Innovations in Modified Atmoshpere Packaging

BY H. LOUIS COOPERHOUSE

Modified atmosphere packaged (MAP) products can be found in almost every aisle of the supermarket today. Billions of packages of refrigerated, frozen and shelf stable foods are sold worldwide every year that are packaged with this proven technology. This array of food products includes potato chips and other snack foods; case-ready fresh meats; fresh produce; hot dogs and other processed meat products; pizza dough and other bread and bakery products; and items as diverse as coffee, fresh pasta and cheese. MAP is a preservation technique that prolongs product shelf life, which directly and positively impacts the profitability and marketability of a food business.

Consumers today demand products that are convenient to purchase, convenient to prepare and convenient to eat. They also seek products that are visually appealing, great tasting, flavorful, fully prepared, varied, nutritious and "fresh." Industry sectors showing some of the greatest growth today, whose products represent these desired consumer attributes, include the fresh-cut produce, value-added dairy and refrigerated sandwich categories. For each of these categories, modified atmosphere packaging happens to be a principal technology that is applied for shelf-life extension.

An interesting and important observation is the fact that, atypical of processed meats, snack foods and other categories that helped develop the MAP category, today's user of MAP technology is much more likely to be a *smaller* company. The number of companies that are utilizing MAP technology is increasing every year; however, more and more of these companies are relatively small and lack the infrastructure and corresponding sophistication that is present in larger companies. Consequently, it is imperative that food safety organizations, industry trade associations, gas and equipment suppliers, and other allied groups organize to provide the education that is needed, so that this technology is utilized effectively and safely.

PROCESS OVERVIEW

In the MAP process, product is packaged in an atmosphere that is different from that of air, which normally contains 78.08% nitrogen, 20.96% oxygen and 0.03% carbon dioxide. MAP helps to delay the onset of product degradation, typically by reducing the amount of oxygen exposed to the product during its shelf life. In high-moisture products, such as cooked entrees and fresh-cut produce, MAP delays microbial and sensory spoilage. In high-fat products, MAP delays rancidity and preserves the smell, taste, texture and appearance. MAP also helps to delay enzymatic browning in produce and staling in bakery products.

Modified atmosphere packaging is a process in which the composition of gases in a package of known permeability is altered after the food is filled, but before the package is sealed. Frequently, MAP is a two-stage process. It begins when a vacuum is first pulled on the product so that as much oxygen can be removed from the system as possible. This is followed by a "backflush" of nitrogen and/or carbon dioxide and/or other gases.

Nitrogen typically is used as a sterile filler gas to dilute the concentration of oxygen and carbon dioxide in the package, thereby reducing the onset of oxidation while also helping to ensure package stability. Carbon dioxide has bacteriostatic and fungistatic properties and its effectiveness is in part due to its ability to penetrate the cellular membrane. This penetration causes intracellular pH changes and disrupts internal enzymatic equilibrium. The gas selectively inhibits the growth of gram-negative bacteria, such as pseudomonads and other related psychrotrophs, which otherwise grow rapidly and produce off-odors and off-flavor. Lactic acid bacteria, such as *streptococci* and *lactobacilli*, are less affected by elevated levels of CO_2. Accordingly, the predominating flora of products stored in modified atmospheres consists of these organisms, which develop more slowly than pseudomonads and related gram-negative bacteria.

Optimal gas mixtures vary widely by product category and can vary dramatically within a product category. In the case of produce, this variability is primarily due to respiratory requirements. Potatoes, radishes and tomatoes are generally considered low respirers, while asparagus, broccoli and mushrooms are considered heavy respirers. Once commodities are cut and handled, product deterioration accelerates as the respiration rate is increased, the tissue becomes more susceptible to oxidative discoloration, and microbial growth is enhanced. With produce, it is critical to match the oxygen transmission rate (OTR) of the packaging material with the respiration rate of the product.

PROLIFERATION OF MAP IN EMERGING GROWTH CATEGORIES

Whereas the application of MAP has reached maturity in certain categories, such as snacks, coffee and processed meats, it is becoming increasingly utilized in refrigerated, prepared convenience foods that meet consumer desires for convenience, quality, variety and health. This is particularly the case with several categories that are growing extremely rapidly, such as fresh-cut produce, value-added dairy products and prepackaged sandwiches. Although MAP is a preservation technology, it is "invisible" to the consumer, since the indication of its presence on product labeling is not typically required. Therefore, it is especially applicable to products that are designed to be "natural" or reduced in preservatives.

Although the application of MAP in the fresh-cut produce category was virtually non-existent some 15 to 20 years ago, this category represents the fastest growing segment in which MAP technology is being applied. The initial application for MAP in the value-added produce segment was the foodservice market, in which precut lettuce was sold to salad bars and to the quick-service restaurant industry. This was followed by prepackaged iceberg lettuce salads that were developed for the retail market, which subsequently evolved such that a wide variety of lettuces, cabbages, carrots and other vegetables are marketed with MAP technology today.

