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Research on food preservation and antibacterial agents

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Abstract: *This article comprehensively expounds the research progress of food preservation antibacterial agents, and details the types, mechanisms of action, and application examples of natural, chemical synthesis, and new preservation antibacterial agents. It also analyzes the challenges and future development trends faced by current research, aiming to provide reference for the in-depth research and application of food preservation antibacterial agents.*

Keywords: *food preservation; Antibacterial agents; Research progress*

1. Introduction

Food is highly susceptible to microbial contamination during production, processing, storage, and transportation, leading to food spoilage, loss of nutrients, and even the production of harmful substances, posing a threat to human health. Food preservation and antibacterial agents, as an important food additive, can effectively inhibit the growth and reproduction of microorganisms, extend the shelf life of food, maintain food quality and flavor, and play an indispensable role in the food industry. With the increasing attention to food safety and health, research on food preservation and antibacterial agents is also deepening, and new, efficient, and safe preservation and antibacterial agents are constantly emerging[1].

2. Classification and Mechanism of Action of Food Preservation and Antibacterial Agents

2.1 Natural preservatives and antibacterial agents

2.1.1 Plant derived preservatives and antibacterial agents

Plant derived preservatives and antibacterial agents mainly come from plant extracts, such as flavonoids, phenols, terpenes, and other substances. These substances have multiple antibacterial mechanisms, such as disrupting the integrity of bacterial cell membranes and causing leakage of intracellular substances; Inhibit the respiratory enzyme activity of bacteria and interfere with their energy metabolism; Affects protein synthesis and nucleic acid replication in bacteria. For example, extracts of citrus peel methoxyflavonoids (PMFs) have strong inhibitory effects on foodborne bacteria and red grape susceptible fungi. Its mechanism of action may be to alter the permeability of the cell membrane, causing leakage of electrolytes and proteins within the cell, thereby inhibiting the growth of microorganisms[2-4].

2.1.2 Microbial derived preservatives and antibacterial agents

Microbial derived preservatives and antibacterial agents are substances with antibacterial activity produced by microorganisms, such as bacteriocins, antibiotics, etc. Taking ε - polylysine as an example, it is a peptide antibacterial agent produced by Streptomyces microorganisms and has broad-spectrum antibacterial activity[5]. Its antibacterial mechanism mainly includes: acting on the cell membrane, changing the permeability of the cell membrane, leading to leakage of intracellular substances; Affects bacterial protein synthesis by binding to ribosomes and interfering with protein translation processes;

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Affects genetic material, inhibits DNA replication and transcription.

2.1.3 Animal derived preservatives and antibacterial agents

Animal derived preservatives and antibacterial agents mainly include chitosan, lysozyme, etc. Chitosan is a natural polysaccharide obtained by deacetylation of chitin, which has inhibitory effects on various bacteria and fungi. The antibacterial mechanism is that the amino groups in chitosan molecules can interact with the negative charges on the surface of bacterial cell membranes, disrupting the structure and function of the cell membrane and leading to leakage of cell contents; Meanwhile, chitosan can also enter the cell and bind to DNA, inhibiting gene expression. Lysozyme can hydrolyze peptidoglycans in bacterial cell walls, causing the cell walls to rupture and the contents to leak out, thereby achieving the goal of antibacterial activity[6-8].

2.2 Chemical synthesis of preservatives and antibacterial agents

2.2.1 Benzoic acid and its salts

Benzoic acid and its sodium and potassium salts are commonly used chemical synthetic preservatives and antibacterial agents. Benzoic acid mainly exists in molecular form under acidic conditions. Molecular benzoic acid has strong lipophilicity and can easily penetrate the cell membrane to enter the cell, inhibit bacterial respiratory enzyme activity, interfere with bacterial metabolic processes, and thus have antibacterial effects. Generally speaking, benzoic acid and its salts have the best antibacterial effect at a pH value of 2.5-4.0[9].

