MAPAX® – modified atmosphere packaging. The ultimate combination for freshness.

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MAP – Modified Atmosphere Packaging.

Winning the race against time.

Nowadays, good food has to be healthy, minimally processed and attractively packaged – as consumers' expectations from foodstuffs are continuously rising. Consequently, demands on food producers and producers of packaging machines and materials are increasing, too.

The consumer of today reacts sensitively when it comes to artificial additives and always wants to have the option of buying and preparing fresh foodstuffs and ready-made dishes that look and taste as if they have come directly from the farm or producer. Food safety and easy access to a rich variety of foodstuffs are very important. Therefore, it is becoming more and more difficult to meet consumers' high expectations. It is also becoming clear that the time factor is crucial.

The challenge: maintaining freshness

From the very moment fruit is picked, corn is harvested or fish is caught, the race against time begins. From now on, natural deterioration and spoilage endanger the quality and shelf-life of the foodstuff. However, external factors also pose a threat to the product's freshness. It is therefore of critical importance how the product is handled in the processing stage, on the filling line or during the chilling process prior to packaging. Particular emphasis must be placed on the packaging stage, because the way the foodstuff is packaged is decisive when it comes to prolonging shelf-life and guaranteeing food safety for the consumer.

The solution: modified atmosphere packaging (MAP)

In order to prevent this loss of natural freshness and quality, an effective and intelligent concept of food preservation has been developed – MAP. By combining food-grade gases with the right packaging materials and machines, MAP can maintain the quality of foodstuffs and extend their shelf-life.

Deterioration processes and the role of gases

Food is a biological, sensitive commodity. Original freshness and shelf-life are affected by the inherent properties of the product just as much as by external factors. Internal factors affecting quality are:

- The type and quantity of microorganisms
- Water activity a_w
- pH value
- Cell respiration
- Food composition

External factors affecting the inherent quality:

- Temperature
- Hygienic conditions
- Gas atmosphere
- Processing methods

Spoilage starts immediately

It is primarily microbial and chemical/biochemical deterioration that destroys food. Microbial deterioration starts immediately after harvesting or slaughtering. The presence of microorganisms can be traced back to the raw materials, the ingredients and the environment. Microorganisms are found everywhere in our surroundings, e.g. on our skin, on tools and in the air. For this reason, good hygienic conditions must be maintained throughout the processing chain. The ways in which microorganisms cause spoilage vary depending on the type of organism and the foodstuff itself. Basically, microorganisms can be divided into two categories: aerobic and anaerobic.

Aerobic organisms require the presence of oxygen (O_2) to survive and multiply. Anaerobic organisms, on the other hand, grow in the absence of oxygen. Aerobic microorganisms include Pseudomonas, Acinetobacter and Moraxella, which spoil food by decomposing and producing substances that give a bad taste and odour.

Anaerobic microorganisms include Clostridium and Lactobacillus. When foodstuffs are handled incorrectly, Clostridium can generate a toxin. Lactobacillus, on the other hand, is a harmless bacterium that turns the food sour by producing lactic acid.

Low temperature is a highly effective inhibitor

Temperature is one of the most important factors controlling microbiological activity. Most micro-organisms multiply optimally in the 20 to 30°C range and show reduced growth at lower temperatures. Careful temperature monitoring is therefore vital during all food handling and distribution stages. Chilling alone, however, will not solve all microbiological problems. There are some psychrophilic bacteria, e.g. Pseudomonas, that multiply at relatively low temperatures. For such organisms, other measures such as modified atmospheres are more effective.

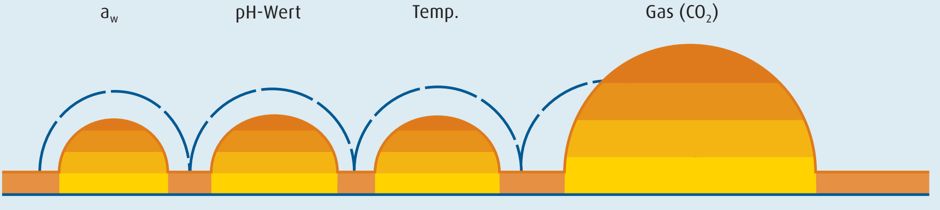
Solubility in water at Pgas = 100 KPa gram/kilogram at 15°C

Carbon dioxide, CO_2	1.97
Argon, Ar	0.06
Oxygen, O_2	0.04
Nitrogen, N_2	0.02

Oxygen causes chemical breakdown

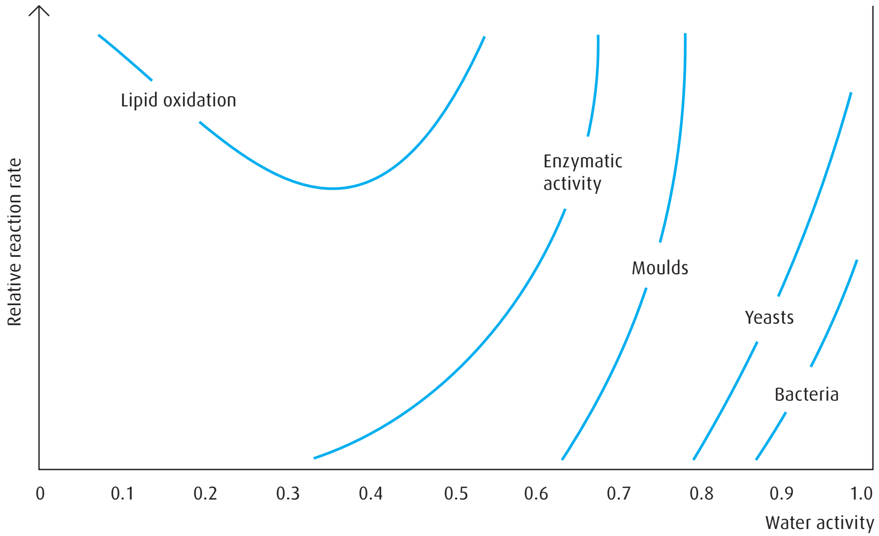
The chemical reactions may be caused by oxidation of vitamins or lipids or by enzymes. The chemical breakdown of lipids is the primary process in dry or dehydrated foodstuffs and in high-fat fish. This is due to the oxidation of unsaturated fats in the presence of atmospheric oxygen, causing the product to turn rancid. Enzymatic reactions caused by polyphenol oxidase, for example, result in brown discolouration of sliced fruits and vegetables. Oxygen, however, is important in maintaining the red colour of cut meat.

Hurdle concept

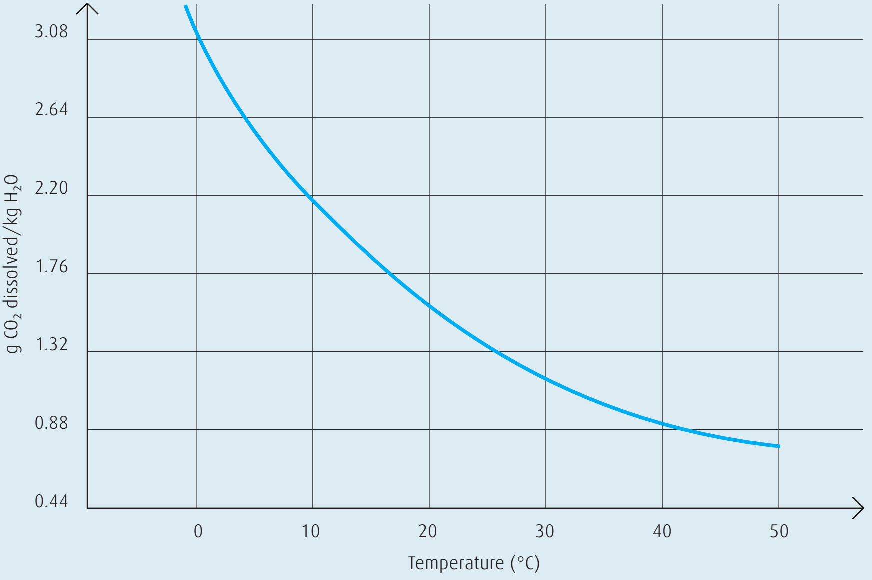


CO_2 contributes to food safety by providing an additional hurdle to the mechanisms that cause spoilage.

Chemical and biological reaction according to water activity



CO_2 solubility in water



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MAP – Benefits.

Packaging solution for fresh herbs

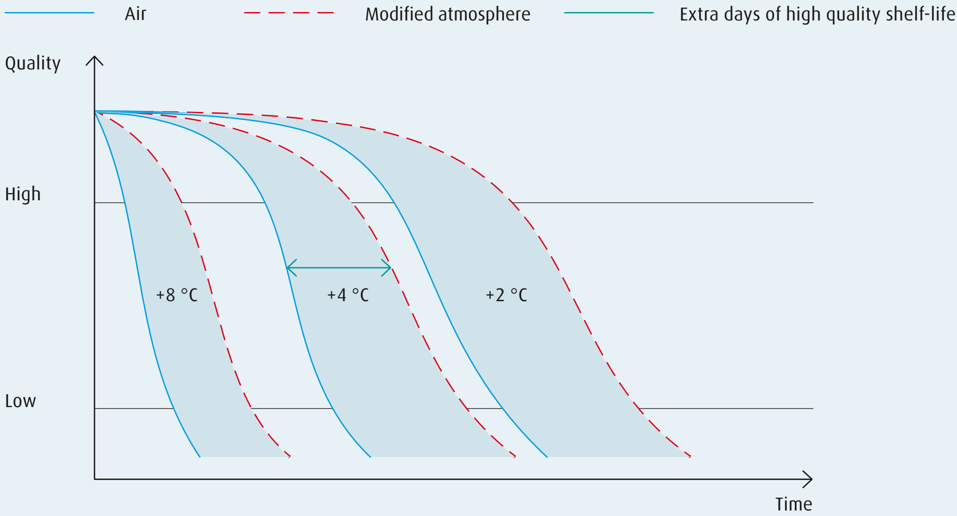
A short story about long-term profits

The success story begins when a consumer decides to buy. Which foodstuffs do they buy and which ones do they refuse? And why? Tailored modified atmosphere packaging (MAP) solutions are based on consumer statistics and intensive market research geared towards actively preempting consumer preferences and buying patterns. By packaging the foodstuff in a modified atmosphere, it is possible to maintain high quality and extend shelf-life by days or even weeks. Products that previously could not be stored fresh throughout the distribution chain can now be offered in shops without sacrificing quality. There are compelling economic advantages for food suppliers using MAP. This technology opens up new markets and simplifies distribution logistics for the successful promotion of sales and profits.

Extending the product range

Using modified atmospheres to extend shelf-life gives food suppliers the opportunity to widen their reach and range by bringing new products to market. They can increase revenue by offering more products in the shops, e.g. fresh pizza or ready-made salads.

High-quality shelf-life is extended when microbial deterioration is inhibited



Increasing productivity, rationalising distribution

MAP simplifies all distribution logistics because goods can be delivered less frequently and across longer distances. This enhances planning flexibility and rationalises the workflow from delivery of a raw material to transport of goods to shops or distribution centres. Due to prolonged shelf-life, food manufacturers are able to supply new markets with their goods and greatly extend their geographical sales region. This is another important advantage when operating in a global market which is increasingly dominated by large-scale companies. In some sectors, there are strong fluctuations in the availability of raw materials. For example, seasonal bottlenecks have to be bridged or peaks balanced. Food suppliers are challenged to ensure a steady stream of fresh produce at all times. A predictable supply also allows them to plan production more efficiently and ensure steady utilisation of human and production resources. All these factors increase the productivity and the efficiency of any company.

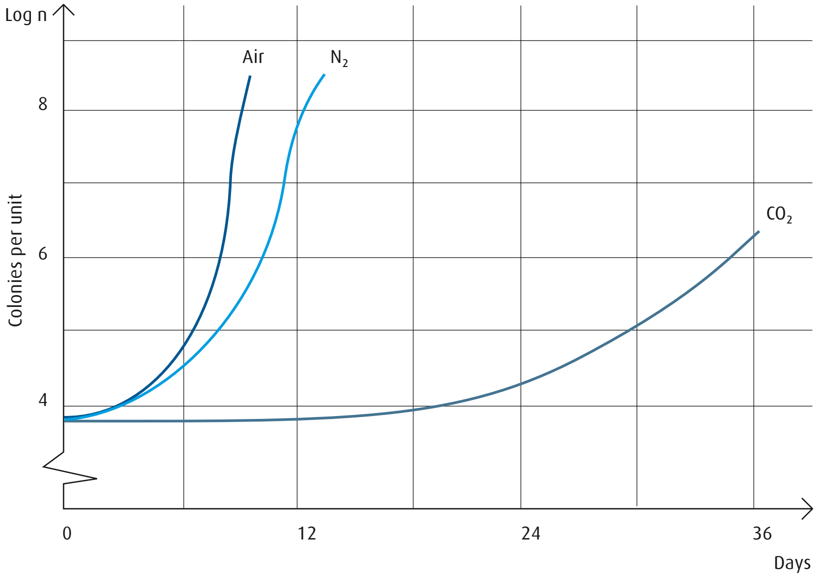
Higher availability, greater market share

By using MAP, days if not weeks of high-quality shelf-life are gained during which fresh produce remains available to consumers. Sales figures soar with every additional day. As many big-name companies have proven, MAP results in successful product sales and raises market share. The bigger the market share, the more consumers react positively to the product. In addition to this, doing away with preservatives increases the sales volume and has a positive effect on the company's image.

