

# Vacuum and Modified Atmosphere Packaging of Fishes

C. O. Mohan, Remya, S and Bindu, J.

Fish Processing Division

ICAR- Central Institute of Fisheries Technology, Cochin

## Introduction

Fish is regarded as highly perishable food commodity which undergoes spoilage if sufficient care is not taken. Various preservation methods have been in place to overcome the spoilage of fish. Chilling and refrigeration is the most preferred preservation method as it helps in preserving fresh like quality. Chilling or icing is reducing the temperature of fish so as to prolong the lag phase of bacteria and helps in reducing the spoilage rate. Fish being one of the most perishable foods, its freshness is rapidly lost even when stored under chilled conditions. Further, consumers demands to have fish in as fresh a state as possible so that the characteristics flavours are retained. Bulk transportation of fresh fish in ice has several limitations like limited extension of shelf life, unnecessary expenditure on freight due to ice, difficulty in handling and maintaining hygienic conditions due to leaching of ice melt water with leaching losses of soluble nutrients and flavouring compounds. Proper packaging will help in improving the keeping quality of fish. Packaging is an important aspect for improving the shelf life and marketability. Packaging enhances the consumer acceptability and hence sale-ability of the product. Traditionally, food packaging is meant for protection, communication, convenience and containment. The package is used to protect the product from the deteriorative effects of the external environmental conditionals like heat, light, presence or absence of moisture, pressure, microorganisms, and gaseous emissions and so on. Packaging is an integral part of the food processing and plays an important role in preventing or reducing the generation of waste in the supply of food. Packaging assists the preservation of the world's resources through the prevention of product spoilage and wastage, and by protecting products until they have performed their function. Basic requirements of a package are good marketing properties, reasonable price, and technical feasibility, utility for food contact, low environmental stress, and suitability for recycling. Simply packing fish is suitable packaging material will enhance the shelf life of chilled and refrigerated fish to 7 to 15 days depending on fish species. However, in the normal packaging the spoilage process will be accelerated due to presence of O<sub>2</sub> in the normal air packing. Alteration in the package atmosphere will help in overcoming the problem of shelf life, which can be achieved by vacuum packaging or modified atmosphere packaging.

## Vacuum Packaging

Important properties by which consumers judge the fish and shell fish products are appearance, texture and flavor. Appearance, specifically color, is an important quality attribute influencing the consumer's decision to purchase. In fresh red meat fishes, myoglobin can exist in one of three chemical forms. Deoxymyoglobin, which is purple, is rapidly oxygenated to cherry red oxymyoglobin on exposure to air. Over time, oxymyoglobin is oxidised to metmyoglobin which results in a brown discoloration associated with a lack of freshness. Low oxygen concentrations favour oxidation of oxymyoglobin to metmyoglobin. Therefore, in order to minimize metmyoglobin formation in fresh red meats, oxygen must be excluded from the packaging environment to below 0.05% or present at saturating levels. Lipid oxidation is another major quality deteriorative process in muscle foods resulting in a

variety of breakdown products which produce undesirable off-odours and flavours. Hence O<sub>2</sub> may cause off-flavours (e.g. rancidity as a result of lipid oxidation), colour changes (e.g. discolouration of pigments such as carotenoids, oxidation), nutrient losses (e.g. oxidation of vitamin E,  $\beta$ -carotene, ascorbic acid) and accelerates microbial spoilage thereby causing significant reduction in the shelf life of foods. Therefore, control of oxygen levels in food package is important to limit the rate of such deteriorative and spoilage reactions in foods. Oxygen level in the package can be controlled by using the vacuum packaging technique in which, the air present in the pack is completely evacuated by applying vacuum and then package is sealed. Vacuum packaging is referred as skin packaging involves removal of air inside the pack completely and maintaining food material under vacuum conditions, so that the oxygen available for the growth of microbes and oxidation will be limited. This will help in doubling the shelf life of fish under chilled conditions. This technique is particularly useful in fatty fishes, where the development of undesirable odor due to the oxidation of fat is the major problem. Vacuum packaging for chilled and refrigerated fishes doubles the shelf life compared to normal air packaging. Application of this to frozen fishes is also commonly followed as it helps in reducing problem of freezer burn. This technique can be applied to fresh meat and fishes, processed meat and fishes, cheese, coffee, cut vegetables etc. One of the important aspects in the vacuum packaging is the use of packaging material with good barrier properties. Normally polyester-polyethylene or nylon-polyethylene laminates are used. Polyester and nylon provide good strength and acts as good barrier to oxygen. Polyethylene proves good heat sealing property and is resistant to water transmission. Typical vacuum packaging machine and vacuum packed fish is shown in Fig 1.