2.2.2 Hydroxybenzoate esters

Hydroxybenzoate esters include methyl, ethyl, propyl, etc. Their antibacterial mechanism mainly involves breaking down the bacterial cell membrane, causing intracellular substances to leak out, and inhibiting bacterial enzyme activity[10]. Compared with benzoic acid and its salts, the antibacterial effect of hydroxybenzoic acid esters is less affected by pH value, and has good antibacterial effect in the pH range of 4-8.

2.2.3 Sorbic acid and its salts

Sorbic acid and its potassium salt are unsaturated fatty acids that can participate in normal metabolism in the human body. They are ultimately oxidized to carbon dioxide and water in the body, and have low toxicity to the human body. The antibacterial mechanism of sorbic acid is achieved by inhibiting the dehydrogenase system in microbial cells, blocking their metabolic processes, and thus achieving antibacterial effects. Sorbic acid and its salts have good antibacterial effects under acidic conditions, with pH values generally below 5-6.

3. New Type of Preservation and Antibacterial Materials

3.1 Metal organic framework materials

Metal organic framework materials (MOFs) are a novel porous material composed of metal ions or metal clusters self-assembled with organic ligands through coordination bonds. The MOFs with enhanced photodynamic properties developed by Professor Xie Jing and Associate Professor Ding Zhaoyang from Shanghai Ocean University have a sterilization rate of 99.999%. This material adopts a dual ligand strategy, with porphyrin and ammonium glycyrrhizinate synergistically inhibiting bacteria, which can increase the production of type II reactive oxygen species, without cytotoxicity or metal escape[11]. It can extend the shelf life of chicken feather vegetables by more than 5 days and fresh fish slices by more than 3 days. The antibacterial mechanism mainly utilizes reactive oxygen species generated by photodynamic action to destroy biological macromolecules such as bacterial cell membranes, proteins, and nucleic acids, thereby achieving the goal of sterilization.

3.2 Soy polysaccharide composite film

Soy polysaccharide composite film is a new type of food packaging material with good film-forming and antibacterial properties. Soy polysaccharide film can improve its physical properties by adding modifiers such as nanoparticles, essential oils, gelatin, etc. The addition of natural antibacterial agents and nanoparticles can enhance its antibacterial and antioxidant properties. For example, adding nano silver particles to soybean polysaccharide film can significantly enhance its

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inhibitory effect on Escherichia coli and Staphylococcus aureus. Nano silver particles can bind to proteins on the surface of bacterial cell membranes, disrupting their structure and function, leading to bacterial death.

3.3 Polyglycerin ester composition

Polyglycerides of fatty acids are composed of a large class of complex and closely related compounds, which are normal components of human diet, including glycerol, monoglycerides, diesters, and triglycerides, as well as individual fatty acids.

Lipophilic non-ionic surfactant, naturally present in breast milk, coconut oil, and American palm oil, with an HLB value of 5.2. At a specific purity, it has safe, efficient, and broad-spectrum antibacterial properties, serving dual functions of emulsification and preservation[12]. The combination of ultra purified polyglycerol esters has a wide range of antibacterial spectra. The antibacterial spectra of glycerol lauric acid esters are listed in Table 1.

