by Claire Koelsch Sand

Vetting Food Packaging

Package selection is highly dependent on the desired shelf life of a product. This shelf life is often dictated by retailers, distribution logistics, and production scheduling or simply the seasonality of brands. To define package needs, understanding why products deteriorate is the first step toward isolating package options based on possible package headspace interactions, predictive package permeability, and shelf-life predictions. After package choices are more defined, shelf-life studies can also help narrow package choice.

Product Deterioration

Product shelf life can directly be affected by changes in moisture, oxidation, and microbial growth and sorption and desorption to and from packaging material. To better define package options, understanding how product deterioration happens is critical. If the mode of product deterioration is not considered before package development is underway, package development efforts lack focus, consume excess time, and likely will not result in the best package selection.

Maintaining optimal product moisture is essential to product quality. Moisture loss, gain, or migration is common in many foods and especially in frozen foods. For example, in frozen foods, freeze and thaw cycles during distribution and in consumer freezers result in freezer burn. When temperatures rise, moisture evaporates from the product and is trapped within the package headspace. When temperatures are lowered again, water within package headspace turns to ice, and the ice accumulates within the package headspace, leaving ice crystals on the product and in large sections inside the package. The difference in moisture within the product and the package headspace is the driving force for moisture migration. And unbound water between cell walls or a burst cell wall due to ice crystal accumulation results in texture, color, and nutrient changes.

"Understanding the kinetics of active compounds in the package headspace is especially relevant to food products that can oxidize. Oxygen absorbers and the ability of oxygen absorbers to work in concert with the package oxygen permeability to extend product shelf life is complex," says Eva Almenar, associate professor, Michigan State University. For example, oxygen absorbing films and sachets effectively reduce oxygen headspace to 0% oxygen. However, the analysis of the optimal package for adequate product shelf life also includes the expense of reducing the oxygen level in production, the package barrier required to restrict oxygen influx, oxidation reaction products that can spur oxidation further, and the absorption capacity of oxygen absorbers or alternatives, such as glucose oxidase and yeast-based product surface treatments. In some cases, allowing volatile oxidation byproducts to escape through the package improves product flavor and odor. This is an area of extensive research. Oxidation rates can vary as a function of the amount of unsaturated fat in products, available oxygen, temperature, and relative humidity. To compare packaging options, accelerated shelf-life studies involve controlled levels of oxygen, temperature, and humidity. Packaging solutions often include modified atmosphere packaging (MAP), oxygen scavengers, oxygen-absorbing film, antioxidants that desorb

***When designing packaging**, researchers at the Bemis Innovation Center collaborate with brands to consider all aspects of supply chain management.* Photo courtesy of Bemis

from film, and superior oxygen barrier layers such as ethylene vinyl alcohol.

Controlling microbial growth involves controlling package headspace. The diversity of microorganisms in existence makes this a complex task. For example, the anaerobic bacterium *Clostridium botulinum* presents a considerable risk in unprocessed seafood kept in vacuum packaging if temperature abuse occurs. Intelligent packaging such as time temperature indicators are used to monitor temperature. Interestingly, package headspace can also be employed to assess microbial growth by using sensors that detect gaseous metabolites in meat. For many clean label products that do not contain mold inhibitors, mold growth is controlled by MAP. In this case, oxygen required for mold growth is removed, and carbon dioxide, which has antimicrobial properties, and nitrogen are added to package headspace.

Sorption

Sorption focuses mainly on the interaction between polymers and food. Many packaging materials contain polymers that come in direct contact with food. For example, the plastisol liner in metal caps are polymer-based as are coatings on paperboard and inside cans. Sorption includes desorption from polymers and adsorption from polymers. For example, desorption from polymers can transfer harmful substances into food, and absorption of flavor and odors into polymers impacts product flavor profiles and can alter package seal strength. Sorption of compounds to and from packaging into package headspace and into products is regulated by the U.S. Food and Drug Administration, the European Union, and other organizations that address indirect or direct food-contact materials. Estimation of partition, solubility, and permeability coefficients of polymers in connection with migrants using group contribution methods has been in use since the early 1990s, and European methods have been refined to predict sorption and permeability highly accurately.

