M.T. and Monfort, J.M. (2002). Enhancement of sakacin K activity against *Listeria monocytogenes* in fermented sausages with pepper or manganese as ingredients.*Food Microbiol.,* **19** : 519-528.

Iraj, Rasoli (2007). Food preservation- a Biopreservative Approach.*Global Sci. Books Food,* **1**(2) : 111-136.

Jack, R.W., Tagg, J.R. and Ray, B. (1995). Bacteriocins of gram positive bacteria.*Microbiol. Rev.,* **59** : 171-200.

Jacob, F., Lwoff, A., Siminovitch, A. and Wollman, E. (1953). Definition de quelquestermesrelatifs a la Iysogenie, *Am. Inst. Pasteur.,* **84** : 222-224.

Jeevaratnam, K., Jamuna, M. and Bawa, A.S. (2005). Biological preservation of foods- Bacteriocins of lactic acid bacteria. *Indian J. Biotechnol.,* **4** : 446- 454.

Joerger, M.C. and Klaenhammer, T.R. (1986). Characterization and purification of helveticin J and evidence for a choromosomally determined bacteriocin produced by *Lactobacillus helveticus*481. *J. Bacteriol*., **167** : 439-446.

Jung, G. (1991). Lantibiotics- ribosomally synthesized biologically active polypeptides containing sulfide bridges and a,b-Didehydroamino acids,' Andewandte Chemie International Edition, **30** : 1051-1068.

Kathir, Viswalingam (2005). Isolation of bacteriocin producing lactic acid bacteria from fermented foods and characterisation of bacteriocins. *Internat. J. Pharmacy & Technol.,* **6** (3) : 7092-7099.

Komitopuloue, Bozirisi, S., Daviese, A., Delves-Broughton, J. and Adams, M.R. (1999). *Alicyclobacillus acidoterrestris* in fruit juices and its control by nisin. *Internat. J. Food Sci. & Technol.,* **34** : 81-85.

Lade, H.S., Chitanand, M.P., Gyananath, G. and Kadak, T.A. (2006). Studies on some properties of bacteriocins produced by *Lactobacillus* species isolated from agro-based waste. *Internet. J. Microbiol.,* **2** : 1.

Maisnier-Patin, S., Deschamps, N., Tatini, S.R. and Richard, J. (1992). Inhibition of listeria monocytogenes in camembert cheese made with nisin producing starter. *Le Lait.,* **72** : 249-263.

Martinez, R.C.R. and De Martinis, E.C.P. (2006). Effect of *Leuconosocmesenteroides*11 bacteriocin in the multiplication control of *Listeria monocytogenes*. *Ciênc. Tecnol. Aliment.,* **26** : 52-55.

Mcauliffe, O., Hill, C. and Ross, R.P. (1999). Lacticin 3147, a broad-spectrum bacteriocin which selectively dissipates the membrane potential. *J. Appl. Microbiol.,* **86** : 251-256.

Messi, P., Bondi, M., Sabia, C., Battini, R. and Manicardi, G. (2001). Detection and preliminary characterization of a bacteriocin (plantaricin 35d) produced by a *Lactobacillus plantarum*strain. *Internat. J. Microbiol.,* **64** : 193–198.

Montville, T.J. and Wikowski, K., In : M.P., Doyle, L.R. Beuchat and Montville, T.J. (Eds). (1997). Food Microbiology Fundamentals and Frontiers. ASM Press, Washington DC, 557-577.

Moreno, I., Lerayer, A.S.L., Baldini, V.L.S. and Leitao, M.F. DE F (2000). Characterization of bacteriocins produced by *Lactococcuslactis*strains.*Brazillian J. Microbiol.,* **31** : 184-192.

Morgan, S.M., Galvin, M., Ross, R.P. and Hill, C. (2001). Evaluation of a spray-dried lacticin 3147 powder for the control of Listeria monocytogenes and Bacillus cereus in a range of food systems.*Letters Appl. Microbiol.,* **33** : 387-391.

Morisset, D., Berjeaud, J.M., Marion, D., Lacombe, C. and Frere, J. (2004). Mutational analysis of mesentericin Y105, an anti-*Listeria* bacteriocin, for determination of impact on bactericidal activity, *in vitro* secondary structure, and membrane interaction. *Appl. & Environmen. Microbiol.,* **70** : 4672-4680.