Table 1 Antibacterial spectrum of glycerol lauric acid ester

bacterium	classification	Oxygen resistance	bactericidal concentration/ug/mL
Staphylococcus aureus	G+	Aerobic bacteria	300
streptococcus pyogenes	G+	Facultative anaerobic bacteria	30
Streptococcus agalactiae	G+	Facultative anaerobic bacteria	30
Group A Streptococcus	G+	Facultative anaerobic bacteria	45
Group C Streptococcus	G+	Facultative anaerobic bacteria	30
Group F Streptococcus	G+	Facultative anaerobic bacteria	20
Group G Streptococcus	G+	Facultative anaerobic bacteria	50
Rod shaped cocci	G+	Facultative anaerobic bacteria	45
streptococcus suis	G+	Facultative anaerobic bacteria	50
Hemolytic streptococcus	G+	Facultative anaerobic bacteria	50
Streptococcus pneumoniae (III)	G+	Facultative anaerobic bacteria	10
Streptococcus pneumoniae	G+	Facultative anaerobic bacteria	10
Enterococcus faecalis	G+	Facultative anaerobic bacteria	100
Listeria monocytogenes	G+	Aerobic bacteria	50
Bacillus anthracis	G+	Aerobic bacteria	50
Bacillus cereus	G+	Aerobic bacteria	50
Bacillus subtilis	G+	Aerobic bacteria	50
Bacillus subtilis	G+	Aerobic bacteria	250
Micrococcus	G+	Aerobic bacteria	9
Streptococcus pyogenes	G+	Anaerobic bacteria	1
Clostridium perfringens	G+	Anaerobic bacteria	1
Aspergillus niger	G+	Aerobic bacteria	137
Neisseria gonorrhoeae	G-	Aerobic bacteria	20
Haemophilus influenzae	G-	Aerobic bacteria	20
gardnerella vaginalis	G-	Aerobic bacteria	10
Campylobacter jejuni	G-	Aerobic bacteria	1
Burkholderia bronchiolitis	G-	Aerobic bacteria	1
Pseudomonas aeruginosa	G-	Aerobic bacteria	Not sensitive
B. cepacia	G-	Aerobic bacteria	500
Pasteurella multocida	G-	Aerobic bacteria	500
Pseudomonas aeruginosa producing melanin	G-	Anaerobic bacteria	50
Fragile pseudomonas	G-	Anaerobic bacteria	50
Clostridium difficile	G-	Anaerobic bacteria	50
Escherichia coli	G-	Aerobic bacteria	Not sensitive
Minnesota Salmonella	G-	Aerobic bacteria	Not sensitive
Gas producing Escherichia coli	G-	Aerobic bacteria	Not sensitive
Proteus mirabilis	G-	Aerobic bacteria	Not sensitive
Shigella flexneri	G-	Aerobic bacteria	Not sensitive
klebsiella pneumoniae	G-	Aerobic bacteria	Not sensitive
Helicobacter pylori	G-	Microaerophilic bacteria	63
Grass mycobacteria	Acid resistant bacteria	Aerobic bacteria	100
Mycobacterium tuberculosis	Acid resistant	Aerobic bacteria	100

ISSN 2616-5910 Vol. 5, Issue 1: 185-192, DOI: 10.25236/AJALS.2024.050125

	bacteria		
Mycoplasma hominis	Cell wall deficient bacteria	Aerobic bacteria	1
Nocardia asteroides	Actinomycetes	Aerobic bacteria	9
Candida albicans	Yeast	Aerobic bacteria	250

3.3.1 Antibacterial and bactericidal mechanism of polyglycerol ester composition

The main sterilization mechanisms of polyglycerol ester combinations are as follows, which are comprehensively introduced in this article:

3.3.1.1 Destruction of bacterial cell membrane

The cell membrane plays a crucial role in maintaining the normal physiological activities of bacteria, as it separates the internal and external environment of bacteria and is responsible for exchanging substances with the outside world. When the cell membrane is damaged, bacteria find it difficult to survive, so using some special substances to destroy the bacterial cell membrane as a means of antibacterial can fundamentally inhibit bacterial growth.

The following are scanning electron micrographs of Pseudomonas aeruginosa treated with linalool, as shown in Figure 1

