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Use of Modified Atmosphere and Ozone Treatment in Fish Preservation

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Abstract: The use of the modified atmosphere packaging has the following advantages: lengthening of the products' shelf-life by 50 to 400%, reduction of economic losses, cost reductions by distributing the product over great distances with the need of fewer shipments and the supply of a better quality product. The purpose of this work was to review and discuss the major effects of the modified-atmosphere packaging, especially carbon dioxide (CO_2), on seafood preservation, as well as on the survival and growth of seafood pathogenic organisms. Microbial growth of ozone treated fish was significantly slower than control sample, resulting in lower counts of bacteria. According to the biochemical tests; ozone treatment had no negative effects on fat, protein and humidity of fish. Peroxide and TVN (Total Volatile Nitrogen) measurements showed that treatment by ozone increased the trout shelf life from 4 days to 6 days. According to the sensory analysis, no obvious changes were observed in color or flavor of the ozone treated trout.

Key words: Fish · Modified atmosphere · Vacuum packaging · Shelf-life · Ozone

INTRODUCTION

Fish production in Brazil has been increasing as a result of the expansion in freshwater aquaculture activities. Due to the country's great freshwater potential, fish cannot be regarded only as an excellent source of food, but also as a source of exportation revenues. Fish has a relatively short shelf-life (12 days) under refrigerated conditions, not presenting hygienic quality even when properly packaged [1]. The shelf-life of many perishable products, such as meat, eggs, fish, poultry, fruit, vegetables and cooked food, is affected by the presence of atmospheric oxygen and is conditioned by three important factors: i) reactions with the atmospheric oxygen; ii) growth of deteriorating aerobic microorganisms; iii) insects attack. Each of these factors, or their combination, leads to alterations in color, flavor, odor and global deterioration of food quality [2]. There has been a recent interest in lengthening fish shelf-life due to the increase in demand for fresh products, which has led to a greater variety of products being packaged under modified atmosphere, in which air composition is altered or "modified". Such increase in fish shelf-life brings great industrial advantages, once it reduces losses in distribution and display of the product at the retail stores, which may lead to improvements in marketing of fresh products and stabilize the supply at reasonable prices [3]. Fish is one of the important resources of the human food. Fish is extremely perishable which restricts its consumption in a reasonably fresh state to the immediate vicinity of where it is caught. Bacteria degrade fish constituents, particularly non-protein nitrogenous compounds, typically associated with fish spoilage [4]. As mentioned by Whittle [5] the nature of fish species, handling and storage conditions are key parameters which affect fish spoilage. Different technologies have been applied in order to reduce the perishability of fish and hence increase its short shelf life. It was demonstrated elsewhere [6] that the use of slurry ice extends the shelf life of sardine and non-fat fish species, such as Farmed Sea Bream, European Hake and shrimp. Since 1920s, scientists have tried to apply the powerful disinfection properties of ozone to slow down the spoilage and improve the safety of fishery products. Ozone (O_3) is generated from oxygen (O_2) by either ultraviolet (UV) radiation or a high voltage electrical discharge. Ozone kills microorganisms by oxidizing and destroying their cell wall. It has the advantage of being able to kill resistant microorganisms such as bacterial spores, cysts and viruses at relatively low concentrations, without requiring a long exposure time. The United States Food and Drug Administration [7] granted "Generally Recognized As

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Safe" (GRAS) status for use of ozone in bottled water in 1982. Ozone was approved by the US Department of Agriculture [8] for reconditioning the recycled poultry chilling water in 1997. Various reports [9] explained the possibility of use of ozone to disinfect the food surfaces. The purpose of this work was to discuss the effects of the modified-atmosphere packaging, especially carbon dioxide (CO_2), on fish preservation, as well as on the survival and growth of fish pathogenic organisms and to investigate the effect of ozone on biochemical properties of fish flesh in order to achieve a better microbial control and improve the shelf life.