Fig 1. Vacuum packaging machine and Vacuum packed fish

#### **Advantages of Vacuum packaging**

- Reduces fat oxidation
- Reduces growth of aerobic microorganisms
- Reduces evaporation
- Reduces weight loss
- Reduces dryness of product
- Reduces freezer burn
- Reduces volume for bulk packs Eg. Tea powder, dry leaves etc
- Extends the shelf life
- Easy to use and maintain the equipment

#### **Disadvantages of Vacuum packaging**

- Cannot be used for crispy products and products with sharp edges
- Requires high barrier packaging material to maintain vacuum
- Creates anaerobic condition, which may trigger the growth and toxin production of *Clostridium botulinum* and the growth of *Listeria monocytogenes*. Additional barriers / hurdles are needed to control these microorganisms
- Capital intensive

Alternative to vacuum packaging, reduced oxygen level in the package can be achieved by using active packaging system like oxygen scavenger. Use of oxygen scavenger is very effective in reducing the oxygen level to <0.01% within 24 h, which helps in preserving the quality of food. This is not capital intensive and can be applied to any products including crispy and products with sharp edges.

#### **Modified Atmosphere Packaging (MAP)**

Marketing of modified atmosphere packaged (MAP) foods have increased, as food manufacturers have attempted to meet consumer demands for fresh, refrigerated foods with extended shelf-life. It is also used widely, as a supplement to ice or refrigeration to delay spoilage and extend the shelf life of fresh fishery products while maintaining a high-quality end product. A modified atmosphere can be defined as one that is created by altering the normal composition of air (78% nitrogen, 21% oxygen, 0.03% carbon dioxide and traces of noble gases) to provide an optimum atmosphere for increasing the storage length and quality

of food/produce. Oxygen, CO<sub>2</sub>, and N<sub>2</sub>, are most often used in MAP. Other gases such as, nitrous and nitric oxides, Sulphur dioxide, ethylene, chlorine, as well as ozone and propylene oxide have been suggested for a variety of products and investigated experimentally. However, due to safety, regulatory and cost considerations, they have not been applied commercially. These gases are combined in three ways for use in modified atmospheres: inert blanketing using N<sub>2</sub>, semi-reactive blanketing using CO<sub>2</sub> : N<sub>2</sub> or O<sub>2</sub> : CO<sub>2</sub> : N<sub>2</sub> or fully reactive blanketing using CO<sub>2</sub> or CO<sub>2</sub> : O<sub>2</sub>. Typical MAP machine and gas composition analyzer is given in Fig 2.

### Development of modified atmosphere packaging

Kolbe was the first to investigate and discover the preservative effect of carbon dioxide on meat in 18<sup>th</sup> century and Coyne was the first to apply modified atmospheres to fishery products as early as 1930's. Modified atmosphere packaging (MAP) is the removal and/or replacement of the atmosphere surrounding the product before sealing in vapor-barrier materials. While technically different many forms of map are also case ready packaging, where meat is cut and packaged at a centralized location for transport to and display at a retail store. Most of the shelf life properties of meat are extended by use of map, but anoxic forms of MAP without carbon monoxide do not provide bloomed red meat color and MAP without oxygen may promote oxidation of lipids and pigments. Advances in plastic materials and equipment have propelled advances in MAP, but other technological and logistical considerations are needed for successful MAP systems for raw chilled fresh meat

### Principle of MAP

The principle of MAP is the replacement of air in the package with a different fixed gas mixture. CO<sub>2</sub> is the most important gas used in MAP of fish, because of its bacteriostatic and fungistatic properties. It inhibits growth of many spoilage bacteria and the inhibition is increased with increased CO<sub>2</sub>-concentration in the atmosphere and reduced temperature. CO<sub>2</sub> is highly soluble in water and fat, and the solubility increases greatly with decreased temperature. The solubility in water at 0 °C and 1 atmosphere is 3.38 g CO<sub>2</sub>/kg water, however, at 20 °C the solubility is reduced to 1.73 g CO<sub>2</sub>/kg water. Therefore, the effectiveness of the gas is always conditioned by the storage temperature with increased inhibition of bacterial growth as temperature is decreased. The solubility of CO<sub>2</sub> leads to dissolved CO<sub>2</sub> in the food product, according to the following equation:



For pH values less than 8, typical of seafood, the concentration of carbonate ions may be neglected.