Reduced spoilage and returns

Fresh food that is not sold in time is returned. This is a large-scale problem that seriously affects productivity. MAP makes it possible for products to maintain a safe level of quality. The results are reduced spoilage and fewer returns.

Bacterial growth on pork in different atmospheres at +4°C



Benefits of packaging with (left) and without (right) MAP

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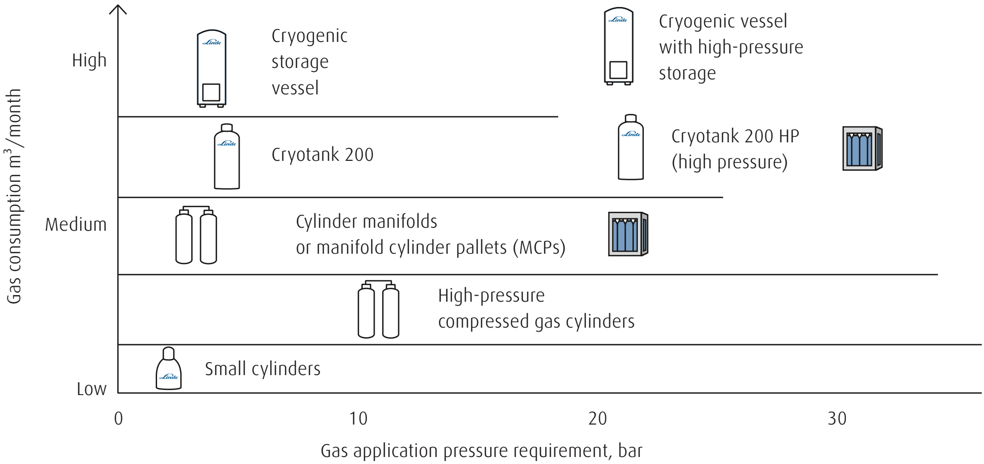
MAP – Food-grade gases and gas supply.

Scientists working in food packaging laboratory.

Matching supply modes to customer volume and pressure needs



Names may vary from country to country.

A gas supply adapted to every application

The gases predominantly used in modified atmosphere packaging (MAP) are carbon dioxide (CO_2), nitrogen (N_2) and oxygen (O_2). These gases are used either alone or in mixtures. The gas properties and the interaction of gases with the food ingredients, e.g. solubility in the foodstuff, should be taken into account when choosing the gas or gas composition.

Linde supplies the food-grade gases CO_2, N_2 and O_2 and other gases authorised for foodstuffs either pre-mixed or as individual gases in cylinders under high pressure. For higher volume needs, these gases can also be supplied as liquids in insulated tanks for subsequent mixing at the packaging machine.

"Food-grade gas" is a specific definition for gases used as a processing aid and/or additive in order to ensure that standards are complied with. Linde's food-grade gases conform to food-grade regulations, e.g. the regulation (EC) 1333/2008 and regulation (EU) 231/2012 on food additives within EU countries and the FDA guidelines in the USA.

N_2 and O_2 are separated from atmospheric air. CO_2 is taken from natural wells or captured as a by-product of, for instance, fermentation processes (wine, beer) or ammonia production. Sometimes it may be more effective and practical to produce nitrogen on site using PSA (pressure swing adsorption) or a permeable membrane plant. If a PSA/membrane system is used, a backup gas supply system is recommended.

Careful evaluations ensure the perfect fit

The best supply option depends on the type of foodstuff, the production volume, the packaging line and also whether the gas is to be used anywhere else in production. It may be preferable to have pre-mixed gases supplied if production is relatively limited or if a new production facility is being started up. When production rates increase and various products are to be packaged, it may be more suitable and more economical to switch over to mixing gases on site. Then a mixer is used and the gases are supplied from cylinders, tanks or PSA/membrane systems.

Each application must be evaluated separately before decisions can be made regarding the supply options and gas mixtures. For quality assurance, regularly checking the gas mixture in the finished packages after sealing is recommended.

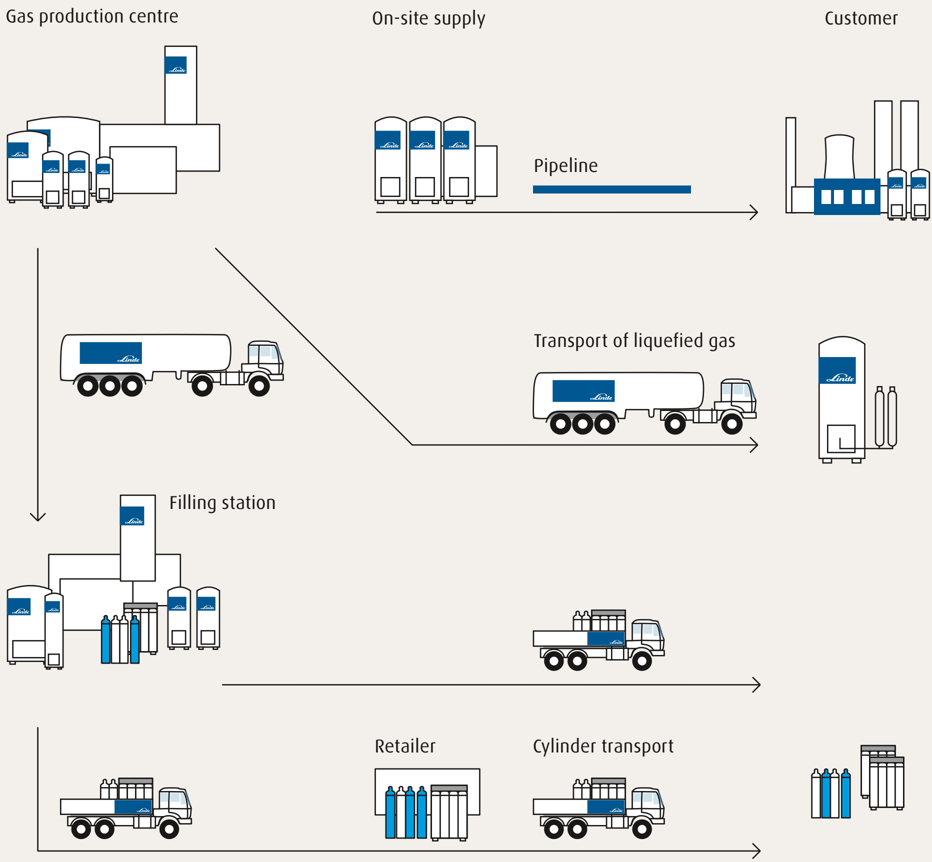
Thorough quality control of food gases

Before the cylinders are filled, they are examined, checked thoroughly and pre-treated if necessary. Each unit is regularly analysed to check for cleanliness and the correct mixture ratio. In addition, various independent institutes regularly inspect gas equipment for compliance with sterility requirements.

Advantages for gas users

- Gas supply solutions tailored to volume and pressure needs
- Security of supply
- Constant quality assurance
- Traceability from source to customer
- High standards in purity

Gas supply



Gas production centre
On-site supply
Customer
Pipeline
Transport of liquefied gas
Filling station
Retailer
Cylinder transport

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MAP – Packaging materials.

Various packaging materials

Perfect food comes in perfect packaging.

Packaging materials are of decisive importance for food quality and shelf-life. Many sophisticated packaging solutions have been developed to prevent rapid deterioration caused by oxygen, light and bacteria or by foreign odour and taste substances that come into contact with the product.

Foodstuff manufacturers have to choose suitable packaging designs and materials while also complying with legal requirements on packaging materials.

For example, they have to examine how to protect the product against quality deterioration from microbial growth, oxidation or dehydration.

Other factors that play a role in the decision include the barrier properties of the packaging against oxygen, light and volatile substances, the water vapour transmission rate, transparency, sealing ability, anti-fogging properties, microwaveability and price.

Various material properties combined

Packaging materials used with all forms of modified atmospheres (with the exception of fruit and vegetables) should have high barrier characteristics. Polymers used include polyester, polypropylene, polystyrene, polyvinyl chloride, nylon, ethylene vinyl acetate and ethylene vinyl alcohol polymers. These are usually laminated or coextruded with polyethylene, which comes into direct contact with the food and is the heat-sealing medium.

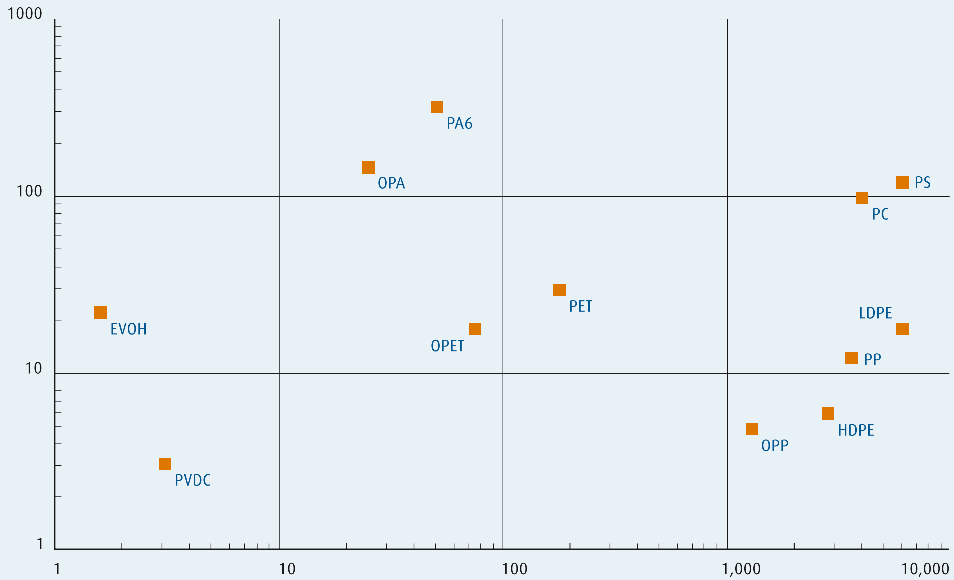
Permeability ratio

N_2	:	O_2	:	CO_2
1	:	5	:	25

Permeability of various basic materials

Permeability H_2O
[g/(m²*d)] at 40 °C/90 % r.H.

Permeability according to film thickness 25 µm



Permeability O_2 [ml/(m²*d*bar)] at 23 °C/75 % r.H.

Primary function of various basic materials

Abbreviation	Basic materials	Primary function
Al	Aluminium	High barrier
APET	Amorphous polyester	Rigidity, gas barrier
CPET	Crystallised polyethylene terephthalate	Rigidity, high temperature resistance, gas barrier
EVA	Ethylene-vinyl acetate	Sealing layers
EVOH	Ethylene-vinyl alcohol	Gas barrier
HDPE	High density polyethylene	Moisture barrier, rigidity, microwave capability, sealing layers
LDPE	Low density polyethylene	Sealing layers
OPA	Oriented polyamide	Gas barrier
OPET	Oriented polyethylene-terephthalate	High temperature resistance, flexibility, puncture resistance
OPP	Oriented polypropylene	Moisture barrier, flexibility, puncture resistance
PA	Polyamide (nylon)	High temperature resistance, flexibility, toughness, partial gas barrier
PAN	Acrylonitrile	Gas barrier
PET	Polyethylene terephthalate (polyester)	Rigidity, partial gas barrier
PP	Polypropylene	Moisture barrier, rigidity, microwave capability
PS	Polystyrene	Rigidity
PVC	Polyvinyl chloride	Rigidity, gas barrier
PVdC	Polyvinylidene chloride	Moisture barrier, gas barrier

Research focuses on developing materials that can be produced and disposed of in an environmentally friendly way, as well as on optimising the packaging material, so that the amount of material is minimised. One development is the use of foamed materials in trays for more attractive presentation. Another development is the use of re-sealable packets for sliced ham, cheese and similar products. The table above shows a list of some typical materials used for product packaging. The exact composition of the film is adapted to the individual product and to the type of package required. To ensure that a modified atmosphere will be retained during the lifetime of the package, several different plastic materials are often combined into a multilayered structure, each layer having its own function. Different plastic materials can therefore be chosen and combined to achieve:

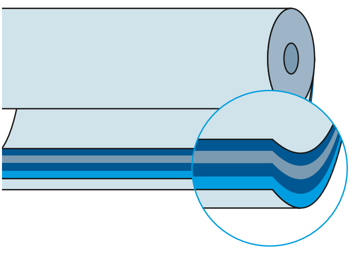
- mechanical strength
- water vapour barriers to prevent weight loss and dehydration
- gas barrier
- gas permeability
- anti-fogging properties (the inside of the material should have a surface that does not allow the formation of water droplets, which reduce transparency)
- sealing properties, i.e. capable of sealing into a tight package while retaining material properties even along the package seal.

