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BACTERIOCINS: A SAFE BIOPRESERVATIVES

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ABSTRACT

The growing threat of antimicrobial resistance has intensified the search for alternatives to conventional antibiotics. Antimicrobial peptides (AMPs) are natural bioactive molecules with broad-spectrum activity against pathogenic microorganisms. Among these, bacteriocins produced by lactic acid bacteria (LAB) are recognized as safe and effective natural food preservatives. They inhibit microbial growth primarily through membrane disruption. Well-known bacteriocins, such as nisin and pediocin, are widely used in food preservation. Owing to their antimicrobial efficacy, safety, and minimal effects on food quality, AMPs and bacteriocins offer promising solutions for enhancing food safety and combating antimicrobial resistance.

KEYWORDS: Antimicrobial peptides, antimicrobial resistance, bacteriocins, food preservation, lactic acid bacteria

INTRODUCTION

The rapid emergence and global spread of antimicrobial resistance (AMR) has become a serious threat to public health and food safety. The widespread and indiscriminate use of antibiotics in human medicine, veterinary practice, and food production has accelerated the evolution of multidrug-resistant microorganisms, reducing the effectiveness of conventional antimicrobial therapies. Therefore, there is an urgent need to find safe, effective, and sustainable alternatives to antibiotics that can control pathogenic microorganisms while minimizing the development of resistance. Among the various alternatives explored, antimicrobial peptides (AMPs) have attracted considerable attention because of their broad-spectrum antimicrobial activity, rapid mode of action, and lower propensity for inducing resistance. These naturally occurring peptides are an essential component of the innate immune system and are widely distributed across bacteria, plants, insects, amphibians, marine organisms, and mammals. Most AMPs are small, cationic, amphipathic molecules that exert their antimicrobial effects by disrupting microbial cell membranes or interfering with essential intracellular processes. Their activity extends against a wide range of microorganisms, including Gram-positive and Gram-negative bacteria, fungi, viruses, and certain parasites.

This article reviews the characteristics, classification, mechanisms of action, and applications of antimicrobial peptides, with particular emphasis on bacteriocins produced by lactic acid bacteria. It also highlights their potential as natural alternatives to conventional antibiotics and chemical preservatives in addressing the growing challenge of antimicrobial resistance while promoting safer and more sustainable food preservation strategies.

ANTIMICROBIAL PEPTIDES: AN ALTERNATIVE TO ANTIBIOTICS

It is the fate of all antibacterials to be fought off by the pathogens they target. The continuous and indiscriminate use of antibiotics has resulted in multi-resistant bacterial strains all over the world. The alarming emergence of resistance among bacteria has led the World Health Organization (WHO) to announce antimicrobial resistance as a main concern (WHO, 1995). For the food microbiologist, there is no doubt that it is necessary to avoid the distribution of bacteria with mobilizable antibiotic resistances (WHO, 1995). There is a lack of efficient and safe preservatives in the food industry. Over the years, massive use of common food safety barriers led to the development of resistance by various food microorganisms. Enteric bacteria are especially tolerant to adverse environmental conditions such as low pH and high salt concentrations, which limits efficiency of some preservation methods.

Consumers demand for natural, preservative-free and minimally processed foods and worldwide concern regarding disease outbreaks caused by food-related pathogens have created a need for development of new classes of antimicrobial agents. The priority for the next decades should be focused in the development of alternative drugs and/or the recovery of natural molecules that would allow the consistent and proper control of pathogen-caused diseases. Ideally, these molecules should be as natural as possible, with a wide range of action over several pathogens and easy to produce. The discovery of two classes of antimicrobial peptides, non-ribosomally synthesized and ribosomally synthesized peptides, of wider distribution present in bacteria, insects, amphibians, crustaceans and other eukaryotes and plants - provided a new therapeutic strategy to fight microorganisms. These are termed "natural antibiotics", because they are active against a large spectrum of microorganisms, including bacteria, filamentous fungi, protozoan and metazoan parasites (Liu *et al.*, 2000; Vizioli and Salzet, 2003). AMPs are often produced as closely related multi-member families that may vary only in a few amino acid residues (Nicolas and Mor, 1995). Despite the enormous variety of sequences and structures, AMPs possess certain common features. They are usually made of less than 50 amino acids, bear a net positive charge due to an excess of basic (often lysine and/or arginine) over acidic residues, and contain about 50% hydrophobic amino acids. They often fold into 3-dimensional amphipathic structures stabilized by cysteine disulphide bridges. Linear peptides lacking cysteines tend to fold, only upon contact with membranes, into a variety of amphipathic helices, pleated-sheets, loops, or less defined extended structures in which positively charged hydrophilic domains are well delineated from hydrophobic domains. These features seem to be the main factors affecting their known and diverse biological activities.

