Principles and Applications of Modified Atmosphere Packaging of Foods

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Preface

Modified atmosphere packaging (MAP) has proved to be one of the most significant and innovative growth areas in retail food packaging of the past two decades.

Bulk modified atmosphere packs have been an accepted form of packaging for meat and poultry in the USA since the early 1970s, but MAP is only now on the verge of being widely adopted. Today there is a substantial wholesale market for bulk packaged fresh vegetables and fruit, and the most significant retail MAP products are fresh pasta, pre-cooked poultry and sausage, and biscuits (a unique American product).

The United Kingdom is the biggest single market for the modified atmosphere packaging of fresh chilled food products, accounting for about half of the total European market. A further quarter is represented by France. The success of MAP in both the British and French markets can be attributed to the large, highly sophisticated food retailing multiples and dense populations existing in both countries.

The rapid growth in MAP products in the United Kingdom resulted from a successful test launch of MAP meat packs by Marks and Spencer plc in 1979. The other major high street food retailers were not slow to appreciate the advantages of MAP in terms of shelf-life and presentation and soon sought to apply it themselves to an extensive catalogue of products. Today the United Kingdom leads the world in terms of market size and range of MAP products. These include red meat and poultry, cooked and cured meats, fish and seafood, fruit and prepared vegetables and salads, cheese, bakery goods and pasta, ready meals, sandwiches and dried foods.

Despite the obvious commercial importance of the MAP process it has not been as extensively covered in the technical literature as might be expected. No truly comprehensive book exists on the subject, embracing all the scientific, technological and commercial aspects in a single text. It is the aim of this volume to redress this deficiency and the twelve international contributors have been carefully selected from industry, academia and the premier food research institutes to provide the necessary practical experience allied to technical knowledge to achieve this objective.

R.T.P.

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1 Introduction

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1.1 Historical background

Since World War II there have been significant changes in the character of food retailing. The corner shop has largely been replaced by the supermarket. Consequently, there have been profound changes in modern food manufacture and packaging.

Today's consumer is becoming increasingly demanding and discriminating, and is concerned about such issues as food safety, diet, additives and product labelling. The search for fresh 'healthy' products of superior quality has inspired one of the major growth sectors in modern food retailing - chilled products. It is in this context that the development of modified atmosphere packaging of foods has taken place so rapidly over the past decade.

The shelf-life of such perishable foods as meat, poultry, fish, fruits and vegetables and bakery products is limited in the presence of normal air by two principal factors - the chemical effect of atmospheric oxygen and the growth of aerobic spoilage microorganisms. These factors either individually or in association with one another bring about changes in odour, flavour, colour and texture leading to an overall deterioration in quality. Chilled storage will slow down these undesirable changes but will not necessarily extend the shelf-life sufficiently for retail distribution and display purposes.

The normal composition of air is 21% oxygen, 78% nitrogen and less than 0.1% carbon dioxide. Modification of the atmosphere within the package by reducing the oxygen content while increasing the levels of carbon dioxide and/or nitrogen has been shown to significantly extend the shelf-life of perishable foods at chill temperatures (Table 1.1).

The use of modified atmospheres for shelf-life extension of food is not a new concept in food preservation. The preservative action of carbon dioxide on flesh foods has been known for over a century. However, it was not until the 1920s and 1930s that basic research was undertaken into the use of modified atmospheres for prolonging the life of fruit, meat and fish. Brown (1922) investigated the effect of different concentrations of oxygen and carbon dioxide at various temperatures on the germination and growth of fruit-rotting fungi. Five years later Kidd and West (1927) studied the effect of atmosphere modification on the storage life of fruit. These

Table 1.1. Estimated shelf-life of MAP products

Product	Air packaged	Modified atmosphere packaged
Beef*	4 days	12 days
Pork*	4 days	9 days
Chicken*	6 days	18 days
Cooked meats*	7 days	28 days
Fish*	2 days	10 days
Bread**	7 days	21 days
Coffee**	3 days	18 months

* Refrigerated storage
** Ambient storage

pioneering experiments resulted in the first commercial controlled atmosphere store for apples being built in Kent, England, in 1929.

Killefer (1930) demonstrated that lamb and pork remained fresh twice as long in 100% carbon dioxide compared with storage in air at chill temperatures. Similar improvements in the keeping quality of pork and bacon (Callow, 1932), beef (Moran *et al.*, 1932) and meat (Tomkins, 1932) were subsequently reported. Haines (1933) found that some of the common meat bacteria took twice as long to multiply to the same number if stored in 10% carbon dioxide at 0°C as they did in air at the same temperature. By 1938, 26% of chilled carcass beef shipped from Australia and 60% of that shipped from New Zealand were being held in a maintained atmosphere of 10% carbon dioxide for forty to fifty days without spoilage.

It was established by Coyne (1932 and 1933) that fillets or whole fish at ice temperature could be kept twice as long if stored in an atmosphere containing a minimum of 25% carbon dioxide. If the carbon dioxide concentration exceeded 80%, however, undesirable visual and textural changes occurred. The work was progressed to a semi-commercial stage but the technique was never adopted by the industry.

For several decades after the 1930s interest in food preservation using modified atmospheres appears to have waned although by the 1960s vacuum packaging had become popular for fresh meat and many dry products. In the 1950s a comprehensive study of the use of carbon dioxide enriched atmospheres for extending the shelf-life of chicken portions was carried out by Ogilvy and Ayres (1951) in the USA. They found that the ratio of shelf-life in a carbon dioxide/air mixture to that in air alone was a linear function of carbon dioxide concentration up to a maximum of 25%. Higher concentrations caused discoloration of the meat. It was not until the 1970s, however, that bulk packs of fresh chicken evacuated then flushed with carbon dioxide were introduced commercially in the USA to extend the shelf-life to 18–21 days in chill storage.

