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Food Packaging History and Innovations

SARA J. RISCH

Science by Design, East Lansing, Michigan 48823

Food packaging has evolved from simply a container to hold food to something today that can play an active role in food quality. Many packages are still simply containers, but they have properties that have been developed to protect the food. These include barriers to oxygen, moisture, and flavors. Active packaging, or that which plays an active role in food quality, includes some microwave packaging as well as packaging that has absorbers built in to remove oxygen from the atmosphere surrounding the product or to provide antimicrobials to the surface of the food. Packaging has allowed access to many foods year-round that otherwise could not be preserved. It is interesting to note that some packages have actually allowed the creation of new categories in the supermarket. Examples include microwave popcorn and fresh-cut produce, which owe their existence to the unique packaging that has been developed.

KEYWORDS: Packaging; barrier; absorbers; antimicrobials

INTRODUCTION

Packaging today plays an important role in the quality of food products by providing protection from environmental, chemical, and physical challenges. This protection can be as simple as preventing breakage of the product to providing barriers to moisture, oxygen, carbon dioxide, and other gases as well as flavors and aromas. Packaging can block light to protect nutrients and colors in a product from deteriorating. In addition to providing passive protection, many packages today play an active role in the quality of a product by helping to maintain a desired atmosphere around the product. As described by Lockhart (*15*), packaging materials have the three primary functions of providing protection, utility, and communication in three different environments. The environments are physical, atmospheric, and human. The goal is to optimize a package to provide for all three functions efficiently in all three environments.

The development of food packaging has evolved as man's lifestyle has changed. For a very long period of time, people simply ate what they could gather in their immediate surroundings. As people shifted from a nomadic lifestyle to staying in a sheltered area, the need arose for containers to store food. Up until the 1800s, there was very little sophistication in packaging materials, with naturally occurring items such as gourds, shells, and leaves (*1*) being used to hold food. Grasses, wood, and bamboo were used to weave baskets. Some of the early materials that could be shaped into food containers were pottery, paper, and glass. The first evidence of pottery and glass being made was about 7000 B.C., yet industrialization of the process by the Egyptians was not seen until about 1500 B.C. (*1*). It is interesting to note that the primary materials used to make glass at that time, limestone, soda, sand, and silica, are the same materials that are used today, although many additives have been developed to color glass and give it varying properties. More details on early packaging materials can be found in *A Brief History of Packaging* by Berger and Welt (*1*). As the Division of Agriculture and Food Chemistry celebrates its 100th anniversary in 2008, it is interesting to note that many of the significant developments in food packaging have occurred in the same period of time. This paper provides a review of some of the innovations that have occurred during that time.

EARLY DEVELOPMENTS IN PACKAGING

The Industrial Revolution brought the development of new manufacturing processes and new materials. Although initially many of them were not intended for food products, they became useful as food packaging materials. Metal cans were initially manufactured for snuff, for which they provided an excellent barrier to maintain the moisture of the product as well as providing protection for the flavor of the product. They later were used in the canning operation that was discovered by Nicholas Appert when he answered a challenge from French Emperor Napoleon Bonaparte to develop a method to preserve food for his army (*11*). Appert used glass bottles with corks secured with wire as a closure to contain food while heating. The glass bottles were fragile and were soon replaced with metal cans, allowing products to be heat processed much more readily to extend their shelf life and prevent spoilage. Paperboard was first used to manufacture folding cartons in the early 1800s. Corrugated boxes that today are widely used as a shipping container to hold a number of smaller packages were developed in the 1850s. Plastics including cellulose nitrate, styrene, and vinyl chloride were discovered in the 1800s but were not used in any packaging until well into the 20th century. Some of the first uses were during World War II with commercialization for food packaging occurring after the war.

One part of a package that was patented in 1892 played a significant role in the development of the beverage industry. William Painter, the founder of what today is Crown Holdings, Inc., patented the crown cork (*7*). This was a metal cap that had a layer of cork inside that gave a good seal against the top of a glass

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bottle. Prior to this invention, glass bottles could not be tightly sealed with a convenient closure and did not provide protection for the products inside the bottles. Products were susceptible to deterioration due to the ingress of oxygen. As plastics and other synthetic materials have been developed, they have replaced the cork to provide a more uniform and tighter seal. In one study, it was found that ingress of oxygen using traditional crown seals with various linears ranged from 0.58 to 1.2 μL per day (*14*). Today, some of the liners in the crown have oxygen-absorbing ability built into them to remove residual oxygen from the headspace in the bottle to slow or eliminate oxidation of the contents of the bottle (*5*).

Biscuits were the first products to be individually packaged and were first sold in the 1890s. They were produced by the National Biscuit Co., which had recently been formed by the merger of several baking companies. They felt that they needed something new to draw attention to the company and developed a biscuit which was lighter and flakier than anything else on the market (*13*). Up until that time, biscuits had been packed in large barrels which sat open at the market. People would pick out as much product as they wanted and put it in a paper bag to take it home. This provided no protection for the quality of the product other than being a dust cover. The new product needed moisture protection to maintain the light, flaky texture, and an individual package was designed with an inner liner to provide that protection. While this may not seem significant today, it was a major step forward in preserving product quality by providing a barrier to moisture to keep the product crisp. This also provided protection from contamination during distribution.