Examples of materials used with certain food products

Food	Material	
	Bottom	Top
Red meat, processed meat, poultry, fresh fish	OPET/PE/EVOH/PE XPP/EVOH/PE EPS/EVOH/PE (XPP and EPS are injection-moulded materials)	OPP/PE/EVOH/PE OPET/PE/EVOH/PE OPA/PE
Sausages	PA/PE	
Pizza, pasta, cheese	OPA/PE	PA/PE
Dry products, coffee, milk powder	Metalised PET/PE	
Chopped lettuce leaves	OPP PS/PE	OPA/PE

Typical multi-film structure

PE EVOH OPET



Packaging of salad with flow-pack machine

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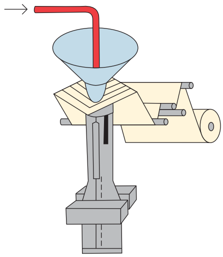
MAP – Packaging machines.

Crisps packed on a vertical flow-pack

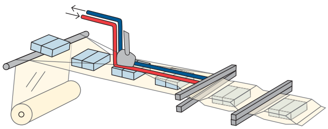
Packaging machines for individual products.

There are five main groups of packaging machines that use modified atmosphere packaging (MAP) technology, depending on the type of product and type of packaging. Although these machines are based on different principles, the basic mode of operation is the same. First, a package is formed (or prefabricated packages are used) and filled with the product. Then the air in the package is replaced by a modified atmosphere. Finally, the package is sealed. These three steps take place either manually or automatically. The methods used to modify the atmosphere include gas flushing or vacuum extraction and then gas injection. The specific gas consumption depends on the type of machine. In gas flushing, the air surrounding the food inside the package is replaced by means of a continuous gas stream before the package is sealed. A continuous flushing process enables high packaging speeds. In the vacuum process, air is extracted from the package and the resultant vacuum is broken by injection with the desired gas mixture. Since this is a two-step process, it is slower than the gas flushing method. However, because the air is almost totally removed, the efficiency of this process with regard to residual oxygen levels is better than in the case of gas flushing.



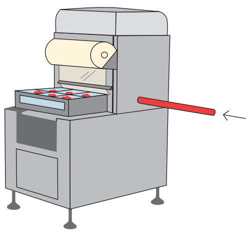
Vertical flow-pack

A film is formed into a tube that is pinched together at one end and sealed over an injection pipe. The product is portioned out into the tube, which is then sealed at the other end and cut off. Gas is continually fed through the tube to purge the air. This machine is mostly used for powdered and bulk products such as coffee and peanuts as well as diced foodstuffs. Sometimes gas flushing may be necessary before packaging.



Horizontal flow-pack

The foodstuffs are fed into a horizontal flowing tube that is constantly formed by a packaging machine. The tube is sealed and cut off along both sides of the product. Gas is flushed into the resultant bag, purging the air. This equipment works fast and uses less complicated film material than a deep-drawing machine. Typical foods are bakery products, sausages, cheese, pizza and salad leaves.



Tray-sealer machine

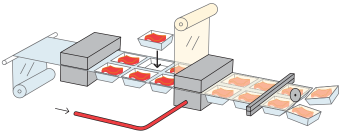
The tray sealer can be operated manually, semi-automatically (illustrated here) or continuously depending on production volumes. This machine can be compared to a deep-drawing machine, but the bottom trays into which the product is placed are ready-made and not formed during the process. Depending on the foodstuff and marketing requirements, a wide range of trays can be used with the tray-sealer machine. These machines are used for most food products, e.g. ready meals, salads, meat and fish.

Gas flow

Gas analyser

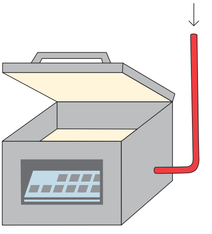
Deep-drawing machine

Film is heat-formed into a tray at a drawing station and the product is then added. Air is extracted, gas is injected and the loaded package is then sealed with a top film. This machine is suitable for foodstuffs such as meat, fish and prepared foods.



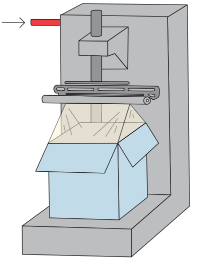
Vacuum chamber machine

The product is inserted into prefabricated bags or trays. The packages are placed in a chamber from which the air is extracted and the pressure is then equalised with gas. The packages are then sealed. This machine type is suitable for small, low-cost production volumes.



Bag-in-box sealing machine

Prefabricated bags are filled with the product. A probe is introduced into the bag and air is extracted. Gas is then fed in, the probe is removed and the bag is sealed. Such equipment is used for large packages of meat, poultry and fish, for example.



Packaging of vegetables with flow-pack machine

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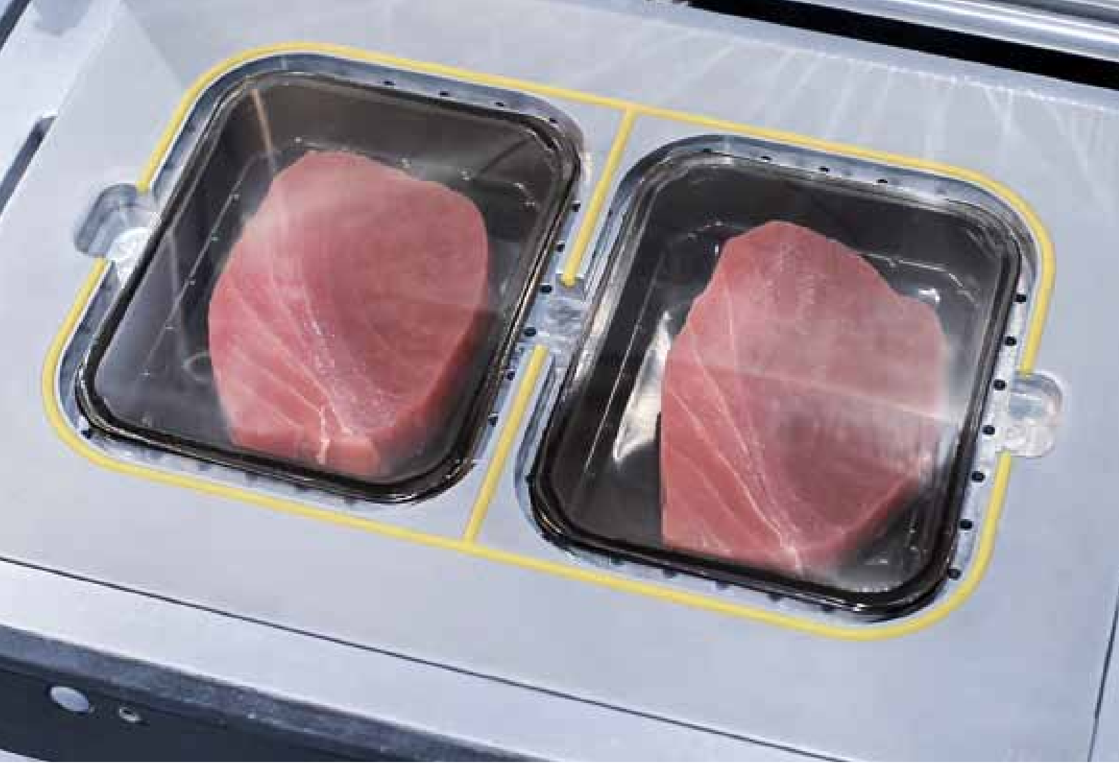
MAPAX® – Packaging concept.

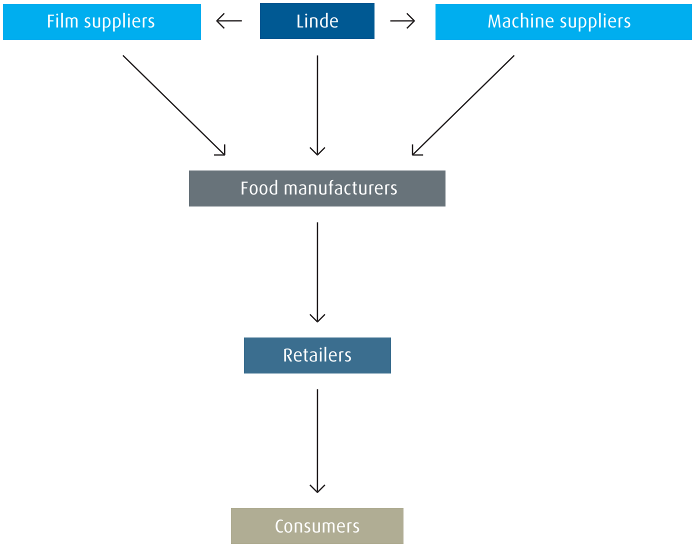


Food-grade gases in action

All-in-one, universal MAPAX solutions

MAPAX is Linde's tailor-made modified atmosphere packaging (MAP) programme based on data relating to foodstuffs, gases and packaging. MAPAX takes the following factors into account:

- → the handling and processing of the product
- → the types and quantity of microorganisms
- → the level of hygiene
- → the delay before packaging
- → the temperature
- → the properties of the packaging material, e.g. permeability
- → the free gas volume of the package
- → the gas mixture
- → the residual oxygen level



Combining experience, research and know-how for fresher food

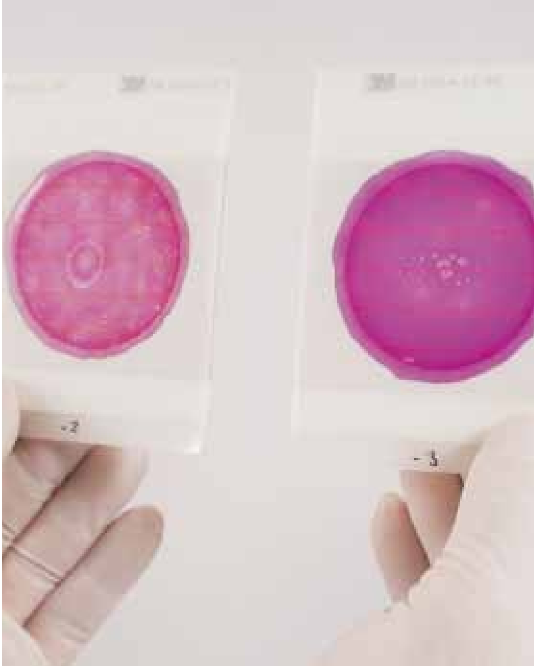
In order to be able to recommend the right MAPAX solution for the application in question, Linde acts as more than a mere supplier of gas. MAPAX is based on close cooperation between the suppliers of the packaging materials, the packaging machines and the gases. The purpose of this collaboration between suppliers is to be able to meet demands for efficient and cost-effective packaging of foodstuffs, with consistent product quality throughout the entire distribution chain and, ultimately, an attractive display in the chilled-food counter. By exploiting the advantages of MAP technology in the right way and by adapting methods to each application, solutions can also be offered to allow the manufacturer to develop new products for sale in new markets.

Linde works closely with food research institutes in many countries, for example SIK (Sweden), VTT (Finland) and Campden (UK). In the laboratories of SIK, for example, various simulations are carried out to determine the potential hazards from microorganisms. Such studies provide the information necessary for determining safe shelf-life periods. Because Linde understands how different bacteria are affected by the combination of temperature/atmosphere and other parameters such as permeability, it can offer a MAPAX solution that will ensure maximum microbiological safety for each foodstuff.

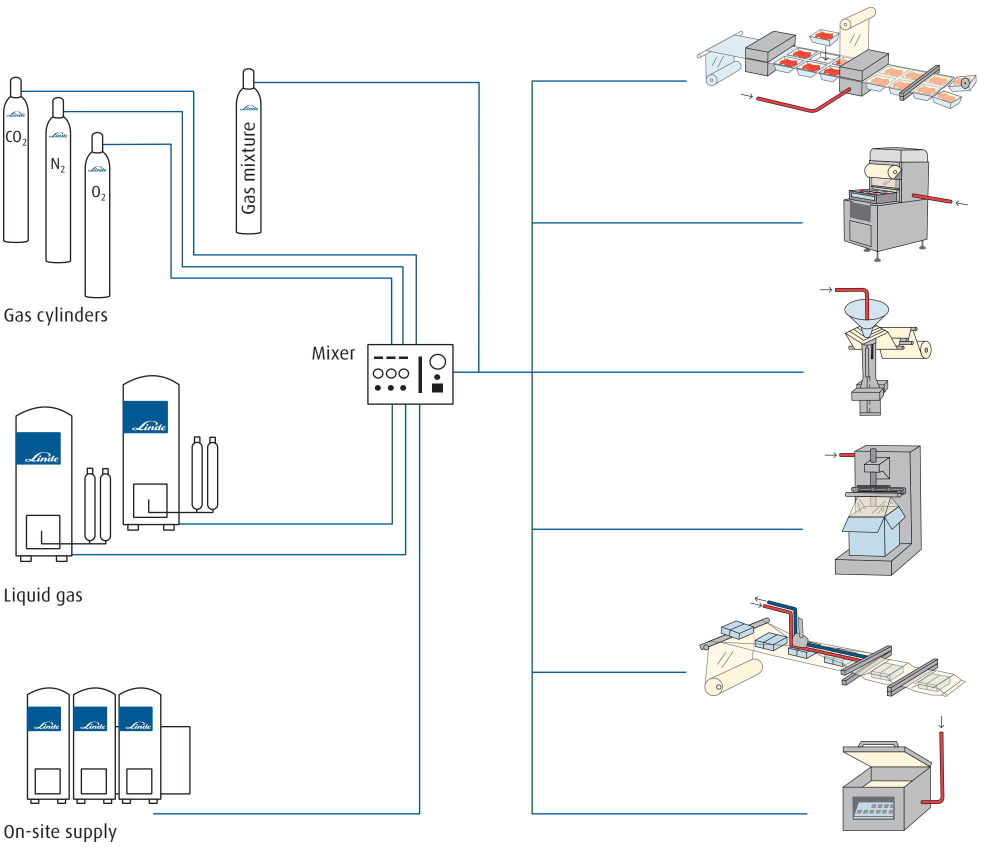
Comparison of shelf-life for products packed in air and MAPAX

