ISBN Number
978-81-969527-0-9

MULTIDISCIPLINARY EDITED BOOK 2024

EVOLUTION

EDITOR
Dr. Manohar Kumar Das

www.vinayamresearch.in
Email: vinayamorg@gmail.com

A Review on Bacteriocin, Sources and Industrial Applications

Ayushi Panda[1], Priya Sutaoney[1*], Dhananjay Pandey[2], Priyambada Singh[1], Renu Tripathi[3]

[1]Department of Microbiology, Kalinga University, Naya Raipur, Chhattisgarh, India
[2]Department of Botany, Govt. Naveen Girls College, Surajpur, Chhattisgarh, India
[3]Department of Home Science, Govt. Kamladevi Rathi Mahila P.G. Mahavidyalaya, Rajnandgaon, Chhattisgarh, India

Email : priyasutaoney@gmail.com

Abstract

Bacteriocins are protein or peptide molecules that bacteria produce on their ribosomes that are capable of killing or preventing microbes that are not part of the generating strain. Both Gram-positive and Gram-negative bacteria are capable of creating bacteriocins. However, Gram-positive species of bacteria, especially lactic acid bacteria, produce the majority of bacteriocins. Nowadays consumer demand for less processed food items that are ready to consume has increased organic methods for preserving food. Recent years have seen an increase in scientific interest in bacteriocins, one type of natural antibacterial molecule. Bacteriocins are a better natural alternative to other chemical food preservatives since the human stomach can safely and effectively handle them. According to numerous studies, bacteriocins are employed in a variety of dietary items, notably milk and other dairy-based meat-based items, aquatic organisms, and drinks. They are also employed in cosmetics, pharmaceuticals, and cancer therapy. Another of the bacteriocin with regulatory authorization for use in food is Nisin. The article overviews bacteriocins, sources, and their potential industrial and biotechnological applications.

Keywords: Bacteriocin, Natural peptides, Antimicrobial proteins, Lactic acid bacteria, Pediocin

Introduction:

Bacteria produce bacteriocins, which are ribosomally synthesised natural peptides, in an extremely hostile polymicrobial environment (Daw *et al.*,1996). They share a close relationship with the strain that creates them. These peptides interact and destroy cells that carry distinct surface receptors and prevents comparable or related bacterial strains from proliferating (Cleveland *et al.*, 2001). Gram-positive (GPB) and Gram-negative (GNB) bacteria produce bacteriocins, which have antibacterial activity and may help eradicate other closely related bacterial species. Although bacteriocins are produced by both GPB and GNB, a great deal of bacteriocins applied now for food preservation come from the secondary metabolism of lactic acid bacteria (LAB). These peptides vary in terms of their activity, self- immunity, structure, biosynthesis process, and gene regulation (Kaur *et al.*, 2013). Although lactic acid bacteria possess a longstanding record of secured usage in the food sector, they are great candidates for the synthesis of bacteriocin for biological control of particular bacterial species (Joerger, 2003). The two most popular methods for using bacteriocins for food bio-preservation are inoculating food with bacteriocin-producing strains and adding purified or semi-purified bacteriocins, which either promote a bactericidal effect with/without cell lysis or a bacteriostatic effect inhibiting cell growth (Dicks *et al*., 2018). There are several additional uses for bacteriocins in addition to their potential use in food processing, including those in the cosmetics, biopharmaceuticals, and animal/poultry feed sectors. The shelf life and expiry dates of food, pharmaceutical, and cosmetic items can be extended by using these bacteriocins as antimicrobial film in packaging materials (Nazari *et al*., 2020). Because of their many advantageous characteristics, bacteriocins are particularly intriguing for numerous applications. This review focuses on bacteriocins including their sources, categorization, biosynthesis, mode of action, use, and antibacterial characteristics. These elements are crucial because bacteriocins might be an effective antibiotic replacement, aiding in battling resistant strains of antibiotics (Lozo *et al*., 2021).

