Bacteriocin: An Ecological Perspective

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Abstract

Bacteriocins, a plentiful, varied group of ribosomally synthesized antimicrobial peptides those are produced by bacteria and archaea. Historically, bacteriocin production have been seen as a key factor in selecting probiotic strains. Bacteriocins can serve as an effective alternative for food preservation and safety. Nisin, w is the only bacteriocin which is widely used as the food preservative. The use of several bacteriocins in food preservation is noted for their role in extending shelf life, serving as additives, and enhancing packaging. Additionally, bacteriocins offer benefits such as boosting the immune system and exhibiting certain anticancer properties.

Introduction

Antimicrobial proteins which are produced by living organisms, are known as antimicrobial peptides due to their comparatively small size. Bacteria produce two types of antimicrobial peptides: the one synthesized by ribosomes (known as bacteriocins); and the other which are not synthesized by ribosomes and lack structural genes that codes for them (Chikindas *et al*., 2018). Bacteriocins are defined as the low molecular weight antimicrobial peptides that are synthesized by the bacterial protein synthesis machinery. They suppress the growth of other bacteria. When bacteriocins produced by a single bacterium inhibit another bacteria of the same species, they have been typically classified as narrow-spectrum bacteriocins. Conversely, if they inhibit bacteria of different genera, they are classified to be the broad-spectrum bacteriocins. Bacterial cells those produce bacteriocins are itself resistant to their own antimicrobial peptides due to specific immunity proteins which are produced by the host cells.

A plenty of Gram-positive, Gram-negative, and archaea bacteria are successfully known to produce bacteriocins. The bacteriocin production was first reported from E. coli in 1925, and named it as "colicins" to exhibit its microbial source (Gratia, 1925). Bacteriocins can also be regarded as "designer drugs" those specifically target the bacterial pathogens. Examples include *Escherichia coli* and certain other members of the family Enterobacteriaceae, those among the few Gram-negative bacteria that produce bacteriocins, as well as lactic acid bacteria and *Bacillus*, which belongs to the Gram-positive group of bacteriocin producers. Bacteriocins possess numerous positive properties that make them highly attractive for various applications. Lactic acid bacteria (LAB) bacteriocins are those which is naturally tolerant to high thermal stress and are active over a wide pH range. These antimicrobial peptides are colorless, odorless, and tasteless, enhancing their potential usability. Additionally, due to their proteinaceous nature they can be easily degraded by proteolytic enzymes. As a result, fragments of bacteriocin does not persist long in the environment, reducing the likelihood of those target strains which interact with the degraded antibiotic fragments.

Mode of Action

Bacteriocins has the ability to inhibit the growth of target organisms through several mechanisms. Thus, these mechanisms can be broadly categorized as those which primarily act on the cell envelope and those which affects protein production and gene expression within the cell. Certain bacteriocins, particularly the one which target Gram-positive bacteria, acts by attacking the cell envelope. Class I bacteriocins, for example, inhibit lipid-II present on the cell membrane, hence disrupting peptidoglycan synthesis. Certain other bacteriocins create pores that disrupt the membrane integrity, leading to inhibition or killing of their target bacteria.

It has been clearly demonstrated that certain members of class I which are also called lantibiotic bacteriocins, like nisin, exhibit a dual mode of action. These bacteriocins can bind to lipid-II, which is crucial for transporting the peptidoglycan subunits from the cytoplasm to the cell wall. This binding disrupts correctly the cell wall synthesis, ultimately leading to death of cells. Additionally, they utilize lipid-II as a docking molecule which are used to initiate membrane insertion and pore formation which will lead to cell death. In the case of lantibiotics which have two peptides, such as lacticin 3147, the dual activities are typically distributed among those peptides. For instance, mersacidin does not form the spores but have the lipid II binding activity (Negash *et al.,* 2020).

A few bacteriocins, through their enzymatic actions exhibits the antimicrobial properties. For example, colicin E2 displays DNase activity, colicin E3 exhibits RNase activity, and megacin A-216 demonstrates phospholipase activity against target organisms. Class II peptides possess a helical structure which is amphiphillic that enables them to insert into the target cell's membrane, causing depolarization and subsequent cell death. In contrast, large bacteriolytic proteins, such as lysostaphin which is the class III bacteriocins, act on the cell wall of Gram-positive targets directly, resulting in the death of the target cell.