Food	Typical shelf-life in air	Typical shelf-life with MAPAX
Raw meat	2–4 days	10–12 days
Raw poultry	4–7 days	10–21 days
Cooked meat/poultry	2–4 days	3–5 weeks
Minced meat	24 hours	4–9 days
Sausages	2–4 days	2–5 weeks
Raw fish	2–3 days	5–9 days
Cooked fish	2–4 days	3–4 weeks
Hard cheese	2–3 weeks	4–10 weeks
Soft cheese	4–14 days	1–3 weeks
Cakes	Several weeks	Up to one year
Bread	Some days	3–4 weeks
Pre-baked bread	5 days	4–6 weeks
Cut salad mix (fresh)	2–5 days	5–10 days
Pasta (fresh)	1–2 weeks	3–4 weeks
Pizza (fresh)	7–10 days	2–4 weeks
Sandwiches (fresh)	2–3 days	15–20 days
Ready meals	2–5 days	7–20 days
Dried foods	4–8 months	1–2 years
Nuts	4–6 months	1–2 years

Quality check for a successful packaging concept



MAPAX offers a complete menu of solutions



Practical experience gives customers peace of mind

Linde has customers in the food processing industry all around the world. Valuable contacts have been established with several leading companies that package their products in modified atmospheres. Over the years, Linde has had the advantage of accumulating experience and know-how from application challenges for which MAPAX has proved to be the answer. Collaboration with the food processing industry has helped Linde to develop modified atmosphere solutions to suit the widest variety of foodstuffs and packaging concepts.

Cost of gas in relation to other factors of production

Gas		machine		package		food
1	:	5	:	10	:	100

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MAPAX® – Best for meat and meat products.

Comparison of two different meat packages – one with modified atmosphere packaging and the other one without

Linde's MAPAX® portfolio meets today's food preservation challenges with bespoke gases and mixtures, application expertise and complementary installation, test and safety services.

Bacteria grow easily on fresh meat

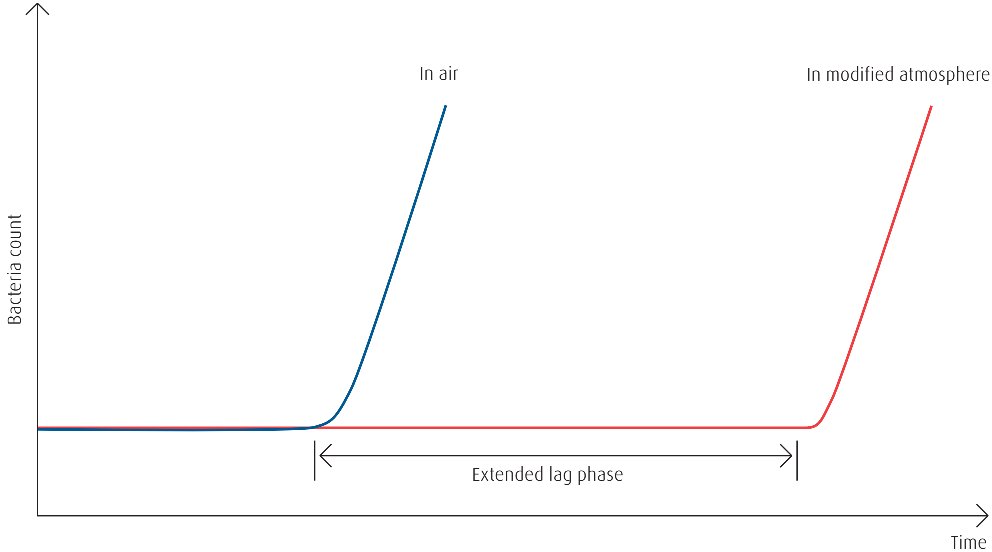
Meat and meat products are particularly susceptible to bacterial growth owing to their high water activity and nutrient content. Meat is sterile to begin with, but when carved up, the surfaces exposed to ambient air provide excellent conditions for the growth of bacteria. Minced meat is naturally even more exposed. For this reason, hygiene and effective temperature control in processing and prepackaging – keeping tools and equipment clean – are vitally important to minimise the contamination of the product with microorganisms.

Red meat requires oxygen

A special problem arises with red meat such as beef with regard to colour changes caused by the oxidation of the red pigment. The atmosphere for fresh meat therefore normally contains high concentrations of oxygen (60–80%) in order to retain the red colour by ensuring high oxygen levels in the meat's myoglobin. Highly pigmented meat such as beef thus requires higher oxygen concentrations than low pigmented meat such as pork. With the right mixtures, the practical shelf-life of consumer-packed meat can be extended from 2–4 days to 5–8 days at 4 °C.

The effectiveness of carbon dioxide

Generally speaking, carbon dioxide has a strong inhibiting effect on the growth of bacteria, of which the aerobic genus Pseudomonas presents the greatest problem for fresh meat.



Bacteria count over time for meat stored in air and in a modified atmosphere at the same temperature. The meat stored in air enters the period of extremely fast growth, the lag phase, well ahead of the meat stored in the modified atmosphere. This is because the CO_2 in the modified atmosphere has dissolved into the surface of the meat, reducing its pH value, inhibiting bacterial growth and thus extending the lag phase, until the point when the inhibiting effects become insufficient to control the bacteria.

Recommended gas mixtures for meat and meat products

Product	Gas mixture	Gas volume / Product volume	Typical shelf-life Air	Typical shelf-life MAP	Storage temp.
Raw red meat	60–80% O_2 + 20–40% CO_2	100–200 ml / 100 g meat	2–4 days	5–8 days	2–3 °C
Minced meat	80–100% O_2 + 0–20% CO_2	100–200 ml / 100 g meat	<24 h	3–4 days	2–3 °C
Raw light poultry	40–100% CO_2 + 0–60% N_2	100–200 ml / 100 g meat	4–7 days	16–21 days	2–3 °C
Raw dark poultry	70% O_2 + 30% CO_2	100–200 ml / 100 g meat	3–5 days	7–14 days	2–3 °C
Sausages	20–30% CO_2 + 70–80% N_2	50–100 ml / 100 g prod.	2–4 days	2–5 weeks	4–6 °C
Sliced cooked meat	30% CO_2 + 70% N_2	50–100 ml / 100 g prod.	2–4 days	2–5 weeks	4–6 °C

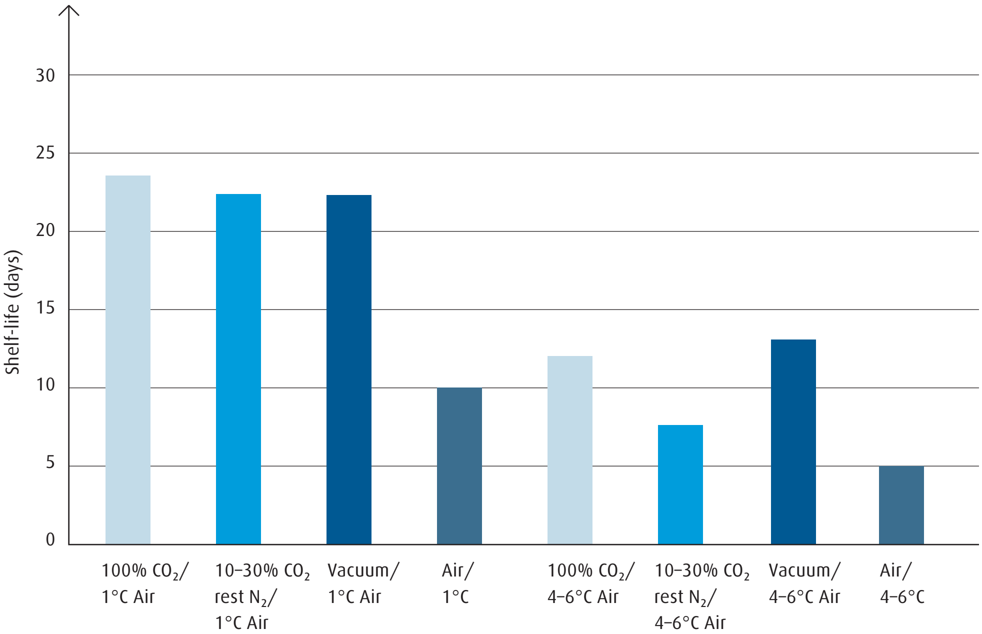
Poultry

Poultry is very susceptible to bacterial spoilage, evaporation loss, off-odour, discolouration and biochemical deterioration. The sterile poultry tissue becomes contaminated during the evisceration process. The practical shelf-life of gas-packed poultry is about 16 to 21 days. The head-space volume should be nearly as large as the product volume. In contrast to red meats, poultry does not undergo irreversible discolouration of the meat's surface in the presence of O_2. The spoilage of raw poultry is mainly caused by microbial growth, particularly growth of the Pseudomonas and Achromobacter species. These aerobic spoilage bacteria are very effectively inhibited by CO_2 in modified atmosphere packaging (MAP). Levels of CO_2 in excess of 20% are required to significantly extend the shelf-life of poultry. Package collapse and excessive drip could be a problem for raw poultry, so if higher levels of CO_2 are used, the gas/product ratio should also be increased. Where package collapse is not a problem (e.g. bulk or master bags), 100% CO_2 is recommended. In both retail and bulk modified atmospheres, N_2 is used as an inert filler gas.

Meat products have different microflora

Deterioration of meat products is most commonly caused by microbial spoilage. Due to the processing operations, for instance marinating, drying, smoking, fermentation, curing and cooking, the microflora in meat products differ from those in raw meat and the spoilage mechanisms are thereby different. This affects the gas composition used in the package. In order to prevent the products from going off, the concentration of carbon dioxide is usually low (20–50%).

Microbiological shelf-life of chicken at different atmosphere/temperature combinations



MAPAX packaging of chicken

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Fresh fish deteriorates very quickly

Fresh fish rapidly loses its original quality due to microbial growth and enzymatic processes. The sensitivity of fish and seafood is caused by its high water activity, neutral pH value (at which microorganisms thrive best) and the presence of enzymes which rapidly undermine both taste and smell. The breakdown of proteins by microorganisms gives rise to unpleasant odours. The oxidation of unsaturated fats in high-fat fish such as tuna, herring and mackerel also results in an unappetising taste and smell. Fish such as herring and trout can turn rancid even before microbial deterioration is detectable.

In order to maintain the high quality of fresh fish products, it is absolutely necessary to keep the temperature as close to 0°C as possible. In combination with the right gas mixture, shelf-life can be extended by a few important extra days. Provided, of course, there has been a continuous cold chain. Cod, flounder, plaice, haddock and whiting are examples of fish that can be stored at 0°C twice as long in a modified atmosphere as in air.

Carbon dioxide: a prerequisite for maintaining quality

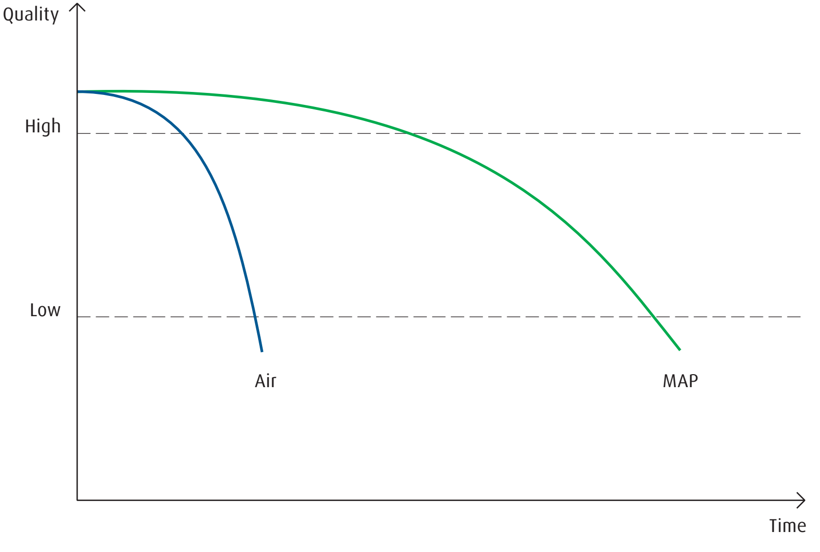
The presence of carbon dioxide is necessary to inhibit the growth of common aerobic bacteria such as Pseudomonas, Acinetobacter and Moraxella. This is primarily because CO_2 reduces the pH value of the product surface. The CO_2 concentration should always be above 20% and can be as high as 50% to achieve the maximum shelf-life extension.

