

## Active and Intelligent Packaging Food-The Development and Application

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**Abstract:** With the continuous improvement of people's quality of life, the demand of consumers to improve the quality of packaged food and extend its shelf life is increasing, and the performance of food packaging has been put forward with higher and higher requirements. Active packaging and intelligent packaging is a new area of packaging technology that can meet the demand for high-quality packaged food. This paper introduces the concepts and applications of different types of active packaging and intelligent packaging. Latest packaging research trends and innovation points; And the application of active and intelligent packaging markets. At present, active packaging can be mainly divided into: Oxygen scavengers, Moisture absorbers, Ethylene scavengers, Flavor and Odor absorber/Release; Intelligent packaging can be divided into: Radio frequency identification tags (RFID), Time-temperature indicators, Freshness indicators. The application of active packaging and intelligent packaging provides great benefits to the food industry. It improves the freshness and shelf life of the food and monitors. It controls the storage conditions from the production site to the final consumer consumption, which has a broad anti-war industry and application prospects.

### 1. Introduction

The public opinion in the market has drawn consumers' attention to the "safe, fresh and sustainable development" of food. Consumers are paying more attention to food safety and increasing demand for food quality. Food packaging is a useful technology that can maintain food quality and extend the shelf life of food. Traditional food packaging is based on the nature of food itself to determine the need for food protection. The materials used for packaging are generally metal, plastic, and so on. Traditional packaging protects products from mechanical damage or biological damage, facilitates storage and transportation, and promotes sales. The development of economic globalization also requires that food packaging can adapt to long-distance transportation and complex transportation. However, traditional systems are reaching their limits with regard to further extension of the shelf-life of packaged food. Moreover, plastic has occupied the food packaging market with its excellent performance and processability. The large-scale use of food packaging materials has led to an increase in the proportion of waste. Plastic does not degrade in the natural environment, causing great harm to the environment. At the same time, plastic is a kind of high molecular polymer. The unreacted free monomers (such as styrene, toluene, ethylbenzene) in plastic may migrate from packaging materials to food, causing harm to the human body. Therefore, the research of new packaging materials that can replace traditional packaging materials is the development trend of the food packaging industry. Active packaging and intelligent packaging conform to this development trend and provide many innovative solutions for food quality maintenance and market demand [1].

Active packaging (AP) is a kind of packaging system, which changes the packaging environment, prolongs the storage period, improves the food safety and sensory characteristics, and keeps the food quality unchanged. Active packaging can be divided into absorption system, release system, and other systems. According to the specific functions, the common active packaging can be divided into oxygen scavengers, moisture absorbers, ethanol emitters, ethylene scavengers, taint scavengers, antimicrobial-releasing systems, and antioxidant active-packaging systems. Intelligent packaging (IP) by sensors passes packaging changes to the consumer [2]. At present, the main intelligent packaging on the market can be divided into three categories through the type of sensor. The first is external indicators in which

the sensor is set on the outside of the package. You can check the change of the external environment temperature, humidity, and physical impact under external force factors. The second kind of sensors placed inside the packaging can effectively detect internal packaging systems, including oxygen, microorganism quantity, physical and chemical indicators of changes. The third type of equipment can be passed between the consumer and commodity information. For example, consumers can scan a special barcode on the outside of the package to get a range of information, including the best time the product is used [3].

Intelligent packaging and active packaging are in response to consumer demand or the trend of industrial production. New packaging is limited to the protection and sales of traditional packaging materials and uses new solutions to delay the shelf life of food or monitor the quality of food. According to the FDA's 2011 report, approximately 1.3 billion tons of food are discarded every year. The application of intelligent packaging and active packaging can improve the problem of food waste. From the global market perspective, the application of intelligent and active packaging in food has increased from 15.5 billion U.S. dollars in 2015 to 16.9 billion at the end of 2018. Facts have been proved that the market's interest in the above two new types of packaging is increasing [4].

This review aims to provide an update of existing active and intelligent systems and present their current food-related applications. In addition, future perspectives on active and intelligent food packaging are discussed.

## **2. Active packaging**

### **2.1 Oxygen scavengers**

The presence of oxygen in food packaging may be due to inadequate evacuation during packaging, poor sealing resulting in oxygen entering the packaging system through the packaging material, or oxygen from the food itself is released into the top space of the packaging [5].