POST WORLD WAR II

After World War II, there was an increasing focus on food and food quality. Many materials including plastics that were developed for war applications found their way into food packaging after the war. There have been a number of developments to improve food quality and allow for consumers to have a wide variety of foods year-round. Plastics are one area that has seen major improvement in materials and their properties. Polyethylene was one of the first plastics used widely for food packaging. There are several types of polyethylene in use today including low-density (LDPE), high-density (HDPE), linear low-density (LLDPE), and very low density (VLDPE). LDPE was the first to be developed by Imperial Chemical Industries in 1933 (*4*). The company received a patent for production of the material that involved compressing ethylene gas and heating it to a high temperature (*9*). The first plastic sandwich bag on a roll was introduced in 1957 (*17*). By 1966, over 25% of all bread sold was in plastic bags made from LDPE. That package still is in wide use for most bread products sold. Some companies have gone back to the use of paper bags for bread to give it an artisanal feel; however, the paper bag does not keep the bread as well and the quality deteriorates much more quickly than when the bread is stored in a plastic bag.

Although plastics have been more widely used as food packaging materials in the past 50−60 years, new developments in plastics have helped to increase the usage. Professor Giulio Natta discovered isotactic polypropylene in 1954 (*12*). The film is often oriented after the casting or forming process by first stretching the material in the machine direction and then stretching it in the crosswise direction to give oriented polypropylene (OPP). This stretching aligns the molecules, making a film with a better moisture vapor barrier, better clarity, and more stiffness. It is widely used as an overwrap for snack foods.

One process that is used to improve barriers even further is metallization. In this process, an aluminum wire is heated to 1700 °C in a large vacuum chamber (*12*). This vaporizes the aluminum, which deposits on the surface of the film as it is run through the chamber. In the case of a 50 gauge polyester film, metallizing improves the moisture vapor transmission rate (MVTR) from 2.0 g/(100 in.^{2}·24 h·90% RH) to 0.05, a 40-fold improvement (*12*).

One process that has improved overall properties of plastic films is coextrusion, developed in 1964 by Hercules (*12*). In this process a film with two or more layers of different types of plastic can be made in one step without the need to laminate the layers together with an adhesive, eliminates the use of solvents, and produces a film in one step instead in needing multiple steps. Because different types of resin or resin blends are being used, it requires careful control of the melt properties and viscosity to ensure the appropriate thickness of each distinct material. It is possible to make structures with much thinner layers than can be made when laminating. Multiple-layer films offer better protection for products as some films are better moisture barriers and others offer better barriers to gases. One example is polyester film, which provides a better gas barrier, whereas polypropylene and ethylene vinyl alcohol (EvOH) films are better moisture barriers. These three can be combined readily in one structure to give protection from both moisture and oxygen permeation.

In the past 15−20 years, only one new plastic has been approved for food contact and that material is polyethylene naphthalene (PEN), which received FDA clearance in 2000 (*18*). Although other new plastics have been developed, the process for clearance from FDA in the form of a letter of no objection is difficult to obtain as extensive safety and environmental evaluations must be performed. It should be noted that PEN has not seen any widespread use in food packaging, due mainly to the high cost of the material. There are a large number of new additives and processing aids that have been allowed.

NEW PACKAGE DEVELOPMENTS

In addition to broad developments in materials, there have been a number of specific packages that have both created new food categories and changed the way that we can deliver a product to the consumer. Metal cans, now typically made of tin-plated steel, have been in use since the early 1800s. It was not until the 1950s that aluminum cans were first manufactured and used. Today, aluminum cans are very widely used, particularly for carbonated beverages. The first aluminum cans were opened with a can opener, similar to the way other metal cans are opened. The first ring pull was introduced in 1963. This facilitated opening a can and being able to drink directly from it. The first ring pulls were not attached to the can and caused concern that someone could choke on them. It was not until 1975 that what is called the stay tab was introduced, which is a ring tab that stays attached to the can.

Another package widely used by the carbonated beverage industry is the 2 L plastic beverage bottle made of polyethylene terephthalate (PET). The concept for the bottle was introduced by Pepsi in 1970, with a patent on the bottle issued in 1973 (*20*). It is interesting to note that this is one of the few packages in the United States that uses a metric size as its standard. The challenge in using PET is that it must provide a barrier to both carbon dioxide and flavors while not contaminating the product with components of the PET that can migrate from the package to the product. Acetaldehyde is one residual component that can be present in PET and can create undesirable flavors in the product if it is not closely controlled. The challenge for smaller bottles was

that the carbonation would be lost via permeation through the PET as a smaller bottle has a larger surface to volume ratio. Smaller bottles are in use today but most of these are either multilayer or have a coating to add the barrier needed.