Depending on the storage temperature (0–2°C), modified atmosphere packaging (MAP) prolongs shelf-life by 3 to 5 days compared with the shelf-life of raw fish in a tray with film over-wrap. Excessively high concentrations can produce undesirable after-effects in the form of lost tissue liquid or, in the case of crabs, an acidic or sour taste.

Recommended gas mixtures for fish and seafood

Product	Gas mixture	Gas volume / Product volume	Typical shelf-life Air	Typical shelf-life MAP	Storage temp.
Raw fish	40–90% CO_2 + 10% O_2 + 0–50% N_2	200–300 ml / 100 g fish	3–5 days	5–14 days	0–2°C
Smoked fish	40–60% CO_2 + 40–60% N_2	50–100 ml / 100 g fish	15 days	30 days	0–3°C
Cooked fish	30% CO_2 + 70% N_2	50–100 ml / 100 g fish	7 days	30 days	0–3°C
Prawns (peeled, cooked)	4% CO_2 + 60% N_2	50–100 ml / 100 g prod.	7 days	21 days	4–6°C

Quality loss in fish preserved in air and MAP



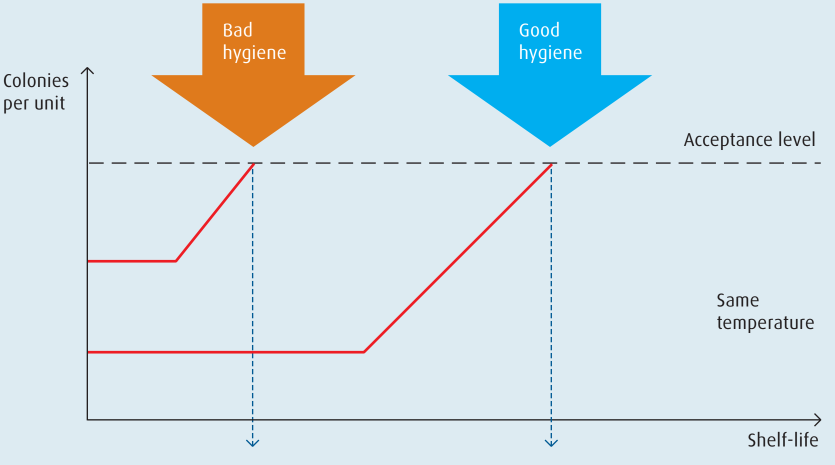
Fish such as cod and plaice kept at 0°C can maintain their high quality for twice as long in the correct modified atmosphere.

Oxygen keeps colour

Oxygen can be used as a component of a modified atmosphere to avoid colour changes and pigment fading in fish and seafood. The gas is also used to prevent the growth of anaerobic microorganisms such as Clostridium, which can produce toxins. However, the risk of Clostridium growth in fish with a short shelf-life packaged in the correct modified atmosphere is negligible. If the temperature is kept below 2°C, there can be no growth.

To combat rancidity, oxygen should not be used in packages of high-fat fish. Nitrogen is more suitable in such cases.

Importance of hygiene for a long shelf-life



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MAPAX® – Best for dairy products.

Linde's MAPAX® portfolio meets today's food preservation challenges with bespoke gases and mixtures, application expertise and complementary installation, test and safety services.

Decomposition of dairy products

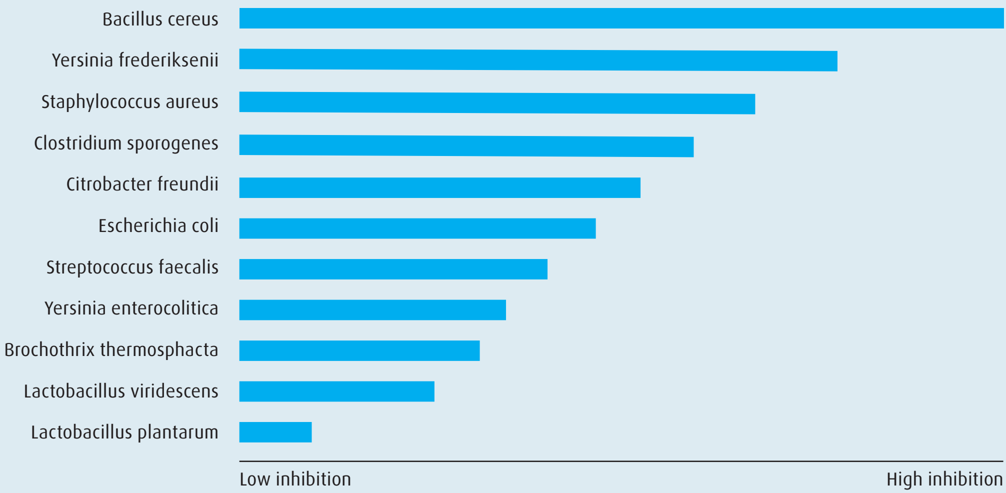
Microbial growth and rancidity are the primary causes of quality deterioration in dairy products.

The type of breakdown depends on the characteristics of the particular product. Hard cheeses with relatively low water activity are normally affected by the growth of moulds, whereas products with high water activity such as cream and soft cheeses are more susceptible to fermentation and rancidity.

Lactobacillus

Lactobacillus, which is widely used in dairy production, may also be a problem as it turns products sour by lowering their pH value. This may be further intensified by the fact that cottage cheese packages, for example, contain incorrect gas atmospheres with excessive levels of carbon dioxide.

The effect of 100% CO_2 on various bacteria



Microorganisms are inhibited to varying degrees by carbon dioxide.

Mould prevented by carbon dioxide

In the packaging of hard cheese, carbon dioxide is the most effective choice. It effectively stops or reduces microbial activity and helps to retain texture. Even carbon dioxide concentrations of just 20% strongly affect the growth of mould fungi. Lactic acid bacteria, a natural constituent of cheese, are affected very little by the surrounding atmosphere. Soft cheeses are also packaged in atmospheres with increased carbon dioxide levels and low oxygen levels to inhibit bacterial growth and rancidity. In packaging for hard cheeses, the carbon dioxide level is up to 100%, and for soft cheeses, the level is usually restricted to 20–40%. This is to prevent the package from collapsing under atmospheric pressure as the carbon dioxide dissolves into the water content.

Recommended gas mixtures for dairy products

Product	Gas mixture	Gas volume / Product volume	Typical shelf-life: Air	Typical shelf-life: MAP	Storage temp.
Hard cheese	80–100% CO_2 + 0–20% N_2	50–100 ml / 100 g cheese	2–3 weeks	4–10 weeks	4–6°C
Hard cheese, (sliced, grated)	40% CO_2 + 60% N_2	50–100 ml / 100 g cheese	2–3 weeks	7 weeks	4–6°C
Soft cheese	20–60% CO_2 + 40–80% N_2	50–100 ml / 100 g cheese	8 days	21 days	4–6°C

Major cheese categories – moisture content

Cheese category	Example varieties	Moisture content (%)
Unripened, soft	Cottage	not >80
	Mozzarella	>50
Ripened, soft	Camembert	48
	Brie	55
Semi-hard	Caerphilly	45
	Limburg	45
Hard	Cheddar	<40
	Gouda	40
	Emmental	38
	Gruyère	38–40
Blue-vein	Roquefort	40–45
	Gorgonzola	40–45
	Stilton	40–45

CO_2/N_2 mixes to avoid package collapse

Value-added cheeses, such as grated or sliced cheddar, are also packed in modified atmospheres. Grated cheese is usually packed in an atmosphere of 50% N_2 and 50% CO_2. The use of nitrogen avoids package collapse.

Adding cultured products to the list

Cultured products such as cottage cheese were not packaged in modified atmospheres until recently. But the demand for longer life has extended modified atmospheres to these products. The shelf-life of cottage cheese packed under carbon dioxide can be extended by a week.

Nitrogen stops cream turning sour

Cream and dairy products containing cream rapidly turn sour in pure carbon dioxide atmospheres. The gas is therefore replaced by nitrogen or a mixture of nitrogen and carbon dioxide. By eliminating oxygen, nitrogen prevents rancidity and the growth of aerobic bacteria.

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Linde's MAPAX® portfolio meets today's food preservation challenges with bespoke gases and mixtures, application expertise and complementary installation, test and safety services.

The permeability of packaging material is vital

A modified atmosphere must be combined with the right packaging material to achieve optimum preservation of fresh fruit and vegetables. If the products are sealed in an insufficiently permeable film, undesirable anaerobic conditions (<1% O_2 and > 2% CO_2) will develop with subsequent deterioration in quality. Conversely, if fruit and vegetables are sealed in a film of excessive permeability, the modified atmosphere will leak out and moisture loss will also lead to accelerated deterioration in quality. Examples of materials that can be used for MAP of fresh produce (fruit and vegetables) are microporous film or LDPE/OPP.

Optimal equilibrium

The key to successful modified atmosphere packaging (MAP) for fresh produce lies in a packaging film of correct intermediary permeability. This enables a desirable equilibrium modified atmosphere (EMA) to be established, where the rate of oxygen and carbon dioxide transmission through the pack equals the produce respiration rate. Typically, optimum EMAs of 3–10% O_2 and 3–10% CO_2 can dramatically increase the shelf-life of fruit and vegetables.

The EMA thus attained is influenced by numerous factors such as the respiration rate, temperature, packaging film, pack volume, fill weight and light. The respiration rate, in turn, is affected by the variety, size and maturity of the produce as well as the extent to which it has been processed. Consequently, determining the optimum EMA of a particular item is a complex challenge that can only be solved through practical experimental tests.

Recommended gas mixtures for fruit and vegetables

Product	Gas mixture	Gas volume / Product volume	Typical shelf-life Air	Typical shelf-life MAP	Storage temp.
Lettuce	5% O_2 + 5–20% CO_2 + 75–90% N_2	100–200 ml / 100 g prod.	2–5 days	5–8 days	3–5°C
Fresh cut salad mix	5% O_2 + 5–20% CO_2 + 75–90% N_2	100–200 ml / 100 g prod.	2–5 days	5–8 days	3–5°C
Fresh cut carrots	2–5% O_2 + 15–20% Co_2 + 75–83% N_2	100–200 ml / 100 g prod.	2–5 days	5–8 days	3–5°C
Fresh herbs	0–5% O_2 + 5–20% CO_2 + 75–95% N_2	100–200 ml / 100 g prod.	1–3 days	10–18 days	3–5°C
Fruit salad mix	0–5% O_2 + 5–20% CO_2 + 75–95% N_2	100–200 ml / 100 g prod.	1 day	3–6 days	3–5°C
Sliced apple	0–5% O_2 + 5–20% CO_2 + 75–95% N_2	100–200 ml / 100 g prod.	1–2 days	8–12 days	3–5°C
Pineapple peeled, cut	5–10%O_2 + 10–15% CO_2 + 75–90% N_2	100–200 ml / 100 g prod.	2–5 days	6–9 days	3–5°C
Pre-peeled potatoes	40–60% CO_2 + 40–60% N_2	100–200 ml / 100 g prod.	0.5 hours	10 days	3–5°C

Finding the right gas/packaging combination

The optimum MAP can be achieved by either sealing the produce in air or gas flushing with 3–10% O_2 and 3–10% CO_2 and 80–90% N_2. As previously explained, modified atmospheres evolve within an air-sealed pack because of produce respiration. However, there may be circumstances when it is desirable to gas flush so that a beneficial EMA is established more quickly. For example, the enzymatic browning of salad vegetables can be delayed by gas flushing compared with air packing. We offer practical tests to demonstrate this for our customers' specific produce. Different conditions may apply for peeled potatoes and apples, which should not be packed with oxygen because of enzymatic reactions that bring about brown discolouration. Pre-peeled potatoes, for example, can be packed in 40–60% CO_2 + 40–60% N_2, prolonging their shelf-life from 0.5 hours to 10 days at 4 to 5°C.

Classification of selected fruit and vegetables according to their respiration rate and degree of perishability in air and 3% O_2

	Respiration rate – CO_2 production ($ml\ kg^{-1}\ h^{-1}$)[a]						Relative respiration rate at 10°C in air
	In air			In 3% O_2			
Commodity[b]	0°C	10°C	20°C	0°C	10°C	20°C	
Onion (Bedfordshire Champion)	2	4	5	1	2	2	Low <10
Cabbage (Decema)	2	4	11	1	3	6	
Beetroot (storing)	2	6	11	3	4	6	
Celery (white)	4	6	19	3	5	12	
Cucumber	3	7	8	3	4	6	
Tomato (Eurocross BB)	3	8	17	2	3	7	
Lettuce (Kordaat)	5	9	21	4	6	14	
Peppers (green)	4	11	20	5	7	9	Medium 10–20
Carrots (whole, peeled)	—	12	26	—	—	—	
Parsnip (Hollow Crown)	4	14	23	3	6	17	
Potatoes (whole, peeled)	—	14	33	—	—	—	
Mango	—	15	61	—	—	—	
Cabbage (Primo)	6	16	23	4	8	17	
Lettuce (Kloek)	8	17	42	8	13	25	
Cauliflower (April Glory)	10	24	71	7	24	34	High 20–40
Brussels sprouts	9	27	51	7	19	40	
Strawberries (Cambridge Favourite)	8	28	72	6	24	49	
Blackberries (Bedford Giant)	11	33	88	8	27	71	
Asparagus	14	34	72	13	24	42	
Spinach (Prickly True)	25	43	85	26	46	77	Very high 40–60
Watercress	9	43	117	5	38	95	
Broad beans	18	46	82	20	29	45	
Sweet corn	16	48	119	14	32	68	
Raspberries (Malling Jewel)	12	49	113	11	30	73	
Carrots (julienne-cut)	—	65	145	—	—	—	Extremely high >60
Mushrooms (sliced)	—	67	191	—	—	—	
Peas in pod (Kelvedon Wonder)	20	69	144	15	45	90	
Broccoli (sprouting)	39	91	240	33	61	121	

[a]mg CO_2 converted to ml CO_2 using densities of CO_2 at 0°C = 1.98, 10°C = 1.87, 20°C = 1.77.

