

How Modified Atmosphere Packaging extends the shelf life of food products

Basics of Modified Atmosphere Packaging

Modified atmosphere packaging (MAP) is well established in the food industry and continues to gain in importance. MAP means, simply put, that the natural ambient air in the package is replaced by a gas or gas mixture, often nitrogen and carbon dioxide. This packaging under a protective atmosphere preserves the quality of fresh produce over a longer period of time, prolongs shelf life, and gives food producers access to a geographically larger market for perishable products. This is suitable for meat and sausage products, fish, dairy products, bread, fruit and vegetables, and convenience products.

Modified atmospheres are not limited to the packaging process. They can also feature as part of the production process, for example, in the storage and transport of fruit and vegetables in halls or containers.

The standards required by modified atmosphere packaging are comparatively high and must be controlled and monitored to ensure safety. Therefore, food manufacturers rely on modern MAP gas technology and various levels of quality assurance for maximum process safety.

Benefits of modified atmospheres

- **Longer shelf life / higher quality**

Food packaged under a protective atmosphere spoils at a much slower rate. Combined with continuous cooling, modified atmosphere packaging can significantly extend the freshness and shelf life. This effect varies depending on the product type. However, a doubling of the shelf life is usually possible. In general, MAP products keep a high quality over a longer period of time and arrive at the consumer in the best possible condition.

- **Less waste**

Longer durability is often associated with fewer problems during long distance shipment – and a longer shelf life. As a result, waste disposal due to spoiled food can often be reduced.

- **More sales opportunities**

Because of the longer shelf life, modified atmosphere packaging typically opens up new geographic markets to manufacturers. Particularly with perishable goods, longer shipment distances can be achieved, and a global market can become a reality.

- **Fewer preservatives**

As packaging under a protective atmosphere extends the shelf life of food, the use of preservatives can be reduced or even completely eliminated in many cases. Consumers get products that do not contain artificial additives.

- **Appealing package design**

Next to functional aspects, the design of the packaging plays a significant role in the competition for consumers. The look and feel, in addition to the quality impression, influence the purchasing behavior. Modified atmosphere packaging is very well suited for the most appealing package design and presentation of the food product.

Limitations of modified atmospheres

- **Comparatively high complexity**

The modified atmosphere packaging process involves comparatively high requirements. Possible failures include incorrect gas composition, leaks due to faulty temperature or pressure distribution, contaminated or worn tools, seal contamination, or defective material. However, with modern MAP technology and comprehensive quality assurance, the risks can be mastered.

- **Cost**

High-quality packaging films, the consumption of gas and the personnel costs for quality control all figure into the cost of modified atmosphere packaging. However, these costs can be minimized with the efficient use of resources.

- **Influence on product quality**

Unlike using preservatives, in most cases, the protective gases are not absorbed by the food and, thus, do not alter the nature or taste of the product. However, there are exceptions to this rule. For example, an excessively high concentration of CO₂ can be absorbed by the food and make it sour. Fortunately, these effects can be avoided with adapted gas mixtures. There are also issues specific to meat. The influence of a very high oxygen concentration on the color and quality of meat is controversial, and modified atmospheres are supposed to make the meat tastier, but data to support this is sparse.

Factors influencing the shelf life of food, and the influence of modified atmospheres

From the time that fruits and vegetables are harvested or animals are slaughtered, the spoilage process begins. This process is often accelerated the more the products are processed, e.g., in the case of cut fruit or minced meat. How long foods remain suitable for consumption varies greatly and depends on various factors, including the content of water and salt, pH value, hygiene conditions during production, storage conditions, such as temperature or humidity, and packaging. Depending on the characteristics and combinations of these factors, food products vary in their sensitivity to microbial or chemical / biochemical spoilage.

Chemical and biochemical spoilage

Directly after harvest or slaughter, chemical processes begin to change the structure or quality. Sometimes this is useful, e.g., dry-aging of meat, which can be seen as a maturation to improve quality. In principle, however, the quality of organic material decreases. For example, the oxidation of fats quickly leads to rancidity.