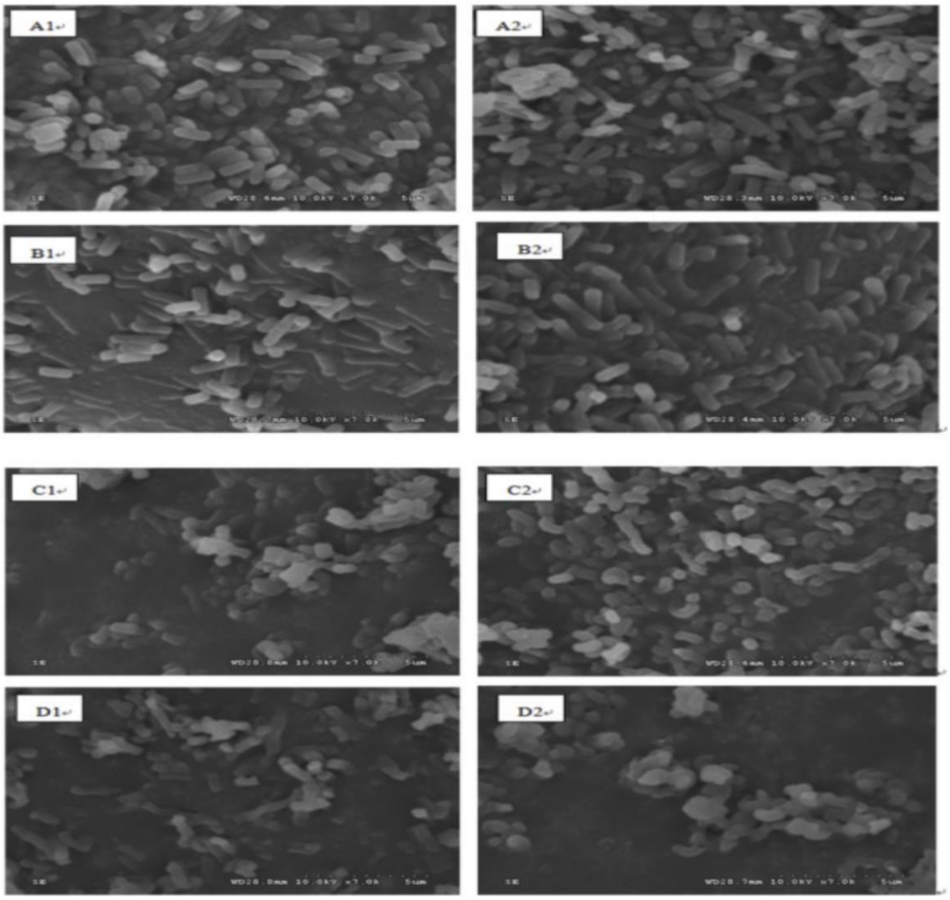

Figure 1 Scanning electron microscopy of Pseudomonas aeruginosa treated with linalool

3.3.1.2 Antibacterial mechanism of polyglycerol esters

The antibacterial effect of polyglycerol esters on Aspergillus niger was found through experiments: Aspergillus niger without polyglycerol esters showed spherical and radial shapes, with smooth spherical shapes and rough radial surfaces with small spines; Refer to Figure 2; And the outer membrane of Aspergillus niger containing polyglycerol esters was damaged, and their morphology wrinkled. See Figure 3.

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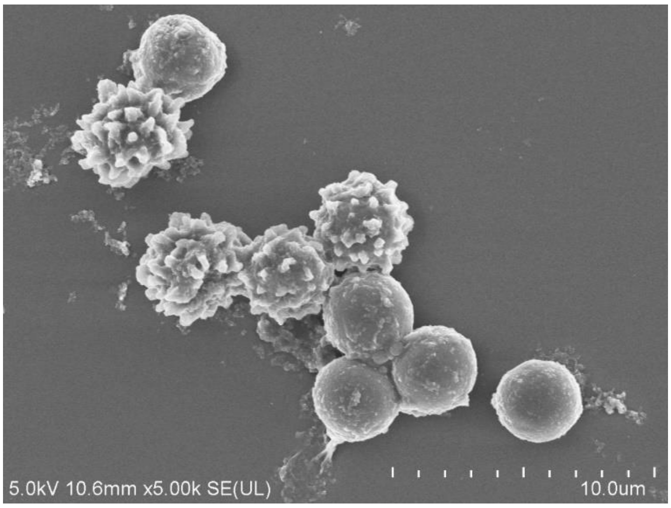