Sources of Bacteriocins:

All types of bacteria are capable of secreting bacteriocins. Bacteriocins made by lactic acid bacteria are of special relevance to Gram-positive bacteria. The natural and distinctive antibiotic compounds known as antimicrobial peptides are generated by various bacteria, animals, plants, and insects (Dicks *et al*., 2018). Contrary to popular belief, bacteriocin producers are not exclusively found in the human gastrointestinal tract; rather, they can be isolated from a wide range of environments, including water, soil, animal intestines, and food products. Researcher interest in learning more about non-traditional sources, particularly food items and animals, has increased recently. The gastrointestinal tract contains microorganisms such as *Lactobacillus*, *Enterococcus*, *Streptococcus*, and *Staphylococcus* that produce bacteriocin. These microorganisms may support the skin's role as the body's first line of defense against infections (Dipta *et al*., 2021). These mediator molecules known as bacteriocins can support the immune system in addition to preventing the development of additional bacteria. The dairy sector benefits from using starter cultures that produce bacteriocins to prevent the spread of food pathogens to fermented foods (Lozo *et al*., 2021). The maturity of dairy products can also be accelerated by secondary cultures with bactericidal capability. Due to the sluggish development of bacteria or the creation of bacteriocins at a late stage of the life cycle, the use of purified and concentrated bacteriocins as dietary supplements is preferred to the use of cultures with the ability to create bacteriocins. The most vital Lactic acid bacteria in fruits and vegetables are *Lacticaseibacillus plantarum*, *Limosilactobacillus fermentum*, *Lactobacillus*, *Weissella* and *Pediococcus* (raw fruits and vegetables, carrots, pineapple, and different fruits). *L. plantarum*, and *L. brevis* are the three most prevalent LAB (lactic acid bacteria) strains found in seafood (Joerger, 2003). It has been demonstrated that lactic acid bacteria strains found in fish and prawns have antibacterial activity against other bacteria including foodborne diseases. The probiotic action of bacteriocin-producing microbe in the fish gut has the potential to inhibit the growth of *Aeromonas hydrophila*. In a research, lactic acid bacteria purified from the gut of the fish Mugil cephalus showed inhibitory activity against fish infections as well as human pathogens (Lozo *et al*., 2021).

Correlation Between Antimicrobial Drugs and Bacteriocins:

When compared, antibiotics are generated by several enzyme complexes, whereas bacteriocins are ribosomally synthesized (Balciunas *et al*., 2013). Bacteriocins frequently have bactericidal or bacteriostatic actions on a small range of microorganisms, whereas standard antibiotics have a larger range. Additionally, many bacteriocins are more potent than antibiotics in smaller amounts against their target microorganisms (Gulluce *et al*., 2013). Because they are thought to have been a part of many of the foods ingested since ancient times, bacteriocins are frequently regarded as being more natural. Bacteriocins are inactivated by digestive tract enzymes like trypsin and pepsin, therefore they do not change the microbial community of the gastrointestinal tract (Negash and Tsehai, 2020).

Industrial Applications of Bacteriocin:

Food Industry:

Domesticated animals are reared as livestock in agricultural settings to supply labor and goods including milk, meat, eggs, furs, and leathers. Proteins, lipids, and vitamins are all components that people require on a daily basis and are provided by livestock as food sources (Chikindas *et al*., 2018). To maintain the health of the cattle and increase the economy, increased output, correct nutrition, and hygiene are crucial. Animals on farms are nevertheless susceptible to bacterial and viral infections (Arthur *et al*., 2014). Mastitis, post-weaning diarrhea, arthritis, endocarditis, and septicemia are a few examples of infectious illnesses in cattle that are brought on by bacteria. Milking cattle frequently suffer from mastitis. It illustrates how bacterial infection, chemical burns, or thermal injury can cause inflammation of the mammary gland and the tissue beneath it. Microorganisms like *Staphylococcus aureus*, *Streptococcus dysgalactiae*, and *Streptococcus uberis*, commonly cause mastitis by infecting the milking equipment. Mastitis harms the tissues and ducts that secrete milk and, in severe cases, can be fatal if left untreated (Yan *et al*., 2021). There are restrictions on utilizing antibiotic therapies to address this issue, such as gentamicin, which might cause the growth of microorganisms that are antibiotic-resistant. Post-weaning diarrhoea (PWD) is another infectious condition that can spread often in pigs. PWD is brought on by an *E. coli* infection in pigs' intestines, which results in diarrhea, dehydration, growth retardation in piglets who survive, and mortality without therapies. Numerous studies have looked at the use of antimicrobial compounds or bacteriocin from LAB or other bacteria that exhibit inhibitory power to suppress or kill the infections in livestock as an alternative to antibiotics. However, there are fewer bacteriocins, such as nisin, lacticin, garvicin, and macedocin, that have been demonstrated to be safe for animals to consume (Chikindas *et al*., 2018). Food preservation has made considerable use of bacteriocins. Numerous studies have been conducted on the use of bacteriocins in the food sector, notably in dairy, egg, vegetable, and meat products. A broad-spectrum lactic acid bacteriocin used as a food preservative, pediocin PA-1 has very potent action against

Listeria monocytogenes. The three ways to incorporate bacteriocins into a portion of food to increase its safety are adding a component that has previously been fermented with a bacteriocin-producing strain, or using a bacteriocin-producing culture to substitute all or part of the starter culture in fermented foods to produce bacteriocin in situ (O'Connor *et al*., 2020). Bacteriocins can also be used to improve the sensory aspects of food, such as accelerating proteolysis or resolving the cheese's gas-blowing defect. Another application for bacteriocins is bioactive packaging, a technique that can protect food from external contaminants and increase food shelf life (Yang *et al*., 2014).

Bacteriocin in Cancer Therapy:

Bacteriocins, classified as peptides with cationic properties, preferentially bind to cancerous cell membranes which are negatively charged as opposed to usual cellular membranes, which are neutral in charge (Hoskin and Ramamoorthy, 2008). Furthermore, the preferential attachment of bacteriocins to cancer cells can be attributed to differences in the fluidity of cancerous cell membranes. Cancer cells have more fluid membranes than normal cells, which makes membrane destabilization easy (Molujin *et al*., 2022). According to certain research, bacteriocins are effective against tumor growth when used to treat cancer. Because they may be added to food organically and legally. Bacteriocins could be the best candidate for a potential anti-tumor drug. Several bacteriocins, notably the pore-forming colicin A and E1, inhibited the proliferation of 11 human tumor-cell lines along with a human standard fibroblast line (MRC5) (Chumchalova and Smarda, 2003). RNAase activity colicin E3 and pore-forming colicin U, however, failed to exhibit this potential to restrain growth. Although colicin D, E2, E3, and pore-forming colicin A may decrease the viability of murine leukemia cells P388. Colicin E1 and E3 produce pores lowered v-myc-transformed chicken monoblasts (Fuska *et al*., 1979). Thirty-two among 77 colorectal cancer patients whose feces were used by Bures *et al*., (1986) to isolate *E. coli* produced bacteriocins. Furthermore, bacteriocin-producing *E. coli* was discovered in the feces of 102 of 160 healthy persons confirming that colicins created by intestinal bacteria could potentially prevent colorectal cancer in people. Colicins holds less potential in cancer treatment. Bacteriocin-producing probiotic supplements may also assist in reducing your risk of acquiring cancer. According to a recent study by Joo *et al*., (2012), nisin has the potential to stop cancer cells from proliferating. Last but not least, compared to normal cells, cancer cells have much more microvilli on their membranes, increasing their surface area and making them more susceptible to the binding of antimicrobial peptides. In cell lines examined with bacteriocin, the other bacteriocin, such as rec-pediocin CP2, exhibits noticeably more cytotoxicity and chromosomal DNA damage (Negash and Tsehei, 2020).

