Review Article

Review on Application of Antibacterial Peptides in Food Preservation

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ABSTRACT

Scope and Approach: This review will outline the characteristics, functions, qualities, kinds, and mechanisms of action of AMPs and how they are used in food preservation.

Insight: With evolution of several mutant strains of microorganisms, a rise in the microbial resistance to effective treatments have been observed. Antimicrobial proteins and peptides are generally found in animals, plants, and microorganisms and are of great interest to medicine, pharmacology, and the food industry. These peptides are capable of inhibiting pathogenic microorganisms. They possess the ability to attack parasites, while causing little or no damage to the host cells. Antimicrobial peptides (AMPs) are a class of small peptides that widely exist in nature and they are an important part of the innate immune system of different organisms. AMPs have a wide range of inhibitory effects against bacteria, fungi, parasites and viruses. To synthesise anti-microbial peptides - chemical, enzymatic and recombinant techniques are used. Bacteriocins are particularly grouped as proteins or peptides produced by bacteria. This paper will systematically represent the anti-microbial peptides having the ability to act as natural preservatives and their application in food preservation (i.e. bio- preservation).

Keywords: Antimicrobial peptide, food safety, spores, bacteriocin, food preservation.

INTRODUCTION

A very important aspect of the foodindustry is the preservation technique which involves certain processes which increases the shelf life of the food. Approximately 1.3 billion tons of food is wasted every year. This represents around 1/3 of all food generated for human consumption is lost due to spoilage which results in a huge economic loss. Contamination can occur at any point during processing, storage, transport or distribution. To avoid spoilage in most cases chemicals are used for preservation. Chemical use can bring about deterioration of human health and lower down the nutritive value of food. Chemicals like sodium nitrate and potassium bromate have shown carcinogenic properties. That's where antimicrobial peptides come into play with an edge over the chemical preservatives due to their ability to preserve food without degrading its qualityand minimizing the toxic effects. It is crucial to find microbes for bio preservation to enhance food safety and standardization with the aim to reduce the rising levels of food spoilage.

History

Alexander Fleming is believed to have discovered the first antimicrobial peptide. In the late 1920s, Fleming identified Lysozyme as an antimicrobial peptide and laid the foundation of modern innate immunity. Bactericidal activities were observed by Fleming when he treated bacterial culture plates of a person having acute coryza. Therefore he termed it as lysozyme activity because of its capacityto 'lyse' bacterial cells. At first the structures of two AMPs named cecropinsA and B were characterized from the haemolymph of *Hyalophora cecropia* (cecropia silk moth). Tyrocidine, an antimicrobial peptide, was discoveredto have activity against both Gram-positive and Gram-negative bacteria in 1941. Defensin, an antibacterial peptide, was first isolated from rabbit leukocytes in 1956. Xenopus laevis produced the first anionic antimicrobial peptide in 1990.

Nisin

One example of an antibacterial proteininvolved in food preservation is called Nisin. Nisin is a natural peptide produced by certain strains of the bacteria Lactococcus lactic. It has been used as a food preservative for over 50 years and is recognized as safe by regulatory agencies such as the U.S. Food and DrugAdministration (FDA).

Nissin has strong antibacterial propertiesand is effective against a wide of harmful bacteria such as Listeria, Staphylococcus and Streptococcus. It works by disrupting the cell membranes of these bacteria, preventing their growth and multiplication.