The fresh-cut produce category is projected to evolve considerably in the years ahead because of continual advances and applications of packaging technology. New fresh-cut fruit offerings that incorporate MAP and other technologies are now available, including pre-cut honeydew, pineappl, and mixed fruit salads with a 10- to 14-day shelf life, and presliced apples with a three- to six-week shelf life. Innovations in packaging technologies also have created opportunities for new product concepts, such as component products that allow the user to combine fresh and processed ingredients for a "freshly-prepared" or "freshly-assembled" salad product. Such products are now being offered to foodservice operators and retail customers, in which fresh and/or processed ingredients, dressings, and/or seasonings are separately packaged or integrated into the product and combined at store, on the go, or at home. As a result, salads that have become quite popular in restaurants, such as chicken Caesar salad, chef salad, and Cobb salad, are now appearing for the first time in the retail marketplace.

Food Safety Concerns

MAP is not by any means a "magic bullet" that will individually provide for product safety and shelf-life extension. In fact, because MAP results in a dramatic change in the *time* it takes for product to spoil and the *type* of bacteria that will cause this spoilage, it can create significant additional risk. This is due to a several factors such as extremely low oxygen levels, lack of bacterial competition, prolonged shelf life and potential for temperature abuse–conditions which can favor the growth of pathogenic organisms, which are otherwise quite fastidious and less likely to grow.

MAP and other forms of reduced oxygen packaging minimize the activities of spoilage organisms that normally give warning about potentially unsafe conditions. Concerns about modified atmosphere packaging are well founded because of the potential for growth of anaerobic or facultative anaerobic bacteria, such as *Clostridia*, which could cause food poisoning *before* food spoilage was organoleptically detectable. Reduced oxygen packaging contributes to the potential of botulism (caused by *Clostridium botulinum*) and other pathogens by providing greater time and opportunity for outgrowth.

The U.S. Food and Drug Administration (FDA) has been working in concert with the Institute of Food Technologists (IFT) and recently published a report entitled, "Analysis and Evaluation of Preventive Control Measures for the Control and Reduction/Elimination of Microbial Hazards on Fresh and Fresh-Cut Produce." In this study, it is noted that although only two MAP produce products (coleslaw mix and ready-to-eat salad vegetables) have been implicated in foodborne illness outbreaks to date (botulism and salmonellosis), the potential for growth of pathogens is quite significant, especially in the fresh-cut produce industry.

Currently, there is concern that psychrotrophic foodborne pathogens, such as *L. monocytogenes, Y. enterocolitica* and *A. hydrophila*, as well as non-proteolytic *C. botulinum*, *Salmonella* spp., *E. coli* O157:H7 and *Shigella* spp., can be potential health risks when present on MAP produce. Because reduced microflora exist in MAP products, *L. monocytogenes*, for example, can grow at low temperatures to potentially harmful levels during the extended storage life, while remaining organoleptically acceptable. Because many of these bacteria, in addition to enteric viruses such as hepatitis A, have been implicated in produce outbreaks, there is concern about their behavior under modified atmosphere conditions.

The FDA/IFT report recommends that the elimination or significant inhibition of spoilage microorganisms should not be practiced, as their interaction with pathogens may play an integral role in product safety. It is generally believed that with the use of permeable films, spoilage will occur before toxin production is an issue; MAP of produce, however, should always incorporate packaging materials that will not lead to an anoxic package environment when the product is stored at the intended temperature. This report recommends that the percentage of O_2 in a modified atmosphere for fruits and vegetables for both safety and quality fall between 1% and 5%.

Application of Hurdle Technologies

Modified atmosphere packaging is but one of many potential "hurdle" technologies that can be applied to prolong product quality and increase shelf life. In

Suppliers of MAP Process

A network of complementary suppliers is required to facilitate an effective MAP solution. This network includes suppliers of gas, packaging equipment, trays, film and analytical testing equipment. These companies can serve as excellent resources for further information on MAP applications.

Suppliers of Gases
The following companies provide gases used for MAP applications in food packaging:
- BOC Group
- Air Liquide
- Praxair
- Linde
- Air Products

Suppliers of MAP Equipment
Other suppliers involved in MAP include companies whose packaging equipment incorporates gases just prior to sealing. The sealing of the primary package can occur in an in-line vertical or horizontal form-fill-seal machine, in a tray-sealing machine that uses preformed trays, or in a horizontal or vertical chamber or snorkel machine that seals preformed bags.
- Multivac
- Robert Reiser & Co.
- Convenience Food Systems
- Ilapak
- Orics
- Hayssen
- Harpak
- CVP Systems

Film and Resin Suppliers
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- Cryovac Sealed Air
- DuPont
- Eastman

Analytical Equipment
Instrumentation utilized to verify gas amounts are a critical part of the process.
- PBI-Dansensor
- Mocon

the case of fresh-cut produce, for example, raw material control and superior agricultural practices are critical first steps towards an acceptable marketable product. Variety, source, season, initial maturity, processing maturity, slicing and cutting equipment, chemical or other treatments and dips, packaging environment, temperature management, shipping, and handling all affect the sensory acceptability and attainable shelf life of fresh-cut produce–and impact product safety. New technologies have been recently introduced, and others are on the horizon, that will enable even greater alternatives towards the development of refrigerated prepared products that meet consumer needs for safety, as well as quality, convenience and overall value.

