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Active Packaging: Innovating Preservation for a Fresher Tomorrow

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Introduction

In today's bustling world, where convenience often trumps everything else, the importance of food preservation cannot be overstated. Yet, with traditional preservation methods showing limitations, a new champion has emerged in the realm of packaging – Active Packaging. This innovative technology is revolutionizing the way we keep our food fresh, extending shelf life, and ensuring quality. Active packaging refers to a type of packaging technology designed to interact actively with the environment surrounding the packaged product. Unlike traditional packaging, which primarily serves as a passive barrier, active packaging systems incorporate elements that actively modify or control the internal atmosphere of the package. This active interaction can help extend the shelf life of products, maintain product quality and enhance safety by addressing factors such as moisture levels, oxygen content and microbial growth. Active packaging may employ various mechanisms, including oxygen scavenging, moisture absorption, antimicrobial release and ethylene removal, among others. Overall, active packaging plays a dynamic role in preserving the freshness and integrity of packaged goods, particularly perishable items such as food and pharmaceuticals.

Components of active packaging

1. Oxygen scavengers

Oxygen scavengers were first marketed in Japan in 1976 by the Mitsubishi Gas Chemical Co. Ltd. under the trade name Ageless TM. Oxygen scavengers are the most commercially important among active packaging. The common most well-known oxygen scavengers are applied in the form of small sachet containing various iron-based powders combined with a suitable catalyst which have capability of reducing oxygen levels to less than 0.01% in the pack. Non-metallic scavengers use organic reducing agents such as ascorbic acid, ascorbate salts or catechol. Enzymic oxygen scavenging systems are also used with either glucose oxidase or ethanol oxidase which could be incorporated into sachets, adhesive labels or immobilised onto packaging film surfaces. Following are some examples of oxygen scavengers used in food industry

- Laminate containing a ferrous oxygen scavenger which can be thermoformed into a tray which has been used commercially for cooked rice.
- Oxygen scavenging plastic (PET) beer bottles.
- Light activated oxygen scavenger plastic packaging materials for Beverage industry

2. Carbon dioxide scavengers/emitters

There are many commercial sachet and label devices which can be used to scavenge or to emit carbon dioxide. A mixture of calcium oxide and activated charcoal has been used in polyethylene coffee pouches to scavenge carbon dioxide. Dual-action oxygen and carbon dioxide scavenger sachets and labels are more common and are commercially used for canned and foil pouched coffees in Japan and USA. Carbon dioxide emitting sachet and label devices can either be used alone or combined with an oxygen scavenger.

3. Ethylene scavengers

Ethylene (C_2H_4) is a plant growth regulator which accelerates the respiration rate and subsequent consequences of horticultural products such as fruits, vegetables and flowers. Potassium Permanganate ($KMnO_4$) immobilised on an inert mineral substrate such as alumina or silica gel. $KMnO_4$ oxidises ethylene to acetate and ethanol and in the process changes colour from purple to brown and hence indicates its remaining ethylene scavenging capacity.Activated carbon-based scavengers with various metal catalysts can also effectively remove ethylene.

4. Ethanol emitters

Ethanol is an antimicrobial agent particularly effective against mould but can also inhibit the growth of yeasts and bacteria. Ethanol can be sprayed directly onto food products just prior to packaging. A practical and safer method of generating ethanol is through the use of ethanol-emitting films and sachets. All of these films and sachets contain absorbed or encapsulated ethanol in a carrier material which allows the controlled release of ethanol vapour.

5. Preservative releasers

There is a potential use for antimicrobial and antioxidant packaging films which have preservative properties for extending the shelf life of a wide range of food products. Some commercial antimicrobial films and materials have been introduced, primarily in Japan. One widely reported product is a synthetic silver zeolite which is in contact with packaging film that release slowly antimicrobial silver ions into the surface of food products. The anti-microbial agents generally used on packaging materials include organic acids, e.g. propionate, benzoate and sorbate, bacteriocins, e.g. nisin, spice and herb extracts, e.g. from rosemary, cloves, horse radish, mustard, cinnamon and thyme, enzymes, e.g. peroxidase, lysozyme and glucose oxidase, chelating agents, e.g. EDTA, inorganic acids, e.g. sulphur dioxide and chlorine dioxide and antifungal agents, e.g. imazalil and benomyl. The major potential food applications for antimicrobial films include bread, cheese, fruits and vegetables.

