



Structure, mode of action and application of pediocin natural antimicrobial food preservative: A review

Alaa Kareem Niamah

Department of Food Science, College of Agriculture, University of Basrah, Basrah, Iraq

*Corresponding author: e-mail: alaakareem2002@hotmail.com

Received 14 May 2018; Accepted 8 July 2018; Available online 20 July 2018

Abstract: Pediocin is a low molecular weight (2.7-17 KDa) cationic molecules compose of a hydrophilic N-terminal part containing the pediocin box (YGNGV) motif and a hydrophobic or amphiphilic C-terminal variable part which is produced by some of *Pediococcus* bacteria. Pediocin has inhibition properties against several sensitive bacterial cells and acts on the cytoplasmic membrane during pores formation. Pediocin intervenes with the absorption of amino acids in phospholipids of cytoplasmic membrane from target cells. The pediocin molecule has unique properties such as the thermostability and detaining of activity at a wide pH values and resistance to some proteases enzymes. Pediocin has inhibition activity against many food spoilage bacteria and pathogenic bacteria including several bacterial genera such as *Listeria*, *Clostridium*, *Bacillus*, *Aeromonas*, *Staphylococcus*, *Lactobacillus* and *Enterococcus*. This review will assist in learning the challenges that yet require to attention to apply pediocin in food industries as food preservative.

Keywords: Food preservative, *Pediococcus*, Bacteriocin, Pediocin, antimicrobial.

Introduction

Bacteriocins are antimicrobial peptides or toxins peptides which produced from bacteria in end stationary phase or death phase to inhibit bacterial species which are genetically closely related. Some species of yeasts and *Paramecium* had been inhibited by killing factors (bacteriocins) (Cotter *et al.*, 2013). Some yeasts such as *Saccharomyces boulardii* can peptides produce like bacteriocins which is called protein killer (Niamah *et al.*, 2017b, c).

The produced bacteriocins from Gram positive bacteria such as lactic acid bacteria are classified into four classes depending on their molecular weight, heat resistance and the presence of modified amino acids (Cotter *et al.*, 2005; Niamah, 2010; Perez *et al.*, 2014). Class I: called is lantibiotics which contains modified amino acids after DNA translation. Nisin is the most exclusive component of class I (Jung, 1991). Class II: defined as peptide of small molecular weight (<10 kDa),

heat-stable, non-modified amino acids and that shows strong antilisterial activity. Pediocin is the most characterized component of the class II (Eijsink *et al.*, 2002; Rodríguez *et al.*, 2002). Class III: Large molecular weight (>30 kDa), unstable heat proteins, predominantly it is produced by enzymatic activity (Nilsen *et al.*, 2003). Class IV: complex or globular proteins, composed of peptides with carbohydrate or lipid (Maqueda *et al.*, 2004; Gabrielsen *et al.*, 2014).

Pediocin is one of class IIa group. It is produced from *Pediococcus* spp. The *Pediococcus* genus is Gram-positive, homofermentative and belongs to Lactobacillaceae family (Haakensen *et al.*, 2009). *Pediococcus* genus includes several species such as *P. acidilactici*, *P. pentosaceus*, *P. damnosus*, *P. cellicola*, *P. parvulus*, *P. stilesii*, *P. inopinatus*, *P. claussenii* and *P. ethanolidurans* (Franz *et al.*, 2006). The production of bacteriocin from these species is called pediocin. Some studies added symbols with Pediocin word such as pediocin AcH (Bhunja *et al.*, 1988), pediocin SJ-1 (Schved *et al.*, 1993), pediocin JD (Christensen and Hutkins, 1994), PA-1 (Rodríguez *et al.*, 2002) and pediocin PaF-11 (Marwati *et al.*, 2017).

Pediocin activity in foods is affected by many factors such as pH, heat treatment, proteolytic enzymes, salts and storage time (Niamah, 2010). The mode of action of pediocin is making pores in the cytoplasm of the targeted cells then reducing the intracellular pH and inhibits protein stimulation which is responsible for energy production in the cell (Bhunja *et al.*, 1991; Gabrielsen *et al.*, 2014).

Nisin and pediocin have been used as food preservatives like fermented sausage (Woraprayote *et al.*, 2016; Castellano *et al.*, 2017), fermented vegetables and dairy

products (Verma *et al.*, 2017), these bacteriocins, added bacteria starters are possibly produced during fermentation or may be added pure bacteriocin to food. In this review, we will research on the full papers and published literatures of pediocins. Topics such as pediocin structure, action mode of pediocin, spectrum of pediocin activity and pediocin applications in foods will be discussed in detail.

Pediocin structure

Pediocin peptide consists of 40-44 amino acids, its molecular structure has 4 molecules of lysine, 3 molecules of histidine, one molecule of aspartic acid and 4 molecules of cysteine which linked by disulfide bonds in site (C9-C14) and (C24-C44) of pediocin structure (Chikindas *et al.*, 1993).