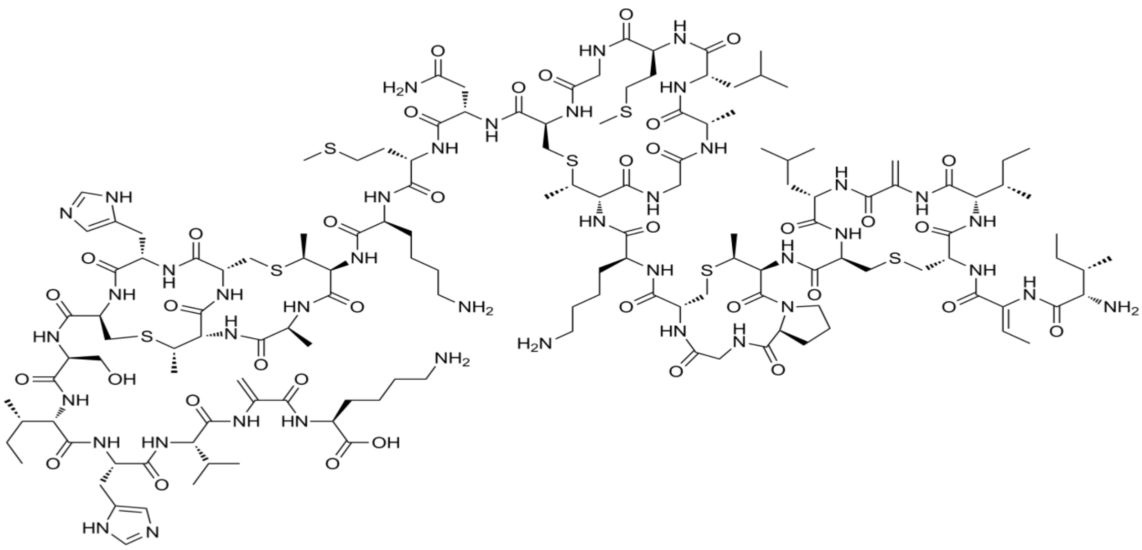
Nisin is commonly added to a variety of foods including cheese, meat, canned foods, and beverages. Its use as a preservative allows for longer shelf-life and helps to prevent spoilage and foodborne diseases.

Pediocins

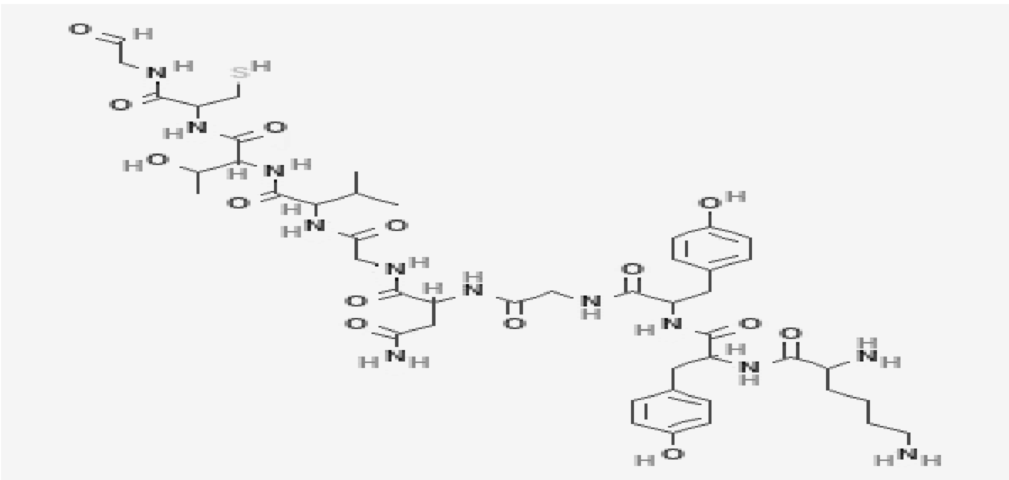
Pediocins are classified as small unmodified peptides belonging to subclass IIa of bacteriocin. They have low molecular weight (2.7-17 kDa) and are produced by some Pediococcus bacteria. Pediocins show a wide range of antimicrobial activity against Gram- positive bacteria which are particularly pathogenic in nature such as Listeria monocytogenes by forming pores in the membrane of the cytoplasm. It is capable of exercising it's antimicrobial activity at very low temperatures (-70 C) and are resistant to heat. They can withstand the action of RNase, DNase, lipase and lysozyme. The most common pediocins which are hydrophobic and heat resistant are obtained from the strains of *P. acidilactici*, *P. damnosus*, and *P.pentosaceus*.

