Plant Archives Volume 20 No. 2, 2020 pp. 7487-7492 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

CLASSIFICATION, MECHANISM OF ACTION AND APPLICATIONS OF BACTERIOCINS FROM LACTIC ACID BACTERIA : A REVIEW

Anwar A. Abdulla

Biology Department, College of Science, University of Babylon, Iraq.

Abstract

Lactic acid bacteria (LAB) are Gram-positive cocci or rods. They are catalase-negative, non-spore forming, aerotolerant anaerobes. LAB ferment glucose to lactic acid with or without CO_2 and ethanol. LAB may produce a group of potent antimicrobial peptides that exhibit bactericidal activity called bacteriocins, these peptides work against organisms closely related to the bacteriocin producing LAB strain. Certain bacteriocins may prevent the growth of some Gram-positive pathogens, spoilage bacteria, and yeasts. They may even inhibit the growth of some Gram-negative species. These properties caused LAB to be a subject for research as a source of probiotics and as bio-preservatives. The aim of the present review is to delineate the use of lactic acid bacteria and their bacteriocins.

Key words: Bacteriocin; classification; Applications; LAB.

Introduction

Bacteriocins produced by lactic acid bacteria (LAB) are potent antimicrobial peptides or proteins that are active against, closely related bacterial species, Based on its biochemical and genetic properties, bacteriocins are classified into three classes (Nes *et al.,* 1996; Lopetuso *et al.,* 2019). Bacteriocins produced by LAB have antimicrobial activity at concentrations that are lower than antimicrobial peptides from eukaryotic origin., presumably due to their interaction with a specific receptor on target cells (Nissen-Meyer *et al.,* 2001).

Lactic acid bacteria (LAB) are a group of fastidious Gram-positive rods or cocci, with high tolerance for low pH. They are aerotolerant and might be non-aerobic. They cause carbohydrate fermentation for energy. Additionally, they produce lactic acid and are catalase-negative, (De Vuyst and Leroy, 2007; Kaban and Kaya, 2008). The LAB is under the phylum Firmicutes, class Bacilli and order Lactobacillales. LAB classification is based on cell morphology, range of growth temperature, mode of glucose fermentation and patterns of sugar utilization. (Quinto *et al.,* 2014). Lactic acid bacteria include various major genera.

Lactobacillus, Lactosphaera, Leuconostoc, Lactococcus, Enterococcus, Carnobacterium, Oenococcus, Streptococcus, Tetragenococcus, Melissococcus, Pediococcus, Streptococcus, Weissella, Aerococcus, Vagococcus, Bifidobacterium, Microbacterium and *Propioni bacterium.* The most common species of Lactic acid bacteria are: *Lactobacillus acidophilus,* L. *Casei,* L. *rhamnosus,* L. *plantarum,* L. *delbrueckii bulgaricus,* L. *reuteri,* L. *fermentum, Bifidobacterium bifidum, B. adolecentis, B. longum, B. adolecentis, B. breve, Enterococcus faecalis,* (Garrity, 1984; Dellaglio *et al.,* 1994; Carr et al., 2002).

There are more that one hundred species under the genus of Lactobacillus. Which are largely exist in materials that are rich in carbohydrate. LAB are commonly used in fermentations of food and improvement of texture and test of fermented foods. (Van Geel-Schuttená *et al.,* 1998; Walter, 2008; Khalid, 2011; Hati *et al.,* 2013). Lactobacilli are also used in food preservation.

Ecologically, LABs are found naturally in soil, water, sewage, plant silage, decomposing plant materials and fruits. They are part of the microbiota on the intestines, mouth, skin, urinary and genital organs of humans and animals. Lactobacilli have a beneficial effect on the ecosystems (Todorov, 2009; König *et al.,* 2009; Djadouni

***Author for correspondence :** E-mail : alhussainybio@yahoo.com

and Kihal, 2012; Devi *et al.,* 2013; Liu *et al.,* 2014). LAB have been used in different applications such as starter cultures in food and feed fermentations, pharmaceuticals, probiotics and as biological control agents (Leory and De Vuyst, 2004; (Diep & Nes, 2002).

Preservation using various chemicals is associated with serious side effects. (Stevenson, 2010). Therefore, interest in using LAB and their bioproducts bio-preservatives such as bacteriocin and/or other substance for application in non-fermentative preservation. s, and some LAB strains are used as probiotics as natural competitive microbiota. (Fuller, 1989; Parada *et al.,* 2003) LAB may be used to make starter culture using specific conditions. (Cintas *et al.,* 2001).

