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Original Article: Solutions to Improve Shelf Life and Quality of Food Products with New Technologies

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A B S T R A C T

Today, with the growth of population and changing consumption patterns, the demand for food products with longer shelf life and higher quality has increased. Food spoilage caused by microbial factors, oxidation and enzymatic activity leads to significant food waste and economic losses every year. Therefore, the use of new technologies is essential to maintain the quality and increase the shelf life of food products. With the increasing demand for safe and high-quality food products, the use of new technologies in the food industry has become essential to improve the shelf life and quality of products. This review article examines new technologies such as smart packaging, nanotechnology, non-thermal processing such as high-pressure pasteurization and electrical pulses, and the use of natural antimicrobial materials. The results show that these technologies not only increase the shelf life of products, but also maintain their nutritional and sensory quality. The challenges in applying these technologies and possible solutions to overcome them are also discussed.

Introduction

Today, with the growth of population and changing consumption patterns, the demand for food products with longer shelf life and higher quality has increased. Food spoilage caused by microbial factors, oxidation and enzymatic activity leads to significant food waste and economic losses every year. Therefore, the use of new technologies is essential to maintain the quality and increase the shelf life of food products. This article reviews new solutions in this field and analyzes their impact on the food industry. In recent years, advanced technologies such as nanotechnology, smart packaging and non-thermal preservation methods have been significantly used in the field of maintaining the quality and increasing the shelf life of food. Nanotechnology helps to improve the physical and chemical properties of food by making changes at the nanoscale. For example, nanoparticles can act as antimicrobial agents and prevent the growth of bacteria and fungi (1, 2).

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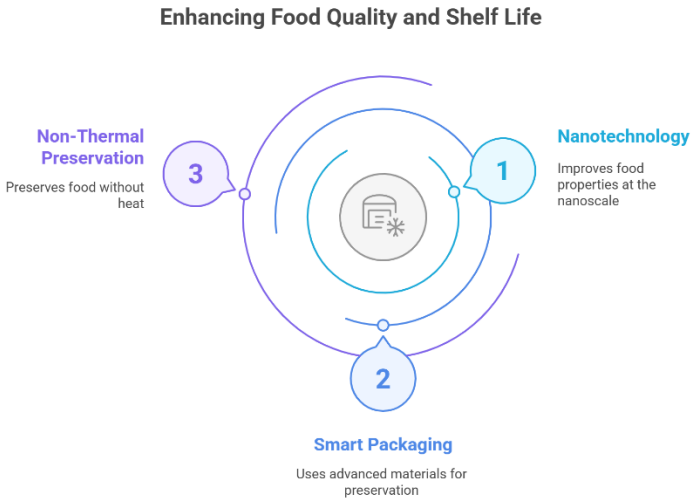

Figure 1. New technologies in preserving food quality

Smart packaging is another notable innovation in this area. This type of packaging uses sensors and indicators to provide accurate information about the condition of food and inform consumers when it is best to consume it. This technology allows manufacturers to manage their inventory more effectively and prevent food waste. In addition, non-thermal preservation methods such as high pressure and UV radiation have recently gained popularity. These techniques have attracted the attention of many manufacturers because they preserve the nutritional value and taste of products. With these methods, microorganisms can be effectively destroyed while maintaining the quality and freshness of food (3,4). Finally, awareness of consumption patterns and the growing needs of society will lead the food industry to further innovations. By combining science and technology, a bright future will be created for high-quality and long-lasting food products. These developments not only help reduce food waste, but can also lead to improved public health and environmental sustainability.

Research implications

1- Smart and active packaging:

Smart packaging uses sensors and indicators to monitor the condition of the product over time. Active packaging also maintains product quality by absorbing oxygen, moisture, or releasing antimicrobial agents. This type of packaging is especially important in the food and pharmaceutical industries. Using new technologies, smart packaging has the ability to send information to mobile devices or computers. This allows consumers to be aware of the details of the product's condition and take necessary actions if there are any worrying changes (5).

