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, dairy products, bread, fruits and vegetables, fish or convenience products.

Modified atmospheres are not only used in packaging. They can feature as part of the production process, e.g. in the case of minced meat, or of storage and transport, for example of fruit and vegetables in halls or containers.

The standards required by Modified Atmosphere Packaging are comparatively high, and have to 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 much slower. 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. Normally, 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 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. A global market can become a reality.

- **Fewer preservatives**

Packaging under a protective atmosphere extends the shelf-life of food, meaning in many cases that the use of preservatives can be reduced or even completely eliminated. 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 and the quality impression influence the purchasing behaviour. Modified Atmosphere Packaging is very well suited for the most appealing packaging 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: incorrect gas composition or 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.

- **Relatively high cost**

In addition to high-quality films, the consumption of gas and the personnel costs for quality control are particularly costly. However, these costs can be minimised with 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. But there are exceptions to this rule. For example, an excessively high concentration of CO2 can be absorbed by the food and make it sour. However, these effects can be avoided with adapted gas mixtures. The influence of very high oxygen concentration on the quality of meat is controversial. Modified atmospheres are supposed to make the meat more chewy. Data to support this is, however, 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, such as cut fruit or minced meat. How long foods are durable, which means suitable for consumption, is very different and depends on various factors, e.g. the content of water and salt, pH value, hygiene conditions during production, storage conditions such as temperature or humidity, packaging. Depending on the characteristics and combinations of these factors, food products are differently sensitive to microbial or chemical / biochemical spoilage.

Chemical and biochemical spoilage

Directly after harvesting of plant or slaughter of animal material, 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 a rancidity of the product.

Microbial spoilage

Microorganisms are a major threat to the shelf-life and quality of food. On the one hand, they influence colour and smell, but they can also lead to health hazards and make the products uneatable. 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 together 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 (CO_2) and nitrogen (N_2) are mainly used as protective gases in food packaging. Carbon monoxide (CO) or argon (Ar) is also common in some countries. Oxygen (O_2) is also used in some cases.

Oxygen (O_2) essentially 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. In some cases – typically red meat – processing is deliberately carried out with high oxygen concentrations, in order to prevent the red colour from becoming ‚pale, and to inhibit the growth of anaerobic organisms.

Carbon dioxide (CO_2) is colourless, odourless and tasteless. It has an oxidation-inhibiting and growth-inhibiting effect on most aerobic bacteria and moulds. The gas is frequently used to increase the shelf-life of food. The shelf-life of packaged or stored food is normally longer, the higher the CO_2 content. Nevertheless, many products can become sour if the dosage is too high. In addition, the gas can diffuse out of the packaging or be absorbed by the product – and the packaging thereby collapses. The use of supporting or filling gases can slow down this effect.

Nitrogen (N_2) is an inert gas and owing to its production process, is typically 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 hence remains longer in the packaging.

Carbon monoxide (CO) is colourless, odourless and tasteless. Similar to oxygen, carbon monoxide is sometimes used to retain the red colour of, primarily, meat. The required concentrations are very low. In some countries, including the EU, the use of carbon monoxide for modified atmospheres is nonetheless prohibited in foods.

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 (H_2) and helium (He) feature in modified atmospheres in some applications. However, these gases are not used to extend 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 on the food products and are expensive and not easy to handle, their use is rare. The most common method for leak testing is the detection of CO_2 which is the core component in many MAP processes.

If food is packaged under a protective atmosphere, this must be indicated on the label. In addition, according to EU Regulation 95/2/EC, the gases used must be listed with their corresponding E-number. The E numbers for the most important gases are:

Argon E 938
Helium E 939
Carbon dioxide E 290
Oxygen E 948
Nitrogen E 941
Hydrogen E 949