Interestingly, the coatings, sealants, and adhesives of packaging as well as components within polymers can be part of the package headspace and affect product flavor and safety. For example, phthalate, a plasticizer commonly associated with polyvinyl chloride and polypropylene, has been restricted in the European Union since 2008 due to its toxicity. Also, Proposition 65 in California led to major research on the migration from plastics into food. And in the 1970s, incomplete polymerization of polyvinyl chloride led to the migration of the vinyl chloride monomer (a known carcinogen) until the polymerization process was refined. More recently, the migration of bisphenol A (BPA) from the polymer-based coating inside packaging was addressed by replacing coatings. "More adsorption and desorption studies are needed, especially due to recent increased use of active packaging and recycled materials; concerns about BPA, some plasticizers like phthalates, and nano-sized compounds; and a change in polymer type in metal- and paper-based packaging materials," Almenar says. She is conducting absorption/desorption studies on bio-based plastics to investigate chemical resistance, leaching of plasticizers, and other compounds. As recyclable bio-derived materials such as polyethylene furanoate and polytrimethylene furandicarboxylate gain popularity, how the sorption properties may be different from polymers that are not bio-derived is worth analysis.

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Predicting Shelf Life

Rapid vetting of new package options to meet cost, distribution, and sustainability requirements is possible when shelf life can be predicted. Shelf-life models are available and are based on package permeability and rates of degradative reactions. Because many deteriorative reactions are governed by oxygen and water vapor, oxygen transmission rate (O_2TR), carbon dioxide transmission rates, and water vapor transmission rate (WVTR) are major variables in predicting shelf life. Often, because of product complexities, certain O_2TR and WVTR are targets for specific products. With new products and package shapes with varying thickness, predictions are more complex. For example, packaging professionals use O_2TR values to screen packaging options in a relative sense or use finite element modeling and analysis to predict and design for specific package O_2TR and WVTR. Finite element modeling has a distinct advantage because necessary permeability can be built into package design. Packaging suppliers can provide assistance in this regard.

While water vapor permeability measurements and their relative humidity dependence are well understood, measuring oxygen permeability as a function of relative humidity is more complex. Instrumentation is being refined rapidly since the ability to measure oxygen permeability at different relative humidity levels is essential. O_2TR values are often reported as 0% relative humidity, but few foods and environments have 0% relative humidity, and some polymer properties are altered by humidity exposure. So shelf-life predictions based on O_2TR are challenging and oxygen barrier requirements are needed to isolate package options.

The need to get products to the market faster and reduce risk continues to impact decision making. Bemis, Neenah, Wis. (bemis.com), has developed a

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Ready-to-eat cereals *and other shelf products require assessment to determine which packaging preserves shelf life.*

collaborative process to help brands succeed in this fast-paced environment. Chris Trave, senior development engineer at Bemis, recognizes that successful launches require getting packaging suppliers involved "early in the product development process to assess the needs of the product and implications to packaging to ensure compatibility." This cooperative process saves time and resources in the value chain. "We consider all aspects of the supply chain from concept to commercialization, including shelf life, package design, retail channel optimization, shelf impact, and consumer research. This all happens at out innovation center, where customers can go from ideation to package prototyping in one day," Trave says. "The research and development team at Bemis Innovation Center applies [its] product and package expertise to speed up the development process and get the product in front of consumer [and] market evaluation and shelf-life studies more quickly."

Shelf-Life Testing

Before package decisions are finalized, shelf-life studies are needed. While food simulants and predictive modeling are often used to narrow down material choices, the complexity of food and multi-component packaging demands testing with the actual product and package. Many packaging suppliers offer analysis that customers may not have and assist customers with shelf-life studies. Packages made from production or unit molds must be assessed for how well they protect the product. However, shelf-life studies simply take valuable time in the package development process. This is especially relevant for products with extended shelf life such as cereal and condiments since results from shelf-life testing would take up to 12 months. For this reason, a correlation between actual shelf life and accelerated shelf life is developed for each product and package. Accelerated shelf-life testing is based on how product quality declines and accelerating this decline without creating other competing factors. For example, to accelerate mold growth in bread, increasing the temperature of storage can alter what mold will grow and what other deteriorative reactions will happen. Accelerated shelf-life testing focuses on accelerating the cause of deterioration in actual shelf life so that rapid and accurate predictions can be made. **FT**

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