Table 1. Smart Packaging

Description	Criteria
Smart and active packaging are technologies that monitor the condition of the product over time and maintain its quality.	Definition
Food and pharmaceutical industries (most important areas of application)	Applications
Using sensors and indicators to monitor product status	

Ability to send information to mobile devices and computers	Smart Packaging Features
Absorbs oxygen and moisture to prevent spoilage	Active Packaging Features
Release of antimicrobial agents to maintain product health and longevity	
Continuous control and monitoring of product quality	Benefits
Instant notification to consumers and producers in the event of worrying changes	
Increasing consumer confidence in product quality	
Helping to maintain the freshness and quality of food and pharmaceuticals	Importance
Reducing waste and wastage of resources in the storage and transportation process	
Improving consumer health and safety	
Utilizing new technologies to further develop intelligent systems	Future Outlook
Wider use in other industries such as clothing, medical equipment, etc.	

In addition, active packaging not only helps to extend the shelf life of products, but also reduces waste. These systems help to maintain the freshness and quality of food by detecting and managing environmental conditions such as temperature and humidity. For example, some packages have indicators that change color to indicate product spoilage and alert the consumer. In today's fast-paced world, these technologies allow manufacturers to respond more accurately to customer needs. Given the increasing concerns about food safety and quality, smart and active packaging is recognized as an effective tool in creating transparency and trust between manufacturers and consumers (6,7). Similarly, this new approach not only affects product quality, but also improves the shopping experience. Consumers will feel more confident in their choices by knowing the true condition of the product. Ultimately, these developments in packaging can lead to a sustainable and responsible supply chain in which both producers and consumers are mindful of their environmental impacts and help conserve natural resources.

2- Nanotechnology in the food industry

Nanomaterials with antimicrobial properties and improved mechanical properties of packaging help increase shelf life. Nano capsules are also effective in the controlled release of preservatives. This advanced technology not only helps protect food products from microorganisms, but also preserves their freshness and true flavor. For example, silver nanoparticles are used in new packaging due to their antimicrobial properties and can effectively prevent the growth of bacteria and fungi. This new method allows for a safe and hygienic environment for food and assures consumers that the products they purchase are of high quality (8). In addition, the use of Nano capsules in packaging allows for the gradual and controlled release of preservatives. This method increases the shelf life of products and allows consumers to enjoy greater freshness and nutritional value. For example, in the dairy industry, Nano capsules containing enzymes and vitamins can effectively play a role in maintaining the quality and improving the nutritional value of products. Finally, with the advancements in

science and new technologies, we can expect that in the near future, smarter and more efficient packaging will be introduced to the market that will not only help preserve and preserve food better, but also take steps to reduce food waste and protect the environment. These developments are a turning point in the packaging industry that can have positive effects on food quality and safety (9,10).

3- Non-thermal processing technologies:

A) High-pressure pasteurization (HPP)

Extends product shelf life by inactivating microbes without destroying nutrients. High-pressure pasteurization (HPP) is an innovative method that uses high pressure to inactivate microbes and bacteria in food. This process is designed to effectively increase the safety of products, while also helping to preserve their nutrients and natural flavor. As a result, foods that undergo this method are not only improved in terms of safety, but also in terms of quality, which is very important for today's health-conscious consumers (11).

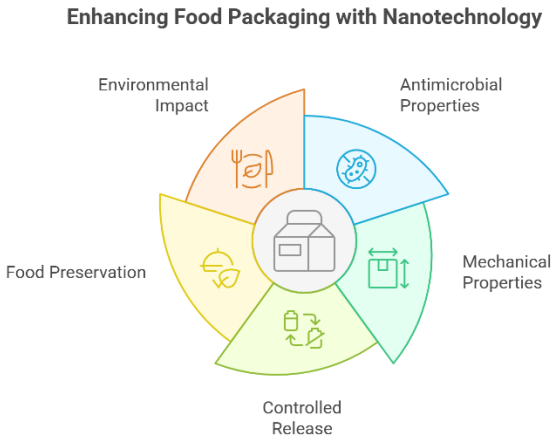

Figure 2. High-pressure pasteurization process

This advanced technique allows manufacturers to significantly extend the shelf life of their products without the need for chemical preservatives. For this reason, HPP is recognized as a sustainable and environmentally friendly solution that helps reduce food waste and maintain product quality. By using this method, manufacturers can easily respond to the growing market demand for healthy and fresh foods while also improving the consumer experience (12).

