Effect of modified atmosphere packaging on the physical and sensory properties of smoked oyster (*Saccostrea cucullata*) during refrigerated storage

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Abstract

This research aimed to extended the shelf-life of smoked oyster (*Saccostrea cucullata*) using modified atmosphere packaging (MAP) in combination with storage at low temperatures. The physical and sensorial changes occurring in the smoked oyster samples were monitored when packed and stored under different gas compositions as follow; 35% CO_2: 60% N_2: 5% O_2 (T35), 50% CO_2: 50% N_2 (T50), 80% CO_2: 20% N_2 (T80) and atmospheric air for the control sample (TC). All samples were stored refrigerated storage at 4 °C. It was found that T50 had the lowest changes ($p \leq 0.05$). The maximum shear force applied before the product breaks for the T50 sample was the highest, when compared with other samples ($p \leq 0.05$). While the measured colour changes of the T50 sample were the lowest. Sensory qualities of the T50 stored samples had higher acceptance scores than those of the other stored conditions throughout the trials. While smoked oyster packed in T80 and T35 had shelf lifes of 26 and 20 days, respectively, based on the odor test results compared with smoked oyster kept in atmospheric air (TC), which had the shortest shelf life of only 14 days.

Keywords: Smoked oyster / Modified atmosphere packaging / Quality

INTRODUCTION

Oyster is an economically important fishery resource which is highly valued and consumed worldwide. It has the largest farmed shellfish yield with more than 4 million tons of oysters being consumed annually worldwide (NOAA, 2008). Oysters are filter feeders and water in the vicinity of the oyster beds can impact the quality of the oysters. Microorganisms and chemicals can be accumulated from the marine environment (Rippey, 1994). Smoking of fish has a long worldwide tradition as a means to preserve the quality and increase the shelf life of the products by reducing the moisture content which aids microbial spoilage and is usually combined with addition as salt which inhibits bacteria by osmotic dessication. The preservative effect of smoking is the presence of some antimicrobial compounds in smoke such as phenols and formaldehyde (Goulas and Kontominas, 2005). However, the final product is often displayed in plastic bags and under aerobe conditions, which exposes the products to deterioration by aerobic microbial growth.

As a consequence, more and more consumers demand safe, attractive, easy to consume seafood products, with a prolonged shelf life. Modified atmosphere packaging (MAP) of seafood products has been shown to delay senescence and maintain the quality of seafood products such as sardines, shucked fresh oyster and steam-cooked rainbow trout during storage (Özogul et al., 2004, Teerawut et al, 2014, Kaba and Corapci, 2014). It is well known that modification of the gas composition within the package by increasing the levels of CO_2 and/or N_2 and thus decreasing the O_2 concentration can be an effective way by inhibiting growth of both spoilage and pathogenic aerobic microorganisms and delay enzymatic spoilage (McMillin, 2008). Carbon dioxide slows the respiration of many microorganisms and has bacteriostatic properties. Oxygen inhibits the growth of anaerobic microorganisms, but it promotes the growth of aerobic microbes. Nitrogen is an inert and tasteless gas that displaces oxygen and prevents package collapse and hence protects the product from physical damage although it has no antimicrobial activity (Mastromatteo et al., 2010). A high concentration of O_2 may also cause quality deterioration through lipid and protein oxidation (Zakrys et al., 2008) and CO_2 concentrations near to 100% may affect seafood pH, promoting protein denaturation and a decrease in water retention capacity (Qian et al.,2013). These issues can be avoided by selecting intermediate CO_2 levels (Del Nobile et al., 2009). In the light of these considerations, the present work was investigated the effect of MAP in combination with low temperature storage on the physical and sensorial attributes of smoked oysters. In order to test this hypothesis, various physical and sensory characteristics of the smoked oysters, packed under different gas compositions of MAP and refrigerated at 4 °C were evaluated.

MATERIALS AND METHODS

Raw material and preparation of smoked oyster

Live fresh oysters (*Saccostrea cucullata*) with the size of 20 oysters/ kg were purchased from Worralak oyster farm at Chonburi, Thailand. The oysters were kept in ice with an oyster/ice ratio of 1:2 (w/w) and transported to the Department of Aquatic Science, Burapha University within 20-30 mins. Upon arrival, the oysters were washed to remove sea mud on the shells. In order to preserve their original quality, they were stored in a refrigerator at 4 °C until the smoking process. Fresh oysters were heated at 95 ± 2°C for 5 min and then drained for 3 min. Each oyster was shucked to remove the flesh using a sterile surgical knife under an aseptic condition. The cooked oysters were hot-air dried at 60 °C for 120 min and mixed with smoked powder (Vicchi Enterprise Co., Ltd, Thailand) with an oyster/smoked powder/dried seasoning powder (Nguansoon Co., Ltd, Thailand) ratio of 100:1:1 (w/w) before soaking in soy bean oil at 80 °C for 45 min (Teerawut et al., 2011).

