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SHELF LIFE EXTENSION OF VARIOUS TYPES OF FISH MEAT USING SELECTED MODIFIED ATMOSPHERE PACKAGING (MAP) METHODS, REVIEW

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Modified Atmosphere Packaging (MAP) is well known and has been used for decades as a popular method for food packaging in with the objectives of prolonging the shelf life. Carbon dioxide, nitrogen and oxygen are the most common gases used in this regard. Carbon dioxide and oxygen are used in MAP because of their great effects as preservative. The shelf life extension using these gases depends on many factors such as appropriate gas composition, the ratio between gas and product volume, storage temperature and hygienic practice of processing and packaging. In this reviews the effect of MAP in inhibiting growth of spoilage as well as pathogenic bacteria in selected fish/fish products. It could be used as a guide for fishery producers and processors when shelf life extension is mentioned.

Keywords: Fish, Shelf life, Modified Atmosphere Packaging (MAP), Microbial growth

INTRODUCTION

Packaging technologies are very important in order to protect products against deteriorative effects. These effects may include physical, biochemical and microbial activities from environmental influences. This involves maintenance of quality in packed food, retardation of spoilage, and extension of shelf-life (Restuccia *et al.,* 2010). Packaging technologies may also involve other functions such as convenience, containment, marketing and communication (Lee, 2010). Modified Atmosphere Packaging (MAP) is considered as an effective food preservation method (Chouliara *et al*., 2007). MAP is well known method of shelf life extension a variety of foods including fresh meat and poultry (Chouliara *et al*., 2007). MAP in general can be classified according to Seydim *et al.* (2006) into two main categories: high-oxygen modified atmospheres and low (including vacuum packaging, CO_2 gas flushing and N_2 gas flushing). Wicklund *et al.* (2006) reported that MAP of red meat for retail sale can prolong the microbiological shelf life when compared with traditional oxygen-permeable overwrap.The acceptance value of vacuum-packaged retail fresh and cooked meat has been low because of its dark reddish purple color (Jayasingh *et al*., 2001). A combination of vacuum packaging and refrigeration storage is believed to be the most effective method of MAP that currently used for extending shelf life of uncooked meats. There are several research works have been recently reported using many types of meat with different methods of MAP (Yuan *et al*., 2012; Aida Cachaldora, 2013; Kapetanakou *et al*., 2014; Meredith, 2014; Sisse Jongberg *et al*., 2014 and Chenglong Liu, 2014). The

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objective of this review article is to highlight various methods using MAP on shelf life extension of selected types of meats.

