DOI: 10.55522/jmpas.V13I6.6758 ISSN NO. 2320 – 7418

International peer reviewed open access journal

Journal of Medical Pharmaceutical and Allied Sciences

Journal homepage: www.jmpas.com CODEN: JMPACO

Review article

Bacteriocin: as a promising Bio-preservative for food products

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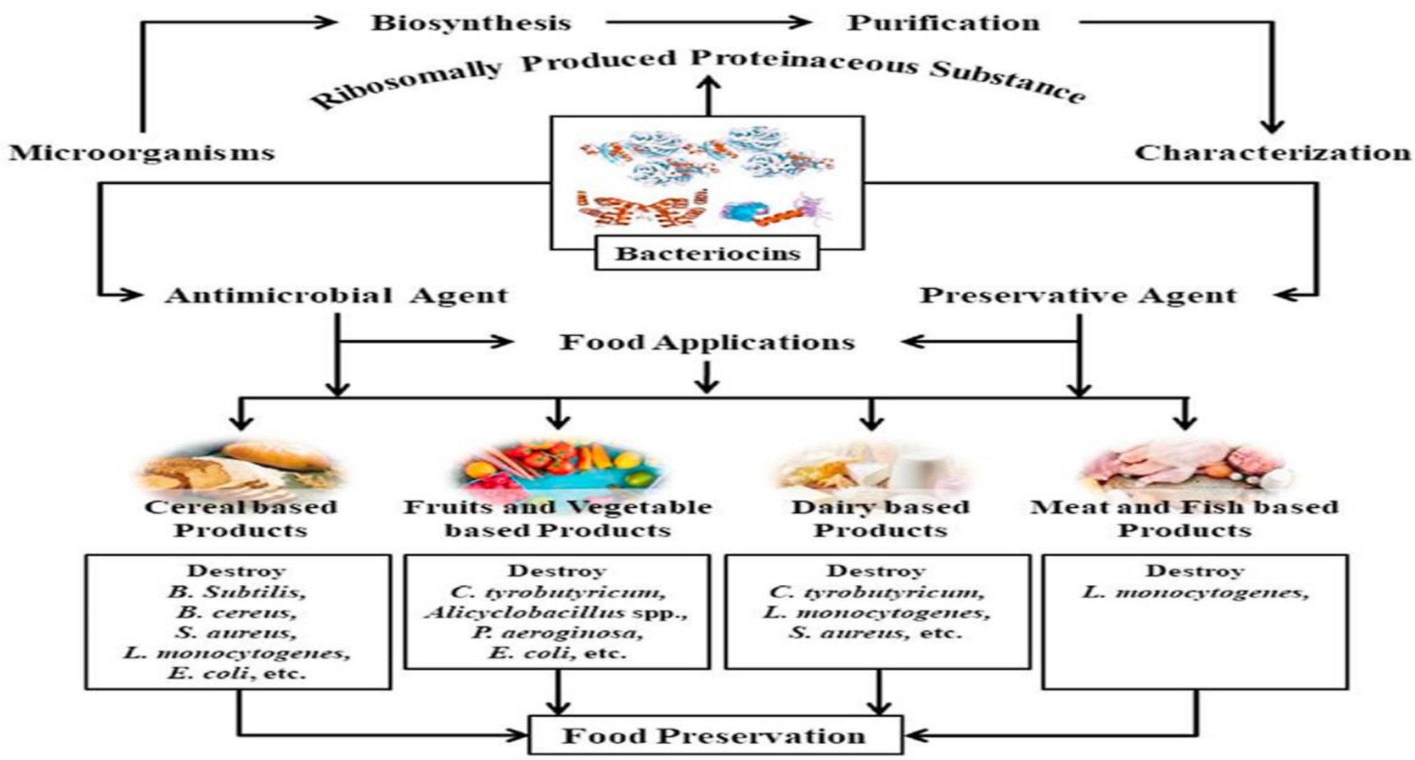
Received - 11-11-2024**, Revised** - 27-11-2024, **Accepted** - 14-12-2024 **(DD-MM-YYYY)**

Refer This Article

Garima Verma, Rishabh Chitranshi, Anil Pandey, Hem Chandra Pant, Sunil Kumar, Anam Chaudhary, Parul Saini, 2024. Bacteriocin: as a promising bio preservative for food products. Journal of medical pharmaceutical and allied sciences, V 13 - I 6, Pages - 6909 – 6915. Doi: https://doi.org/10.55522/jmpas.V13I6.6758.