[b]Unless stated, produce is whole and unprepared.

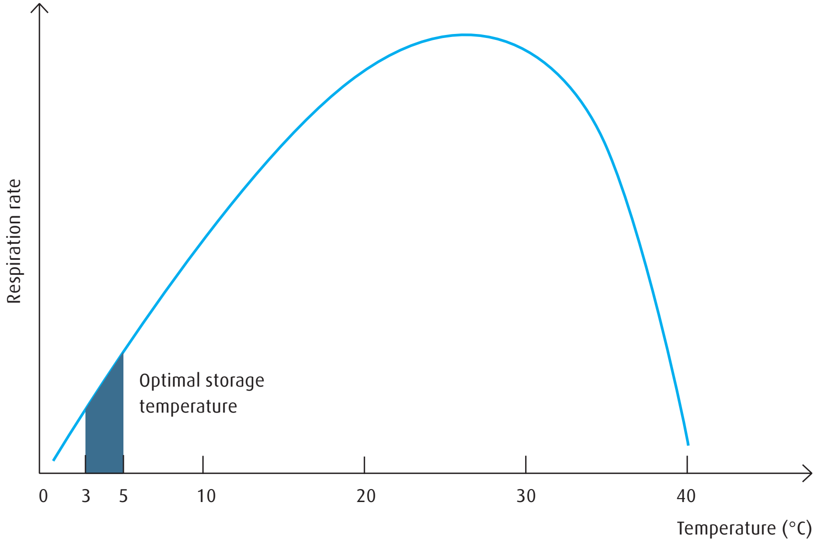
Respiration of fruit and vegetables

All living plants respire, i.e. different organic compounds, mainly sugar compounds, provide energy to other life processes in the cells. This conversion of sugar to energy needs oxygen. Air contains 21% oxygen. When sufficient oxygen is available, the respiration is aerobic. If the concentration of oxygen drops, respiration becomes anaerobic. Anaerobic oxidation leads to intermediate products with undesirable odours. Respiration is a complicated process which involves a series of enzymatic reactions. The entire aerobic process can be described in simplified form as:

sugar + oxygen (O_2) →
carbon dioxide (CO_2) + energy + water

The respiration rate is measured as generated ml CO_2/kg x hour or as used ml O_2/kg x hour.

Respiration rate depends on the temperature



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MAPAX® – Best for dry foods.

Linde's MAPAX® portfolio meets today's food preservation challenges with bespoke gases and mixtures, application expertise and complementary installation, test and safety services.

The key to keeping dry foods fresh

Drying food to preserve it is a time-honoured practice. Everything from tea, coffee and spices through milk and cocoa powder to dried fruit and beans can be dehydrated to prevent spoilage. However, these dried foods still contain unsaturated fats of varying concentrations. This makes them sensitive to oxidation and rancidity.

The role of oxygen

Even small amounts of oxygen in food packaging may compromise quality and make dried products impossible to sell. The oxygen concentration thus has a major impact on the shelf-life. The oxidation process can be effectively inhibited with a modified atmosphere, which involves replacing oxygen in the package with nitrogen, carbon dioxide or a mixture of the two. Packages containing particularly sensitive dry foodstuffs, such as powdered milk for babies, should have oxygen levels of less than 0.2%. As light can have a big effect on oxidation reactions, the modified atmosphere packaging (MAP) of dried foods should ideally also act as a light barrier.

Recommended gas mixtures for dry foods

Product	Gas mixture	Gas volume / Product volume	Typical shelf-life Air	Typical shelf-life MAP	Storage temp.
Instant tea	100% CO_2	50–100 ml / 100 g prod.	5 days	20 days	20–25°C
Dry coffee (ground)	N_2 or CO_2	50–100 ml / 100 g prod.	4 weeks	24 weeks	20–25°C
Milk powder	100% N_2	50–100 ml / 100 g prod.	12 weeks	52 weeks	20–25°C
Nuts	100% N_2	50–100 ml / 100 g prod.	12 weeks	52 weeks	20–25°C
Crisps	100% N_2	50–100 ml / 100 g prod.	5 days	20 days	20–25°C
Dry soup	100% N_2	50–100 ml / 100 g prod.	5 days	20 days	20–25°C

The role of water

Deterioration reactions in food are also influenced by water activity. This is not the same as water content. Water activity refers to the rate at which water becomes available for microorganism, chemical and biochemical reactions. It is defined as the ratio between the vapour pressure of a product and the vapour pressure of pure water under the same conditions. Hence a low level of water activity will help to prevent microbiological spoilage. Moisture also has a big impact on the appeal of dried snacks. Consumers expect their snacks to be crispy, which means the packaging must provide a barrier against water vapour.
In the case of dried soups and instant drinks, water vapour is similarly problematic as it causes powders to clump and look unappetising. Here also, MAP with a moisture barrier can help avoid these undesirable effects.

MAPAX for coffee – protecting valuable aroma and flavour.

Protecting form and flavour

A modified atmosphere not only keeps dried fruit and snacks crisp and fresh, it can also help protect the goods. The gas cushion forms a protective shield around sensitive products, making sure they reach the consumer undamaged. And in the case of products such as coffee, where aroma plays such an important role in the perception and experience of the consumer, an impermeable modified atmosphere can help lock in flavour and aroma.

Perfect balance for dried foods

With MAPAX®, Linde has developed a range of modified atmospheres specifically to address the challenges involved in preventing spoilage of dried foodstuffs. Our MAPAX application engineers would also be happy to help you run detailed tests to establish the optimum gas mixture and packaging properties for your dried foods. By optimising properties such as permeability, gas barrier and mechanical strength, you can extend shelf-life by valuable weeks and months.

THE LINDE GROUP

MAPAX® – Best for bakery products.

Linde's MAPAX® portfolio meets today's food preservation challenges with bespoke gases and mixtures, application expertise and complementary installation, test and safety services.

Carbon dioxide slows mould growth on bread

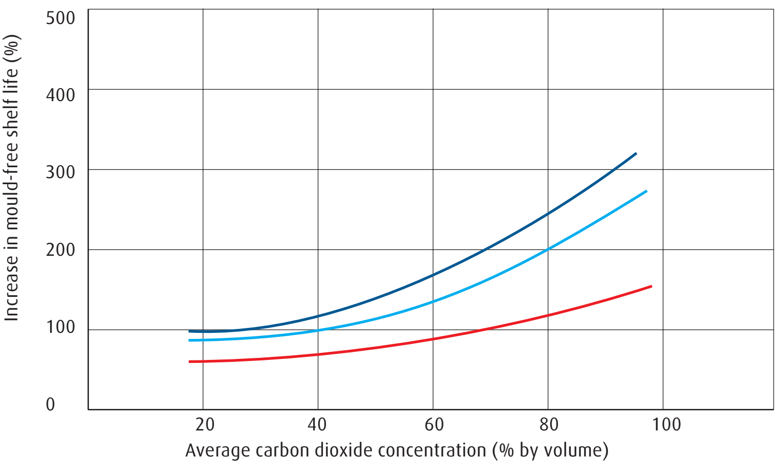
The main spoilage factors for bakery products are mould growth and chemical breakdown. Fermentation may cause problems in filled bakery products. Since the water activity of bakery products is low, the growth of microorganisms other than mould is seldom a problem. To reduce the risk of mould and spore contamination, very good hygienic conditions are required, e.g. a clean room. Mould is an aerobic microorganism, so it can be effectively controlled by carbon dioxide and low oxygen content, which subsequently extends shelf-life by many valuable days.

Modified atmosphere packaging (MAP) is especially suitable for rye bread, sweet bakery products and certain pies. For Danish pastries and other iced bakery products, excessive levels of carbon dioxide can worsen the appearance of the icing by dissolving into the fat content and causing it to "melt away". If the carbon dioxide concentration is balanced by nitrogen, the product's appearance remains unchanged. The loss or adsorption of moisture in bakery products is prevented by a barrier material.

Recommended gas mixtures for bakery products

Product	Gas mixture	Gas volume / Product volume	Typical shelf-life: Air	Typical shelf-life: MAP	Storage temp.
Pre-baked bread	100% CO_2	50–100 ml / 100 g prod.	5 days	20 days	20–25°C
Cakes	50% CO_2 + 50% N_2	50–100 ml / 100 g prod.	15 days	60 days	20–25°C
Fresh dough	50% CO_2 + 50% N_2	50–100 ml / 100 g prod.	3–7 days	18–31 days	5°C
Pastries/ doughnuts	30% CO_2 + 70% N_2	50–100 ml / 100 g prod.	7 days	21 days	20ºC
Sliced bread	50% CO_2 + 50% N_2	50–100 ml / 100 g prod.	2 weeks	2 months	20ºC
Sandwiches	30% CO_2 + 70% N_2	50–100 ml / 100 g prod.	3–7 days	10–28 days	0–4°C
Cream cakes	30% CO_2 + 70% N_2	50–100 ml / 100 g prod.	3–4 days	21 days	0–4°C

Increase in shelf-life for different bakery products at various levels of CO_2 concentration



Product	ERH %	Storage temp.
Part-baked bread (dark blue line)	91	21°C
Fruit pies (light blue line)	95	27°C
Part-baked rolls (red line)	88	21°C

*ERH: Equilibrium Relative Humidity

The importance of managing O_2 levels

Bread is a very porous product with a lot of air bubbles inside it. Once it has been packed, the air inside the bread and the modified atmosphere will balance each other out and the low O_2 content within the package will rise naturally by a few percentage points. The choice of machine has an impact on the O_2 level in the packaging and thus on the shelf-life. Horizontal flow-packers and thermoforming machines are typically used to pack bread in a modified atmosphere.

Horizontal flow-packers

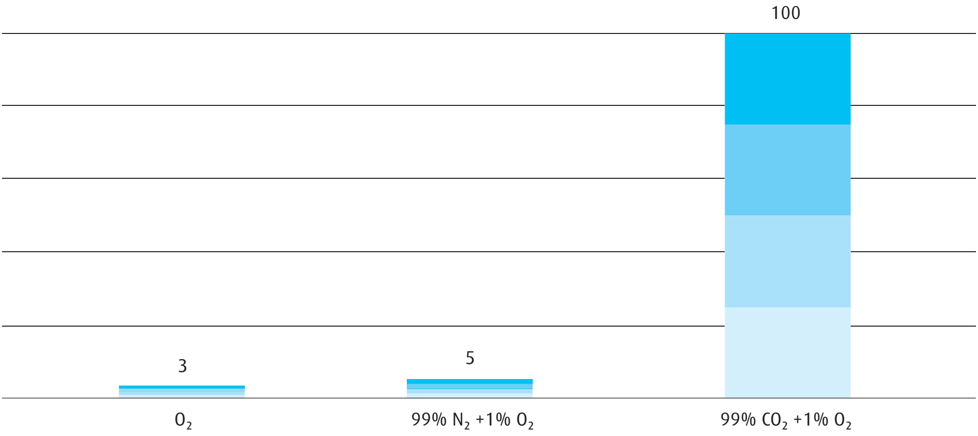
This packaging technology flushes gas into the packages to replace the air. This usually results in higher final oxygen levels because the flush effect mixes the modified atmosphere gas with the air around the product. In the case of flow-packers, oxygen levels are around 2–5%. Any concentration above that would have a detrimental effect on the shelf-life.

Thermoformers

Thermoformers can combine vacuum packing with MAP. This flexibility enables further reductions in the oxygen level. With many – but not all – breads, this enables manufacturers to extract as much oxygen from the packaging as possible. With both packaging technologies (flow-pack & thermoforming), the modified atmosphere must be combined with the right packaging material to optimise shelf-life overall.

A note on the staling process

The use of MAP has little or no effect on the rate at which bakery products go stale. Staling is caused by starch retrogradation. Staling rates increase at chilled temperatures and therefore most bakery products eaten cold are normally stored at ambient temperature. For bakery products eaten hot, such as pizza bases, the staling process is reversed during the reheating cycle.



Time (days) to reach mould development on toast in various atmospheres and at 20 °C.
The toast was initially infected with mould.

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MAPAX® – Best for prepared foods and catering.

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Prepared foods – a challenge due to the variety of ingredients

The deterioration of prepared foods varies considerably from one product to another. If meat is one of the main ingredients, as in ravioli or lasagna, it spoils differently than, for instance, pasta. One major difficulty associated with prepared foods is the introduction of microbial contamination during the manufacturing process. This means that stringent demands are placed on hygiene as well as on the raw materials during the production process. The most serious breakdown processes are caused by the growth of microorganisms and by oxidation. In addition, bakery products sometimes go stale, leading to rancidity, discolouration and loss of taste. A fresh pizza, for example, stored without modified atmosphere packaging (MAP) at 4°C to 6°C, spoils in about a week. High quality can be maintained for some extra weeks by packaging the product in a modified atmosphere with a low oxygen concentration and high carbon dioxide level. In the case of pizza, the concentration of oxygen should be less than 1.5%.

