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BACTERIOCIN AS AN EFFECTIVE FOOD PRESERVATIVE: A SYSTEMATIC REVIEW

Purwaniati[1,2*], Rahmana Emran Kartasasmita[1]

[1]School of Pharmacy, Institute Teknologi Bandung, Ganesha 10, Bandung, Indonesia, 40116

[2]Pharmacy Faculty, Universitas Bhakti Kencana, Soekarno-Hatta 754, Bandung, Indonesia, 40614

Email : purwaniati@bku.ac.id

ABSTRACT

This systematic review was prepared to obtain research gaps on the application of bacteriocin in food preservation. Bacteriocin is a well-known GRAS (generally recognized as safe) bacterial metabolite molecule. Therefore, its application to the preservation of food ingredients or processed food products is an exciting part. Science Direct is a single database containing many publications on food preservatives. Thirty articles were produced worthy of review from the database after the screening, eligibility test, and quality appraisal stages. Nisin became the first bacteriocin to be used internationally as a preservative. Nisin is also studied and developed in various innovations with better applications. High protein foods are objects of preservation that continue to require creation.

Keywords: antimicrobial activity, bacteriocin, food preservative, lactic acid bacteria

AbbreviationsGRAS: generally recognized as safeLAB: lactic acid bacteria

Introduction

Bacteriocins are low molecular weight protein molecules produced by various strains of bacteria, including lactic acid bacteria (LAB), which have antimicrobial activity. The antimicrobial activity of bacteriocin is primarily against food spoilage bacteria and certain types of fungi (Verma *et al*., 2022). Bacteriocins are generally thermostable (Pattanayaiying *et al*., 2019). Bacteriocin-producing bacteria can produce self-immunity proteins that protect themselves from the impact of these bacteriocins. The defence mechanism of this self-immunity protein can be carried out by scavenging bacteriocin or through competitive antagonism at the bacteriocin receptor (de Freire Bastos *et al*., 2015) (Soltani *et al*., 2021).

Some bacteriocins have a broad spectrum and some narrow range (Cotter *et al*., 2005). The limited spectrum of bacteriocins then triggers its application in food preservation efforts. This action then gave rise to the term bio preservatives. The application of bacteriocin can be: 1). pure bacteriocin (pure isolate), 2). producing cultures, or 3). Containing fermentation (Verma *et al*., 2022). The term bio preservative explicitly means using antimicrobial compounds produced by microorganisms to preserve food. Bacteriocin is the most common example. Bacteriocins are generally made from the well-known LAB GRAS (Generally recognized as safe). LAB has long been used in various food products, for instance, in the fermentation of milk, fruit, and vegetables. Traditionally, LAB is also known as food-grade bacteria (Chapot-Chartier & Kulakauskas, 2014)(Verma *et al*., 2022).

LAB is a group of gram-positive bacteria capable of producing lactic acid. This group of bacteria does not have catalase enzyme activity. The presence of the LAB since hundreds of years ago has been proven to have no adverse effects on health (GRAS). LAB can maintain food quality by producing several metabolites, including bacteriocins that can inhibit the growth of microorganisms that spoil food (Cotter *et al*., 2005).

Bacteriocins can be divided into classes I, II, and III. The classes are organized according to molecular size and other distinctive properties. Type I bacteriocins are low molecular weight (<5 kDa) proteins. It is also known as lantibiotic due to a lanthionine ring in the structure of this class of bacteriocins. The ring is present because of the formation of a thioether group between the amino acid cysteine and serine or threonine. The pathways of synthesis, modification and transport of lantibiotics also differ from those of other classes of bacteriocins. The type I lantibiotic is formed due to dehydration of serine and threonine by the enzyme LanB and cyclization by LanC, which causes the formation of an elongated and flexible molecular structure (Koponen *et al*., 2002). Type II lantibiotic is formed due to the presence of the LanM enzyme, which plays a role in both dehydration and cyclization processes, thus creating a globular and rigid molecular structure (Sandiford, 2020). Type III and IV antibiotics are better known as lantipeptides. This is because the two types of lantibiotics do not have

antimicrobial activity, or their antimicrobial activity is fragile. However, both have the potential for use in other clinical services, such as antiallodynic (Meindl *et al*., 2010). Lantipeptide type III is formed by an enzyme activity that produces three functions: the LanKC enzyme, which acts as a lyase, kinase, and cyclase (Sandiford, 2020). Lantipeptide type IV is formed due to modification by the enzyme LanL (van der Donk & Nair, 2014).

