

Discover the ultimate combination for freshness.

MAPAX[®] solutions for packaging in modified atmosphere prolong shelf-life the natural way.



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MAP – an innovative response to food deterioration.



Taking a leaf out of nature's book, Linde provides innovative solutions to seal in the natural freshness and flavor of foodstuffs – without the use of chemical preservatives.

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. There is a strong trend towards being able to purchase and prepare fresh foodstuffs and readymade dishes at any time, as if they came directly from the food manufacturer. Food safety and easy access to all kinds of foodstuffs are very important. Therefore, it is becoming more and more difficult to meet consumers' great 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 (internal factors like water activity, pH-value, type and quantity of product microorganisms) endanger the quality and shelf-life of the foodstuff. However, external factors (hygienic conditions while processing, temperature etc.) 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: MAP

In order to prevent this loss of natural freshness and quality, an effective and intelligent concept of food preservation has been developed – MAP. Through the use of natural gases and adequate packaging materials and machines, the quality of foodstuffs is maintained and their shelflife enhanced.



In the race against time, you profit by rationalizing your logistics. Even perishable products can be transported farther, still arriving fresh and appetizing for sale over an extended period.

MAP benefits.



A short story about long-term profits

The success story begins with the consumers' buying decision. Which foodstuffs do they buy and which ones do they refuse? And why? MAP individual packaging solutions are based on consumer statistics and intensive market research in order to be able to react directly to 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 decisive economic advantages for the particular companies using MAP. This technology opens up new markets and simplifies distribution logistics for the successful promotion of sales and profits.

Extending the product range

Packaging with protective gases and thus increasing the product's shelf-life offers the possibility of successfully establishing new products on the market and thus extending the product range. Revenues are increased by offering more products in the shops, e.g. fresh pizza or ready-made salads.

Increasing productivity, rationalizing distribution

MAP simplifies all distribution logistics because goods can be delivered less frequently and across longer distances. This enhances planning flexibility and rationalizes the workflow from the delivery of the raw material to transporting the goods to the shops or intermediate stores. Due to prolonged shelf-life, the food manufacturer is able to provide new markets with his goods and radically extend his geographical sales



region. This is another important advantage when operating on 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 bottle-necks have to be bridged or peaks balanced. The supply of products of consistently high quality has to be guaranteed at any time. Output can be arranged regularly, consequently utilities and workforce remain balanced throughout. All these factors increase the productivity and the efficiency of the company.

Higher availability, greater market share

By using MAP, days if not weeks of high quality shelf-life are gained during which your products are available to the consumers. Sales figures soar with every additional day. As many renowned companies have proved, MAP results in successful product sales and raises the market share. The bigger the market share, the more consumers react posi-

tively 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.

MAP – Modified Atmosphere Packaging.



Low temperatures are very important for the shelf-life of chilled food

Deterioration processes and appropriate gases

Food is a biological, sensitive substance. 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
- MAP – Modified Atmosphere Packaging

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 bring about 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 odor. 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 microorganisms 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 defenses must be resorted to, such as a modified atmosphere.

oxidation of unsaturated fats in the presence of atmospheric oxygen, causing the product to turn rancid. Enzymatic reactions caused by polyphenol oxidase, for example, bring about the brown discoloration of sliced fruits and vegetables. Oxygen, however, is important in maintaining the red color of cut meat.

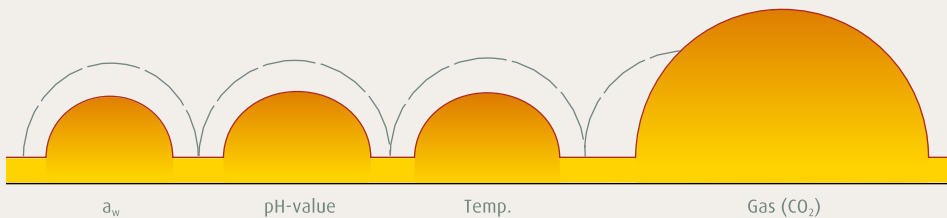
Oxygen causes chemical breakdown

The chemical reactions may be oxidation of vitamins or lipids or caused 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

Solubility in water at P_{gas} = 100 KPa gram/kilogram at 15 °C.

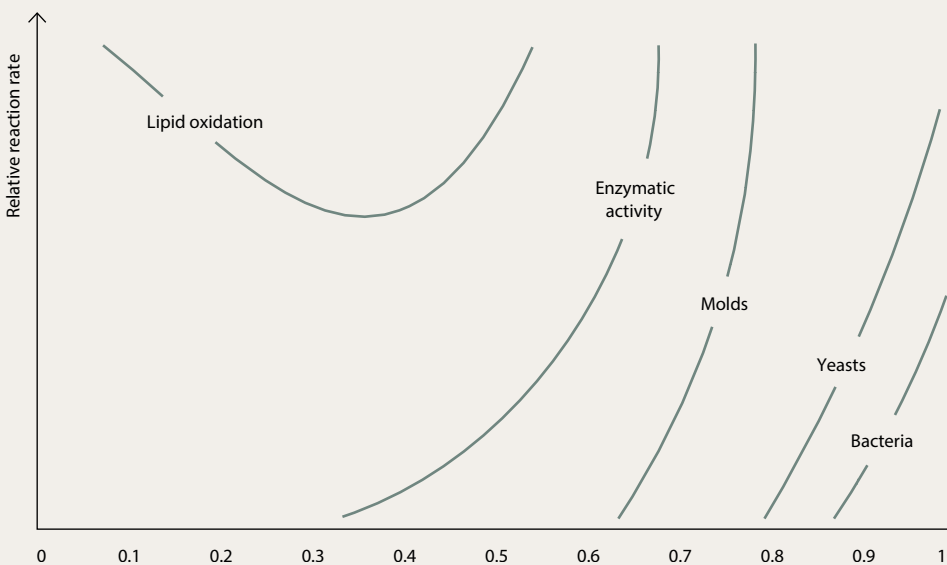
Carbon dioxide, CO ₂	1.62
Argon, Ar	0.06
Oxygen, O ₂	0.04
Nitrogen, N ₂	0.02

Hurdle concept

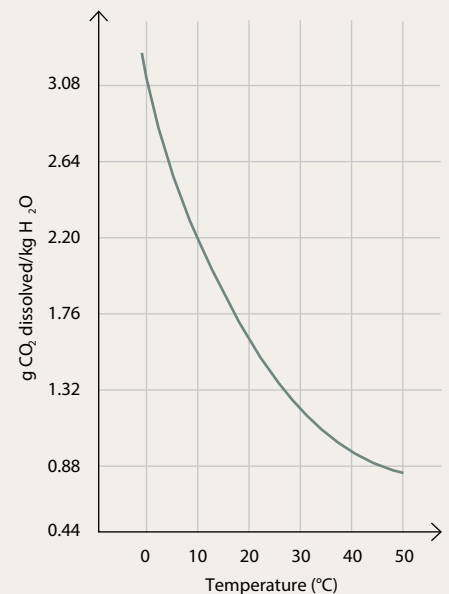


CO₂ provides an extra hurdle for chilled food safety

Chemical and biological reaction according to water activity



CO₂ solubility in water





From food preservation to the protection of natural quality

Present developments are moving away from the previous preservative methods that physically or chemically alter the product toward less severe methods that leave the product unchanged. The methods that represent the ultimate attempt to protect the inherent quality of a food product range from processes such as high-pressure and microwave methods to various packaging techniques, e.g. oxygen absorption, vacuum, sous-vide techniques and MAP. MAP is a natural shelf-life-enhancing method that is growing rapidly on an international scale. It often complements other methods. The correct gas mixture in modified atmosphere packaging maintains high quality by retaining the original taste, texture and appearance of the foodstuff. The gas atmosphere must be chosen with due consideration of the particular foodstuff and its properties. For low-fat products with a high moisture content, it is especially the growth of microorganisms that has to be inhibited. On the other hand, should the product have a high fat content and low water activity, oxidation protection is the most important. The MAP gas mixtures usually consist of the normal air gases: carbon dioxide (CO₂), nitrogen (N₂) and oxygen (O₂). Microorganism growth can also be inhibited to a certain extent with the help of other gases such as nitrous oxide, argon or hydrogen. Each of the gases has its own unique properties that affect its interaction with the foodstuffs. The gases are used in mixed atmospheres, in suitable proportions or by themselves.

Carbon dioxide inhibits microbial activity

Carbon dioxide is the most important gas in the field of MAP technology. Most microorganisms such as mold and the most common aerobic bacteria are strongly affected by carbon dioxide. The growth of anaerobic microorganisms, on the other hand, is less affected by this gas atmosphere. Carbon dioxide inhibits microbial activity by effectively dissolving into the food's liquid and fat phase, thereby reducing its pH-value, and by penetrating biological membranes, causing changes in permeability and function.

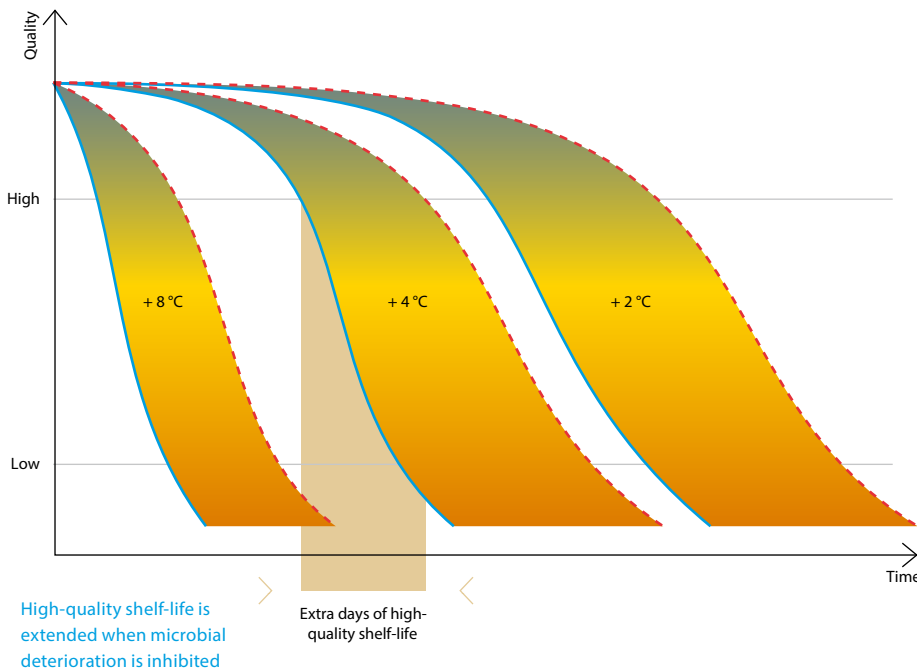
Nitrogen – inert and stabilizing

Nitrogen is an inert gas. It is primarily used to replace oxygen in packaging and thereby prevents oxidation. Owing to its low solubility in water, nitrogen also helps to prevent package collapse by maintaining internal volume.