ABSTRACT

Owning to their high nutritional value, high moisture content, and acidic makeup, dairy products are highly perishable. To keep these goods safe and of high quality, they need to be well preserved. Failure to do so results in disease outbreaks and human sickness. These food-borne diseases are major, expensive public health hazards on a global scale. Therefore, proper manufacturing methods, good hygienic standards, etc., are frequently used in the food sector to maintain the quality and safety of goods. There are numerous methods of preservation, starting with low temperature methods such as freezing, refrigeration, etc. and moving up to thermal methods like pasteurization, sterilization, and chemical preservation. The use of contemporary preservation methods including biopreservation, irradiation, and hurdle technology is also widespread today.



A fundamental method of food preservation is bio-preservation, which Utilize of the antibacterial properties of naturally occurring organisms and their metabolites and is able to rationally and in harmony with ancient methods of food preservation and contemporary demands for food safety and quality. The effectiveness of biological antibacterial systems, such as lactic acid bacteria (LAB) and their metabolites such as bacteriocins, is a key component of the biopreservation strategies used to preserve a variety of foods. The amphiphilic properties of some bacteriocin lead to pore development, which disrupts the targeted organisms' cell membranes. As we are all aware, occasionally.

Keywords: Bacteriocin, Antimicrobial peptides, Bio-preservation, Food & dairy industries.

INTRODUCTION

Currently, the shelf-life of a product, which is typically shortened by pathogens, is the main concern in the food sector. Several techniques, including heating, freezing, and chemical preservatives, are utilized to treat these infections. However, recently, bio-preservation techniques, which use bacteriocins specifically, have emerged as a result of advancements in the field of food preservation [25].

Since the times of Robert Koch and Louis Pasteur, environmental microorganisms have been under scientific supervision [39]. In 1929, Alexander Fleming released the antibiotic penicillin, which made it possible to fight particular pathogens [21]. The food industry forbids the use of therapeutic antibiotics, as they pose risks for antibiotic resistance in pathogens [1], they have antibiotic properties and are produced by lactic acid bacteria, bacteriocins such as those produced in the digestive system of humans are not considered true antibiotics. We may easily prevent mistakes between bacteriocins and antibiotics by adhering to these features [9].

Bacteriocins are physiologically active proteins or complex proteins that have antibacterial effects on other bacteria, primarily closely related species [38]. They are bacteriocidal polypeptides produced via ribosomal synthesis [28]. Bacteriocins are a largely varied group that are typically chosen for testing and application as particular antagonists against pathogenic bacteria [46]. The use of bacteriocins can occasionally be restricted for a variety of reasons, and cost is still a significant barrier to employing it more widely [13]. The highly specialized antibacterial protein was referred to as "bacteriocine" by Jacob and others [36].

The term "bacteriocins" refers to a class of antibacterial proteins created by the deadly manufacture of proteins that are adsorbed to particular cell receptors and have a very specific range of function. Later, plasmids were included along with this known relationship with bacteriocin [17]. Since then, the definition has been updated to include the characteristics of bacteriocins made by Gram-positive bacteria. Although there may be a few exceptions, bacteriocins from Gram-positive bacteria typically do not have specialized adsorption receptors, unlike colicins [42]. They have a wider variety of target bacteria and, on average, a lower molecular weight. They also have various models for cell transport and release. Currently, Gram-positive bacterial bactericidal peptides or proteins are commonly referred to as bacteriocins.

Background of Bacteriocin

Gratia made the initial discovery of "proncipev" in 1925. This substance was created when one strain of *E. coli* battled another strain of *E. coli*. Gratia and Fedricq referred to it as a "concine" in 1946, and subsequently in 1953.

Classification of Bacteriocin

Owning to their origin and unique actions against distinct microorganisms, lactic acid bacteria (LAB) have developed many types of bacteriocins over the years. The majority of bacteriocins are 20–60 amino acid residues long and are cationic, hydrophobic, or amphiphilic compounds [11]. Bacteriocins are primarily grouped into three major classes, with several subgroups, based on their structure, activity, and target mechanisms. A summary of the different kinds of bacteriocins and their sources is provided in Table 1 [32].