Effect of Biological Changes on Shelf Life

The changes in quality of fish can be controlled by inhibiting microbial growth, enzymatic freshness and biochemical changes during handling and storage. Spoilage in fish depends on chemical components of their muscles as well as their different spices. Pereira de Abreu *et al*. (2010) mentioned that those changes together with microbial growth and enzymatic induced activities are involved in muscle degradation. This degradation of muscle structure is thought to be caused by enzymes called proteinases such as cathepsin B, D and M and calpain (Godiksen *et al*., 2009). Earlier, An *et al*. (1994) reported that cathepsins enzymes possibly caused degradation of myofibrils in Pacific whiting fillets kept at 0 °C. On other research, Pantazi *et al*. (2008) found that from microbial viewpoint, *Pseudomonas* spp. is the main organism responsible for deterioration of Mediterranean swordfish proteins.Continuous hydrolysis of Myosin Heavy Chain (MHC) was observed on of rainbow trout muscle stored in iced for five days which resulted in firmness of the fish muscle (Godiksen *et al*., 2009). On the other hand, no changes were observed in Mg2+-Ca2+-ATPase, Ca2+-ATPase or Mg2+-ATPase of sea bass (*Latescalcalifer*) actomyosin but Mg2+-EGTA-ATPase activity gradually increased when the fish stored at refrigeration temperature for 12 days. However, conducted research by Chomnawang *et al.* (2007) revealed that Ca2+-ATPase activities of catfish fillet decreased during storage of 15 days at temperature of 4 °C. Benjakul *et al.* (2003) reported that the loss in Ca2+-sensitivity of myofibrillar protein could be an indicator of the proteolytic degradation of tropomyosin and modification of actin-myosin interaction by oxidation of sulfhydryl (SH) group of myosin. Thanonkaew *et al*. (2006) found that the color changes of cuttlefishare accompanied with the development of rancid odorsduring frozen storage. Off-odor in both development inred tilapia (*Oreochromismossambicus* × O. *niloticus*) and seabass (*Latescalcarifer*) was correlated with lipid oxidationduring 15 days of storage at 0 °C. Thiansilakul *et al.* (2010) reported that lipid hydrolysis can occurwith the action of enzymes. The majority of lipolysis in moststored fish originates from microorganisms and endogenous enzymes mainly triacyl lipase and phospholipase (Aryee *et al*., 2007). An increase in pH has beenobserved with some types of fish partially with increasing the storage time during iced or chilled storage. Masniyom *et al.* (2002) and Ocano-Higuera *et al.*(2009) found that the pH increasedthroughout the chilled storage of cazon fish and seabass. The shelf-life of chilled fish is generally limited due to the growth of Gram-negative microorganisms such as *Aeromonas,Shewanellaputrefaciens*and *Pseudomonas*under aerobic condition (Ravi-Sankar *et al.*, 2008). Proteinases such as and cathepsin D, B and L andcalpain play an important role on degradation of fish muscle structure (Godiksen *et al.,*2009). An *et al.* (1994) reported that cathepsins was the main enzyme caused degradation of myofibrils in Pacific whiting fillets occurred at 0 °C. However, Pantazi *et al*. (2008) found that *Pseudomonas* spp. is the main organism responsible for deterioration of proteins. Masniyom *et al.* (2004) claimed that no changes were observed in Mg2+-Ca2+-ATPase, Ca2+-ATPase or Mg2+-ATPase of sea bass (*Latescalcalifer*) actomyosin but gradual increase in Mg2+-EGTA-ATPase activity during refrigerated were recorded during storage of 12 days. In another research, Chomnawang *et al.* (2007) reported a decrease in Ca2+-ATPase activities of catfish fillet when stored at 4°C for 15 days. These changes in Ca2+-sensitivity and ATPase activities could be due to the proteolysis.Microbial spoilage of fish can be caused by the activities of microorganisms. The main microorganisms caused the spoilage on chilled fish are gram-negative bacteria (*Shewanella*spp.and *Pseudomonas* spp.) grown on Gram and Huss (2000). Several spoilage bacteria including *S. putrefaciens*and *Pseudomones*spp. produce inosine monophosphate or hypoxanthine from inosine. An increase in pH was observed in some fish with increasing the storage time during chilled storage (Masniyom *et al.*, 2002). Gram-positive bacteria such as *Bacillus, Micrococcus, Clostridium, Staphylococcus* spp., *Cornynebacterium, Streptococcus* and *Brochothricthermosphacta* were found to be the most dominant microorganisms in tropical marine fish (Al Bulushi *et al.*, 2010). Furthermore, *microorganism like Acinetobacter,Aeromomas, Bacillus, Clostridium, Escherichia, Micrococcus,Pseudomonas, Salmonella* were described as prolific biogenic amines-forming bacteria (Al Bulushi *et al.*, 2010).