According to Henry's law, the concentration of CO<sub>2</sub> in the food is dependent on the water and fat content of the product, and on the partial pressure of CO<sub>2</sub> in the atmosphere. The growth inhibition of microorganisms in MA is determined by the concentration of dissolved CO<sub>2</sub> in the product. The preservation effect of MAP is due to the drop in surface pH in MA products because of the acidic effect of dissolved CO<sub>2</sub>, but this could not entirely explain all of CO<sub>2</sub>'s bacteriostatic effect. The possibility of intracellular accumulation of CO<sub>2</sub> would upset the

normal physiological equilibrium by slowing down enzymatic processes. Thus, the effect of CO<sub>2</sub> on bacterial growth is complex and four mechanisms of CO<sub>2</sub> on micro-organisms has been identified:

1. Alteration of cell membrane functions including effects on nutrient uptake and absorption
2. Direct inhibition of enzymes or decrease in the rate of enzyme reactions
3. Penetration of bacterial membranes, leading to intracellular pH changes
4. Direct changes in the physico-chemical properties of proteins.

Probably a combination of all these activities account for the bacteriostatic effect. A certain amount (depending on the foodstuff) of CO<sub>2</sub> has to dissolve into the product to inhibit bacterial growth. The ratio between the volume of gas and volume of food product (G/P ratio) should be usually 2 : 1 or 3 : 1 (gas : food product). This high G/P ratio is also necessary to prevent package collapse because of the CO<sub>2</sub> solubility in wet foods. The CO<sub>2</sub> solubility could also alter the food-water holding capacity and thus increase drip.

The major function of carbon dioxide in MAP is to inhibit growth of spoilage microbes. Carbon dioxide (CO<sub>2</sub>) is soluble in both water and lipid it has a bacteriostatic and fungistatic properties. Carbon dioxide lowers the intra and extra cellular pH of tissue including that of microorganisms. It affects the membrane potential and influence the equilibrium of decarboxylating enzymes of microorganisms. CO<sub>2</sub> increases the lag phase and a slower rate of growth of microbes during logarithmic phase. This bacteriostatic effect is influenced by the concentration of CO<sub>2</sub>, the partial pressure of CO<sub>2</sub>, volume of headspace gas, the type of microorganism, the age and load of the initial bacterial population, the microbial growth phase, the growth medium used, the storage temperature, acidity, water activity, and the type of the product being packaged. Pathogens like *Clostridium perfringens* and *Clostridium botulinum* are not affected by the presence of carbon dioxide and their growth is encouraged by anaerobic conditions. In general, carbon dioxide is most effective in foods where the normal spoilage organisms consist of aerobic, gram negative psychrotropic bacteria. The CO<sub>2</sub> is flushed into the modified atmosphere package by evacuating the air and flushing the appropriate gas mixture into the package prior to sealing. Another method to create a modified atmosphere for a product is either to generate the CO<sub>2</sub> and/or remove O<sub>2</sub> inside the package after packaging or to dissolve the CO<sub>2</sub> into the product prior to packaging. Both methods can give appropriate packages with smaller gas/product ratio to the package. The solubility of CO<sub>2</sub> decreases with increasing temperature, hence MAP products should be stored at lower temperatures to get the maximum antimicrobial effect. Also the temperature fluctuations will usually eliminate the beneficial effects of CO<sub>2</sub>. The rate of absorption of CO<sub>2</sub> depends on the moisture and fat content of the product. If product absorbs excess CO<sub>2</sub>, the total volume inside the package will be reduced, giving a vacuum package look known as “pack collapse”. Excess CO<sub>2</sub> absorption along with “pack collapse” results in the reduction of water holding capacity and further drip loss to the products.

The major function of oxygen is to avoid anaerobic condition which favors the growth and toxin production of *C botulinum* and growth of *L monocytogenes*. Oxygen in the MAP is also useful to maintain the muscle pigment myoglobin in its oxygenated form, oxymyoglobin. In fresh red meats, myoglobin can exist in one of three chemical forms. Deoxymyoglobin, which is purple, is rapidly oxygenated to cherry red oxymyoglobin on exposure to air. Over time,

oxymyoglobin is oxidised to metmyoglobin which results in a brown discoloration associated with a lack of freshness. Low oxygen concentrations favour oxidation of oxymyoglobin to metmyoglobin. Therefore, in order to minimize metmyoglobin formation in fresh red meats, oxygen must be excluded from the packaging environment to below 0.05% or present at saturating levels. High oxygen levels within MAP also promote oxidation of muscle lipids over time with deleterious effect on fresh meat color. O<sub>2</sub> in MA-packages of fresh fish will also inhibit reduction of TMAO to TMA.