B) Pulsed electric foam (PEF): Preserves the quality of heat-sensitive products by destroying microbial cells. Pulsed electric foam (PEF) is an innovative technique in the food industry that has revolutionized the preservation processes of heat-sensitive products. This technology uses high-voltage electrical pulses to destroy microbial cell walls, thereby reducing microbial load and increasing product shelf life. This method not only helps to preserve the natural quality and flavor of foods, but also prevents undesirable changes in texture and color (13,14). In addition, electrical pulses help to preserve the nutritional value and sensory properties of products by reducing the need for heating. This technology allows manufacturers to market foods with greater purity and freshness, so that consumers have an enjoyable experience of consuming healthy and quality foods. In this way, PEF not only helps to improve the safety and shelf life of products, but also leads to a sustainable and efficient supply chain (15).

4- Use of natural antimicrobial substances

Natural substances such as plant essential oils, bacteriocins, and phenolic compounds are a good alternative to chemical preservatives. These substances not only help to preserve the freshness and quality of food products, but are also free from the harmful side effects that may occur following the use of chemical preservatives. Essential oils, with their unique aromas and flavors, serve as a natural option to enhance consumer appeal and enjoyment. For example, essential oils extracted from mint or rosemary not only add a pleasant flavor to foods, but also have antiseptic properties that help fight bacteria and fungi. Bacteriocins, proteins produced by microorganisms, can act as a defensive shield against harmful bacteria. These compounds can increase the shelf life of products by creating an unfavorable environment for the growth of pathogenic bacteria. In addition, phenolic compounds, with their antioxidant properties, help prevent spoilage and oxidation of foods, and this ability is crucial for maintaining nutritional value and preventing color and flavor changes (16,17).

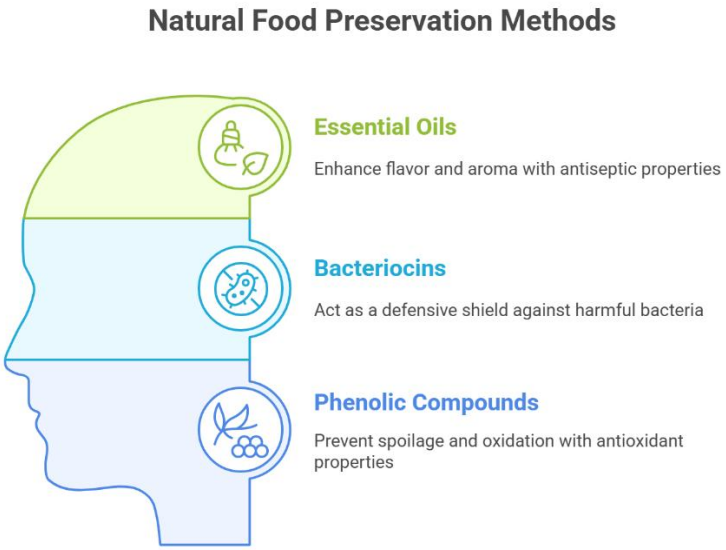

Figure 3. Natural preservatives offer more health benefits than chemical alternatives

Using these natural ingredients not only helps improve the quality and safety of our foods, but also represents an important step towards protecting the environment and reducing our dependence on synthetic chemicals. As consumers become more aware of the health and quality of products, the use of these natural alternatives will become more common in the food industry over time and can be considered a sustainable approach to modern food production. Ultimately, these changes will not only benefit consumers but also manufacturers. By offering healthier and more natural products, they can gain customer trust and loyalty and establish their position in today's competitive market (18,19).