Effects of MAP on Shelf-Life Extension

Modified Atmosphere Packaging (MAP) is currently successfully in commercial application for inhibiting spoilage of different types of fish and their products and extending shelf-life. In many research works (Hansan *et al.*, 2007; Mohan *et al.*, 2008; Hansan *et al*., 2009; Mohan *et al.*,

2009; Fernández, 2010; Torrieri *et al*., 2011; Yassoralipour *et al*., 2012; Macé *et al.,* 2013 and Yesudhason *et al.,* 2014). This could be associated with a number of interrelated factors, such gas favorable consumer perception of MAP technology and as developments on new food packaging materials (Ashie *et al.,* 1996 and Lee, 2010). An increase in shelf-life of nine days was observed on fresh Mediterranean swordfish kept under vacuum condition compared with aerobic packaging (Pantazi *et al.,* 2008). Nitrogen gas (N_2) was used in MAP as a filler to prevent package collapse because of its low solubility in water and also it inhibited the growth of aerobic spoilage microorganisms and reduced lipid oxidation (Farber, 1991). It was reported that O_2 could be used in low concentrations in fish products to avoid the outbreak of strictly anaerobic pathogens such as nonproteolytic *C. botulinum* (Rutherford *et al*., 2007). Carbon dioxide (CO_2) commonly becomes more effectively as an antimicrobial agent in fish because of its fungistatic and bacteriostatic properties. It is able to dissolve into the liquid phase in fish muscles and this could be associated with the increased carbonic acid (Banks *et al.,* 1980). The ratio of the volume of gas and volume of food product (G/P ratio) may need to be twice the volume of meat for adequate microbial retardation, although CO_2 is dissolved and absorbed into the meat surface during storage (McMillin, 2008). Ozogual *et al.* (2004) and Goulas *et al*. (2005) stored mussel (*Mytilusgalloprovincialis*) under refrigeration temperature using CO_2 in MAP and found an increase in CO_2 in the range of 60-80%, which mainly due to an extension in the lag phase of organisms of the fish. On the other hand, 100% CO_2 enriched atmosphere could lower microbial counts of rainbow trout (Arashisar *et al.,* 2004). CO_2 commonly becomes more effective as an antibacterial agent when its concentration is increased. It retards the microbial growth of spoilage microorganisms such as and *Shewanella*spp. and *Pseudomonas* spp. Emborg *et al.* (2005) claimed that microbial growth is generally inhibited by higher carbon dioxide concentration but *P. phosphoreum*was found to be more resistant to CO_2. Moreover, it was found that in higher concentration of CO_2 (80%) the growth of microorganism in mussel was inhibited (Goulas *et al.,*2005). lipid oxidation occurs in many types of fish particularly when stored in inappropriate conditions. For instance, during frozen storage color changes of cuttlefish were found to be accompanied with the development of rancid odors (Thanonkaew *et al*., 2006). Moreover, in both red tilapia (*Oreochromismossambicus* × O. *niloticus*) and seabass (*Latescalcarifer*) off-odor development was found to be correlated with lipid oxidation during 15 days of iced storage (Thiansilakul *et al.,* 2010). Aryee *et al*. (2007) reported that majority of lipolysis in most stored fish were as a result of activities of endogenous enzymes and microorganisms. These mainly include triacyl lipase and phospholipase. Earlier, an increase in values of 1, 2- diacylacylglycerol and Free Fatty Acid (FFA) were observed in minced mackerel during storage at 2-3 °C for 15 days (Hwang and Regenstein, 1993). Young *et al*. (2014) investigated shelf life of both cooked and raw black tiger prawns (Penaeusmonodon). The samples were cooked-chilled and packed in a combination of gases consisting 40% CO_2, 30% O_2 and 30% N_2 in vacuum pouches for 14 days. It was found that the method of MAP was most efficient at preserving their sensorial and textural properties. At both storage temperatures, this method also increased the lag phase of microbial growth which could be consider as most effective method due to prawns preserved textural, sensorial qualities and lowered microbial counts.

