



Bio Preservation an Ecofriendly Approach for Ensuring Food Safety and Longevity

*Sayan Chakraborty, Bridgete Princey C E, Debtanu Bera and Santanu Maiti
Fisheries College and Research Institute, Thoothukudi, Tamil Nadu, India

*Corresponding Author's email: chakrabortyj469@gmail.com

In recent years, advanced techniques is used in the microbiological and food processing industries, which have significantly reduced the risk of product spoilage and foodborne illnesses, but they have not completely removed it. Foodborne diseases rank second in respiratory infections causing illness in Europe, with an estimated 50,000 to 300,000 cases of acute gastroenteritis for every million people each year [1]. During the period from 1993 to 1998, Spain reported that there were 5,517 food poisoning incidents. These incidents affected 69,553 people and resulted in 6,820 hospitalizations, according to the WHO's 7th surveillance report [2]. Each year, between 250 and 350 million people in the United States face acute gastroenteritis. Between 22% and 30% of these cases are believed to be caused by foodborne diseases. The main culprits are dairy products, seafood, eggs, poultry, and contaminated meat [3]. Some of the most common bacterial pathogens include *Salmonella*, *Campylobacter jejuni*, *Escherichia coli* O157:H7, *Listeria monocytogenes*, *Staphylococcus aureus*, and *Clostridium botulinum* [4]. Microorganisms and their associated compounds can also be used for food preservation. Lactic acid bacteria (LAB) are used for fermenting food products, which improves the texture and flavour of the food while serving as a means of bio-preservation. Lactic acid bacteria, including genera like *Lactococcus*, *Streptococcus*, *Lactobacillus*, and *Pediococcus*, convert sugars into lactic acid, an essential step in food fermentation. Lactic acid, along with other byproducts from LAB metabolism like hydrogen peroxide, diacetyl, acetoin, and various organic acids, acts as a natural preservative. These compounds change the properties of food to prevent the growth of spoilage bacteria. Producing bacteriocins likely benefits bacteria by killing or inhibiting rival microorganisms that share the same environment or compete for resources. The food industry leverages LAB's bacteriocin production as an effective method to fight unwanted bacteria, which can be more appealing to consumers.

Currently, only two bacteriocins are available commercially: Nisin and Pediocin PA-1. Nisin, produced by *Lactococcus lactis*, is sold under the brand name Nisaplan™. It is a natural food preservative approved by the FDA and is used in over 48 countries. Nisin is effective against various Gram-positive bacteria, including the common foodborne pathogen *Listeria monocytogenes*. Pediocin PA-1, produced by *Pediococcus acidilactici*, is available under the brand name ALTA™ 2431 [8].

Bio-Preservation Method

As mentioned earlier, bio preservation extends the shelf life and safety of food by using antimicrobial chemicals and/or natural or controlled microbiota. Fermentation, which relies on the growth of microorganisms, is one of the most common methods for bio preservation of food. These microorganisms can occur naturally in food or be added. Most of them are lactic acid bacteria, which produce organic acids and other substances with antimicrobial properties. They also contribute unique Flavors and textures to food items. Historically, fermentation's natural processes have protected many foods from spoilage. Today, fermented

foods make up 60% of the diet in developed nations and are becoming increasingly popular [9]. This method ensures consistency by intentionally applying different microbial systems (starter or protective cultures) to raw ingredients to maintain product quality and safety. Fermented foods typically involve starter cultures made from one or more microorganisms to initiate fermentation during production, particularly in the dairy industry [10]. The selection of bacteria depends on the food type, aiming to create the desired Flavor while positively influencing the nutritional, chemical, and biological properties of food, making it appealing to consumers. Microorganisms must meet specific criteria for Generally Recognized as Safe (GRAS) status and must not pose toxicity or pathogenic risks.