Class I Bacteriocins (Lantibiotics)

Class I bacteriocins are known as lantibiotics, which are characterized by the presence of unusual amino acids, including lanthionine (Lan), methyllanthionine (MeLan), dehydroalanine, and dehydrobutyrine. These peptides typically have molecular weights less than 5 k Da and contain specific post-translational modifications. There are two types of lantibiotics in Class I: Type A and Type B.

Type A lantibiotics

Are elongated peptides that are positively charged? They exert their antimicrobial activity by creating pores in bacterial membranes [15].

Type B lantibiotics

Are smaller and often globular peptides that can either be negatively charged or neutral? Their antimicrobial mechanism usually involves the inhibition of enzymatic functions essential for cell wall biosynthesis or other cellular processes.

Class II Bacteriocins (Heat-Stable Peptides)

Class II bacteriocins consist of heat-stable, non-lantibiotic peptides, usually with molecular weights less than 10 kDa. These peptides typically consist of standard amino acids and can be further subdivided into three smaller groups [26].

Class II A

Bacteriocins, such as pediocin-like peptides, often share a conserved N-terminal sequence (Tyr-Gly-Asn-Gly-Val-Xaa-Cys), which is key to their antimicrobial activity. Pediocin, for instance, is particularly noted for its effectiveness against *Listeria monocytogenes*, making it a popular choice in food preservation [26].

Class II B

Bacteriocins include more complex peptides that are less potent in their antimicrobial action compared to Class II A peptides.

Class II C

Bacteriocins are small, heat-stable, and secreted via the Sec pathway [31]. They are also known for their relatively narrow spectrum of activity.

Class III Bacteriocins (Large, Heat-Labile Peptides)

Class III bacteriocins consist of large peptides with molecular weights greater than 30 kDa. These peptides are typically heat-labile and have less utility in food science due to their instability at higher temperatures. Their high molecular weight and structural complexity make them less commonly used in industrial applications compared to Class I and II bacteriocins [26].

Another subclass of bacteriocins, which requires the presence of a protein or carbohydrate moiety to function, has been suggested by some scientists. However, due to their relatively low biochemical activity, these bacteriocins are not typically included in the primary classification groups [6].

Table 1: Sources of bacteriocin

Bacteriocin	Source
Class I type A Lantibiotics	
Nisin	*Lactococcus lactis*
Lactocin	*Lactobacillus seki*
Epidermin	*Staphylococcus epidermis*
Gellidermin	*Staphyloccus galinarum*
Lacticin 481	*L. lactis*
Class I type B Lantibiotics	
Mersacidin	*Bacillus subtilis*
Cinamycin	*Streptomyciscinnamoneus*
Ancovecin	*Streptomyci spp*
Class II A	
Pediocin PA-1/Ach	*Pediococcus acidi lactici*
Sakacin A	*L.sake*

Commercially Available Bacteriocins

Bio-preservatives has to fulfil requirements of being nontoxic, stable, should not affect the organoleptic properties of the food products, economical, accepted by recognized authorities, and used in low concentration for their use on commercial scale[32]. Although many other type of bacteriocin such as subtilin, cerein, thuricin, plantaricin etc [3]. have been isolated and characterized from different bacteriocin producing strains of bacteria[8] yet, till date only commercially produced bacteriocins are nisin (*Lc. lactis*) and pediocin (*P. acidilactici*) and others are still in a process of getting commercial status to be used as 46 food preservatives. Nisin, having broad spectrum of antimicrobial activity, has only been given the GRAS status biopreservatives by Food and Drug Administration and was extremely effective in a number of food systems including canned foods and dairy products to prevent food spoilage and increase shelf life [10]. Nisin was found effective antimicrobial against almost all gram-positive bacteria in food. Nisin applications as a food preservative was first evaluated in swiss cheese [25] where it effectively prevented blowing (gassing) attributable to the growth of clostridia.

