Technical Report～～～～～～～～～～～～～～～～～～～～～～～～～～～～～～～

Active Packaging Technologies for Food Packaging Applications

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The increase in consumer demand for healthier, fresher, high quality foods with little-to-no preservatives has increased the need for packaging technology that can provide a higher level of protection. Active packaging technologies are being incorporated into different packaging formats to provide this advanced level of protection. This type of packaging technology offers a variety of benefits over standard passive packaging materials and can be designed to preserve product freshness and provide the food processor with more options for protecting their product quality. Many of these technologies can be incorporated directly into flexible packaging materials, eliminating the addition of a sachet inside the package. Sealed Air Corporation offers a line of active packaging technologies in their Cryovac Freshness Plus™ portfolio which are designed to protect product color, flavor, nutrients and aroma. These packaging materials consist of oxygen scavenging films, active barrier films and odor scavenging materials. This article is a review of the materials' performance and applications.

1. Introduction

Packaging that effectively maintains product quality is essential for meeting the market demands of minimally processed products that are fresher and healthier but still have adequate shelf-life. Some of the more popular packaging technologies gaining ground in the market place are various active packaging options. Active packaging is used in conjunction with other food processing and packaging methods to improve the preservation of food and beverage products.[1] Active packaging differs from passive packaging by interacting with the atmosphere inside the package and/or with the product to maintain the nutrient and sensory quality, inhibit the growth of microorganisms, and protect against environmental contaminants. Examples of active-packaging technology include oxygen scavenging, odor scavenging, moisture absorbers, carbon dioxide emitters and scavengers, time-temperature indicators and the integration of antimicrobials. Many of these technologies can be incorporated directly into the polymer matrix of the packaging materials. These technologies may also be used in sachets that are placed freely into the package or glued in label form to the inside of the package.[2] The use of polymeric oxygen scavengers eliminates the need for adding a sachet or label into the package, which can be a liability from a consumer ingestion of sachet contents or the intermingling of sachet components with the product.

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The damaging effects of oxygen on food products are well documented and are easily detected in changes of the product color, odor, and taste. Oxidative degradation can also initiate nutrient loss, product rancidity and microbial spoilage, which are all influenced to a great extent by the presence of oxygen. The problems with oxidation are further complicated by changes in products as the market place looks for fresher, healthier products with fewer additives. To meet these demands processors are offering additive-free products and introducing more organic products. Reducing or eliminating food additives requires packaging that provides greater protection against oxidation. As processors look to remove trans-fatty acids and add "healthier oils," the use of unsaturated fats and oils is increased. Fats and oils which are already susceptible to oxidation have a higher potential to oxidizing as the degree of unsaturation in the oil increases.[3)] Reduction or total removal of headspace oxygen along with the prevention of ingress has been shown to decrease the oxidative effects and prolong product shelf life and quality.

Oxygen exposure is typically minimized by the use of vacuum packaging or use of a modified atmosphere package (MAP). MAP formats involve the removal of the initial air and replacement with a single gas or mixture of gasses, usually with reduced oxygen. One of the primary exceptions is high-oxygen packaging of some fresh meats. MAP is typically used to extend product shelf life by reducing oxygen and/or increasing gases, such as carbon dioxide, in the food product environment.[4 5 6)] However with both MAP and vacuum packaged product, it is difficult to remove all of the oxygen from the package. The result is free oxygen in the package, which is available to interact with the product.

Another source of oxygen is ingress from the environment through the packaging material itself. Although barrier technology for flexible polymeric films is greatly improved and retards the rate of oxygen ingress, over time environmental oxygen is able to migrate through the package material. The reduced oxygen environment in vacuum and MAP packages creates a partial pressure difference that can in effect increase the rate of oxygen permeation into the package. Even with the use of high barrier packaging materials, extended shelf lives can result in detrimental amounts of oxygen reaching the product. The other potential source of oxygen is air entrapped in the product itself. Entrapped or dissolved oxygen is commonly overlooked or ignored during the packaging process, but, over time, the oxygen can migrate out of the product, which provides a source of oxygen available for oxidative reactions.

The use of active packaging materials that contain oxygen scavengers can help protect products from all the different sources of oxygen. In MAP product, a rapid oxygen scavenger can minimize or eliminate the available oxygen in the package headspace, thus reducing the negative oxidation reactions. This same oxygen scavenging technology can be used in vacuum packaged product or packages with minimal amounts of headspace using an active barrier film. The active barrier materials incorporate the oxygen scavenging polymer into the barrier layer of the film and actively bind oxygen migrating into the package. The active barrier properties of both the oxygen scavenging films and active barrier films work to absorb ingress oxygen before it can reach the product. This provides processors with a number of packaging options to help protect against oxidation.