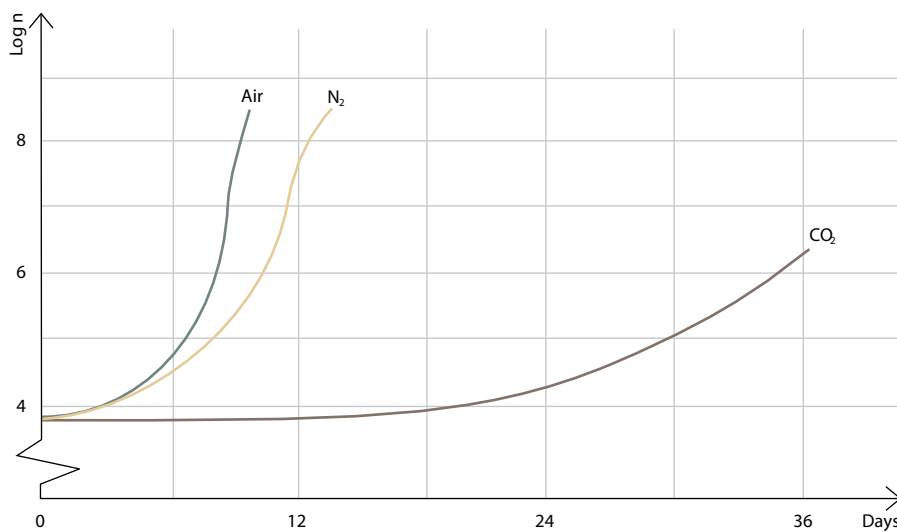
Oxygen level should be as low as possible

For most foodstuffs, the package should contain as little oxygen as possible to retard the growth of aerobic microorganisms and reduce the degree of oxidation. However, there are exceptions. Oxygen helps to preserve the oxygenated form of myoglobin, which gives meat its red color. Oxygen is required for food and vegetable respiration.

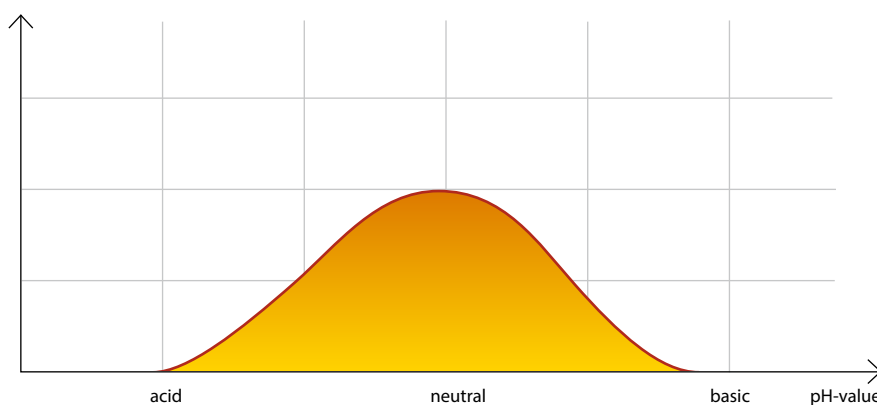
Chemical and biological reaction according to water activity



Colonies per unit



Growth rate of microorganisms



MAP is used to increase the shelf-life of foodstuffs as well as to improve the quality of the packaged product. The key to this technology lies in varying the concentration of different gases (generally CO₂, N₂ and O₂) in coordination with the respective product. The most important prerequisites for successful MAP technologies are: good original quality of the product and the raw materials, appropriate temperature control, good hygienic conditions (e.g. HACCP system), the use of gaseous mixtures appropriate to the product and the use of appropriate and tight packaging. Particularly the last point, the optimization of packaging, is a decisive factor for the efficiency of MAP. The packaging must have appropriately low oxygen/gas permeability as well as tight sealings, otherwise too much gas can penetrate. Generally, the share of residual oxygen in each package should be less than 1–2 %. In the case of higher oxygen values, MAP cannot be used to its best advantage as far as oxidation protection is concerned. Exceptions to this rule are special MAP atmospheres, e.g. for fresh meat, which work with high concentrations of oxygen. If carbon dioxide is used, its bacteriostatic effect, in a concentration which allows it to unfold its bacteriostatic effect, is part of the modified atmosphere, the minimum concentration of this gas should be 20 %.



Dr. Michael Washuetti, Head of Department of Modified and Active Packaging of Packaging Institute Vienna, Austria

Growth of microbes as a function of the medium

Perfect food comes in perfect packaging.



Tailored solutions for any kind of product

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 odor and taste substances that come into contact with the product.

The manufacturer of foodstuffs faced with choosing suitable packaging designs and materials has many important decisions to make, and also has to comply with general legal demands for packaging materials.

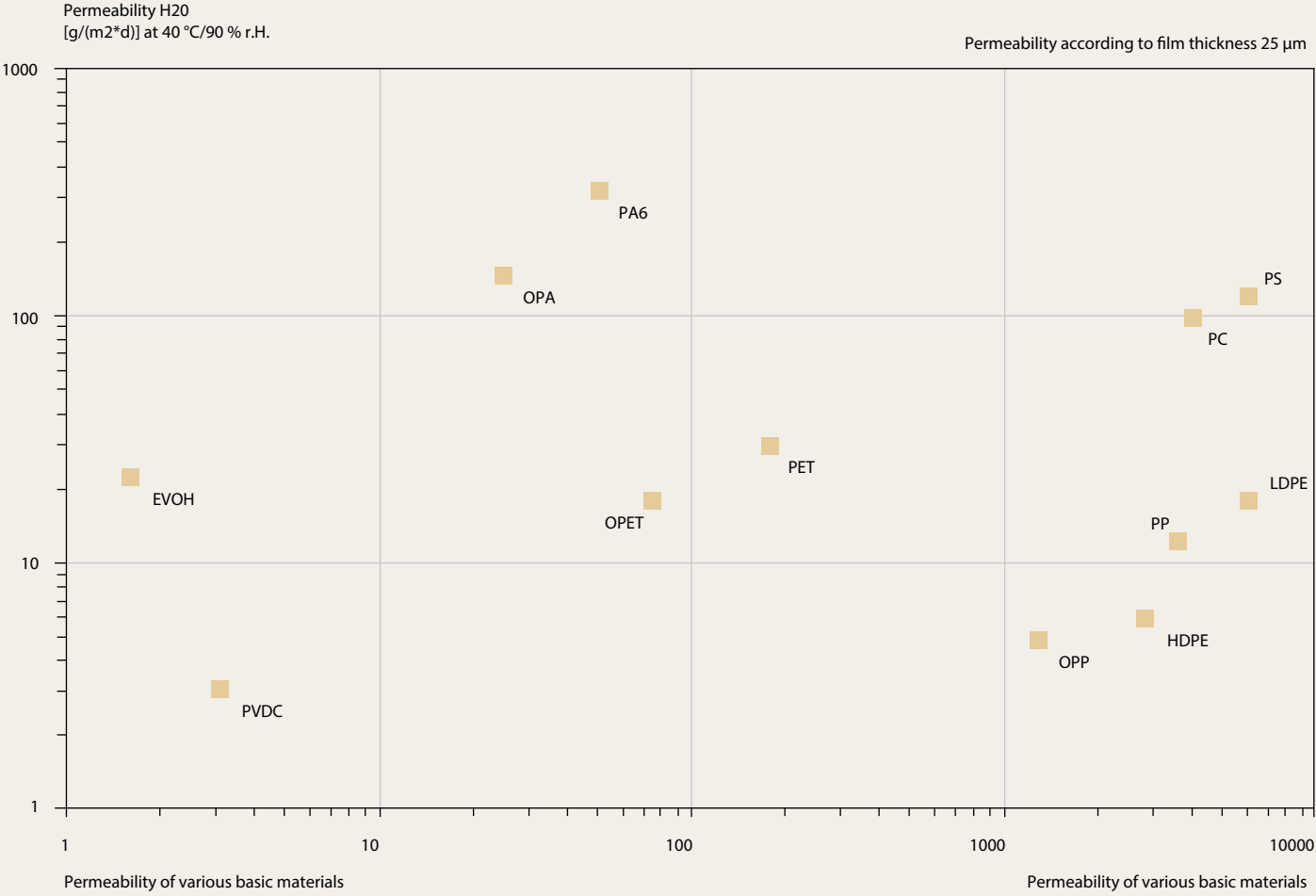
What does the product require in the way of packaging as protection against quality deterioration from microbial growth, oxidation, dehydration, etc.? What barrier properties does the packaging provide against oxygen, light and volatile substances?

What water vapour transmission rate should the packaging have? What applies with regard to the material's transparency, sealing ability, anti-fogging properties, microwaveability or price?

Various material properties combined

Packaging materials used with all forms of MAP foods (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.

Chemical and biological reaction according to water activity



Relation permeability

N ₂	:	O ₂	:	CO ₂
1	:	5	:	25





Primary function of various basic materials

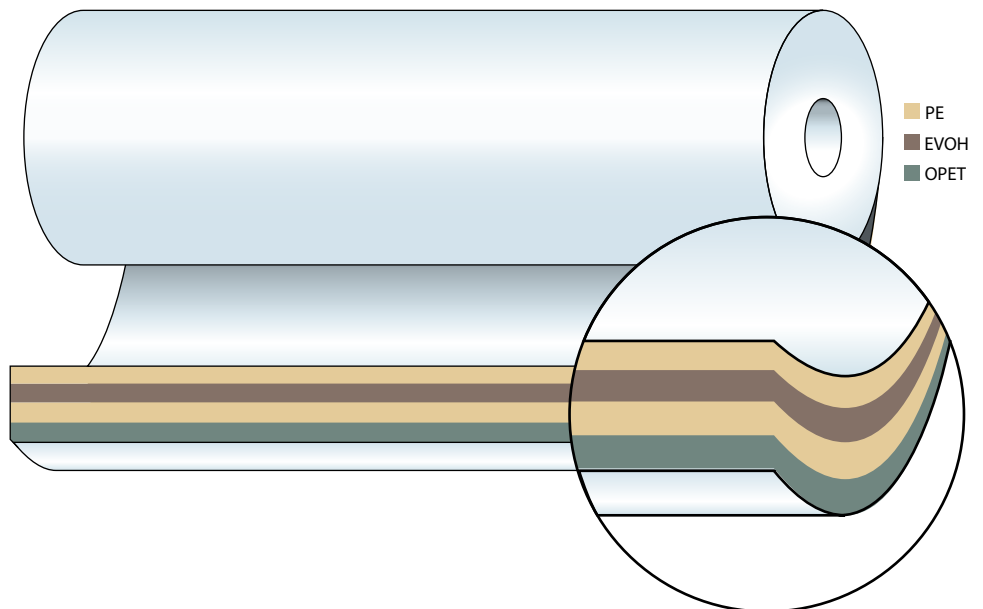
Abbreviation	Basic materials	Primary function
Al	Aluminum	high barrier
APET	amorphous polyester	rigidity, gas barrier
CPET	crystallized polyethylene terephthalate	rigidity, high temperature resistance, gas barrier
EVA	ethylene-vinyl acetate	sealing layers
EVOH	ethylene-vinyl alcohol	gas barrier
HDPE	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, some gas barrier
PAN	acrylonitrile	gas barrier
PET	polyethylene terephthalate (polyester)	rigidity, some 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

Examples of materials for some food products

Food	Material	
	Bottom	Top
Red Meat, processed meat, poultry, fresh fish	OPET/PE/EVOH/PE/ XPP/EVOH/PE	OPP/PE/EVOH/PE
	EPS/EVOH/PE	OPET/PE/EVOH/PE
	(XPP and EPS are expanded materials)	OPA/PE
Sausages	PA/PE	
Pizza, pasta, cheese	OPA/PE PA/PE	
Dry products, coffee, milk powder	Metalized PET/PE	
Cut salads	OPP PS/PE	OPA/PE



Importance of hygiene for shelf-life of fish



Research work strives to use environmentally friendly materials both for manufacture and for subsequent combustion as well as for optimizing the packaging material, so that the amount of material is minimized. One development is the use of foamed materials in trays in order to be able to offer an attractive package. Another development is the use of reclosable packages, e.g. for sliced ham, cheese etc. In the table below is a list of some typical materials used with products. 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 multi-layered structure, each layer having its own function.