LAB inhibitory effect on the growth of pathogenic microorganisms has been reported. Additionally, it was demonstrated that extracts from LAB isolates could destroy mycotoxins in addition to probiotic capabilities and antimicrobial activities. (Naidu *et al.,* 1999; Todorov, 2009). Several microorganisms produce antimicrobials or peptide that has exhibit: antibiotics, determental effects against fungal species as well as some viruses.. Bacteriocin is one of these extracts. (Klaenhammer *et al.,* 1994; Moreno *et al.,* 2000). Bacteriocins are ribosomally-synthesized bactericidal peptides that are inhibitory to different pathogens (Lopetuso *et al.,* 2019), Fig. 1. It is produced by lactic acid bacteria and have drawn growing attention, as they are active at a nanomolar concentration with no toxicity. Bacteriocins are protein in nature and readily destroyed by digestive tract enzymes.

Bacteriocins are made at the ribosomal sites of the cell. Therefore it is possible to improve their features to increase their effectiveness and spectrum of action (Saavedra *et al.,* 2004). Lactic acid bacteria (LAB) are known to produce lactic acid from glucose. However their main importance is related to their ability to produce bacteriocins and related substances that have preservative effects through preventing the growth of pathogens and food spoilage bacteria. (Alakomi *et al.,* 2000; De Vuyst and Leroy, 2007).

Sugar fermentation results in a reduction in pH due to the production of lactic and other organic acids that are known for their inhibitory effect of the prolefration of harmful agents. Organic acids are made liposoluble via low PH and that facilitate their passage through cell membrane to reach the cytoplasm of pathogens (Haller *et al.,* 2001). LAB grows optimally at pH 5.5–5.8. LAB have sophisticated needs for growth requirements including vitamins, minerals in addition to several amino acids, fatty acids, peptides, nucleotide bases and carbohydrates (Khalid, 2011). Additionally, it has been applied as a bio-preservative for foods nearly 25 years and in the control of human pathogens (Balciunas et al., 2013; Parada, 2007). Bacteriocins are largely small peptides (<10 kDa) that are amphiphilic cationic, and heat-stable, which are permeable through cell membranes. (Zacharof and Lovitt, 2012). The DNA of LAB has a low G + C content (König and Fröhlich, 2009). Bacteriocins can be categorized into four different groups on the base of based on some common features such as structure, molecular weight, resistance to heat, biochemical and genetic characteristics (Cotter et al.,