BACTERIOCINS FROM LAB

Lactic acid bacteria (LAB) are industrially important organisms because of their fermentative ability as well as health and nutritional benefits. Moreover, they are generally regarded as safe for incorporation into food products (Gasser, 1994). The ability of lactic acid bacteria to inhibit the growth of various Gram positive and/or Gram-negative bacteria is well known and attributed to the production of organic acids such as lactic acid and acetic acid, hydrogen peroxide, bacteriocins, bacteriocin like substances and possibly biosurfactants. Bacteriocins are ribosomally synthesized, extracellular peptides/proteins produced by bacteria, exhibiting bacteriostatic or bactericidal activity against closely related bacteria. Bacteriocin producing species have been identified among all the genera that comprise the LAB including *Lactococcus*, *Lactobacillus*, *Pediococcus*, *Leuconostoc* and *Carnobacterium* (Klaenhammer, 1998). Consumers have been consistently concerned about possible adverse health effects from the presence of chemical additives in their foods. As a result, consumers are drawn to natural and “fresher” foods with no chemical preservatives added. This perception, coupled with the increasing demand for minimally processed foods with long shelf life, has stimulated research interest in finding natural but effective preservatives such as bacteriocins. Bacteriocins, produced by LAB, may be considered natural preservatives or bio preservatives that fulfil these requirements. Klaenhammer (1993) observed that bacteriocins might take many forms and elicit bactericidal activity beyond species that are closely related to or confined within the same ecological niche. Bacteriocins are ribosomally synthesised, and because of their proteinaceous nature, bacteriocins are synthesised via a common ribosomal biosynthesis mechanism involving transcription and translation. Bacteriocins kill their target by causing dissipation of Proton Motive Force (PMF) and leakage of small intracellular substances through pore formation in the cell membrane of sensitive bacteria. Most characterised bacteriocins are heat stable, nontoxic and susceptible to degradation by proteolytic enzymes present in the gastrointestinal tract (Abrioul *et al*., 2003).

Based on common elements, bacteriocins are classified into four well defined classes (Klaenhammer, 1988).

1. Class I bacteriocins (lantibiotics): These are post-translationally modified to contain amino acids such as lanthionine and β-methyllanthionine and several dehydrated amino acids so they are called lantibiotics. They are further divided into two subgroups A and B, based on structural features and their mode of killing.

a. Type A lantibiotics: Leader peptides are cleaved by a serine protease. They kill the target cell by depolarising the cytoplasmic membrane. Type A lantibiotics are linear and larger than type B lantibiotics and range in size from 21 to 38 amino acids. Nisin is the best-known and best-studied Gram-positive bacteriocin and has been approved as a food additive by the FDA.
b. Type B lantibiotics have a more globular secondary structure and are smaller than type A (the largest is 19 amino acids in length). Leader peptides are cleaved by an ABC transporter. Type B lantibiotics function through enzyme inhibition. Thus, mersacidin interferes with cell wall biosynthesis.

2. Class II bacteriocins (small heat-stable non-lantibiotics): These are small, heat-stable, non-lanthionine-containing peptides, not post-translationally modified, ranging in size from 30 to 60 amino acids, and they are usually positively charged at neutral pH. They are divided into four subgroups:

I. Class IIa (pediocin-like bacteriocins with a strong antilisterial effect) is the largest group, and its members are distinguished by a conserved amino-terminal sequence YGNGV[YSTH]C[X4]C and a shared strong inhibitory activity against *Listeria*. Because of their effectiveness against the food pathogen *Listeria*, class IIa bacteriocins are currently attracting much interest as potential natural and non-toxic food preservatives. Like type A lantibiotics,

   Class IIa bacteriocins act through the formation of pores in the cytoplasmic membrane. Examples include Pediocin PA-1 and pediocin AcH (*Pediococcus acidilactici)*, sakacins A and P (*L. sakei*), leucocin A *(Leuconostoc gelidum)*, enterocins A and P (*E. faecium*), and carnobacteriocin (*Carnobacterium sp*.).

   Class IIa bacteriocins (pediocin-like bacteriocins) are active against *Listeria* spp., and comprise the largest and most studied group.

II. Class IIb (bacteriocins whose activity depends on the complementary activity of two peptides). These form pores composed of two different peptides in the membrane of their target cells. This group includes lacticin F and lactococcin G.

III. Class IIc (sec-dependent secreted bacteriocins) includes bacteriocins that are sec-dependent, such as acidocin B and enterocin P, which can be included in both class IIa and class IIc.

