# Your in-depth guide to Modified Atmosphere Packaging

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# Freshline® food solutions for Modified Atmosphere Packaging

Welcome to the Air Products one stop guide to Modified Atmosphere Packaging (MAP). In this handbook you'll find all you need to know about the most effective methods of increasing shelf-life, preserving quality and improving packaging presentation.

MAP has helped many food manufacturers and processors to realise the benefits of using gas mixtures to improve the shelf-life, or enhance the appeal, of many food segments.

Please do not hesitate to contact one of our dedicated MAP specialists on 0800 389 0202 and 1800 99 50 29 or email apukinfo@airproducts.com and ieinfo@airproducts.com

# Ingredients

# Why Air Products?

Air Products is one of the leading industrial gas companies in the world. With customers in healthcare, technology, energy, and industrial markets worldwide. The food processing industry is one of our key areas of expertise.

Founded in 1940 we've become widely recognised for innovation, operational excellence and commitment to safety and the environment.

Our team of experts cares about our customers, supports them and enables their growth with new solutions, building long lasting relationships.

**Air Products Campus UAB Matgas building**
08193 Bellaterra, Barcelona, Spain
T. +34 93 592 9955

At Air Products, we work closely with food research centers and institutes in many countries. In addition we have our own R&D laboratory in the food preservation area, giving services to all Europe.

Thanks to that our MAP specialists can work with you to trial and test your food products to develop the appropriate solution for your requirements. Furthermore, we also collaborate closely with the suppliers of machines and packaging materials to identify the correct gas mixture for each food product.

## Research acknowledgments

**Air Products gratefully acknowledges the advice, assistance and information provided by IRTA and Campden BRI.**

### IRTA – Research & Technology Food & Agriculture

IRTA is a Research Institute owned by the Government of Catalonia. Its purpose is to contribute to the modernization, competitiveness and sustainable development of agriculture, food and aquaculture sectors; the supply of healthy and quality foods for consumers; and generally improving the welfare of the population.

IRTA and Air Products have been collaborating since 1996 on research, development and technology transfer in areas related to agri-food. In April 2013 both institutions signed a Framework Collaboration Agreement in order to deepen their scientific and technical relations with the intention of increasing efforts and to develop together research projects and technology transfer in the agri-food sector.

**IRTA**

Torre Marimon

08140 Caldes de Montbui, Barcelona, Spain

T. 902 789 449

irta.cat

## Campden BRI

Campden BRI is the largest membership-based food and drink research centre in Europe. It provides the range and quality of technical and support services you would expect of a world class organisation. It undertakes research and development for the many industries associated with agriculture, food and drink manufacture, distribution, retailing and food service.

As an independent organisation, Campden BRI is able to invest in technologies, skills and quality management systems to the benefit of the whole food and drink sector, and has achieved 9001 certification for all UK activities. Many of the technical services are UKAS accredited.


**Campden BRI**
Chipping Campden, Gloucestershire GL55 6LD
T +44(0)1386 842000
F +44 (0)1386 842100
information@campdenbri.co.uk
campdenbri.co.uk

## Acknowledgements

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# Freshline® equipment and services for the food industry

When it comes to Modified Atmosphere Packaging, cooling, chilling, freezing and wastewater treatment, no one has more experience in the field than Air Products.

In 1965 we helped pioneer liquid nitrogen technology for ultra-fast cryogenic freezing.

Since then, Air Products has been supplying quality gases, gas enabled freezing or chilling equipment and technical services to the food industry around the world. Through continuous research and development, we will work closely with you to find the systems that precisely fit your requirement.

To find out more about the broad and flexible range of applications and equipment Air Products has developed for your industry, please visit our websites:

**airproducts.co.uk/food**
**airproducts.ie/food**

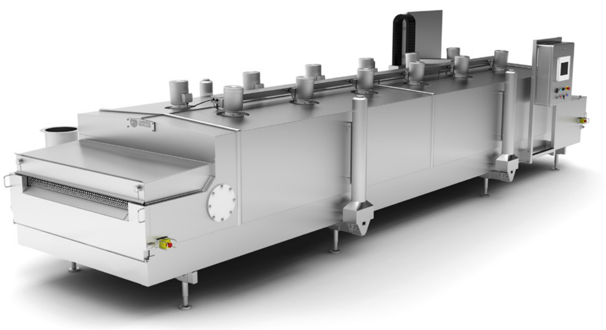
## What is cryogenic freezing?

Freezing techniques have developed through time and traditional mechanical or blast freezers, which are still the most widely used systems, are now positioned alongside newer technologies that have a number of advantages over their predecessors. Cryogenic freezing is one of them. Cryogenic freezing consists of using extremely cold liquid nitrogen or carbon dioxide to freeze different types of products very quickly.

### Why use cryogenic freezing?

In industrial food production processes, cryogenic freezing has considerable advantages, such as:

- Significant reduction in freezing time
- Reduction in the size of the ice crystals
- Reduction in weight loss caused by dehydration
- Reduction in enzyme and oxidative deterioration
- Increase in quality and improvement in the texture
- Improvements to the appearance and colour
- Microbial stability
- Flexibility in production
- Low financial investment
- Reduction in space taken up by the equipment



## Freshline® Superfresh solutions

Combining the best of two worlds for healthy chilled or frozen products that stay fresh for even longer.

Through systematic scientific studies the Air Products R&D team has developed a proven method which optimises the synergetic effect of combining cryogenic freezing and Modified Atmosphere Packaging to extend the shelf-life of your products. The studies have demonstrated that this methodology effectively delays the different aspects of food deterioration after thawing periods. This process can help you:

- Enter new markets
- Save costs by dealing with seasonality or supply chain constraints
- Extend your product's shelf-life
- Reduce waste and reach your sustainability targets.

The process can be applied to various types of products, which can then be sold frozen or chilled. Also, when thawed in the right conditions it allows a "can be refrozen" claim to be used for all the products tested until the editing of this booklet.

# Freshline® Modified Atmosphere Packaging solutions

Freshline® MAP solutions is more than a range of pure Food Grade gases, it is a complete service to the industry, offering access to gases, services and technologies that reflect Air Products' continuing commitment to its customers. The benefits of Freshline® MAP solutions include an online food selector, that ensures producers and retailers use the optimum gas mixtures for different products, and a team of on-the-road specialists who bring advice and analysis direct to your premises.

For advice and information on all aspects of MAP,
please call us on 0800 389 0202
and 1800 99 50 29
or email apukinfo@airproducts.com
and ieinfo@airproducts.com.

**airproducts.co.uk/food**

## What is MAP?

Once a fruit, vegetable or animal product is harvested or slaughtered it remains in a suitable environment for bacteria which continue to function using the available carbohydrate, protein, fat and nutrients. These continuing processes lead to degradation including undesirable colour changes, loss of flavour and poor texture. The action of enzymes also causes deterioration of foods.

Modified Atmosphere Packaging is a shelf-life extension technique. MAP is food packaging in which the earth's normal breathable atmosphere has been modified in some way.

Usually combined with lowered temperatures, it is a highly effective method for extending the shelf-life of food. Shelf-life can be prolonged in some applications by creating a simple vacuum in the package (vacuum packaging) and in these cases there is almost a complete absence of gas. In others, special permeable films allow naturally respiring produce to form its own atmosphere without the addition of external gases.

In Europe, MAP mainly involves the use of three gases — carbon dioxide, nitrogen and oxygen, although other gases are used where regionally acceptable. Products are packed in a single gas or a combination of these three gases depending on the physical and chemical properties of the food.

## Why use MAP?

- Extension of shelf-life
- Minimisation of waste
- Quality
- Increased distribution possibilities
- Reduced need for artificial preservatives

## Extension of shelf-life

Depending on the product, shelf-life can be usefully extended by between 50% and 500% using MAP techniques.

## Minimisation of waste

Having a greater shelf-life available enables a store to order more efficiently and to reduce wastage.

## Quality

There are obvious quality advantages for both retailer and consumer in having food that deteriorates at a much slower rate on its journey from production area to store, and then onward to the domestic kitchen, refrigerator or freezer.

## Increased distribution possibilities

Because of the extended product shelf-life, increased distribution is one of those areas in which the introduction of MAP is more than just "another benefit". For companies with the right product, the potential to increase the range of delivery can produce exciting changes and opens the door to a global market.

## Reduced need for artificial preservatives

In a world which is becoming increasingly "green" in its outlook, a world where every consumer is a watchdog for the environment, there are points to be earned by the retailer who can get rid of as many additives as possible to have a clean label and show that its food is basically fresh and natural.

## MAP gases — the basics

Freshline® MAP describes the gases, gas mixtures and services that bring the benefits of Modified Atmosphere Packaging to food manufacturers and suppliers. Freshline® Food Grade gases from Air Products are a range of high purity gases delivered either as a liquid in stainless steel microbulk or bulk containers, or as a gas in high pressure cylinders or onsite gas generation, all dedicated for use only in the food industry. Selecting the correct mixture of gases for MAP is not always simply a matter of choosing a combination that is proven to provide the longest shelf-life.

MAP of red meat demonstrates the balancing act that retailers are sometimes obliged to carry out in order to squeeze the best results from this technology. Once it is accepted that it can, in certain cases, make economic sense to sacrifice some shelf-life to ensure an enhanced visual appearance it is then necessary to establish which mixtures produce the best results for each different product.

## Effects of each gas on food products

MAP gases are food additives authorised by the EU according to the Commission Regulation (EU) No 1130/2011.

### Carbon dioxide ($CO_2$) (E 290)

Carbon dioxide inhibits the growth of most aerobic bacteria and moulds. Generally speaking, the higher the level of $CO_2$, the longer the achievable shelf-life. However, $CO_2$ is readily absorbed by fats and water—therefore, most foods will absorb $CO_2$. Excess levels of $CO_2$ in MAP can cause flavour tainting, drip loss and pack collapse. It is important, therefore, that a balance is struck between the commercially desirable shelf-life of a product and the degree to which any negative effects can be tolerated. When $CO_2$ is required to control bacterial and mould growth, a minimum of 20% is recommended.

### Nitrogen ($N_2$) (E 941)

Nitrogen is an inert gas and is used to exclude air and, in particular, oxygen. It is also used as a balance gas (filler gas) to make up the difference in a gas mixture, to prevent the collapse of packs containing high-moisture and fat containing foods, caused by the tendency of these foods to absorb carbon dioxide from the atmosphere. For Modified Atmosphere Packaging of dried snack products 100% nitrogen is used to prevent oxidative rancidity.

### Oxygen ($O_2$) (E 948)

Oxygen causes oxidative deterioration of foods and is required for the growth of aerobic micro-organisms. Generally, oxygen should be excluded but there are often good reasons for it to be present in controlled quantities including:

- To maintain fresh, natural colour (in red meats for example)
- To maintain respiration (in fruit and vegetables)
- To inhibit the growth of anaerobic organisms (in some types of fish and in vegetables).

### Safety note

Oxygen should not be used in concentrations over 21% unless the packaging machinery is compatible.

### Argon (Ar) (E 938)

Argon has the same properties as nitrogen. It is a chemically inert, tasteless, odourless gas that is heavier than nitrogen and does not affect micro organisms to any greater degree. It is claimed to inhibit enzymic activities, microbial growth and degradative chemical reactions (CCFRA R&D Report 125). Hence it can be used in a controlled atmosphere to replace nitrogen in most applications. Its solubility (twice that of nitrogen) and certain molecular characteristics give it special properties for use with vegetables. Under certain conditions, it slows down metabolic reactions and reduces respiration.

Work carried out by Air Products has shown that argon demonstrates some properties, which are beneficial to the MAP process; however, the argument for replacing nitrogen with argon is marginal, especially when the additional costs of the gas and associated piping are taken into account.

## Other gases:

Gases non authorised as food additives for MAP according  to the Commission Regulation (EU) No 1130/2011.

### Carbon Monoxide (CO)

Carbon monoxide is a toxic, colourless, odourless, flammable gas. It is stable at up to 400°C with respect to decomposition into carbon and oxygen. Results have shown that the use of carbon monoxide (CO) in MAP with high levels of $CO_2$ has resulted in increased shelf-life together with retention of the bright red colour of meat cuts. The use of CO in MAP is not allowed in Europe.

### Ozone ($O_3$)

Ozone gas is an unstable form of oxygen which has been noted for its oxidising and disinfecting properties and use in the preservation of food. It can only be delivered safely up to about 15% concentrations in air or oxygen, having only a half life of 20min in clean water. One of its major benefits is that it will break down to harmless elemental oxygen. Because of its instability it is generated onsite from clean air or oxygen close to where it is required.

The application of ozone gas in MAP, to improve both shelf-life and safety, has been the focus of much research. But a successful offering is limited due to ozone's non-specific oxidising capacity and short life. This means it is just as likely to attack the pack as the microbial contaminants, and any effect will be only for the first few minutes of the pack's life. After this, the ozone will have reacted, leaving slightly higher oxygen content. Too much ozone can cause pack damage or discolouration, and may oxidise the surface of the product causing the release of nutrients which will encourage growth of the organisms you are trying to control.

*Sorheim, O., Nissen, H., Aune, T. and Nesbakken, T. (2001) Carbon monoxide in meat packaging. *Business Briefing Foodtech.*

## What is shelf-life?

The shelf-life of a product is the time after production during which it remains acceptable for consumption. The end of the shelf-life is, therefore, the point at which it becomes unacceptable.

A more detailed definition (IFST, 1993) of shelf-life is the time during which the food product will:

- Remain safe
- Be certain to retain desired sensory, chemical, physical and microbiological characteristics
- Comply with any label declaration of nutritional data when stored and handled under the recommended condition

## What influences shelf-life?

The shelf-life will be influenced by many aspects of Good Manufacturing Practice (GMP) and product formulation, e.g. pH (acidity), salt level or water activity and preservatives. Combinations of these factors are often used together to achieve stability, known as hurdle technology.

It is recommended that product shelf-life is determined by following a Shelf-life Evaluation Sequence as described in Campden BRI Guideline No 46. The process involves a logical sequence from product concept to full scale production and it is important to identify early in the sequence what characteristics of the food and method of production and storage, will influence the shelf-life. For example, factors to consider include:

- Raw materials
- Product formulation
- Processing
- Packaging, including gas atmosphere
- Hygiene
- Distribution
- Storage
- Consumer handling

These factors exert their effects on microbiological, chemical and physical parameters within the food, which often result in a loss of sensory quality. The point at which these effects influence the product, such that the change becomes noticeable or the product unacceptable is the endpoint. It is the time taken to reach the end-point that has to be determined when assessing product shelf-life. The packaging format often has a significant influence on the acceptable, durable life of chilled foods. Consideration needs to be given, particularly to products designed as multiportion or bulk commodity packs, to the effect of opening the pack on product durability. It may be necessary to qualify any shelf-life coding (Use By/Best Before) with clear instructions on the packaging limiting the time available from opening to consumption and indicating, where necessary, any specific handling instructions to the consumer.