Oxygen in the package will be for a lot of food quality. Shelf life has a negative impact because it can lead to oxidation product or promote the growth of aerobic microorganisms, including such as lipid oxidation lead to rancidity), color changes (such as chlorophyll and carotenoids, such as plant pigment discoloration, meat oxidation) and nutrient losses (such as the oxidation of vitamin E), a series of changes.

Oxygen also promotes the growth of microorganisms (such as aerobic bacteria) and insects, and it has a considerable effect on respiration rate and ethylene production.

The removal of oxygen can extend the shelf life of food appropriately, and the application of oxygen scavengers can solve this problem. In general, existing oxygen removal technologies utilize one or more of the following mechanisms: iron powder oxidation, ascorbic acid oxidation, photosensitive dye oxidation, enzyme oxidation (e.g., glucose oxidase/catalase and alcohol oxidase), ferrite salts, unsaturated fatty acids (e.g., oleic and linoleic acids), and combinations of these compounds [6].

At present, commercial bag-type iron-based oxygen removal agents are Ageless (Mitsubishi Gas & Chemicals, Japan), ATCO1 (Stanta Industries, France), The Freshlizers Series (Toppan, Japan) Printing, Inc., and FreshPax1 (Multisorb Technologies, Inc.) [7]. The main advantage of these products is that they can reduce the oxygen content by 0.01%.

### **2.2 Moisture absorbers**

Many foods require the control of water, whether in liquid or gaseous form. The leakage of liquids (water, blood, or other fluids) from meat products and fish can reduce the quality of the product [2]. High water content is conducive to the growth of microorganisms, leading to the softening of dry and brittle products, such as high water content can lead to the lumping or hardening of milk powder. Excessive water loss may also promote fat oxidation [6].

To prevent microorganisms from growing in these nutrient-rich exudates, absorbent materials containing organic acids and surfactants are often added to the packaging system to absorb the liquids. Packaged products with high headspace relative humidity are susceptible to temperature fluctuations during transportation or storage, conducive to condensation and mist formation [4].

In such foods, the use of an antifogging additive to reduce the interfacial tension between the condensed water and the film contributes to the transparency of the film, allowing the consumer to clearly see the packaged food, but does not affect the amount of water present in the container [5]. In some cases, it can remove excess liquid water, while in other cases, it can control the relative humidity in the headspace [8].

### **2.3 Ethylene scavengers**

For most fresh produce, high or low levels of ethylene in the storage environment affect their shelf life. Most fruit and vegetable products release ethylene after harvest. Ethylene is a plant hormone that promotes the ripening of fruits and vegetables. It causes the softening and degradation of chlorophyll, which inevitably degrades fruits and vegetables after harvest [5].

Ethylene scavengers are useful for preserving ethylene-sensitive fruits and vegetables such as apples, kiwi, bananas, mangoes, and tomatoes.

At present, the following mechanisms of action have been widely used in the market. One of the main mechanisms of ethylene scavengers is the oxidation of ethylene to carbon dioxide and water using potassium permanganate [9]. In general, the permanganate content is between 4% and 6%. It is prepared on a substrate conducive to the REDOX process. In the process of REDOX, various substances can also be added as catalysts. When potassium permanganate oxidizes ethylene acetate and ethanol, the color changes from purple to brown. The color change indicates the remaining capacity of the potassium permanganate to absorb ethylene. But potassium permanganate cannot come into direct contact with food because of its toxicity. Other systems are based on the ability of certain materials to absorb ethylene [10]. For example, at higher relative humidity, palladium has a higher ethylene adsorption capacity than permanganate-based scavengers. The use of palladium in conjunction with charcoal helps to prevent the accumulation of ethylene [11].

### **2.4 Flavor and Odor absorber/Release**

In Europe, Article 4 (3) of Directive 1935/2004(58) indicated: “Active materials and articles shall not bring about changes in the composition or organoleptic characteristics of food, for instance by masking the spoilage of food, which could mislead consumers” [5]. The addition of flavors and odors can increase the desirability of the food to the consumer, improve the aroma of the fresh product itself, or enhance the flavor of the food when it is unpackaged.

These flavors and aromas are released slowly and evenly during the shelf life of the packaged product. The release can be controlled to occur during the opening of the package or during food preparation.

The gradual release of odors can counteract the natural loss of taste or odor from products with a long shelf life [12].