IV. Class IId includes other bacteriocins such as lactocin A and B.

***3. Class III bacteriocins*:** These are large heat-labile proteins. They include helveticins J and V and lactacin B.

***4. Class IV bacteriocins (cyclic peptides)*:** These require lipid or carbohydrate moieties for their activity. Little is known about the structure and function of this proposed class. The group has yet to be confirmed by purification and biochemical characterization. These bacteriocins include leuconocin S and lactocin 27.

Interest has been resurgent for research on bacteriocins in the last few decades for application as natural biopreservatives. Bacteriocins are non-toxic because of their inactivation by human digestive tract proteases. In addition, no flavor or textural changes are associated with their use as biopreservatives in different food systems. Bacteriocins have attracted scientific attention in recent years not only as promising safe and natural food additives but also as potential chemotherapeutic agents. The original and most intensively studied, lantibiotic, "nisin" (a bacteriocin produced from *Lactococcus lactis*) has a long record of safe use. It has been approved by US Food and Drug Administration FDA (Food and Drug Administration, 1988) and is one of only few bacteriocins to have been applied commercially. It has antibacterial activity against many Gram-positive bacteria including food-borne pathogens such staphylococci, bacilli, clostridia and mycobacteria. Currently it is used as food preservative in more than 40 countries worldwide (Delves-Broughton, 1990). The use of pediocin PA-1 is covered by several Europe and US patents (Boudreaux and Matrozza 1992; Vandenbergh *et al*., 1989). Both nisin and pediocin PA-1 have applications in dairy and canned products. Recently Hidalgo (2007) showed that Enterocin AS-48, a bacteriocin from *Enterococcus faecalis* AS-48 is very stable with respect to pH and temperature and has a broad action spectrum against numerous bacteria, including pathogenic bacteria transmitted by food, which makes it a suitable molecule for use as a biopreservatives.

CONCLUSION

Antimicrobial peptides, particularly bacteriocins produced by lactic acid bacteria, have emerged as promising natural alternatives to conventional antibiotics and chemical food preservatives. Their broad-spectrum antimicrobial activity, safety, heat stability, and susceptibility to degradation by digestive enzymes make them attractive candidates for food preservation and therapeutic applications. With the rapid rise of antimicrobial resistance and increasing consumer demand for minimally processed, preservative-free foods, bacteriocins offer an effective and sustainable approach to enhancing food safety and quality. Although nisin and a few other bacteriocins have already achieved commercial success, continued research is needed to discover novel antimicrobial peptides, improve their production, and expand their applications. Overall, antimicrobial peptides represent a valuable strategy for combating foodborne pathogens and addressing the global challenge of antibiotic resistance.

REFERENCES

Abriouel, H., Valdivia, E., Martinez-Bueno, M., Maqueda, M., and Galvez, A. (2003). *Journal of Microbiological Method,* 55: 599-604.

Bourdreaux, D.P. and Matrozza, M.A. (1992). Method composition for extending the shelf life of processed meats. United States Patent 5137319.

Delves-Broughten, J. 1990. Nisin and its uses as a food preservative. *Food Technology,* 44: 100-117.

Food and Drug Administration. 1988. Nisin preparation: Affirmation of GRAS status as a direct human food ingredient. Food and Drug Administration, Federal Register, 53: 11247.

Gasser, F. (1994). Bull. Ins. Pasteur, 92: 45-47

Klaenhammer, T.R. (1993). Antimicrobial and bacteriocin interactions of the lactic acid bacteria. In: Proceedings of the 6th International Symposium on Genetics & Industrial Microorganisms (H. Heslot, J. Davies, J. Florent, L. Bobichon, G. Durand and L. Penasse, eds). *French Society of Microbiology,* 1: 433-445.

Klaenhammer, T.R. (1998). *Biochemie.*, **70:** 337-349.

Liu, Y., Luo, J., Xu, C., Ren, F., Peng, C., Wu, G and Zhao, J. (2000). Purification, characterization, and molecular cloning of the gene of a seed-specific antimicrobial protein from pokeweed. *Plant Physiology,* 122: 1015-1024.

Nicolas, P and Mor A. (1995). Peptides as a weapon against microorganisms in the chemical defense system of vertebrates. *Annual Review Microbiology*, 49: 277–304.

Vendenbergh, P.A., Pucci, M.J., Kunka, B. S. and Vedamuthu, E.R. (1989). Method for inhibiting *Listeria monocytogenes* using bacteriocins. European Patent Application 89101125.6.

Vizioli, J, and Salzet, M. (2003). Antimicrobial peptides: new weapons to control parasitic infections? *Trends in Parasitology,* 19: 32-40.

WHO (1995) The use of essential drugs. Sixth report of the WHO expert committee. WHO Tech. Rep. Ser.no. 850. Rome: WHO.

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