## End of shelf-life

For most perishable chilled food products, the end-point will depend on a number of factors. In some cases, the end-point may be defined by levels of micro-organisms present based on recommended guidance (HPA, 2009; IFST, 1999). In other cases, the end of life may be determined by sensory or biochemical deterioration. The emphasis on the specific end-point criteria will vary between different products and must be defined during the shelf-life evaluation process.

## Shelf-life testing methods

There are a number of methods for determining the shelf-life of different food products including microbiological, chemical and sensory evaluation. Different factors will affect the end of shelf-life depending on the product, packaging and conditions surrounding the product. Shelf-life testing can be carried out during development and pilot scale production of the product but should always be carried out once full scale production has been reached.

### Microbiological testing

The type of product and gas mixture used will influence the growth of specific groups of micro-organisms. Packing in an oxygen free environment will allow anaerobic organisms to grow whereas products packed in the presence of oxygen will permit the growth of aerobic micro-organisms. Sampling should be carried out regularly during shelf-life testing on a minimum of three to five samples per sampling date per pack format.

### Biochemical testing

Colorimeters can be used to measure colour changes with different food products. A colorimeter may pick up slight changes not noticed by the human eye. Chromatography can be used to measure changes of the volatile compounds in the food product during storage. Changes in nutritional content can be measured during shelf-life to determine if there are any significant changes.

### Sensory evaluation

There are a number of different formats for carrying out sensory evaluation on products. The product can be assessed for appearance, odour, texture and flavour to determine end of shelf-life. Specific individual attributes of the product such as ripeness, degree of fermentation, juiciness, strength, acidity and moistness can be observed by trained sensory assessors.

## Microbial spoilage

Micro-organisms not only discolour food, rot it, and make it offensive to smell and eat—they can also present serious public health hazards.

Micro-organisms present in a food product originate from either the raw materials and ingredients or from contamination. The means by which such micro-organisms cause spoilage are varied and depend on the organisms present and the food product on which they are growing. The ability of these organisms to grow and cause spoilage in the product is dependent on the intrinsic properties of the food and the extrinsic factors applied to the food. Examples of microbes include Pseudomonas species and Acinetobacter/ Moraxella species which cause off odours and flavours; Lactobacillus species and Streptococcus species cause souring; and Escherichia coli causes gas formation. Visual spoilage of microbial origin can take a variety of forms, including discolouration, pigmentation, surface growth, cloudiness and rotting.

## Chemical and biochemical spoilage

When animal or vegetable material is removed from its natural source of energy and nutrient supply, chemical changes begin to occur which lead to deterioration in its structure. These changes can be slowed using MAP techniques. For example, unsaturated fats and oils tend to combine with oxygen in the atmosphere. In some fatty foods, this oxidation can lead to rancidity development - a process that can be slowed with good effect if the food is packaged in a low oxygen atmosphere.

## Four types of micro-organisms that can be controlled by MAP

Bacteria, yeasts and moulds have different respiratory and metabolic needs and can be grouped into four types, according to their oxygen requirement for metabolic and growth processes.

- **Aerobic Microbes** – require oxygen or air for respiration and growth, e.g. Pseudomonas species, some Bacillus species, Acinetobacter/Moraxella species, Micrococcus species, film yeasts and moulds. Therefore some control of these organisms can be obtained by excluding oxygen from a pack.
- **Anaerobic Microbes** – do not require oxygen or air to grow and many are inhibited or killed by the presence of small quantities of oxygen, e.g. Clostridium species.
- **Microaerophilic Microbes** – require low levels of oxygen for optimum growth. Some also require increased levels of carbon dioxide for optimum growth, e.g. Campylobacter and Lactobacillus species.
- **Facultative Anaerobic Microbes** – can respire and grow with and without the presence of air or oxygen, e.g. Escherichia coli, Staphylococcus aureus, Listeria monocytogenes, Brochothrix species, Salmonella species, Vibrio species, fermentative yeasts and some Bacillus species.

# Minimum growth conditions of selected micro-organisms

This table lists various species and indicates approximate growth and survival limits with the various other factors being optimal, e.g. minimum growth temperatures are for growth in optimal neutral pH, high $a_w$ (water activity) microbiological media.

| Micro-organism | Minimum pH for Growth[1] | Minimum $a_w$ for Growth[2] | Anaerobic Growth (e.g. in vacuum pack) | Minimum Growth[1] Temp °C |
|---|---|---|---|---|
| Aeromonas hydrophila | <4.5[3] | 0.97 | Yes | –0.1 |
| Bacillus cereus | 4.4 | 0.93 | Yes | 4 |
| Campylobacter species | 4.9 | 0.987 | No[4] | 30.5 |
| Clostridium botulinum | | | | |
| Proteolytic A, B, F | 4.6 | 0.94 | Yes | 10 |
| non-proteolytic B, E, F | 4.7 | 0.97 | Yes | 3.3 |
| Clostridium perfringens | 4.5 | 0.93 | Yes | 12 |
| Escherichia coli | 4.4 | 0.935 | Yes | 7–8 |
| Lactic acid bacteria e.g. Lactobacillus | 3.5 | 0.90 | Yes | 4 |
| Listeria monocytogenes | 4.3 | 0.92 | Yes | –0.4 |
| Pseudomonas species | 5.0 | 0.97 | No | 0 |
| Salmonella species | 3.8 | 0.92 | Yes | 4 |
| Shigella species | 4.8 | 0.96 | Yes | 6 |
| Staphylococcus aureus | 4.0 | 0.83 | Yes | 7 |
| Vibrio parahaemolyticus | 4.9 | 0.94 | Yes | 5 |
| Yersinia enterocolitica | 4.4 | 0.96 | Yes | –1.3 |
| Yeasts | 1.5 | 0.62 | Yes | Pink yeast –34 |
| Moulds | 1.5 | 0.61 | No | Unspecified moulds –12 |

Reproduced with kind permission of Campden BRI. Taken from Campden BRI Guideline No. 46. Evaluation of Product Shelf-life for Chilled Foods (2004).

[1] Minimum growth characteristics are given for each factor when other conditions are optimum for growth. If more than one factor is present, it is likely that these minimum characteristics will change. These figures are indicative and not representative of all strains in all foods.

[2] Using salt.

[3] For Aeromonas species.

[4] Micro-aerophylic requiring limited levels of oxygen to grow.

# Quality assurance/General recommendations

## Food hygiene

Rigorous and systematic control of hygienic practices is essential from reception and storage of raw materials, to preparation, MAP, storage, distribution, retailing, and final consumption. Strict conditions of hygiene must be maintained to prevent cross contamination with food poisoning micro-organisms.

Chilled stores, distribution vehicles and display cabinets must have sufficient refrigeration capacity to maintain the recommended product temperatures of MA packed chilled foods. This refrigeration capacity must be able to cope with conditions of high ambient temperatures and frequent door openings where applicable.

Chilled stores, distribution vehicles and display cabinets are designed only to maintain the temperature of already chilled foods and cannot be relied upon to reduce the temperature of inadequately cooled foods. The proper refrigerated temperature of each batch of product must be assured prior to chilled storage, distribution and retail display. Careful monitoring of temperature during storage and distribution is critical and must form part of a quality assurance programme based on Hazard Analysis and Critical Control Point (HACCP) principles.

Temperature monitoring, either of the air surrounding the product or the product itself, is strongly recommended. Such monitoring ensures that the refrigeration equipment is functioning properly. If monitored temperatures fall outside specified ranges, then corrective action must be taken immediately.

## Quality assurance tests

Quality assurance procedures should be devised and based on HACCP principles. This will require input from technically competent personnel capable of identifying the critical control points in the system, establishing appropriate control options and monitoring procedures for those points and enforcing compliance. In large operations this may be best achieved by appointing a quality assurance manager. A corporate approach involving personnel from all disciplines is essential for HACCP to be fully effective.

## The hazard analysis and critical control point concept—an introduction

Hazard Analysis and Critical Control Point (HACCP) was developed in the 1960s primarily by the Pillsbury Company to assure the safety of food manufactured for astronauts. It uses a proactive preventative approach to all stages of food manufacture including storage, distribution and retail. This is potentially much more effective than traditional end product testing in assuring safe food. Internationally it has become the pre-eminent food safety management system. It has become a legal requirement in many countries, particularly for fish and meat products. Systems based on the principles of HACCP have been incorporated into EU food hygiene directives. New regulations from the EU came into force on January 1, 2006; these make systems based on HACCP a legal requirement for all food businesses except those in primary production. HACCP is a basic requirement of food standards, such as the BRC Global Standard-Food.

Prior to developing a HACCP system a food business must have in place effective prerequisite programmes, based upon Good Manufacturing Practice (GMP) and Good Hygiene Practice (GHP). These will provide a firm foundation for the HACCP and will manage the low risk food safety hazards as well as legal, quality and commercial issues. These will be of site-wide relevance and not specific to a particular step of the process, specific food safety hazards will be managed through the HACCP system. Typical prerequisites would include cleaning procedures, personal hygiene rules, pest control and maintenance procedures. Effective prerequisite programmes enable the HACCP system to focus on significant food safety hazards, particularly at the critical points of the process.

Guidance on HACCP produced by the Codex Alimentarius Commission in their Food Hygiene Basics Texts is widely used. Codex defines seven principles that should be followed by food businesses developing and maintaining HACCP systems.

## HACCP Principles

| | |
|---|---|
| **Principle 1** | Conduct a hazard analysis. *Prepare a flow diagram of the steps in the process. Identify and list the hazards with their causes and specify the control measures.* |
| **Principle 2** | Determine the critical control points (CCPs). *A decision tree can be used.* |
| **Principle 3** | Establish critical limit(s) *which must be met to ensure that each CCP is under control.* |
| **Principle 4** | Establish a system to monitor control of the CCP *by scheduled testing or observations.* |
| **Principle 5** | Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control *or is moving out of control.* |
| **Principle 6** | Establish procedures for verification to confirm that the HACCP is working effectively, *which may include appropriate supplementary tests, together with a review.* |
| **Principle 7** | Establish documentation concerning all procedures and records appropriate to these principles and their application. |

**N.B.** The wording given in italics is not included in the principles of HACCP as documented by the Codex Alimentarius Commission but is included here as additional explanatory notes.

## Key Stages of application

Codex also provides guidance on how to apply these principles following a number of key stages. It has been suggested that there are 14 key stages:

| | |
|---|---|
| **Stage 1** | Define terms of reference/scope of the study |
| **Stage 2** | Select the HACCP team |
| **Stage 3** | Describe the product |
| **Stage 4** | Identify intended use |
| **Stage 5** | Construct a flow diagram |
| **Stage 6** | On-site confirmation of flow diagram |
| **Stage 7** | List all potential hazards associated with each process step, conduct a hazard analysis and consider any measures to control |
| **Stage 8** | Determine CCPs |
| **Stage 9** | Establish critical limits for each CCP |
| **Stage 10** | Establish a monitoring system for each CCP |
| **Stage 11** | Establish a corrective action plan |
| **Stage 12** | Verification including validation |
| **Stage 13** | Review the HACCP system |
| **Stage 14** | Establish documentation and record keeping |

A food manufacturer will need to identify and analyse potential and realistic hazards at all stages of their operation, typically from intake of raw materials to at least despatch. Where relevant, biological, chemical and physical hazards should be considered. The business will need to determine the measures it uses to control the significant food safety hazards. Critical Control Points (CCPs) will be determined using professional judgement and experience. Critical limits must be set for the controls at the CCPs and these must be monitored at an appropriate frequency. A corrective action plan must be developed to enable effective management of situations where critical limits are not achieved. Procedures must be in place to ensure the HACCP systems are working effectively and this must include review. The business must prepare and use appropriate procedures and records.

A number of organisations offer training in how to develop, maintain and audit HACCP systems; many offer courses registered with awarding bodies such as the Royal Institute of Public Health (RIPH, www.riph.co.org).

**REFERENCES** Anon. (2014). Food Hygiene Basic Texts (Fifth Edition). Codex Alimentarius Commission. Gaze, R. E. (Ed) (2003). *HACCP: A Practical Guide* (Third Edition) Guideline 42. Campden BRI.

## Vulnerability Assessment

Food safety looks at the 'hazards' to accidental contamination. Food defence identifies the 'vulnerabilities' to intentional contamination.

A documented vulnerability assessment should be carried out on all or groups of raw food materials to assess the risk of adulteration of substitution.

A vulnerability assessment is the process of identifying, quantifying and prioritising the vulnerabilities of a system. By conducting a vulnerability assessment of a food production facility or process, the most vulnerable points in the infrastructure can be identified. Resources can be focused on the most susceptible points to mitigate against the threat of intentional contamination.

There are a number of key points which should be taken into consideration including; historical evidence of substitution of adulteration, economic factors which make adulteration or substitution attractive, sophistication of routine testing to identify adulterants, nature of the raw materials and ease of access to the raw material in the supply chain.

Following the vulnerability assessment, mitigation strategies can be implemented along the supply chain as preventative measures where operations have been identified as vulnerable to ensure the foods produced are safe and secured. *Food Safety Modernization Act (FSMA), Section 106*. The BRC Global Standard Issue 7 - Clause 5.4.2


## Gas analysis

It is important to ensure that the correct gas mixture is used in Modified Atmosphere packs so that the forecast shelf-life is achieved. For these reasons, routine gas analysis of Modified Atmosphere packs should be included in quality assurance programmes. Analysis of the gases within Modified Atmosphere packs can help to identify a fault with seal integrity (refer to page 35 or new page), MAP materials, MAP machinery or gas mixing prior to MAP. Corrective action must be taken if the gas analysis of Modified Atmosphere packs shows that the gas compositions lie outside the agreed tolerances. Monitoring of these gases is usually undertaken at two points.

### On-line measurement

On-line analysers are installed on to MAP machinery and are capable of continuously monitoring gas levels during gas flushing and prior to heat sealing. Machinery fitted with such analysers can automatically stop operation if the gas mixture is outside pre-determined tolerance levels.

### Batch measurement

Periodically a check sample of packaged product is taken off line to measure the concentrations of each gas within the pack. This is usually achieved by inserting a needle into the package and the sample is drawn into the analyser.

## Equipment

Gas analysis of Modified Atmosphere packs involves the detection and measurement of oxygen and carbon dioxide with nitrogen balance gas being inferred by difference. Most instruments used to carry out these measurements utilise a pumped sampling system to draw the gas sample through a probe inserted into the pack. Sensors used to measure oxygen include zirconium oxide, electrochemical fuel cells and paramagnetic types. The most popular sensor used to measure oxygen is the zirconium oxide type, as it is non-depleting, fast responding and accurate for both low and high level oxygen measurement. For lower cost, battery operated instruments, electrochemical fuel cells are used to measure oxygen, with the disadvantage that the sensor will degrade with age and does not respond as quickly or as accurately as a zirconium sensor.