The charge of pediocin is positive between (+3) and (+7) when pH=6 while the isoelectric point (Ip) is 8.6-10 (Venema *et al.*, 1997). The N-terminus of pediocin contains hydrophilic amino acids and β -sheet structure. The C-terminus of pediocin contains amphiphilic amino acids and α -helical structure. The location of pediocin box in N-terminus of pediocin structure (Fig 1).

The calculated molecular weight of pediocin during the amino acids series was 4624 or 4628 Dalton depending on the presence or absence of disulfide bonds. The molecular weight of pediocin was estimated by SDS-polyacrylamide gel electrophoresis and it was found 6094.8 Dalton (Niamah, 2010), while it was 16500 Dalton by gel filtration method (Gonzalez and Kunka, 1987). Electrospray mass spectrometry showed disulfide bonds in pediocin structure which is oxidizing molecules causing an increase in the molecular weight of pediocin (Daba *et al.*, 1994).

Action mode of pediocin

The cytoplasmic membrane of bacteria such as lactic acid bacteria is closely related genetically and it is the target of pediocins. Pediocin has three mechanisms to inhibit the bacteria: -1) work pores made in cytoplasm membrane of cell target, 2) collapse pH intracellular of bacteria target, 3) inhibition of proton motive force for energy production in the bacterial cell. Pediocin was linked with

cell target through active sites such as negative charges of phospholipids groups in cell wall. Past studies which related between amount lipoteichoic acid in cell wall of gram positive bacteria (G^+) and increased pediocin activity against (G^+) bacteria. The higher pediocin activity when acid concentration is increased in the walls of bacterial cells (Perez *et al.*, 2015; Wang *et al.*, 2015).

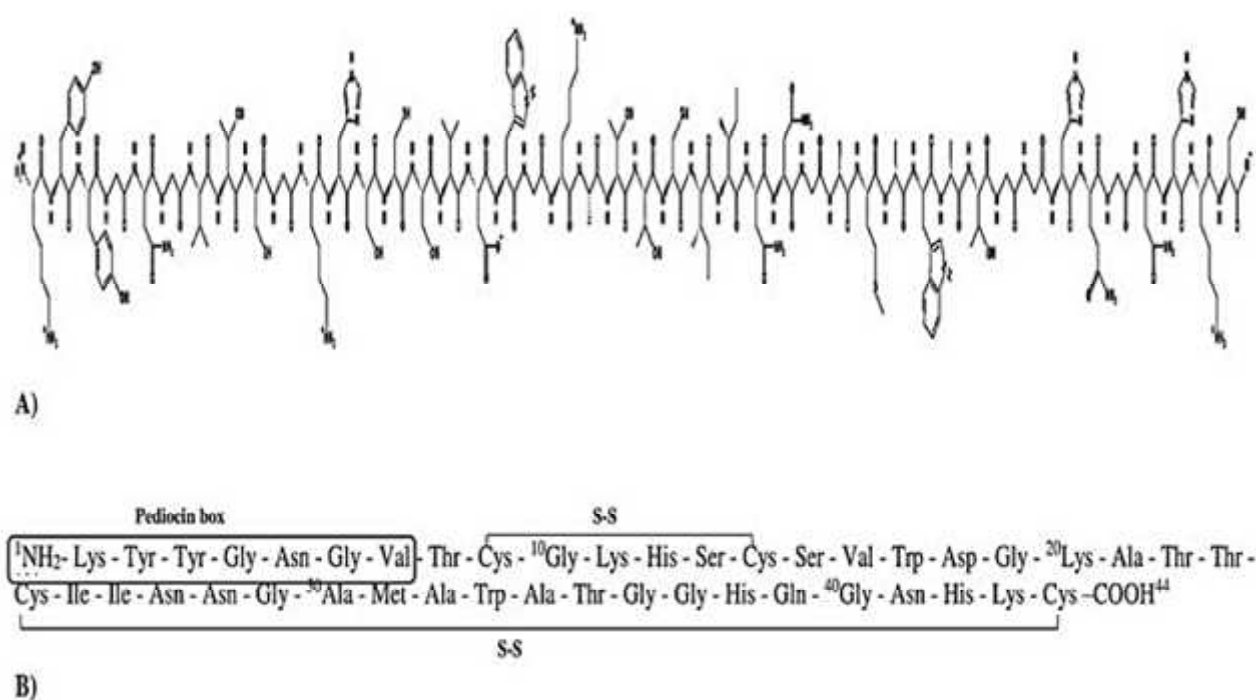


Fig. (1): Pediocin structure. A) amino acid structure of pediocin, B) active sites of pediocin

Montville and Chen (1998) showed three main steps for the inhibition activity of pediocin against bacteria 1) linking pediocin with cytoplasm membrane of the targeted cell. 2) entering pediocin molecule into the targeted cell. 3) formation of complexes between pediocin and the cell components such as enzymes, proteins and DNA. Then autolysis of the targeted cell (Fig 2). However, *Bacillus* and *Clostridium* spores do not adsorb the pediocin. After their germination and growth in culture media, the sensitive bacteria cells adsorb the pediocin

and are inhibited (Todorov *et al.*, 2016).