The aroma inside the package also plays a major role in communicating the freshness of a particular product. Undesirable odor compounds can be given off by many food products during storage. These aromas are referred to as “confinement odors” and are perceived as a reduction in product quality.[1] The package can assist with preserving the desirable fresh product smells, but it can also function to protect against confinement odors. Odor compounds arise from various sources like lipid oxidation, Maillard reactions, product degradation, and the interaction of degradation products.[7] While many of these aromas can be minimized or eliminated by hindering these reactions, some products are still prone to developing confinement odors. These confinement odors can overpower the desired product aroma and create a perception of lost quality and freshness. Minimizing or eliminating these off-odors protects the product aroma and helps maintain freshness. Odor removers incorporated into the package can scavenge the malodorous compounds that can be generated by oxidative and nonoxidative biochemical deterioration.[1] Use of odor scavenging materials can assist processors with maintaining the desired product aroma throughout the product life.

2. Methodology

The headspace scavenging rates were measured with packages formed on a Multivac R230 equipped with a Cryovac Model 4212 Scavenging Initiation System (SIS). Packages were produced with OS2030 lidstock film (3.1 mil gauge) and T6070B bottom web film (7.0 mil gauge) formed into 25 mm deep pockets. The OS2030 lidstock received an approximate cumulative dose of 400 mJ/cm^2 immediately before creating the finished packages. Packages were flushed with approximately 1% oxygen with nitrogen residual and stored at ambient and refrigerated conditions. The package volumes contained approximately 480 cc of headspace. The headspace oxygen concentration was analyzed by injecting 5 cc of headspace into a Mocon PacCheck 400 on day 0, 1, 2, 4, and 7. Four replicate packages were produced, and day four average scavenging rates were calculated for ambient and refrigerated conditions.

$$\text{Average Rate} = \text{Total cc } O_2 \text{ scavenged after 4 days}/(0.0238\ m^2 \cdot \text{Time})$$

Active barrier performance was assessed by measuring the headspace oxygen concentration of 4” x 7” pouches containing 30 ml of deionized water. A flow meter was used to fill the water pouches with 300 cc of pure nitrogen gas and samples were stored at 40 ^{o}C. The headspace measurements were made by injecting 5 cc of headspace into a Mocon PacCheck 400. Oxygen ingress was then plotted over time to measure the rate of ingress compared to a passive barrier structure.

Odor scavenging evaluations were conducted on a HP5890 Gas Chromatograph (GC) fitted with a J&W GS-GasPro column held at 50°C isothermally for 8 minutes and a thermal conductivity detector. Samples consisted of 0.5 gm of film in a 24 ml glass vial capped with a mininert value and tested in triplicate. The glass vials were injected with 250 µl of concentrated H_2S or methanethiol gas and measured over a 24-hour period. Each sampling consisted of 250 µl of headspace from the vials injected into the GC.

3. Evaluations

The oxygen scavenging films offered by the Sealed Air Corporation under their Cryovac Freshness Plus™ product line are designed to rapidly remove headspace oxygen. The film scavenging reaction is initiated by a patented activation system that exposes the film to a specific spectrum of UV light. The scavenging reaction continues with no additional stimulus until the scavenging capacity is exhausted. This allows the processor to activate the film "on demand" when they are ready to package their products. The activation systems are designed to interface with the packaging equipment in order to activate the oxygen scavenging film right before sealing the package.

The scavenging rate of this film was evaluated by calculating the average oxygen scavenging rate four days after the packaging procedure. The test shows that an average of 33 to 48 cc of oxygen was consumed by a square meter of film per day even after the majority of the oxygen had been removed by the film and the gas flush packaging operation. This rapid depletion of even trace amounts of headspace oxygen offers a significant benefit over passive barrier films by minimizing the product exposure to oxygen and continually protecting against oxidation during the shelf life (See Figure 1). The film will also rapidly remove any additional oxygen migrating out of the product and into the package headspace.

