Chapter 15

Vacuum packaging & MAP

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There is ever increase in the demand for good quality food product with improved quality and shelf life. Over the years, packaging have brought out a revolution in the marketing and distribution of food products including fish. Among the food categories, seafood ranks 3rd with respect to consumption which explains the importance of fish. Fish is a vital source of food for people. It is the most important single source of high-quality protein, providing approximately 16% of the animal protein consumed by the world's population (Food and Agriculture Organisation (FAO), United Nations, 1997). By any measure, fishes are amoung the world's most important natural resources. Annual exploitation from wild populations exceeds 90 million tones, and total annual trade exceeds $ US 55 billion. Additionally, with over 25000 known species, the biodiversity and ecological roles of fish are being increasingly recognized in aquatic conservation, ecosystem management, restoration and aquatic environmental regulation.

Like any other food commodities, fish is one of the highly perishable items 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 saleability 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, 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_2 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 fish and shell fish products are appearance, texture and flavour. Appearance, specifically colour, 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_2 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, β-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, which is also referred as skin packaging involves removal of air inside the pack completely and maintaining food material under vacuum conditions, so that 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 odour 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 aspect 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 provides 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_2, and N_2, 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_2, semi-reactive blanketing using

$CO_2 : N_2$ or $O_2 : CO_2 : N_2$ or fully reactive blanketing using CO_2 or $CO_2 : O_2$. Typical MAP machine and gas composition analyser 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 18th 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_2 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_2-concentration in the atmosphere and reduced temperature. CO_2 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_2/kg water, however, at 20 °C the solubility is reduced to 1.73 g CO_2/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_2 leads to dissolved CO_2 in the food product, according to the following equation:

$$CO_2\,(g) + H_2O\,(l) \longleftrightarrow HCO_3^- + H^+ \longleftrightarrow CO_3^{2-} + 2H^+$$

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

$$CO_2 + H_2O \quad H_2CO_3 \longleftrightarrow HCO_3^- \longleftrightarrow H^+$$

According to Henry's law, the concentration of CO_2 in the food is dependent on the water and fat content of the product, and on the partial pressure of CO_2 in the atmosphere. The growth inhibition of microorganisms in MA is determined by the concentration of dissolved CO_2 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_2, but this could not entirely explain all of CO_2's bacteriostatic effect. The possibility of intracellular accumulation of CO_2 would upset the normal physiological equilibrium by slowing down enzymatic processes. Thus, the effect of CO_2 on bacterial growth is complex and four mechanisms of CO_2 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_2 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_2 solubility in wet foods. The CO_2 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_2) 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_2 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_2, the partial pressure of CO_2, volume of headspace gas, the type of micro organism, 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, gramnegative psychrotropicbacteria. The CO_2 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_2 and/or remove O_2 inside the package after packaging or to dissolve the CO_2 into the product prior to packaging. Both methods can give appropriate packages with smaller gas/product ratio to the package. The solubility of CO_2 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_2. The rate of absorption of CO_2 depends on the moisture and fat content of the product. If product absorbs excess CO_2, the total volume inside the package will be reduced, giving a vacuum package look known as "pack collapse". Excess CO_2 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 favours 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 colour. O_2 in MA-packages of fresh fish will also inhibit reduction of TMAO to TMA.

Nitrogen (N_2) 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_2 into the product. Nitrogenis used to prevent package collapse because of its low solubility in water and fat. Nitrogen is used to replace O_2 in packages to delay oxidative rancidity and to inhibit the growth of aerobic microorganisms. The exact combination to be sued depends on many factors such as the type of the product, packaging materials and storage temperature. The gas ratio normally used are 60% CO_2 and 40%

N_2, for fatty fishes and 40% CO_2, 30% O_2 and 30% N_2 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 colour of the product is preserved
- The product retains its form and texture
- Reduces the growth of microogranisms
- 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 analyser 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_2 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 analyser

Table 1. Shelf life of fishery products in air, vacuum and modified atmosphere packs

Type of fish	Storage temp (^0C)	Atmosphere $CO_2 : N_2 : O_2$	Shelf life (Days)
Catfish (ns) fillets	4	Air	13
	4	75 : 25 : 0	38–40
	4	Vacuum	20–24
Cod (*Gadus morhua*) fillets	1	Air	9
	1	60 : 40 : 0	12
Cod (*G. morhua*) fillets	2	40 : 60 : 0	11
	2	40 : 40 : 20	13
Cod (ns) fillets	4	Air	20–24
	4	75 : 25 : 0	55–60
	4	Vacuum	24–27
Cod (ns) fillets	0	40 : 30 : 30	12.5
	0	Vacuum	9
Cod (*G. morhua*) whole	2	100 : 0 : 0	10
	2	60 : 40 : 0	10
	2	40 : 60 : 0	9–10
	2	Vacuum	8–9
	2	Air	~7
Cod (*G. morhua*) whole/fillets	0	Air	12–13
	0	25 : 75 : 0	20
Cod (*G. morhua*) fillets	4	100 : 0 : 0	40–53
Cod, blue (*Arapercis colias*)	3	100 : 0 : 0	49
	3	Vacuum	14
	3	Air	14
Haddock (*Melanogrammus aeglefinus*) whole	0	40 : 30 : 30	10
	0	Air	8
Haddock (*M. aeglefinus*) fillets	0	60 : 20 : 20	14
	0	Air	10
Herring (*Clupea harengus*) whole and fillets	0	60 : 40 : 0	14
	0	Air	12
Salmon (ns) fillets	4	Air	24–27
	4	75 : 25 : 0	55–62
	4	Vacuum	34–38
Snapper (*Chrysophrys auratus*) fillets	-1	Air	9
	-1	40 : 60 : 0	9
	-1	100 : 0 : 0	18