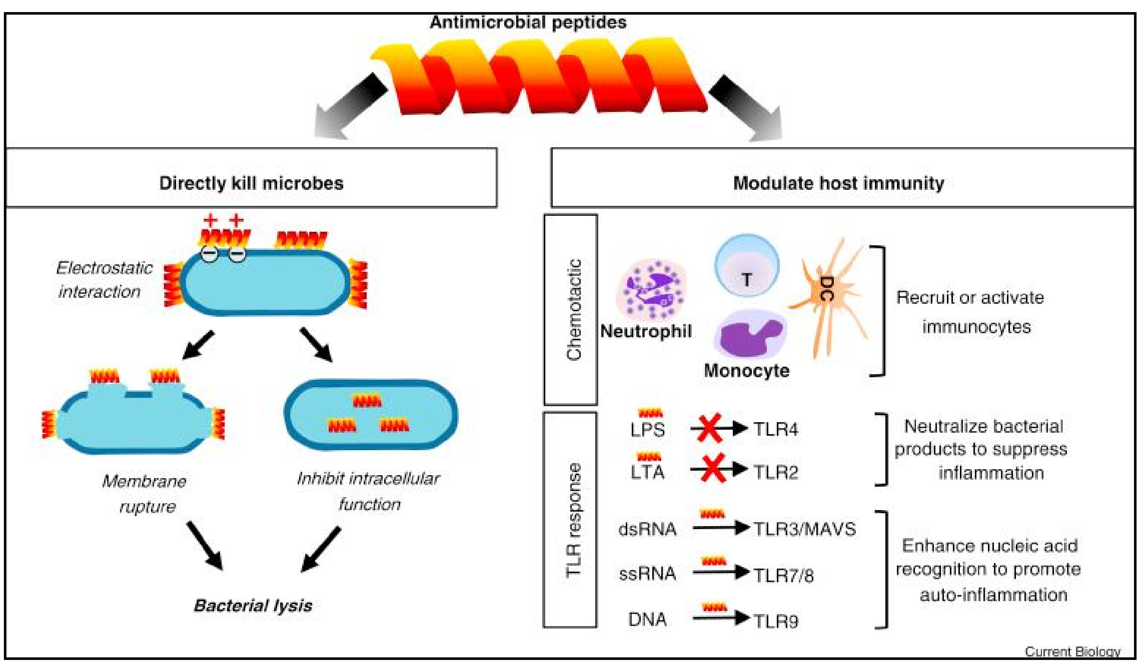

Fig. 1: Diverse mechanisms of action of antimicrobial peptides (Ibrahim, 2019).

2005; González-Martínez *et al.,* 2003; Klaenhammer *et al.,* 1994; Kozak *et al.,* 1978).

Classification of LAB Bacteriocin

Bacteriocins are antimicrobial peptides or proteins produced by some microorganisms including LAB (Nes *et al.,* 2002). Bacteriocins are peptides of small molecular structures consisting of of 30-60 amino acids, The structures are, amphiphilic helices and are resistant to 100°C for 10 min. They have different spectrum of activity. Their mechanisms of action are also variable. Bacteriocin-producing – Through the expression of a specific immunity protein that is encoded in the bacteriocin operon is expressed by LAB to protect them from their own bacteriocins., (Parada *et al.,* 2007). Recently, four classes of bacteriocins : I; II; III and IV of were described table 1, Their classification is based on producing hosts, molecular weight, physicochemical properties, intrinsic function and amino acid sequence. Genes that control the production of bacteriocins are located on the chromosomes or plasmids. They have minimal genetic machinery that includes immunity proteins which prevent self-toxicity.

Bacteriocins action site are the cytoplasmic membrane of target bacteria targeting the vesicles of energized membrane which leads to disruption of the motive force of protons. (Parada *et al.,* 2007). Through this mechanism, pores are created in the membranes of the targeted cells which leads to dissipation of proton motive force, leakage of nutrients and depletion of ATP and metabolites. This mechanism varies according to the classes of bacteriocins (Driessen *et al.,* 1995; Bennik *et al.,* 1997; Montville and Chen 1998; Herranz *et al.,* 2001). To form a pore, bacteriocins have to interact with the cytoplasmic membrane of target cells. The disadvantage of site action is due to the fact inhibition affect closely related organisms, and in the process they which may include beneficial bacteria used in creating starter cultures while activity, against Gram-negative contaminants and food spoilers may not be affected whereas specific pathogens might be effectively targeted.... Sensitivity of Gram-negative bacteria to bacteriocins has been improved by adding chelating agents. (Parada *et al.,* 2007).

Class I bacteriocins, the lantibiotics, are peptide that contain the polycyclic thioether amino acids lanthionine or methyllanthionine, in addition to the unsaturated amino acids dehydroalanine and 2 aminoisobutyric acid. The molecular mass, ranges between 2 to 3 kDa with no net charge or a net negative charge (Deegan *et al.,* 2006; Parada *et al.,* 2007). Class II LAB bacteriocins are heat-stable, nonlanthionine-containing peptides that range between 30 to 60 amino acids (Jung and Sahl,1991). Class III bacteriocins are large heat-labile proteins (Barefoot and Klaenhammer, 1984; Vaughan *et al.,* 1992).

Mode of action of Bacteriocins

Bacteriocins are proteins or peptide molecules that are extracellularly released. These peptides exhibit inhibitory effect against species of microorganisms that are largely related to the LAB. (Tagg *et al.,* 1976). Most LAB bacteriocins are cationic peptides at a neutral pH, hydrophobic in nature and amphiphilic, containing 20 to 60 amino acids (Kuipers *et al.,* 2000). Whether Bacteriocins exhibit bactericidal or bacteriostatic effect to target cells depend on the dose and degree of purity of bacteriocin as well as, physiological state of the indicator cells and experimental conditions (Cintas *et al.,* 2001). Bacteriocin bactericidal effect of bacteriocins causes lysis

Table 1: Various Classes of Bacteriocins.