Figure 2 Morphology of strains without added polyglycerol ester

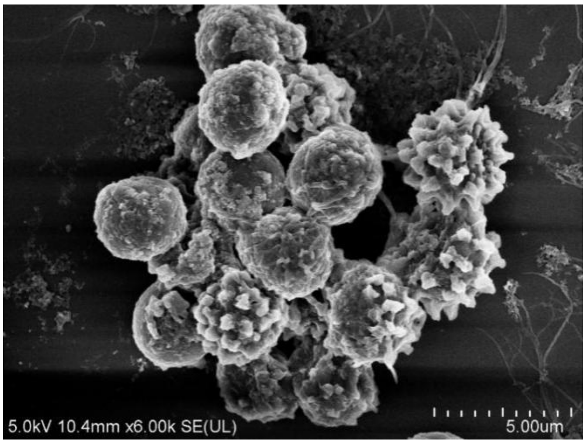

Figure 3 Morphology of strains with added polyglycerol esters

3.3.1.3 Effects of polyglycerol esters on Escherichia coli

The experimental results showed that Pseudomonas aeruginosa without added polyglycerol ester had normal morphology, no adhesion, and a smooth outer membrane, as shown in Figure 4; Pseudomonas aeruginosa with added preservative polyglycerol ester adhered together, and the outer membrane appeared as large areas of bubbles, which were destroyed and completely lysed, as shown in Figure 5[10-12].

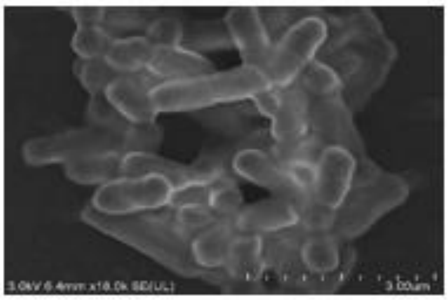

Figure 4 Morphology of bacterial strains without added preservative polyglycerol ester

ISSN 2616-5910 Vol. 5, Issue 1: 185-192, DOI: 10.25236/AJALS.2024.050125

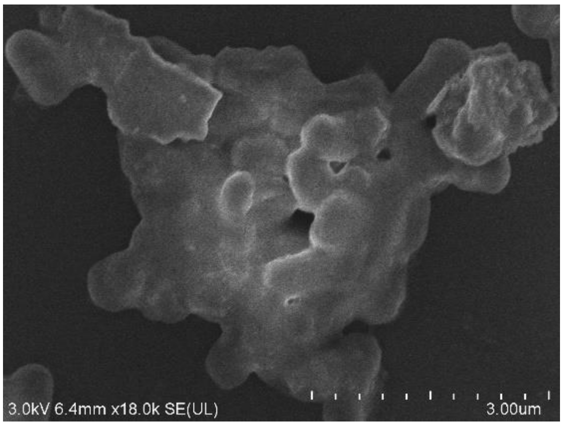

Figure 5 Morphology of bacterial strains with added preservative polyglycerol ester

4. Application research on food preservation and antibacterial agents

4.1 Application in the field of food

4.1.1 Meat preservation

In meat preservation, the combination of natural preservatives such as tea polyphenols, lactobacillus streptococci, and sodium lactate can extend the shelf life of fresh meat. When the optimal ratio of tea polyphenols, sodium lactate, and streptomycin is 0.02%, 0.25%, and 0.04%, the shelf life of cold fresh meat can be extended to 9 days. Tea polyphenols have dual effects of antioxidant and antibacterial. Lactococcin can effectively inhibit Gram positive bacteria, while sodium lactate can regulate the water activity of meat products. The synergistic effect of the three extends the shelf life of cold fresh meat.

4.1.2 Preservation of Fruits and Vegetables

Citrus peel extract of methoxyflavonoids can be used for fruit and vegetable preservation. Research has shown that citrus peel extract of methoxyflavonoids has a good preservation effect on red grapes, which can reduce the decay rate and grain drop rate of red grapes after 12 days of storage, and reduce the loss of nutrients. The main preservation mechanism is to inhibit the growth of microorganisms on the surface of grapes, while reducing the respiration of fruits and delaying the aging process of fruits[13-15].