Different plastic materials can therefore be chosen and combined to achieve:

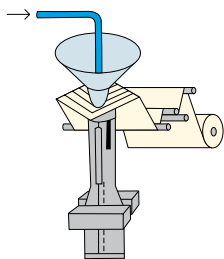
- mechanical strength
- water vapour barriers to prevent weight loss and dehydration
- gas barrier
- gas permeability
- anti-fogging properties (the inside of the material should have a surface that does not allow the formation of water droplets, which reduce transparency)
- sealing properties, i.e.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

Packaging machines for individual products.



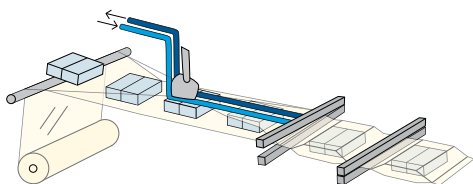
There are five main groups of packaging machines used with MAP technology, depending on the type of product. Although these machines are based on different principles, the basic mode of operation is the same. First, a package is formed (or prefabricated packages are used) and filled with the product. 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 inside the package is replaced by a

continuous gas stream that dilutes the air surrounding the food product before the package is sealed. Since this dilution is continuous, the packaging rate can be high. 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.



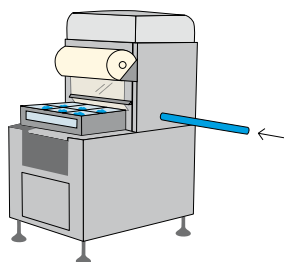
Vertical flow-pack

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 food-stuffs. Sometimes gas flushing may be necessary before packaging.



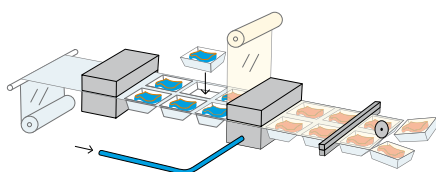
Horizontal flow-pack

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 the deep-drawing machine. Typical foods are bakery products, sausages, cheese, pizza and green salads. One special technique is BDF (Barrier Display Film). In this technique, a special BDF is used to pack the food product on a tray in MAP. The trays then pass through a heating tunnel where the film shrinks around the packages, enclosing them in the modified atmosphere.



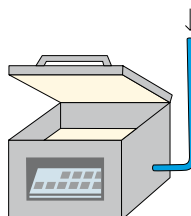
Tray-sealer machine

The tray-sealer can be operated manually, semiautomatic (illustrated here) and continuously depending on production size. This machine can be compared to the deep-drawing machine, but the bottom trays into which the product is put are ready-made and not formed during the process. Depending on the foodstuff and marketing aspects, 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.



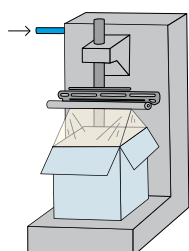
Deep-drawing machine

Film is heat-formed into a tray on a lower conveyor belt and the product is then added. Air is extracted, gas injected and the loaded package is sealed by welding on a film from an upper conveyor belt. This machine is suitable for foodstuffs such as meat, fish and prepared food.



Vacuum chamber machine

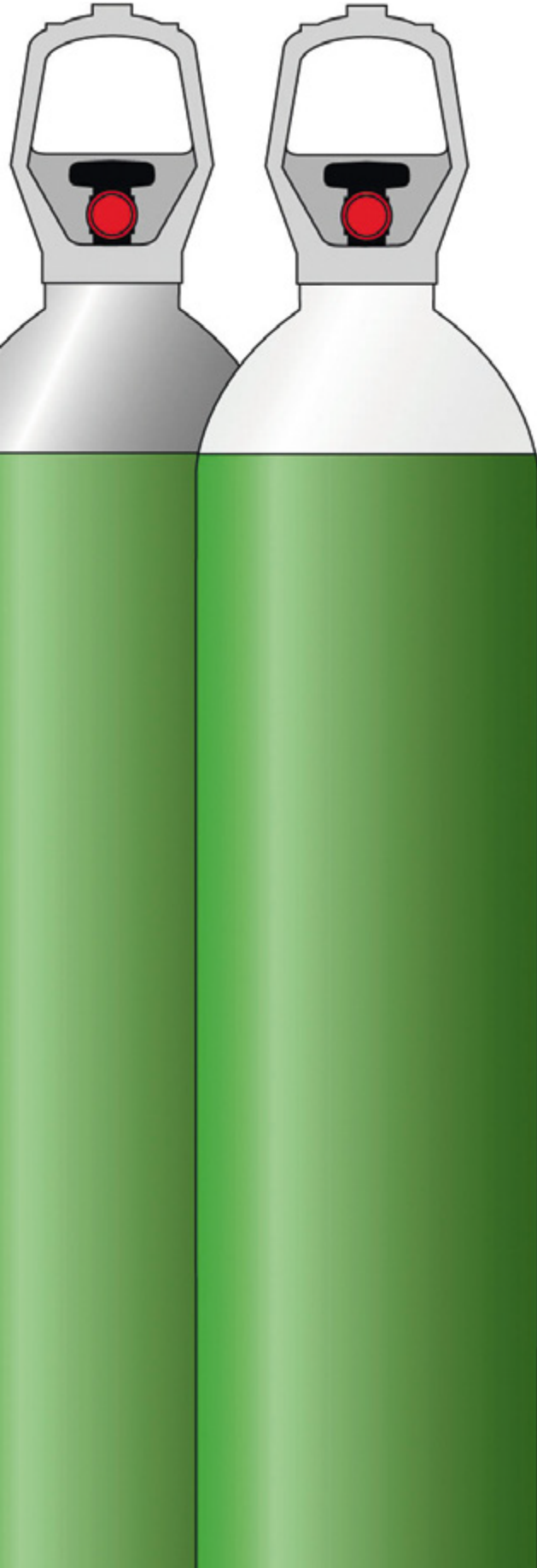
The product is inserted into prefabricated bags or trays. The packages are placed in a chamber from which the air is extracted and the pressure then equalized with gas. The packages are then sealed by welding. This machine type is suitable for small production volumes at a relatively low cost.



Bag-sealing machine bag-in-box

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

Linde: BIOGON® food grade gases and gas supply.



A gas supply adapted to every application

The gases predominantly used in MAP storage are carbon dioxide (CO₂), nitrogen (N₂) and oxygen (O₂). 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.

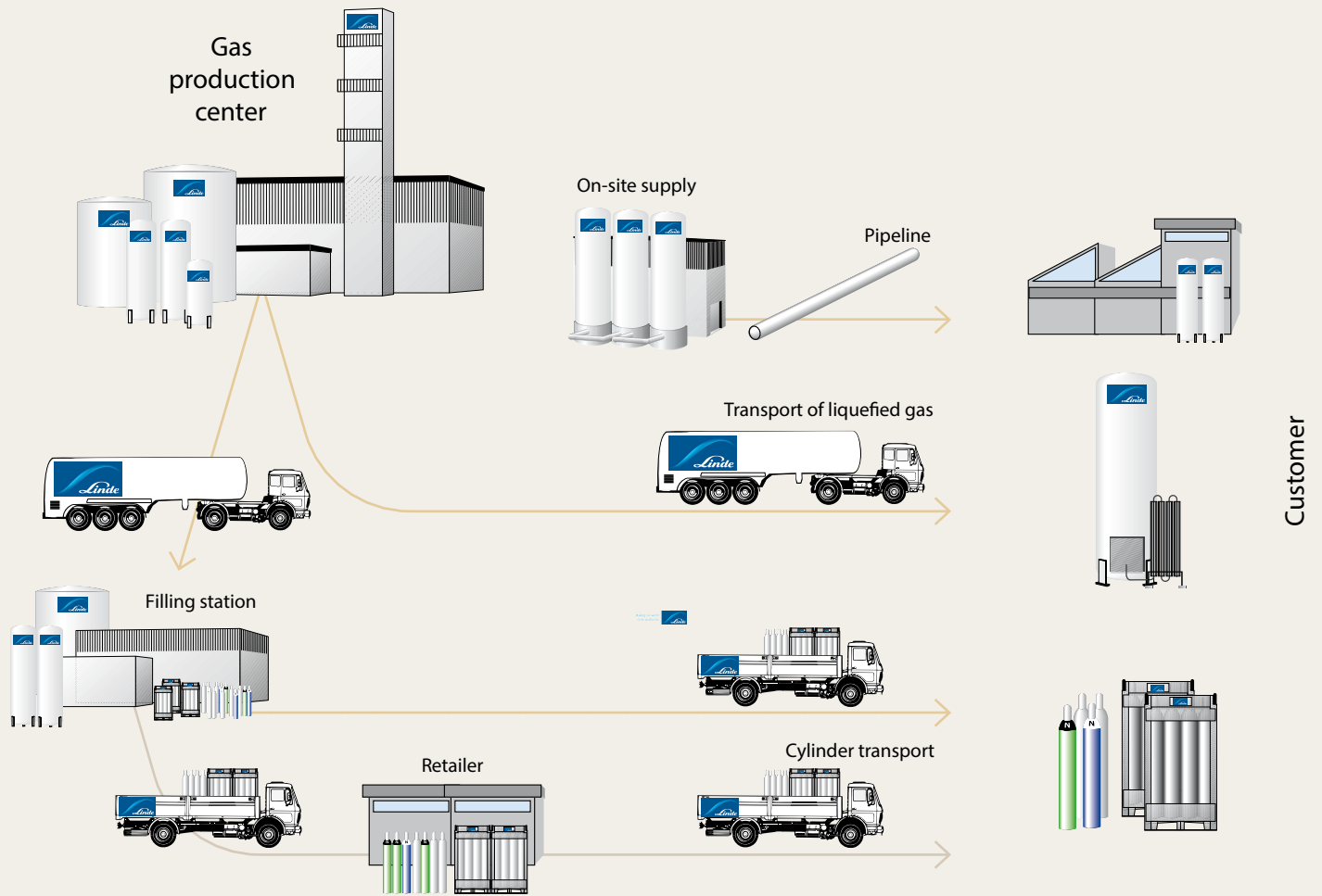
Linde supplies the food grade gases carbon dioxide (CO₂), nitrogen (N₂), oxygen (O₂) and other gases authorized for foodstuffs either premixed, as individual gases in cylinders under high pressure, or as liquids in insulated tanks for subsequent mixing at the packaging machine. "Food-grade gas" is a specific definition for gases used as a processing aid and/or additive in order to ensure that standards are complied with. Linde food grade gases conform to "food-grade" regulations, e.g. the EC directive 96/77/EC on food additives within the EU countries and the FDA guidelines in the USA. N₂ and O₂ are separated from the atmospheric air. CO₂ is taken

Common examples of Linde food mixtures.

Examples	Gas components (%)		
	O ₂	CO ₂	N ₂
BIOGON® N			100
BIOGON® C		100	
BIOGON® O	100		
BIOGON® NC 20		20	80
BIOGON® NC 30		30	70
BIOGON® OC 25	75	25	
BIOGON® OCN 25 09	66	25	9

Names may vary from country to country.

Gas supply



from natural wells or as a byproduct 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 back-up gas supply system is recommended.

Careful evaluations precede each choice

The supply option that may be best 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 premixed 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/memb-

rane 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 ready packages after sealing is recommended.

Thorough quality control of food gases

Before the cylinders are filled, they are examined, checked thoroughly and pretreated if necessary. Each unit is regularly analyzed to check for cleanliness and correct ratio of the mixture. In addition, examinations of certain rules relating to other components and sterility are made in rotation by independent institutes.

MAPAX[®] solutions for packaging in modified atmosphere by Linde.