Subsequently, nisin use as preservatives was investigated with a large variety of fresh and processed foods. The results obtained by Holla (1990) have indicated that pediocin PA-1 and Pediocin AcH can be used as biopreservation to control both spoilage and pathogenic Gram-positive bacteria in liquid milk, ice cream and cheese. Fowler and Gasson (1991) suggested that a reasonable level of nisin for use in processed cheese is 3.75-12.5 mg/Kg finished products. Different studies have shown that the addition of low concentrations of nisaplin (10-50 mg/Liter) to pasturized milk substaintially reduced the bacterial count and increased shelf-life [17].

Table 2: Some commercially produced bacteriocins

Bacteriocin	Commercial name	Producer Strain	Manufacture
Nisin	Nisaplin	*Lc. Lactis*	Danisco, Copenhagen Denmark
Pediocin PA1	ALTA 2431	*P. acidilactici*	Kerry Biosciences Carrigaline, Ireland
Nisi*n	MAYNISIN	*Lactococcus* sp.	MAYSA GIDA San ve Tic. A.S, Turkey
Nisin	Nisitrol	*Lactococcus* sp.	Bimal Pharma Pvt. Ltd., India
Nisin	SAFRESH™	*Lactococcus* sp.	Wuhan Amth Biotechnology Co. Ltd., China
Nisin	YP-1000 Nisin	*Lc. Lactis*	China (National) Abrasives Corp., China

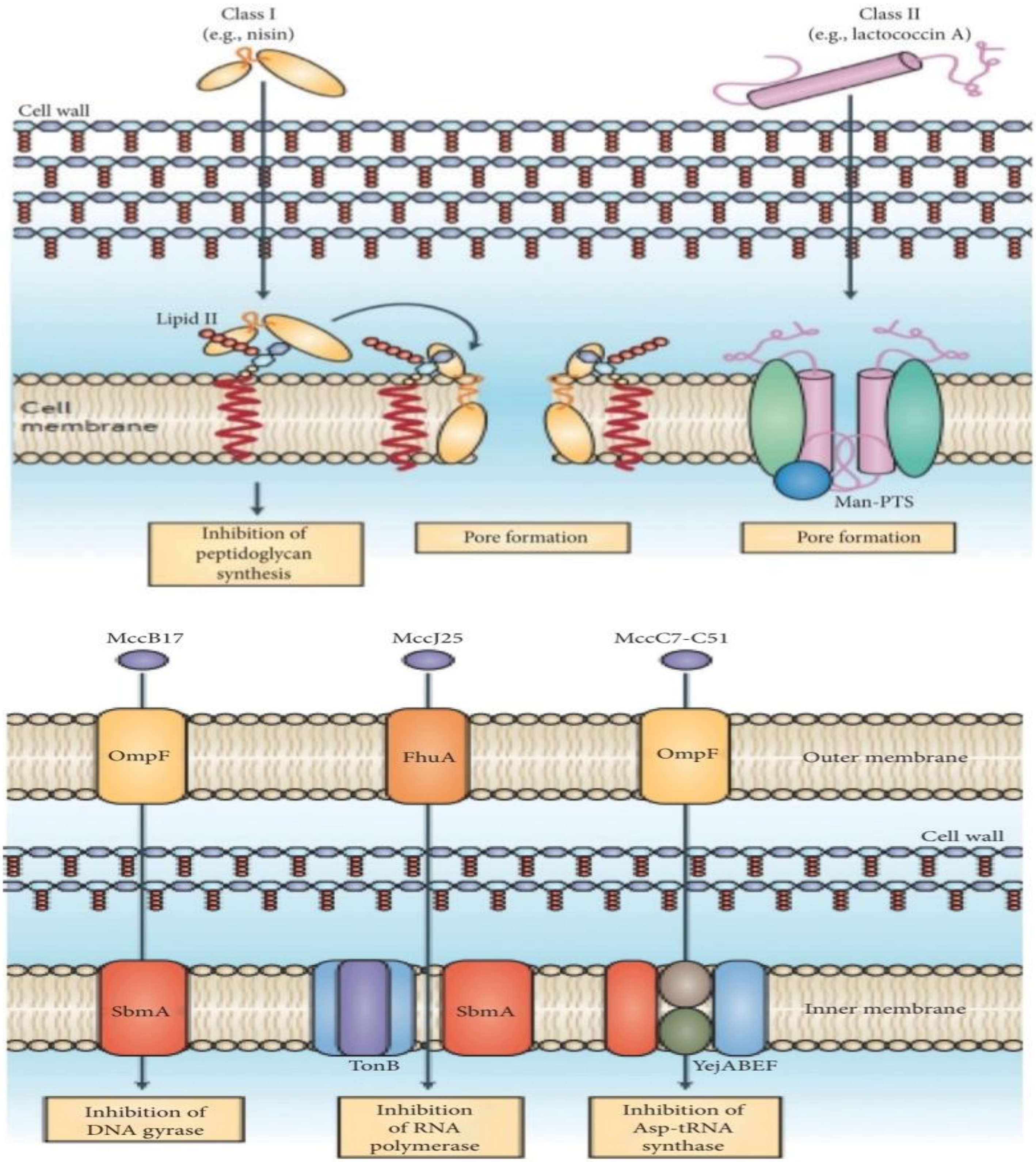
Application of Bacteriocin in Various Food Industries