Microbial spoilage

Microorganisms are a major threat to the shelf life and quality of food. On the one hand, they influence color and smell, but they can also lead to health hazards and make the products inedible. The source of the microorganisms is either the food itself or an impurity that cannot be completely excluded in the production and packaging process.

The changes due to chemical / biochemical and microbial spoilage can be significantly slowed by MAP techniques, combined with cooling. Various gases and mixtures with different properties are used to slow the process of spoilage as much as possible.

Typical gases for modified atmosphere packaging

Carbon dioxide (CO₂) and nitrogen (N₂) are the main protective gases used in food packaging. Carbon monoxide (CO) and argon (Ar) are also common in some countries, for example, in the US. And oxygen (O₂) is also used in some cases.

Oxygen (O₂) causes food to spoil due to oxidation and forms the ideal preconditions for aerobic microorganisms to grow. As a result, oxygen is frequently excluded from modified atmosphere packaging. However, in some cases processing is deliberately carried out with high oxygen concentrations, for example, with red meat. Oxygen prevents the red color from becoming pale, and it inhibits the growth of anaerobic organisms.

Carbon dioxide (CO₂) is colorless, odorless and tasteless. Due to its oxidation-inhibiting and growth-inhibiting effects on most aerobic bacteria and molds, the gas is frequently used to increase the shelf life of food. As the shelf life of packaged or stored food is normally longer, the CO₂ concentration is higher. Nevertheless, many products can become sour if the CO₂ concentration is too high. In addition, the gas can diffuse out of the packaging or be absorbed by the product, causing the packaging to collapse. The use of supporting or filling gases can slow down this effect.

Nitrogen (N₂) is an inert gas and, owing to its production process, is typically of relatively high purity. It is usually used for displacing air, especially atmospheric oxygen, in food packaging. This prevents the oxidation of food and inhibits the growth of aerobic microorganisms. It is frequently used as a supporting or filling gas as it diffuses very slowly through plastic films and, therefore, remains longer in the packaging.

Carbon monoxide (CO) is colorless, odorless and tasteless. Similar to oxygen, carbon monoxide is sometimes used to retain the red color of meat. The required concentrations are very low, in the ppm range.

Argon (Ar) is inert, colorless, odorless and tasteless. Owing to the similarity of its properties to those of nitrogen, argon can replace nitrogen in many applications. It is believed that certain enzyme activities are inhibited and argon slows metabolic reactions in some types of vegetables. Due to the marginal effects and the higher price compared to nitrogen, its use is rather rare.

Hydrogen (H₂) and helium (He) feature in modified atmospheres in some applications. However, these gases are not used to extend the shelf life. They are used as trace gases for some leak detection systems available on the market. The relatively small molecular size of the gases allows rapid escape through packaging leaks. Since these gases otherwise have no positive properties in regard to the food products and are expensive and difficult to handle, their use is rare. The most common method for leak testing is the detection of CO₂ which is the core component in many MAP processes.

If food is packaged under a protective atmosphere, gases must meet the FDA Food Code 2009: Annex 6 - Food Processing Criteria.

Foods suited to modified atmosphere packaging

Modified atmosphere packaging is suitable for a wide range of food products. While traditionally mainly dairy products, meat products and bread were packaged under a protective atmosphere, now MAP is increasingly used for other foods, such as fish, coffee, fruit and vegetables. In addition, modified atmosphere packaging is driven by the growing popularity of ready-made meals and convenience products.

Meat and sausage products

Meat and sausage products are highly susceptible to spoilage from microbial growth. As this growth is enhanced by high moisture and nutrient content, raw meat is especially prone to spoilage. No matter whether beef, pork or poultry, spoilage begins from the moment of slaughter and continues throughout the butchering process. Besides stringent hygiene standards and continuous cooling, modified atmospheres can significantly extend the shelf life of meat and sausage products – with CO₂ as the most important among the protective gases. At concentrations above 20%, CO₂ can considerably reduce microbial growth. In the case of red meat, there is also the risk of oxidation of the red pigments. The meat will lose its color, becoming gray and unappetizing in appearance. This is especially true with beef. To combat this problem, a high oxygen concentration in protective gas packaging can

prevent oxidation. In addition, a very low carbon monoxide concentration (approx. 0.4% or 4000 ppm) can further help to retain the red color.