Properties of pediocin

The Class II of bacteriocins is divided into the pediocin-like bacteriocins and the two-peptide bacteriocins. The known produced pediocin from species of *Pediococcus* genus is mostly small structure, hydrophobic peptides, thermally stable and bears low temperatures even at -80°C. Pediocin activity is maintained in a wide range of pH at 2-10. It is sensitive to general proteases enzymes such as pepsin, papain and trypsin (Table 1).

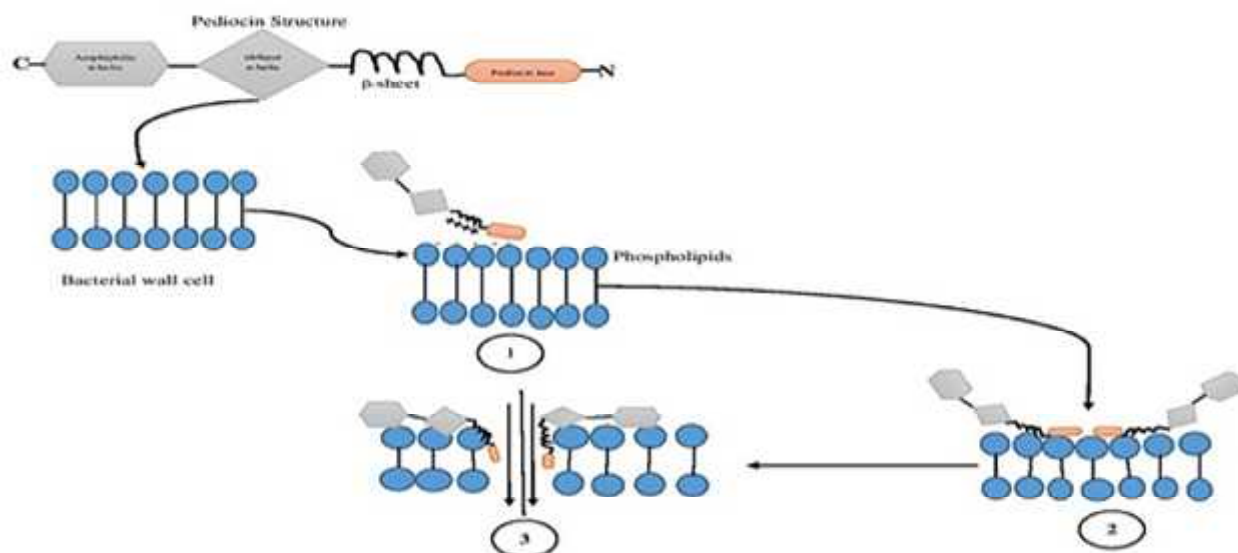


Fig. (2): The schematic diagram of the pores formation of pediocin in sensitive cell walls, (1) Adsorption pediocin on the cell walls, (2) hydrophobic interaction, (3) pores formation in cell wall.

Table (1): The properties of some pediocin types (heat stable, pH and proteases enzymes resistance).

[+: Activity reaction (50-100) %, L: Low activity (<50), ND: not tested].

Pediocin types	Treatments								References
	Temperatures		pH	proteases enzymes					
	100°C/ 30 min	121°C/ 15min		Trypsin	chymotrypsin	Pepsin	Proteinase K	Papain	
AcH	ND	+	+	L	L	ND	L	L	Bhuni <i>et al.</i> (1998)
F, A	ND	+	+	L	L	ND	L	L	Osmanagaoglu <i>et al.</i> (1998)
ACCEL	+	+	+	ND	ND	ND	ND	ND	WU <i>et al.</i> (2004)
SA-1	+	+	+	+	+	+	L	+	Anastasiadou <i>et al.</i> (2008)
AK	+	+	+	±	ND	ND	L	L	Niamah (2010)
PA-1	+	+	+	L	L	ND	L	ND	Osmanagaoglu <i>et al.</i> (2011)
NCIM	+	+	+	L	L	L	L	L	Mandal <i>et al.</i> (2014)

Spectrum of pediocin activity

Generally, the pediocin has inhibition activity against gram positive bacteria and gram negative bacteria (Table 2). Daeschel and Klaenhammer (1985) studied the inhibitory spectrum of pediocin products from *P. pentosaceus* FBB61 and *P. pentosaceus* L7230 which showed inhibition activity

against *Pediococcus* spp., *Lactobacillus brevis* and *Lactobacillus plantarum*. The starters contain *P. acidilactici* had higher inhibition activity against *Listeria monocytogenes*. These starters are used in fermented meat and other food products (Lewus *et al.*, 1991).

Green *et al.* (1997) and Anastasiadou *et al.* (2008) showed spectrum of pediocin SA-1 which is produced from *P. acidilactici* NRRL B 5627 with inhibition activity against bacteria that spoilage food or pathogenic bacteria such as *Bacillus cereus* LMG13569, *Clostridium sporogenes* NCTC533, *Clostridium thiaminolyticum* ATCC15579, *Enterococcus faecalis* NCTC8176, *Leuconostoc mesenteroides* ATCC19254, *Micrococcus flavus* ATCC400, *Listeria monocytogenes* ATCC19111, *Salmonella carnosus* LMG13564 and *Lactobacillus brevis* ATCC8287. But it did not inhibits activity against *Salmonella enteritidis* ATCC13076.