Lactic Acid Bacteria

Genera *Lactobacillus*, *Pediococcus*, *Leuconostoc*, *Lactococcus*, and *Streptococcus* are all members of the LAB family. Other members include *Weissella*, *Vagococcus*, *Tetragenococcus*, *Oenococcus*, *Aerococcus*, *Carnobacterium* and *Enterococcus*. They are a naturally occurring group of gram-positive, nonmotile, non-spore-forming, rod- and coccus-shaped bacteria. These organisms can ferment carbohydrates into lactic acid while producing little other acids. The G+C content in their DNA is less than 55%. The physiological and technological traits of LAB make them appealing for various applications, including lactose and citrate fermentation, proteolytic activity, and resistance to bacteriophages [11]. They can adhere to surfaces and produce polysaccharides, and show strong tolerance to freezing and lyophilization. They also help colonize the digestive mucosa and synthesize antimicrobial compounds. LAB often have GRAS status and play a crucial role in food fermentation, as many foods are fermented using them. In dairy product production, various strains serve as starter or protective cultures, which are also used in vegetable and meat products. The most significant benefit of these microbes is their ability to maintain the nutritional value of raw materials by prolonging their shelf life and preventing spoilage caused by pathogenic and spoilage microorganisms. They achieve this by competing for nutrients and producing inhibitory compounds, such as bacteriocins, hydrogen peroxide, and organic acids.

Lab Bacteriocins

Bacteriocins are antimicrobial ribosomally generated peptides that are produced by bacteria, especially LAB members. Many, if not all, bacterial species manufacture these peptides, which destroy closely related microbes [16]. Proteases in the gastrointestinal tract inactivate them because of their nature. The majority of LAB bacteriocins that have been found thus far are cationic, thermostable compounds with hydrophobic patches and up to 60 amino acid residues. After generating fatal damage and activating autolysin to break down the cellular wall, electrostatic interactions with negatively charged phosphate groups on target cell membranes are assumed to play a role in the initial binding, pore formation, and eventual cell death [17,18].

Classification of Bacteriocins from Gram-Positive Bacteria

Class I: Lantibiotics (Lanthionine-containing bacteriocins)

- These are small peptides (<5 kDa) that undergo extensive post-translational modifications [12].
- They contain unusual amino acids such as lanthionine, β -methyl lanthionine, and dehydrated amino acids (dehydroalanine and dehydrobutyrine) [12].
- They are generally heat-stable.
- **Mode of action:** They typically bind to lipid II, a crucial component in cell wall synthesis, and/or form pores in the cell membrane, leading to cell death.
- **Examples:** Nisin, a well-known food preservative, and subtilin.

Class II: Non-lantibiotics (non-modified bacteriocins)

- These are also small (<10 kDa), non-modified, heat-stable peptides [13].
- They do not contain the extensive post-translational modifications characteristic of lantibiotics. They may have disulfide bridges or other minor modifications.

- This class is further divided into several subclasses:
- ✓ **Class II a: Pediocin-like bacteriocins.** Characterized by an N-terminal consensus sequence (YGNGV) and a potent activity against *Listeria monocytogenes*. Examples: Pediocin PA-1, Enterocin A.
- ✓ **Class II b: Two-peptide bacteriocins.** These require two different peptides acting synergistically to achieve full antimicrobial activity. Examples: Lactococcin G, Plantaricin A.
- ✓ **Class II c: Circular bacteriocins.** The N- and C-termini of the peptide are joined to form a cyclic structure, making them highly resistant to proteases. Examples: Enterocin AS-48, Reutericyclin.
- ✓ **Class II d:** A miscellaneous category for bacteriocins that do not fit into the other subclasses.

Class III: Large, heat-labile proteins

- These are larger bacteriocins with a molecular weight generally >30 kDa.
- They are heat-labile, meaning they are easily inactivated by heat [14].
- They often function as enzymes that degrade the cell wall of the target bacterium.
- **Examples:** Helveticin J, Enterolysin A.

Class IV

The circular antibacterial peptide, an interesting and unique kind of antimicrobial material produced not only by bacteria but also by plants and mammalian cells, is included in Class IV, a new class. The presence of head-to-tail peptide chain ligation, which results in molecules without an origin or an end, is what sets them apart. Enterocin AS-48 was the first circular protein to be identified [19].

