

Emergent Preservation and Packaging Techniques for Food Storage

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Food storage is a fundamental method of ensuring food safety, minimizing waste, and maintaining a healthy lifestyle. It involves the proper handling, preservation, and containment of food items to prevent spoilage and contamination. Efficient food storage methods are essential for the food industry to extend the shelf life of perishable goods and maintain their quality. Food preservation is a vital aspect of human civilization, ensuring the availability of nutritious and safe food throughout the year. It is the process of treating and handling food to stop or slow down spoilage, loss of quality, edibility, or nutritional value, and thus allowing for longer storage, which ultimately reduces food wastage. Food packaging plays a vital role in preserving the quality and safety of food items, extending their shelf life, and ensuring they reach consumers in optimal condition. Food packaging serves several essential functions, making it an integral part of the modern food supply chain. Some of the emerging food preservation techniques through packaging are:

Modified Atmosphere Packaging and Its Variants

In the realm of fruit preservation and processing, innovative techniques are reshaping the industry. Modified Atmosphere Packaging (MAP) has been a go-to method for preserving fresh-cut fruits like pomegranate arils, apples, kiwifruits, honeydew, and pineapples. Conventionally, MAP involves using approximately 3 to 5% O₂ and 5 to 10% CO₂ within the package, which slows down the deterioration of the product and extends its shelf life. What's noteworthy is the recent trend of combining MAP with other methods, such as physical, chemical, or radiation techniques, ushering in a new era of fruit preservation. Particularly intriguing is the use of essential oils with antimicrobial properties, such as eugenol, thymol, or menthol, in conjunction with MAP. These oils not only aid in preserving the fruits but also enhance their texture and color. By inhibiting the action of cell wall degrading enzymes, they effectively reduce weight loss and delay undesirable color changes, ensuring the

fruits stay fresh and appealing for a more extended period. Additionally, the introduction of aromatic compounds like hexanal, 2-(E)-hexenal, and hexyl acetate represents a significant advancement. These compounds not only extend the shelf life of fruits but also enhance their safety by exhibiting antimicrobial properties against gram-negative bacteria.

This dual-action approach not only prolongs the freshness of the product but also addresses critical food safety concerns, making these techniques highly promising for the food industry. Incorporating these cutting-edge methods into fruit preservation not only ensures a consistent supply of fresh, high-quality fruits but also contributes significantly to reducing global food wastage. Continued research and innovation in this field hold the potential to revolutionize fruit preservation, ensuring consumers worldwide have access to fresh and safe fruits for a longer time.

Active and Intelligent Packaging

Active Packaging

Active packaging systems actively interact with the packaged food or the environment, offering functionalities that extend the product's shelf life and maintain its quality. These packages release active substances or absorb undesirable elements, thereby preserving the freshness and safety of the food.

Examples of Active Packaging:

- **Oxygen Scavengers:** These remove oxygen from the package, slowing down oxidation and spoilage.
- **Ethylene Scavengers:** These absorb ethylene gas, which is responsible for the ripening of fruits and vegetables.
- **Antimicrobial Films:** These release antimicrobial agents, inhibiting the growth of bacteria and molds.
- **Moisture Regulators:** These control humidity levels within the package, preventing moisture-related deterioration.

Intelligent Packaging

Intelligent packaging, also known as smart packaging, incorporates sensors, indicators, or labels that provide real-time information about the condition of the packaged product. These technologies enable constant monitoring of factors like temperature, freshness, and authenticity, offering valuable data throughout the supply chain.

Examples of Intelligent Packaging:

- **Time-Temperature Indicators:** These change color or display messages when a certain temperature threshold is exceeded, indicating potential spoilage.
- **Gas Sensors:** These detect specific gases emitted by food products, providing insights into freshness.
- **QR Codes and RFID Tags:** These allow consumers and producers to access detailed information about the product's origin, processing, and expiration date.

Edible Films and Coatings

In the field of food preservation, ground-breaking techniques involving edible films and coatings are revolutionizing the way we maintain food quality and safety. Unlike traditional packaging, these methods involve applying thin layers of edible materials directly onto food surfaces, forming a protective shield that extends shelf life and preserves sensory and nutritional attributes. These edible films and coatings are typically made from bio-based materials known as biopolymers, sourced sustainably from food industry residues and undervalued protein components like corn zein, gelatin, and casein, as well as lipids such as shellac resin and triglycerides, and polysaccharides like starch, chitosan, and carrageenan. Chitosan, a polysaccharide abundant in nature, is a notable example and has gained attention for its non-toxicity, biocompatibility, antimicrobial properties, and ability to form films. The application of these edible films and coatings, often enriched with active compounds, is particularly prominent in the preservation of fish and fishery products.

Techniques such as dipping, spraying, or using fluidized beds are employed to apply these coatings

directly onto the food surface. By inhibiting the growth of spoilage and pathogenic microorganisms, these coatings effectively maintain or enhance the quality and sensory attributes of fishery products throughout their storage period. This inhibitory action leads to a significant extension of the products' shelf life, making these innovative preservation methods vital in the food industry.