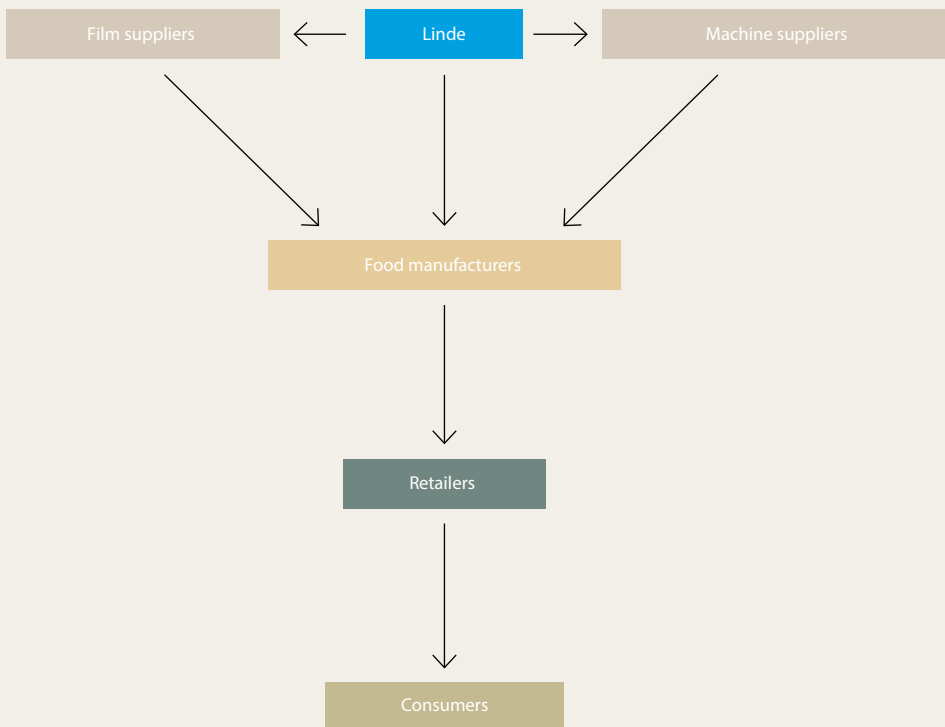
Discover the secrets of freshness – discover MAPAX[®] solutions

All in one – MAPAX[®] solutions functions everywhere

MAPAX[®] concept from Linde is a tailor-made MAP program based on the necessary data relating to foodstuffs, gases and packaging. MAPAX[®] concept takes into consideration:

- 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

MAP industrial infrastructure



Combining experience, research and knowhow 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 concept is based on close cooperation between the suppliers of the packaging material, the packaging machines and the gases. The purpose of this collaboration between suppliers is to be able to meet demands for an efficient and cost-effective packaging of foodstuffs, with consistent product quality throughout the entire distribution chain and ending as an attractive display in the chilled-food counter. The goal of this cooperation, by exploiting the advantages of MAP technology in the right way and by adapting methods to each application, is also to be able to offer solutions that make it possible for the manufacturer to develop new products for sale on new markets.

Linde works closely with food research institutes in many countries, e.g. SIK (Sweden), VTT (Finland), 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 has access to know-how dealing with how different bacteria are affected by the combination of temperature/atmosphere and other such parameters as permeability, a MAPAX solution can be offered that will ensure maximum microbiological security for each foodstuff.



Linde expert explaining MAPAX[®] concept to the customer

Practical experience gives confirmed safety solutions

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. For a number of years, Linde has had the advantage of accumulating experience and know-how from applications for which MAPAX[®] solutions for modified atmosphere has proved to be the answer. The collaboration with the food processing industry has contributed greatly to facilitating the choice of a suitable atmosphere and packaging material for individual applications.

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

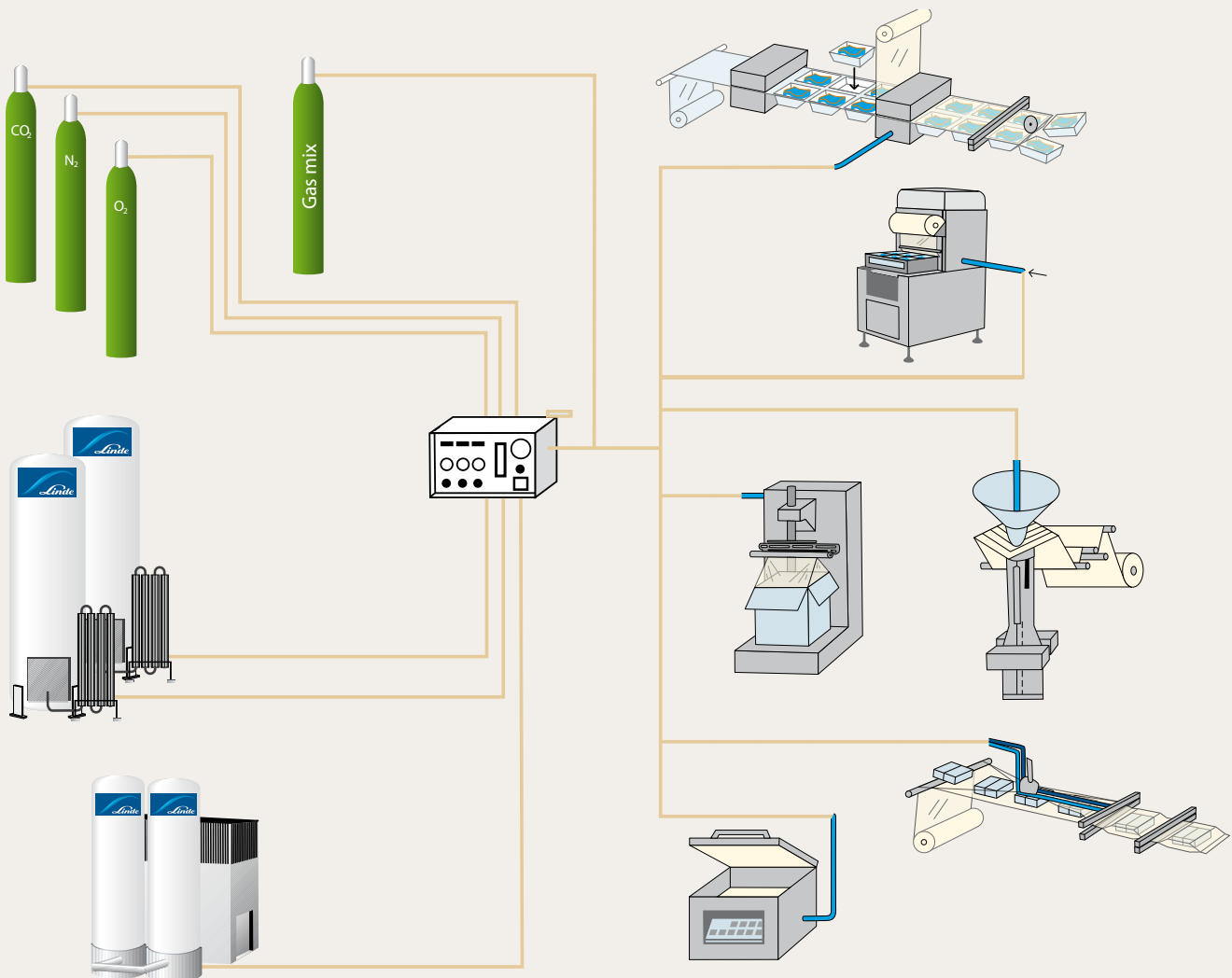
Food	Typical shelf-in air	Typical shelflife life with MAPAX® concept
Raw red meat	2-4 days	5-8 days
Raw light poultry	4-7 days	16-21 days
Raw dark poultry	3-5 days	7-14 days
Sausages	2-4 days	2-5 weeks
Sliced cooked meat	2-4 days	2-5 weeks
Raw fish	2-3 days	5-9 days
Cooked fish	2-4 days	3-4 weeks
Hard 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 2	weeks
Pre-baked bread	5 days	20 days
Fresh cut salad mix	2-5 days	5-10 days
Fresh pasta	1-2 weeks	3-4 weeks
Pizza	7-10 days	2-4 weeks
Pies	3-5 days	2-3 weeks
Sandwiches	2-3 days	7-10 days
Ready meals	2-5 days	7-20 days
Dried foods	4-8 months	1-2 years

Cost relations – Rules of thumb

Gas	machine	package	food			
1	:	5	:	10	:	100

The gas cost plays a small part in MAP

MAPAX® offers a complete menu of solutions



Keep it fresh



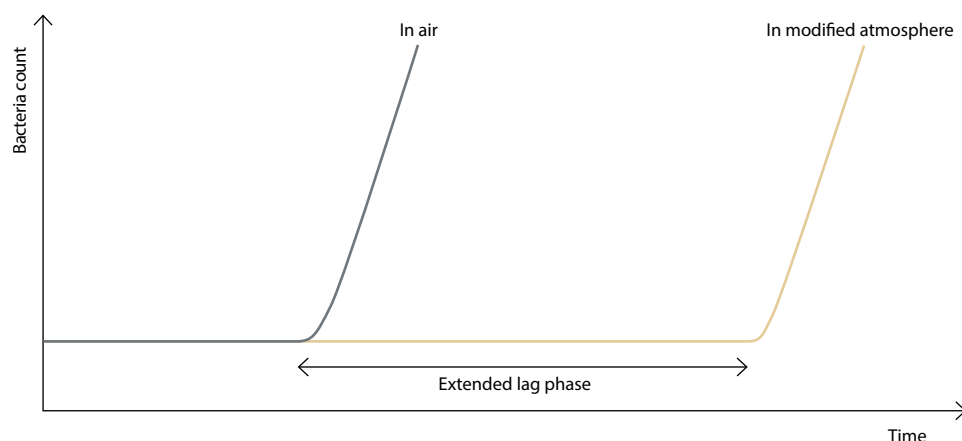




MAPAX® – best for meat and meat products.



The "lag" phase



Bacteria count according to 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 "log" 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 and therefore inhibiting bacterial growth during the "lag" phase, until the point when the inhibiting effects become insufficient to control the bacteria.