Spectrum of pediocin activity

Generally, the pediocin has inhibition activity against gram positive bacteria and gram negative bacteria (Table 2). Daeschel and Klaenhammer (1985) studied the inhibitory spectrum of pediocin products from *P. pentosaceus* FBB61 and *P. pentosaceus* L7230 which showed inhibition activity against *Pediococcus* spp., *Lactobacillus brevis* and *Lactobacillus plantarum*. The starters contain *P. acidilactici* had higher inhibition activity against *Listeria monocytogenes*. These starters are used in fermented meat and other food products (Lewus *et al.*, 1991).

Table (2): Some pediocin types produced by *Pediococcus* genus and indicator bacteria.

Pediocin type	Produced bacteria	Indicator bacteria	References
AcH	<i>P. acidilactici</i> H	<i>Lactobacillus plantarum</i> <i>Lactobacillus</i> spp.	Biswas <i>et al.</i> (1991)
SJ-1	<i>P. acidilactici</i> SJ-1	<i>Clostridium perfringens</i> <i>Listeria monocytogenes</i> .	Schved <i>et al.</i> (1993)
L50	<i>P. acidilactici</i>	<i>L. monocytogenes</i> <i>Staphylococcus aureus</i> <i>L. monocytogenes</i>	Cintas <i>et al.</i> (1995)
AcM	<i>P. acidilactici</i> M	<i>C. perfringens</i> , <i>Bacillus coagulans</i> <i>B. cereus</i> <i>Aeromonas hydrophila</i> .	Elegado <i>et al.</i> (1997)
ST18	<i>P. pentosaceus</i> ST18	<i>Pediococcus</i> spp. <i>Listeria innocua</i> <i>Lactobacillus plantarum</i> .	Todorov and Dicks (2005)
PD-1	<i>P. damnosus</i>	<i>Listeria</i> spp.	Anastasiadou <i>et al.</i> (2008)
AK	<i>P. acidilactici</i> AK	<i>S. aureus</i>	Niamah (2010)
NV 5	<i>P. acidilactici</i> LAB 5	<i>Enterococcus faecalis</i> <i>Leuconostoc mesenteroides</i>	Mandal <i>et al.</i> (2010)
PA-1	<i>P. acidilactici</i> J347-29	<i>Oenococcus oeni</i> <i>Listeria monocytogenes</i>	Díez <i>et al.</i> (2012)
P34	<i>P. pentosaceus</i> 34	<i>Enterococcus faecium</i> <i>E. faecium</i> <i>E. faecalis</i>	Kaur <i>et al.</i> (2014)
KJBC11	<i>P. pentosaceus</i> KJBC11	<i>Listeria monocytogenes</i>	Sadishkumar and Jeevaratnam (2017)

Green *et al.* (1997) and Anastasiadou *et al.* (2008) showed spectrum of pediocin SA-1 which is produced from *P. acidilactici* NRRL B 5627 with inhibition activity against bacteria that spoilage food or pathogenic bacteria such as *Bacillus cereus* LMG13569, *Clostridium sporogenes* NCTC533, *Clostridium thiaminolyticum* ATCC15579, *Enterococcus faecalis* NCTC8176, *Leuconostoc mesenteroides* ATCC19254, *Micrococcus flavus* ATCC400, *Listeria monocytogenes* ATCC19111, *Salmonella carnosus* LMG13564 and *Lactobacillus brevis* ATCC8287. But it did not inhibitors activity against *Salmonella enteritidis* ATCC13076.

Pediocin applications in foods

During in the last decade of the 21th century these was great concern about its side effect of chemical additives in food which arises the emergence of many diseases it is believed that the chemical additives are the direct or indirect causes of these diseases. Researchers worldwide were looking for natural food or fresh food with no additives, or discover natural substances that are highly effective in food preservation, including bacteriocins such as Nisin or Pediocin which are used to improve food safety and increase its shelf life without side effect. Pediocin has been commercially produced under the name “AltaTM 2341” and is used in the USA and European countries as a preservative especially in meat products to inhibit the growth of *Listeria monocytogenes* (Porto *et al.*, 2017).

Microbial starters (bacteria and yeast) are capable to produce inhibitory proteins were used in inhibition of pathogenic bacteria. These starters are traditionally used in manufacturing of fermented sausage, fermented vegetables, fermented olives, dairy

products and fermented grains food (Niamah, 2017; Niamah *et al.*, 2017a). There are four mechanisms for adding pediocin to food, 1) Using Pediocin producing bacteria as starter in fermented food. 2) Adding purified or semi-purified pediocin into food matrix. 3) Using fermented food by pediococci and introducing as a component in the manufactured food. 4) Food packaging films are incorporated with pediocin.