DISCUSSION

This article attempted to identify the effect of ozone treatment on the shelf life of fish. It was found that suitable treatment by ozone before any storage; improves the microbiological and biochemical qualities of fish specimens and consequently prolongs their shelf life. Combination of ozone treatment and cold storage (at 4 °C) will increase the fish shelf life considerably. A summary of the results of measurements are as follows:

- Ozone treatment of fish significantly slows down its bacterial growth, resulting in lower counts of bacteria.
- Ozone removes the contaminants from the fish skin causes to higher protein number.
- Ozone treatment increases the shelf life of fish and helps in longer preservation time.
- Ozone has no negative impact on the biochemical properties of fish such as humidity, protein and free fat.
- Ozone leaves no residue on the fish and creates no changes on its color and flavor[8].

Packaging and Combined Processes: Food preservation is based on combined methods, which can be used for the quality improvement of conventional products or the development of new products. They assure stability and safety, resulting in products presenting adequate sensory and nutritional properties [9]. Along the latest three decades, there has been an increase in gas packaged food products in the market. This increase has brought improvements to the packaging industry, which has lead to the development of high barrier polymers and thermomold packaging equipment. Gas packaging is simply an extension of the vacuum packaging technology. Food packaging under modified atmosphere employs different gases, such as CO_2, N_2 and O_2, with CO_2 probably being the most common and effective gas, whether associated with other gases or not [10]. There are several techniques through which the atmosphere around a product can be modified and, frequently, there may be some confusion about the terminology used [11]. The two most relevant techniques applied to fish and its related products are: - *Modified Atmosphere Packaging – MAP*: the air inside the packaging is replaced by a specific gas or a mixture of gases that differ from the air composition. The proportions of each gas are established, the mixture is introduced into the packaging and no further control is carried out during storage [11]; - *Vacuum packaging*: the product is placed inside a type of packaging presenting low permeability to oxygen, the air is exhausted and the packaging is sealed. The gaseous atmosphere of the vacuum packaging is reduced, but it is probably altered during storage, thus considered modified due to a 10 to 20% increase in the CO_2 amount produced by microbial activity. This CO_2 may inhibit the growth of undesirable microorganisms. The three main commercially used gases in modified atmosphere packaging are: carbon dioxide (CO_2), nitrogen (N_2) and oxygen (O_2). CO_2 is soluble, not only in water, but also in lipids, being the main responsible factor for the bacteriostatic effect in modified atmospheres. Its general effects on microorganisms are an intensification of their latest growth stage and a decrease in the growth rate during the logarithmic stage [12]. The bacteriostatic effect is influenced by the CO_2 concentration, the initial bacterial population, the storage temperature and the product being packaged [13]. In food presenting high moisture and/or fat contents, such as fish, beef and poultry, the excessive absorption of CO_2 may lead to a phenomenon known as “packaging collapse” [14]. Increase in dripping is caused by the dissolution of gases on the muscles surface in atmospheres containing high CO_2 levels (>60%), reduced pH and, consequently, low protein water retention ability [15]. As a consequence, high CO_2 concentrations promote organoleptic changes as, for example, texture alterations in meat. N_2 can be used as an inert gas in smaller proportions than CO_2. O_2 can also be employed, providing fish does not undergo color alterations [16, 17], several theories can explain the ways that CO_2 influences bacterial cells, the most important being:

- Alterations in cell membranes functions, including effects on nutrients;
- Direct inhibition of enzymes or decrease in enzymatic reactions;

- Penetration in the bacterial membranes, leading to changes in the intra-cell pH;
- Direct alterations in physic-chemical properties of proteins. N_2 is an insipid and inert gas, showing low solubility in water and lipids. It is used for displacing the oxygen from the packaging, decreasing oxidative rancidness and inhibiting the growth of aerobic microorganisms [16]. Due to its low solubility, it is used as a filling gas, preventing the possible packaging collapse caused by the accumulation of CO_2.