Recommended gas mixtures for meat and meat products

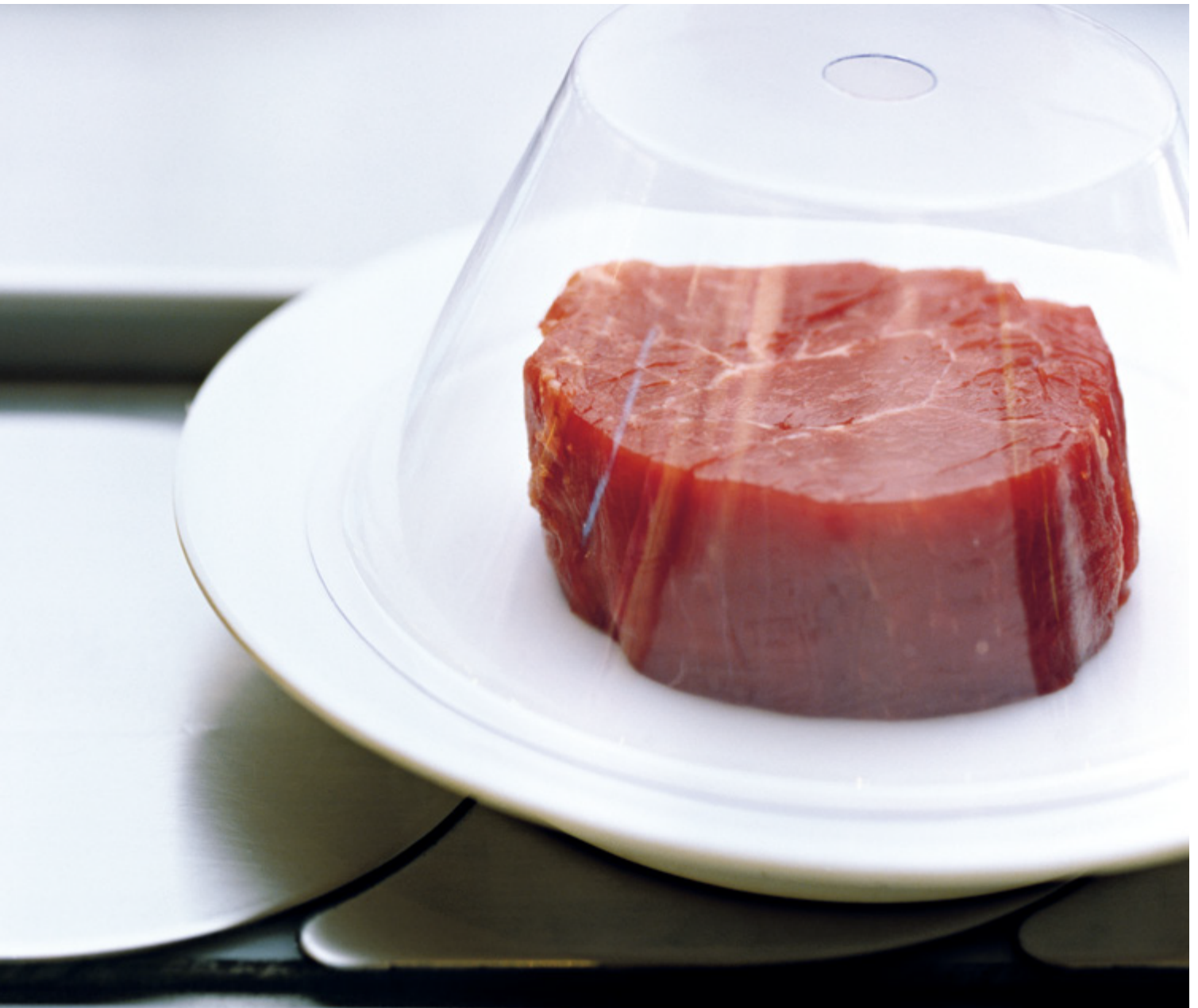
Product	Gas mixture	Gas volume Product volume	Typical shelf-life	Typical shelf-life	Storage temp.
			Air	MAP	
Raw red meat	60–80 % O_2 +	100–200 ml	2–4 days	5–8 days	2–3 °C
	20–40 % CO_2	100 g meat			
Raw light poultry	40–100 % CO_2 +	100–200 ml	4–7 days	16–21 days	2–3 °C
	0–60 % N_2	100 g meat			
Raw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

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 the 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 – is vitally important to minimize the contamination of the product with microorganisms.

Red meat requires oxygen

A special problem arises with red meat such as beef with regard to color 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 color 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

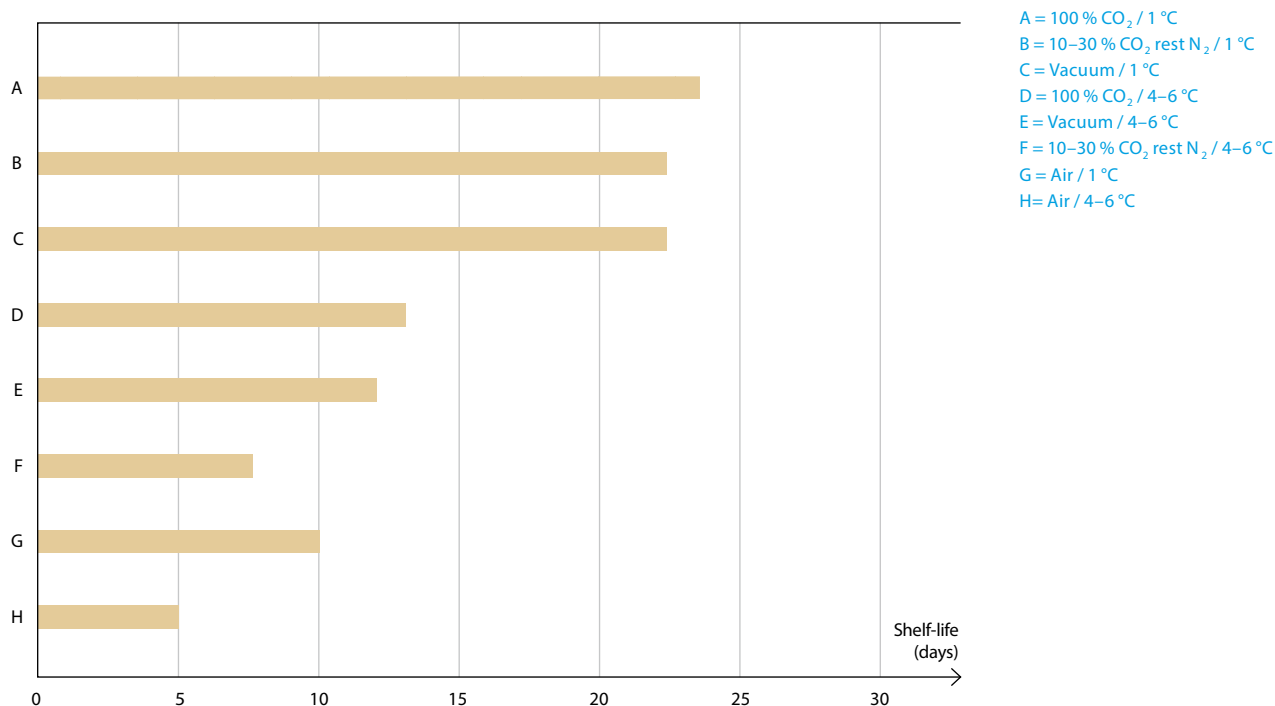
Generally speaking, carbon dioxide has a strong inhibiting effect on the growth of bacteria, of which the aerobic genus *Pseudomonas* presents the greatest problem for fresh meat.

MAPAX® packaging in modified atmosphere of chicken products

To meet customer demands for chicken that is fresh, easy to prepare and salmonella- free, one of the major chicken companies on the Swedish market started packaging a selection of their chicken products using a special BDF (Barrier Display Film) and Modified Atmosphere

Packaging for bulk packs of whole chickens and a wide range of natural and marinated ready-to-eat chicken products. In this technique, BDF is used to pack the chicken on a tray in a modified atmosphere. The trays then pass through a tunnel where the film shrinks around the packages, enclosing them in the modified atmosphere. This way MAPAX solutions not only increases shelf-life from about 4 days to nearly 21 days but also simplifies distribution, the packaged products look more attractive and customers find the fresh products easy to prepare for the table. For the company, the introduction of fresh products using MAPAX solutions has increased their competitive edge at home and has opened up possibilities for the export of their chicken products to other countries. As a result, they intend to convert their facilities to the production of fresh rather than frozen products.

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



One of the leading meat-processing companies in Poland is Balcerzak i Spółka Sp. z o.o. This is a very modern plant located in the western part of Poland, employing 700 people. They mostly serve the Polish market in cooperation with the largest supermarket chains, and also sell their goods to the EU and eastern markets. They are famous for their tasty, thin, dry smoked pork and poultry sausages. They have a very modern packaging department with 4 high-capacity packaging machines, and MAPAX solutions.

package some 65–70 different kinds of products in MAP, mostly sausages. 80% of the MAP-packaged products are prepared and offered as bulk packages, e.g. 1–3 kg of sausages in one unit, the remaining 20% are small, individual consumer packs. We also pack fresh raw meat in modified atmospheres.

Why did you start using MAPAX® concept in 1999?

In 1999 we packed only 3 product groups in modified atmospheres. Using this technology helped us to increase our sales dramatically. The reason for using MAP was, first of all, the market demand, especially from supermarket chains, for longer shelf-life, optimally organized production and transport, and better hygiene for packaged products. The economic factor is also important: water loss is reduced. What kinds of products do you pack in modified atmospheres? Nowadays, we



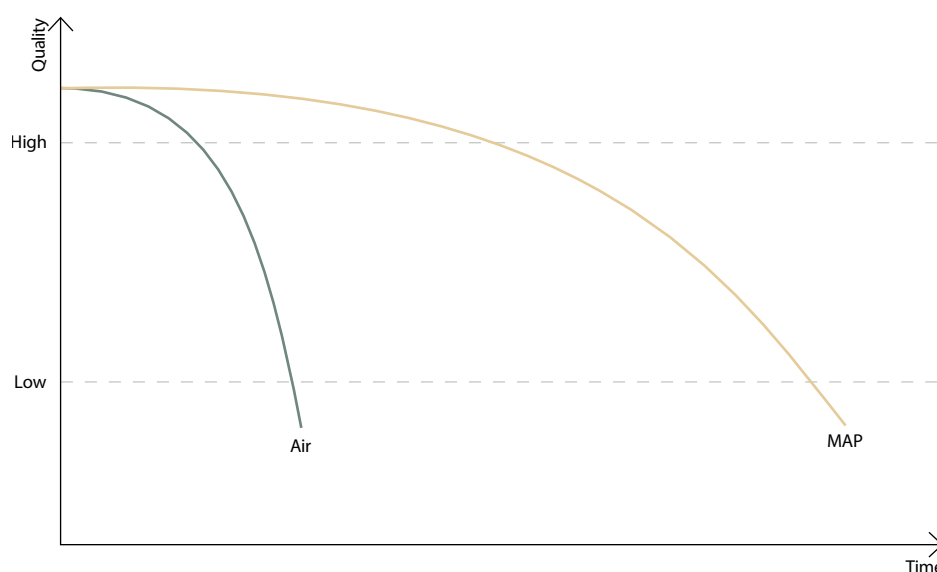
Marzena
Wojdanowicz,
Quality Manager,
Balcerzak i Spółka
Sp. z o.o., Poland



MAPAX[®] – best for fish and seafood.



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



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

Recommended gas mixtures for fish and seafood

Product	Gas mixture	Gas volume Product volume	Typical shelf-life		Storage temp.
			Air	MAP	
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
Cooked fish	30 % CO ₂ + 70 % N ₂	50–100 ml 100 g fish	7 days	30 days	0–3 °C
	Prawns (peeled, cooked)	40 % CO ₂ + 60 % N ₂	50–100 ml 100 g prod.	7 days	21 days

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 odors. The oxidation of unsaturated fats in high-fat fish such as tuna, herring and mackerel also results in an unappetizing 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 temperatures 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. One condition, naturally, is an unbroken chain of refrigeration. 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*. At levels above 20 % in sufficiently large package volumes, growth in fish is primarily inhibited because carbon dioxide reduces the pH-level of the tissue surface. The carbon dioxide concentration is normally 50 % in practical situations.

Depending on the storage temperature (0–2 °C), modified atmosphere packaging prolongs shelf-life by 3 or 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.