Munoz, A., Ananou, S., Galvez, A., Martinez-Bueno, M., Rodriguez, A., Maqueda, M. and Valdivia, E. (2007). Inhibition of*Staphylococcus aureus* in dairy products by enterocin AS-48 produced *in situ* and *ex situ*: bactericidal synergism through heat and AS-48. *Internat. Dairy J.,* **17** : 760-769.

Munoz, A., Maqueda, M., Galvez, A., Martinez-Bueno, M., Rodriguez, A. and Valdivia, E. (2004). Biocontrol of psychrotrophicenterotoxigenic *Bacillus cereus* in a non fat hard type cheese by an enterococcal strain-producing enterocin AS-48. *J. Food Protection,* **67** : 1517-1521.

Narayanapillai Udhayashree, Duraisamy Senbagam, Balakrishnan and Senthil Kumar (2012). Production of bacteriocin and their application in food products.*Asian Pacific J. Tropical Biomedicine*, S406-S410.

Nath, Swarnadyuti, Chowdhury, S., Dora, K.C. and Sarkar, S. (2014). Role of biopreservation in improving food safety and storage. *J. Engg. Res. & Applications,* **4**(1) : 26-32.

Nath, Swarnadyuti, Chowdhury, Supratim, Sarkarand, Srikanta and Dora, K.C. (2013). Lactic Acid Bacteria – A Potential BiopreservativeIn Sea Food Industry. *Internat. J. Adv. Res*., **1**(6), 471-475.

Nielsen, J.W., Dickson, J.S. and Crouse, J.D. (1990). Use of a bacteriocin produced by pediococcusacidilactici to inhibit listeria monocytogenes associated with fresh meat. *Appl. & Environ. Microbiol.,* **56** : 2142-2145.

Nunez, M., Rodriguez, J.L., Garcia, E., Gaya, P. and Medina, M. (1997). Inhibition of Listeria monocytogenes by enterocin 4 during the manufacture and ripening of Manchego cheese. *J. Appl. Microbiol.,* **83** : 671- 677.

Nykanen, A., Lapvetelainen, A., Heitanen, R.M. and Kallio, H. (1989). Synergistic inhibition of Listeria Monocytogenes on cold-smoked rainbow trout by nisin and sodium lactate.*Lebensmittel-Wissenschaft and Technologies,* **35** : 543-548.

Parada, J.L., Sambucetti, M.E., Zuleta, A. and Rio, M.E. (2003). Lactic acid fermented products as vehicles for probiotics.In-*New Horizons in Biotechnology*. Kluwer Academc Publishers, pp 335-351. Boston, Londres.

Rodrigueze, Calzada, J., Arques, J.L., Rodriguez, J.M., Nunez, M. and Medina, M. (2005). Antimicrobial

activity of pediocin-producing Lactococcuslactis on Listeria monocytogenes, Staphylococcus aureus and Escherichia coli O157:H7 in cheese.*Internat. Dairy J.,* **15** : 51-57.

Ross, R.P., Galvin, M., Mcauliffe, O., Morgan, S.M., Ryan, M.P., Twomey, D.P., Meaney, W.J. and Hill, C. (1999). Developing applications for lactococcalbacteriocins. *Antonie van Leeuwenhoek,* **76** : 337-346.

Ross, R.P., Morgan, S. and Hill,C. (2002). Preservation and fermentation: past, present and future. *Internat. J. Food Microbiol.,* **79** : 3-16.

Ryan, M.P., Rea, M.C., Hill, C. and Ross, R.P. (1996). Bacteriolytic activity caused by the presence of a novel lactococcal plasmid encoding lactococcins A, B, and M. *Appl. & Environ. Microbiol.,* **62** : 612-619.

Saavedra, J.M., Abi-Hanna, A., Moore, N. and Yolken, R.H. (2004). Long-term consumption of infant formulas containing live probiotic bacteria: tolerance and safety. *American J. Clinical Nutrition,* **79**(2) : 261-267.

Sahl, H.G. and Bierbaum, G. (1998). LANTIBIOTICS: Biosynthesis and biological activities of uniquely modified peptides from Gram-positive bacteria. *Annual Rev. Microbiol.,* **52** : 41-79.

Schobitz, R.P., Borquez, P.A., Costa, M.E., Ciampi, L.R. and Brito, C.S. (2006). Bacteriocin likesubstance production by *Carnobacteriumpiscicola*in a continuous system with three culture brooths.Studyof antagonism against *Listeria monocytogees*in vacuum packaged salmon. *Brazillian J. Microbiol.,* **37** : 52-57.

