Effects of Transportation Hazards on High Barrier Flexible Packaging Films

Kyle Dunno
Sealed Air Corporation
kyle.dunno@sealedair.com

ABSTRACT

Two flexible food packaging barrier material film structures were employed for this research study to evaluate the effects of over-the-road truck transport. The films containing different barrier materials, ethylene-vinyl alcohol (EVOH) or aluminum oxide (AlOx), were selected based on their abundant use within the flexible food packaging arena. Pouches were formed and filled with tomato paste before being thermally processed then palletized for shipment. Pouches were shipped over-the-road via truck transport a distance of 2,500 miles. After transport, the oxygen transmission rate (OTR) of the pouches located on the bottom and top layers of the palletized loads were obtained and compared to reported OTR for the respective film structures. Reported OTR matched closely with pouches located on the bottom layers, but did not correlate with pouches from the top layers. Comparing the two materials, the OTR results from the bottom layers of each pallet were not significantly different from each other (p > 0.05). The OTR results of the two barrier materials showed there was a statistical difference in OTR when comparing the top layer pouches (p < 0.05). Results from this study showed it is imperative to evaluate packaging materials in the environment and application it will be utilized in order to develop an optimum packaging solution.

KEY WORDS

transportation, high barrier films, OTR

1.0 INTRODUCTION:

Flexible packaging continues to grow as a solution for many types of food products. In the food service market sector, flexible packaging is becoming a popular alternative to the traditional industrial canning method. This is due to applications where the ability to microwave, visibility of
the product and metal detection are of importance [1]. While these features provide advantages to the manufacturer and consumer, flexible packages typically have slower filling speeds and lack the physical durability when compared to the metal can.

Metal packaging materials provide ultimate barrier protection, but flexible packages, made from polymers are permeable [2]. To reduce the permeability in flexible packages, high-barrier packaging films and coatings, such as ethylene-vinyl alcohol (EVOH) and aluminum oxide (AlOx), are utilized in place of traditional metal packaging materials. These materials have become increasingly used in applications for food package systems. In most corporate settings, materials are selected by matching the product requirements and candidate materials to either determine the shelf life obtainable in a specific material, or to determine which material will supply a specified shelf life [3]. The information used to arrive at this solution is typically obtained from a material data sheet. The material data sheet can be a useful tool to evaluate the attributes of the material in steady state, but is usually limited in providing performance or application metrics and analysis techniques. For example, materials such as EVOH can experience an adverse effect as a result of thermal processing, which is commonly referred to as retort shock [4]. This phenomenon has an adverse effect on the performance and shelf life of products packaged in this material. Inorganic barrier coatings such as AlOx improve the gas barrier properties, but are susceptible to defects in the coating oxide, pinholes, grain boundaries, and microcracks [2].

One key area, especially for food packaging, is the distribution channel and environment a packaged product will travel through to arrive at a customer or consumer. Common distribution channels packaged products pass through are truck, rail and aircraft transportation. Through the different distribution channels, packages are subjected to dynamic hazards having an adverse effect on the packaged product. These dynamics hazards are characterized as shock, vibration, compression and environmental stresses. All packages will be exposed to some combination of these hazards, so it is imperative to fully understand them when designing and developing packaging solutions.

Standard industry practice for evaluating the toughness of a flexible packaging material is to stress the materials using a Gelbo flex tester. Gelbo flex testing typically is used for comparative studies when evaluating the toughness of different film structures. Though this testing practice is regularly used, there is not a clear correlation between the number of cycles (flexes) to a particular transportation environment. Research has shown the abuse from being transported causes breakdown in the barrier as a result of flexing during the distribution hazards [5]. The breakdown in the barrier can allow more oxygen ingress than was originally calculated for during material development and selection, resulting in a shorter shelf life than predicted [6].

This research evaluated how over-the-road truck transport affects the oxygen permeability of flexible packages containing different high barrier solutions. The oxygen transmission rate (OTR) of the pouches will be used to compare the films. In addition, the effect of pouch location on the pallet was also evaluated.