ACTIVE PACKAGING

There are different types of active packaging. One type, referred to as a susceptor, is used for microwave foods, including popcorn. The first bag of microwave popcorn was sold in 1971. The package was a simple paper bag. It was not until the package including a microwave susceptor was introduced in the mid-1980s that the product became a large success. The package consists of two layers of paper with a metalized PET film (susceptor) laminated between the layers of paper in a position so that it lies on the floor of the microwave oven. The metallized film is produced in the same way described earlier but with a thinner layer of metal that interacts with the microwave energy and heat to temperatures of 200 °C or higher (a thicker layer such as that used for packaging for overwrap would reflect microwave energy instead of absorbing it). The heat generated gives the energy needed to get the kernels to pop. Without the susceptor, the product will have a large number of unpopped kernels. One initial patent for the popcorn bag was issued in 1988 (*19*). In a later legal challenge, the patent was invalidated due in part to failure to site all of the appropriate prior art in some communication with the patent office as the patent and its continuations were being prosecuted. This technology is used for other microwave products including pizza, hand-held sandwiches, and French fries. For these products, it helps the surface to dry and enhances browning and crisping.

In addition to the technical challenge of stabilizing the metallized film on a paper substrate, there was concern about the safety of the packaging materials. The package got to a higher temperature than was anticipated by any FDA regulations (*6*). The FDA was concerned about the possibility for migration from the package and the potential for components of the package to degrade during heating, creating low molecular weight unknown compounds that could also migrate into the food in the package (*16*). Industry came together to develop analytical methodology to measure the potential for migration of both volatile and nonvolatile components from the susceptor packaging (*2*). Although FDA had issued an advanced notice of proposed rulemaking (ANPR) in 1989 (*10*), it eventually abandoned the ANPR as industry had provided the necessary data to show the safety of the package.

One other type of active packaging material is one that can absorb oxygen. As was mentioned earlier in relation to the liners of crowns for beer bottles, oxygen absorbers can be built into packaging to remove residual oxygen from around product or a sachet with material (typically iron oxide) can be placed inside the package.

Some companies are exploring means of incorporating flavors into packaging to maintain the quality of the flavor and have it release at the time of consumption. One package has been developed by Lee Reedy. Flavors and nutritional supplements are sealed into the cap for a bottle. When the cap is twisted to open the bottle, a small plastic blade cuts the seal and releases the nutrients and flavor into the beverage (*8*). This preserves the quality and freshness of the flavors and supplements until the time of consumption.

NEW PACKAGE DEVELOPMENTS

Another package that has created a new category in the supermarket is the film used for fresh-cut vegetables. The vegetables are still respiring so the film needs to be breathable to both carbon dioxide and oxygen while providing a barrier to moisture (*3*). Different vegetables respire at different rates, requiring films with different permeabilities. This is just one type of controlled atmosphere packaging. There are many others where the atmosphere around the product is specifically changed to prolong the shelf life of the food. Any time the atmosphere is modified or controlled, the appropriate packaging material must be used to maintain the desired atmosphere and not allow the gases to permeate through the package.

The Tetra Pack Co. was founded in 1951 in Sweden. The main product of the company is a laminated packaging material that combines paperboard for rigidity, foil for a light and gas barrier, and plastic as both a barrier and sealant layer. The package is formed on a special machine that also fills the product into the formed package. The product can fill aseptically, resulting in a product with the shelf life of a canned product but much less heat stress. The package is used for some products in the United States but has found much greater acceptance in other countries.

An entirely new way of presenting a product was introduced by Dean Foods in 1998. Known as the Dean's milk chug, this package is a high-density polyethylene blow-molded bottle with a screw cap. Although milk had been sold in large containers with a screw cap, this was the first company to launch single-serving containers with a screw cap. In addition to making milk a portable beverage, a significant advantage is that the HDPE bottle provides a light barrier to help prevent deterioration in the flavor of the milk.

SUMMARY

These are just a few of the wide variety of innovations in food packaging that have brought convenient and higher quality foods to the consumer. There are several emerging issues companies are now facing that will continue to drive innovation. One of the largest concerns surrounds the sustainability of packaging materials. Considerable research is underway by companies and organizations to understand and address sustainability. A complete discussion of this is beyond the scope of this paper. There are a number of organizations worldwide working in this area including the Sustainable Packaging Coalition in the United States and the Sustainable Packaging Alliance in Australia. Both biobased and biodegradable materials are being investigated as potential substitutes for petroleum-based plastics.

Packaging has allowed us to have a wide variety of foods year-round that would not be possible without the protection of the package. Foods now have a longer shelf life, resulting in less loss due to spoilage. Packaging also provides for convenience with products that can be heated in the package and products that can be purchased as single-serve items. Demand for quality food has driven packaging innovation, and innovations in packaging have helped to create new food categories and added convenience.

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