Three of the larger applications taking advantage of this increased oxygen protection are sliced luncheon meats, semi-dry meat products and fresh pasta. Thinly sliced luncheon meats use the oxygen scavenging film to delay the oxidative deterioration of flavor and color to maintain product integrity throughout its shelf life. The semi-dry meat applications converted from oxygen scavenging sachets to the oxygen scavenging film. This change to the polymeric oxygen scavenging film eliminated the regular consumer problems of mixing products with sachets and sachet contents while maintaining the desired product color during the life of the product. The fresh pasta manufactures launched the use of oxygen scavenging film to increase the product shelf life which was dictated by microbial and mold growth.[8)] Increases in shelf life provided manufacturing benefits with longer product runs and more distribution flexibility. All of these applications take advantage of the increased oxygen protection gained with headspace scavenging film.

Table 1. Headspace Scavenging Results

Storage Conditions	Average Rate (cc/(m^2*day))	
	Mean	**Standard Deviation**
Ambient	48.5	0.27
Refrigerated	33.0	0.49

The packaging of crusty rolls with a combination of CO_2 and N_2 (60% CO_2) was an effective deterrent against mold growth but the anaerobic environment was not totally effective without incorporation of an oxygen scavenger to ensure that the headspace oxygen concentrations never exceed 0.05%.[9] Other applications including several non-food products (pharmaceutical, medical devices, inks, coatings, etc.) are also using or testing the oxygen scavenging films to achieve the necessary oxygen protection in flexible materials.

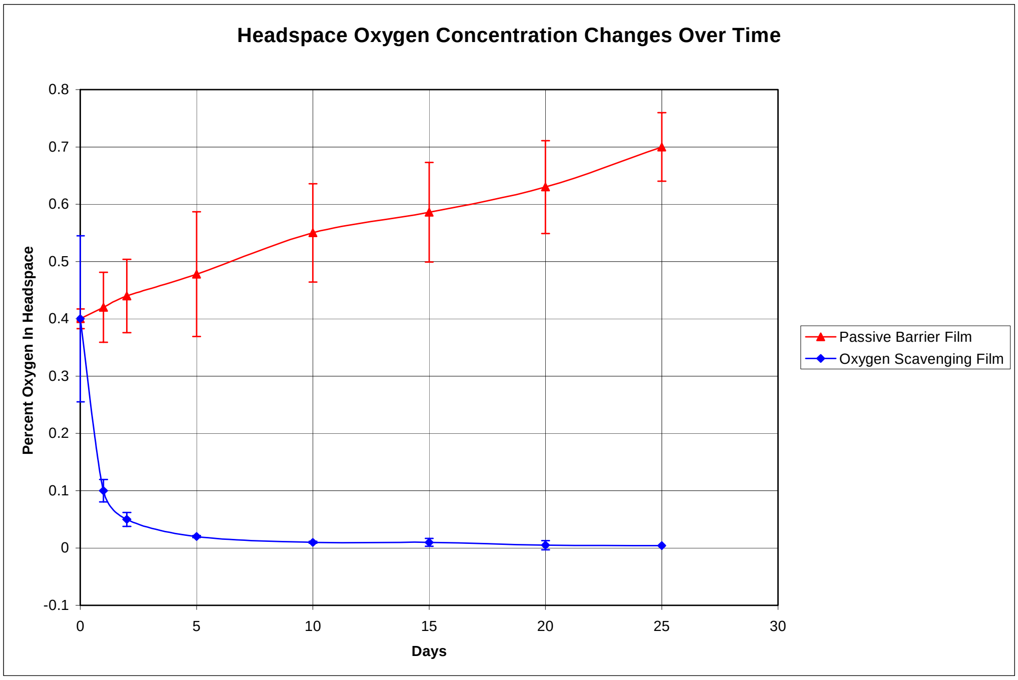

Figure 1. Passive Barrier Verses Active Barrier

The active barrier materials incorporate the oxygen scavenging polymer into the barrier layer of a film to provide protection primarily from environmental oxygen. These materials were specifically designed for vacuum-packaged applications and packages with minimal headspace. These materials are produced active but can be handled and stored like all other packaging materials. The enhanced oxygen barrier properties come from the binding of any oxygen migrating into the film. This was demonstrated by packages containing water and held at elevated temperatures. Standard passive barrier films exhibit a slow but constant increase in the amount of headspace oxygen when stored at these less-than-favorable conditions. The active barrier films prevent this increase in headspace oxygen concentration by actively binding any oxygen migrating into the film. Regular oxygen transmission testing was run on the active barrier materials, but this analysis is too quick to capture any changes in transmission rates once the capacity of the scavenging polymer is exhausted. Therefore, ingress testing was used to assess the oxygen barrier performance over time. The results showed the active barrier still maintained a very low ingress rate after 77 days (See Figure 2).