Other literature classifies lantibiotic into Ia, Ib, and Ic into three subclasses. The classification is based on the shape of the molecule. Subclass Ia is elongated molecules. Nisin is an example of an Ia lantibiotic. Lanthioptic Ib is a globular molecule. Finally, lantibiotic Ic is a multi-component lantibiotic. Mersacidin and lacticin are examples of Ib and Ic lantibiotics, respectively (Özel *et al*., 2018)(Sandiford, 2020)(Yi *et al*., 2022).

Class II bacteriocins are more stable at high temperatures than class I. These bacteriocins are grouped into four subclasses; IIa (pediocin-like), for example, pediocin, IIb (two-peptide), for instance, plantaricin A and F, IIc (cyclic peptide), AS-48 for example and IId (miscellaneous) garvicin KS. And class III bacteriocins are bacteriocins with large molecular weights (>10 kDa) and are very stable at high temperatures. Helveticin J is an example of a class III bacteriocin (Yi *et al*., 2022).

Nisin was the first bacteriocin approved for use as a food preservative. Nisin was discovered in the 1920 and 1930s. It was first introduced as a preservative in 1951 in cheese preservation. Nisin has been commercially available since 1957 under the trade name Nisaplin® (Delves-Broughton, 1996). Other bacteriocins commercially known as food preservatives include carnobacteriocin BM1, piscicolin 126, and carnocyclin A (Micocin®), which are recommended as feed additives for broiler rabbits. Therefore, it is expected to produce meat that has a better microbiological profile, the bacteriocin is proven to be effective in inhibiting the growth of *Listeria monocytogenes* bacteria (Koné *et al*., 2018).

This meta-synthesis focuses on research publications that use bacteriocins to preserve different food products. This meta-synthesis is expected to show the research gap in using bacteriocins in food preservation. Furthermore, it will be able to inspire further research that is more effective in finding new bacteriocins or exploring bacteriocins that have been found previously.

Methods

This meta-synthesis was prepared as an attempt to find research gaps from previous studies that have been published. Thus, it is expected to stimulate new research that better answers the needs of the time. This meta-synthesis aims to explain new findings from a group of similar studies and increase certainty in applying these research results (Walsh & Downe, 2005). This meta-synthesis is based on the ENTREQ (Enhancing Transparency in Reporting the Synthesis of Qualitative Research) guidelines. This ENTREQ presents meta-synthesis in 5 main groups, namely: introduction, methods and methodology, literature search and selection, appraisal, and synthesis of finding (Tong *et al*., 2012). This systematic review is critical in determining health guidelines (Moher *et al*., 2009), likewise, in

the case of food preservatives. The systematic review will help determine policy or further research steps on a suitable preservative to be developed in food preservation.

Search Strategy

The input articles in this meta-synthesis are open access articles in The Direct Science database. The articles have been published since 1950. A comprehensive search was carried out using the SPIDER technique (Sample, Phenomenon of interest, design, evaluation, and research type). SPIDER was used because it was considered to have better specificity in searching a database than other techniques such as PICO (Population, Intervention, Comparison, and Outcomes) (Methley *et al*., 2014). The list of articles that met the inclusion criteria was then manually reviewed.

Unique terms or keywords play a vital role in the search for the article being studied. Other keywords and phrases with the same meaning includes food preservatives, bacteriocin, antimicrobial activity, antifungal, antibacterial, and preservation tests. To intensify the search, the Boolean operator was also used. The word "or" was used to distinguish synonyms "and" combine search terms. The optimal number of articles was significant in this meta-synthesis. The goal is to obtain a representative number of samples to ensure their validity (Bakla, 2020).

Eligibility Criteria and Study Selection

Articles included in this meta-synthesis must meet the following criteria: 1). The test sample is from food ingredients or other edible products, 2). The phenomenon of interest is testing the effectiveness of preservation on food or other edible products after adding certain elements suspected of acting as preservatives, 3). The preservatives are included in the bacteriocin category, either as pure isolates, fractions, or extracts, 4). The articles contain public research results (data from field research) which are conducted using experimental methods, 5). The papers are published in English.