For $CO_2$ measurement, either infra-red or thermal conductivity sensors are used. Infra red sensors are gas specific and will require more frequent servicing than thermal conductivity sensors. These are non gas specific as they are not subject to the same degradation that can occur with infra red sensor light sources. Analysers available include bench top, transportable or battery operated portable versions, the choice of instrument being dependent on the factory environment and gas sensor type.

Calibration of these instruments is typically carried out by operators using standard gases. Alternatively, some models include an auto calibration facility which avoids users having to calibrate their own instruments. Instrument features that are generally available to help QA personnel to analyse gas readings include alarm settings, printing, data logging and downloading facilities, which enables readings to be imported into spreadsheet software packages.

## Gas supply modes

A variety of pure Food Grade gases and gas mixtures are available for the many different MAP applications. The size and nature of the MAP operation tends to dictate the type of supply system preferred.

### Standard Freshline® cylinders

Standard single cylinders offer the small and medium volume user a low cost, versatile mode of supply. They are available either as pre-mixed gas cylinders, or as single gases for individual use or mix onsite. For customers who use substantial quantities of single cylinders, and who have a fork lift truck, the option of a pack of cylinders offers significant savings in cylinder handling.

### Freshline® Plus cylinder

Specially developed to offer new standards of hygiene and safety

The Air Products Freshline® Plus cylinder is the first cylinder designed to minimise the risk of contamination entering your clean food production environment. Every cylinder is fitted with an integrated bacterial filter and protected with an antimicrobial coating from BioCote®.

The cylinder is fitted with a 0.2 micron sintered anti-microbial filter for extra protection and safety. Air Products is setting new hygiene and safety standards in the food packaging environment.

Our aim is to give you peace of mind that you are introducing the purest gas into your food packaging environment every time.


## CryoEase® solutions

A cost-effective, reliable mode of gas supply that is an alternative to cylinders.

Using small tank trucks and on-site storage containers, CryoEase® solutions provides the advantages of bulk supply to customers whose usage is less than traditional bulk delivery volumes, and is available in a variety of sizes.

## Bulk delivery solutions

For the majority of customers who have a consistently high gas consumption, the supply and storage of gas in liquid bulk is the most economical and convenient mode of supply. Liquid gas will be regularly delivered to customers into a static tank stored on their site. Telemetry systems can be installed which alert the gas company when the tanks require refilling.

## PRISM® Onsite-Gas generation

When the volumes of gas needed are extremely high, the most cost effective solution is to have a PRISM® on-site gas generation system.

The PRISM® system is typically sited within your production facility with a dedicated pipe supplying gases directly to the points of use.

There are different on-site gas generation solutions available depending on your gas purity, pressure, volume and flow requirements.

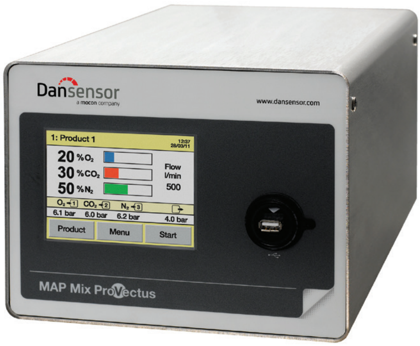
## Mixing systems

The appropriate mode of supply of Air Products' Freshline® gases for food applications is tailored to suit each customer and situation, and gas mixers are available in a range of options to match. The design and choice of gas mixer is driven by the customer and the economics involved with the supply.

For food companies packing a similar range of products it may be beneficial to use preset mixers. These units are available in a range of flows. Benefits of this type of installation include:

- Economic supply of food grade mixed gases
- Simple external installation of equipment
- Simple internal pipe-work system
- The mix is tamper-proof to protect the process and quality control
- The equipment requires minimal maintenance






For food companies packing a varied range of products and maybe a complicated arrangement of packing machines with frequent product changes, it may be beneficial to use an adjustable gas mixer. These are available in flow rates to suit the common MAP gas requirements in either two or three gas combinations.

The relative benefits of this type of installation are:

- Flexible supply of food grade mixed gas
- More portable arrangement of equipment
- The mixtures can be adjustable to meet the demands of production

Some gas mixers incorporate alarms for gas supply failure and an electrical supply would be required. In some cases gas mixers will require a receiver, with the size dependent upon the type and flow rate of the packaging machine. Further details of the types and sizes available for use in the food industry can be obtained by contacting the companies listed in the Acknowledgments page.

In an age where cost is permanently under scrutiny, the industry has had to find ways of producing cheaper materials. Ultimately the cost of a material can only be assessed when the line efficiency is also taken into account. With cost taken out of the packaging operation, materials are sometimes specified which are only just capable of performing to the required standard. In such instances where there is no margin for error, when an external factor comes into play, such as inexperienced operators, failures result. The material can only therefore be considered to be cost effective if all failures and rejects are taken into account. Every re-pack will result in a waste of some or all of the following: product, film, gas, label, labour and overhead.

## MAP materials

There is a wide range of packaging materials for Modified Atmosphere Packaging. When choosing materials, the following consideration must be taken into account:

### Packaging format

- Pouch
- Flowrap (horizontal or vertical)
- Tray lid
- Thermoforming

### Gas transmission rates and barrier properties

The choice of films for MAP is largely determined by their gas and water vapour transmission rates. Materials such as polyester (PET), nylon (PA), polyvinylidene chloride (PVdC) and ethylene vinyl alcohol copolymer (EVOH) provide good gas barriers but in many cases poor water vapour barriers.

### Water vapour and aroma barrier properties

Polythene, polypropylene and ethylene vinyl acetate have gas transmission rates which are too high to maintain a chosen gas mixture or vacuum for long enough to provide an adequate shelf-life for most products. However, they are good barriers to water vapour and hence prevent products drying out or dry products becoming moist.

### Heat sealability

It is important that a hermetic seal is formed in order that there are no leaks and the gas mixture is maintained within the pack. Typical sealing layers are LDPE, PP, EVA, Metallocine and Surlyn (registered name with Dupont).

### Seal strength and quality

This is dictated by temperature, pressure and dwell time. It is necessary therefore to specify a material that will perform to within the parameters of the sealing cycle and line speed. It is also very important that there is compatibility between the materials being sealed together to ensure the required integrity and characteristics (i.e. peelable or permanent).

## Transparency

Anti-mist coatings applied to the top web or anti-fog master batch added to the material during extrusion, prevent the formation of water droplets on the inside surface allowing the product to remain clearly visible. The choice of material itself can also effect the pack presentation depending on its clarity and gloss.

## Thermoformability

Materials may be formed to produce either rigid trays for later lidding applications or semi-rigid/flexible pockets for an inline form fill and seal application.

In general, materials in rigid applications possess relatively poor gas barrier properties at low thickness. The thickness, however, that is necessary to achieve acceptable pack rigidity increases the gas barrier properties to a level suitable for many applications. As the thickness of a formed tray/pocket has a direct relation to the barrier properties, it is essential to consider forming tool design, material flow characteristics and film thickness when choosing a material. Further barrier may be added into structures, such as EVOH, to help with extending shelf-life further.

## Types of films

Typical films for use as lidding materials or to produce packs on horizontal or vertical form-fill-seal machines are multi-layer structures that depending on the food to be packaged, could be made of materials such as: PP, PET, EVOH, PE, etc.

Base webs or pre-formed trays are often made from PP or PET/PE laminates.

- **Laminates** — Two or more layers of material laminated via heat, adhesive or tie layer.
- **Co-extruded** — Two or more layers of material extruded at the same time.

Each process gives its own benefits and properties and consultation with a quality film supplier will assist in the most appropriate selection.

- **Semi-permeable and permeable films** — For fresh fruit and vegetables, relatively high permeable films are often used in order that an Equilibrium Modified Atmosphere can be achieved by the respiring products. Films such as EVA or plasticised PVC have high gas transmission rates. An alternative way of achieving these high levels of transmission is to produce films with microperforations which have high but reasonably controllable levels of permeability. By matching the size and number of perforations to the respiration rate of the produce, a suitable film can be manufactured for most applications.
- **Specialist applications** — The ever growing use of the microwave is leading to the use of more PP trays or formings and PP based lidding films. These kind of films may also be utilised where a form of heat treatment is needed such as pasteurisation or sterilisation.

Steam cooking in the microwave using PP or co-extrusions of PP, APET and polycarbonate trays or formings is possible with various types of "venting" lids. Lids can include technology either in the film or actual valves/labels which will release the pressure build up at a defined point.

The use of susceptor (Die-Electric) layers in films can be used to create an ovenable effect in the microwave. Microwave energy is converted by the susceptor into radiant heat to give a browning/crisping to products such as bread or pastry. Specialist coatings are also available to improve the effect further.

Pre formed trays are also available as CPET, pressed foil and ovenable board offering an option of dual ovenability to the customer.

## Seal integrity and gas leak testing


Seal integrity of Modified Atmosphere packs is a critical control point since it determines whether a Modified Atmosphere pack is susceptible to external microbial contamination and air dilution of the contained gas mixture. Sealing conditions must be specified to suit the particular combination of MAP machinery and MAP materials to ensure that a hermetic seal of a specified quality is achieved. Essential checks on heat sealing should include proper alignment of the sealing heads or jaws, dwell time, temperature, pressure and machine speed. Great care should be taken to ensure that the seal area is not contaminated with product, product drip or moisture since seal integrity may be reduced. The seal integrity of Modified Atmosphere packs should be inspected at regular intervals. There are many types of leak testing equipment from small water bath non traceable gases to inline $CO_2$ detectors. Seal integrity tests may be non-destructive or destructive.

Further advice may be sought from suppliers of MAP materials and from our MAP experts.

## Typical film structures and their uses

| Structure | Applications | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thermoformed Blisters and Trays | MAP | Hot Filling | Chilled Food | Frozen Food | Pasteurisation | Sterilisation | Microwavable | Dual Ovenable | Printing | Lamination |
| APET | ● | | | | | | | | | ● | ● |
| APET/PE | ● | ● | | ● | | | | | | | |
| APET/EVOH/PE | ● | ● | | ● | | | | | | | |
| PC/APET/PC | ● | | ● | ● | ● | ● | | ● | ● | | |
| CPET | ● | | ● | ● | ● | ● | | ● | ● | | |
| APET/PETBlend/APET | ● | | | | | | | | | ● | ● |
| PS/PE | ● | | | ● | ● | | | | | ● | |
| PS/EVOH/PE | ● | ● | ● | ● | ● | ● | | | | ● | |
| PS/PETG | ● | | | ● | ● | | | | | ● | |
| PP/PE | ● | ● | ● | ● | | ● | | ● | | ● | |
| PP/EVOH/PE | ● | ● | ● | ● | | ● | | ● | | ● | |
| PP/EVOH/PP | ● | ● | ● | ● | | ● | ● | ● | | ● | |
| EPP/EVOH/PE | ● | ● | ● | ● | ● | ● | | ● | | | |
| PP/PA/PE | ● | ● | ● | ● | | ● | | ● | | ● | |
| PP/PA/PP | ● | ● | ● | ● | | ● | ● | ● | | ● | |
| PETBlend | ● | | | ● | ● | | | | | | |
| PETBlend/PE | ● | ● | | ● | ● | | | | | | |
| PETBlend/EVOH/PE | ● | ● | | ● | ● | | | | | | |
| EPETBlend/PE | ● | ● | | ● | ● | | | | | | |
| EPETBlend/EVOH/PE | ● | ● | | ● | ● | | | | | | |
| PVC | ● | | | | | | ● | | | ● | ● |
| PVC/PE | ● | ● | ● | ● | ● | | ● | | | ● | |
| PVC/EVOH/PE | ● | ● | ● | ● | ● | | ● | | | ● | |

## Abbreviations of commonly used MAP materials

| | |
|---|---|
| ABS | Acrylonitrile butadiene styrene |
| Al | Aluminium |
| APET | Amorphous polyester |
| AlOX | Aluminum oxide |
| CPET | Crystalline polyester |
| EPP | Expanded polypropylene |
| EPS | Expanded polystyrene |
| EVA | Ethylene vinyl acetate |
| EVOH | Ethylene vinyl alcohol copolymer |
| HDPE | High density polyethylene |
| HIPS | High impact polystyrene |
| LDPE | Low density polyethylene |
| LLDPE | Linear low density polyethylene |
| MOPP | Metallised orientated polypropylene |
| MP | Microperforated film |
| MPET | Metallised polyester |
| MPOR | Microporous film |
| OPA | Orientated polyamide (nylon) |
| OPP | Orientated polypropylene |
| OPS | Orientated polystyrene |
| PA | Polyamide (nylon) |
| PC | Polycarbonate |
| PE | Polyethylene |
| PET-P | Polythene terephthalate (commonly known as polyester) |
| PLA | Polylactic acid |
| PP | Polypropylene |
| PS | Polystyrene |
| PSHT | Polystyrene (high temperature) |
| PVC | Polyvinyl chloride |
| PVdC | Polyvinylidene chloride |
| UPVC | Unplasticised polyvinyl chloride |

## Active and Intelligent Packaging

Active packaging concepts can be defined as packaging concepts which actively change the condition of the packed food to:

- Extend shelf-life
- Improve safety
- Improve sensory properties

. . . while maintaining the quality of the food.

Conditions of the packed food include physiological (e.g. respiration of vegetables), physical (e.g. dessication), chemical (e.g. lipid oxidation), infestation (insects) or microbiological states (e.g. spoilage bacteria, toxin producing bacteria).

Therefore it can be concluded that active packaging is not one technology, like MAP, but a collection of technologies in response to specific problems.

Active packaging concepts can be divided into three major categories, namely:

- Active scavenging concepts
- Active releasing concepts
- Other active packaging concepts

## Active scavenging concepts

### Oxygen scavengers

Removal and control of oxygen in package headspace and in solutions of food and beverages have been a target for the food technologists for a long time. In the last decade, the application of vacuum and Modified Atmosphere Packaging appeared successful in extending the shelf-life and quality of the food. However, aerobic spoilage can still occur because of residual oxygen in headspace. The residual content of oxygen may be due to:

- Oxygen permeability of the packaging material
- Small leakages through poor sealing
- Air enclosed in the food
- Inadequate evacuation and/or gas flushing

Oxygen scavengers can be applied to packaging materials in different manners, such as:

- Sachets and labels containing oxygen scavenging components
- Closures, mainly used for plastic beer bottles
- Oxygen scavenging films


Oxygen scavengers are by far the most commercially important type of active packaging. They have been on the market since 1976.