2.0 MATERIALS AND METHODS

The film structures utilized in this research study are referred to as Film X and Film Y. Film X incorporates a 14.0 µm ethylene vinyl alcohol (EVOH) as the barrier layer. Film Y places a 12.2 µm polyethylene terephthalate (PET) coated aluminum oxide (AlOx) barrier in the film structure. For each film structure, the barrier is the middle layer. These film structures were selected in order to determine if they could be used to extend the shelf life for a
selected product type. Table 1 displays the material properties associated with the films used during this evaluation. An OnPack 2070 (Cryovac®, Duncan, SC, USA) produced individual pouches filled with tomato paste. The pouches were thermally processed and packaged inside 44 ECT (Edge Crush Test) corrugated containers. Corrugated containers were robotically palletized and stretch wrapped in a 3 x 2 x 3 wrapping pattern with 50% overlap using 90 gauge stretch film for shipment.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>OTR 23°C 100% in/50% out (cm³/m²-day-atm)</th>
<th>Film Thickness (μm)</th>
<th>Pouch Width (mm)</th>
<th>Product</th>
<th>Target Volume (oz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film X</td>
<td>&lt;0.2</td>
<td>&lt;0.2</td>
<td>630</td>
<td>Tomato Paste</td>
<td>108</td>
</tr>
<tr>
<td>Film Y</td>
<td>&lt;0.2</td>
<td>&lt;0.2</td>
<td>630</td>
<td>Tomato Paste</td>
<td>108</td>
</tr>
</tbody>
</table>

Thirty corrugated cases of each film sample were produced. Each corrugated case contained six pouches that were configured as shown in Figure 1. These pallets were shipped less than truckload (LTL) an approximate distance of 2,500 miles for visual inspection (leakers). For each pallet, all packages were examined visually for seal failure resulting in product loss. At the conclusion of the visual inspection, pouches were randomly selected from each of the pallets in order to conduct oxygen transmission rate analysis of the films after distribution. For the oxygen transmission rate evaluation, pouches were selected from the bottom and top layers of both pallets.

![Figure 1. Corrugated container schematic (side view)](image)

Oxygen transmission rates were measured using a Mocon two-cell Oxtran 2/20 (Mocon Controls Inc, Minneapolis, MN) and was operated according to ASTM D3985 [7]. OTR represents the ease with which oxygen passes the films when submitted to a gradient in the partial pressure of O₂ across the films [8]. Sample film pieces (100 cm²) were cut using a stainless steel template. Film samples for the oxygen transmission rate evaluation were removed from the same location on all of the pouches. Figure 2 displays the general area of the pouch the samples were obtained from. This area was selected as it was shown to have a high concentration of flex cracking and stress whitening. The oxygen transmission rate testing was conducted at 23°C and 100% RH (inside) / 50% RH (outside) a performed in triplicate for each material type and pouch location.

![Figure 2. Location of samples collected for OTR testing](image)
3.0 RESULTS AND DISCUSSION

During the visual inspection of the packages, no visible product loss was observed as a result of the field transportation study. No seal failures or other pouch defects were noted for either of the two developmental film structures. Based on the results from the visual inspection (leak detection), further analysis was performed to understand if the transmission rates of the pouches had changed as a result of the over-the-road truck transportation.

Comparing the oxygen transmission rates in Tables 1 and 2, it was observed the oxygen transmission rates from Table 1 matched closely with the pouches from Table 2 located on the bottom of the pallet. The oxygen transmission rates from Table 1 did not correlate with those from Table 2 located at the top of the pallet. These results indicate changes to film attributes can occur as a result of application and usage of the film throughout the entire supply chain. Although each environment will be different, the application and use do affect the film’s attributes [6].