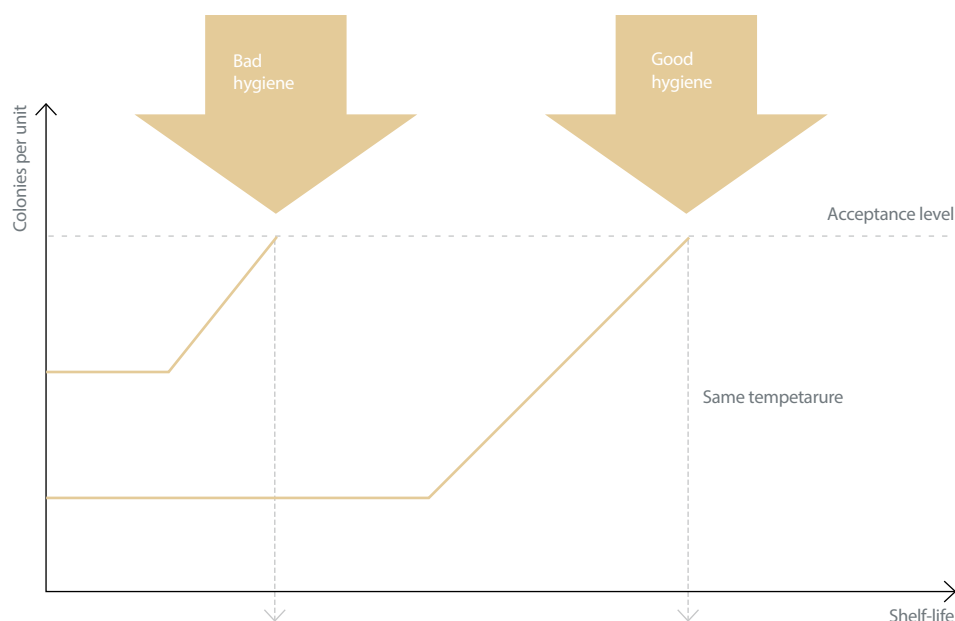


Oxygen keeps color

Oxygen can be used as a component of a modified atmosphere to avoid color 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 toxin. However, the risk of *Clostridium* growth in correctly modified atmosphere packaged fish with a short shelf-life 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 shelf-life of fish



Development of shrimp packaging

Linde works alongside some of the leading shrimp producers in Europe. After blanching and chilling and, in the case of brown shrimps, peeling, the shrimps are packed for chilled distribution to wholesalers throughout Europe. In order to be able to satisfy the demand for high-quality non-frozen fresh shrimps, the company replaced the use of preservatives and rather bulky bags by packaging solutions using MAPAX. Legislation was forcing the industry to minimize the use of preserva-

tives. Furthermore, the market wanted fresh shrimps packed in smaller consumer packs that were easier to handle, free from leakage and odor problems and with a much improved shelf-life. As a result of the change in packaging technique, the quality of the product has been raised and the consumer is presented with an attractive and more convenient product. The shelf-life has increased from one to three weeks. MAPAX solutions has also made it possible to develop a new range of products and has finally given the company an even better position within the tough European market.

Marian Seafood is owned by the Tine Norske meierier (National Dairies) and Norsk Kjøtt. It is a fairly young company with a small administration.

Marian's main targets are:

To supply the market with fresh fish by means of meal solutions which are time-saving, tasty and which support a healthy lifestyle.

To build up a segment of fresh seafood products by increasing access.

The fish types we package are cod, salmon and haddock, suitable for traditional home-cooked fish meals.

To encourage an even larger part of the population to eat fish on a regular basis, we supply spices/herbs and a sachet of ready sauce with the product as well as cooking suggestions suitable for each type of fish.

To ensure the required shelf-life for our products, we use the MAPAX concept from Linde, a member of the Linde Group. This involves the use of foodgrade gases in the correct mixture. The gas mixture is tailor-made to prevent unwanted microbial growth, as well as filling the package so that it retains a natural shape and looks good.

All these improvements to the fish product will benefit the consumer, who in turn will be able to buy absolutely fresh fish every day, packaged in gas and a super hygienic environment. With MAPAX solutions, our products reach a shelf-life of 10 days.

Technical features

Packaging machine: Polimoon,

Automatic tray-sealer

Tray: HDPE

Top film: PA/PE



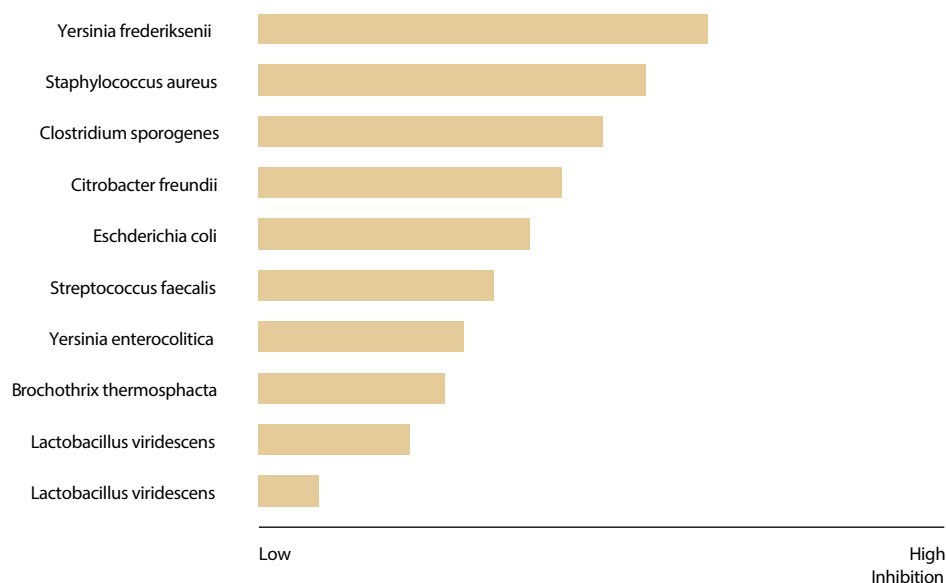
Per Simon Slettebø,
Director Marian Seafood,
Norway



MAPAX[®] – best for dairy products.



The effect of 100 % CO₂ on various bacteria



Microorganisms are inhibited to varying degrees by carbon dioxide

Product	Gas mixture	Gas volume Product volume	Typical shelf-life		Storage temp.
			Air	MAP	
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
Cooked fish	30 % CO ₂ + 70 % N ₂	50–100 ml 100 g fish	7 days	30 days	0–3 °C
	Prawns (peeled, cooked)	40 % CO ₂ + 60 % N ₂	50–100 ml 100 g prod.	7 days	21 days

Recommended gas mixtures for dairy products

Type of breakdown for dairy products

Microbial growth and rancidity are the primary causes of the 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 molds, whereas products with high water activity such as cream and soft cheeses are more susceptible to fermentation and rancidity.

Lactobacillus, which is much used in the dairy industry, 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.

Mold prevented by carbon dioxide

In the packaging of hard cheese, carbon dioxide is used first and foremost. It effectively stops or reduces microbial activity and helps to retain texture. Even carbon dioxide concentrations of just 20 % strongly affect the growth of mold 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 %. The reason for this is to prevent the package from collapsing under atmospheric pressure as the carbon dioxide dissolves into the water content.



MAPAX[®] packing of cheese slices

CO₂/N₂ 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 % N₂ and 50 % CO₂. The use of only 50 % CO₂ avoids package collapse.

Cultured products as a new application

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



MAPAX[®] packing of cheese slices in modified atmosphere

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

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 keeping out oxygen, nitrogen prevents rancidity and the growth of aerobic bacteria.

MAPAX[®] improves marketability of cheese slices

The advantages of MAPAX[®] concept can be clarified using the example of an important supplier of Dutch cheese and butter products in Holland. Cheese slices are packaged either individually or in packs of

up to 120 slices. When the company started packaging cheese slices, they used the best alternative available at that time, vacuum packing. But this method has a number of disadvantages, especially for cheese. Because there is no free space around the cheese, its aroma and taste does not develop, it takes on a rubbery look in the package and the slices are very hard to separate. The decision was therefore made to present customers with an attractive, high-quality product by converting the production lines to MAPAX[®] concept. The new technique ensured high quality during production, vastly improved the product appearance and extended its high-quality shelf-life. These factors led to greater market acceptance of the product and to an extreme increase in sales.

Based in the heart of Wisconsin's dairy industry, Alto Dairy Cooperative has a century of experience in manufacturing and marketing cheese. Alto's 975 member farms supply five million pounds of milk to their two cheese-making facilities each day. This milk is turned into consistently high-quality cheese products by Alto's skilled production team, and marketed throughout the United States. Alto Dairy produces over 550,000 pounds of cheese per day in two state-of-the-art facilities.

Quality in – Quality out

As part of Alto's mission statement, they vow to "provide top-quality natural cheeses and value-added by-products to the global market place" and to "develop state-of-the-art manufacturing plants." The best way to provide a high-quality product that will last through the chain of distribution is by using MAPAX[®] gas packaging solutions. With a modified atmosphere, the taste, texture, and odor of the product doesn't deteriorate, which is not true of other methods of extending shelf-life.

Since 1997, Linde, a member of the Linde Group, has been providing a constant supply of nitrogen to Alto's Waupun facility by means of an onsite generation plant, as well as effecting traditional bulk liquid nitrogen deliveries.

Application:

Modified Atmosphere Packaging

Product: Shredded cheeses – Cheddar, Mozzarella 3/4, 1, 2, 5, & 15 lb. sealed, clear plastic bags

Gas mixture: 70 % N₂, 30 % CO₂

Storage temp.: 40 °F (4 °C)

Residual O₂ level: Less than 0.5 %

Shelf-life: 30–90 days

Packaging machine: Hayssen Ultima (3 lines)



Pamela Ferch,
Alto Dairy, Alto,
Wisconsin, U.S.A.



MAPAX® – best for fruits and vegetables.





Recommended gas mixtures for fruits and vegetables

Product	Gas mixture	Gas volume	Typical shelf-life	Typical shelf-life	Storage temp.	
		Product volume	Air	MAP		
Lettuce	5 % O ₂ + 5–20% CO ₂ +	100–200 ml				
			2–5 days	5–8 days	3–5 °C	
		100 g prod.				
	75–90 % N ₂		2–5 days	6–11 days	3–5 °C	
	80 % O ₂ + 20 % N ₂					
Fresh cut	5 % O ₂ + 5–20% CO ₂ +	100–200 ml	2–5 days	5–8 days	3–5 °C	
salad mix	75–90 % N ₂	100 g prod.				
				2–5 days	6–11 days	3–5 °C
	80 % O ₂ + 20 % N ₂					
Pre-peeled	40–60 % CO ₂ +	100–200 ml				
potatoes	40–60 % N ₂	100 g prod.	0.5 hours	10 days	3–5 °C	

The permeability of packaging material is vital

Packaging material of the correct permeability must be chosen for the successful MAP of fresh fruits and vegetables. If the products are sealed in an insufficiently permeable film, undesirable anaerobic conditions (<1 % O₂ and >20 % CO₂) will develop with subsequent deterioration in quality. Conversely, if fruits and vegetables are sealed in a film of excessive permeability, little or no modified atmosphere will result and moisture loss will also lead to accelerated deterioration in quality. Examples of materials that can be used for MAP of fresh produce (fruits and vegetables) are microporous film or LDPE/OPP.

Optimal equilibrium modified atmosphere prolongs shelf-life

The key to successful MAP of fresh produce is to use a packaging film of correct intermediary permeability where a desirable equilibrium modified atmosphere (EMA) is established when the rate of oxygen and carbon dioxide transmission through the pack equals the produce respiration rate. Typically, optimum EMAs of 3–10 % O₂ and 3–10 % CO₂ can dramatically increase the shelf-life of fruits 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 is affected by the variety, size, maturity and intensity of produce preparation. Consequently, determining the optimum EMA of a particular item of produce is a complex problem that can only be solved through practical experimental tests.