6. Moisture absorbers

Excess moisture cause food spoilage which can be reduced by using various absorbers or desiccants which in turn helps in maintaining food quality and extending shelf life by inhibitingmicrobial growth and moisture related degradation of texture and flavour. Several c ompanies manufacture moisture-drip absorbent pads, sheets and blankets which consist of two layers of a microporous non-woven plastic film, such as polyethylene or polypropylene, between which is placed a superabsorbent polymer capable of absorbing up to 500 times its own weight of water which is used for foods such as meats, fish, poultry, fruit and vegetables. Typical superabsorbent polymers include polyacrylate salts, carboxymethyl cellulose (CMC) and starch copolymers which have a very strong affinity for water.

7. Flavour/odour adsorbers

The interaction of packaging with food flavours and aromas has long been recognized. Commercially, very few active packaging techniques have been used to selectively remove undesirable flavours and taints, but many potential opportunities exist.

Debittering of pasteurised orange juices by using cellulose triacetate or acetylated paper into orange juice packaging material is one of the examples for such methods. BMH™ powder can be incorporated into packaging Removal of aldehydes such as hexanal and heptanal from package headspaces has its applications in foods such as snack foods, cereals, dairy products, poultry and fish.

8. Temperature controlled packaging

Temperature control active packaging includes the use of innovative insulating materials, self-heating and self-cooling cans. Self-heating aluminium and steel cans and containers for coffee, tea and ready meals are heated by an exothermic reaction which occurs when lime and water positioned in the base are mixed. Self-cooling cans have also been marketed in Japan. The endothermic dissolution of ammonium nitrate and chloride in water is used to cool the product.

Quality indicators

Time / temperature indicators may be fixed to the package which monitors the product temperature exposure throughout the supply chain. They will indicate how long the food product was above the thresh hold temperature. They provide a non-reversible record of temperature exposure that is accurate and easy to interpret. This chart summarizes the key components of active packaging and their respective roles in preserving the quality, safety, and shelf life of packaged products.

Role of active packaging in dairy products

Active packaging plays a crucial role in the dairy industry by helping to extend the shelf life, maintain freshness, and ensure the safety of dairy products. Here are some specific ways in which active packaging benefits the dairy industry:

1. **Extended Shelf Life:** Active packaging systems with oxygen scavengers help to reduce the oxygen levels within the packaging, which can slow down the oxidation process in dairy

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products. This extends the shelf life of products such as milk, cheese, and yogurt, reducing waste and allowing for longer distribution periods.

2. **Preservation of Freshness:** By controlling moisture levels, active packaging helps to preserve the freshness and texture of dairy products. Moisture-absorbing components prevent excess moisture from accumulating, which can lead to spoilage or deterioration of product quality.
3. **Microbial Control:** Active packaging may incorporate antimicrobial agents that inhibit the growth of spoilage microorganisms and pathogens in dairy products. This helps to enhance food safety and reduce the risk of microbial contamination, particularly in products such as cheese and yogurt.
4. **Prevention of Flavor and Aroma Loss:** Oxygen scavengers in active packaging prevent oxidation of fats and oils in dairy products, preserving their flavors and aromas. This helps to maintain the characteristic taste and quality of products like butter and cream.
5. **Reduced Food Waste:** By extending the shelf life of dairy products, active packaging helps to reduce food waste throughout the supply chain. This is particularly important in the dairy industry, where perishable products can quickly spoil if not properly preserved.
6. **Improved Product Presentation:** Active packaging with features such as resealable closures or portion control helps to enhance the convenience and usability of dairy products for consumers. This can lead to increased consumer satisfaction and brand loyalty.
7. **Regulatory Compliance:** Active packaging systems equipped with temperature and humidity sensors help dairy manufacturers comply with regulatory requirements for product storage and transportation. This ensures that products are maintained under optimal conditions to meet quality and safety standards.

Conclusion

Active packaging is revolutionary technology holds the key to addressing some of the most pressing challenges in food preservation and packaging. it's a dynamic solution that actively interacts with the packaged product, employing various mechanisms to extend shelf life, enhance quality, and ensure safety. Active packaging has potential across industries, from food and beverage to pharmaceuticals, healthcare, and consumer goods. Looking ahead, the future of active packaging is bright and promising. With ongoing advancements in materials science, biotechnology, and smart packaging technology, we can expect to see even more innovative solutions that push the boundaries of preservation and sustainability.