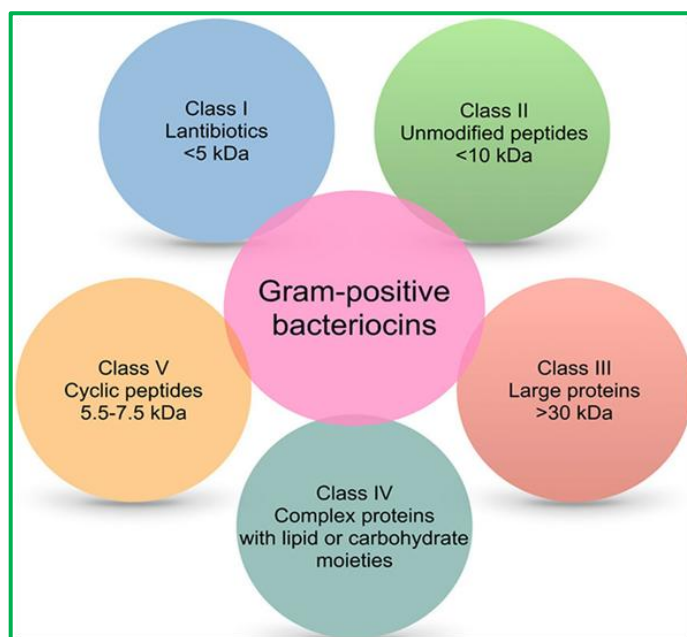


Fig 1. Structure-based classification of Gram-positive bacteriocins

Bio Preservation of Seafood Products

Lactic acid bacteria (LAB) create bacteriocins, which have drawn interest due to their potential as natural food preservatives. In order to improve food safety and shelf life, biopreservation uses microorganisms or their metabolites to prevent spoiling and harmful bacteria [20]. Three primary methods are employed: (1) adding purified or semi-purified bacteriocins, (2) incorporating products fermented with bacteriocin-producing strains, and (3) inoculating foods with LAB that produce bacteriocin [22]. Research has demonstrated the efficacy of bacteriocins and protective cultures against *Listeria monocytogenes* in vacuum-packed cold-smoked fish. For instance, *sakacin P* and *Lactobacillus sakei* cultures inhibited *L. monocytogenes* in cold-smoked salmon [23]; *Carnobacterium piscicola*, even when non-bacteriocin-producing, suppressed *L. monocytogenes* through nutrient competition [24]; nisin, carnocin UI49, and bavaricin A extended the shelf life of brined shrimp [21].

Conclusion

To improve food safety and increase shelf life, bio-preservation makes use of natural microflora and/or their antimicrobial metabolites. The use of regulated or beneficial bacteria and their bioactive substances helps prevent pathogenic germs and spoiling in seafood. This method—known as hurdle technology—is frequently used in conjunction with other preservation strategies to increase microbiological stability, safety, and preserve nutritional

and sensory quality. Temperature control, water activity (a_w), pH, redox potential, chemical preservatives, vacuum or modified-atmosphere packaging, high hydrostatic pressure (HHP), UV treatment, and the use of lactic acid bacteria (LAB) that produce bacteriocins or other antimicrobial substances are common obstacles [11,26].