In meat and meat products

Powdered Pediocin was produced from milk-based media and applied to plastic bags for meats and poultry packaging samples. The samples were inoculated with *Listeria monocytogenes* and storage for 12 weeks at 4°C. The bags reduced the viability numbers of *L. monocytogenes* after this storage time (Ming *et al.*, 1997). Nieto-Lozano *et al.* (2010) showed that the highest activity of pediocin PA-1 (5000 bacteriocin units/ml) produced by *Pediococcus acidilactici* MCH14 against *L. monocytogenes* and *Clostridium perfringens* in Spanish dry-fermented sausages samples. The pediocin reduced the numbers of this bacteria after storage time for 60 days at 10°C. *P. acidilactici* LAB 5 which produce pediocin was isolated from vacuum-packed fermented meat product. This pediocin has higher inhibition active against food spoilage and human pathogenic bacteria like some species of *Enterococcus*, *Listeria*, *Leuconostoc* and *Staphylococcus* (Mandal *et al.*, 2008).

The pediocin AcH/PA-1 produced by *Pediococcus pentosaceus* OZF isolated from human breast milk and applied on chicken meat products which were radiated and inoculated with Log. 5.0 CFU/g of *L. monocytogenes* and purified pediocin. A significant decrease of *L. monocytogenes* viability after packaging and store of 4 weeks

at 4°C (Kiran and Osmanagaoglu, 2014). In another study, the pediocin produced by *P. pentosaceus* and *Murraya koenigii* berries used as the antimicrobial and antioxidant in goat meat emulsion during storage period of 9 days at 4 °C. The effects of pediocin and *Murraya koenigii* berries combination had higher inhibition activity against *L. innocua* after storage period (Kumar *et al.*, 2017).

In milk and dairy products

Milk and dairy products are the best media for pathogenic bacteria and bacteria related with food spoilage bacteria such as *Listeria monocytogenes*, *Salmonella* sp., *Staphylococcus aureus*, *Campylobacter* sp. and *Yersinia* sp. (Niamah, 2012; Abbas *et al.*, 2017). Motlagh *et al.* (1992) mentioned pediocin activity against *L. monocytogenes* in cottage cheese, sauce cheese and ice cream after storage at 4°C and 32°C. The numbers of *L. monocytogenes* bacteria reduced in cheese samples with pediocin during storage period compared with the control sample. Direct application of pediocin PA-1 produced by *Pediococcus* genus as an antibacterial against *L. monocytogenes*. *Pediococcus* genus is not able to ferment lactose quickly, making it metabolically unsuitable for dairy fermentation products. In spite of growth of *Pediococcus* species being grow weakly in milk and dairy products, but using Log. 9.0 CFU/mL of *Pediococcus* as starter inhibited the growth of *L. monocytogenes* in milk samples (Ming *et al.*, 1997). The produced Pediocin PA-1 by *Pediococcus pentosaceus* NCDC 273 when it used 2.04×10^5 AU/mL of pediocin PA-1 increased the shelf life of raw buffalo milk and reduced the total viable numbers of bacteria (Verma *et al.*, 2017).

In other foods

Despite the prolongation of shelf life in food products by the addition of organic acids such as sorbic acid, benzoic acid and lactic acid, interest about the use of these organic acids have led investigators to search, produced bacteriocins from lactic acid bacteria is using for food preservation. Pediocin has a distinct scientific application to inhibit *L. monocytogenes* in the production of some fermented foods, especially in planned fermentation process where specific bacteria of starter cultures are used. By mixing pediocin through the formulation of the raw product, infection and pollution bacteria problems in the final product could be reduced. Muriana (1996) who showed to add pediocin to eggs whole led to reduce the survival of *L. monocytogenes*. Edible film coatings added with produced pediocin from *Pediococcus pentosaceus* could also be a great alternative to preserve minimally processed papaya (*Carica papaya* L.) fruits (Narsaiah *et al.*, 2015).

Conclusions

Pediocins produced by *Pediococcus* spp. have promising antimicrobial activity. It is possibly used as direct to safe antimicrobial food addition on could by produced by the added starters bacteria. Presently, partly purified or concentrated of produced pediocin used as a food additive a substitute for preservatives of foods. Addition of pediocin pour concentrated beside started may be more affective and could be promising for new functional food production. Pediocin can use within functional food. Producing mixture of bacteriocins by lactic acid bacteria with high effectiveness and low cost could certainly improve their opportunities to use in the consumer foods.

Acknowledgments

The author is grateful to Dr. Deepak Kumar Verma from Department of Agricultural and Food Engineering, Indian Institute of Technology, Kharagpur, India, to support the research by new references.