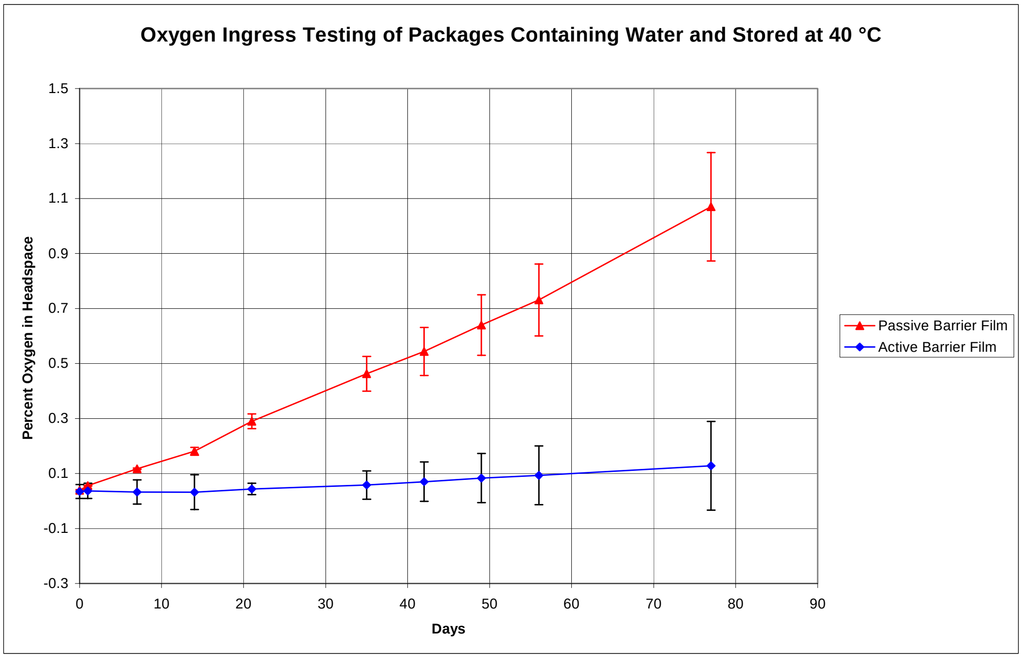

Figure 2. Active Barrier Ingress Testing

The applications using these materials are long shelf life processed meats and clear foil pouch replacements. The processed meat products are vacuum packed products that have a shelf life in excess of 8 months. The extended shelf life of these products relies on the active barrier films to preserve the quality particularly in the latter part of the product life. The foil replacement applications were driven by the demand to see the product in the package for quality control purposes and for displaying the product. The high oxygen-barrier requirements were retained with the active barrier films while offering product visibility.

Odor scavenging materials were tested for absorption of hydrogen sulfide and methanethiol which are two volatiles routinely responsible for sulfur odor. The odor scavenging films rapidly removed the hydrogen sulfide (See Figure 3) and methanethiol (See Figure 4) from glass vials injected with these compounds.