Foodstuffs suited to Modified Atmosphere Packaging

Modified Atmosphere Packaging is suitable for a wide range of food product. While traditionally mainly dairy products, meat products or bread were packaged under protective atmosphere, now MAP is more and more used for other foods like fish, coffee, fruit or 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, especially raw meat, are very prone to spoiling due to microbial growth, on account of their high moisture and nutrient content. No matter whether beef, pork or poultry – spoilage begins from the moment of slaughter and especially after butchering. Besides high hygiene standards and permanent cooling, modified atmospheres can significantly extend the shelf-life of meat and sausage products. CO_2 is the most important among the protective gases. At concentrations above 20 %, CO_2 can considerably reduce microbial growth. In the case of red meat, there is also the risk of oxidation of the red colour pigments. The meat will lose its red colour, becoming grey and unappetising in appearance. This oxidation is especially prominent with beef. A high oxygen content in protective gas packaging can prevent oxidation. A low carbon monoxide content (approx. 0,5 %) can also help to retain the red colour of meat. However, the use of this gas is not allowed in the EU, for example. Poultry is especially sensitive to rapid spoilage and is therefore subject to higher requirements for permanent cooling. Here too, a modified atmosphere with CO_2 content will extend the shelf-life. A high oxygen content is also used for poultry without skin so as to retain the colour of the meat. The CO_2 can partly be absorbed by the foods. To prevent the packaging from collapsing, nitrogen is used as a supporting gas.

Sausage and meat products, e.g. marinated or smoked meat pieces, react very differently depending on the preparation. Longer shelf-lives can be afforded by the use protective gases right from the start. The CO_2 content should not be too high with these products, in order to prevent a sour taste.

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 the neutral pH value as an ideal precondition for microorganisms as well as special enzymes that negatively affect taste and odour. Fish, which is rich in fatty acids, also becomes rancid quickly. The most important element for a longer shelf-life is cooling close to 0° Celsius. Modified atmospheres with minimum 20 % CO_2 also retard the growth of bacteria. CO_2 components around 50 % are frequently used. Higher CO_2 concentrations can lead to undesirable side effects such as liquid loss or a sour taste. In the case of low-fat fish and shellfish, O_2 is also used in the packaging. This prevents a fading or loss of the colour, while at the same time serving as a growth inhibitor for some types of bacteria. When dealing with shellfish and crustaceans, special attention should be paid to ensuring a CO_2 content that is not too high. This can be discerned most clearly by a sour taste, while these products absorb CO_2 the most, as a result of which the packaging can collapse. Nitrogen as an inert supporting gas prevents this effect.

Dairy products

Cheese is predominantly spoiled by microbial growth or rancidness. A continuous cooling chain essentially extends the shelf-life of products. With hard cheese, there is a risk of mould formation upon contact with oxygen. As a result, vacuum packaging was frequently used in the past, even though these are awkward to open and can leave unattractive marks behind on the product at the same time. CO_2 effectively prevents mould formation, but does not otherwise affect the maturation of the cheese. Soft cheese can quickly become rancid. This problem can also be tackled with CO_2 modified atmospheres. However, as soft cheese absorbs CO_2 to a significantly higher extent, there is a risk of the packaging collapsing. A correspondingly lower CO_2 content should therefore be chosen. In the case of milk products such as yoghurt or cream, there is a risk of the products absorbing too much CO_2 and becoming sour. A lower CO_2 content should therefore be chosen.

Milk powder, above all for use in baby food, 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

With bread, cake and biscuits, the shelf-life is primarily affected by potential mould formation. A high standard of hygiene during production and packaging can significantly minimise this risk. Packaging involving a modified atmosphere with CO_2 and without oxygen largely prevents the products from becoming mouldy and extends the shelf-life. To prevent the packaging from collapsing owing to CO_2 absorption by the products, nitrogen is used as a supporting gas in many cases.

Fruit and Vegetables

Modified atmospheres in packaging make it possible to offer consumers fresh and untreated products – in other words succulently fresh fruit and vegetables – with a long shelf-life. At the same time, fruit and vegetables are subject to very special requirements in regard to the nature of the packaging and atmosphere. This is because – in contrast to other food – fruit and vegetables continue breathing after the harvest and consequently require an oxygen content in the packaging. Furthermore, the packaging film does not have to be fully tight. By taking the product's breathing and the permeability of the film, typically via micro-perforation, into account, the composition of carbon dioxide, nitrogen and low amounts of oxygen ideal for the product can be maintained. The term used here is an EMA (equilibrium modified atmosphere). The gas composition is individually adapted to the corresponding product.