Classes of bacteriocin	Description	Sub type	Example	Producing bacteria
Class I (Lantibiotics)	Peptides (<5 kDa) that are Heat stable, and contain lanthionine and methyllanthionine	A-Lantibiotics B-Lantibiotics	Nisin, Lacticin, Subtilisin	*Lactococcus lactis*; *Lactobacillus plantarum* LL441; *Lactococcus lactis* subsp. *lactis* DPC3147
Class II (Bacteriocins)	Peptides (<10 kDa) that are Heat-stable, do not contain lanthionine	IIa; IIb; IIc	Pediocin, Leucocin	*Enterococcus faecium* NKR-5-3; *Lactobacillus acidophilus*; *Lactococcus lactissubsp*. cremoris 9 B4
Class	Peptides (>10 kDa) that are Heat-sensitive and hydrophilic	Subtype IIIa: Bacteriolytic Subtype IIIb: Non bacteriolytic	Helveticin	*Lactobacillus helveticus* 1829; *Lactobacillus helveticus* 481
Class IV	complex conjugated proteins (~5.5–7.5) that are Heat-stableand hydrophobic carbohydrate or lipid		Plantaricin	*Enterococcus faecalis*

of target cells (Bierbaum and Sahl, 1991). Bacteriocins sites of binding to target cells are teichoic, teichuronic and lipoteichoic, acids that are located on the cell wall of target bacteria which leads to their release causing activation of autolytic enzymes. These enzymes are electrostatically linked to these polymers (Bierbaum and Sahl, 1991; Jack *et al.,* 1995). Additionally, production of bacteriocin is highest at the end of the exponential and early stationary phase (Daba and Simard, 1993; Thomas *et al.,* 2001). Bacteriocin-encoding are organized in operon clusters and may be located on chromosome or in association with transpons or on plasmids (Aymerich *et al.,* 1996; Quadri *et al.,* 1997; Me tivier *et al.,* 1998; Deegan *et al.,* 2006). Several studies reported that detection of bacteriocin gene was approximately 3500-4000 bp in the PCR products which isolated from *Lactobacillus acidophilus* L. lactis subsp. Lactis (Garde *et al.,* 2001; Taale *et al.,* 2013; Abdulla, 2014).

Applications of Bacteriocin

Safety and quality of foods are important to human health. Due to the limitations of the current food preservation methods use of bacteriocins among new methods of food preservation, has been extensively evaluated, (Zacharof and Lovitt, 2012). The application of bacteriocins and bacteriocin-producing microorganisms in food industry is an interesting growing trait as consumer confidence in chemical preservatives has been gradually weakened. Due to the the extensive use of antimicrobials in humans and animals resistance to bacterial antibiotic has emerged as a significant problem. (Lipsitch *et al.,* 2000; Yoneyama and Katsumata, 2006). LAB bacteriocins are natural antimicrobial peptides or proteins with very interesting potential applications in the food industry consistent with, preserving people's health through enhancing the sustainability of food (De Vuyst *et al.,* 1994; Cleveland *et al.,* 2001). Bacteriocins can also be used to improve food quality through protecting from contaminants (Beasley and Saris, 2004).

Conclusion

Bacteriocins that are produced by lactic acid bacteria are increasingly considered as safe alternatives to current reagents in food technology. As current preservatives are chemicals that have harmful effects including cancers and microbial resistance to antibiotics the use of bacteriocins in food industry is an increasing trend to avoid the drawback associated with the current methods for food preservation.

References

Alakomi, H.L., E. Skyttä, M. Saarela, T. Mattila-Sandholm, K. Latva-Kala and I.M. Helander (2000). Lactic acid permeabilizes Gram-negative bacteria by disrupting the outer membrane. *Appl. Environ. Microbiol.,* **66:** 2001-2005.

Abdulla, A.A. (2014). Antimicrobial Activity of *Lactobacillus acidophilus* that carry the Bacteriocin Gene. *Int. J. Curr. Microbiol. App. Sci.,* **3(6):** 269-276.

Aymerich, T., H. Holo, L.S. Ha ®varstein, M. Hugas, M. Garriga and I.F. Nes (1996). Biochemical and genetic characterization of enterocin A from *Enterococcus faecium*, a new antilisterial bacteriocin in the pediocin family of bacteriocins. *Appl. Environ. Microbiol.,* **62:** 1676-1682.