Sources of Antimicrobial Peptides

Sr. No	Source of Antimicrobial Peptide	Name of Antimicrobial Peptide	Function
1.	Insect	Cecropin A	It has promising action againstfungus.
		Attacins	They constitute an active formof inducible immune protein P5.
		Pyrrhocoricin	It promotes ATPase activity.
		Defensins	Bactericidal activity againstmulti-drug resistant strains of Pseudomonas.
2.	Milk	β-casein	Production of extracellularenzymes to kill pathogens
3.	Amphibians	Magainins	Cidal activity against gram- positive and gram-negative bacteria, fungi and protozoa.
4.	Bacteria	Pediocin, Nisin	Antibacterial activity against pathogenic bacteria such as Listeria monocytogenes



Structure of Nisin



Structure of Pediocin

Mechanism of Antimicrobial Peptides

The mode of action in antimicrobial peptides generally follows the interactions which happens between the peptides and the cellular membranes, constituents andits composition. Membrane permeability plays a major role in these processes because they can lyse the cells on entering. Few models have been shown for better understanding of the mechanism ofantimicrobial peptides.

Barrel-Stave model

Arrangement of antimicrobial peptides around the bacterial membrane in the formof a bundle occurs in this model. The first step of this model involves peptide binding with the membrane as it happens in a monomer. The phospholipid layer of bacterial membrane which consists ofhydrophobic chains of fatty acids attaches with the positive terminal of the peptide. Clustering of peptides lead to the pore formation. In the final stage, the bacterial cell dies.

Carpet model

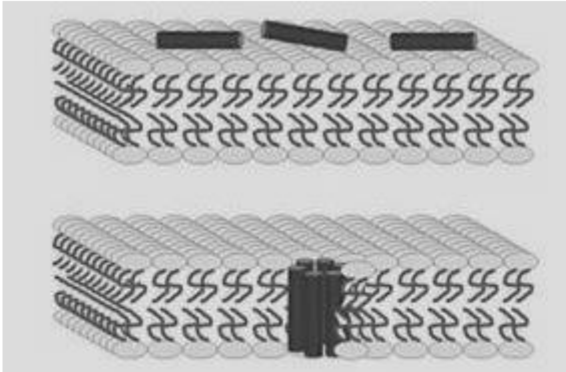
It is also known as detergent model. In thismodel, a parallel accumulation of peptides around the microbial membrane is observed which leads to membrane destabilization. When the clustered peptides gain maximum intensity, the lipid membrane of bacteria gets penetrated by the molecules. This results in the disruption of microbial membrane.

Aggregate model

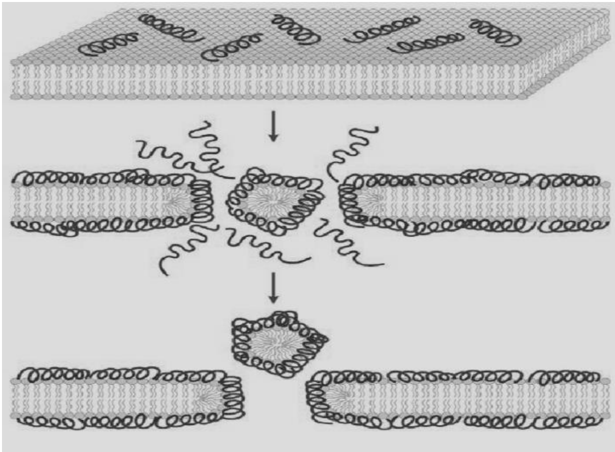
As a result of electrostatic interaction between the hydrophilic regions of the peptides and the phospholipid layers of the membrane, the peptides are observed toget attached in this model. Aggregates with sphere like structure contains water molecule which release fluids resulting in membrane disruption. Antimicrobial peptides inhibit translational and transcriptional processes by binding onto the cell wall, nucleic acids, etc. They interact with lipid bilayers and form pores.

