

Novel Approaches in Food Preservation: High-Tech Solutions

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Abstract

Novel approaches in food preservation involve the use of high-tech solutions to improve food quality, safety, and shelf life. These approaches include the combination of edible coatings with non-thermal processing technologies. Edible coatings, made from food-grade ingredients, can provide mechanical and barrier properties to enhance the quality and safety of coated foods. Non-thermal processing techniques such as high hydrostatic pressure, pulsed light, ultrasound, and radiation technologies can be used to inhibit the growth of microorganisms on packaged foods. Nanotechnology also plays a significant role in food preservation by offering novel properties to overcome the limitations of conventional methods. Nano-coatings, nanoparticle coatings, and nano-composites have been explored to enhance the shelf life of fruits and other food products without affecting their phytochemical properties. These high-tech solutions in food preservation aim to meet consumer demands for nutritional value, functional properties, health benefits, and fresh-like appearance.

Keywords: Novel Approaches, Food Preservation, Nanotechnology and Non-Thermal Processing.

Introduction

Food preservation is a crucial aspect of ensuring food availability, safety, and quality [1]. Traditional methods of preservation, such as refrigeration, freezing, and canning, have been widely used for centuries [2]. While these methods have played a significant role in food preservation, they have their limitations in terms of shelf-life extension and maintaining nutritional quality.

Therefore, there is a growing need for novel approaches in food preservation that can address these limitations and provide high-tech solutions. The advent of technology has opened up promising avenues for preserving food in innovative ways. High-tech solutions offer the potential for longer shelf life, improved nutritional value, enhanced safety, and reduced wastage. This article aims to explore several novel approaches in food

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preservation that leverage advancements in technology, including thermal and non-thermal processing methods, as well as smart packaging solutions. In the realm of thermal processing, high-tech techniques like ohmic heating technology and high-pressure processing have gained attention. Ohmic heating technology utilizes electrical currents to rapidly heat food, offering advantages such as reduced processing time, better nutrient retention, and improved product quality. High pressure processing, on the other hand, employs pressure to inactivate spoilage microorganisms while preserving the sensory and nutritional attributes of the food. Non-thermal processing methods, such as pulsed electric field (PEF) technology [3] and ultraviolet (UV) light technology, have also emerged as effective means of food preservation. PEF technology subjects food to short, high-voltage electrical pulses, which can destroy microorganisms without the need for excessive heat. UV light technology, on the other hand, utilizes specific wavelengths of light to inhibit the growth of microorganisms and extend the shelf life of various food products. In addition to these processing methods, smart packaging plays a vital role in prolonging food shelf life. Active and intelligent packaging solutions, which incorporate elements such as antimicrobial agents, oxygen absorbers, and freshness

indicators, actively interact with the food to maintain its freshness and quality. Furthermore, the integration of nanotechnology in packaging offers potential advantages, such as enhanced barrier properties, antimicrobial effects, and real-time monitoring capabilities. As technology continues to advance, emerging techniques are making their way into the field of food preservation. Cold plasma technology, which employs ionized gas to inactivate microorganisms, holds promise for its effectiveness and potential application in various food products. High-pressure homogenization, a technique that subjects food to high pressure and shear forces, has also shown potential in preserving food by disrupting the cellular structure of microorganisms. Moreover, novel preservation techniques like pulsed light technology and ozone treatment are being explored for their ability to inactivate microorganisms and protect food quality. Pulsed light technology uses intense flashes of light to destroy microorganisms on food surfaces, while ozone treatment utilizes ozone as a powerful antimicrobial agent.

Importance of food preservation:

Food preservation plays a critical role in ensuring the availability of safe and nutritious food for consumers. It helps prevent spoilage, extend shelf life, and reduce food

wastage. Effective preservation methods allow for the distribution and storage of food over longer periods, making it accessible to consumers in various regions. Additionally, food preservation is essential for maintaining the nutritional value of perishable foods, as it helps preserve vitamins, minerals, and other valuable nutrients.

Traditional methods and their limitations:

Traditional methods of food preservation, such as refrigeration, freezing, and canning, have been widely practiced for many years. While these methods have been highly effective, they have certain limitations. For example, refrigeration and freezing only slow down the growth of microorganisms but do not eliminate them completely. Canning, although capable of providing longer shelf life in some cases, can lead to a loss of essential nutrients and alter the sensory properties of food. Moreover, traditional preservation methods may not always be suitable for certain types of food or may require significant energy consumption.