The reported preservation test can be carried out on preservation with a single preservative or combination. Bacteriocins are the main focus of this meta-synthesis. These bacteriocins can be served as a single preservative or combined with bacteriocins or preservatives from other classes. Articles that display data on bacteriocin preservatives but not for food preservation purposes or using preservatives not from bacteriocins, were excluded.

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) flowchart was used to show the article screening process. The process flow diagram can be seen in Figure 1. The search process began with searching for articles in the Science Direct database using appropriate keywords as the identification stage. Identification resulted in 257 articles, which continued at the screening stage. Screening was carried out in 2 main stages, metadata screening and full-text screening. Metadata screening was done by exporting article metadata in RIS (Research Information System) format. The RIS file was then imported into the Mendeley Desktop software, and an "update details" was performed to ensure the citation format was correct.

Mendeley also detected duplicate articles. No same articles were seen on Mendeley. The metadata file was then re-exported, still in RIS format, as input in the following process, namely metadata screening with the help of the NVIVO 12 Plus application. Screening using Cluster Analysis with Pearson Correlation Coefficient as a similarity metric and Word Frequency Query left 218 articles.

The 218 articles were screened by title and abstract and articles that were not researched (review articles or book chapters) were excluded. This process left 77 articles. The next screening was done by doing full-text screening and determining its suitability with the inclusion criteria that had been set. Thirty articles were included in this review.

Quality Appraisal

Critical Appraisal Skills Programs (CASP) assesses the articles quality. It assesses the quality of a paper using ten questions about the report. These assessment points include research objectives, methodology, sampling method, data collection and analysis, reflexivity, ethical considerations, information of research finders, and significance of research results. The list of questions used is a case study control. This appraisal consists of 3 parts; A, B, and C. Part A contains six questions that test the validity of the research results. Part B examines the results of the research itself. In addition, part C questions the chances of the research results being applied to a population (CASP, 1994). The results of the quality appraisal can be seen in Table 1.

Data Extraction and Synthesis Of Finding

Data extraction was done by creating an extraction table (Table 2). The first author created the extraction table, which was then checked for relevance by the second author. The extraction table contains the author's name and year of publication, research objectives, food samples, types of bacteriocins tested, bacteriocin-producing bacteria, and research results. The NVIVO 12 Plus application was used to assist in processing and encoding data.

Results

Characteristics of the study

The meta-synthesis involved 30 articles with published year of 2022 (n=6), 2021 (n=2), 2020 (n=1), 2019 (n=2), 2018 (n=2), 2017 (n=2), 2016 (n=2), 2015 (n=1), 2014 (n=1), 2013 (n=1), 2012 (n=1), 2009 (n=3), 2008 (n=1), 2003 (n=3), 1992 (n=1), 1991 (n=1). The data for the publication of bacteriocins as food preservatives have been relatively stable in the past five years, increasing rapidly in 2022. Judging from the country where the research was conducted, China dominated (n=7), followed by Brazil (n=5), Spain (n=4), Egypt (n=4), United States (n=2), Portugal, Ireland, Turkey, Thailand, South Africa, Bulgaria, Italy, Japan and France 1 publication each. Critical appraisal data show all reviewed articles present case study data in testing materials that have the potential as preservatives in food preservation. The study objectives have been clearly stated in each article. The experimental method used aims to answer the research objectives. The resulting data is presented in a well systematic manner. All research results seem to have the opportunity to be applied, However, further research

certainly needs to be conducted to ensure their efficiency.

Discussion

Finding From Thematic Synthesis

Type of Bacteriocin

In terms of the type of bacteriocin explored, nisin is the most favourite, where 13 of them studied nisin as the active ingredient. Trends show an increasing need to produce food packaging materials that function as preservatives (antimicrobial). Plantaricin (n=2) is a new bacteriocin showing its potential as a food preservative. Other bacteriocins that can be used as food preservatives are bicyclic (n=1), hyicin 4244 (n=1), enterocin (n=1), and other bacteriocins whose molecular structure cannot be determined (n=11). As the most popular bacteriocin to be used as a food preservative, nisin is also the most modified in its use.