Balciunas, E.M., F.A.C. Martinez, S.D. Todorov, B.D.G. de Melo Franco, A. Converti and R.P. de Souza Oliveira (2013). Novel biotechnological applications of bacteriocins: *A review. Food Control,* **32(1):** 134–142.

Barefoot, S.F. and T.R. Klaenhammer (1984). Puriûcation and characterization of the *Lactobacillus acidophilus* bacteriocin lactacin-B. *Antimicrob. Agents Chemother,* **26:** 328–34.

Bennik, M.H.J., A. Verheul, T. Abee, G. Naaktgeboren-Stoffels, L.G.M. Gorris and E.J. Smid (1997). Interactions of nisin and pediocin PA-1 with closely related lactic acid bacteria that manifest over 100-fold differences in bacteriocin sensitivity. *Appl. Environ. Microbiol.,* **63:** 3628–3636.

Bierbaum, G., and H.G. Sahl (1991). Induction of autolysis of *Staphylococcus* stimulants 22 by pep 5 and nisin and influence of the cationic peptides on the activity of the autolytic enzymes. In G. Jung & H.G. Sahl (Eds.), Nisin and novel lantibiotics (pp. 386–396). Leiden, The Netherlands: Escom Publishers.

Beasley, S.S. and P.E.J. Saris (2004). Nisin-producing *Lactococcus lactis* strains isolated from human milk. *Journal of Applied and Environmental Microbiology,* **70:** 5051-5053.

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

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

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

Cotter, P.D., C. Hill and R.P. Ross (2005). Bacteriocins: Developing innate immunity for food. *Nature Reviews Microbiology,* **3:** 777–788 https:// doi.org/10.1038/ nrmicro1273.

Daba, L.H. and Simard (1993). Influence of growth conditions on Production and actions of mesenterocin 5 by a strain of Leuconostoc mesenteroides. *Appl. Microbiol. Biotechnol.,* **39:** 166-173.

Deegan, L.H., P.D. Cotter, H. Colin and P. Ross (2006). Bacteriocins: biological tools for bio-preservation and shelf-life extension *International Dairy Journal,* **16:** 1058-1071.

De Vuyst, L. and E.J. Vandamme, Antimicrobial Potential of Lactic Acid Bacteria, in: (1994). Bacteriocins of Lactic Acid Bacteria, 17. L. De Vuyst and E.J. Vandamme, eds., Blackie Academic and Professional, London pp. 91-149.

De Vuyst, L. and F. Leroy (2007). Bacteriocins from lactic acid bacteria: Production, purification and food applications. *J. Mol. Microbiol. Biotechnol.,* **13:** 194-199.

Dellaglio, F., H. De Roissart, M.C. Curk and D. Janssens (1994). Caractéristiques générales des bactéries latiques. In-*Bactéries Latiques*, H. De Roissart and F.M. Luquet, Lorica.

Diep, D.B. and I.F. Nes (2002). Ribosomally synthesized antibacterial peptides in gram-positive bacteria. *Current Drug Targets,* **3(2):** 107-122.

Devi, M., L.J. Rebecca and S. Sumathy (2013). Bactericidal activity of the lactic acid bacteria *Lactobacillus delbreukii*. *J. Chem. Paharm. Res.,* **5:** 176-180.

Djadouni, F. and M. Kihal (2012). Antimicrobial activity of lactic acid bacteria and the spectrum of their biopeptides against spoiling germs in foods. *Braz. Arch. Biol. Technol.,* **55:** 435-443.

Driessen, A.J.M., H.W. Van den Hooven, W. Kuiper, M. Van den Kemp, H.G. Sahl, R.N.H. Konings and W.N. Konings (1995). Mechanistic studies of lantibiotic-induced permeabilization of phospholipid vesicles. *Biochemistry,* **34:** 1606–1614.

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

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

González-Martínez, B.E., M. Gómez-Treviño and Z. Jiménez-Salas (2003). Bacteriocinas de probióticos. Rev. Salud Pública y Nutrición, 4.

Garde, S., E. Rodriguez, P. Gaya, M. Medina and M. Nunez (2001). PCR detection of the structural genes of nisin Z and lacticin 481 in *Lactococcus lactis* subsp. lactis INIA 415, a strain isolated from raw milk Manchego cheese. *Biotechnol. Lett.,* **23:** 85-9.