Traditional food preservation techniques have been practiced for centuries to extend the shelf life and maintain the quality of food products. Some commonly used methods include drying, salting, and fermentation.

Drying: Drying involves removing moisture from food products, which hinders

the growth of microorganisms and enzymatic activity. Methods such as sun drying, air drying, or using dehydrators are employed to preserve fruits, vegetables, herbs, and meats.

Salting: Salting draws out moisture from food items and creates an environment that inhibits microbial growth. It has been traditionally used for preserving fish, meats, and vegetables.

Fermentation: Fermentation is a process that utilizes microorganisms such as bacteria, yeasts, or molds to transform carbohydrates into organic acids or alcohol. This process not only preserves the food but also enhances flavors and textures of products like sauerkraut, kimchi, yogurt, and cheese.

Limitations and challenges associated with traditional methods:

Traditional food preservation techniques have certain limitations. Drying may lead to loss of nutritional value, alteration in texture, and potential degradation of flavor in some cases. Salting, while effective for certain foods, can result in the loss of desirable characteristics such as tenderness and flavor. Fermentation, although a popular method, requires careful monitoring and control to ensure safety and consistency.

Need for innovative approaches to address modern food preservation demands:

In the face of evolving food preservation needs, there is a need for

innovative approaches that can overcome the limitations of traditional methods. Modern demands for convenience, extended shelf life, and food safety call for new solutions. Innovative approaches can address challenges such as maintaining nutritional value, enhancing sensory attributes, and ensuring microbial safety. These approaches may involve high-tech solutions, emerging technologies, and novel preservation techniques to meet the demands of modern consumers and the food industry.

The need for novel approaches:

Given the limitations of traditional food preservation methods, there is a growing need for novel approaches that can overcome these challenges and offer improved preservation techniques. Novel approaches in food preservation aim to enhance food safety, extend shelf life, and maintain the quality and nutritional integrity of food products. By harnessing advanced technologies, these high-tech solutions provide innovative ways to preserve food while addressing the complexities and demands of modern food systems. These novel approaches offer opportunities to improve food access, reduce waste, and meet the rising global demand for safe and nutritious food.

High-Tech Solutions in Food Preservation

A. Thermal Processing:

Thermal processing is a high-tech solution in food preservation that utilizes heat to extend shelf life and improve food safety. Two notable techniques within thermal processing are ohmic heating technology and high-pressure processing.

1. Ohmic heating technology:

➔ **Principle and advantages:** Ohmic heating technology, also known as Joule heating [4], involves passing an electric current through food to generate heat internally. This method offers several advantages, including rapid and uniform heating, reduced processing time, improved nutrient retention, and enhanced product quality. Ohmic heating ensures efficient heat transfer throughout the food, resulting in inactivation of microorganisms and preservation of sensory attributes.

➔ **Applications in food preservation:**

Ohmic heating technology finds applications in various food preservation techniques, such as blanching, pasteurization, and sterilization. It is particularly suitable for liquid and pumpable food products like soups, beverages, sauces, and fruit juices. Ohmic heating can effectively destroy spoilage microorganisms, lengthening the shelf life of these

products while maintaining their nutritional value and sensory characteristics.

2. High-pressure processing:

High-pressure processing (HPP), also known as cold pasteurization, subjects food products to extremely high pressure to inactivate microorganisms and enzymes. This preservation method involves placing packaged food in a high-pressure vessel, usually at pressures between 300 to 900 MPa (megapascals). The pressure is applied uniformly, penetrating deep into the food, resulting in microbial inactivation and enzymatic activity reduction.

Advantages and applications: High-pressure processing offers several advantages, including minimal nutrient loss, preservation of sensory properties, and elimination of the need for heat, which preserves product color, flavor, and texture. HPP is commonly used for processed meats, ready-to-eat meals, seafood, beverages, and fruits and vegetables. It effectively extends the shelf life of these products by reducing spoilage microorganisms and enzymes present, while maintaining quality and nutritional integrity.

Incorporating these thermal processing techniques, such as ohmic heating technology and high-pressure processing, into food preservation practices provides innovative ways to prolong the shelf life of various food

products while ensuring safety, quality, and nutritional value. These high-tech solutions have shown promising results in the industry and offer considerable potential for widespread application in the future.

B. Non-Thermal Processing:

Non-thermal processing techniques have gained recognition as high-tech solutions in food preservation due to their ability to effectively control spoilage microorganisms while minimizing the impact on the sensory and nutritional properties of food. Two notable methods within non-thermal processing are pulsed electric field (PEF) technology and ultraviolet (UV) light technology.