Safety Issues of MAP Used for Fish Packaging

When MAP is used for shelf-life extension of fish, the combination between elevated CO_2 and MAP reduce microbial growth and enzymatic activity. It was found that generally gram negative aerobic bacteria are more resistant in MAP. However, *L. monocytogenes*, *E. coli, S. aureus*and *C. botulimun*outbreaks have attracted the attention widely (Kimura *et al.,* 1999). Growth of pathogens such as *Salmonella* spp., and *E. coli* and *L. monocytogenes*were observed widely (Kimura *et al.,* 1999). CO_2 at a level of 80% was found to be significant in reducing growth rate of *L. monocytogenes*in buffered nutrient broth at 7.5 °C (Hendricks and Hotchkiss, 1997). In another study, it was claimed that modified atmosphere using CO_2 (100% CO_2) reduced the growth of *L. monocytogenes*significantly when packs stored at 3 °C compared to vacuum or air packaging (Rutherford *et al.,* 2007). Growth of *E. coli* O157 and L. *monocytogenes*were retarded in the fish packaged under combination of pyrophosphate and MAP but microbial growth did not inhibited completely (Masniyom *et al.,* 2006). Toxin produced by *C. botulinum*is considered as a major concern in relation to safety of MAP fish and their products (Ravi-Sankar *et al.,* 2008). Earlier, Cann *et al.* (1984) found salmon and trout inoculated with spore of *C. botulinum*and kept in MAP at 10-20 °C spoiled before they became toxic. Toxin has been found in both vacuum and MAP packed of fish fillets prior to the fish being determined as spoiled (Arritt *et al.,* 2007). It was reported that a combination between

storage temperature and MAP played a major role in shelf-life the extension as it was noticed in *C. botulinum*growth, and the toxin production in retail type packages of fresh salmon fillets (Peck *et al.*, 2008).

CONCLUSION

Modified Atmosphere Packaging (MAP) can be used to extend the shelf life of various types of fish and their products. This can be achieved through retarding microbial growth in fish/fish productswhich leads to a delay in spoilage, decreasing chemical and physical changes and compounds deterioration as well as. However, combined applications of MAP and other treatment are found to be effective methods in quality maintenance and shelf life extension in the presence of good application practice. Therefore, Modified Atmosphere Packaging (MAP) is a very effective food preservation application that can protect fish/ fish products from environmental influence.

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of Modified Atmosphere Packaging and Vacuum Packaging on Chemical Sensory and Microbiological Changes of Sardines (*Sardinapilchardus*)", *Food Chem.*, Vol. 85, pp. 49-57.

APPENDIX

Table 1: Selected Methods of MAP Used for Various Types of Fish/Fish Product

Reference	Method of MAP Used	Name of the Fish/Fish Product Used in MAP
(Soccol *et al.*, 2005)	The samples were packed under 60% CO_2/40% O_2 modified atmosphere at a 2:1 (gas/fish) proportion, that is, 1000 mL of gas mixture per 500 g of fish	Nile tilapia (Oreochromisniloticus)
(Lauzon *et al* ., 2002)	The effects of modified atmosphere (CO_2/N_2: 60/40) in bulk storage of both redfish and the fish fillets. The samples were stored on ice in the cooling room (0-2 °C) till sensory rejection	Redfish
(Mace *et al* ., 2013)	Salmon cubes was placed in 3 plastic trays, each containing ~250 g portions (one for each analysis date), and packed under modified atmosphere (50% CO_2 and 50% N_2) and a low gas permeability film (low density polyethylene). All batches of inoculated salmon cubes and the control were stored at 8 °C for 12 days	Salmon (Salmosalar) fillets
(Emborg *et al.*, 2005)	Fresh tuna samples were stored either in Vacuum-Packed (VP) or Modified Atmosphere-Packed (MAP) at 1.0 8C for 28 days of storage. For MAP, 60% CO_2/40% N_2 or 40% CO_2/60% O_2 were used.	Tuna (Thunnusalbacares)
(Fernández *et al.*, 2010)	Pieces fish samples (approximately 30 g of each) were packed into bags using modified atmospheres (initial CO_2 content from 30 to 100%, remainder nitrogen) at a gas:product ratio of approximately 3:1 using a Technovac vacuum packer. The samples were then stored at a range of temperatures between 0 -10 °C	Atlantic salmon (Norway and Chile)
(Hansan *et al* ., 2007)	The samples of the fish were packaged. Two to three cod loins (around 500 g) were placed on trays (expended polystyrene) with built-in absorbent drip pads. Each tray was put into a vacuum bag measuring 25 × 32. 5 cm × 115 cm. A gas mixture of 50.0% CO_2-45.0% N_2 - 5% O_2 was injected to modify the atmosphere and the bags were heat-sealed individually and stored at temperature of 1.5 °C or -1 °C). The shelf-life of cod loins was evaluated	fresh cod loins (*Gadusmorhua* L.)
(Masniyom *et al* ., 2013)	Fillets samples weighing approximately 90-100 g were placed in vacuum bag (15 cm × 25 cm) with gas permeability (O_2 transmission rate of 46.6 cm^3 m-2 day-1 at 38 °C, 1 atm pressure). The samples were prepared in different three packaging systems, system (1) packaged in air; (2) packaged using vacuum and (3) packed under MAP using a mixture of 60% CO_2, 10% O_2 and 30% N_2. The bags were sealed and the samples were stored at 4 °C for 18 days.	Tilapia (*Oreochromisniloticus*) fillets