Hati, S., S. Mandal and J.B. Prajapati (2013). Novel starters for value added fermented dairy products. *Curr. Res. Nutr. Food Sci.,* **1:** 83-91.

Haller, D., H. Colbus, M.G. Gänzle, P. Scherenbacher, C. Bode and W.P. Hammes (2001). Metabolic and functional properties of lactic acid bacteria in the gastro-intestinal ecosystem: a comparative in vitro study between bacteria of intestinal and fermented food origin system. *Appl. Microbiol.,* **24:** 218-226.

Herranz, C., Y. Chen, H.J. Chung, L.M. Cintas, P.E. Hernandez, T.J. Montville and M.J. Chikindas (2001). Enterocin P selectively dissipates the membrane potential of *Enterococcus faecium* T136. *Appl. Environ. Microbiol.,* **67:** 1689-1692.

Ibrahim, O.O. (2019). Classification of Antimicrobial Peptides Bacteriocins and the Nature of Some Bacteriocins with Potential Applications in Food Safety and Bio-Pharmaceuticals. *EC. Microbiology,* **15:** 591-608.

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

Jung, G. and H.G. Sahl (1991). Lantibiotics: a survey. In Nisin and Novel Lantibiotics, pp. 1-34. Leiden, The Netherlands: ESCOM.

Kaban, G. and M. Kaya (2008). Identification of lactic acid bacteria and Gram-positive catalase-positive cocci isolated from naturally fermented sausage (sucuk). *J. Food Sci.,* **73:** M385-M388.

Khalid, K. (2011). An overview of lactic acid bacteria. *Int. J. Biosci.,* **1:** 1-13.

König, H. and J. Fröhlich (2009). Lactic acid bacteria. In Biology of Microorganisms on Grapes, in Must and in Wine; H. König, G. Unden, J. Fröhlich Eds.; Springer: Heidelberg/Berlin, Germany.

Klaenhammer, T.R., C. Fremaux and Y. Hechard (1994). Activité antimicrobienne des bactéries lactiques. In-*Bactéries Latiques*, H. De Roissart and F.M. Luquet, Lorica.

Kozak, W., J. Bardowski and W.T. Dobrzanski (1978). Lactostrepcins-acid bacteriocins produced by lactic acid streptococci. *Journal of Dairy Research,* **45(2):** 247-257.

Kuipers, O.P., G. Buist and J. Kok (2000). Current strategies for improving food bacteria. *Res. Microbiol.,* **151:** 815-822.

Leroy, F. and L. De Vuyst (2004). Functional lactic acid bacteria starter cultures for the food fermentation industry. *Trends in Food Science and Technology,* **15:** 67-78.

Liu, W., H. Pang, H. Zhang and Y. Cai (2014). Biodiversity of lactic acid bacteria. In Lactic Acid Bacteria; Y. Zhang, Y. Cai, Eds.; Springer Science + Business Media: Dordrecht, The Netherlands.

Lipsitch, M., C.T. Bergstrom and B.R. Levin (2000). The epidemiology of antibiotic resistance in hospitals: paradoxes and prescriptions. *Proc. Natl. Acad. Sci. USA,* **97:** 1938-1943.

Lopetuso, L., M. Giorgio, A. Saviano, F. Scaldaferri, A. Gasbarrini and G. Cammarota (2019). Bacteriocins and bacteriophages: Therapeutic weapons for gastrointestinal diseases? *International Journal of Molecular Sciences,* **20(1):** 183.

Me tivier, A., M.F. Pilet, X. Dousset, O. Sorokine, P. Anglade, M. Zagorec, J.C. Piard, D. Marion, Y. Cenatiempo and C. Fremaux (1998). Divercin V41, a new bacteriocin with two disulphide bonds produced by *Carnobacterium divergens* V41: primary structure and genomic organization. *Microbiology,* **144:** 2837-2844.

Moreno, I., A.S.L. Lerayer, V.L.S. Baldini and M.F. d F. Leitão (2000). Characterization of bacteriocins produced by *Lactococcus lactis* strains. *Braz. J. Microbiol.*, **31:** 184-

192.

Montville, T.J. and Y. Chen (1998). Mechanistic action of pediocin and nisin: recent progress and unresolved questions. *Appl. Microbiol. Biotechnol.,* **50:** 511-519.