Bacterial Spores inactivated by AMPs

Bacterial spores are widely distributed in the environment and can contaminate food at various stages of manufacturing. Due to their adaptability, spores and spore-forming bacteria must be controlled in food since their survival in processed foods and subsequent germination underfavourable conditions would reduce shelf life, result in food deterioration, and cause food poisoning. Foodborne infections caused by toxin production, particularly in canned goods, in addition to food deterioration. For example, the emetic, exo, and neurotoxins produced by Bacillusand Clostridium species are known to cause certain symptoms brought on by eating contaminated foods. After the germination of the spores and throughout growth, vegetative cells typically produce bacterial toxins in Clostridium and Bacillus sp. Therefore, it is sufficient toprevent the spores of certain bacteria genera from germinating in foods rather than completely eradicate them in order to ensure food safety. Food products can be heated to a certain temperature to eliminatethe spores but that is always not beneficial.Some food products are heat-sensitivewhich means if they are exposed to high temperatures, their quality may be degrade and the nutritious value can come down.So that's where antimicrobial peptides help us. AMPs are added directly onto the food so that they can synthesize certainenzymes or generate some processes which would inhibit the pores without actually reducing the nutritious value.



Barrel-stave model



Carpet model

Benefits of AMPs

Increase in health problems depicts thatfood preservation is a serious issue which need to be resolved. The bacteriocin is a very safe option due to the following reasons –

a) They do not actively interact on coming in contact with protease enzyme.

b) They are resistant to heat and can maintain pH.

c) They do not have eukaryotic cells.

d) They are capable of destroying awide range of food spoiling pathogens,

e) They are very susceptible to be used for their dual nature of being protease sensitive in the gastrointestinal tract but very efficient in pathogen handling.

Limitations and drawbacks

Isolation of several number of AMPs have taken place from various natural sourcestill date, but very few among them have proven to be suitable for commercial use. The reason behind the successes of only few naturally occurring peptides when used commercially is due to the – (a) toxic effects experienced by the host cell, (b) incapable to remain active at physiological concentrations of salt, (c) very sensitive to the action of protease degradation due toits short half-life, (d) appropriatetechniques are not available for focusingon the AMPs delivery at the exact site, (e) change in pH.

CONCLUSION

With time the microbial population is gaining resistance against the pre-existing antibiotics. The AMPs act as remedial agents due to their ability to slow down therate at which microbes build resistant against the existing antibiotics. The AMPs can be used alone or they can be combinedwith selected conventional antibioticsagainst the specific microbial strains which are known to be drug resistant. With proper knowledge about the mode of action of AMPs, new synthetic AMPs can be designed which might be used to target particular strains of microbes. Furtherdevelopment may lead to the creation of certain AMPs to minimize the cytotoxiceffects and resist protease activity.

Future Aspects

Huge amounts of food are lost globally due to the spoilage by pathogenic microorganisms. The existing techniquesto control the food wastage has become a challenge that needs to be resolved. The AMPs can have a great impact on this global issue. To witness the absoluteability of the AMPs, further studies needto be conducted relating to thedevelopment of AMPs to have a better understanding about their activities and interactions. Various biological andchemical procedures can used to assess thestructures and functions of the AMPs. Solid Phase Peptide Synthesis can be very effective. AMPs can be used as therapeutic agents for their ability to prevent microbialgrowth in food, but they can have cytotoxic effects which maybe harmful for humans. Therefore, there is a need to isolate and design few particular AMPs in which the toxins would be absent and some desirable characteristics can be incorporated. Nisin and Pediocin are the only two antimicrobial peptide that have been used in food preservation, so there is a need to isolate and characterize other AMPs which might have similar influence in the field of food preservation.

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