Moisture and composition affect deterioration rate

Choosing the best CO to N_2 ratio for prepared food packages depends on the deterioration processes that would otherwise limit shelf-life. The composition of food and, most importantly, the water activity determine the speed of microbiological growth, oxidation and enzymatic activity – as do the processing steps before packaging. As a rule, the higher the level of water activity, the higher the CO_2 concentration should be.

The values in the table to the far right are affected by the use of modified atmospheres. As described in our "MAP - Modified Atmosphere Packaging" flyer, the use of modified atmospheres provides extra support in ensuring the safety of chilled food.

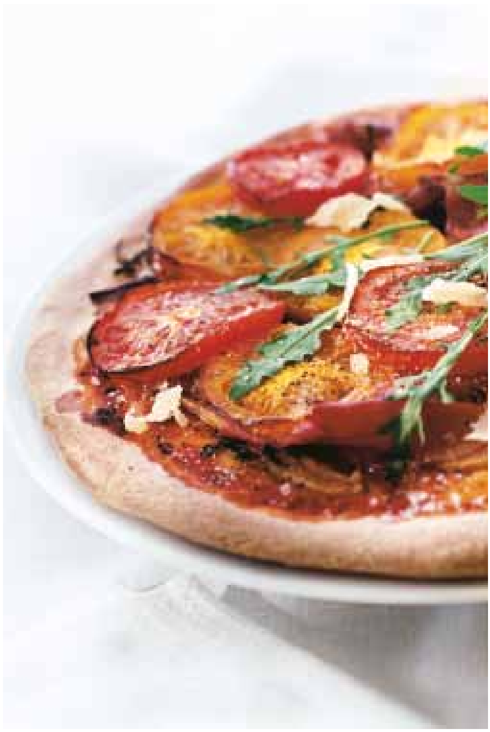
Recommended gas mixtures for prepared foods and catering

Product	Gas mixture	Typical shelf-life Air	MAP	Storage temp.
Fresh pizza	30–60% CO_2 + 40–70% N_2	1 week	3 weeks	2–4°C
Fresh pasta	30–60% CO_2 + 40–70% N_2	1 week	3 weeks	2–4°C
Sandwiches	20–30% CO_2 + 70–80% N_2	3–7 days	10–28 days	2–4°C
Ready meals	30–60% CO_2 + 40–70% N_2	4 days	21 days	2–4°C
Fresh herbs	0–5% O_2 + 5–20% CO_2 + 75–90% N_2	1–3 days	10–18 days	2–4°C
Sliced onions	10–20% CO_2 + 80–90% N_2	1 day	4–6 days	2–4°C
Wraps	20–30% CO_2 + 70–80% N_2	2 days	6–10 days	2–4°C
Salad with chicken	30% CO_2 + 70% N_2	1 day	6–10 days	2–4°C

Multi-component products have special demands

Each product in a prepared food represents a complex challenge. Particularly difficult are varied combinations such as sandwiches, filled pasta, salads, pizza and spring rolls. Since several different ingredients, each with its own special inherent properties, make up the product, in-depth know-how is required to establish the right gas mixture that will best inhibit deterioration and maintain quality.

MAP is an important aid and safety measure, since prepared foods kept in the wrong environments can spoil very quickly, especially in the case of food products with a neutral pH value.



Minimum growth conditions for selected microorganisms in chilled modified atmospheres

Type of microorganism	Minimum pH value for growth	Minimum a_w for growth	Minimum growth temperature
Aeromonas hydrophila	4.0	na*	0.0°C
Bacillus cereus	4.4	0.91	4.0°C
Clostridium botulinum (proteolytic A, B and F)	4.8	0.94	10.0°C
Clostridium botulinum (non-proteolytic E)	4.8	0.97	3.3°C
Clostridium botulinum (non-proteolytic B and F)	4.6	0.94	3.3°C
Clostridium perfringens	5.5	0.93	5.0°C
Enterobacter aerogenes	4.4	0.94	2.0°C
Escherichia coli	4.4	0.9	4.0°C
Lactobacilli	3.8	0.94	4.0°C
Listeria monocytogenes	4.4	0.92	–0.1°C
Micrococci	5.6	0.9	4.0°C
Moulds	<2.0	0.6	<0.0°C
Pseudomonas species	5.5	0.97	<0.0°C
Salmonella species	3.8	0.92	4.0°C
Staphylococcus aureus	4.0	0.83	7.7°C
Vibrio parahaemolyticus	4.8	0.94	5.0°C
Yeasts	1–5.0	0.8	–5.0°C
Yersinia enterocolitica	4.5	0.96	–1.3°C

na* = data not available

Meeting the needs of the catering industry

The catering industry has always been challenged to supply fine foods that are fresh and of the highest quality. Last-minute production is very often required to fulfil these demands. In most cases, this is an inefficient and very expensive way to operate. By using Linde's MAPAX® technology in your kitchen or production facilities, you will reduce stress to a minimum and be able to plan the coming days or weeks of production even more effectively. Well-organised food production coordinated with MAPAX technology will clearly improve utilisation of human and production resources, give you better control over purchasing and storage and extend your shelf-life. The most common and beneficial way of using this packaging method in catering, hotel or restaurant kitchens is to get ahead of the "mise-en-place" production. For example, if you slice cheese and ham for the breakfast buffet on a daily basis, you can reduce this task to once or twice a week. The number of slices stays the same, but you work more efficiently. This is also true when preparing fresh meat cuts for the grill. Packing sandwiches and chilled food for out-of-hours service and other market segments is a cost-efficient and hygienic way of selling your produce.

To reach the desired shelf-life and maintain the good quality of your products, it is vital to keep constant control over both the product and packaging temperature.

Sandwiches packed using MAPAX

Preparing sandwiches is a complicated process where different items are placed on top of each other, for example brown bread with butter, prawns, mayonnaise, lemon, lettuce, parsley and red pepper, or baguette with butter, ham, cheese, lettuce and red pepper, or brown bread with butter, smoked salmon, scrambled eggs, lettuce and parsley. The individual items influence each other because they provide different conditions for bacterial growth. By packaging in MAP, the shelf-life is extended by 5–7 days if the product is packed in 30% CO_2 in N_2 at a storage temperature of 2–4°C. A typical packaging material is PA/PE. The use of MAPAX technology for packaging sandwiches makes it possible to prepare them in advance and thereby reduce labour costs in the evenings and at the weekends, for example.

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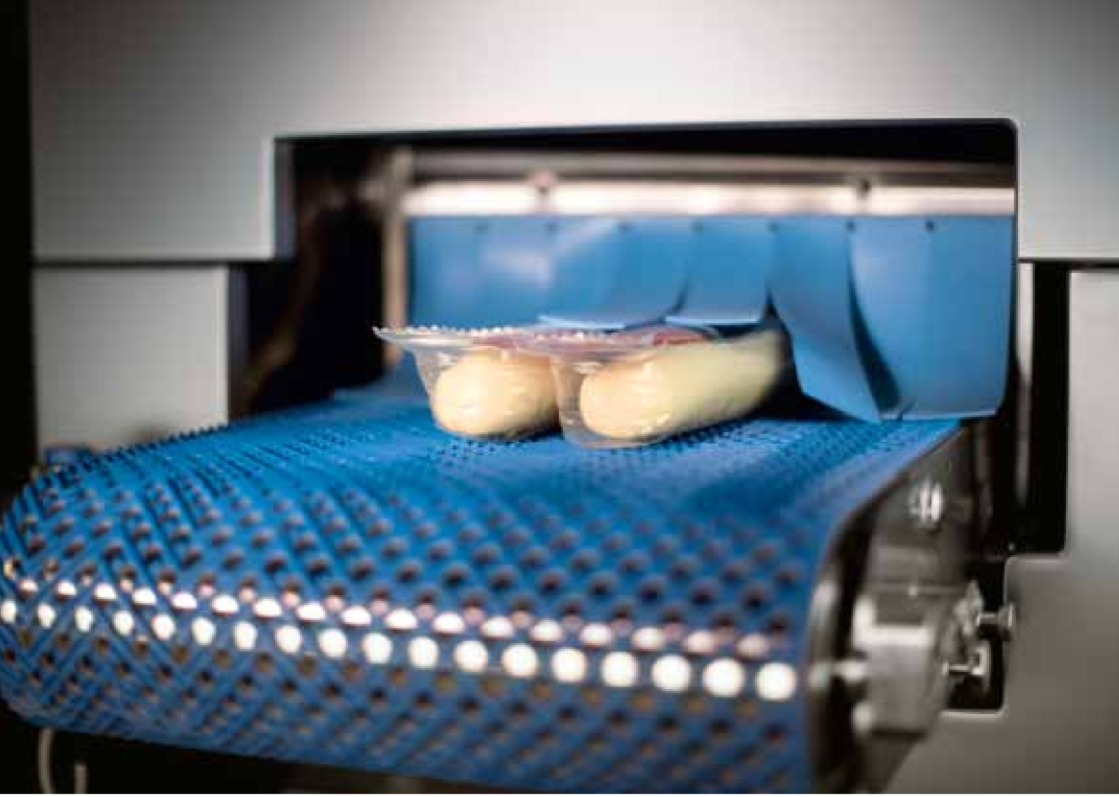
MAPAX® – Leak detection.



MAPAX® LD for high-precision leak detection in all kinds of packaging.

Preserving freshness

Modified atmosphere packaging (MAP) is a popular and proven way to preserve the quality and freshness of foods on their way from the field or producer to the retailer. They are also an effective way to extend shelf-life in the shop – by anything from days to months in the case of dried foodstuffs. However, the effectiveness of MAP can only be guaranteed if the package is correctly sealed and intact. Consequently, leak testing is becoming an increasingly important part of end-to-end packaging concepts. It is the only way for producers to ensure that every package that leaves the processing line is in perfect condition.

Wide spectrum of testing methods

There is a wide choice of methods available for leak testing. One of the most common is sampling, where random packages are selected for inspection. However, this can be a costly approach as an entire batch may have to be discarded if a leak is detected. In addition, the random nature of sampling affords limited assurance overall.

Integrated into the production line, in-line tests provide more coverage and are much better suited to highly automated food production processes. Many food producers would welcome a leak detection method that is reliable, cost-effective and fast enough to enable each package to be inspected without slowing down the production line. The ability to pinpoint single defective packages would eliminate the expense involved in repacking or discarding entire batches.

MAPAX® LD

MAPAX LD is Linde's innovative and accurate leak detection technology for high-speed, non-destructive in-line results. It uses a MAPAX gas mixture containing up to 4% hydrogen during the packaging process. This does not affect the quality of food. A sensor in the machine instantly detects the presence of hydrogen and triggers an alarm if a package is leaking. The faulty package or packages can be instantly removed from the production line and the rest of the batch continues as usual.

Benefits of MAPAX® LD at a glance

- → In-line detection and removal of faulty packages
- → Higher productivity, less downtime
- → Cost savings due to reduction in rejects
- → Enhanced customer experience with consistently high quality levels
- → Low-maintenance design

MAPAX LD machine, side view

Looking ahead

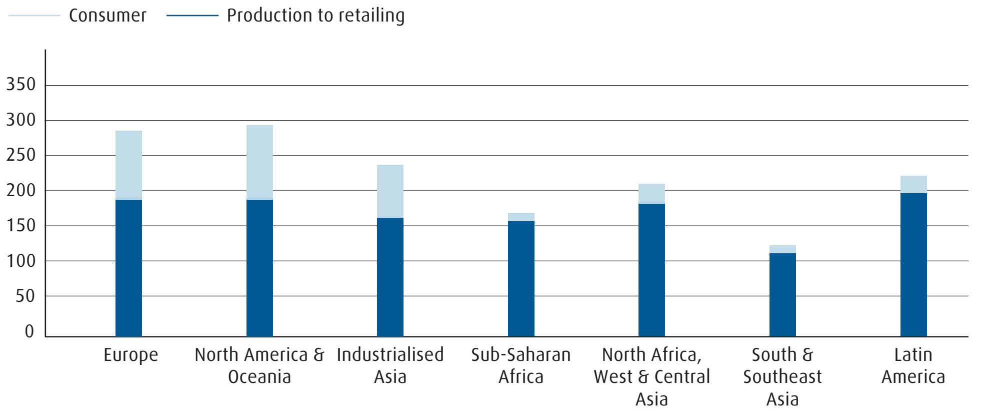
The only way to meet rising demand among retailers and consumers for fresh, perfect foodstuffs of consistently high quality is to tighten control over sub-standard packages. Leak detection will increasingly be viewed as a critical control point in the food production process. Effective, future-proof Hazard Analysis and Critical Control Points (HACCP) concepts in compliance with EU regulation 852/2004 on the hygiene of foodstuffs will most likely rely more and more on gas-enabled, in-line leak detection concepts such as MAPAX LD as they are the most reliable and flexible way to identify, evaluate and mitigate risks to food safety.