The challenge of preserving the quality of fresh-cut fruits, exacerbated by their high water content, has been a significant issue in conventional packaging systems. The primary culprits behind rapid deterioration are gases, contaminating bacteria, and molds. Fresh-cut fruits are especially vulnerable due to increased enzymatic activity induced by wounds, affecting cell walls and membranes. However, a promising solution lies in the development of edible films. These innovative films serve as barriers, effectively minimizing water loss and controlling gaseous exchange. They prove invaluable in mitigating the adverse effects of ethylene-mediated senescence in respiring fruits. What makes edible films particularly noteworthy is their adaptability; they can be enhanced to perform multiple functions. For instance, by incorporating antimicrobial agents, these films have the potential to eradicate spoilage-causing microbes, enhancing the fruits' shelf life significantly.

Furthermore, these films can be tailored to introduce various flavors, adding a layer of versatility to their functionality. In essence, the development of these edible films marks a crucial advancement in the preservation of fresh-cut fruits. By addressing issues related to water loss, gas exchange, and microbial contamination, they not only extend the fruits' shelf life but also enhance their overall quality. This innovation represents a vital stride in the evolution of food packaging, ensuring that consumers can enjoy high-quality, fresh fruits for more extended periods.

The edible coatings could be single, bilayered or multilayered, i.e., composite coatings formed by depositing one type of material (like polysaccharide/protein) followed by deposition of another type (like lipid) and this imparts better protection from microbial spoilage, controls water loss/gain, and gaseous exchange from the surface

layers. The principal benefit of the barrier films could be improved by enhancing the coating properties by incorporating nanosized organic or inorganic materials, biological, or synthetic matrices to fabricate nanocomposite films that exhibit better barrier, mechanical, and functional properties and thus lengthen/maintain the quality of the fresh produce for longer periods desirable for storage and transportation time lags. The novel edible films can be value-added by addition of functional ingredients as encapsulated nutraceuticals like vitamins, water-insoluble flavonoids, and other flavor/color enhancing phytochemicals, antioxidants like anthocyanins, carotenoids for avoiding discoloration of the cut surface and antimicrobial agents like bacteriocins (natural), biogenic nanoparticles of silver, titanium, or zinc (inorganic synthesized) to curb the growth of spoilage causing microbes. Overall, these advancements in edible films and coatings signify a dynamic and sustainable approach to food preservation, offering a promising future where food items can be stored longer, reducing waste and ensuring higher quality for consumers. As research in this field progresses, these techniques are poised to play a pivotal role in the evolution of food preservation and packaging.

Nanocomposites for Packaging

Nanocomposite materials represent a cutting-edge advancement in materials science, encompassing various dimensional forms such as one-dimensional, two-dimensional, three-dimensional, and amorphous structures. These materials are characterized by their composition of distinctly different components, intricately mixed at the nanometre scale. In comparison to conventional packaging materials, nanocomposites offer a plethora of additional advantages.

Firstly, nanocomposites exhibit enhanced strength and elasticity, making them ideal candidates for robust and durable packaging solutions. Their improved biodegradability is a significant environmental boon, aligning with the global shift towards sustainable materials. Additionally, nanocomposites allow for superior control over gaseous molecules, a crucial feature for the

development of high-performance packaging materials.

Traditionally, nanocomposite materials consist of three primary components: the matrix material, the filler, and the filler interface material. What sets nanocomposites apart is that at least one of these components is in the nanoscale order, which opens up a realm of possibilities for innovative applications in various fields, including advanced packaging solutions. The meticulous combination of these components at the nanoscale not only enhances the material's overall properties but also paves the way for the development of next-generation packaging materials that are not only stronger and more environmentally friendly but also offer precise control over the preservation environment. This groundbreaking technology represents a significant leap forward in the evolution of packaging materials, promising improved performance and sustainability for the future.

Bio-Based and Biodegradable Packaging

Bio-Based Packaging

Bio-based packaging materials are derived from renewable resources such as plants, agricultural residues, or biomass. Unlike conventional plastics, which are derived from fossil fuels, bio-based materials are sourced from nature. Common sources include corn, sugarcane, potatoes, and other plant-based polymers.

Advantages

- **Sustainability:** Bio-based materials are renewable and reduce dependency on finite fossil fuel resources.
- **Lower Carbon Footprint:** They typically have a lower carbon footprint compared to conventional plastics.
- **Biodegradability:** While not all bio-based plastics are biodegradable, some are designed to break down naturally, reducing their impact on the environment.

Biodegradable packaging

Biodegradable packaging materials are designed to decompose naturally in the environment, primarily through the action of microorganisms, into

natural substances like water, carbon dioxide, and biomass. These materials are often used for single-use items like food packaging, disposable utensils, and bags.

Advantages

- **Reduced Environmental Impact:** Biodegradable materials break down over time, reducing litter and pollution.
- **Waste Management:** Biodegradable packaging reduces the strain on landfills and waste management systems.
- **Versatility:** Biodegradable materials can be used for various applications, including packaging, agricultural films, and disposable items.

Challenges and Considerations:

- **Biodegradation Conditions:** Biodegradable materials require specific conditions to break down effectively, such as adequate moisture, temperature, and microbial activity. In some environments, they may persist if these conditions are not met.

- **Certification Standards:** The lack of standardized certifications for biodegradable products can lead to confusion. Certifications like “OK Compost” provide assurance of biodegradability.
- **Land Use:** The production of bio-based materials may compete with food production and raise concerns about land use and resource allocation.

Conclusion

In conclusion, emergent preservation and packaging techniques offer a holistic approach to food storage. By combining advanced technologies, sustainable practices, and intelligent systems, these methods not only prolong the shelf life of food but also ensure its safety, quality, and environmental responsibility. As research continues and these techniques become more widespread, they hold the promise of transforming the future of food storage and consumption.

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