Bacteriocins as Food-bio Preservatives

The use of bacteriocins as food-biopreservatives may be an effective approach to control food spoilage and food borne pathogenic bacteria. The use of bacteriocin in heat possessed food may reduce the thermal process intensity and both improve the nutritional and organoleptic properties of the food and minimize the heat processing costs. Two relatively recent factor accelerating interest in LAB bacteriocin are the increasing incidence and detection of food-borne diseases and the emerging consumer resistance to highly processed foods [27]. Food processors are faced with the dilemma of how to best manufacture attractive minimally prepared food without chemical preservatives and preference for minimally processed foods reflect consumer's perception of what constitutes a natural and healthy food. Food fermented with LAB has a positive image among consumers as healthy and natural substances with yoghurt, dahi and sour-dough based bread being examples.

Much recent interest has centred on the potential use of LAB bacteriocin are possible replacement or adjuncts to preservatives that have fallen out of favour with consumers. The safe and efficacious use of nisin for the past 30 years is encouraging and provided the precedent for continued research on and evaluation of LAB bacteriocin as an emerging class of food preservatives. Recently progress was reported on the on-going EUFAIR project whose aim is to improved quality and safety of agro industrial products by developing novel combination of natural antimicrobial system in conjugation the reduced level of traditional physical and chemical preservation process [20]. It was reported that test with a novel bacteriocin in model system representing the general composition of dairy products indicated that high levels were required to inhibit *B. cereus* at high abuse temperature an emulsifier was also found to be necessary as fat had a negative effect on bacteriocin activity.

Figure 1: (A) & (B) showing mechanism action of bacteriocin of Gram-positive and Gram-negative [16].



(A) **(B)**

Dairy Industry

Dairy Industry Bacteriocins have wide applications in dairy industry especially during the fermentation of the products. Nisin from *Lc. lactis* and pediocin PA1 produced from *P. acidilactici* PAC1.0 has found their application in dairy industry. Ryan *et al*. (1996) reported the application of lacticin 3147 producing transconjugants to control non-starter Lactic acid bacteria in cheese. Addition of Lactococcin ABM helped in 38 early lysis and release of intracellular enzymes from starter culture and helped in early ripening of Cheddar cheese (O‟Sullivan *et al*., 2002). Use of bacteriocin producing starter cultures was advantageous in protecting fermented foods from transmission of food-borne pathogens as compared to starter cultures lacking bacteriocins. Secondary cultures with bacteriocin producing potential may also contribute to fasten the ripening of dairy products by killing microbes in the primary starter culture. Broad spectrum acidocin CH5 (Chumchalava, 2004), acidocin 1B (KyoungSik *et al*., 2007) and acidocin AA11 (Abo-Amer, 2007) were reported to have application in fermented products to prevent the growth of pathogenic bacteria. Bacteriocins contributed to the development of flavour and quality of food products. During ripening of cheese, the starter cell culture showed lysis to release proteinases and peptidases which contributed to flavour development in cheese [40].