Poultry is particularly sensitive to rapid spoilage and, therefore, subject to stricter cooling requirements. Here, too, a modified atmosphere with CO₂ will extend the shelf life. A high oxygen concentration is also used for poultry without skin in order to retain the color of the meat. As CO₂ can be partially absorbed by food, nitrogen is added as a supporting gas to prevent the packaging from collapsing.

Sausage and meat products, e.g., marinated or smoked meat, react differently depending on the preparation. While shelf life is inherently longer than that of raw meat, it can also be positively influenced with protective gases. The CO₂ concentration should not exceed recommended limits with these products, however, or a sour taste may occur.

Fish and Seafood products

Fish and seafood are some of the most sensitive foods. They are at risk of rapidly declining in quality and spoiling, even shortly after the catch. The reason for this lies in seafood's neutral PH value – an ideal precondition for microorganisms, as well as special enzymes that negatively affect taste and odor. Fish, which is rich in fatty acids, also becomes rancid quickly. The most important element for a longer shelf life is cooling close to 32°F, but modified atmospheres with at least 20% CO₂ also slow the growth of bacteria, and CO₂ concentrations around 50% are frequently used. As with other foods, higher levels of CO₂ can lead to undesirable side effects, such as liquid loss or a sour taste. In the case of low-fat fish and shellfish, oxygen is also used in the packaging. This prevents a fading or loss of color, while simultaneously serving as a growth inhibitor for some types of bacteria. When dealing with shellfish and crustaceans, special attention should be paid to ensuring a CO₂ concentration that is not too high. As these products absorb the most CO₂, there's a greater risk of sour taste. In addition, there's a greater risk of package collapse. However, using nitrogen as an inert supporting gas prevents this effect.

Dairy products

Cheese is predominantly spoiled by microbial growth or rancidness. While a continuous cooling chain extends the shelf life, in the case of hard cheese, there is a risk of mold formation upon contact with oxygen. As a result, vacuum packaging was frequently used in the past, even though this type of packaging is awkward to open and can leave unattractive marks on the product. Modified atmosphere packaging with CO₂, on the other hand, effectively prevents mold formation – without the undesirable effects of vacuum packaging – but does not otherwise affect the maturation of the cheese.

Soft cheese can quickly become rancid. While this problem can also be tackled with CO₂, soft cheese absorbs this gas at a greater rate than other types of cheese, resulting in a risk of sour taste and package collapse. Therefore, a lower CO₂ and higher nitrogen concentration should be used. Likewise, dairy products such as yogurt and cream can absorb too much CO₂ and become sour; these products should be packaged with an even lower concentration of CO₂.

Powdered milk, frequently used in baby formula, is a highly sensitive product. It is especially important to ensure that oxygen is displaced from the packaging in order to extend the shelf life. In practice, packaging is carried out in pure nitrogen with as low a residual oxygen content as possible.

Bread and Cake

The shelf life of bread, cake and cookies is primarily affected by mold formation. Although a high standard of hygiene during production and packaging can significantly minimize this risk, using a modified atmosphere with CO₂ (and without oxygen) minimizes the risk considerably further, greatly extending the shelf life. Because these products may absorb CO₂, nitrogen is often included as a supporting gas to prevent package collapse.

Fruit and Vegetables

Modified atmosphere packaging makes it possible to offer consumers fresh and untreated products – in other words, succulent fruit and vegetables – with a long shelf life. At the same time, fruit and vegetables are subject to unique requirements regarding the nature of the packaging and atmosphere. In contrast to other types of food, fruit and vegetables continue breathing after the harvest and, consequently, require an oxygen concentration in the packaging. Furthermore, the packaging film doesn't have to be airtight. By taking the product's respiration and the permeability of the film (typically via micro-perforation) into account, the ideal composition of CO₂, nitrogen and low amounts of oxygen can be maintained. The term used here is EMA – equilibrium modified atmosphere. The gas composition is individually adapted to the corresponding product.