Schobitz, R., Zaror, T., Leon, O. and Costa, M. (1999). A bacteriocin from *Carnobacteriumpiscicola*for the control of *Listeria monocytogenes*in vacuumpackaged meat. *Food Microbiol.,* **16** : 249-255.

Stevens, K.A., Sheldon, B.W., Klapes, N.A. and Klaenhammer, T.R. (1991). Nisin treatment for inactivation of *Salmonella* species and other Gram negative bacteria. *Appl. & Environ. Microbiol.,* **57** : 3613-3615.

Stiles, M.E. (1996). Biopreservation by lactic acid bacteria. *Antonie van Leeuwenhoek,* **70** : 331-345.

Sulzer, G. and Busse, M. (1991). Growth inhibition of Listeria spp. on Camembert cheese by bacteria producing inhibitory substances. *Internat. J. Food Microbiol.,* **14** : 287-296.

Tahiri, I., Desbiens, M., Kheadr, E., Lacroix, C. and Fliss, I. (2009). Comparison of different application strategies of divergicin M35 for inactivation of Listeria monocytogenes in cold-smoked wild salmon.*Food Microbiol.,* **26** : 783–793.

Thomas, L.V. and Delves-Broughton, J. (2001). New advances in the application of food preservative nisin. *Res. Adv. Food Sci.,* **2** : 11-22.

Todorov, S.D., Vaz-Velho, M. and Dicks, L.M.T. (2003). Isolation and partial characterization of bacteriocins produced by four lactic acid bacteria isolated from traditional South African beer. *Electronic J. Environ., Agric. & Food Chem***2**(4) : 1-6.

Torodov, S.D. and Dicks, L.M.T. (2004). Effect of medium components on bacteriocin production by *Lactobacillus pentosus* ST151BR, a strain isolated from beer produced by the fermentation of maize, barley and soy flour. *World J. Microbiol. & Biotechnol.,* **20** : 643-650.

Torodov, S.D. and Dicks, L.M.T. (2005). *Lactobacillus plantarum*isolated from molasses produces bacteriocins active against Gram-negative bacteria. *Enzyme & Microbial Technol.,* **36** : 318- 326.

Vandenbergh, P.A. (1993). Lactic acid bacteria, their metabolic products and interference with microbial growth. *FEMS Microbiol. Rev.,* **12** : 221-238.

Vaugham, E.E., Daly, C. and Fitzgerald, G.F. (1992). Identification and characterization of helveticin V- 1829, a bacteriocin produced by *Lactobacillus helveticus*1829. *J. Appl. Bacteriol.,* **73** : 299-308.

Vazquez, J.A., Gonzalez, M.P. and Murado, M.A. (2005). Effects of lactic acid bacteria cultures on pathogenic microbiota from fish.*Aquaculture,* **245** : 149-161.

Vedamuthu, E.R., Henderson, J., Marugg, J. and Van Wassear, P. (1992). The Dairy *Leuconostoc:* Use in Dairy Products In: Quest International Flavour and Food Ingredient Company, pp173-292. Bridgewater, NJ, USA.

Venema, K., Chikindas, M.L., Seegers, J.F.M.I., Haandrikman, A.J., Leenhouts, K.J., Venema, G. and Kok, J. (1997). Rapid and efficient purification method for small, hydrophobic, cationic Bacteriocins: purification of lactococcin B and pediocin PA-1. *Appl. & Environ. Microbiol.,* **63** : 305-309.

Weiss, A. and Hammes, W.P. (2006). Lactic acid bacteria as protective cultures against Listeria spp. on cold-smoked salmon. *European Food Res. & Technol*., **222** : 343–346.

Wessels, S., Jelle, B. and Nes, I. (1998). Bacteriocins of the Lactic Acid. Bacteria: An Overlooked Benefit for Food Reports of the Danish Toxicology Centre, Denmark.

Wigley, R.C., Robinson, R.K., Batt, C.A. and Patel, P.D. (Eds) (1999). Encyclopaedia of Food Microbiology,pp.

2084-2095.Academic Press, Oxford, U.K..

Zottola, E.A., Yezzi, T.L., Ajao, D.B. and Roberts, R.F. (1994). Utilization of cheddar cheese containing nisin as an antimicrobial agent in other foods.*Internat. J. Food Microbiol.,* **24** : 227-238.

Zuckerman, H. and Ben Avraham, R. (2002). Control of growth of L-monocytogenes in fresh salmon using Microgard (TM) and Nisin.*Lebensmittel-Wissenschaft und-Technologie,* **35** : 543-548.

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