Thorough cleaning along with hygienic processing are the fundamental preconditions for long-lasting freshness. Modified atmospheres, in conjunction with corresponding 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, readymade meals are very different. Above all, multi-component products such as ready-made pizzas or sandwiches contain many different foods with differing shelf lives and spoilage properties. In the majority of cases, modified atmospheres can significantly extend the shelf-life without using oxygen. Mixtures of CO_2 and nitrogen are used here. The concentration of the gases is oriented to the content of the product. If, for example, there is a risk that large volumes of CO_2 will be absorbed by the product, the nitrogen content should be chosen higher to prevent the packaging from collapsing.

Snacks and Nuts

Snack products, for example potato crisps or peanuts, primarily involve problems associated with the fat content of the food. There is a risk of oxidation, whereby the products can quickly become rancid if the packaging is not optimal. To extend the shelf-life, it is therefore important to minimise the contact with oxygen. Modified atmospheres with 100 % nitrogen are frequently used. In this way, a premature spoilage can be prevented, while these atmospheres also provide protection from mechanical damage to sensitive products, e. g. potato crisps 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 CO_2, N_2 or Ar. The composition of the gases is chosen according to the type of wine.

Coffee

As a dried product, coffee is relatively insensitive to spoilage by microorganisms. However, the risk of the fatty acids it contains oxidising and making the product rancid is greater. To prevent this, oxygen is excluded from coffee packaging. Instead, a modified atmosphere comprising pure nitrogen is frequently used in coffee sachets or capsules.

Examples of gas mixture compositions

Product	**O_2**	**CO_2**	**N_2**
Raw red meat	70	23-30	0-10
Raw offal	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
Yoghurt	0	0-30	70-100
Milk powder	0	0-20	80-100
Crispy breads	0	50-100	0-50
Cakes, buicuits	0	50	50
Fruit / Vegetables, fresh	3-10	3-10	80-90
Vegetables, cooked	0	30	70
Ready-made meals	0	30-60	40-70
Pasta/Pizza	0	30-60	40-70
Sandwiches	0	30	70
Snacks/Crisps/Peanuts	0	0	100
Wine, white / Rosé	0	20	80
Wine, red	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 packaging can have serious effects - from the loss of nutrients, taste, colour 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. But even when using best available technology, failures can't be completely avoided. So comprehensive quality assurance activities are essential. These can begin during the packaging process, 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 rigour can it be ensured 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 Modified Atmosphere Packaging. Various types of machines from several suppliers do the job.

Hand vacuum chamber machines are the most simple 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 normally automatic packaging lines are used. So called **thermoform-fill-seal machines** are using 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. Main difference: The trays are not made inside the machine but are pre-formed and just 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 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. Today, 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 and long shelf-life food. But above all they offer high flexibility to the user. At the push of a button different mixtures can be produced in the shortest time on one packaging line, depending on the requirements of the product. WITT offers gas mixing and metering systems for all packaging machines used in the food industry, no matter whether it's vacuum packaging, thermos forming, flow pack or chamber packaging machine. The gas mixing systems are adjusted to the specific product type and processes, and require only basic installation requirements.

Gas analysers

Gas analysers are essential for quality control in the MAP process. The monitoring can be done as continuous analysis during the packaging process or batch sampling after the packaging process. For continuous analysis, a gas analyser module is integrated into the gas mixing system. The gas analyser monitors the correct composition of the gas mixture. Sample testing is part of the quality control system of almost every company working with modified atmospheres. Via a needle, a sample is taken from the package. High quality gas analysers use modern sensors, very precise and rapid and requiring a very low gas volume. They are therefore also suited to packs with very small headspace, and 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 has to be fully leak tight. As a freshness guarantee to retailers and consumers, package leak detection can also provide competitive advantage. Leak testing prevents needless returns, loss of prestige, legal consequences and, worst case, loss of business. To optimise quality assurance, the user can choose between solutions for sample or in-line testing – based on CO_2 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. This is not toxic but accumulates unnoticed in closed rooms and replaces 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 in the workplace is 0.5 percent. At five percent, headaches and dizziness may occur; eight percent and more leads to unconsciousness or even death. The 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.

For food and vegetables, controlled atmospheres are not just used in packaging but also for the control of ripening control, in special ripening chambers with the help of ethylene. By using gas analysers, the ambient atmosphere can be monitored.