Modifications were made to increase the effectiveness of antimicrobials and the flexibility of their use. Nisin or other bacteriocins are very likely to be developed as packaging for food products which at the same time prevents the proliferation of microbes or minimizes the risk of contamination from the environment. The packaging product is in the form of an edible coating. This edible coating seems to be one of the best preservation techniques for products such as sausages and cheese. There are at least five articles that publish this type of research. The combination of bacteriocin preservative, an antimicrobial with bacteriocin or other preservative categories, is also potential to be developed given that every antimicrobial has the potential for resistance. This antimicrobial combination will potentially reduce the risk of resistance. Generally, a variety of preservatives provides a more substantial preservative effect. Physical preservation techniques are also sometimes combined with bacteriocins. The physics techniques include HHP (López-Pedemonte *et al*., 2003) and HIPEF (Sobrino-Lopez *et al*., 2009).

Judging from the type of food tested, milk and dairy products, including cheese, were the most studied types of food (n=18). Meat and processed meat products (n=5) were next in line, followed by fish-based foods (n=2), wheat grains (n=1), tomatoes (n=1), and other food products (n=2). These data indicate that high-protein foods are foods that need preservation. The discovery of new preservatives that are effective and efficient in preserving high-protein foods, such as milk and dairy products, meat and processed meat products, and fish and processed fish products, is still a challenge and opportunity.

The most widely used test microbes were *Listeria sp*., especially *Listeria monocytogenes* (n=14), and *Staphylococcus sp*., especially *Staphylococcus aureus* (n=11). Fungi were rarely tested (n=1). Other bacteria that were also used as test bacteria included: *Bacillus cereus* (n=1), *Pseudomonas sp*. (n=1), and other bacteria that had the potential to spoil food.

Conclusion

Bacteriocin is still a promising LAB metabolite to continue to be developed into feed and food preservatives. Preservative ingredients or high-protein food products are still a good focus. Research on bacteriocins should also examine the various application

techniques in food technology, so hat bacteriocin is easier and more efficient to use. Finding and isolating new bacteriocins are also still an exciting research area. Bacteriocins are known to be safe, but safety studies are still very much needed.

Author's contribution

The first author searched for all the articles reviewed and compiled them into a systematic review The second author, beside reviewing all articles, performed a review and correction towards the systematic review compiled by the first author.

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Tabel 1. Quality appraisal of all articles analysed using the approach of Critical Appraisal Skills Programs Qualitative Research Checklist

Artikel (Name, Year)	CASP Items											
	1	2	3	4	5	6a	6b	7	8	9	10	11
(Thuault *et al*., 1991)	v	v	v	v	v	v	x	v	v	v	v	v
(Jung *et al*., 1992)	x	v	v	v	v	v	x	v	v	v	v	v
(Arakawa *et al*., 2009)	x	v	v	v	v	v	x	v	v	v	v	v
(Mathot *et al*., 2003)	v	v	x	v	x	v	x	v	v	v	v	v
(Benech *et al*., 2003)	v	v	v	v	v	v	x	v	v	v	v	v
(Arqués *et al*., 2008)	v	x	v	v	v	v	x	v	v	v	v	v
(Sobrino-Lopez *et al*., 2009)	v	v	v	v	v	v	x	v	v	v	v	v
(Ruiz *et al*., 2009)	v	v	v	v	v	v	x	v	v	v	v	v
(da Silva Malheiros	v	v	v	v	v	v	x	v	v	v	v	v

et al., 2012)												
(Duarte *et al*., 2013)	v	v	v	v	v	v	x	v	v	v	v	v
(Anacarso *et al*., 2014)	v	v	v	v	v	v	x	v	v	v	v	v
(de Souza Barbosa *et al*., 2015)	v	v	v	v	v	v	x	v	v	v	v	v
(Oladunjoye *et al*., 2016)	v	v	v	v	v	v	x	v	v	v	v	v
(Meira *et al*., 2016)	v	v	v	v	v	v	x	v	v	v	v	v
(Sangcharoen *et al*., 2017)	v	v	v	v	v	v	x	v	v	v	v	v
(Figueiredo & Almeida, 2017)	v	v	v	v	v	v	x	v	v	v	v	v
(Lv *et al*., 2018)	v	v	v	v	v	v	x	v	v	v	v	v
(Lin *et al*., 2018)	v	v	v	v	v	v	x	v	v	v	v	v
(Shehata *et al*., 2019)	v	v	v	v	v	v	x	v	v	v	v	v
(Kaya & Simsek, 2019)	v	v	v	v	v	v	x	v	v	v	v	v
(Castilho *et al*., 2020)	v	v	v	v	v	v	x	v	v	v	v	v
(Xin *et al*., 2021)	v	v	v	v	v	v	x	x	v	v	V	v
(Nyhan *et al*., 2021)	v	v	v	v	v	v	x	v	v	v	v	v
(Liu *et al*., 2022)	v	v	v	v	v	v	x	v	v	v	v	v
(Du *et al*., 2022)	v	v	v	v	v	v	x	v	v	v	v	v
(Jiang *et al*., 2022)	v	v	v	v	v	v	x	v	v	v	v	v
(Ning *et al*., 2022)	v	v	v	v	v	v	x	v	v	v	v	v
(Zhao *et al*., 2022)	v	v	v	v	v	v	x	v	v	v	v	v
(Silva *et al*., 2022)	v	v	v	v	x	v	x	v	v	V	v	v
	Comments: Author does not display inhibition zone data and lower case the number of microbial growing on control											