References

1. Ananou, S., Maqueda, M., Martínez-Bueno, M., & Valdivia, E. (2007). Biopreservation is an ecological approach to improve the safety and shelf life of foods. *Communicating current research and educational topics and trends in applied microbiology*, 1(2), 475-487.
2. J. B. Luchansky, Antonie van Leeuwenhoek, 76: 335 (1999).
3. K., Schmidt, C. Tirado (Eds). Seventh report 1993-1998. WHO Surveillance programme for control of foodborne infections and intoxications in Europe Berlin, 2001, pp 321-333.
4. P.S., Mead, L., Slutsker, V., Dietz, L.F., McCaig, J.S., Bresee, C., Shapiro, P.M., Griffin, R.V., Tauxe, Emerging Infectious Diseases 5: 607-625 (1999).
5. B.J. McCabe-Sellers, S.E. Beattie, Journal of American Dietetic Association **104**, 1708-1717 (2004).
6. Deegan, L. H., Cotter, P. D., Hill, C., & Ross, P. (2006). Bacteriocins: biological tools for bio-preservation and shelf-life extension. *International dairy journal*, 16(9), 1058-1071.
7. Tagg, J. R., Dajani, A. S., & Wannamaker, L. W. (1976). Bacteriocins of Gram- positive bacteria. *Bacteriology Reviews*, 40, 722–756.
8. W.H., Holzapfel, R., Geisen, and U., Schillinger, International Journal of Food Microbiology **24**, 343-362 (1995).
9. R.C., Wigley, In: R.K., Robinson, C.A., Batt, and P.D., Patel, (Eds). Encyclopaedia of Food Microbiology, Academic Press, Oxford, U.K., 1999, pp 2084-2095.
10. R.C., Wigley, In: R.K., Robinson, C.A., Batt, and P.D., Patel, (Eds). Encyclopaedia of Food Microbiology, Academic Press, Oxford, U.K., 1999, pp 2084-2095
11. S. Nath, S. Chowdhury, S. Sarkar, and K.C.Dora, Lactic Acid Bacteria – A Potential Biopreservative In Sea Food Industry, International Journal of Advanced Research, 1(6), 2013, 471-475
12. A. Guder, I. Wiedeman, and H.G. Sahl, Post translationally modified bacteriocins, the lantibiotics. *Biopolymers* 55, 2000, 62-73.
13. I. F. Nes and H. Holo, Class II antimicrobial peptides from lactic acid bacteria, *Peptide Science*, 55(1), 2000, 50–61.
14. R. Bauer, M. L. Chikindas, and L.M.T Dicks, Purification, partial amino acid sequence and mode of action of pediocin PD-1, a bacteriocin produced by *Pediococcus damnosus*, *International Journal of Food Microbiology*, 101(1), 2005, 17–27.
15. T.R. Klaenhammer, Genetics of bacteriocin produced by Lactic acid bacteria. *FEMS Microbiology Reviews*, 12(1-3), 1993, 39-85.
16. R.W., Jack, J.R., Tagg, and B., Ray, *Microbiology Reviews* **59**, 171-200 (1995).
17. A., Gálvez, E., Valdivia, M., Martínez-Bueno, and M., Maqueda, *Journal of Applied Bacteriology* **69**, 406-413 (1990).
18. T. Abee, *FEMS Microbiology Letters* **129**, 1-10(1995).
19. M., Maqueda, A., Gálvez, M., Martínez-Bueno, M.J., Sánchez-Barrena, C., González, A., Albert, M., Rico, and E., Valdivia, *Current Protein and Peptide Science* **5**, 399-416 (2004)
20. Cleveland, J., Montville, T. J., Nes, I. F., & Chikindas, M. L. (2001). Bacteriocins: Safe, natural antimicrobials for food preservation. *International Journal of Food Microbiology*, 71(1), 1–20.
21. Einarsson, H., & Lauzon, H. L. (1995). Biopreservation of brined shrimp by bacteriocins. *Food Research International*, 28(6), 689–694.
22. Galvez, A., Abriouel, H., López, R. L., & Omar, N. B. (2007). *Bacteriocin-based strategies for food biopreservation*. Springer.

23. Katla, T., Møretrø, T., Sveen, I., Aasen, I. M., Axelsson, L., Rørvik, L. M., & Naterstad, K. (2001). Inhibition of *Listeria monocytogenes* in cold-smoked salmon by addition of sakacin P and/or live *Lactobacillus sakei*. *Food Microbiology*, 18(4), 431–439.
24. Nilsson, L., Huss, H. H., & Gram, L. (1997). Inhibition of *Listeria monocytogenes* on cold-smoked salmon by *Carnobacterium piscicola*. *Journal of Food Protection*, 60(9), 1071–1075.
25. Niskänen, A., Nurmi, E., & Lunden, J. (2000). The effect of nisin and sodium lactate on *Listeria monocytogenes* in vacuum-packed cold-smoked rainbow trout. *International Journal of Food Microbiology*, 62(1–2), 91–98.
26. S. Ananou, M. Maqueda, M. Martinez- Bueno, and E. Valdivia, Biopreservation, an ecological approach to the safety and shelflife of foods, Communicating Current Research and Educational Topics and Trends in Applied Microbiology. A. Mendez-Vilas (Ed.), 2007, 475.