Thorough cleaning and hygienic processing are the fundamental preconditions for long-lasting freshness. Modified atmospheres, in conjunction with cooling, can be used to extend the shelf life of fresh produce while achieving an attractive packaging design at the point of sale.

Pasta and ready-made meals

The nature and composition of fresh pasta and, in particular, ready-made meals vary greatly. Products such as ready-made pizzas or sandwiches contain many different ingredients with a variety of shelf lives and spoilage properties. In the majority of cases, modified atmospheres can significantly extend the shelf life without using oxygen. Mixtures of CO₂ and nitrogen are used with the concentration of gases adjusted to the content of the product. If, for example, there is a risk that large volumes of CO₂ will be absorbed by the product, the nitrogen concentration should be increased to prevent the packaging from collapsing.

Snacks and Nuts

Snack products containing fats, for example, potato chips or peanuts, are at increased risk of oxidation, whereby the products can quickly become rancid if the packaging is not optimal. To extend the shelf life, it is critical that contact with oxygen is minimized. In this case, modified atmospheres with 100% nitrogen are frequently used. Not only does this prevent premature spoilage, the nitrogen atmosphere also provides protection from mechanical damage to sensitive products, such as potato chips in conventional packets.

Wine

Gases or gas mixtures are often used to protect wine in the different phases of its production process and to retain the quality of the product. They are mainly used to avoid contact with oxygen and prevent microbial deterioration. The tank headspace is replaced with an inert gas or a gas mixture, for example, of CO₂, N₂ or Ar. The composition of the gases is chosen according to the type of wine.

Coffee

As a dried product, coffee is relatively immune to spoilage by microorganisms. However, due to its fatty acid content, the product may turn rancid as a result of oxidation. To prevent this, coffee is packaged to exclude oxygen. Instead, a modified atmosphere comprising pure nitrogen is frequently used in coffee bags or capsules.

Examples of gas mixture compositions

Product	O ₂	CO ₂	N ₂
Raw red meat	70	23-30	0-10
Raw entrails and internal organs	80	20	0
Raw poultry with skin	0	30	70
Raw poultry without skin	70	20-30	0-10
Cooked meat and sausage products	0	20-30	70-80
Raw low-fat fish	20-30	40-60	20-40
Raw high-fat fish	0	40	60
Cooked / smoked fish	0	30-60	40-70

Shellfish and crustaceans	30	40	30
Hard cheese	0	30-100	0-70
Soft cheese	0	10-40	60-90
Sliced cheese	0	30-40	60-70
Cream cheese	0	100	0
Yogurt	0	0-30	70-100
Powdered milk	0	0	100
Bread	0	50-100	0-50
Cakes and cookies	0	50	50
Fresh fruit and vegetables	3-10	3-10	80-90
Cooked vegetables	0	30	70
Ready-made meals	0	30-60	40-70
Pasta and pizza	0	30-60	40-70
Sandwiches	0	30	70
Snacks, chips and peanuts	0	0	100
White wine and Rosé	0	20	80
Red wine	0	0	100
Coffee	0	0	100

Quality control of modified atmosphere packaging

Modified atmosphere packaging makes comparatively high demands on the packaging process, especially on the sealing process. Many sources of error can lead to leaks, usually micro-leaks. Right from the point of mixing the gases and introducing them into the package, maximum care is required. A faulty mixture or leaking package can have serious effects – from the loss of nutrients, taste, color or structure, to a bad smell or infestation with microorganisms. Depending on the product, health risks to the consumer cannot be completely eliminated.