Respiration rate – CO₂ production (ml kg⁻¹ h⁻¹)

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

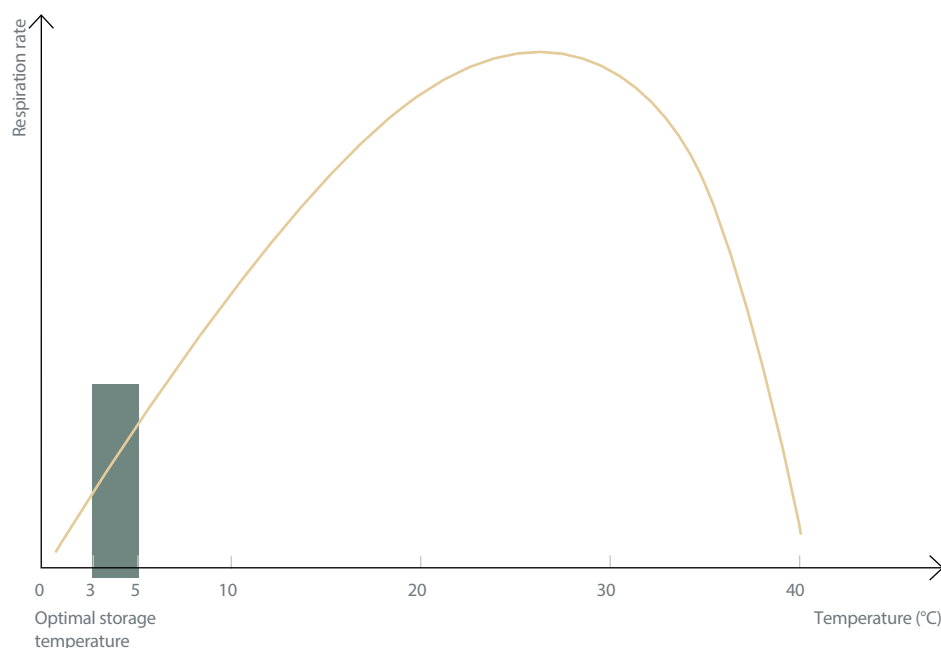
^amg CO₂ converted to ml CO₂ using densities of CO₂ at 0 °C = 1.98, 10 °C = 1.87, 20 °C = 1.77.

^bUnless stated, produce is whole and unprepared.

Classification of selected fruit and vegetables according to their respiration rate and degree of perishability in air and 3% O₂



Respiration rate depends on the temperature



Finding the right gas/packaging combination for fresh produce

The beneficial MAP of fresh produce can be attained by either sealing the produce in air or gas flushing with 3–10 % O₂ and 3–10 % CO₂ and 80–90 % N₂. 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 longer than with air packing. Practical experimental tests should be undertaken to demonstrate this. Different conditions may apply for peeled potatoes and apples, which should not be packed with oxygen because of enzymatic reactions that bring about brown discoloration. Pre-peeled potatoes, for example, can be packed in 40–60 % CO₂ + 40–60 % N₂ prolonging their shelf-life from 0.5 hours to 10 days at 4 to 5 °C.

DAUNAT S.A., a Breton company, produces sandwiches and mixed salads for the French market. It is the market leader with 62 million pre-packed sandwiches sold in 2001 under names such as “BISTRO VITE” and “DAUNAT”. There are two production sites located in Guingamp and Sevrey in Bourgogne, which develop mixed salads to meet customer needs and the requirements of market logistics.

High quality must be guaranteed at all stages in the distribution and sale of fresh products. For the last ten years, this company has been solving the problems linked to product preservation by using Modified Atmosphere Packaging. They selected machines, films and gas mixes. By using MAP, the products keep their high-quality freshness for periods from 8 to 15 days.

Respiration of fruits and vegetables

All unharvested plants respire, i.e. different organic compounds, mainly sugar compounds, provide energy to other life processes in the cells. This process needs oxygen. Air contains 21 % oxygen but the earth has a much lower concentration. When oxygen is available, the respiration is aerobic. Anaerobic respiration is an undesirable form of respiration which takes place without oxygen. 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 (O₂)
carbon dioxide (CO₂) + energy + water

The respiration rate is measured as generated ml CO₂/kg x hour or as used ml O₂/kg x hour.

Recipes for mixed fresh salads are complex and the right combination of packaging film and gas mix makes sure that the quality is maintained. MAPAX is the solution for preserving the quality and freshness of fruits and vegetables. Thanks to the MAPAX solution, you can find fresh produce in gas stations, fast food restaurants, supermarkets and vending machines.

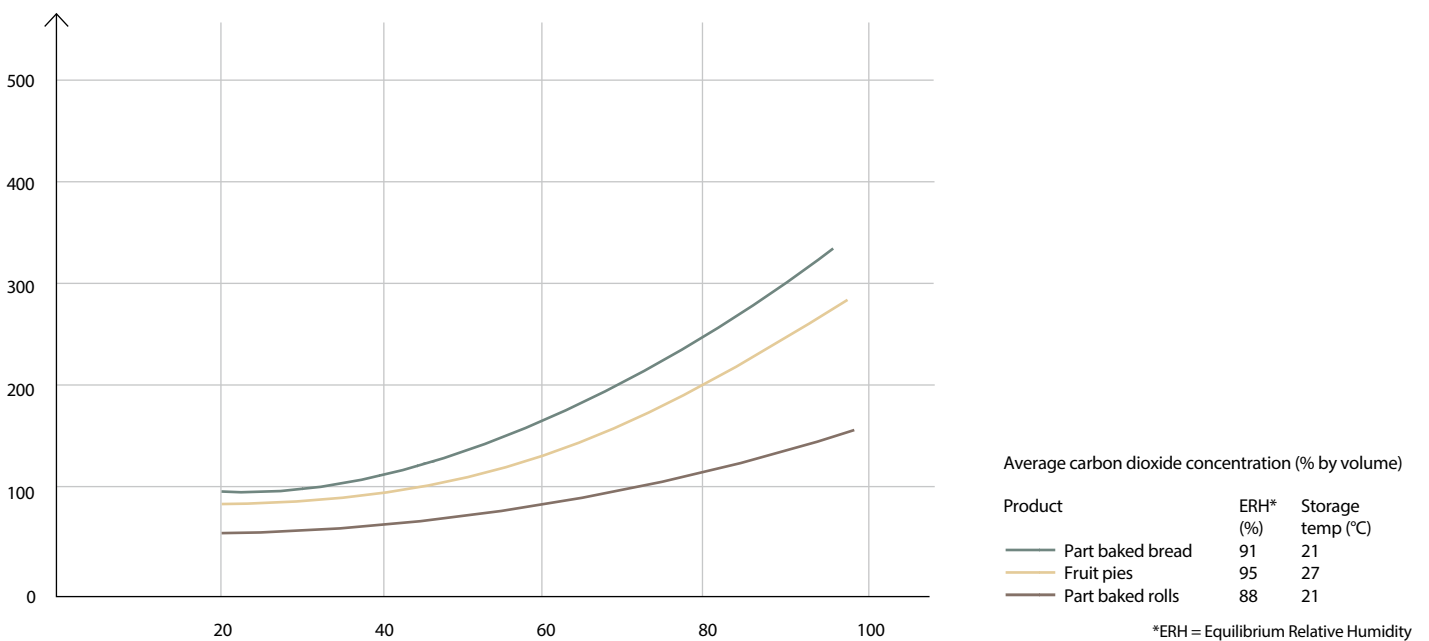
DAUNAT S.A.
Brittany, France



MAPAX® – best for dry foods and bakery products.



Increase in mold-free shelf-life (%)



Increase in shelf-life for different bakery products at various levels of CO₂ concentration

Recommended gas mixtures for dry foods and bakery products

Product	Gas mixture	Gas volume Product volume	Typical shelf-life	Typical shelf-life	Storage temp.
			Air	MAP	
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
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
Peanuts	100 % N ₂	50–100 ml	12 weeks	52 weeks	20–25 °C

Low residual oxygen important

Dry foodstuffs such as potato chips, peanuts, coffee and spices as well as powdered milk or potatoes and cocoa products contain more-or-less unsaturated fats. These products are therefore sensitive to oxidation and rancidity. High-quality shelf-life is therefore totally dependent on the oxygen concentrations in the packaging. Even small amounts of oxygen may destroy quality and make the products impossible to sell. Packages containing particularly sensitive dry foodstuffs such as powdered milk for babies should have oxygen levels of less than 0.2 %. The detrimental processes can be effectively inhibited by replacing the oxygen in the package with nitrogen or carbon dioxide or a mixture of the gases. One prerequisite for maintaining an optimum modified atmosphere is naturally that the package is provided with oxygen and moisture barriers. How the products were initially protected from oxygen is also decisive. It may be necessary to reduce the oxygen level in the processing of the product.

Carbon dioxide slows mold growth on bread

The main spoilage factors for bakery products are mold 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 mold is seldom a problem. To reduce the risk of mold and spore contamination, very good hygienic conditions are required, e.g. a clean room. Mold is an aerobic microorganism, it can be effectively controlled by carbon dioxide and low oxygen content, which subsequently extends shelf-life by many valuable days. MAP is especially suitable for rye bread, sweet bakery products and different pies. For Danish pastry 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.



Packaging of cakes in Brazil

A note on staling

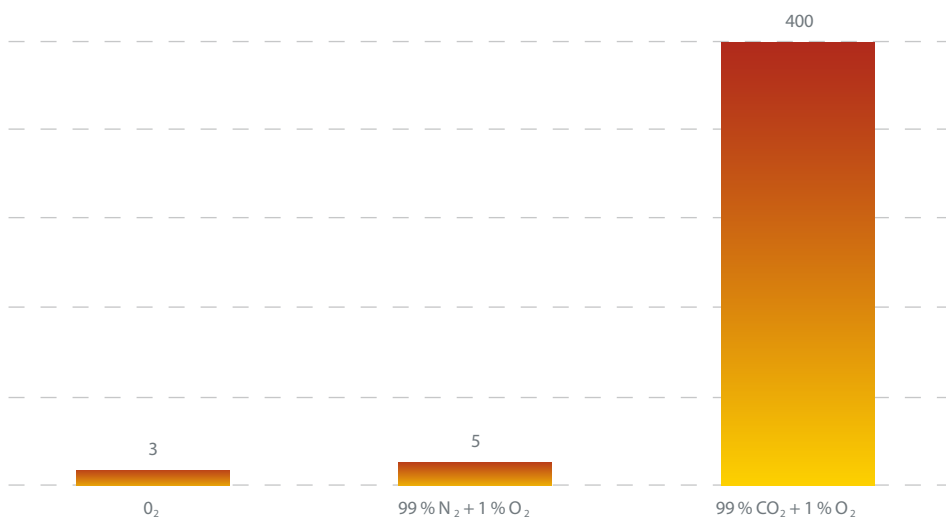
The use of MAP has little or no effect on the rate of staling. Staling is caused by starch retrogradation. Staling rates increase at chilled temperatures and therefore most bakery products eaten cold are normally stored at ambient temperature. For bakery products eaten hot, such as pizza bases, the staling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

Extending the geographical coverage with MAPAX[®] packaging in modified atmosphere

Linde Gas works together with customers all over the world. One good example of successful collaboration concerns a producer of high-quality cakes in Brazil. The company's goal was to launch different products

and flavors, and they also had to ensure the high quality of the products during distribution. This second point is of vital importance since Brazil is a large country and the intention is to expand to more distant regions. A safe method for coping with the huge distances and hot temperatures was found in MAPAX[®] solutions. Linde, a member of the Linde Group, was deeply involved right from the beginning, giving advice on gas mixtures and packaging films to provide extended shelf-life with the best possible product quality. In order to achieve these goals, Linde modified the Brazilian flow pack machine for use with MAP packaging, and developed the gas injection system.

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



KiMs Norway is a part of the Nordic snacks company Chips Scandinavian Company. It is the leading snacks company in the Nordic countries. The company is located in Skreia, north of Oslo. KiMs has approx. 70 employees and its main products are chips, peanuts and other snacks. The annual sales volume is 7,000 tons. The deep-frying process means our snack products contain a high fat percentage of vegetable oils (fat content 25–35 %) and are very prone to rancidity. To ensure high quality throughout the product’s shelf-life, it is very important to avoid sunlight and of course oxygen.

MAPAX® concept problem/solving

KiMs Norway use an OSS nitrogen supply system from Linde, a member of the Linde Group, for the domestic production of nitrogen in the MAP snack-packaging process. We work with a residual oxygen percentage of 1–3 %. MAPAX® concept gives us quality advantages for our products. We achieve better product quality throughout the storage period. It is very important for us to use the correct packaging material.