Bakery Products and Ingredients

Wheat doughs used for preparation of various bakery products may be contaminated with bacteria resulting in bread defects, including ropiness and enterotoxins production. Bacteriocin at low concentration (14 AU/g) was reported effective against vegetative cells of *B. subtilis*, *B. licheniformis*, *B. cereus* and *B. pumilus* strains under experimental conditions, while its higher concentration (23 AU/g) was required in killing of endospores [42]. *S. aureus* inhibition was also observed with addition of AS-48 in liquid caramel, pumpkin comfiture or diluted almond cream [42]. Bacteriocins were effective against *S. aureus*, *B. cereus* and *L. monocytogenes* in various desserts including baker cream, soy-based desserts and 39 gelatin puddings [42]. Listeria contamination has been decreased by >2 log cfu per package by packaging hot dogs with cellulose based films containing 10000 and 7500 AU/mL nisin [24].

Alcoholic Beverages

Growth of undesirable microorganisms may result in deterioration of the characteristics of alcoholic beverages. Bacteriocins were produced by food-grade lactic acid bacteria and helped in preventing the development of food spoilage bacteria. In the case of wine, it offered the additional advantage of allowing a decrease of sulphurous anhydride levels in wine. Effect of nisin alone and in combination with metabisulphite on red wine indicated measurable reduction of microbial population in the samples with low metabisulphite concentration combined with nisin, thereby, resulting in the preservation of wine spoilage during the ageing and storage process [40]. A composition prepared by fortifying wort with nutritional supplement, inoculating with nisin producing culture followed by fermentation led to high shelf stability without affecting flavour and aroma of beer.

Commercially Available Bacteriocins

Biopreservatives has to fulfil requirements of being non-toxic, stable, should not affect the organoleptic properties of the food products, economical, accepted by recognized authorities, and used in low concentration for their use on commercial scale [31]. Although many other type of bacteriocin such as subtilin, cerein, thuricin, plantaricin etc., [4]. have been isolated and characterized from different bacteriocin producing strains of bacteria [15] yet, till date only commercially produced bacteriocins are nisin (*Lc. lactis*) and pediocin (*P. acidilactici*) and others are still in a process of getting commercial status to be used as 46 food preservatives. Nisin, having broad spectrum of antimicrobial activity, has only been given the GRAS status biopreservatives by Food and Drug Administration and was extremely effective in a number of food systems including canned foods and dairy products to prevent food spoilage and increase shelf life[5] Nisin was found effective antimicrobial against almost all gram-positive bacteria in food. Nisin applications as a food preservative was first evaluated in swiss cheese [15], where it effectively prevented blowing (gassing) attributable to the growth of clostridia.

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Table 2: Commercially produced bacteriocins

Bacteriocin	Commercial name	Producer Strain	Manufacture
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Pediocin PA1	ALTA 2431	*P. acidilactici*	Kerry Biosciences Carrigaline, Ireland
Nisin	MAYNISIN	*Lactococcus* sp.	MAYSA GIDA San ve Tic. A.S, Turkey
Nisin	Nisitrol	*Lactococcus* sp.	Bimal Pharma Pvt. Ltd., India
Nisin	SAFRESH™	*Lactococcus* sp.	Wuhan Amth Biotechnology Co. Ltd., China
Nisin	YP-1000 Nisin	*Lc. Lactis*	China (National) Abrasives Corp., China

CONCLUSION

Currently, the dairy industry's most researched microbial defence strategy is bio-preservation using Bacteriocin. To determine its precise efficacy to particular compounds with antibacterial activity, numerous studies are still ongoing. The quality of biological antimicrobial systems, such as lactic acid bacteria (LAB) and/or their bacteriocins, bacteriophages, and bacteriophage-encoded enzymes, is primarily dependent on the bio-preservation procedures used for different foods. In order to give food products their typical texture and flavor, they are commonly utilized in the food business. They are often used bio-preservatives in the industrialized world and aid in preserving the safety and quality of food. As everyone is aware, chemical preservatives can occasionally have harmful health effects on consumers through a variety of chemical reactions with food and other substances. Occasionally, they can even form carcinogenic chemicals, such as sodium nitrate and sodium nitrite, which are lethal to humans. Thus, contemporary preservation methods such as irradiation, hurdle technologies, and biopreservation are creating a means of releasing humanity from the harmful effects of chemical preservation methods.

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