Modified atmosphere packaging, therefore, requires modern, high quality equipment and uncompromising standards of hygiene. Even with the best available technology, however, failures can't be completely avoided. Thus, comprehensive quality assurance activities are essential. These can begin during the packaging process by using inline gas analysis, which constantly monitors the composition of the modified atmosphere. After packaging, the packages must be tested for the correct gas mixture and for leaks. Only with this level of rigor can you ensure that the full benefit of modified atmosphere packaging is achieved and that the customer receives a top quality product.

Gas technology for modified atmosphere packaging

Packaging machines

There is no one special packaging machine for MAP. Various types of machines from several suppliers will do the job.

Hand vacuum chamber machines are the simplest type of MAP machines. They are operated manually and are suitable especially for smaller companies. Pre-formed bags are put into the chamber and filled with the product. After closing the chamber, the machine creates a vacuum and replaces the air with the modified atmosphere before the packaging is finally sealed.

For larger packaging volumes automatic packaging lines are typically used. So-called **thermoform-fill-seal machines** use packaging film from a roll. The film is heated inside the machine and formed onto trays, which get filled with food product. The next steps are similar to the hand chamber machine but are done automatically. In a vacuum chamber the air is replaced by a gas mixture. The trays are then sealed. **Tray-sealer machines** function

in a similar way. The main difference is that the trays are not made inside the machine but are pre-formed and then sealed with a film.

Form-fill-seal or flow-pack machines are a further type of machine. Horizontal or vertical machines are available. These machines form a tube from a film and place the product inside. The air inside the tube is replaced by permanent flushing with a modified atmosphere before the individual packs are sealed.

Gas mixers and meterers

In the packaging process the air inside the package is replaced by a gas or a gas mixture. Pre-mixed modified atmospheres are available in different mixtures and under several brand names. However, in most cases on-site gas mixers are used to create these gas mixtures. MAP gas mixers provide verified gas quality and safety in the packaging process – for germfree food preservation. But above all they offer great flexibility to the user. At the push of a button, different mixtures can be produced quickly on one packaging line, depending on the requirements of the product. There are gas mixing and metering systems for all packaging machines used in the food industry: vacuum packaging, thermo forming, flow pack or chamber packaging machines. Often gas mixing systems can be adjusted to your specific product type and processing with only basic installation requirements.

Gas analyzers

Gas analyzers are essential for quality control in the MAP process. Gas analysis can be done continuously during the packaging process or after as a sample test. For continuous analysis, a gas analyzer module is integrated into the gas mixing system where it monitors the correct composition of the gas mixture. In sample testing, a key element of quality control for any company working with modified atmospheres, a sample is taken from the package via a needle. High quality gas analyzers use modern sensors and are extremely precise and fast. And with a minimal gas volume requirement for testing, they're suitable for packages of all sizes, including those with a small head-space or a very low volume of gas inside the package. All data is logged and can be archived for complete QA documentation.

Leak detection

Modified atmospheres perform only if the protective gas remains inside the package. The package must be fully leak tight. As a freshness guarantee to retailers and consumers, package leak detection can provide a competitive advantage. Leak testing prevents needless returns, loss of prestige, legal consequences and loss of business. To optimize quality assurance, the user can choose between solutions for sample or in-line testing – based on CO₂ or a water bubble test. Package leak detection systems reliably detect even the smallest leak and are easy to operate. Furthermore, all tests can be digitally logged and documented for customers.

Ambient air monitoring

Gas monitoring systems for ambient air protect employees and make the use of gases such as carbon dioxide safer. CO₂ is odorless and may accumulate unnoticed in closed rooms and replace the oxygen in the air. A concentration of 0.3 percent carbon dioxide in ambient air can be a health hazard. The allowed maximum concentration at the workplace is 0.5 percent. At five percent headache and dizziness may occur; at eight percent and beyond, unconsciousness or even death. A gas level warning unit permanently monitors the concentration of the respective gas in the ambient air and activates an acoustic and visual alarm when individually definable limits are exceeded. Simple and effective.

In the case of fruit and vegetables, controlled atmospheres are not just used in packaging but also for ripening control in special ripening chambers with the help of ethylene. By using gas monitors, the atmosphere can be monitored for a safe level of this gas.