O_2 generally stimulates the growth of aerobic bacteria and may inhibit the growth of exclusively anaerobic bacteria, although anaerobic microorganisms show different sensitivity levels to oxygen. The presence of oxygen may cause oxidative rancidity problems in fish presenting high lipids contents, promoting the formation of low molecular weight aldehydes, ketones, alcohols and carboxylic acids. Thus, the use of O_2 in modified atmospheres is generally avoided with this kind of fish, in order to minimize such effects. The use of O_2 in modified atmosphere packaging for fish is supported by Debevere and Boskou [17], who stated that there are evidences showing that the use of O_2 reduces the exudation in fish during storage. The authors suggested that O2 can be used in low-fat fishes. Dorsa e*t al.* [18], claimed that the use of O_2 associated with N_2 or CO_2 gives a false idea of reducing botulism risks in fresh-packed fish and may lead to illusory safety. Different types of fish, storages, temperatures and modified atmosphere packaging (MAP) have been used. MAP associated to high CO_2 levels improves the stability of fresh fish, increasing its shelf-life [17]. Gas mixtures presenting 40% CO_2, 30% N_2 and 30% O_2 have been recommended for low-fat fish and a 40-60% CO_2 mixture, in equilibrium with N2, has been recommend for fatty fish. Problems related to temperature abuses can occur with all manufactured foods, once the bactericidal and bacteriostatic effects of CO_2 vary with temperature. Lack of refrigeration at any period throughout the product's shelf-life may allow the growth of microorganisms that had been inhibited by CO_2 during storage at low temperatures. Facultative anaerobic microorganisms and aerobic pathogens resistant to the antimicrobial effects of CO_2, but which were unable to grow at low temperatures, can also thrive as the result of temperature abuses [17]. Elliott, and Gray, [19] revised the temperature effects on the solubility and inhibition of CO_2 And they concluded that, disregarding the synergetic mechanism between temperature and solubility, all evidences show that increases in temperature reduce solubility and increase microbial growth, which is proportionally higher in MAP than under atmospheric air. The use of high hygienic-sanitary quality raw materials represents an important factor for the successful use of modified atmosphere packaging. Besides initially using high quality raw materials, the use of good hygiene practices during fishing, the selection of the right packaging material and a good temperature control are also necessary [18]. Farber [20], developed a minimally processed product made from grass carp (*Ctenopharyngodon idella*) washing fish fillets using sodium hypochlorite and brine and vacuum packing, achieving shelf-life periods of 30 and 60 days, when the product was kept under refrigeration temperatures of 8°C and 2°C, respectively. The effects of carbonic acid on cod (*Gadus morhua*) fillets packed in semipermeable film and kept at 1°C were tested by Fey and Regenstein [21]. The carbonic acid increased the shelf-life from 7 to 21 days. However, the organoleptic quality was considered to be poor. Results indicated that the carbonic acid was as effective as the 98% CO_2 controlled atmosphere. Gibson *et al.* [22] observed that bacterial growth and organoleptic deterioration in cod (*Gadus morhua*) fillets decreased slightly under 60% CO_2 atmosphere at 1oC. The small differences between samples kept in MAP and those kept in atmospheric air increased along with the storage period. As to fish surface pH, values of 6.6 and 7.5 were observed using MAP and atmospheric air, respectively. The chemical, physical and microbiological alterations in raised catfish (*Silurus glanis*) were evaluated during storage period by Hintlian and Hotchkiss [23].

Considerations: The success of the MAP depends on various factors such as: good initial quality of the product, good hygiene practices during fishing, selection of the right packaging material, a safe packing equipment, good maintenance and control of temperature, a proper gas mixture for the product and the gas/product ratio. The ideal CO_2 concentration depends on the fish species, initial microbial population, gas/fish ratio and on the packing method. The most used CO_2 concentrations are between 40 and 60%.

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