4.2 Application in the Medical Field

In the medical field, food preservation and antibacterial agents also have certain applications. For example, in the treatment of skin diseases, some antibacterial agents can be used to treat eczema, acne, etc., by inhibiting the growth of bacteria on the skin surface and reducing inflammatory reactions. In the disinfection of operating rooms and medical equipment, antibacterial agents can effectively kill or inhibit bacteria, preventing surgical infections and the growth of bacteria on medical equipment.

4.3 Application in the field of daily necessities

In the field of daily necessities, food preservation and antibacterial agents also play an important role. Adding antibacterial agents to detergents can effectively kill bacteria on items such as clothing and tableware, improving cleaning effectiveness. Adding antibacterial agents to sanitary napkins, diapers, and other hygiene products can prevent bacterial growth and protect the health of users.

5. Challenges and Trends in the Research of Food Preservation Antibacterial Agents

5.1 Challenges Faced

5.1.1 Selective Issues

Different antibacterial agents have different inhibitory effects on different types of bacteria. In

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practical applications, how to choose the appropriate antibacterial agent to inhibit specific microorganisms is a problem that needs to be solved. For example, some antibacterial agents have good inhibitory effects on Gram positive bacteria, but have poor effects on Gram negative bacteria.

5.1.2 Security Issues

Some antibacterial agents may pose potential hazards to human health or the environment. Although some chemically synthesized antibacterial agents have significant antibacterial effects, they may have toxic side effects, such as excessive use of benzoic acid and its salts, which may burden the human liver and kidneys. In addition, the extensive use of antibacterial agents may also lead to environmental pollution, such as affecting the microbial communities in soil and water bodies.

5.1.3 Bacterial resistance issues

With the widespread use of antibacterial agents, bacterial resistance is gradually increasing. Bacteria can develop resistance to antimicrobial agents through genetic mutations, acquisition of resistance genes, and other means, leading to a decrease in the antibacterial effect of antimicrobial agents. For example, some bacteria have developed resistance to commonly used antibiotic inhibitors, limiting their application in food preservation.

5.2 Development Trends

5.2.1 Green and Environmental Protection

Developing low toxicity and biodegradable antibacterial agents is one of the future development directions. Antibacterial agents extracted from natural plants and microorganisms, such as plant derived flavonoids and microbial derived bacteriocins, have the characteristics of being natural, safe, and biodegradable, and are receiving increasing attention. In addition, the development of biodegradable antibacterial materials, such as adding antibacterial agents to biodegradable packaging materials, can also reduce environmental pollution.

5.2.2 Efficient and broad-spectrum

It is crucial to develop antibacterial agents that can effectively inhibit multiple bacteria in order to address the issue of bacterial resistance, we need to study the mechanism of action of antibacterial agents, design and synthesize new antibacterial agents, or modify and modify the structure of existing antibacterial agents to enhance their antibacterial activity and broad-spectrum.

5.2.3 Joint application

Combining different types of antibacterial agents and exerting their synergistic effects can improve the antibacterial effect, while reducing the amount of single antibacterial agent used and minimizing the development of bacterial resistance. For example, combining natural antibacterial agents with chemically synthesized antibacterial agents, or combining multiple natural antibacterial agents, may achieve better antibacterial effects.

5.2.4 Intelligence

Develop intelligent preservation and antibacterial materials using advanced technologies such as nanotechnology and biosensors. For example, by combining nano antibacterial agents with intelligent packaging materials, when the number of microorganisms in food reaches a certain threshold, the packaging materials can send signals to remind consumers that the freshness of the food has changed; or to develop an intelligent preservation system that can automatically adjust the release of antibacterial agents based on environmental factors such as temperature and humidity.

6. Conclusion

Food preservation and antibacterial agents have wide applications in the food industry, medical field, and daily necessities field. Natural preservation antibacterial agents, chemically synthesized preservation antibacterial agents, and new preservation antibacterial materials each have their own characteristics and advantages, playing important roles in different application scenarios. However, current research on food preservation and antibacterial agents still faces issues such as selectivity, safety, and bacterial resistance. In the future, research on food preservation and antibacterial agents will develop towards green and environmentally friendly, efficient and broad-spectrum, combined application, and intelligence, continuously meeting people's needs for food safety and quality.

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