Note: v (yes); - (can't tell); x (no)

Section A:

1. Did the study clearly address the focused issue?
2. Did the author use an appropriate method to answer the questions?
3. Were the cases recruited acceptably?
4. Were the controls selected in an acceptable way?
5. Was the exposure accurately to minimize bias?
6. a. aside from the experimental intervention, were the groups treated equally?

   b. have the authors taken into account the potential confounding in the design and/or their analysis?

   Section B:

7. How large was the treatment effect?
8. How precise was the estimate of the treatment effect?

Section C:

9. Do you believe the result?
10. Can the results be applied to the local population?
11. Do the results of this study fit with other available evidence?

Tabel 2. Table extraction of the article in this study

Article (name, year)	Bacteriocin name's	Producing Bacteria	Food sample	Inhibited Microbes (Microbial test)	Results
(Thuault *et al*., 1991)	Bacteriocin from Lactic acid bacteria	Lactic acid Bacteria	Milk	*Clostridium tyrobutyricum, Lactobacillus helveticus*, and *Streptococcus thennophilus*	Bacteriocin exerts a bactericidal effect against *Clostridium tyrobutyricum, Lactobacillus helveticus*, and *Streptococcus thennophilus.*
(Jung *et al*., 1992)	Nisin	Not mentioned	Fluid milk	*Listeria monocytogenes*	The antibacterial activity of nisin decreased with the increasing fat content in milk. Adding a non-ionic emulsifier (Tween 80) increased nisin activity at any fat concentration while adding an anionic emulsifier (lecithin) did not affect nisin activity.
(López-Pedemonte *et al*., 2003)	Nisin, combined with high hydrostatic pressure (HHP)	*Lactococcus lactis*	Milk	Spores of *Bacillus cereus*	The greatest spore inactivation occurred with the addition of 1.56 mg/L nisin milk with 400 MPa HHP
(Mathot *et al*., 2003)	Bacteriocin from *Streptococcus termophylus* 580	*Streptococcus termophylus* 580	Hard cheese	*Clostridium tyrobutyricum*	Bacteriocin slightly inhibited the growth of Clostridium tyrobutyricum. Its inhibitory activity drops drastically in the stationary phase.
(Benech *et al*., 2003)	Nisin Z in liposome-encapsulated nisin Z	*Lactococcus lactis* ssp. *Lactis biovar*, *Lactobacillus casei* L2A	Lactobacillus added-cheddar cheese	*Lactobacillus casei*	Cheese made with the addition of Lactobacillus casei and liposome-encapsulated nisin Z produces cheese with better quality and taste
(Arqués *et al*., 2008)	Nisin, reuterin, and lactoperoxidase system	*Lactococcus lactis* and *Lactobacillus reuteri*	Cuajada (curdle milk)	*Listeria monocytogenes* and *Staphylococcus aureus*	The combination of N+LPS or N+R+LPS effectively prevented the growth of *Listeria monocytogenes* up to day 12. Meanwhile, *Staphylococcus*