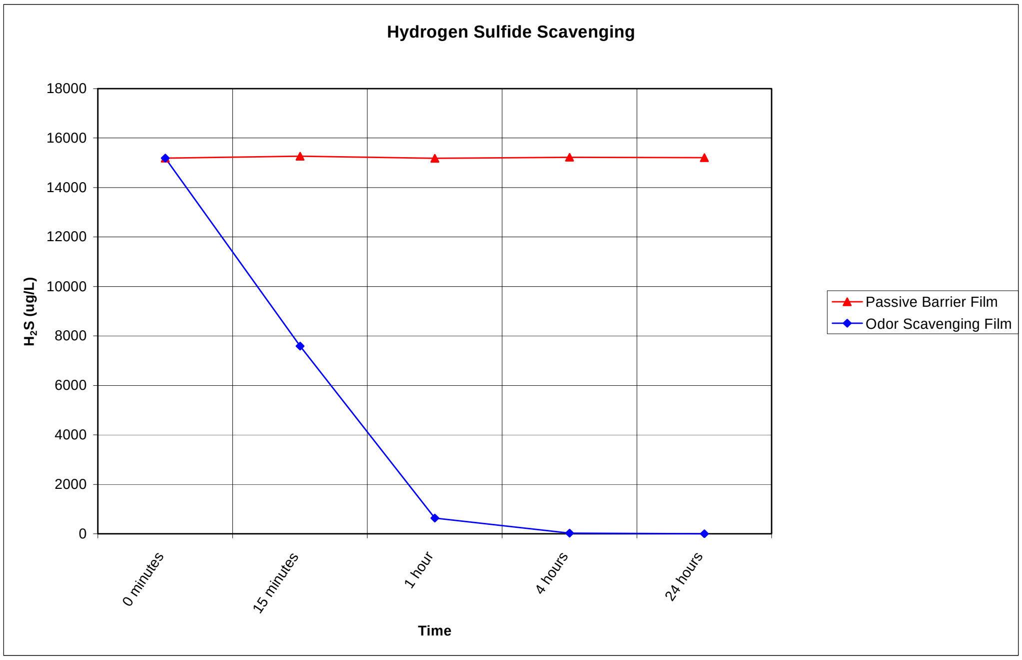

Figure 3. Hydrogen Sulfide Absorption by Odor Scavenging Film

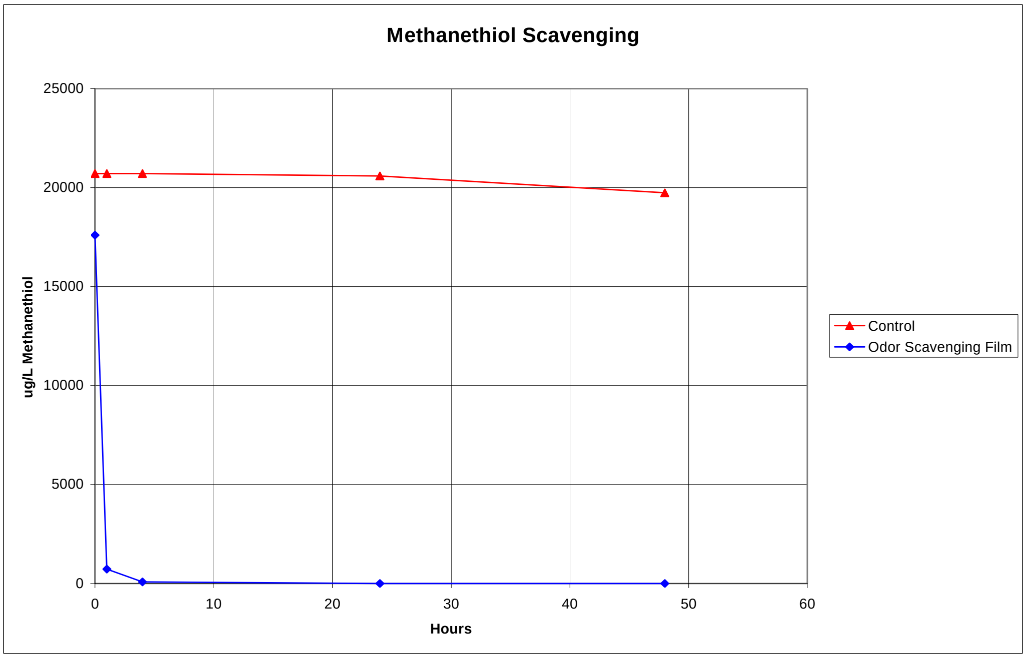

Figure 4. Methanethiol Absorption by Odor Scavenging Film

This same technology is being used to remove confinement odors in a variety of processed meats. During the life of the product, malodorous volatiles collect in the headspace of the packages using barrier films. Several processors have converted to the odor scavenging materials to reduce or eliminate the concentration of sulfur smells and other off-odor volatiles. This imparts additional protection of the product aroma especially toward the end of the product life.

4. Conclusion

A significant volume of food and nutritional supplements are wasted due to inadequate packaging and limited storage life.[10] Appropriate food packaging can impede product deterioration, retain the positive effects of processing, preserve or add to the safety and quality of food, and improve shelf life.[11] The Cryovac Freshness Plus™ materials offered by Sealed Air Corporation present various options for safeguarding against assorted forms of product deterioration that take place during storage. Both the active barrier materials and oxygen scavenging materials provide an increased level of protection from oxygen for products using flexible packaging. Reducing product exposure to oxygen is proven to protect nutrients, color and flavor components in food products while reducing or eliminating the formation of oxidative by-products. The use of packaging with oxygen scavengers that remove residual oxygen after the packaging procedure can minimize this deterioration in quality.[9] The product application dictates which scavenging material would provide the most favorable protection that can benefit both consumer and producers. Odor control is also beneficial in protecting the product freshness and consumer perception of product quality. Consumers always expect and like to smell good flavors when they first open a food package.[12] The odor scavenging materials present another packaging option to protect product quality and maintain the desired product aroma throughout the shelf life. Active packaging technologies continue to progress and offer processors more packaging options as they respond to new consumer demands and market trends.

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