Oxygen scavenging systems can be used for many applications, including beer, meat products, bread, snack foods and many others. In recent years a lot of evidence has been found that oxygen scavenging systems have a positive influence on food quality and can extend shelf-life. They have the following (desired) effects:

- Protection against mould and yeast growth
- Protection against growth of aerobic micro-organisms
- Protection against lipid oxidation
- Protection against discoloration
- Protection against loss of taste and flavour
- Protection against loss of nutritive elements

## Other available active and intelligent packaging technologies available include:

**$O_2$ Emitter/$CO_2$ absorber**

Employed to sustain a predetermined pack atmosphere within elevated oxygen Controlled Atmosphere (CA) packed whole and prepared fresh produce, in order to achieve a quality maintained, extended shelf-life.

**Moisture absorbers**

Employed, as pads or sachets, almost exclusively to absorb free water created as “drip-loss” from fresh products such as meat, fish, prepared fruit and whole soft fruits.

**$CO_2$ absorbers & emitters**

Both can be employed in CA and conventional MA packed food products, to sustain, or to help attain, a predetermined or pack atmosphere in order to achieve a quality maintained, extended shelf-life

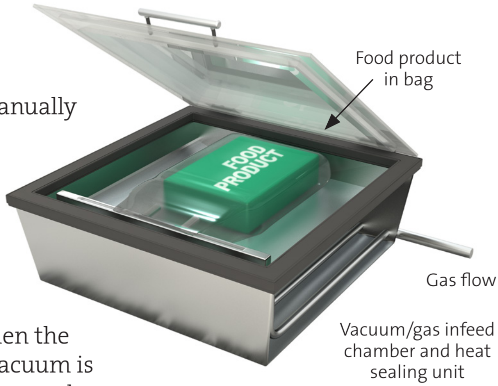
**Other developments include:**

- Food spoilage indicators
- Time temperature labels

# Modified Atmosphere Packaging machinery

## Vacuum chambers (VC)

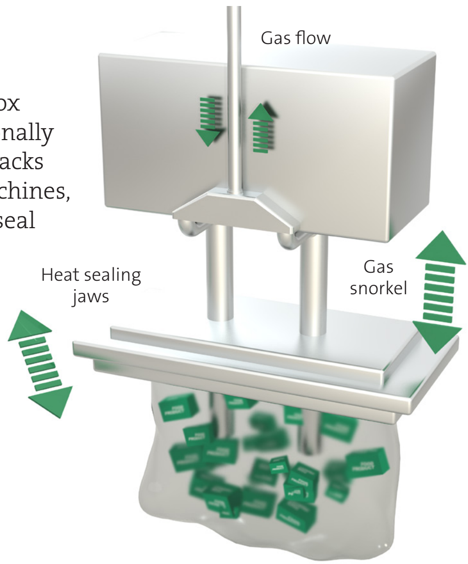
These machines use preformed bags and utilise the compensated vacuum technique to replace air. Preformed high-barrier bags are manually placed within the chamber before evacuation, back-flushing with the desired gas mixture, and heat sealing. These machines can be used for small scale production of vacuum or gas flushed catering packs.

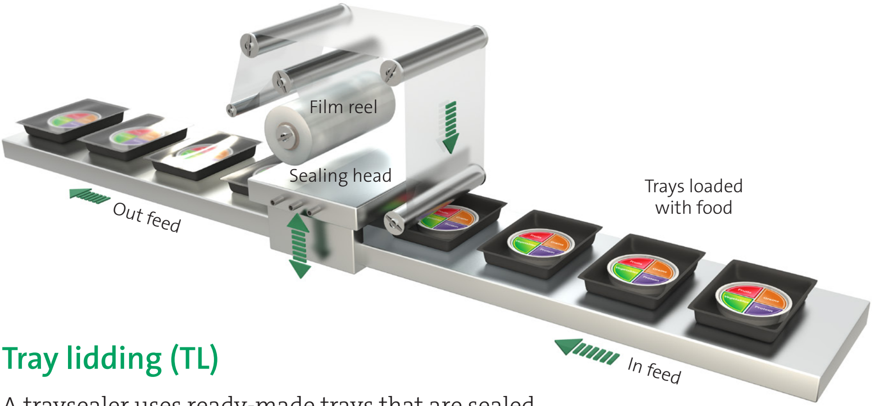



The product to be packaged is put into a film pouch and placed in the vacuum chamber. When the lid has been closed, the programmed level of vacuum is produced in both the vacuum chamber and the pouch. The pouch is then either sealed in a vacuum (vacuum package) or the chamber (and thus the pouch as well) is filled with a Freshline® MAP gas before the sealing operation (modified atmosphere package).

## Snorkel-type (ST)

These machines use the compensated vacuum technique to produce bulk MA catering bag-in-box packs. Alternatively, they can gas flush conventionally packaged retail products, such as overwrapped packs of red meat, into large master packs. In these machines, preformed plastic bags are positioned on a heat seal mandrel and retractable snorkels pull a vacuum and then back-flush with a desired gas mixture before heat sealing.





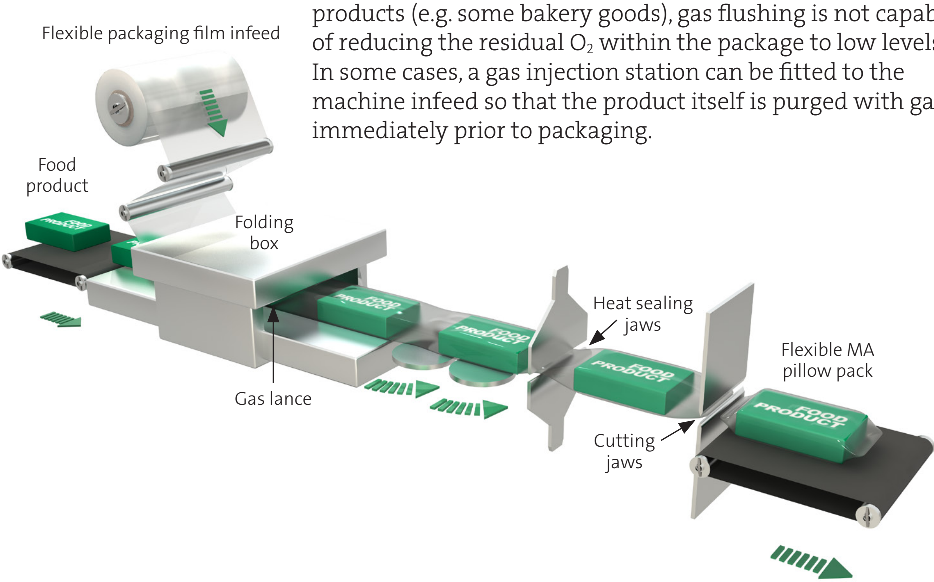

## Tray lidding (TL)

A traysealer uses ready-made trays that are sealed in much the same way as a thermoformer. The top web of packaging material (lid film) covers the filled pockets/trays. The air is evacuated from the sealing die and protective gas is added.

Then the pack is sealed by the application of heat and pressure. Tray lidding machines are available from tabletop (manual) for the small producer, to fully automatic inline versions for larger processors.

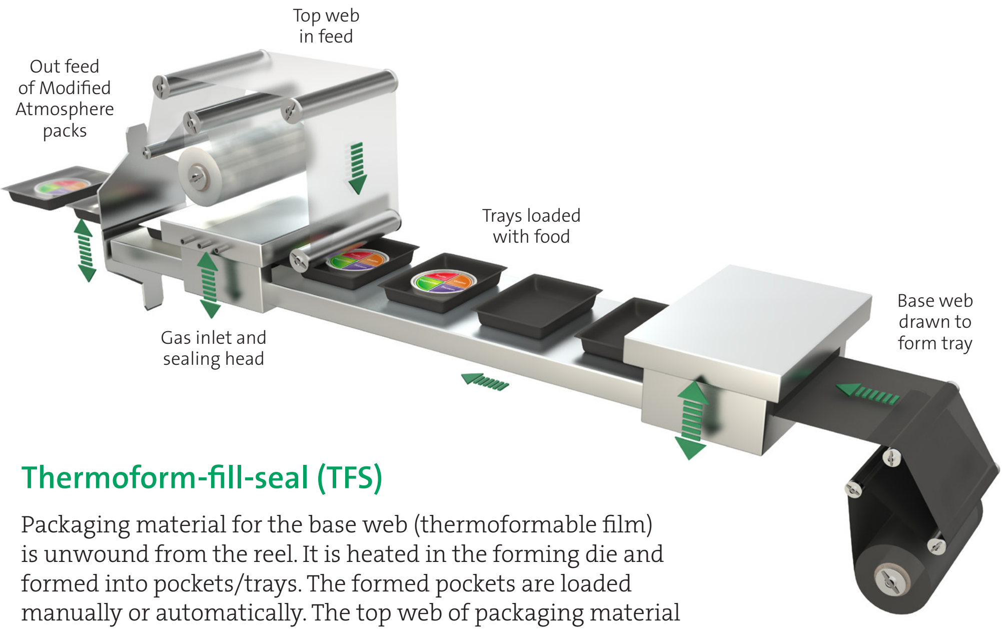
## Horizontal form-fill-seal (HFFS)

These so-called flow-pack machines (see diagram) are capable of making flexible pillow-pack pouches from only one reel of film. Horizontal form-fill-seal machines can also overwrap a pre-filled tray of product. The air from the package is removed by a pulse of gas or continuous gas flushing, but gas mixtures containing levels of $O_2$ > 21% cannot be used due to the use of hot sealing jaws at the end of the machine. For certain very porous products (e.g. some bakery goods), gas flushing is not capable of reducing the residual $O_2$ within the package to low levels. In some cases, a gas injection station can be fitted to the machine infeed so that the product itself is purged with gas immediately prior to packaging.



## Vertical form-fill-seal (VFFS)

A vertical machine forms a tube, it then fills with product (in most cases dropped from an overhead multi-weigher), purges with gas and then seals. At the same time film is transported vertically downwards. VFFS machines are predominantly used for packaging foods in powder, granular, shredded and dried form.

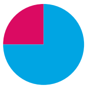



## Thermoform-fill-seal (TFS)

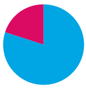
Packaging material for the base web (thermoformable film) is unwound from the reel. It is heated in the forming die and formed into pockets/trays. The formed pockets are loaded manually or automatically. The top web of packaging material (lid film) covers the filled pockets/trays. The air is evacuated from the sealing die and protective gas is added. Then the pack is sealed by the application of heat and pressure. The web of packs is cut across the machine direction initially. Production of the individual packs is completed after the longitudinal cutting operation.

## At-a-glance guide to recommended MAP gas mixtures

Oxygen ($O_2$) Carbon Dioxide ($CO_2$) Nitrogen ($N_2$)

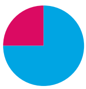


**Raw red meat (lamb,beef, pork)**
$O_2$ .......... 70–80%
$CO_2$ ....... 20–30%



**Raw offal**
$O_2$ .......... 80%
$CO_2$ ....... 20%

**Raw poultry and game birds**
$O_2$ .......... 0–20%
$CO_2$ ....... 30–40%
$N_2$ .......... 60–70%



**Poultry, dark portion and cuts**
$O_2$ .......... 70–80%
$CO_2$ ....... 20–30%

**Raw fish (low fat white)**
$O_2$ .......... 30%
$CO_2$ ....... 40%
$N_2$ .......... 30%

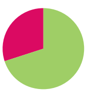
**Raw fish (oily)**
$CO_2$ ....... 40%
$N_2$ .......... 60%

**Crustaceans and molluscs (ie. prawns)**
$O_2$ .......... 30%
$CO_2$ ....... 40%
$N_2$ .......... 30%

**Cooked and cured meats**
$CO_2$ ....... 30–40%
$N_2$ .......... 60–70%

**Cooked and cured fish and seafood**
$CO_2$ ....... 30–40%
$N_2$ .......... 60–70%

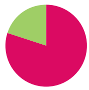
**Cooked and cured poultry and game**
$CO_2$ ....... 30–40%
$N_2$ .......... 60–70%



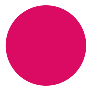
**Ready meals**
$CO_2$ ....... 30%
$N_2$ .......... 70%

**Combination products**
$CO_2$ ....... 30–40%
$N_2$ .......... 60–70%

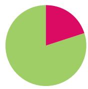
**Fresh pasta products**
$CO_2$ ....... 50%
$N_2$ .......... 50%



**Bakery**
$CO_2$ ....... 30–70%
$N_2$ .......... 0–70%

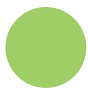


**Hard cheese (ie. cheddar)**
$CO_2$ ....... 100%



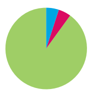
**Grated hard cheeses**
$CO_2$ ....... 0–30%
$N_2$ .......... 70–100%

**Soft cheeses**
$CO_2$ ....... 40%
$N_2$ .......... 60%



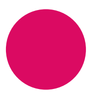
**Dried food products**
$N_2$ .......... 100%

**Cooked vegetables**
$CO_2$ ....... 30–40%
$N_2$ .......... 60–70%



**Fresh fruit and vegetables**
$O_2$ .......... 5%
$CO_2$ ....... 5%
$N_2$ .......... 90%

**Liquid food and beverages**
$N_2$ .......... 100%



**Carbonated soft drinks**
$CO_2$ ....... 100%

# The Freshline® Food Fact Finder

This section contains information on recommended gas mixtures, storage temperatures, achievable shelf-lives, principal spoilage mechanisms and organisms, possible food poisoning hazards, typical MAP machines, typical types of packages, and examples of typical MAP materials for a comprehensive list of individual food items within 16 food categories.

In addition, concise technical advice is provided on various aspects of good manufacturing and handling practice, typical retail and bulk MAP machines, and typical retail and bulk package formats. A glossary of MAP materials abbreviations is also provided on page 35.

## Find information on the following food categories


## Raw red meat

The two principal spoilage mechanisms affecting the shelf-life of raw red meats are microbial growth and oxidation of the red oxymyoglobin pigment.

When red meat is kept under proper chilled conditions, the controlling influence on the shelf-life of the product is the rate of oxidation of the red oxymyoglobin pigment to its brown oxidised form, metmyoglobin. For this reason, high concentrations of $O_2$ are necessary for the MAP of red meats in order to maintain the desirable bright red colour for a longer period. Highly pigmented red meats, such as venison and wild boar, require higher concentrations of $O_2$.