References

- Abbas, B.A.; Ghadban, M.K. & Alghanim, A. M. (2017). Microbial evaluation of milk and milk products during a past two decades, in Basrah southern Iraq, a review. Annual Research & Review in Biology, 14(2): 1-8.
- Anastasiadou, S.; Papagianni, M.; Filiouis, G.; Ambrosiadis, I. & Koidis, P. (2008). Pediocin SA-1, an antimicrobial peptide from *Pediococcus acidilactici* NRRL B5627: Production conditions, purification and characterization. Bioresource Technol., 99(13): 5384-5390.
- Bhunia, A.K.; Johnson, M.C. & Ray, B. (1988). Purification, characterization and antimicrobial spectrum of a bacteriocin produced by *Pediococcus acidilactici*. Appl. Microbiol., 65(4): 261-268.
- Bhunia, A.K.; Johnson, M.C.; Ray, B. & Kalchayanand, N. (1991). Mode of action of pediocin AcH from *Pediococcus acidilactici* H on sensitive bacterial strains. Appl. Microbiol., 70(1): 25-33.
- Biswas, S.R.; Ray, P.; Johnson, M.C. & Ray, B. (1991). Influence of growth conditions on the production of a bacteriocin, pediocin AcH, by *Pediococcus acidilactici* H. Appl. Environ. Microbiol., 57(4): 1265-1267.
- Castellano, P.; Pérez Ibarreche, M.; Blanco Massani, M.; Fontana, C. & Vignolo, G.M. (2017). Strategies for pathogen biocontrol using lactic acid bacteria and their metabolites: A focus on meat ecosystems and industrial environments. Microorganisms, 5(3): 38.
- Chikindas, M.L.; García-Garcera, M.J.; Driessen, A.J.; Ledebor, A.M.; Nissen-Meyer, J.; Nes, I.F.; Abee, T.; Konings, W.N. & Venema, G. (1993). Pediocin PA-1, a bacteriocin from *Pediococcus acidilactici* PAC1. 0, forms hydrophilic pores in the cytoplasmic membrane of target cells. Appl. Environ. Microbiol., 59(11): 3577-3584.
- Christensen, D.P. & Hutkins, R.W. (1994). Glucose uptake by *Listeria monocytogenes* Scott A and inhibition by pediocin JD. Appl. Environ. Microbiol., 60(10): 3870-3873.
- Cintas, L.M.; Rodriguez, J.M.; Fernandez, M.F.; Sletten, K.; Nes, I.F.; Hernandez, P.E. & Holo, H. (1995). Isolation and characterization of pediocin L50, a new bacteriocin from *Pediococcus acidilactici* with a broad inhibitory spectrum. Appl. Environ. Microbiol., 61(7): 2643-2648.
- Cotter, P.D.; Hill, C. & Ross, R.P. (2005). Bacteriocins: developing innate immunity for food. Nat. Rev. Microbiol., 3(10): 777-788.
- Cotter, P.D.; Ross, R.P. & Hill, C. (2013). Bacteriocins-a viable alternative to antibiotics. Nat. Rev. Microbiol., 11(2): 95-105.
- Daba, H.; Lacroix, C.; Huang, J.; Simard, R. E. & Lemieux, L. (1994). Simple method of purification and sequencing of a bacteriocin produced by *Pediococcus acidilactici* UL5. Appl. Bacteriol., 77(6): 682-688.
- Daeschel, M.A. & Klaenhammer, T.R. (1985). Association of a 13.6-megadalton

- plasmid in *Pediococcus pentosaceus* with bacteriocin activity. Appl. Environ. Microbiol., 50(6): 1538-1541.
- Díez, L.; Rojo-Bezares, B.; Zarazaga, M.; Rodríguez, J.M.; Torres, C. & Ruiz-Larrea, F. (2012). Antimicrobial activity of pediocin PA-1 against *Oenococcus oeni* and other wine bacteria. Food Microbiol., 31(2): 167-172.
- Eijsink, V.G.; Axelsson, L.; Diep, D.B.; Håvarstein, L.S.; Holo, H. & Nes, I.F. (2002). Production of class II bacteriocins by lactic acid bacteria; an example of biological warfare and communication. Antonie Leeuwenhoek, 81(1-4): 639-654.
- Elegado, F.B.; Kim, W.J. & Kwon, D.Y. (1997). Rapid purification, partial characterization, and antimicrobial spectrum of the bacteriocin, Pediocin AcM, from *Pediococcus acidilactici* M. Int. J. Food Microbiol., 37(1): 1-11.
- Franz, C.M.; Vancanneyt, M.; Vandemeulebroecke, K.; De Wachter, M.; Cleenwerck, I.; Hoste, B.; Schillinger, U.; Holzapfel, W.H. & Swings, J. (2006). *Pediococcus stilesii* sp. nov., isolated from maize grains. Int. J. Syst. Evol. Microbiol., 56(2): 329-333.
- Gabrielsen, C.; Brede, D.A.; Nes, I.F. & Diep, D.B. (2014). Circular bacteriocins: biosynthesis and mode of action. Appl. Environ. Microbiol., 80(22): 6854-6862.
- Gonzalez, C.F. & Kunka, B.S. (1987). Plasmid-associated bacteriocin production and sucrose fermentation in *Pediococcus acidilactici*. Appl. Environ. Microbiol., 53(10): 2534-2538.
- Green, G.; Dicks, L.M.T.; Bruggeman, G.; Vandamme, E.J. & Chikindas, M.L. (1997). Pediocin PD-1, a bactericidal antimicrobial peptide from *Pediococcus damnosus* NCFB 1832. Appl. Microbiol., 83(1): 127-132.
- Haakensen, M.; Dobson, C.M.; Hill, J.E. & Ziola, B. (2009). Reclassification of *Pediococcus dextrinicus* (Coster and White 1964) Back 1978 (Approved Lists 1980) as *Lactobacillus dextrinicus* comb. nov., and emended description of the genus *Lactobacillus* Int. J. Syst. Evol. Microbiol., (3): 615-621.
- Jung, G. & Sahl, H.G. (1991) Lantibiotics: a survey. Pp: 1-34. In: Jung, G. and Sahl, H.G., (Eds.). Nisin and novel lantibiotics. ESCOM Science. 490pp.
- Kaur, G.; Singh, T.P.; Malik, R.K.; Bhardwaj, A. & De, S. (2014). Antibacterial efficacy of nisin, pediocin 34 and enterocin FH99 against *L. monocytogenes*, *E. faecium* and *E. faecalis* and bacteriocin cross resistance and antibiotic susceptibility of their bacteriocin resistant variants. J. Food Sci. & Tech., 51(2): 233-244.
- Kiran, F. & Osmanagaoglu, O. (2014). Inhibition of *Listeria monocytogenes* in chicken meat by pediocin AcH/PA-1 produced by *Pediococcus pentosaceus* OZF. Agro Food Industry Hi Tech., 25(6): 66-69.
- Kumar, Y.; Kaur, K.; Shahi, A. K.; Kairam, N. & Tyagi, S. K. (2017). Antilisterial, antimicrobial and antioxidant effects of pediocin and *Murraya koenigii* berry extract in refrigerated goat meat emulsion. LWT-Food Sci. & Tech., 79:135-144.
- Lewus, C.B.; Kaiser, A. & Montville, T.J. (1991). Inhibition of food-borne bacterial pathogens by bacteriocins from lactic acid bacteria isolated from meat. Appl. Environ. Microbiol., 57(6): 1683-1688.