Nitrogen (N<sub>2</sub>) is an inert and tasteless gas, and is mostly used as a filler gas in MAP, either to reduce the proportions of the other gases or to maintain pack shape by preventing packaging collapse due to dissolution of CO<sub>2</sub> into the product. Nitrogen is used to prevent package collapse because of its low solubility in water and fat. Nitrogen is used to replace O<sub>2</sub> in packages to delay oxidative rancidity and to inhibit the growth of aerobic microorganisms. The exact combination to be used depends on many factors such as the type of the product, packaging materials and storage temperature. The gas ratio normally used is 60% CO<sub>2</sub> and 40% N<sub>2</sub>, for fatty fishes and 40% CO<sub>2</sub>, 30% O<sub>2</sub> and 30% N<sub>2</sub> for lean variety fishes. Shelf life of different fishes packed under vacuum and MAP at different storage conditions are given in Table 1.

### **Advantages of MAP**

- The natural color of the product is preserved
- The product retains its form and texture
- Reduces the growth of microorganisms
- Product retains its vitamins, taste and reduces fat oxidation
- The need to use preserving agents is reduced
- Helps in marketing products to distant locations
- Improved presentation –clear view of product
- Hygienic stackable pack, sealed and free from product drip
- Longer durability of perishable food / decrease of spoilage
- Extends the shelf life of fish in chilled / refrigerated storage by 2 – 3 times
- Helps in reducing post-harvest loss

### **Disadvantages of MAP**

- Capital intensive due to high cost of machinery
- Cost of gases and packaging materials
- Additional cost of gas analyzer to ensure adequate gas composition
- No control over the gas composition after packing
- Increase of pack volume which will adversely affect transportation cost and retail display space
- Benefits of MAP are lost once the pack is opened or leaks
- High concentration of CO<sub>2</sub> may favour anaerobiosis
- Strict maintenance of temperature has to be ensured to avoid the risks of *C botulinum* and *L monocytogenes*.

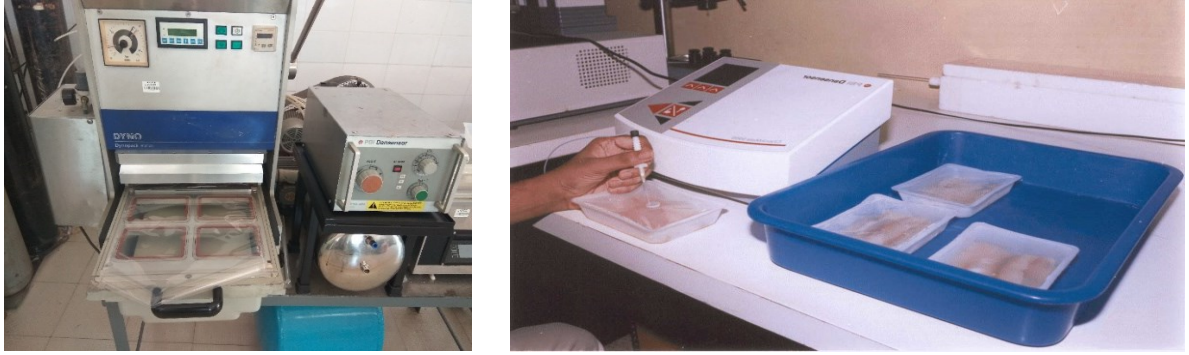


Fig 2. Modified Atmosphere packaging equipment and Gas composition analyzer

Apart from vacuum packaging and modified atmosphere packaging, smart packaging technologies, particularly active packaging can be used in place of these capital intensive technologies. For both vacuum packaging and MAP, capital investment is very high for purchase of machineries and food grade gases, in case of MAP. This is limiting its adoption in developing and under-developed countries. This can be overcome by adopting active packaging technologies, particularly oxygen scavenger in place of vacuum packaging and CO<sub>2</sub> emitter in place of MAP. These are not only cheap but they are also very effective.