Discussion

Each of these technologies has its advantages and limitations. For example, smart packaging is expensive, but it reduces waste. Nanotechnology has raised concerns about the potential toxicity of nanoparticles. Non-thermal technologies also require advanced equipment. However, combining several technologies, such as active packaging with HPP, can yield better results. This combination can help improve the quality of food products while significantly extending their shelf-life. For example, active packaging using HPP (high-

pressure processing) technology can help preserve the freshness and flavor of food while preventing the growth of harmful microorganisms. This method is particularly effective for products that spoil quickly, such as fruits and vegetables (20). On the other hand, advances in information technology have also impacted the packaging industry. The use of smart sensors and tracking systems can help manufacturers obtain accurate information about the status of products in the supply chain. This data allows them to make timely quality improvements or necessary changes to the production process. However, there are many challenges along the way. High research and development costs, the need for new training and skills for the workforce, and environmental concerns are among the issues that cannot be ignored. For example, many new packaging products may ultimately contribute to the problem of plastic waste unless more sustainable solutions are found to manage these materials (21). Ultimately, the future of the packaging industry depends on our ability to effectively combine new technologies with sustainable approaches. Only then can we achieve solutions that not only help improve the quality and safety of products, but also make more efficient use of natural resources and minimize negative impacts on the environment. Integrating creativity, science, and social responsibility can be the key to success in this area.

Recommendations

1- Develop applied research: More studies on the impact of new technologies on food quality and safety are necessary.
2- Cost reduction: Optimizing technologies to make them cost-effective in the food industry.
3- Industrial education: Educating producers about the benefits of new technologies.
4- Standards development: Establishing legal frameworks for the safe use of nanotechnology and new technologies.

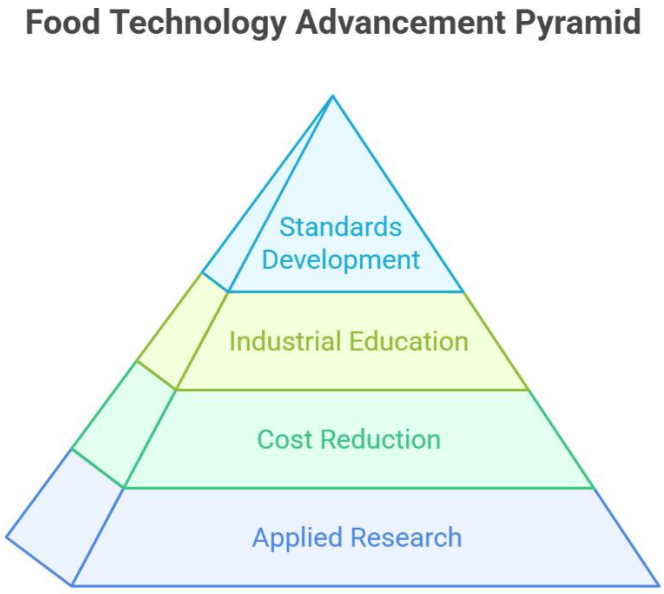

Figure 4. Food Technology Strategies

Conclusion

New technologies such as smart packaging, nanotechnology, and non-thermal processing have great potential to improve the shelf life and quality of food products. Despite technical and economic challenges, investment in this area can lead to reduced food waste and safer products. Future research should focus on the efficiency, cost-effectiveness, and consumer acceptance of these technologies. New

technologies such as smart packaging, nanotechnology, and non-thermal processing have opened up new horizons in the field of shelf life and quality improvement of food. Despite existing technical and economic challenges, these scientific advances promise to reduce waste and increase product safety in the hands of consumers. In particular, smart packaging can provide accurate information about the nutritional status with advanced sensors and analysis capabilities and help producers and consumers make better decisions. In addition, nanotechnology can significantly increase shelf life by improving the physical and chemical properties of food. This technology, using nanoparticles, can create protective films and coatings that not only prevent the entry of contaminants, but also preserve the odor and taste of food. On the other hand, non-thermal processing, as a new method for preserving the quality and nutritional value of products, can help reduce the need for high heat and, as a result, the loss of vitamins and nutrients. These techniques not only help improve the final quality of food products, but can also be effective in reducing energy consumption and production costs. In this regard, future research should focus on three key axes:

- ✓ Increasing the efficiency of technologies.
- ✓ Economicizing processes.
- ✓ Attracting consumer trust and acceptance.

In order to achieve these goals, cooperation between universities, research centers and industry is essential. By creating a dynamic and innovative ecosystem, a promising future for the food industry can be achieved, where the quality and safety of food products are at the highest level and waste is minimized.

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