- Mandal, B.A.R.N.A.L. I.; Chowdhury, R. A. N. J. A. N. A. & Jee, C.B. (2014). Purification and characterization of pediocin produced by *Pediococcus acidilactici* NCIM 2292. Int. J. Pharm. Sci., 6(6): 357-361.
- Mandal, V.; Sen, S.K., & Mandal, N.C. (2008). Optimized culture conditions for bacteriocin production by *Pediococcus acidilactici* LAB 5 and its characterization. Indian J. Biochem. Biophys., 45(2): 106-110.
- Mandal, V.; Sen, S.K. & Mandal, N.C. (2010). Assessment of antibacterial activities of pediocin produced by *Pediococcus acidilactici* LAB 5. J. Food Safety, 30(3): 635-651.
- Maqueda, M.; Gálvez, A.; Bueno, M.M.; Sanchez-Barrena, M.J.; González, C.; Albert, A.; Rico, M. & Valdivia, E. (2004). Peptide AS-48: prototype of a new class of cyclic bacteriocins. Curr. Protein Pept. Sc., 5(5): 399-416.
- Marwati, T., Richana, N., Harmayani, E., & Rahayu, E.S. (2017). Characterization of Pediocin PaF-11 from *Pediococcus acidilactici* F-11 as Biopreservatives. Proceedings of ICFSN, 37-40.
- Ming, X.; Weber, G.H.; Ayres, J.W. & Sanding, W.E. (1997). Bacteriocins applied to food packaging materials to inhibit *Listeria monocytogenes* on meats. J. Food Sci., 62(2):413-415.
- Montville, T.J. & Chen, Y. (1998). Mechanistic action of pediocin and nisin: Recent progress and unresolved questions. Appl. Microbiol. Biotech., 50(5): 511-519.
- Motlagh, A.M.; Holla, S.; Johnson, M.C.; Ray, B. & Field, R.A. (1992). Inhibition of *Listeria* spp. in sterile food systems by pediocin AcH, a bacteriocin produced by *Pediococcus acidilactici* H. J. Food Protect, 55(5): 337-343.
- Muriana, P.M. (1996). Bacteriocins for control of *Listeria* spp. in food. J Food Protect., 59(13): 54-63.
- Narsaiah, K.; Wilson, R.A.; Gokul, K.; Mandge, H.M.; Jha, S.N.; Bhadwal, S.; Anurag, R.K.; Malik, R.K. & Vij, S. (2015). Effect of bacteriocin-incorporated alginate coating on shelf-life of minimally processed papaya (*Carica papaya* L.). Postharvest Biol Technol., 100: 212-218.
- Niamah, A.K. (2010). Production of pediocin like bacteriocin from a local isolate of *Pediococcus acidilactici* and using it as foods preservative. Ph. D. Thesis, Coll. Agriculture, Univ. Basrah, 177pp.
- Niamah, A.K. (2012). Detection of *Listeria monocytogenes* bacteria in four types of milk using PCR. Pak. J. Nutr., 11(12): 1158-1160.
- Niamah, A.K. (2017). Physicochemical and microbial characteristics of yogurt with Added *Saccharomyces boulardii*. Curr. Res. Nut. Food Sci. J., 5(3): 300-307.
- Niamah, A. K.; Sahi, A.A. & Al-Sharifi, A.S. (2017a). Effect of feeding soy milk fermented by probiotic bacteria on some blood criteria and weight of experimental animals. Probiotics & Antimicrob. Prot., 9(3): 284-291.
- Niamah, A.K.; Al-Manhel, A.J. & Al-Shawi, M.J. (2017b). Isolation, purification and characterization of antimicrobial peptides produced from *Saccharomyces boulardii*. Int. J. Pept. Res. Ther., (In press).
- Niamah, A.K.; Al-Manhel, A.J. & Al-Shawi, M.J. (2017c). Study of inhibitory spectrum of metabolic extract from *Saccharomyces*