Aerobic spoilage bacteria, such as *Pseudomonas* species, which are normally predominant on red meats are inhibited by $CO_2$. Consequently, to create the dual effect of red colour stability and microbial inhibition, gas mixtures containing 20-30% $CO_2$ and 70-80% $O_2$ are recommended for extending the chilled shelf-life of red meats from 2-4 days to 5-8 days and even longer. A gas/product ratio of 2:1 is often recommended. The maintenance of recommended chilled temperatures and good hygiene and handling throughout the butchery, MAP, distribution and retailing chain is also of vital importance in ensuring the safety and extended shelf-life of red meat products.

Red meats provide an ideal medium for the growth of a wide range of spoilage and food poisoning microorganisms. It should be noted that raw red meats are subsequently cooked before consumption and thorough heating is sufficient to kill the vegetative cells of food poisoning bacteria. Consequently, the risk of food poisoning is greatly minimised by proper cooking.

## Food items

Beef, goat, hare, horse, lamb, pork, rabbit, veal, venison and wild boar.

## Recommended gas mixtures

70–80% $O_2$, 20–30% $CO_2$

## Exceptions:

- Venison, wild boar – 80% $O_2$, 20% $CO_2$

## Storage temperature

**Legal maximum*:** 8°C

**Recommended:** –1°C to +2°C

## Achievable shelf life

**In air:** 2–4 days

**In MAP:** 5–8 days

## Principle spoilage organisms and mechanisms

*Pseudomonas* species (in air), *Brochothrix* species, *Lactic acid* bacteria, *Micrococci, Enterobacteriaceae,* yeasts and moulds.

## Food poisoning hazards include

*Clostridium* species, *Salmonella* species, *Staphylococcus aureus*, *Bacillus* species, *Listeria monocytogenes*, E.coli and E.coli O157. *Yersinia enterocolitica* can be important for pork.

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

## Typical types of package

**Retail**

Tray and lidding film

## Examples of typical MAP materials

**Retail**

Tray:

- PVC/PE
- APET/PE
- EPS/EVOH/PE

Lidding film:

- PET/PVdC/PE
- PET/PE-EVOH-PE
- OPA/PE-EVOH-PE
- OPP/PE-EVOH-PE

** The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*For more detailed information on raw red meat see relevant Datasheet available through the Air Products website.*

## Raw offal

The two principal spoilage mechanisms affecting the shelf-life of raw offal are microbial growth and oxidation of the red pigment to its brown oxidised form. For this reason, high concentrations of $O_2$ are necessary for the MAP of raw offal in order to maintain the desirable red colour for a longer period.

Aerobic spoilage bacteria, such as *Pseudomonas* species, which are normally predominant on raw offal are inhibited by $CO_2$. Consequently, to create the dual effect of red colour stability and microbial inhibition, a gas mixture containing 20% $CO_2$ and 80% $O_2$ is recommended for extending the chilled shelf-life of raw offal from 2–6 days to 4–8 days. A gas/product ratio of 2:1 is recommended.

Many types of raw offal, particularly liver, kidney, brain, foie gras, giblets and sweetbreads, tend to suffer from excessive drip, especially in the presence of $CO_2$, and thus only a maximum of 20% $CO_2$ should be used. The potential problem of excessive drip can be controlled by using the retail three-web pack.

The maintenance of recommended chilled temperatures and good hygiene and handling throughout the butchery, MAP, distribution and retail chain is also of vital importance in ensuring the safety and extended shelf-life of raw offal products. Raw offal provides an ideal medium for the growth of a wide range of spoilage and food poisoning micro-organisms.

It should be noted that raw offal products are subsequently cooked before consumption and thorough heating is sufficient to kill the vegetative cells of food poisoning bacteria. Consequently, the risk of food poisoning is greatly minimised by proper cooking.

## Food items

Liver, kidney, heart, sweetbreads, tongue, tripe, ox tail, neck, giblets, foie gras, feet or trotters.

## Recommended gas mixtures

80% $O_2$, 20% $CO_2$

## Storage temperature

**Legal maximum*:** 8°C

**Recommended:** –1°C to +2°C

## Principle spoilage organisms and mechanisms

*Pseudomonas* species (in air), *Brochothrix* species, *Lactic acid* bacteria, *Micrococci, Enterobacteriaceae,* yeasts and moulds.

## Food poisoning hazards include

*Clostridium* species, *Salmonella* species, *Staphylococcus aureus*, *Listeria monocytogenes*, E.coli and E.coli O157.

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

TWTFFS – Three web thermoform-fill-seal

**Vacuum skin pack Bulk**

VC – Vacuum chamber

ST – Snorkel-type

## Typical types of package

**Retail**

Tray and lidding film , three web pack

## Examples of typical MAP materials

• PVC/PE

• APET/PE

• HDPE

• EPS/EVOH/PE

Lidding film:

• PET/PE-EVOH-PE

• OPA/PE-EVOH-PE

• OPP/PE-EVOH-PE

** The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*For more detailed information on raw offal see relevant Datasheet available through the Air Products website.*

## Raw poultry and game

For chilled raw poultry and game the principal spoilage mechanism is microbial growth, particularly growth of *Pseudomonas* species and *Achromobacter* species. These aerobic spoilage bacteria are very effectively inhibited by inclusion of $CO_2$ in MAP.

Levels of $CO_2$ in excess of 20% are required to significantly extend the shelf-life of raw poultry and game birds. For retail MA packs of raw poultry and game, the proportion of $CO_2$ in the gas mixture should not be higher than 35% since pack collapse and excessive drip may be induced. Pack collapse is not a problem for bulk MA master packs and hence 100% $CO_2$ is recommended. In retail MA packs, a mixture of 30% $CO_2$, 70% $N_2$ is often recommended.

The achievable shelf-life of MA packed raw poultry and game will depend on the species, fat content, initial microbial load, gas mixture, and temperature of storage. Possible food poisoning risks can be minimised by maintenance of recommended chilled temperatures, good hygiene and handling practices throughout and adequate cooking prior to consumption.

## Food items

Capon, chicken, duck, goose, grouse, Guinea hen, partridge, pheasant, pigeon, poussin/cornish hen, quail and turkey.

## Recommended gas mixtures

Dependent upon customer preferences in some cases high levels of oxygen are used to preserve the nice red colour of the meat.

Whole: 30%–60% $CO_2$, 40–70% $N_2$

Portions: 20–30% $CO_2$, 20–70% $O_2$, 0–50% $N_2$

Bulk: 100% $CO_2$

## Storage temperature

**Legal maximum*:** 8°C

**Recommended:** –1°C to +2°C

## Achievable shelf life

**In air:** 4–7 days

**In MAP:** 10–21 days

## Principle spoilage organisms and mechanisms

*Pseudomonas* species (in air), *Brochothrix* species, *Lactic acid* bacteria, *Enterobacteriaceae,* yeasts and moulds.

## Food poisoning hazards include

*Clostridium* species, *Salmonella* species, *Staphylococcus aureus*, *Listeria monocytogenes*, Campylobacter species, E.coli and E.coli O157.

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

**Bulk**

VC – Vacuum chamber

ST – Snorkel-type

## Typical types of package

**Retail**

Tray and lidding film

**Bulk**

Bag-in-box, master pack

## Examples of typical MAP materials

**Retail**

Tray:

- PVC/PE
- APET/PE
- HDPE
- EPS/EVOH/PE

Lidding film:

- PET/PE-EVOH-PE
- OPA/PE-EVOH-PE
- OPP/PE-EVOH-PE
- PET/PVdC/PE

**Bulk**

- PA/PE
- PA/EVOH/PE

** The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*For more detailed information on raw poultry and game see relevant Datasheet available through the Air Products website.*

## Selected raw reddish poultry

For selected raw, reddish poultry, the principal spoilage mechanisms are aerobic microbial growth and oxidation of the red pigment to its brown oxidised form.

Aerobic spoilage bacteria, particularly *Pseudomonas* species, are very effectively inhibited by inclusion of $CO_2$ in MAP. High concentrations of $O_2$ are necessary to maintain the desirable red colour of raw, reddish poultry products for a longer period. To create the dual effect of red colour stability and microbial inhibition, a gas mixture containing 70% $O_2$ and 30% $CO_2$ is recommended. A gas/product ratio of 2:1 is recommended. The achievable shelf-life of MA packed raw, reddish poultry products will depend on the species, fat content, initial microbial load, gas mixture, and temperature of storage. Possible food poisoning risks can be minimised by maintenance of recommended chilled temperatures, good hygiene and handling practices throughout, and adequate cooking prior to consumption.

## Food items

Dark poultry mince, other skin-off poultry, skin-off chicken, skin-off turkey, sliced dark Poultry and turkey mince.

## Recommended gas mixtures

70% $O_2$, 30% $CO_2$

## Storage temperature

**Legal maximum*:** 8°C

**Recommended:** –1°C to +2°C

## Achievable shelf life

**In air:** 3–5 days

**In MAP:** 7–14 days

## Principle spoilage organisms and mechanisms

*Pseudomonas* species (in air), *Brochothrix* species, *Lactic acid* bacteria, *Enterobacteriaceae,* yeasts and moulds.

## Food poisoning hazards include

*Clostridium* species, *Salmonella* species, *Staphylococcus aureus*, *Listeria monocytogenes*, Campylobacter species, E.coli and E.coli O157.

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

## Typical types of package

**Retail**

Tray and lidding film

## Examples of typical MAP materials

**Retail**

Tray:

- PVC/PE
- APET/PE
- H/PE

Lidding film:

- PET/PE-EVOH-PE
- OPA/PE-EVOH-PE
- OPP/PE-EVOH-PE
- PET/PVdC/PE

** The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*For more detailed information on selected raw reddish poultry see relevant Datasheet available through the Air Products website.*

## Raw fish and seafood

The principal spoilage mechanisms affecting the quality of fish and seafood are the result of microbial and oxidative activities. Fish and seafood products are very perishable due to their high $a_w$, neutral pH, and presence of autolytic enzymes which cause the rapid development of undesirable odours and flavours.

Fish normally have a particularly heavy microbial load owing to their cold water origins, method of capture and transport to shore, evisceration and retention of skin in retail portions. Microbial activity causes a breakdown of fish protein, with resulting production of undesirable fishy odours. Oxidative rancidity of unsaturated fats in oily fish also results in other additional offensive odours and flavours.

MAP is a very effective technique for delaying microbial spoilage and oxidative rancidity in fish and seafood products. MAP is particularly effective at extending the shelf-life of white fish products. For white fish, crustaceans and molluscs, a gas mixture containing 30% $O_2$, 40% $CO_2$, and 30% $N_2$ is recommended. A gas mixture containing 40% $CO_2$ and 60% $N_2$ is recommended for oily fish products. The inclusion of $CO_2$ is necessary for inhibiting common aerobic spoilage bacteria, such as *Pseudomonas* species (in air).

However, for retail packs of fish and other seafood, too high a proportion of $CO_2$ in the gas mixture can induce pack collapse, excessive drip, and in cold-eating seafood products such as crab, an acidic, sherbet-like flavour.

$O_2$ is necessary to prevent the growth of *Clostridium botulinum* type E, colour changes and bleaching, and reduce drip in MA packs. A gas/product ratio of 2:1 is recommended.

Only the highest quality fish and seafood should be used to benefit from the extended shelf-life advantages of MAP. The achievable shelf-life will depend on the species, fat content, initial microbial load, gas mixture, and temperature of storage. The maintenance of recommended chilled temperatures and good hygiene and handling practices throughout the entire capture-to-consumption chain is essential for ensuring the safety and extended shelf-life of fish and seafood products.

# Raw, low fat, white fish and seafood

## Food items

Bream, brill, catfish, cod, coley, croaker, dab, dover and lemon sole, flounder, grouper, haddock, hake, halibut, hoki, huss, jackfish, john dory, mullet, monkfish, pike, plaice, pollack, red snapper, sea bass, shark, skate, turbot and whiting.

## Recommended gas mixtures

30% $O_2$, 40% $CO_2$, 30% $N_2$

## Storage temperature

**Legal maximum*:** 8°C

**Recommended:** –1°C to +2°C

## Achievable shelf life

**In air:** 2–4 days

**In MAP:** 4–6 days

## Principle spoilage organisms and mechanisms

*Pseudomonas* species (in air), *Lactic acid* bacteria, *Enterobacteriaceae, Shewanella* species, *Photobacterium* species, *Aeromonas* species.

## Food poisoning hazards include

*Clostridium botulinum* (non-proteolytic E, B and F), *Vibrio parahaemolyticus, Salmonella species* and *Listeria monocytogenes*.

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

## Typical types of package

**Retail**

Tray and lidding film

## Examples of typical MAP materials

**Retail**

Tray:

- PVC/PE
- APET/PE
- HDPE
- EPS/EVOH/PE

Lidding film:

- PET/PE-EVOH-PE
- OPA/PE-EVOH-PE
- OPP/PE-EVOH-PE
- PET/PVdC/PE

** The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*For more detailed information on raw fish and seafood see relevant Datasheet available through the Air Products website.*

## Raw high fat oily fish and seafood

### Food items

Bluefish, carp, eel, Greenland halibut, herring, mackerel, pilchard, rock salmon, salmon, sardines, shad, sprats, swordfish, trout, tuna and whitebait.

### Recommended gas mixtures

40% $CO_2$, 60% $N_2$ with an oxygen residual.

### Storage temperature

**Legal maximum*:** 8°C

**Recommended:** –1°C to +2°C

### Achievable shelf life

**In air:** 2–3 days

**In MAP:** 4–6 days

### Principle spoilage organisms and mechanisms

*Pseudomonas* species (in air), *Lactic acid* bacteria, *Enterobacteriaceae, Shewanella* species, *Photobacterium* species, *Aeromonas* species.

### Food poisoning hazards include

*Clostridium botulinum* (non-proteolytic E, B and F), *Vibrio parahaemolyticus, Salmonella species* and *Listeria monocytogenes.*

### Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

### Typical types of package

**Retail**

Tray and lidding film

### Examples of typical MAP properties

**Retail**

Tray:

- PVC/PE
- APET/PE
- HDPE
- EPS/EVOH/PE

Lidding film:

- PET/PE-EVOH-PE
- OPA/PE-EVOH-PE
- OPP/PE-EVOH-PE
- PET/PVdC/PE

## Crustaceans and molluscs

### Food items

Abalone, clams, cockles, conch, crab, crayfish, cuttlefish, lobster, mussels, octopus, oysters, prawns, scallops, sea urchins, shrimp, squid, whelks and winkles.

### Recommended gas mixtures

30% $O_2$, 40% $CO_2$, 30% $N_2$

### Storage temperature

**Legal maximum*:** 8°C

**Recommended:** –1°C to +2°C

### Achievable shelf life

**In air:** 2–3 days

**In MAP:** 4–6 days

### Principle spoilage organisms and mechanisms

*Pseudomonas* species (in air), *Lactic acid* bacteria, *Enterobacteriaceae, Shewanella* species, *Photobacterium* species, *Aeromonas* species.