1. Pulsed Electric Field (PEF) technology:

➡ Working principle and benefits:

Pulsed Electric Field (PEF) technology involves the application of short, intense electrical pulses to food products. These pulses create tiny pores in the cell membranes of microorganisms, causing their inactivation. PEF treatment offers several benefits, including minimal heating, reduced nutrient loss, improved taste and texture retention, and extended shelf life without the need for excessive heat or chemical preservatives.

➡ Usage in preserving foods: PEF technology finds applications in

various food preservation processes, such as pasteurization, juice extraction, and the preservation of liquid and semi-solid foods. It effectively inactivates bacteria, yeasts, molds, and other spoilage microorganisms, while preserving the nutritional properties and sensory characteristics of the treated food. PEF can be particularly advantageous for products like fruit juices, dairy products, liquid eggs, and liquid foods with particulates.

2. Ultraviolet (UV) light technology:

➔ Effectiveness in food preservation:

Ultraviolet (UV) light technology utilizes specific wavelengths of light to control microorganisms [5] by damaging their DNA and preventing their reproduction. UV light effectively inactivates a wide range of pathogens and spoilage microorganisms, including bacteria, viruses, molds, and yeasts. It is a non-thermal preservation method that offers advantages such as minimal impact on food quality, no residual chemicals, and reduced energy consumption.

➔ Applications and limitations:

UV light technology is applicable to various food products and surfaces. It is commonly used for disinfection purposes on food contact surfaces,

packaging materials, and water used in food processing. Additionally, UV treatment is employed for preserving liquid foods, such as fruit juices, dairy products, and beverages. However, UV light has limited penetrating ability, restricting its application to surface treatments. Moreover, it may not be as effective against certain pathogens and may require proper exposure time and intensity adjustments.

Incorporating non-thermal processing

methods like PEF technology and UV light

technology into food preservation practices

provides innovative approaches to control

microorganisms and extend the shelf life of

various food products. These high-tech

solutions offer the potential to enhance food

safety, quality, and sustainability while

minimizing the use of traditional preservation

methods and chemical additives. Ongoing

research and advancements in non-thermal

processing techniques continue to expand their

applications in the food industry.

C. Smart Packaging:

Smart packaging is an emerging high-

tech solution in food preservation that

combines innovative materials and

technologies to actively interact with the food

product, extending its shelf life and

maintaining quality. Two important aspects of

smart packaging are active and intelligent

packaging, as well as the utilization of nanotechnology.

1. Active and intelligent packaging:

➔ Concept and benefits:

Active packaging refers to packaging materials intentionally designed to release or absorb substances into the food environment to extend shelf life. These substances can include antimicrobial agents, oxygen absorbers, moisture regulators, and ethylene scavengers. Intelligent packaging, on the other hand, incorporates sensors and indicators to monitor the freshness, quality, and safety of the packaged food. These technologies can detect temperature changes, gas concentrations, and time-temperature indicators to provide real-time information to consumers and stakeholders.

➔ Examples of active packaging solutions:

Active packaging solutions include oxygen scavenging films, antimicrobial packaging, and modified atmosphere packaging (MAP). Oxygen scavenging films selectively absorb oxygen, preventing oxidation and reducing spoilage in oxygen-sensitive food products. Antimicrobial packaging incorporates natural or synthetic antimicrobial agents in the packaging material to inhibit the growth of microorganisms. MAP involves removing or modifying the air composition within the package to slow down

the microbial growth and maintain product freshness.

2. Nanotechnology in packaging:

➔ Advancements and implications:

Nanotechnology involves manipulating matter at the nanoscale level to create new materials and functionalities. In packaging, nanotechnology offers significant advancements and implications. Nanomaterials can enhance the barrier properties of packaging materials, preventing gas and moisture transfer. They can also provide antimicrobial effects, inhibiting the growth of microorganisms. Additionally, nanosensors can be integrated into packaging to monitor the quality and safety of the food, enabling real-time tracking of various parameters like temperature, pH, and gas concentration.

➔ Potential for extended shelf-life:

The incorporation of nanotechnology in packaging holds the potential for extended shelf life of food products. By providing enhanced barrier properties, nanomaterials can prevent the entry of oxygen, moisture, and other contaminants, thus minimizing spoilage and degradation of food. Antimicrobial nanomaterials can effectively inhibit the growth of microorganisms, reducing the risk of spoilage and foodborne illnesses. Furthermore, nanosensors in packaging can help detect and respond to changes in the food environment,

providing accurate information on product freshness and quality.