- boulardii* yeast against some food related bacteria. Pak. J Food Sci., 25: 104-109.
- Nieto-Lozano, J.C.; Reguera-Useros, J.I.; Peláez-Martínez, M.D.C.; Sacristán-Pérez-Minayo, G.; Gutiérrez-Fernández, Á.J. & de la Torre, A.H. (2010). The effect of the pediocin PA-1 produced by *Pediococcus acidilactici* against *Listeria monocytogenes* and *Clostridium perfringens* in Spanish dry-fermented sausages and frankfurters. Food Control, 21(5): 679-685.
- Nilsen, T.; Nes, I.F. & Holo, H. (2003). Enterolysin A, a cell wall-degrading bacteriocin from *Enterococcus faecalis* LMG 2333. Appl. Environ. Microbiol., 69(5): 2975-2984.
- Osmanagaoglu, O.; Kiran, F. & Nes, I.F. (2011). A probiotic bacterium, *Pediococcus pentosaceus* OZF, isolated from human breast milk produces pediocin AcH/PA-1. Afr J Biotechnol., 10(11): 2070-2079.
- Perez, R.H.; Perez, M.T.M. & Elegado, F.B. (2015). Bacteriocins from lactic acid bacteria: a review of biosynthesis, mode of action, fermentative production, uses, and prospects. Phil Sci. Tech., 8(2): 61-67.
- Perez, R.H.; Zendo, T. & Sonomoto, K. (2014). Novel bacteriocins from lactic acid bacteria (LAB): Various structures and applications. Microb. Cell Fac., 13(1): S3. Doi:10.1186/1475-2859-13-S1-S3.
- Porto, M.C.W.; Kuniyoshi, T.M.; Azevedo, P.O.S.; Vitolo, M. & Oliveira, R.P.S. (2017). *Pediococcus* spp.: An important genus of lactic acid bacteria and pediocin producers. Biotechnol. Adv., 35(3): 361-374.
- Rodríguez, J.M.; Martínez, M.I. & Kok, J. (2002). Pediocin PA-1, a wide-spectrum bacteriocin from lactic acid bacteria. Crit. Rev. Food Sci., 42(2): 91-121.
- Sadishkumar, V. & Jeevaratnam, K. (2017). Purification and partial characterization of antilisterial bacteriocin produced by *Pediococcus pentosaceus* KJBC11 from Idli batter fermented with Piper betle leaves. J. Food Biochem., 42(1): 1-9.
- Schved, F.; Lalazar, A.; Henis, Y. & Juven, B.J. (1993). Purification, partial characterization and plasmid-linkage of pediocin SJ-1, a bacteriocin produced by *Pediococcus acidilactici*. Appl. Microbiol., 74(1): 67-77.
- Todorov, S.D. & Dicks, L.M. (2005). Pediocin ST18, an anti-listerial bacteriocin produced by *Pediococcus pentosaceus* ST18 isolated from boza, a traditional cereal beverage from Bulgaria. Process Biochemistry, 40(1): 365-370.
- Todorov, S.D.; Holzapfel, W. & Nero, L.A. (2016). Characterization of a novel bacteriocin produced by *Lactobacillus plantarum* ST8SH and some aspects of its mode of action. Ann microbial., 66(3): 949-962.
- Verma, S.K.; Sood, S.K.; Saini, R.K. & Saini, N. (2017). Pediocin PA-1 containing fermented cheese whey reduces total viable count of raw buffalo (*Bubalis bubalus*) milk. LWT-Food Sci. Tech., 83: 193-200.
- Wang, J.; Li, L.; Zhao, X. & Zhou, Z. (2015). Partial characteristics and antimicrobial mode of pediocin produced by *Pediococcus acidilactici* PA003. Ann. Microbial., (3):1753-1762.
- Woraprayote, W.; Malila, Y.; Sorapukdee, S.; Swetwiwathana, A.; Benjakul, S. & Visessanguan, W. (2016). Bacteriocins from lactic acid bacteria and their applications in meat and meat products. Meat Sci., 120: 118-132.
- Wu, C.W.; Yin, L.J. & Jiang, S.T. (2004). Purification and characterization of bacteriocin from *Pediococcus pentosaceus* ACCEL. J Agr. Food Chem., 52(5): 1146-1151.