Results from the OTR analysis of each developmental film structure are located in Table 2 and Figure 3. The OTR was greater for all samples located on the top layer of the pallet as compared to the samples located on the bottom layer of the pallet. For example, the top layer OTR for Sample X was 0.97 cm³/(m² x day) as compared to the pouches from the bottom layer which had an average OTR of 0.29 cm³/(m² x day). The increase is due to the vibration being amplified as it was transferred upward through the unit load [10]. The amplified vibration causes the flexible packages located towards the top of the pallet to move and vibrate inside the corrugated container at a higher intensity than those located on the bottom layer resulting in increased folding and abrading of the pouches against each other and the corrugated container.

The OTR results from the bottom layers of each pallet were not significantly different from each other. The OTR results of the two barrier materials showed there was a statistical difference in OTR when comparing the top layer pouches (P-value < 0.05). This statistical difference is a result of the AlOx coating flexing and cracking under the vibration and movement inside the corrugated case during transportation [11]. Although both film structures suffered flex cracking and stress whitening, the film containing the AlOx barrier had abundantly more flex cracking as compared to the film containing the EVOH barrier. The flex cracking for the film structure with AlOx resulted in higher OTR.

Table 2. Oxygen transmission results and corresponding material thickness

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Thickness (μm)</th>
<th>OTR after Transport 23°C 100% in/50% out (cm³/m²-day-atm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film X - Bottom</td>
<td>138.2 (6.6)</td>
<td>0.29 (0.02)</td>
</tr>
<tr>
<td>Film X - Top</td>
<td>142.3 (7.4)</td>
<td>0.97 (0.02)</td>
</tr>
<tr>
<td>Film Y - Bottom</td>
<td>141.3 (2.9)</td>
<td>0.30 (0.01)</td>
</tr>
<tr>
<td>Film Y - Top</td>
<td>140.9 (2.3)</td>
<td>3.89 (0.24)</td>
</tr>
</tbody>
</table>
values as compared to the developmental material constructed from EVOH. This is due to EVOH having superior flex cracking resistance and therefore not as susceptible to the flexing from the transportation environment [12]. As noted earlier, the top layers experience greater vibratory motion than the bottom layers of the pallet explaining why pouches from the bottom layer were not significantly different and pouches from the top layer were when comparing the two developmental materials.

In addition to the OTR evaluation, pouches from the top layers of the pallet were further examined using optical microscopy. The same pouch area used for the OTR evaluation was used for the microscopy analysis. Figure 4 provides a cross-sectional view of both film structures captured using optical microscopy using a 50X magnification. Observations from viewing Film X and Film Y showed defects to both barrier layers from each film type. Oxygen permeation through high barrier coatings is dominated by flow through these defects in the coating [13]. The probability of enhancing and increasing the defects of the barrier coating are as a result of the vibration from the over-the-road truck transport [14]. The microcracks were more prevalent in Film Y containing the AlOx barrier coating as compared to Film X having the EVOH barrier.

Figure 4. Microscopic inspection of films (L: Film X and R: Film Y)

![Average Film OTR Analysis and Thickness](image)

**Figure 3. Average film thickness and OTR test results**

*Effects of Transportation Hazards*
4.0 CONCLUSIONS

Conducted was an examination of oxygen transmission rates of two common barrier films used in the flexible food packaging industry. The study compared both films using the reported oxygen transmission rate and the oxygen transmission rate obtained from conducting an in use application field study. Oxygen transmission rates for flexible high barrier pouches were greater than the reported values after having gone through over-the-road truck transportation. The prominent source of the increased transmission rate was the breakdown of the barrier layer due to the combined shock and vibration transport hazards. The breakdown of the barrier layer was more significant in the AlOx coating than the EVOH barrier layer. Results from this study showed transportation hazards had a large effect on the performance of the package, which can ultimately affect the quality of the food product.

Additionally, results showed it is imperative to evaluate packaging materials in the environment and application it will be utilized. Having this knowledge will lead to a better understanding of the total package development process and provide the optimum packaging solution. Without conducting applicable material tests and evaluation, the packaging solution will be limited and likely not have a high correlation with field results.

5.0 REFERENCES