### Food poisoning hazards include

*Clostridium botulinum* (non-proteolytic E, B and F), *Vibrio parahaemolyticus, Salmonella species* and *Listeria monocytogenes.*

### Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

### Typical types of package

**Retail**

Tray and lidding film

### Examples of typical MAP materials

**Retail**

Tray:

- PVC/PE
- APET/PE
- HDPE
- EPS/EVOH/PE

Lidding film:

- PET/PVdC/PE
- PET/PE-EVOH-PE
- OPA/PE-EVOH-PE
- OPP/PE-EVOH-PE

** The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*For more detailed information on raw fish and seafood see relevant Datasheet available through the Air Products website.*

## Cooked, cured and processed meat products

The principal spoilage mechanisms for meat products are microbial growth, colour changes and oxidative rancidity. In cooked, uncured, meat products, the heating process should kill vegetative bacterial cells, inactivate degradative enzymes, and fix the colour. Problems with such products arise primarily from post-process contamination and/or poor hygiene and handling practices.

Some uncooked, uncured, meat products (such as beef burgers and British sausages) will contain sulphur dioxide (often added in the form of sodium metabisulfite). This additive (use of which is restricted to products having a minimum of 6% cereal content) is an effective preservative against a wide range of spoilage mechanisms.

Cured meat products, whether cooked or not, owe their characteristic pink colour to the use of nitrite which interacts with the myoglobin in the meat to form nitrosylmyoglobin. Although this pigment is fairly stable it is prone to oxidative bleaching, especially when exposed to light. Cured meat products should therefore be packaged with the exclusion of oxygen. The addition of nitrite and salt will inhibit most food poisoning bacteria. This inhibition may, however, be compromised in products formulated with reduced levels of salt, nitrite or other preservatives. Caution must be exercised in assessing the potential effects of any changes in product formulation. Simple cooked meats without any added preservatives may be at risk from growth of *Clostridium botulinum* under anaerobic MAP and incorrect chilled storage.

Meat products containing appreciable levels of unsaturated fat are liable to be spoiled by oxidative rancidity, but MAP with the elimination of oxygen will inhibit this.

## Food items

Bacons, beef burgers, black pudding, charcuterie, chopped pork and ham, cooking sausages, corned beef, frankfurters, haggis, hams, luncheon meats, meat jerky, meat slices, ox tongue, pastrami, pâtés, pepperoni, potted meats, rillettes, roast meats, salami, smoked reindeer, smoked venison, terrines and wurst sausages.

## Recommended gas mixtures

30–40% $CO_2$, 60–70% $N_2$

## Storage temperature

**Legal maximum*:** 8°C

**Recommended:** 0°C to +3°C

## Achievable shelf life

**In air:** Cooked and cured meats 1–3 weeks, salami, etc. 3–6 months

**In MAP:** Cooked and cured meats 3–7 weeks, salami, etc. 4–8 months

## Principle spoilage organisms and mechanisms

*Brochothrix* species, *Lactic acid* bacteria, *Enterobacteriaceae*, yeasts and moulds Oxidative rancidity colour change for cured meats (red/pink to brown/grey/green).

## Food poisoning hazards include

*Clostridium* species, *Salmonella* species, *Staphylococcus aureus*, *Listeria monocytogenes*, E.coli and E.coli O157.

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

## Typical types of package

**Retail**

Tray and lidding film, tray inside pillow pack, pillow pack

## Examples of typical MAP materials

**Retail**

Tray:

- PVC/PE
- APET/PE
- HDPE
- EPS/EVOH/PE

Lidding and/or pillow pack film:

- PET/PVdC/PE
- PET/PE-EVOH-PE
- OPA/PE-EVOH-PE
- OPP/PE-EVOH-PE
- MPET/PE
- MOPP/PE

* *The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

**NB**: *Salami, pepperoni, etc. may be ambient stable depending on formulation.*

*For more detailed information on cooked, cured and processed meat products see relevant datasheet available through the Air Products website.*

## Cooked, cured and processed fish and seafood products

The principal spoilage mechanisms for cooked, cured and processed fish and seafood products are microbial growth and oxidative rancidity. For cooked products, the heating process should kill vegetative bacterial cells and inactivate degradative enzymes. Consequently, spoilage of cooked fish and seafood products is primarily due to post-cooking contamination by microorganisms and oxidative rancidity which can be minimised by MAP with $CO_2/N_2$ mixtures and good hygiene and handling practices. A gas/product ratio of 2:1 is recommended.

Cured and processed fish and seafood products contain relatively high levels of salt which effectively inhibits a wide range of spoilage micro-organisms. Cooked, cured and processed fish and seafood products contain high levels of unsaturated fat which is prone to oxidative rancidity. However, MAP with $CO_2/N_2$ mixtures is effective at inhibiting such undesirable oxidative rancidity. Possible food poisoning hazards are primarily due to post-cooking, curing or processing contamination which can be minimised by maintenance of recommended chilled temperatures and good hygiene and handling practices.

The reduced $a_w$ and/or addition of salt in most cooked, cured and processed fish and seafood products inhibit most food poisoning bacteria, particularly *Clostridium botulinum*. This inhibition may be compromised in products formulated with lower salt or other preservatives as is becoming increasingly popular. Caution must be exercised to assess the potential effects of any changes in product formulation. Simple cooked fish and seafood products without any added preservatives are likely to be at greater risk from growth of *Clostridium botulinum* under anaerobic MAP conditions and incorrect chilled storage.

## Food items

Bloaters, Bombay duck, buckling, cod's roe, cold smoked fish, fish galantine, fish rillettes, fish terrines, hot smoked fish, kippers, potted fish, potted shellfish, salt cod, salted anchovies, salted caviar, salted fish roes, salted jellyfish, seafood pâtés, smoked haddock, smoked halibut, smoked mackerel, smoked salmon, smoked trout and taramasalata.

## Recommended gas mixtures

30% $CO_2$, 70% $N_2$ with an oxygen residual.

## Storage temperature

**Legal maximum*:** 8°C

**Recommended:** 0°C to +3°C

## Achievable shelf life

**In air:** 5–10 days

**In MAP:** 7–21 days

## Principle spoilage organisms and mechanisms

*Oxidative rancidity, Pseudomonas* species (in air), *Lactic acid* bacteria, *Enterobacteriaceae, Shewanella* species, *Photobacterium* species, *Aeromonas* species.

## Food poisoning hazards include

*Clostridium botulinum* (non-proteolytic E, B and F), *Vibrio parahaemolyticus, Salmonella* species, *Staphylococcus aureus, Listeria monocytogenes.*

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

HFFS – Horizontal form-fill-seal

## Typical types of package

**Retail**

Tray and lidding film, tray inside pillow pack, pillow pack

## Examples of typical MAP materials

**Retail**

Tray:

- PVC/PE
- APET/PE
- HDPE
- EPS/EVOH/PE

Lidding and/or pillow pack film:

- PET/PVdC/PE
- PET/PE-EVOH-PE
- OPA/PE-EVOH-PE
- OPP/PE-EVOH-PE
- MPET/PE
- MOPP/PE

** The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*For more detailed information on fish and seafood products see relevant Datasheet available through the Air Products website.*

## Cooked, cured and processed poultry and game bird products

The principal spoilage mechanism for cooked, cured and processed poultry and game bird products is microbial growth. For cooked products, the heating process should kill vegetative bacterial cells and inactivate degradative enzymes. Consequently, spoilage of cooked poultry and game bird products is primarily due to post-cooking contamination by micro-organisms which can be minimised by MAP with $CO_2/N_2$ mixtures and good hygiene and handling practices. A gas/product ratio of 2:1 is recommended. Cured and processed poultry and game bird products contain relatively high levels of salt and/or other preservatives which effectively inhibit a wide range of spoilage microorganisms.

Possible food poisoning hazards are primarily due to post-cooking, curing or processing contamination can be minimised by maintenance of recommended chilled temperatures and good hygiene and handling practices. The reduced $a_w$ and/or addition of salt and/or other preservatives in most cooked, cured and processed poultry and game bird products inhibit most food poisoning bacteria.

** The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*For more detailed information on cooked, cured and processed poultry and game bird products see relevant Datasheet available through the Air Products website.*

## Food items

Capon galantine, chicken ballotine, chicken roll, cured game birds, cured poultry, duck ballotine, duck pâté duck galantine, pheasant galantine, pigeon galantine, smoked chicken, smoked duck, smoked poussin, smoked turkey, turkey bacon, turkey ballotine, turkey galantine and turkey roll.

## Recommended gas mixtures

30–40% $CO_2$, 60–70% $N_2$

## Storage temperature

**Legal maximum*:** 8°C

**Recommended:** 0°C to +3°C

## Achievable shelf life

**In air:** 5–10 days

**In MAP:** 7–21 days

## Principle spoilage organisms and mechanisms

*Pseudomonas* species (in air), *Brochothrix* species, *Lactic acid* bacteria, *Enterobacteriaceae,* yeasts and moulds.

## Food poisoning hazards include

*Clostridium* species, *Salmonella* species, *Staphylococcus aureus*, *Listeria monocytogenes*, *Campylobacter* species, E.coli and E.coli O157.

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

HFFS – Horizontal form-fill-seal

**Bulk**

VC – Vacuum chamber

ST – Snorkel-type

## Typical types of package

**Retail**

Tray and lidding film, tray inside pillow pack, pillow pack

**Bulk**

Bag-in-box, master pack

## Examples of typical MAP materials

**Retail**

Tray:

- PVC/PE
- APET/PE
- HDPE
- EPS/EVOH/PE

Lidding and/or pillow pack film:

- PET/PVdC/PE
- PA/PVdC/PE
- PET/PE-EVOH-PE
- OPA/PE-EVOH-PE
- OPP/PE-EVOH-PE
- MPET/PE
- MOPP/PE

**Bulk**

- PA/PE
- PA/EVOH/PE

## Ready meals and other cook-chill products

Cook-chill is a catering or food processing system whereby food is hygienically prepared, pasteurised and rapidly chilled to between 0°C and 3°C. The food is then stored at 0°C to 3°C before being reheated to 70°C for two minutes (or the thermal equivalent) prior to consumption.

Under UK Department of Health (1989) guidelines for cook-chill, the maximum recommended shelf-life for such products is five days. However, these guidelines only refer to cook-chill products intended for the catering market, and the possibility exists for such products to have longer permitted shelf-lives if packed under MA or cooked under vacuum (sous vide) by food manufacturers for the retail market.

The Advisory Committee for the Microbiological Safety of Foods (1992: 'Report on Vacuum Packaging and Associated Processes') has concluded that chilled foods with a shelf-life shorter than 10 days should, if kept at chilled temperatures, present a minimal risk of the growth and toxin production by *Clostridium botulinum*.

The principal spoilage mechanism for ready meals and other cook-chill products is microbial growth, which is primarily due to post-cooking contamination and/or poor temperature control. The pasteurisation cooking process should kill vegetative bacterial cells, inactivate degradative enzymes, and also fix the colour. However, heat resistant spores, such as those from *Clostridium* species and *Bacillus* species, will survive the cooking process and may germinate if recommended chilled temperatures are not maintained.

The other possible food poisoning hazards can arise from post-cooking contamination as a result of poor hygiene and handling practices and faulty seal integrity. Poor temperature control will exacerbate the problem of microbial growth. Therefore, it is recommended that strict control over temperature, hygiene and handling be maintained throughout. The use of additional barriers to microbial growth (such as acidification, use of preservatives and/or reduction in $a_w$), wherever appropriate, is strongly recommended. MAP can significantly extend the shelf-life of ready meals and other cook-chill products. Apart from delaying microbial spoilage, the use of $CO_2/N_2$ gas mixtures has also been found to delay the development of oxidative warmed-over flavour. A gas/product ratio of 2:1 is recommended.

## Food items

Casseroles*, ready meals containing fish, ready meals containing game-bird, goulash*, ready meals containing meat, ready meals containing offal, ready meals containing pasta, ready meals containing poultry, sauces*, ready meals containing seafood, soups* and ready meals containing vegetables.

## Recommended gas mixtures

30–50% $CO_2$, 50–70% $N_2$

## Storage temperature

**Legal maximum*:** 8°C**

**Recommended:** 0°C to +3°C***

## Achievable shelf life

**In air:** 2–5 days

**In MAP:** 5–10 days

## Principle spoilage organisms and mechanisms

*Pseudomonas* species (in air), *Lactic acid* bacteria, *Enterobacteriaceae,* yeasts and moulds.

## Food poisoning hazards include

*Clostridium* species, *Salmonella* species, *Staphylococcus aureus*, *Bacillus* species, *Listeria monocytogenes*, E.coli and E.coli O157, *Yersinia enterocolitica* can be important for pork products.

## Typical MAP machines*

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

## Typical types of package

**Retail**

Retail: Tray and lidding film, tray inside pillow pack

## Examples of typical MAP materials

**Retail**

Tray:

- UPVC/PE
- APET/PE
- EPS/EVOH/PE

Lidding and/or pillow pack film:

- PET/PVdC/PE
- PA/PVdC/PE
- PC/EVOH/EVA
- MPET
- MOPP

* *Pumpable products can be $N_2$ sparged and retail packed into cartonboard gabletopped containers, pots, tubs, or barrier stand-up pouches. CAP can be used for bulk packs.*

** *The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*** *As recommended by the Department of Health (1989). Guidelines for cook-chill and cook-freeze catering systems.*

*For more detailed information on ready meals and other cook chill products see relevant Datasheet available through the Air Products website.*

## Combination products

Combination products are made up of two or more different food components. Due to the vast differences in the intrinsic properties of these products and the interactions between separate components in the same food product, only generalisations regarding spoilage mechanisms, possible food poisoning hazards, achievable shelf-lives, and gas mixtures can be made. Food manufacturers considering using MAP for such products must carry out detailed shelf-life evaluations to determine the optimal gas mixture, spoilage mechanisms, etc. The principal spoilage mechanisms likely to affect combination products are microbial growth and oxidative rancidity. $CO_2/N_2$ gas mixtures are recommended to effectively inhibit microbial spoilage and rancidity development and hence significantly extend shelf-life. Staling is a problem for bakery combination products and MAP appears to have little effect on the rate of staling. Consequently, shelf-life extensions under MAP for cold-eating bakery combination products are only marginal. Moisture migration between different components of certain combination products is also a spoilage mechanism which is unaffected by MAP. It should be noted that many combination products are cooked products or contain cooked ingredients. Consequently, the possible food poisoning hazards associated with these types of products are primarily due to post-cooking and/or post-packaging contamination. These food poisoning hazards can be minimised by adequate cooking and maintenance of recommended chilled temperatures and good hygiene and handling practices.