It is essential that other hurdle technologies be utilized in conjunction with MAP, because we cannot rely exclusively on the maintenance of refrigerated conditions to assure the safety of perishable foods. In fact, refrigeration alone is not enough to prevent the growth of some infectious or toxigenic microorganisms. With so few bacterial cells necessary to cause certain types of foodborne disease, growth on infested produce, for example, is not a requirement for human infection, as with most other pathogens. In addition, post-process contamination, even at low levels, may create a situation in which pathogenic microorganisms may grow to high levels and cause illness and potentially cause death. Therefore, in the design of perishable food products, other barriers to microbial growth *must* be incorporated into these foods to yield a safe and stable system. Application of these barrier technologies has been shown to significantly reduce levels of food spoilage and pathogenic microorganisms such as *E. coli* O157:H7, *Salmonella, Listeria* and *Campylobacter.*

Hurdles can include the incorporation of acidulants, antimicrobial agents, antioxidants, heat, and processes that control water activity. In addition, nonthermal processing hurdles can be applied such as ultra high pressure processing, irradiation, and pulsed light and pulsed electric field processing. Hurdles can also be applied during the packaging process, and include the application of clean room packaging, active packaging systems, intelligent packaging systems, and a variety of alternative packaging materials, in addition to the usage of MAP. Temperature is, however, the most important and most obvious criterion for maximizing the shelf life of refrigerated prepared products. Synergistic results are frequently achieved when hurdles are used in combination, and are a very important consideration.

Adequate food safety of refrigerated foods can only be achieved with a high degree of assurance by formulating, adapting and using a Hazard Analysis and Critical Control Point (HACCP) approach. HACCP techniques assess everything from raw ingredients to product packaging and distribution, define the locations at which potential hazards (microbial, chemical, and physical) may occur, and establish a means of monitoring these points to eliminate these hazards. By judicious application of HACCP systems, the food processor can implement a program whereby safe production conditions are achieved.

Innovative Applications and Further Research

Over the past few years, a number of packers of fresh prepared green vegetables in the United Kingdom have begun experimenting with oxygen levels that are between 70% and 100%. This "oxygen shock" treatment of superatmospheric oxygen levels has been found to be very effective in inhibiting enzymatic discoloration, preventing anaerobic fermentation reactions, and inhibiting aerobic and anaerobic microbial growth since the optimal oxygen level for growth (21% for aerobes, 0-2% for anaerobes) is surpassed. As with most MAP gases, superatmospheric O_2 has varied effects depending on the commodity, and further research will be required to understand the application of this technique in the fresh-cut produce industry.

Another area of promise is the use of edible films, in which antimicrobial compounds are incorporated directly onto the product, and in which the product is packaged under MAP conditions. There have been many studies investigating the migration of antimicrobials such as sodium benzoate, benzoic acid, propionic acid and potassium sorbate from coatings into food. The FDA/IFT report concludes that the most advantageous use of these films for antimicrobial properties would be the formation of a monolayer lipid and sorbic acid film, or a bilayer film composed of a hydrophilic base layer coated with a thin layer of lipid containing sorbic acid. Research is needed in order to produce coatings with good surface tension that will stick to produce.

The FDA/IFT report identified the need for further research so that industry will be better able to safely apply modified atmosphere packaging principles. These areas included:

- Investigation of the antimicrobial effect of superatmospheric oxygen levels.
- Study of interactions of background microflora with foodborne pathogens in various modified atmospheres used for produce, as well as the effects of different gaseous environments on the survival and growth of bacterial foodborne pathogens on whole and fresh-cut produce.
- Examination of the potential for growth of C. botulinum in a wide variety of modified atmosphere packaged produce stored at mildly abusive temperatures such as 7C-12C. Evaluation of other hurdles besides temperature to prevent botulinum toxin production.
- Examination of the influence of different atmospheres, background microflora and storage temperatures on the survival and growth of L. monocytogenes on MAP fresh-cut produce.
- Investigation of the behavior of verotoxin-producing E. coli on fresh and fresh-cut product, both under MAP and without MAP.
- Exploration of the survival of the enteric pathogens Y. enterocolitica and Campylobacter spp. and the behavior of foodborne viruses and protozoan parasites on MAP produce.
- Examination of hurdle technology, or the combination of novel methods of food treatment and packaging, for example, irradiation used with MAP and antimicrobial films used in combination with MAP.
- Evaluation of the use of intelligent packaging systems.

As the food industry increases its knowledge about the uses of modified atmosphere packaging, it will not only continue to achieve greater shelf life extension that consumers demand in fresh and processed foods but increase the safety attributes of these products, as well.

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