Technical features

KiMs Norway use the vertical Polaris packaging machine from Wood

man USA. Film: Laminated foil consisting of two layers of OPP where the inner layer is coated with a thin layer of aluminum. For this type of foil, packing with nitrogen ensures a sufficiently low residual O₂ level. The shelf-life is 9 months. When packaging nuts, we use a three-layer laminate of polypropylene, polyester and polyethylene. It gives a very good sealing quality. All nuts have a very high fat content, so again, they are very prone to rancidity when exposed to air. The residual O₂ level in the nut packets is 0.5 %. The high product quality remains very stable throughout the nuts’ shelf-life of 6 months.



Stein Rønne,
Quality Manager KiMs,
Norway

Cerealia Unibake Germany, based in Verden, Lower Saxony, is a member of the Scandinavian Cerealia group, the largest European manufacturer of deep-frozen bakery products. Under the well-known brand name Hatting, we produce not only an extensive range of frozen products for bulk consumers, but also fresh semibaked goods and deep-frozen bakery specialties for grocery retailers. The Cerealia Group with sales of more than 620 Million Euro, operates throughout Europe and Japan.

Cerealia Unibake Germany supplies grocery retailers with pre-baked baguettes, packaged in a protective atmosphere. This protective gas is taken from a tank system which guarantees a continuous supply. By using a protective atmosphere suited to our products, our aim is to increase shelflife without using chemical additives. In combination with

corresponding packaging material and good hygienic conditions, we supply our customers with firstclass products. This is in line with our global philosophy.



Jens Kasberek,
Technical Manager
Cerealia Unibake,
Germany



MAPAX® – best for prepared foods and catering.



Recommended gas mixtures prepared foods and catering

Product	Gas mixture	Gas volume Product volume	Typical shelf-life	Typical shelf-life	Storage temp.
			Air	MAP	
Pizza	30–60 % CO ₂ +	50–100 ml	1 week	3 weeks	2–4 °C
	40–70 % N ₂	100 g prod.			
Pasta	30–60 % CO ₂ +	50–100 ml	1 week	3 weeks	2–4 °C
	40–70 % N ₂	100 g prod.			
Sandwiches	30 % CO ₂ +	50–100 ml	2 days	10 days	2–4 °C
	70 % N ₂	100 g prod.			
Ready meals	30–60 % CO ₂ +	50–100 ml	4 days	21 days	2–4 °C
	40–70 % N ₂	100 g prod.			

Minimum growth conditions

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

Minimum growth conditions for selected microorganisms which may be associated with chilled MA packed foods

Prepared foods – a challenge due to variety of ingredients

The deterioration of prepared foods varies considerably with the product. 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; and sometimes also by staling – leading to rancidity, discoloration and loss of taste. A fresh pizza, for example, left out in the open air at 4 °C to 6 °C, is spoiled 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 affects deterioration rate

The relationship between carbon dioxide and nitrogen in prepared food packages mainly depends on the moisture content of the product, but also on the composition of the food. This determines the speed of microbial growth, oxidation and enzymatic activity. The higher the water activity, the higher the carbon dioxide concentration in the package.

The values in the table to the right are affected by the use of modified atmospheres. As described on pages 8–11, the use of modified atmospheres provides extra support in ensuring the safety of chilled food.



Multi-component products have special demands

Each product in the area of prepared foods represents a complex problem. Particularly difficult are such varying combinations 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 regarding the right gas mixture that will best inhibit deterioration and maintain quality. Modified Atmosphere Packaging is an important aid and safety measure, since prepared foods kept in the wrong environments can spoil very fast, for example in the case of food products with a neutral pH-value. Meeting the needs of the catering industry

The catering industry has always been

subject to demands for fresh, delicate and high-quality food. Therefore, last-minute production is very often required to fulfill these demands. In most cases, this is an inefficient and very expensive way to operate. By using MAPAX packaging in modified atmosphere in your kitchen or

production facilities, you will reduce stress to a minimum and be able to plan the next days or weeks of production in a very professional way. Well-organized food production coordinated with MAPAX solutions will clearly improve your economic efficiency in terms of man-power, give you better control over purchase, storage and a significantly longer shelf-life. The most common and beneficial way of using the packaging method in the 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 overtime 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 of the temperature, with regard to both the products and the packaging room. It is crucial to use only first-class foodstuffs and handle them as little and as carefully as possible.



MAPAX[®] concept for packing of sandwiches

Sandwiches packed using MAPAX[®]

Sandwiches are a complicated system where different items are placed on top of each other, for example dark bread with margarine, shrimps, mayonnaise, lemon, lettuce, parsley and red pepper, or baguette with margarine, ham, cheese, lettuce and red pepper, or dark bread with margarine, smoked salmon, scrambled eggs, lettuce and parsley. The

individual items influence each other because of the various conditions provided for bacterial growth. By packaging in MAP, the shelflife is extended by 5–7 days if the product is packed in 30 % CO₂ in N₂ at a storage temperature of 2–4 °C. Typical packaging material is PA/PE. The use of MAPAX[®] for packaging sandwiches makes it possible to prepare them in advance and thereby reduce the cost for preparing sandwiches in the evenings and at the weekends, for example.

Dedicated to traditional quality

The Netherlands have five producers of meal components for the main Oriental cuisines: Indonesian, Thai and Chinese. One of these is De Tropen at Rijswijk, supplier to famous names such as Martinair Catering, Golden Tulip Hotels, exhibition centres such as the Koninklijke Nederlandse Jaarbeurs and a national chain of department stores.

Every day, 15 specialists are kept busy creating some two tons of mainly Indonesian meal components for complete Indonesian “rice tables”. Managing Director Coorengel prefers not to pasteurize his dishes because of the loss of flavor. He decided on Modified Atmosphere Packaging with premixed gases (30 % carbon dioxide and 70 % nitrogen) to ensure that the quality is maintained right to the end of the use-by date for the almost ninety dishes that the company prepares. For this purpose,

De Tropen uses two tray sealers. Expansion plans? “Yes,” says Coorengel, “but in a controlled way and with no more than 25 staff. Next year I expect to achieve a daily production of 3 tons of quality Asian products, primarily through increased demand from existing clients. We currently supply only a limited number of the hotels that make up the Golden Tulip chain and the same is true of the department store chain. I already know that the number of branches is due to increase significantly in the next twelve months.”

Jelle Coorengel,
Managing Director
De Tropen,
Rijswijk, The Netherlands

FAQ – Frequently Asked Questions.

Food

How far can I extend the shelf-life of my products by using a 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 booklet for MAPAX solutions.

Can I freeze a product which is packed in a modified atmosphere?

Yes – but during thawing the product will lose a lot of liquid and will not look very appetizing if it remains in the sealed package. Make sure the packaging material is suitable for freezing.

There is a white substance on the sausage that can easily be wiped off. What is it?

These are calcium compounds or salt (not table salt) which come(s) from the product and an excessively high residual oxygen level. Control the residual oxygen level and feel free to contact your local application engineer for help with the measurements.

There are some pale gray, almost white spots on the smoked sausage. The sausage is 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 goes along with 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.

Which gas or gas mixture can prevent the greenish coloring on the ham I produce?

This greenish coloring is caused by bacteria grown naturally during processing. There is no gas or mixture which can change this afterwards.

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

The myoglobin molecule, which is responsible for the color of meat and meat products, turns different colors with different gases. For recommendations relating to the correct gas mixture, see the chapter MAPAX – best for meat and meat products.

The sliced meat product we pack under MAP turns gray. Sometimes only spots on the meat have different colors. 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 the BIOGON family are controlled constantly and the wrong labelling or filling of a cylinder is almost impossible. The gray 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 and no longer matches the light exposure, additives could have been changed or the

process could have been altered. Even the 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 MAP packages?

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 minimize the problem.

When I open the food package, I can smell a specific odor. How can we explain this?

In most cases when food is properly stored, this is a normal phenomenon. Each product generates its own odor 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/maturing/aging of meat?

Meat can be successfully ripened in mixtures of CO₂ and N₂. The mixture depends on the type of meat and how it is cut.

Gas

Which gas mixture should I use?

It depends on the type of food product, the shelf-life you need and the user of the product. For specific information, refer to the booklet for MAPAX solutions 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 flow-meter and various piping considerations. It is recommended to start with the premixed 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 proportions 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 flow into 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 work with your local Linde representative to know when it is the appropriate time to switch from cylinders to a bulk tank operation.

What about safety for the use of gases?

We provide information and training on safety by means of meetings and documentation (security paper). Each country has its own security regulations for the use of gas. These regulations must be followed and integrated into your quality systems.

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

Please contact the machine supplier to check whether the machine is suitable for operation with high oxygen gas mixtures. The machine has to be equipped for high oxygen use.

What are the functions of different gases?

The most important gas is CO₂, since it delays the growth of microorganisms by dissolving into the food. N₂ is used to replace O₂ and thereby decrease deterioration. It is also used as a buffer gas. O₂ is used to keep the red color of meat and for the respiration of fruits 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, labelling and handling of food-grade gases as additives.

Packaging

Does the package have to be labelled with the information "MAP packaged"?

That depends on regional regulations. For the EU countries, if the durability of a food has been extended by being packaged in a permitted packaging gas, it must be marked by the words "Packaged in a protective atmosphere".

What head space (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 antifogging 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.

The packages blow up over time. Is the product fermenting?

This is nearly always the CO₂ which is generated by the product. It 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 CO₂ through natural fermentation; this process can sometimes continue after packing and cause an unwanted "blow-up". 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. CO₂ 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 CO₂ 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 on mixture and residual O₂ level. It is important to establish good routines in this matter to avoid large amount of produce being packed with an incorrect result. Your Linde application engineer will assist you by choosing the 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 are 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.

Glossary.

Acinetobacter

A genera of common food-borne bacteria. They are classified as aerobic Gram-negative short rods.

Active packaging

Active packaging employs a packaging material that interacts with the internal gas environment to extend the shelf-life of the food. Such new 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 completely 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® food grade gases

BIOGON® is the trademark for foodgrade gases.

CA

Controlled Atmosphere.

Carbon dioxide

CO₂ has a slightly acidic odor. 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 which the bacteria are 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.

CPU

Amount of microorganism measured as colonies per unit.

EMA

Equilibrium Modified Atmosphere.

Enzymatic reaction

Chemical reactions catalyzed 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.

HACCPA

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 nonmotile, non-sporulating bacteria that produce lactic acid as a major or sole product of fermentative metabolisms. All rodshaped lactic acid bacteria are placed in one genus called Lactobacillus.

MAP

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

MAPAX® solutions for packaging in modified atmosphere

A tailor-made MAP solution based on data about the food, the gases and the packaging.

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 onsite 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.

Moraxella

A genus of aerobic Gram-negative rod or coccoid-shaped bacteria that are present in the mucous membranes of man and/or animals.

Mold

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 color of the meat.

Nitrogen

N₂ is an inert gas with low solubility in water. Air contains approximately 78 % nitrogen.

Nitrous oxide

N₂O dissolves easily in liquid. It is mainly used for whipping cream.

Nutritional content

Expresses the amount of nourishing compounds, e.g. carbohydrates, fats, proteins and vitamins.

Oxidation

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

Oxygen

O₂ 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 rodshaped bacteria, ecologically important in soil and water owing to their large capacity for the mineralisation of 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 product user.

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

aw. The ratio of the water vapour pressure of a material to the vapour pressure of pure water at the same temperature.

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Getting ahead through innovation.

With its innovative concepts, Linde is playing a pioneering role in the global market. As a technology leader, our task is to constantly raise the bar. Traditionally driven by entrepreneurship, we are working steadily on new high-quality products and innovative processes.

Linde offers more. We create added value, clearly discernible competitive advantages and greater profitability. Each concept is tailored specifically to meet our customers' requirements – offering standardized as well as customised solutions. This applies to all industries and all companies regardless of their size.

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