## Food items

Battered fish, battered meats, battered poultry, battered seafood, bouchée, breaded fish, breaded meats, breaded poultry, breaded seafood, burritos, enchiladas, falafels, filled crêpes, filled pancakes, filled rolls, pasta containing fish, pies containing fish, kebabs, pasta containing meat, pies containing meat, omelettes, pasties, pâtés en croûtes, pizzas, pasta containing poultry, pies containing poultry, quiche, roule au fromage, sandwiches, satays, sausage rolls, pasta containing seafood, pies containing seafood, soufflés, spring rolls, stuffed pitta bread, tacos, tostadas and vol au vents.

## Recommended gas mixtures

30–50% $CO_2$, 50–70% $N_2$

## Storage temperature

**Legal maximum*:** 8°C

**Recommended:** 0°C to +3°C

## Achievable shelf life

**In air:** 2–7 days

**In MAP:** 3–21 days

## Principle spoilage organisms and mechanisms

*Pseudomonas* species (in air), *Brochothrix* species, *Lactic acid* bacteria, *Enterobacteriaceae,* yeasts and moulds.

## Food poisoning hazards include

*Clostridium* species, *Salmonella* species, *Staphylococcus aureus*, *Bacillus* species, *Listeria monocytogenes*, E.coli and E.coli O157.

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

HFFS – Horizontal form fill seal

## Typical types of package

**Retail**

Tray and lidding film, tray inside pillow pack, pillow pack

## Examples of typical MAP pmaterials

**Retail**

Tray:

- UPVC/PE
- HDPE
- EPS/EVOH/PE

Lidding and/or pillow pack film:

- PET/PVdC/PE
- PA/PVdC/PE
- PC/EVOH/EVA
- MPET
- MOPP
- OPP/PVDC

** The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*For more detailed information on combination products see relevant Datasheet available through the Air Products website.*

## Fresh pasta products

The principal spoilage mechanisms affecting fresh pasta are yeast and mould growth, due to the lower $a_w$ of these products.

For green fresh pasta, it may be desirable to exclude light in order to reduce undesirable light-induced discoloration. Hence, light barriers such as colour printed, pigmented or metallised films are commonly used.

As with all other MA packed food products, the maintenance of recommended storage temperatures and good hygiene and handling practices will help to minimise food poisoning hazards. MAP can significantly extend the shelf-life of pasta. $CO_2/N_2$ gas mixtures are used to inhibit microbial growth and any possible harmful oxidative reactions. A gas/product ratio of 2:1 is often used. Pasta varieties having lower $a_w$ values will tend to have longer shelf-lives in both air and under MA.

## Food items

Capelli, fettucine, funghini, fusilli, linguine, macaroni, pasta shells, spaghetti, tagliarini, tagliatelle, trenette, tubetti, vermicelli and zitioni.

## Recommended gas mixtures

50% $CO_2$, 50% $N_2$

## Storage temperature

**Legal maximum*:** 8°C

**Recommended:** 0°C to +5°C

## Achievable shelf life

**In air:** 1–2 weeks

**In MAP:** 3–4 weeks

## Principle spoilage organisms and mechanisms

Yeasts and moulds, colour change (green to brown/grey) for green pasta.

## Food poisoning hazards include

*Staphylococcus aureus*, *Bacillus* species.

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

HFFS – Horizontal form-fill-seal

VFFS – Vertical form-fill-seal

## Typical types of package

**Retail**

Tray and lidding film, tray inside pillow pack, pillow pack

## Examples of typical MAP materials

**Retail**

Tray:

- UPVC/PE
- HDPE
- EPS/EVOH/PE

Lidding and/or pillow pack film:

- PET/PVdC/PE
- PA/PVdC/PE
- PC/EVOH/EVA
- MPET
- MOPP
- OPP/PVdC

** The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*For more detailed information on fresh pasta products see relevant Datasheet available through the Air Products website.*

## Bakery products

The principal spoilage mechanisms for non-dairy bakery products are mould growth, staling, and moisture migration. Yeasts may cause a problem in certain filled or iced products. Since the $a_w$ of non-dairy bakery products is generally less than 0.96, bacterial growth is inhibited and rarely a problem. However, it is possible that Staphylococcus aureus and Bacillus species may be able to grow in certain products and hence pose a potential food poisoning hazard. Consequently, good hygiene and handling practices must be observed throughout.

The use of MAP can significantly extend the shelf lives of non-dairy bakery products. Since moulds are aerobic micro-organisms, they are very effectively inhibited by $CO_2/N_2$ gas mixtures. A gas/product ratio of 2:1 is often used. Moisture migration from the pack is prevented by using barrier materials for MAP. MAP appears to have little effect on the rate of staling. It should be noted that staling rates are increased at chilled temperatures and hence most cold-eating bakery products are normally stored at ambient temperatures.

For hot-eating bakery products, such as pizza bases, the staling process, which is caused by starch retrogradation, is partially reversed during the reheating cycle.

## Food items

Bagels, bread puddings, breads, buns, cheesecakes, crêpes, croissants, crumpets, Danish pastries, fruit breads, fruit cakes, fruit pies, fruit strudels, fruit tarts, meringue cakes, muffins, nan bread, nut breads, pancakes, par-baked breads, pitta bread, pizza bases, pretzels, sponge layer cakes, swiss rolls, taco shells, tortillas, vegetable breads and waffles.

## Recommended gas mixtures

30–100% $CO_2$, 0-–70 % $N_2$

## Storage temperature

**Legal maximum*:** 8°C

**Recommended:** 0°C to +5°C

## Achievable shelf life

**In air:** 0–14 days

**In MAP:** 4–12 weeks

## Principle spoilage organisms and mechanisms

Yeasts, moulds staling, physical separation, moisture migration

## Food poisoning hazards include

*Staphylococcus aureus, Bacillus* species

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

HFFS – Horizontal form-fill-seal

## Typical types of package

**Retail**

Retail: Tray and lidding film, tray inside pillow pack, pillow pack

## Examples of typical MAP materials

**Retail**

Tray:

- UPVC/PE
- HDPE
- EPS/EVOH/PE

Lidding and/or pillow pack film:

- PET/PVdC/PE
- PA/PVdC/PE
- PC/EVOH/EVA
- MPET
- MOPP
- OPP/PVdC

* *The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*For more detailed information on bakery products see relevant Datasheet available through the Air Products website.*

## Dairy products

The principal spoilage mechanisms affecting dairy products are microbial growth and oxidative rancidity. The type of spoilage affecting dairy products will depend on the intrinsic properties of the different products. For example, low $a_w$ products such as hard cheeses are generally spoilt by mould growth, whereas higher $a_w$ products such as creams and soft cheeses are susceptible to yeast and bacterial spoilage, oxidative rancidity, and physical separation.

MAP can significantly extend the shelf-lives of dairy products. Similar shelf-lives are achieved for MAP as opposed to vacuum packaging. Hard cheeses are generally packed in $CO_2$ gas which is very effective at inhibiting mould growth. Soft cheeses are packed in $CO_2/N_2$ gas mixtures, which can also inhibit bacterial spoilage and oxidative rancidity. For soft or grated cheese, 30% $CO_2$, 70% $N_2$ is recommended. MAP is particularly effective for crumbly cheeses such as Lancashire and grated cheese where vacuum packaging would cause undesirable compression.

MAP is not recommended for mould-ripened cheeses since $CO_2/N_2$ gas mixtures would kill desirable mould growth, causing it to turn an unpleasant yellow. Creams are adversely affected by $CO_2$-containing atmospheres which cause acidification of the cream, giving it a sharp rather than smooth taste. Consequently, $N_2$ is recommended for MAP of creams and cream containing products. A gas/product ratio of 2:1 is recommended. By exclusion of air, $N_2$ is also capable of inhibiting aerobic microbial growth and oxidative rancidity. Aerosol creams use nitrous oxide ($N_2O$) as a propellant, which also inhibits oxidative rancidity.

Other dairy products such as butter and yoghurt are not usually MA packed but would benefit from packaging under $N_2$. Possible food poisoning hazards associated with dairy products are primarily due to either inadequate pasteurisation or cross-contamination during or after packaging. Consequently, adequate pasteurisation, the maintenance of recommended chill temperatures, and good hygiene and handling throughout are essential for ensuring the safety of dairy products.

## Food items

Aerosol creams, blue and white mould-ripened cheeses*, butter, cream cakes, creams, custards, fresh cheeses, grated cheeses, hard cheeses, margarine, semi-hard cheeses, sliced cheeses, soft cheeses and yoghurts.

## Recommended gas mixtures

Hard cheeses except mould-ripened cheeses: 100% $CO_2$

Grated and soft cheeses except mould-ripened cheeses:
0–30% $CO_2$, 70%–100 % $N_2$

Other dairy products: 100% $N_2$

Exceptions – Aerosol creams:
Nitrous oxide ($N_2O$)

## Storage temperature

**Legal maximum*:** 8°C**

**Recommended:** 0°C to +5°C

## Achievable shelf life

**In air:** 1–4 weeks

**In MAP:** 2–12 weeks

## Principle spoilage organisms and mechanisms

*Pseudomonas* species (in air), *Brochothrix* species, *Lactic acid* bacteria, *Enterobacteriaceae,* yeasts and moulds, Oxidative rancidity, Physical separation.

## Food poisoning hazards include

*Clostridium* species, *Salmonella* species, *Staphylococcus aureus*, *Bacillus* species, *Listeria monocytogenes*, E.coli and E.coli O157.

## Typical MAP machines

**Retail**

TFFS - Thermoform-fill-seal

PTLF - Preformed tray and lidding film

HFFS - Horizontal form-fill-seal

VFFS - Vertical form-fill-seal

## Typical types of package***

**Retail**

Retail: Tray and lidding film, tray inside pillow pack, pillow pack.

## Examples of typical MAP materials

**Retail**

Tray:

- UPVC/PE
- HDPE
- EPS/EVOH/P

Lidding and/or pillow pack film:

- PET/PVdC/PE
- PA/PVdC/PE
- PC/EVOH/EVA
- MPET
- MOPP
- OPP/PVdC

* *Mould-ripened blue and white cheeses are not usually MA packed since $CO_2/N_2$ gas mixtures would inhibit desirable mould growth.*

** *The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*** *Tubs and pots are commonly used for yoghurts, soft cheeses, margarine, creams, custards, and butter.*

*For more detailed information on dairy products see relevant Datasheet available through the Air Products website.*

## Dried food products

The principal spoilage mechanism affecting dried foods containing a high proportion of unsaturated fatty acids, such as cereals, potato crisps, nuts, cocoa powder and dried milk, is oxidative rancidity. This damaging reaction is very effectively inhibited by MAP in $N_2$. A gas/product ratio of 2:1 is often used. Due to the very long achievable shelf-lives in MAP for dried foods, MAP materials must have very high moisture and gas barrier properties. Metallised films possess these necessary properties. Certain dried foods, such as dried baby milk, are particularly susceptible to oxidative rancidity and residual $O_2$ levels should be below 0.2%.

In order to achieve very low residual $O_2$ levels, $O_2$ scavengers may be incorporated into MA packs. These $O_2$ scavengers may also be used for other low $a_w$ foods such as bakery products. The low $a_w$ of dried foods will prevent the growth of bacteria, yeasts and moulds. It should be noted, however, that many food poisoning bacteria may survive on dried foods, particularly herbs and spices, and may pose a hazard when subsequently reconstituted or used as an ingredient in high $a_w$ foods. Consequently, strict standards of hygiene and handling should be observed to minimise such food poisoning hazards.

## Food items

Cocoa powders, coffees, dehydrated milk, dried and salted fish, dried and salted seafood, dried beans, dried cereals, dried colourings, dried flavourings, dried fruits, dried herbs, dried lentils, dried mushrooms, dried pasta, dried snack foods, dried spices, dried vegetables, flours, nuts, potato crisps and teas.

## Recommended gas mixture

100% $N_2$

## Storage temperature

**Recommended:** Ambient

## Achievable shelf life

**In air:** 4–8 months

**In MAP:** 1–2 years

## Principle spoilage organisms and mechanisms

Oxidative rancidity, moisture loss or gain.

## Food poisoning hazards include

Many food poisoning bacteria may survive on low $a_w$ dried foods. They will not grow on dried foods but may pose a possible food poisoning hazard upon reconstitution or when used as an ingredient in other high $a_w$ foods.

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

HFFS – Horizontal form-fill-seal

VFFS – Vertical form-fill-seal

## Typical types of package

**Retail**

Tray and lidding film, pillow pack

## Examples of typical MAP materials

**Retail**

Tray:

- UPVC/PE
- HDPE
- EPS/EVOH/PE

Lidding and/or pillow pack film:

- PET/PVdC/PE
- PA/PVdC/PE PC/EVOH/EVA
- MPET
- MOPP
- OPP/PVdC

*For more detailed information on dried food products see relevant Datasheet available through the Air Products website.*

## Cooked and dressed vegetable products

The principal spoilage mechanisms affecting cooked vegetable products are microbial growth and oxidative rancidity. MAP with $CO_2/N_2$ mixtures is very effective at inhibiting these spoilage mechanisms, thereby significantly extending the shelf-life of such products. A gas/product ratio of 2:1 is recommended. For cooked vegetable products, the heating process should kill vegetative bacterial cells and inactivate degradative enzymes. Consequently, spoilage of cooked vegetable products is primarily due to post-cooking contamination by micro-organisms which can be minimised by good hygiene and handling practices. Similarly, dressed vegetable products can be spoiled by post-packaging contamination.

Possible food poisoning hazards associated with cooked vegetable products include the germination and growth of heat resistant spores if recommended chilled temperatures are not maintained. The other possible food poisoning hazards can arise from post-cooking contamination as a result of poor hygiene and handling practices and faulty seal integrity. Poor temperature control will also exacerbate the problem of microbial growth.

Dressed vegetable products usually have a pH $< 4.0$ and hence virtually all possible food poisoning bacteria are inhibited. Spoilage of dressed vegetable products is primarily due to enzymic browning and microbial growth of acid tolerant lactobacilli, yeasts and moulds. For both cooked and dressed vegetable products, it is recommended that strict control over temperature, hygiene and handling be maintained throughout.

## Food items

Bean chillies, bhajis, broccoli in cheese, bubble and squeak, cauliflower cheese, coleslaw, cooked beans, cooked beetroot, cooked potatoes, corn fritters, garlic, mushrooms, lentil cutlets, nut cutlets, other dressed salads, pakoras, pasta salads, pilafs, potato cakes, potato salads, Quorn® dishes, rice salads, rissoles, stuffed aubergines, stuffed peppers, stuffed tomatoes, stuffed vine leaves, vegetable bakes, vegetable chillies, casseroles containing vegetables, vegetable pastas, vegetable crumbles, vegetable curries, vegetable dosas, vegetable flans, vegetable pilau, vegetable shepherd's pie and vegetarian burgers.