By integrating active and intelligent packaging solutions, as well as utilizing nanotechnology, food producers and manufacturers can improve the preservation of food products while ensuring safety and quality. Smart packaging offers benefits such as extended shelf life, improved food safety, reduced food waste, and enhanced consumer trust. Continued research and development in this field will further expand the capabilities and applications of smart packaging in the food industry, revolutionizing the way we preserve and consume food.

Emerging Technologies in Food Preservation

A. Cold Plasma Technology

Cold plasma technology is a cutting-edge approach in food preservation that harnesses the properties of plasma for effective food safety and quality improvement [6]. Plasma is commonly referred to as the fourth state of matter, where a gas is ionized to form a mixture of positively charged ions, negatively charged electrons, and neutral species.

Utilization in food preservation:

Cold plasma technology offers several advantages in food preservation. It has antimicrobial properties, which can eliminate harmful pathogens and spoilage

microorganisms on the surface of food products. It also has the potential to extend shelf life, enhance quality attributes, and reduce the need for chemical preservatives. Cold plasma can be used in various forms, such as direct or indirect treatment of food surfaces, packaging materials, and even inactivation of microorganisms in liquid foods.

Challenges and future prospects:

Despite its promising applications, cold plasma technology still faces challenges in terms of scalability, cost-effectiveness, and regulatory approval. Adapting the technology to large-scale food production and ensuring its safety and consumer acceptance remain areas that require further research. Future prospects also include exploration of novel plasma sources and optimization of treatment parameters to maximize its effectiveness.

B. High-Pressure Homogenization

High-pressure homogenization (HPH) is a novel preservation technique that involves subjecting food samples to high pressures to disrupt their structures. This disruption leads to reduced particle size, improved stability, and enhanced preservation properties. The process involves forcing the food through a small orifice at high pressure, causing shear forces and shock waves, which can effectively inactivate microorganisms and improve the homogeneity and texture of the product.

Applications in preservation:

HPH has shown promising results in preserving various food products, including dairy, fruit and vegetable juices, and sauces. It can improve the stability, texture, and sensory properties of these products, while also extending their shelf life through microbial inactivation. The technique has been particularly effective in reducing the activity of heat-resistant enzymes and controlling microbial growth.

Potential drawbacks and ongoing research:

While HPH has many benefits, it also has some potential drawbacks. The process can cause changes in the organoleptic properties of food products, such as color, texture, and taste. Moreover, the equipment required for HPH can be expensive, making it less accessible for small-scale food processors. Ongoing research is focused on minimizing these drawbacks and optimizing the process parameters to achieve the desired preservation effects while maintaining the sensory characteristics of the food.

C. Novel Preservation Techniques

1. Pulsed Light Technology:

Pulsed light technology is a non-thermal preservation technique that uses short-duration, high-energy pulses of broad-spectrum light to inactivate microorganisms on food surfaces. The pulses of light lead to the photochemical destruction of microorganisms by damaging their DNA, proteins, and cell

membranes. Pulsed light technology has shown effectiveness in reducing microbial populations on various food products, including fruits, vegetables, meats, and seafood. It can be used as a decontamination method in food processing facilities and as a surface treatment for packaged foods. The technique offers rapid and non-toxic microbial inactivation, making it an attractive alternative to traditional preservation methods.

2. Ozone Treatment:

Ozone as a preservation agent:

Ozone is a powerful oxidizing agent that exhibits broad-spectrum antimicrobial activity [7]. Ozone treatment involves the application of ozone gas or ozonated water to food products, leading to the inactivation of microorganisms and the removal of any residual pesticides or chemicals.

Application in food processing:

Ozone treatment has been used in various food processing steps, including washing, rinsing, and disinfection. It can be applied to fruits, vegetables, and seafood

Conclusion

Food preservation technologies have advanced significantly in recent years, with the development of high-tech solutions such as high hydrostatic pressure (HHP) processing, non-thermal processing techniques, and innovative packaging systems. HHP processing, which applies high pressure to

food products, can bring about structural and functional changes without affecting quality attributes. Non-thermal processing techniques like pulsed light, ultrasound, and radiation technologies can inhibit the growth of microorganisms on packaged foods, improving safety and extending shelf life. Innovative packaging systems contribute to freshness, prolonged shelf life, and reduced food waste. These advancements in food preservation technologies not only enhance food safety and quality but also contribute to sustainability by reducing waste and energy consumption. Overall, high-tech solutions in food preservation offer the potential to create high-quality, safe, and sustainable food products.

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