Need to tackle food waste

Experts estimate that up to one third of food is wasted globally every year. In the EU, a significant – if not the largest – block of wastage occurs during food/drink manufacturing processes and at the retail/wholesale stages.

Both producers and retailers are challenged to find effective ways to meet consumer expectations for cosmetically perfect food while also reducing waste-induced costs by preventing food from spoiling.

Per capita food losses and waste (kg/year) at production and consumption stages, in different regions



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MAPAX®. FAQs.

Gas.

Which gas mixture should I use?

It depends on the type of food you produce, the shelf-life you need and the way your product is consumed. For detailed information, refer to the specific MAPAX® flyers and your local Linde application engineer. Tests will probably need to be conducted to decide the optimum mixture.

I am just starting out with the MAP system. What equipment do I need?

Most systems require a minimum of a regulator, a flowmeter and piping. It is recommended to start with the pre-mixed single cylinders. Contact your local Linde application engineer to see what else might be needed.

Is it better to purchase pre-mixed cylinders or to purchase pure gases and mix them on site?

This depends on the volume and the type of production at your facility. If the volumes are large or your plant produces various products with different gas requirements, it would be better to mix the right gases on site.

Where can I place the cylinders that I am using?

Ideally you would want them out of the processing area for quality and hygiene reasons. Please refer to your local regulations.

How much pressure do I need to supply to my machine?

This depends on the type of machine and the type of product being run. Consult your machine manufacturer as well as your local Linde application engineer.

If I use more gas, will using individual cylinders become more expensive?

Yes. As your business grows, so will your gas consumption. It is important to consult your local Linde representative to work out the best time to switch from cylinders to a bulk tank supply mode.

What about safety for the use of gases?

We provide safety information and training. Each country has its own safety regulations for the use of gas. These regulations must be followed and integrated into your quality systems. Our specially trained experts will support you here.

What precautions should be taken when using gas mixtures with a high oxygen content?

Please contact the machine supplier to check whether the machine is suitable for operation with mixtures containing high oxygen levels. The machine has to be specified for high oxygen ratings.

What are the functions of different gases?

The most important gas is CO_2, since it delays the growth of microorganisms by dissolving into the food. N_2 is used to replace O_2 and thereby decrease deterioration. It is also used as a buffer gas. O_2 is used to keep the red colour of meat and for the respiration of fruit and vegetables. The gases are normally used in mixtures to suit the needs of the specific product.

Why should I use food-grade gases?

Industrial gases do not meet the legal demands relating to the quality, traceability, labelling and handling of food-grade gases as additives.

Food.

How far can I extend the shelf-life of my products by using an MAP system?
That depends on many factors such as food product, temperature, hygiene, package and gas mixture. Generally, shelf-life can be increased by a period ranging from days to several weeks. For specific information, see the MAPAX booklet for your particular product.

Can I freeze a product that is packed in a modified atmosphere?
Yes- but it would be more effective and efficient to first freeze the product and then pack it in a modified atmosphere. Make sure the packaging material is suitable for freezing.

Which gas or gas mixture can prevent the greenish colouring on the ham I produce?
This greenish colouring is caused by bacteria grown naturally during processing. There is no gas or mixture that can change this afterwards.

The meat I pack under MAP loses its colour, but the colour reappears after I open the package. Am I using the right gas mixture?

The myoglobin molecule, which is responsible for the colour of meat and meat products, turns different colours with different gases. For recommendations relating to the correct gas mixture, see the flyer "MAPAX – Best for meat and meat products".

The sliced meat product I pack under MAP turns grey. Sometimes only spots on the meat have different colours. Could that be caused by a wrongly filled gas cylinder, or is it caused by the gas mixture in general?

The gases and mixtures in our food-grade gases are controlled constantly and the wrong labelling or filling of a cylinder is almost impossible. The grey spots may be caused by a number of factors. To give you just a few ideas: the UV filter of the films could have been changed so that it no longer matches the light exposure, additives could have been changed, or the process could have been altered. Even raw materials like water and meat can vary. Maybe the optimum gas mixture is not being used, or there is an excessively high residual oxygen level in the package or condensed water that can fall down from the lid. Contact your local Linde engineer for tests.

Why does drip loss appear in fresh meat in a modified atmosphere?

Drip loss is caused by meat handling and processing. Carbon dioxide and oxygen are absorbed and metabolised by the product and microorganisms, creating a partial vacuum inside the container. In fresh meat packaging, this vacuum may be strong enough to actually squeeze water from the meat if insufficient nitrogen is present in the headspace. This can result in drip inside the package. Adding nitrogen should minimise the problem.

When I open the food package, I can smell a specific odour. How can we explain this? In most cases when food is properly stored, this is a normal phenomenon. Each product generates its own odour which consists of many volatile compounds that collect in the headspace of the package. Wait a minute after opening. If the smell continues, please check the quality further.

Which gas or gas mixture should be used for the ripening of meat?

Meat can be successfully ripened in mixtures of CO_2 and N_2. The mixture depends on the type of meat and how it is cut.

There are some pale grey, almost white spots on smoked sausages. The sausages are rinsed, cooled in a cryogenic freezer and then packed in MAP. How can I prevent this?

There may be a number of reasons for these spots, for example, a local low temperature area could arise during the cooling process that often comes before the slicing. Cryogenic freezing involves very low temperatures that can cause bleaching. Contact your application engineer to check the freezer. Changes in various steps of the process may influence this.

Packaging.

Does the package labelling have to indicate that the produce is packaged in a modified atmosphere?

That depends on regional regulations. For EU countries, if the durability of a food has been extended by being packaged in a modified atmosphere, the packaging must state: "Packaged in a protective atmosphere".

What headspace (gas volume) is used in the package?

That depends on the food product and type of package. The gas volume / product volume ratio lies between 0.5 for sausages and 2 for fish.

I get condensation in my package – what's wrong?

The most likely reason is the temperature difference between the product and the storage temperature. We can improve packaged product visibility by using anti-fogging films. The product should always have the lowest possible temperature at the moment of packaging and be kept at the same temperature or lower during storage. The package could also be punctured. Check the residual oxygen.

My packages inflate over time. Is the product fermenting?

This is nearly always due to the CO_2 which is generated by the product. This can be caused by too high temperatures (exceeding 4°C) over a certain time. This process cannot be reversed by cooling the product down again. Some products, such as hard cheeses, develop CO_2 through natural fermentation; this process can sometimes continue after packing and cause an undesirable inflated effect. The package can also be contaminated and develop unwanted gases which cause it to expand. Check immediately with your food lab.

Why do MAP packages collapse?

This is a normal physical phenomenon that often happens to products with a high water content. CO_2 is a basic compound in MAP mixtures and dissolves easily in the water and fat phase of a product kept at low temperatures. That's why the amount of CO_2 in the head-space decreases and creates a small degree of underpressure inside the package.

How do I know that I have the right gas volume and mixture in the package?

There are several types of gas analysers on the market. They are easy to use and will give you fairly accurate answers to questions about mixtures and residual O_2 levels. It is important to establish good routine checks to make sure you do not package a large amount of produce and end up with a less-than-optimum outcome. Your Linde application engineer will assist you by advising on the mixture and equipment best suited to your needs.

Why does the residual oxygen in the package increase over time?

There are a few reasons why this might happen. There could be a leak in the package or the oxygen barrier may not be high enough. Moreover, air (containing 21 % oxygen) could have been trapped within the product during packaging (cakes and breads for example). However, the most common reason is leaks in the sealing.

How much residual oxygen is recommended in the package?

This depends very much on the product. Consult your local Linde application engineer.

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MAPAX®. Glossary.

Active packaging
Active packaging employs a packaging material that interacts with the internal gas environment to extend the shelf-life of food. Such technologies continuously modify the gas environment (and may interact with the surface of the food) by removing gases from or adding gases to the headspace inside a package. Examples of active packaging systems are oxygen scavenging, carbon dioxide production, water vapour removal, ethylene removal and ethanol release.

Aerobic organism
An organism that normally grows in the presence of air (20% oxygen).

Anaerobic organism
An organism that normally grows in the absence of air (20% oxygen) or oxygen. Anaerobes can be "strict" (obligate) anaerobes, i.e. they can be killed by oxygen, or "facultative" anaerobes, i.e. they can grow under either aerobic or anaerobic conditions.

Anti-fogging properties
Film manufacturers produce a high surface tension film with hydrophilic properties that allows moisture to wet the surface in order to avoid fogging.

Argon
Ar is an inert gas with low solubility in water. Air contains approximately 1% argon.

Bacteriostatic effect
Capable of inhibiting bacterial growth without killing microorganisms.

Biochemical process
Process or phenomenon in a living organism or biological system described in chemical terms.

BIOGON®
BIOGON® is the trademark for food-grade gases from Linde available in certain countries.

CA
Controlled atmosphere.

Campylobacter
A genus of microaerophilic bacteria, some forms of which can cause serious health issues.

Carbon dioxide
CO_2 has a slightly acidic odour. It dissolves easily in water and thereby inhibits the growth of many microorganisms. Air contains approximately 0.03% carbon dioxide.

Catalyst
A substance that regulates the rate of a chemical reaction and itself remains unchanged.

Clostridium
A genus of bacteria classified as gram-positive rods, anaerobic endospore formers with a fermentative mode of metabolism.

Controlled atmosphere
The atmosphere surrounding food is changed and then controlled during storage.

CFU
Colony-forming units are used to measure the number of microorganisms.

EMA
Equilibrium Modified Atmosphere.

Enzymatic reaction
Chemical reactions catalysed by enzymes.

Enzyme
Globular protein that is the catalyst of a biological system.

ERH
Equilibrium Relative Humidity.

Fermentation
Anaerobic energy-yielding metabolism of cells.

Gas flushing
Flushing with gas or gas mixture to establish a modified atmosphere.

HACCP
Hazard Analysis and Critical Control Point. A systematic approach to the identification, evaluation and control of food safety hazards.

Inert gas
A gas that does not react with other substances under normal temperatures and pressures.

Lactic acid bacteria
Gram-positive bacteria, usually non-motile, non-sporulating bacteria that produce lactic acid as a major or sole product of fermentative metabolisms. All rod-shaped lactic acid bacteria are placed in one genus called Lactobacillus.

Leak detection
Quality assurance method to check whether food packages have leaks.

Listeria
Facultatively anaerobic bacteria causing serious human disease.

MAP
Modified Atmosphere Packaging. This means altering the composition of the atmosphere inside a package so that it differs from that of normal air.

MAPAX®
MAPAX® is a tailor-made MAP solution developed and delivered by Linde based on data about food, gases and packaging.

MAPAX LD
In-line leak detection system from Linde.

Master-pack
Consumer packages (over-wraps) are packed in a big flexible pack that is gas-flushed.

Membrane
A membrane consists of numerous layers of very thin polymer film, bundled into fibres. It is used to produce nitrogen on site by exploiting the variations in velocity at which different gas molecules pass through polymer materials.

Mesophilic bacteria
Organisms living in the temperature range around that of warm-blooded animals. This means those that grow well between 20°C and 45°C.

Microorganism
All microscopic forms of life, which includes such forms as bacteria, fungi, viruses, protozoa and algae.

Modified atmosphere
An atmosphere differing from that of normal air. Normally the oxygen content is reduced and the carbon dioxide content is increased.

Mould
Aerobic food-spoilage microorganisms. They tolerate low water activity and a low pH value.

Myoglobin
The principal pigment in fresh meat. The form it takes is of prime importance in determining the colour of the meat.

Nitrogen
N_2 is an inert gas with low solubility in water. Air contains approximately 78% nitrogen.

Nitrous oxide
N_2O dissolves easily in liquid. It is mainly used for whipping cream.

Nutritional content
Expresses the nutritional content, e.g. carbohydrates, fats, proteins and vitamins.

Oxidation
Chemical reaction with oxygen resulting in unwanted changes, e.g. rancidity and vitamin loss.

Oxygen
O_2 is a very reactive gas with low solubility in water. Air contains approximately 21% oxygen.

pH value
Expresses acidity (pH 0–6), neutrality (pH 7) and alkalinity (pH 8–14).

PSA
Pressure swing adsorption. This technology is used to produce nitrogen on site. It is based on the ability of activated carbon to capture and retain oxygen from the air under certain conditions, while allowing nitrogen to pass through.

Protein
Macromolecules built up of amino acids with peptide bonds.

Pseudomonas
A genus of an aerobic gram-negative rod-shaped bacteria, ecologically important in soil and water owing to their large capacity to mineralise organic matter.

Psychrophilic bacteria
These bacteria are able to grow at low temperatures, i.e. 0°C to 5°C.

Rancidity
Oxidation of lipids.

Respiration
Aerobic energy-yielding metabolism of cells.

Shelf-life
The period between packaging a product and its use, during which the quality of the product remains acceptable to the consumer.

Shelf-life technology
The methods for enhancing shelf-life.

Sous-vide
The sous-vide technique entails packaging a food product in a vacuum, then preparing it at high temperature (70 to 80°C), and quickly chilling it down to 2 to 4°C.

Thermophilic bacteria
Organisms that grow at elevated temperatures, i.e. above 55°C.

Water activity
a_w. The ratio of the water vapour pressure of a material to the vapour pressure of pure water at the same temperature.


Food
Gas
Packaging

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