The gradual release of odors can counteract the natural loss of flavor or odors from the long shelf life of products. As Eka Noble commercializes BHM powder, combining BHM powder with traditional packaging materials such as paper and cardboard gives this new packaging material the ability to absorb the undesirable odors produced by aldehydes, absent to produce UOP’S.

The absents deodorant powder, as an additive, is added to the packaging material to eliminate unwanted odors and tastes [5].

## **3. Intelligent packaging**

### **3.1 Radiofrequency identification tags (RFID)**

In contrast to sensors and indicators, RFID is an independent form of smart packaging based on electronic information. It uses radio-frequency electromagnetic fields to transmit data from tags attached to objects so that people can trace all kinds of information about products [13].

RFID is superior to traditional barcode or manual recording systems because it is more accurate and allows information to be read without visual contact. RFID technology has a strong ability to read information. It can work under extreme temperatures and different pressures [6]. At the same time,

because of their ability to read and write memory, they are often combined with TTI or biosensors to collect information such as time, temperature, microbial data, etc.

In recent years, RFID systems have been widely used due to their numerous applications, such as monitoring security and access control and supply chain tracking in many food industries. RFID tags can be attached to food, cars, medicines, livestock, clothing or property, and can even be implanted in pets. The system has been used in the temperature monitoring of perishable food [13].

### **3.2 Time-temperature indicator**

Time-temperature indicator as a display product accumulated time-temperature history of equipment or smart tags, by time accumulated temperature effect to real-time monitor and record the product from the manufacturing, storage, and transportation to the consumer temperature history of each link, ensure food quality and safety of the actual, the quality of products are widely used in easy to decay [14].

According to the different working principles of color change in the indicator, the time and temperature indicator can be divided into four types: physical, chemical, biological, and enzyme [15].

Physical time-temperature indicators mainly rely on physical changes (such as physical diffusion) between colored substances, closely related to temperature and time [16]. Physical time-temperature indicators include diffusion time-temperature indicators, nano time-temperature indicators, etc.

Chemical time-temperature indicator depends on the chemical reaction between molecules or compounds to produce color changes. Its reaction rate is affected by temperature and time [17].

Biological Time-Temperature Indicator identifies the indicator's color by detecting the acidity produced by microorganisms in specific temperature and time conditions change.

The temperature indicator is an important factor in producing color change, while the hydrolysis and the enzymatic reaction of enzymes have a higher correlation with temperature. Compared with other types of TTI [17], enzyme TTI has the characteristics of stable performance, low production cost, and good controllability.

### **3.3 Freshness indicator**

The freshness index is used to indicate whether the quality of the product has been compromised. The package is usually equipped with an irreversible discoloration device that informs the consumer whether the package has deteriorated and whether the package is an intact part of the product or the full circulation history [3]. Some examples described below are internal or external indicators used to monitor running time, time temperature, humidity, vibration abuse, and gas concentration changes. The Shockwatch<sup>®</sup>M indicator manufactured by 3M provides a physical example (the shock indicator). The indicator consists of a closed glass capillary tube. It has a red liquid in one tube and dispersion in the other tube. When the two ends of the content are mixed, the tube turns red due to vibration. Another example of a freshness indicator is a diamine dye sensor system. Diacetyl is a volatile metabolite released by microbes that spoil the meat. The diacetyl can react with the dye through permeable meat packaging to change the color of the indicator [18].

## **4. Conclusion**

Improving consumers' requirements for food storage quality leads to the innovation and development of new packaging technology.

The research and development of environmentally friendly, active, and intelligent packaging materials is the focus of research in the field of food packaging. Active packaging and intelligent packaging are more and more widely used in all kinds of food packaging. However, the development of active and intelligent packaging is faced with a series of problems and challenges: (1) legal hurdles: In the international market, due to the different regulations on food safety in different countries, the legality of the same food packaging will be different in different countries. Just as the EU has very strict legislation on new packaging, the concept of active packaging and intelligent packaging, which are common in the US and Australian market, has not been introduced to Europe (2) technical

difficulties: The main technical obstacle to an intelligent system is the development of an interactive freshness indicator that can directly measure a product's pollution level or quality level as a parameter. (3) the cost is still high: Compared with traditional packaging, the cost of intelligent packaging and active packaging is still high. Lowering the cost of new packaging would allow these new technologies to be more widely used, allowing for a wider range of products. Remains into this, continuous research and development will help to active and intelligent packaging technology in the future food industry to get the more extensive application.

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