					aureus was more resistant to the single preservative or the combination (the growth of *Staphylococcus aureus* was detected from day 3).
(Sobrino-Lopez *et al*., 2009)	Enterocin AS-48 (AS-48), nisin, and lysozyme alone or its combination combined with a high-intensity pulsed electric field (HIPEF)	*Lactococcus lactis* (nisin), *Enterococcus faecalis* (AS-48)	Milk	*Staphylococcus aureus*	Milk preservation with AS-48 or the combination of AS-48 and nisin followed by HIPEF gave the best preservation effect.
(Arakawa *et al*., 2009)	Gassericins A dan T	*Lactobacillus gasseri* LA39 and LA158	Custard cream	Gram-positive and gram-negative bacteria	The antibacterial spectrum of gassericin is broader than nisin A. Gassericin A 49 arbitrary units/mL, which gradually inhibits growth in gram-positive bacteria. The addition of 0.5% glycine caused total growth inhibition. Gram-negative bacteria did not grow, probably because custard cream was not a suitable medium.
(Ruiz *et al*., 2009)	nisin, and its combination with rosemary and ethylenediaminetetraacetic acid (EDTA)	*Lactococcus lactis*	Ready-to-eat turkey ham	*Listeria monocytogenes*	Nisin or nisin in combination with rosemary or EDTA was able to inhibit the growth of Listeria monocytogenes in ham. Still, neither of these combinations was able to eliminate Listeria monocytogenes.
(da Silva Malheiros *et al*., 2012)	Bacteriocin-like substance (BLIS), peptide P34 from Bacillus sp, P34, encapsulated in nanovesicles from partially purified soy lecithin.	*Bacillus sp.* P34	Milk	*Listeria monocytogenes*	Encapsulated BLIS was more effective in inhibiting the growth of Listeria monocytogenes than free BLIS at temperatures of 30 or 7. The inhibitory activity of both decreased by about 50% on day 4, but relatively no further decrease until day 21.

(Duarte *et al*., 2013)	Hyicin 4244	*Staphylococcus hyicus*	Skim milk	30 foodborne pathogens	Hyicin 4244 was able to inhibit the growth of all test bacteria in the food matrix (skim milk).
(Anacarso *et al*., 2014)	Bacteriocin from *Lactobacillus pentosus* 39	*Lactobacillus pentosus* 39	Fresh salmon fillets	*Aeromonas hydrophilic* and *Listeria monocytogenes*	The addition of bacteriocin was proven to inhibit the growth of the two tested microbes. In Aeromonas hydrophyla, there was a decrease in the number of colonies by 2.1 CFU/g and 3.6 CFU/g in Listeria monocytogenes.
(de Souza Barbosa *et al*., 2015)	Bacteriocin from *Lactobacillus curvatus*	*Lactobacillus curvatus*	Salami	*Listeria monocytogenes*	Bacteriocin from Lactobacillus curvatus MBSa2 caused the most significant decrease in the number of pathogens until product storage was 10-20 days. These bacteriocins are peptides with molecular weights of 4457.9 Da and 4360.1 Da, homologous to sakacins P and X.
(Oladunjoye *et al*., 2016)	Nisin combined with organic salts (sodium citrate or sodium acetate)	*Lactococcus lactis*	Fresh-cut tomato	*Listeria monocytogenes*	Both nisin and organic acids inhibited the growth of Listeria monocytogenes, but the combination of the two gave more effective inhibition (nisin 5000 UI/ml and sodium citrate 5%)
(Meira *et al*., 2016)	Nisin	*Lactococcus lactis*	Soft cheese	*Listeria monocytogenes, Clostridium perfringens*, and *Staphylococcus aureus*	Starch/halloysite/nisin nanocomposite films were developed as antimicrobial packaging. Nanocomposite films with two g/100 g nisin significantly reduced bacteria count, and six g/100 g nisin inhibited Listeria monocytogenes.
(Sangcharoen *et al*., 2017)	Nisin, in combination with chelating agent (ascorbic acid, EDTA, potassium sorbate,	*Lactococcus lactis*	Skim milk	*Staphylococcus enteritidis* and *Micrococcus luteus*	The mixture of nisin, ascorbic acid, and EDTA gave the most significant inhibition effect on bacterial growth.