Bacteriocin in Woman's Health Care:

Gardnerella vaginalis, *Mobiluncus*, *Staphylococci*, and *Streptococci* were all inhibited in their proliferation by fermenticin HV6b, a class IIa antimicrobial peptide produced by *Lactobacillus fermentum* and isolated from the human vaginal environment (Negash and Tsehai, 2020). Fermenticin has a specific spermicidal and sperm immobilization effect. It is now feasible to make vaginal creams with fermenticin HV6b or *Lactobacillus fermentum*

HV6b that can protect the human vagina against microbial infections and act as contraceptives (Daba *et al*., 2022).

Bacteriocin in Clinical Medicine:

The medical community considered penicillin's antibacterial activities against a number of disease-causing microbes as an important contribution to the treatment of various disorders caused by bacteria or viruses (Yang *et al*., 2014). Numerous novel antibiotics were developed and used in the 1950s and 1960s for the treatment of infectious illnesses. However, after 1985, the discovery of new antibiotics started to decline. Meanwhile, there was a considerable surge in the discovery of germs that were resistant to antibiotics, posing a hazard to people (Schofs *et al*., 2020). People were made aware of this issue and encouraged to look into alternate antimicrobial compounds that may be used to prevent or destroy infections. Many researchers suggested using bacteriocin, a proteinaceous substance instead of antibiotics to treat infectious diseases due to its low toxicity (Daba *et al*., 2022). Bacteriocin, which may be used to treat a number of human health conditions, including mastitis, respiratory tract infections, cancer, infections of the digestive tract, dermatitis, diarrhea, dental caries, respiratory tract infections, and infections of the circulatory system, has been the subject of numerous studies. The bacteriocins nisin, salivaricin, mersacidin, enterocin, gallidermin, epidermin, and fermencin are used to treat infectious infections in people. A Group of bacteriocins called Lantibiotics have immense pharmaceutical uses like blood pressure treatment, inflammation and allergy treatment, skin infection treatment, mastitis infection treatment, herpes treatment, dental caries treatment, and peptic ulcer treatment (Leite *et al*., 2020).

Bacteriocin in Skincare:

The hypothesis that some probiotics may assist in regulating the skin's lipid barrier, immune system, and microbiota, resulting in the preservation of skin, is supported by scientific studies and factual reports (Kang *et al*., 2009). Propionibacterium acnes induced inflammatory acne lesions on patients when treated topically. ESL5, a bacteriocin produced by *Enterococcus faecalis* SL-5, significantly reduces inflammatory lesions and pimples compared to a placebo lotion (Vogel and Spellerberg, 2021).

Conclusion:

The need for discovering and creating a fresh class of antimicrobial medications is increasing due to the rise in multi-drug resistant illnesses in recent years. In order to replace the old antibiotics, many new antibacterial compounds have also been developed. However, it is difficult to find new antimicrobial compounds, thus employing biotechnology to merge two current bacteriocins into an innovative bacteriocin may be a rapid fix. The antibacterial activities of bacteriocins against harmful pathogens are widely established. As a result, bacteriocins' applications in both food and healthcare have gained prominence throughout time. Bacteriocins have been proposed as a food industry solution to the problems of food degradation and food sickness. However, only nisin, produced by *Lactococcus lactis*, and pediocin PA-1, produced by *Pediococcus acidilactici*, are currently commercially accessible bacteriocins. The brands for these goods are Nisaplin TM and ALTA TM 2431, respectively. Fortunately, consumer preferences for lightly processed meals without chemical preservatives are growing, as are legal requirements. Since there is a wide diversity of antibiotic peptides and proteins, it is expected that they will work differently on different target bacteria and under different environmental conditions. It is crucial to identify the appropriate conditions to use any particular bacteriocin as environmental factors determine how effective are these peptides. Despite the fact that it is impossible to predict the size of the market and that research and development expenses would be high, the fact that nisin has found commercial success in certain applications implies that bacteriocin usage is not insurmountably hindered by financial limitations. Further characterizing and testing of medicinally beneficial bacteriocins should be the main focus of future research.

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(Regd., under MSME)
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ISBN 978-81-969527-0-9
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