Naidu, A.S., W.R. Bidlack and R.A. Clemens (1999). Probiotic spectra of lactic acid bacteria (LAB). *Crit. Rev. Food Sci. Nutr.,* **38:** 13-126.

Nes, I.F., D.B. Diep, L.S. Håvarstein, M.B. Brurberg, V. Eijsink and H. Holo (1996). Biosynthesis of bacteriocins in lactic acid bacteria. *Antonie Leeuwenhoek,* **70:** 113-128.

Nes, I.F., H. Holo, G. Fimland, H.H. Hauge and J. Nissen-Meyer (2002). Unmodiûed peptide-bacteriocins (class II) produced by lactic acid bacteria, p. 81-115. In C.J. Dutton, M.A. Haxell, H.A.I. McArthur and R.G. Wax (ed.), Peptide antibiotics: discovery, modes of action and application. Marcel Dekker, New York, N.Y.

Nissen-Meyer, J., H.H. Hauge, G. Fimland, V.G.H. Eijsink and I.F. Nes (2001). Ribosomally synthesized antimicrobial peptides by lactic acid bacteria: their function, structure, biogenesis and their mechanism of action. *Recent Res. Dev. Microbiol.,* **1:** 141–154.

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

Parada, J.L., C.R. Caron, A.B.P. Medeiros and C.R. Soccol (2007). Bacteriocins from lactic acid bacteria: Puriûcation, properties and use as biopreservatives. *Braz. Arch. Biol. Technol.,* **50:** 521-542. [CrossRef].

Quinto, E.J., P. Jiménez, I. Caro, J. Tejero, J. Mateo and T. Girbés (2014). Probiotic lactic acid bacteria: A review. *Food Nutr. Sci.,* **5:** 1765-1775.

Quadri, L.E.N., M. Kleerebezem, O.P. Kuipers, W.M. de Vos, K.L. Roy, J.C. Vederas and M.E. Stiles (1997). Characterization of a locus from *Carnobacterium piscicola* LV17B involved in bacteriocin production and immunity: evidence for a global inducer-mediated transcriptional regulation. *J. Bacteriol.,* **179:** 6163-6171.

Saavedra, L., C. Minahk, A.P. De R. Holgado and F. Sesma (2004). Enhancement of the enterocin CRL35 activity by a synthetic peptide derived from the NH2-terminal sequence. *Antimicrob. Agents Chemother.,* **48:** 2778-2781.

Stevenson, J. (2010). Recent research on food additives: Implications for CAMH. *Child Adolescent Mental Health,* **15(3):** 130-133.

Tagg, J., A. Dajani and L. Wannamaker (1976). Bacteriocins of gram positive bacteria, *Bacteriol. Rev.,* **40:** 722-756.

Taale, E., A. Savadogo, Z. Cheickna, A.J. Ilboudo and A.S. Traore (2013). Bioactive molecules from bacteria strains: case of bacteriocins producing bacteria isolated from foods. *Current Research in Microbiology and Biotechnology,* **1(3):** 80-88.

Thomas, L.V., M.R. Clarkson and J. Delves-Broughton (2001). Nisin, In Natural Food Antimicrobial Systems, ed. A.S. Naidu. CRC Press, Boca Raton, FL, 463-524.

Todorov, S.D. (2009). Bacteriocins from *Lactobacillus plantarum*-Production genetic organization. *Braz. J. Microbiol.,* **40:** 209-221.

Van Geel-Schuttená, G.H., F. Flesch, B. Ten Brink, M.R. Smith and L. Dijkhuizen (1998). Screening and characterization of Lactobacillus strains producing large amounts of exopolysaccharides. *Appl. Microbiol. Biotechnol.,* **50:** 697-703.

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

Walter, J. (2008). Ecological role of lactobacilli in the gastrointestinal tract: Implications for fundamental and biomedical research. *Appl. Environ. Microbiol.,* **74:** 4985–4996.

Yoneyama, H. and R. Katsumata (2006). Antibiotic Resistance in Bacteria and Its Future for Novel Antibiotic Development. *Biosci. Biotechnol. Biochem.,* **70:** 1060-1075.

Zacharof, M.P. and R.W. Lovitt (2012). Bacteriocins produced by lactic acid bacteria a review article. *APCBEE Procedia,* **2:** 50-56 https://doi. org/10.1016/j.apcbee.2012.06.010.