Applications in food preservation

Bacteriocins have greatly employed in food preservation. Their application in the food industry has been thoroughly researched, especially concerning eggs, vegetables, dairy products and meat. Microorganisms inhabit living surroundings such as soil, sea, river, and air.16 A few of them have the potential to contaminate food and drink, which would cause it to spoil. In the food sector, food spoilage is a constant source of worry since it can lead to foodborne illnesses in humans and ruin the flavor of food and beverages.

Chemical additives were used adversely to preserve food, but due to their toxicity, they have negative impact on human health. Due to this worry, there is a growing market need for natural food preservation solutions free of chemicals in order to prevent health issues. The process of extending the food's shelf life by employing non-pathogenic microorganisms or the metabolites they create is known as "bio-preservation." The most amazing bio-preservative used in food factories inorder to stop the food from spoiling are called bacteriocins, or BLIS, encompass nisin, pedicin, enterocin and leucocin.

Nisin in food preservation

Nisin is crucial in preventing the food from spoilage because it can eliminate or suppress numerous foodborne pathogens across a variety of foods, both in liquid and solid forms. With FDA permission, nisin is utilized in more than 48 countries, and NisaplinTM is marketed as a natural food preservative (Zhang *et al.,* 2020). It works well in a variety of food systems, preventing the growth of numerous Gram-positive bacteria, including numerous significant foodborne diseases like Listeria *monocytogenes.* It is mostly found in dairy and canned foods, and it works particularly well when used to make processed cheese and spreads because it guards against organisms that generate spores and are resistant to heat, like *Bacillus* and *Clostridium.*

Pediocin in food preservation

It is used as a food preservative. Pediocin PA-1 is a broad-spectrum lactic acid bacteriocin with very potent activity against Listeria *monocytogenes.* There are two methods for applying pediocin to food: applying it directly to the food matrix at the ideal concentration or using the *in-situ* method, which involves inoculation of food matrix with strains of Pediococcus, Enterococcus, or Lactobacillus and also with the best control to produce pediocin for preventing the growth of pathogens in food. However, there are certain drawbacks to directly adding pediocin to food, including modifications to its solubility and amphiphilic character. Pediocin is essential in preventing spoilage in both food and beverage. Pediocin PA-1, produced by *Pediococcus acidilactici* MCH14, has been shown to have antimicrobial effects against *L. monocytogenes* and *C. perfringens*, thereby extending the shelf life of fermented meat products.

Enterocin in food preservation

Essentially, there are two approaches to employ enterocin as a food preservative: either add purified or semi-purified enterocin in food to stop it from spoiling, or manufacture it in situ by introducing enterocin-producing strains to food.52. When making dairy products like cheeses, the Enterococcus species are carefully employed as an artisanal starting culture. 51 certain enterococcal strains have the capacity to create enterocin, which can delay the shelf life of food by inhibiting the growth of other foodborne diseases. The food business is undoubtedly benefiting from the in situ bacteriocin synthesis, since the enterococcal strain may be utilized as both a food preservative and a starting culture.

Leucocin in food preservation

Leucocin, which is a class IIa bacteriocin produced by *Leuconostoc* spp., has been shown to have antimicrobial effects. Specifically, Leucocin A, which is produced by *Leuconostoc gelidum* UAL187, inhibits the action of *L. monocytogenes*, aiming in the preservation of milk products, fresh meat, and sausages. In milk preservation, leucocin K7 obtained from *Leuconostoc mesenteroides* K7 has demonstrated inhibitory activity against *L. monocytogenes*, with a minimum inhibitory concentration (MIC) of 28 µg/mL. Additionally, *L. innocua* CIP 80.11, found in Spanish-style dry fermented sausages, has been shown to be suppressed by leucocin B-KM432Bz produced by *Leuconostoc pseudomesenteroides*.

Bacteriocins can also enhance food quality and sensory properties, such as by accelerating proteolysis or preventing gas blowing defects in cheese. Other use of bacteriocins is in bioactive packaging, which helps to protect the food from external contamination, thereby enhancing food safety and extending shelf life.

Conclusion

The antibacterial properties of bacteriocins against harmful microorganisms are well established. Because of this, bacteriocin uses in food have drawn more and more attention over time. In the food sector, bacteriocins have been suggested as a remedy for food illnesses and deterioration. Pediocin PA-1, generated by *Pediococcus acidilactici*, and nisin, produced by *Lactococcus lactis*, are the only bacteriocins that are now produced commercially; they are sold under the brands Nisaplin TM and ALTATM 2431, respectively. Fortunately, there is a trend toward increased customer preferences and regulatory requirements for minimally processed foods free of artificial preservatives. This presents a significant chance by proving that bacteriocins could be used widely in the food business.

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