APPENDIX (CONT.)

Table 2: Shelf Life Extension in Some Types of Fish/Fish Product Packaged Using Various Methods of MAP

Fish Product Used in MAP	Method of MAP Used	Observations and Shelf Life Extension	Reference
Catfish (Pangasiushypophthalmus)	The use of CO_2 in modified atmosphere packaged Pangasius fillets significantly prolonged the shelf life compared to air and vacuum packaged fillets. Combination of 50% CO_2 with 50% O_2 appeared had an additional inhibitory effect on the microbiological growth, most probably on the lactic acid bacteria	MAP 1: 50% CO_2-50% N_2 and MAP 2: 50% CO_2-50% O_2) during storage at 4 °C. The shelf life of the fillets packaged in air, vacuum, MAP 1 and MAP 2 was estimated to be 7, 10, 12 and 14 days respectively.	Noseda *et al*. (2012)
Cod fillets	The sterile muscle samples of about 20 gram were placed in sterile petri dishes and incubated at 0 °C. Six The samples were incubated in atmospheres of 0, 50 and 100% CO_2, the remaining gas being N_2. The samples were analyzed just after preparation, after 2 weeks (0% CO_2), after 3 weeks (50% CO_2) and after 3 months (100% CO_2)	H_2S producing bacteria was inhibited as *S. putrefaciens* maximum concentration found in MAP fish products was very low. Compared to VP, a shelf-life extension of 6-7 days was obtained with 48% CO_2 in MAP. With pure CO_2 the shelf life was only extended by 2-3 days	Paw Dalgaard *et al*. (1993)
Atlantic horse mackerel (Trachurustrachurus) fillets	The samples of the fish was packaged in a modified atmosphere (48% CO_2, 50% N_2 and 2% O_2) and kept at refrigeration temperature (6 °C) for 7 days	The samples showed that *Arthrobacter*, Chryseobacterium, *Photobacterium*, and Pseudoclavibacter (44.5% of total) dominated the microbial composition of the fish at the beginning of storage. It also showed *Yersinia*, *Serratia*, and *Shewanella* dominated at the late spoilage stages (over 57.2% of the total). *Carnobacterium* was was identified at the beginning and end of the storage period. A shelf life of 5 days was obtained	Alfaro and Hernande (2013)
sardine (Sardinapilchardus)	quality and safety parameters of sardines were investigated using Vacuum Packaging (VP), and modified atmosphere packaging (MAP) (60% CO_2 : 40% N_2) for up to 15 days at 4 °C	Bacteria grew most quickly in sardine stored in air, followed by those in VP and the lowest counts were with MAP. For a period of 15 days, concentration of histamine, trimethylamine (TMA) increased to 20 mg/100 g, 13 mg/100 g and 10 mg/100 g for fish stored in air, VP and MAP, respectively. Shelf life extension was found to be 3 days in air, 9 days in VP and 12 days in MAP	Zogula *et al*. (2004)


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