## Recommended gas mixtures

30–50% $CO_2$, 50–70% $N_2$

## Storage temperature

**Legal maximum*:** 8°C*

**Recommended:** 0°C to +3°C

## Achievable shelf life

**In air:** 3–14 days

**In MAP:** 7–21 days

## Principle spoilage organisms and mechanisms

*Pseudomonas* species (in air), *Lactic acid* bacteria, *Micrococci, Enterobacteriaceae,* yeasts and moulds and Enzymic browning.

## Food poisoning hazards include

*Clostridium* species, *Salmonella* species, *Staphylococcus aureus*, *Bacillus* species, *Listeria monocytogenes*, E.coli and E.coli O157.

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

HFFS – Horizontal form-fill-seal

## Typical types of package**

**Retail**

Tray and lidding film, tray inside pillow pack

## Examples of typical MAP materials

**Retail**

Tray:

- UPVC/PE
- HDPE
- EPS/EVOH/PE

Lidding and/or pillow pack film:

- PET/PVdC/PE
- PA/PVdC/PE
- PC/EVOH/EVA
- MPET
- MOPP
- OPP/PVdC

** The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

***Tubs and pots are commonly used for many cooked and dressed vegetable products. For more detailed information on cooked and dressed vegetable products see relevant datasheet available through the Air Products website.*

## Fresh whole and prepared fruit and vegetable products

The principal spoilage mechanisms affecting whole and prepared fresh fruit and vegetable products are microbial growth, enzymic browning, and moisture loss. MAP which results in depleted $O_2$ and/or enriched $CO_2$ levels is very effective at inhibiting these spoilage mechanisms, as well as:

- Reducing respiration
- Delaying ripening
- Decreasing ethylene production and sensitivity
- Retarding textural softening
- Reducing chlorophyll degradation
- Alleviating physiological disorders

Unlike other chilled perishable foods that are MA packed, fresh fruit and vegetables continue to respire after harvesting and any subsequent packaging must take this into account. The products of aerobic respiration are $CO_2$ and water vapour (whereas fermentation products such as ethanol, acetaldehyde and organic acids are produced during anaerobic respiration). Respiration is affected by numerous intrinsic properties of fresh produce as well as various extrinsic factors but, generally speaking, the achievable shelf-life of MA packed produce is inversely proportional to respiration rate. The depletion of $O_2$ and enrichment of $CO_2$ are natural consequences of the process of respiration when fresh fruit or vegetables are stored in a hermetically-sealed package. Such modification of the atmospheric composition results in a decrease in the respiration rate of plant material. If produce is sealed in an impermeable film, inpack $O_2$ levels will fall to very low concentrations where anaerobic respiration will be initiated. Anaerobiosis is usually associated with undesirable odours and flavours and a marked deterioration in product quality.

If fruit or vegetables are sealed in a film of excessive permeability, little or no atmospheric modification will result within the package. In addition, moisture loss will cause undesirable wilting and shrivelling, and therefore fully permeable films are unsuitable for fresh produce packaging. However, if film of correct intermediary permeability is chosen, a desirable equilibrium modified atmosphere (EMA) is established when the rates of $O_2$ and $CO_2$ transmission through the package equal the product's respiration rate. The exact EMA attained will depend on the product's intrinsic respiration rate, but will also be greatly influenced by various extrinsic factors. These factors need to be optimised for each commodity so that the full benefits of MAP can be realised. Consequently, desirable EMAs can passively evolve within a hermetically sealed package without the introduction of a gas mixture.

Respiration characteristics need to be properly matched to appropriate film permeabilities. Generally speaking, commodities possessing extremely high respiration rates need to be packed in extremely high $O_2$ permeable films. By gas flushing produce packages with 5% $CO_2$/5% $O_2$/ 90% $N_2$, it is possible to establish a beneficial EMA more quickly than a passively generated EMA. A gas/product ratio of 2:1 is recommended. Such a procedure may be necessary to delay enzymic browning reactions which could result in spoilage before a passively generated EMA has been established. Only fruit and vegetables of the highest quality should be used for MAP. Hygienic preparation, disinfection in chilled chlorinated water, rinsing and dewatering prior to MAP will help to ensure low microbial counts before chilled storage and distribution. In addition, knowledge of the intrinsic properties of fresh produce (respiration rate, pH, $a_w$, biological structure and ethylene production and sensitivity) and the extrinsic factors to optimise (harvesting, handling, hygiene, temperature, relative humidity, MAP materials and machinery, gas/product ratio and light) will help to ensure the safety and extended shelf-life of MA packed fruit and vegetables.

## Fresh whole and prepared fruit and vegetable products

### Food items

Atlanta sprouts, apples, apricots, artichoke, asparagus, aubergine, avocado, bananas, bean sprouts, beetroot, blackberries, broad beans, broccoli, Brussels sprouts, cabbages, cauliflower, carrots, celery, cherries, chicory, courgettes, cranberries, cucumber, cumquats, fennel, garlic, gooseberries, grapefruit, grapes, green berries, guava, kale, kiwi fruit, leek, lemons, lettuces, limes, lychees, mandarins, mango, mangosteen, marrow, melon, mixed fruit salads, mixed vegetable salads, mulberries, nectarines, olea, onions, oranges, papayas, parsnips, passion fruit, peaches, peas, peppers, pineapple, plums, potatoes, prickly pear, radish, rambutans, raspberries, rhubarb, rocket, shalot, spinach, star apples, strawberries, sweetcorn, swede, tomatoes, turnip, water chestnuts, water cress, watermelon and yams.

## Recommended gas mixtures

5% $O_2$, 5% $CO_2$, 90% $N_2$

## Storage temperature

**Legal maximum*:** 8°C

**Recommended:** 0°C to +3°C

## Achievable shelf life

**In air:**

Whole: 5–21 days

Prepared: 2–5 days

**In MAP:**

Whole: 5–35 days

Prepared: 5–10 days

## Principle spoilage organisms and mechanisms

*Pseudomonas* species (in air), *Lactic acid* bacteria, *Erwinia* species, *Enterobacteriaceae,* yeasts and moulds, Enzymic browning, moisture loss.

## Food poisoning hazards include

*Clostridium* species, *Salmonella* species, *Staphylococcus aureus*, *Bacillus* species, *Listeria monocytogenes*, E.coli and E.coli O157.

## Typical MAP machines

**Retail**

TFFS – Thermoform-fill-seal

PTLF – Preformed tray and lidding film

HFFS – Horizontal form-fill-seal

VFFS – Vertical form-fill-seal

## Typical types of package

**Retail**

Tray and lidding film, tray inside pillow pack, pillow pack.

## Examples of typical MAP materials

**Retail**

Tray:

- UPVC/PE
- HDPE

Lidding and/or pillow pack film:

- OPP
- OPP/PE
- EVA
- MP
- MPOR

** The Food Safety (Temperature Control) regulations 1995 state that the maximum storage temperature for chilled perishable foods is 8°C. There will be flexibility to vary this when scientifically justified. For legal temperature storage requirements, please contact the Campden BRI.*

*For more detailed information on fresh whole and prepared fruit and vegetable products see relevant Datasheet available through the Air Products website.*

## Liquid food and beverage products

The principal spoilage mechanisms affecting perishable chilled fruit juices, liquid yoghurt, milk and vegetable juices are microbial growth and physical separation. Souring is also a principal spoilage mechanism for milk. Ambient stable beverages, such as beers, carbonated soft drinks, ciders, cordials, lagers, liqueurs, mineral waters, wines, and spirits, are also prone to selected microbial and some from oxidative off-flavours.

Perishable chilled fruit juices, liquid yoghurt, milk, and vegetable juices can support the growth of food poisoning bacteria such as Listeria monocytogenes and Staphylococcus aureus. Consequently, it is recommended that strict control over temperature, hygiene and handling be maintained throughout. Liquid food and beverage products are not packed on typical MAP machines, and the types of package typically used include cartonboard containers, glass and plastic bottles, aluminium and steel cans, kegs, barrels, and stainless steel tanks. $N_2$ and/or $CO_2$ sparging, whereby gaseous $N_2$ and/or $CO_2$ is bubbled through liquid food and beverage products, is used to reduce dissolved $O_2$ concentrations. Such gas sparging is commercially used for carbonated soft drinks, beers, lagers, mineral waters, fruit juices, etc, and could be beneficial for other liquid food and beverage products.

## Food items

Beers, carbonated soft drinks, ciders, cordials, fruit juices, lagers, liqueurs, liquid yoghurt, milk, mineral waters, oils, spirits, vegetable juices and wines.

## Recommended gas mixtures

100% $N_2$

**Carbonated soft drinks:**

100% $CO_2$

$N_2$ sparging, whereby gaseous $N_2$ is bubbled through liquid food and beverage products, is used to reduce dissolved $O_2$ concentrations.

## Storage temperature

**Recommended:** Ambient

**Exceptions:** Fruit juices, liquid yoghurt, milk, vegetable juices:

**Legal maximum*:** 8°C

**Recommended:** 0°C to +3°C

## Achievable shelf life

**In air:** Milk: 3 days

Fruit juices, vegetable juices: 1 week
liquid yoghurt: 10 days,
carbonated soft drinks, ciders, cordials, lagers, liqueurs, mineral waters, spirits, wines: 6 months

**In MAP:** Milk: 4–7 days

Fruit juices, liquid yoghurt, vegetable juices: 2–3 weeks

Beers, carbonated soft drinks, ciders, cordials, lagers, liqueurs, mineral waters, spirits, wines: –1 year

## Principle spoilage organisms and mechanisms

Fruit juices, liquid yoghurt, milk, vegetable juices: *Lactic acid* bacteria, *Streptococci* species, *Bacillus* species, yeasts and moulds, souring of milk, physical separation. Other products: yeasts and moulds, oxidative off-flavours.

## Food poisoning hazards include

*Listeria monocytogenes* and *Staphylococcus aureus*.

## Typical MAP machines

Liquid food and beverage products are not packed on typical MAP machines but on specialised filling equipment with in-line $N_2$ sparging capability.

## Typical types of package

**Retail**

Typical retail packages include carton-board gable-top containers, glass and plastic bottles, aluminium and steel cans.

## Examples of typical MAP materials

**Retail**

Tray:

- Glass
- Plastic
- Aluminium
- Steel
- Cartonboard

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*For more detailed information on liquid food and beverage products see relevant Datasheet available through the Air Products website.*

## Definitions and terminology

| | |
|---|---|
| $a_w$ (water activity) | The growth and metabolism of micro-organisms in food depends on the presence of water in an available form. $a_w$ gives a measure of water availability. Microbial stability of many foods is achieved by removing available water (e.g. by drying, or addition of salt, sugar etc.) to reduce the $a_w$. |
| Bulk | Refers to master packs or packs for catering or further processing or any large gas flushed pack containing retail packs. |
| Controlled Atmosphere Packaging (CAP) | A bulk packaging system used for primal cuts of raw red meats. CAP – Controlled Atmosphere Packaging, not to be confused with controlled atmosphere storage, is a system that uses hermetically sealed gas-impermeable packaging materials. The pre-determined pack atmosphere is supported by employing active packaging in the form of $O_2$ generators/$CO_2$ absorbers. |
| CBDF System | Refers to the Cryovac® BDF barrier shrink film MAP system. Perishable food products are placed in a semi-rigid tray and then gas flushed and hermetically sealed within BDF film pouches on a HFFS machine. The MA packs are then passed through a hot air tunnel which causes the seals to heat shrink down to the underside of the pack. |
| Chilled foods | Perishable foods which must be stored at refrigerated temperatures to ensure they remain safe and wholesome within their shelf-life. |
| Contamination | The accidental or deliberate adulteration of a food product or ingredient by the introduction of undesirable microorganisms, toxins, chemicals or foreign matter of any sort. |
| Controlled atmosphere storage | The storage of food in an atmosphere that is different from the normal composition of air. The atmospheric components are precisely adjusted to specific concentrations throughout the storage and distribution of perishable foods. Controlled atmospheres are used in the warehouse storage of whole fruit and vegetables and the road or sea-freight container transport of perishable foods. |
| Disinfection | The reduction of microorganisms by means of heat, chemical and/or physical methods to a level that is consistent with good hygienic practice and food safety. |
| Enzymic browning or discolouration | Browning of cut or damaged fruit and vegetables caused by oxidation of polyphenols. The enzyme is inactivated by heat; in raw products, elimination of oxygen will prolong storage life. |

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| **Equilibrium Modified Atmosphere Packaging (EMAP)** | Use of the respiratory processes of fruits and vegetables to generate or maintain a modified atmosphere. Respiration creates an atmosphere having a reduced content of oxygen and an increased level of carbon dioxide. This slows the process of ageing. |
| **Food hygiene** | All measures necessary to ensure the wholesomeness and safety of food from reception and storage of raw materials to final consumption. |
| **Food poisoning** | Illness associated with consumption of food which contains harmful chemicals, microorganisms or their toxins. |
| **Food spoilage** | Deterioration of food caused by microbiological, chemical, biochemical or physical processes which results in undesirable appearance, texture, odours and/or flavours. |
| **Good manufacturing practice (GMP)** | The combination of manufacturing and quality assurance procedures aimed at ensuring that products are consistently manufactured to their specifications. |
| **Hermetic seal** | A heat and/or pressure closure which constitutes part of a food package and is designed to secure against the transfer of microbial or other contamination from the environment to the product. |
| **Master pack** | A large gas-flushed pack containing consumer packages. Sometimes known as a 'mother pack'. |
| **Modified Atmosphere Packaging (MAP)** | A food preservation technique whereby the composition of the atmosphere surrounding the food is different from the normal composition of air. Unlike controlled atmosphere storage, in MAP there is no way of controlling atmospheric components at specific concentrations once a package has been hermetically sealed. Modified to be a single gas or combination. |
| **pH (value)** | A number which provides an indication of the degrees of acidity or alkalinity: acid (pH value below 7), neutral (pH 7), alkaline (pH value above 7). |
| **Shelf-life** | The period of time from manufacture that a food product remains safe and wholesome under recommended production and storage conditions. |
| **Vacuum packaging** | The removal of all or most of the air within a package without deliberate replacement with another gas mixture. |

**For more information, please contact us at:**


**Air Products PLC**
United Kingdom
2 Millennium Gate
Westmere Drive
Crewe CW1 6AP
T 0800 389 0202
F 01932 258 652
apukinfo@airproducts.com

**Air Products Ireland Ltd.**
Unit 950
Western Industrial Estate
Killeen Road
Dublin 12
T 1800 99 50 29
ieinfo@airproducts.com


tell me more
airproducts.co.uk
airproducts.ie

 332-15-121-EN-Jun18