	sodium lactate, sodium acetate)				
(Figueiredo & Almeida, 2017)	Nisin alone and combined with bacteriophage 100 and or with sodium lactate	*Lactococcus lactis*	Ready-to-eat sliced pork ham	*Listeria monocytogenes*	Bacteriophage 100 was the most effective in inhibiting the growth of *Listeria monocytogenes*, followed by nisin and sodium lactate. The combination of bacteriophage 100 and nisin proved to be more effective.
(Lin *et al*., 2018)	Nisin, sodium nitrite, potassium sorbate, and sodium lactate	*Lactococcus lactis*	Cooked pork sausage	*Staphylococcus aureus* and Staphylococcal enterotoxin A (SEA)	Nisin, sodium nitrite, and potassium sorbate exhibited slow inhibitory activity against *Staphylococcus aureus* and SEA production, while sodium lactate significantly inhibited *Staphylococcus aureus* growth and SEA production.
(Lv *et al*., 2018)	Bacteriocin DY4-2	*Lactabacillus plantarum*	Fresh turbot fillets	*Pseudomonas fluorescens, Pseudomonas aeruginosa, Vibrio parahaemolyticus, Aeromonas sobria* and *Listeria monocytogenes*	The bacteriocin was able to inhibit the growth of the test microbes (broad-spectrum). Bacteriocin has a molecular weight of 1465 Da, is stable at high temperatures (121°C for 30 minutes), stable at pH 2-5-5.5, and sensitive to proteolytic enzymes.
(Shehata *et al*., 2019)	Bacteriocin from lactobacillus sp. RM1 (CFS)	*Lactobacillus sp*. RM1	Wheat grains	Fungi spores	Bacteriocin RM1 inhibited total aflatoxin B1 and A at a 15 mg/ml concentration.
(Kaya & Simsek, 2019)	Not identified	Pathogen-specific bacteriocin (PSB) was isolated from 250 different foods.	Milk	*Bacillus cereus, Listeria monocytogenes, Staphylococcus aureus, Lactobacillus Plantarum, Enterococcus faecalis*	Three bacteriocins with molecular sizes 1219,021, 3346,803, 4853,768 Da effectively inhibit the growth of *Lactobacillus cereus*, *Listeria monocytogenes*, and *Staphylococcus aureus* in milk samples. The bacteriocins work by interfering with the permeability or forming pores in the cell wall.

(Castilho *et al*., 2020)	Partially purified bacteriocin of *Lactobacillus curvatus* UFV-NPAC1	*Lactobacillus curvatus* UFV-NPAC1	Fresh sausage	*Listeria monocytogenes*	Partially purified bacteriocin decreased *Listeria monocytogenes* counts ranging from 1.0 to 3.0 log CFU/g
(Xin *et al*., 2021)	Baicyclicin XIN-1	*Bacillus sp*. XIN-1	Skim milk	*Bacillus cereus*, *Listeria monocytogenes* and *Staphylococcus aureus*	Bacicyclicin XIN-1 has stability over a high temperature and pH range, as well as a broad spectrum of antimicrobial activity. This bacteriocin can inhibit the growth of *Bacillus cereus, Listeria monocytogenes,* and *Staphylococcus aureus*.
(Nyhan *et al*., 2021)	Nisin A and its derivatives	*Lactococcus lactis*	Chocolate milk, frankfurter homogenate	*Listeria innocua*	There were 630 derivatives of nisin produced; there are two combinations of products that show more muscular anti-listeria activity compared to a single-use or compared to nisin, namely CFS from MI7Q+N20P and M17Q+S29E.
(Liu *et al*., 2022)	Nisin in nisin/Tremella fuciformis nanoparticles (NTN) with added live particles (NTN@LP)	*Lactococcus lactis*	Sausage	*Staphylococcus aureus*	NTN@LP has been shown to play a role in biogenic amines in the fermentation process that occurs in sausages and has been shown to inhibit the formation of histamine (> 95%). This proves that NTN@LP has the potential to be developed as a food preservative, especially in sausages.
(Du *et al*., 2022)	Plantaricin GZ1-27	*Lactobacillus plantarum* GZ1-27	Chilled pork	*Staphylococcus aureus*	Plantaricin GZ1-27 combined with chitosan provides a preservative effect on chilled pork. Plantaricin provides a bactericidal effect.
(Silva *et al*., 2022)	Not identified	*Lactococcus lactis* L3A21M1 dan	Fresh cheese	*Listeria monocytogenes*	Bacteriocin coated with alginate-maltodextrin-glycerol formula can preserve and maintain the quality of fresh cheese

		Lactococcus garvieae SJM17			
(Zhao *et al*., 2022)	Plantaricin 827	*Lactobacillus plantarum* 163	Skim milk	*Staphylococcus aureus*	Plantaricin 827 was able to inactivate *Staphylococcus aureus* in skim milk and prolong the shelf life of the milk. Plantaricin 827 inhibited the growth of *Staphylococcus aureus* by inhibiting biofilm formation and interacting with the genomic DNA minor groove in the AT-rich region.

Figure 1. PRISMA flowchart in this review study (Moher *et al*., 2009)