Modified atmosphere packs of the type familiar today in supermarkets did not appear until 1973 in Germany, 1974 in France and 1978 in

Denmark. The thermoformed semi-rigid horizontal form-fill-seal pack system had been invented in 1963. In the UK it was Marks and Spencer in 1979 who paved the way for Britain's pre-eminence today in the world market-place for modified atmosphere products with their test launch of modified atmosphere packaged meat. During the next two years they extended their product range to include bacon, chops, sliced cooked meats, fresh and smoked fish and cooked shellfish. The success of this initiative quickly prompted the other major food retailers to develop their own catalogue of modified atmosphere packaged products.

In North America the adoption of modified atmospheres for shelf-life extension of fresh foods has not been as widespread for both geographical and commercial reasons (Day, 1990). The American market is packer/consumer driven whereas the European market, as already discussed, is retailer driven.

1.2 Definitions, terminology and abbreviations

1.2.1 Modified atmosphere packaging (MAP)

A form of packaging involving the removal of air from the pack and its replacement with a single gas or mixture of gases. The gas mixture used is dependent on the type of product. The gaseous atmosphere changes continuously throughout the storage period due to factors such as respiration of the packed product, biochemical changes and the slow permeation of gases through the container.

1.2.2 Controlled atmosphere packaging (CAP)

A term often used synonymously for MAP. Its use is, however, incorrect as it is not possible to control the atmosphere within the pack once it has been sealed.

1.2.3 Gas packaging

An alternative term commonly used to describe modified atmosphere packaging. It is a misnomer since atmosphere modification can be achieved by simple vacuum or evacuation of the air.

It is also felt to have adverse emotive connotations for the consumer and is consequently a term avoided by many manufacturers and retailers.

1.2.4 Vacuum packaging (VP)

The simplest and most common means of modifying the internal gaseous atmosphere in a pack. The product is placed in a pack made from film of low oxygen permeability, air is evacuated and the package sealed. An evacuated pack collapses around the product so that the pressure inside is seldom much less than atmospheric.

1.2.5 Gas cocktail

A term sometimes used to refer to the gas mixture used to modify the atmosphere within a package.

1.2.6 Controlled atmosphere storage (CAS)

A form of bulk storage where the concentration of gas initially introduced to modify the atmosphere is maintained throughout the period of storage by constant monitoring and regulation. The stores are also refrigerated.

It has been used for over sixty years for the storage of fruit in large sealed chambers in which the levels of carbon dioxide and oxygen can be controlled. More recently it has been successfully used to extend the life of fresh poultry carcasses stored in bulk.

1.2.7 Hypobaric storage

Hypobaric or low pressure storage is another form of controlled atmosphere storage where pressure, temperature and humidity are accurately controlled. It has been used for the storage of soft fruits.

1.3 Methods of atmosphere modification in packaged foods

1.3.1 Vacuum packaging

The earliest form of modified atmosphere packaging developed commercially and still extensively used for such products as primal cuts of fresh red meat, cured meats, hard cheeses and ground coffee. It is not suitable for soft products or bakery products since the vacuum process causes irreversible deformation of the product.

The process involves packaging the product in film of low oxygen permeability and sealing it after first evacuating the air. Under good vacuum conditions the oxygen level is reduced to less than 1%. Due to the barrier properties of the film used, entry of oxygen from outside is restricted. In the case of vacuum-packed meat, respiration of the meat quickly consumes the residual oxygen replacing it with carbon dioxide which eventually increases to 10–20% within the package.

Unfortunately vacuum-packaged meat is unsuitable for the retail market because the depletion of oxygen coupled with the low oxygen permeability of the packaging film causes a change of meat colour from red to brown due to the conversion of myoglobin to metmyoglobin. This is not an acceptable meat colour to the consumer. A further disadvantage is the accumulation of drip during prolonged storage of meat in vacuum packs.

1.3.2 Gas packaging

The desired headspace atmosphere in a modified atmosphere pack can be achieved in two fundamental ways. These are the replacement of air with a gas or gas mixture mechanically or by generating the atmosphere within the package either passively as in the case of fruit and vegetables or actively by using suitable atmosphere modifiers such as oxygen absorbents.

1.3.2.1 Mechanical air replacement. There are two different techniques for mechanical air replacement in a package: (i) gas flushing; and (ii) compensated vacuum.

Gas flushing. The gas-flush process is usually performed on a form-fill-seal machine. A continuous stream of gas is injected into the package to replace the air. This dilutes the air in the headspace surrounding the food product. When most of the air has been replaced the package is sealed. There is a limit to the efficiency of this system since replacement of the air in the package is accomplished by dilution. Typical residual oxygen levels in gas-flushed packs are 2–5% oxygen. This means that the gas-flush technique is not suitable for packaging very oxygen sensitive foods. The great advantage of the gas-flush process is speed since it is a continuous operation.

Flushing with nitrogen has been introduced to extend the shelf-life of beverages. A drop of liquid nitrogen is injected into cans containing beer or carbonated soft drinks immediately before seaming. The liquid nitrogen rapidly evaporates into gas, flushing out oxygen taken up during the filling process. The benefits of flushing cans with nitrogen include increased shelf-life, retention of product aroma and reduced can corrosion.

Compensated vacuum. The compensated vacuum process first applies a vacuum to remove the air from inside a preformed or thermoformed container holding the food and then introduces the desired gas or gas mixture via lances or ports. Machines designed to perform this operation are of the chamber variety. Since this is a two-stage process the speed of operation of the equipment is slower than the gas-flushing technique. Because the air is removed by vacuum, however, the efficiency of the process with respect to residual air levels is much superior.