Modified atmosphere packing and storage

The smoked oysters were divided into four groups and packaged in four different atmospheres using a gas mixer (MAP Mix 9001 - 3/200B, Denmark) and Ultravac (UV 4350, Ultra Vac, Thailand). The packaging material was a 18×25 cm plastic bag made from the copolymer blend polyvinylidene chloride polyamide and cast polypropylene (PVDC/PA/CPP) (S Science Co.,Ltd, Thailand) This material has a low gas permeability (oxygen transmission rate of 10 cm^3/m^2/days atm at 25 °C and water vapour transmission rate of 4 g/m2/days atm at 25 °C). The final gas/product ratio in all pouches was about 2:1 (v/w) for all MAP conditions. The composition of the gas mixtures were adjusted to 35% CO_2: 60% N_2: 5% O_2 (T35), 50% CO_2: 50% N_2 (T50), 80% CO_2: 20% N_2 (T80) by a commercial company (S Science Co., Ltd, Thailand). The smoked oysters were inserted in bags purged with the gas mixture to eliminate air and sealed. For the control group (TC), the smoked oysters were placed in bags and sealed without removal of air. All of the smoked oysters were kept under refrigeration (4 ± 1 °C) for 28 days. Sampling in triplicate was carried out for physical and sensory analysis every 2 days throughout the storage period.

Physical properties

Colour measurement: The surface colour of smoked oysters were measured by a Hunter Lab reflectance colorimeter (CM 3500d, Konica Minolta, Japan) and reported using the CIE system. The parameters L∗, a∗ and b∗ parameters indicate lightness, redness/greenness and yellowness/blueness, respectively (Teerawut et al, 2014). L* represents the amount of white light reflected from the surface with 0 indicating complete absorbance (no reflection and hence black 0-100 representing the highest degree of reflection on white no absorbance hence. a* and b* represents the relative amount of light of specified plain of wavelength ranges reflected or absorbed. This a* refers to red and green colours with positive a* being a dominance of red over green and negative a* means green is stronger. Correspondingly a positive b* value indicates yellow is dominant over blue and a negative b* means blue is strong. The results were expressed as the mean of ten measurements.

Shear strength: Shear strength was determined on the axis of the smoked oyster samples of similar size and weight. The sample was placed on its base and a Warner-Blatzler shear blade was used to press down on the flesh. A computer-controlled TA-XT2 Texture Analyser (Texture Technologies Corp., Scarsdale, NY) was used at a setting of 2 mm/sec. The results were average of 10 oysters/ treatment and were expressed as Newtons per gram of muscle at the point of maximum load before the sample was broken.

Sensory evaluation

Samples taken every 2 days were steamed (80 ± 1 °C for 3 min) and then evaluated by 15 panelists from the Department of Aquatic science with the ages of 20–25, using the 9-point hedonic scale, where 9= like extremely; 7= like moderately; 5= neither like or nor dislike; 3= dislike moderately; 1= dislike extremely (Meilgaard et al., 1990). Panelists were regular consumers of smoked oyster and had no allergies to seafood. All panelists were asked to evaluate for appearance, odour, taste, texture and overall likeness (total acceptance) attributes. Samples were presented in plates coded with three-digit random numbers.

Statistical analyses

All experiments were performed in triplicate. A completely randomized design (CRD) was used for the physical measurements and randomized completely block design (RCBD) was used for the sensory evaluation. Analysis of variance (ANOVA) was performed and means comparisons were done by Duncan's multiple range tests (Steel and Torrie, 1980). Analysis was performed using SPSS statistical software (IBM SPSS Statistics 21).

RESULTS AND DISCUSSIONS

Effect of MAP on physical quality of smoked oyster during refrigerated storage

Colour: The values obtained in the colour determinations (L*, a*, b*) are shown in Figure 1. During storage all the parameters significantly decreased, but a slight decreased in the TC sample compared to the other for L* (lightness) b* (yellowness/blueness) and a* (redness/greenness). The decrease in lightness might be ascribed to an increase in light absorption and decrease in light scattering caused by the denaturation of proteins (Zhang et al., 2015). The decrease in a* values (redness) could be mainly attributed to the degradation of highly unsaturated carotenoids such as astaxanthin and lipid oxidation (Rodriguez-Amaya, 1993), as has been reported in other studies of seafood deterioration. (Zhang et al., 2015, Thiansilakul et al, 2013).

Smoked oyster packed with MAP (T35, T50 and T80) presented significantly higher lightness than the control samples after storage. The lightness of sample T50 was also the highest during the 28 days of chilled storage. In all cases, redness (a*) and yellowness (b*) tended to decrease during storage, meaning that the samples changed colour to greenish and more blue. It is important to emphasise that sample T50 showed the highest colors values during the 28 days of storage. Lower concentrations of O_2 or higher concentrations of CO_2 in modified air might play a more important role in the inhibition effect on the degradation of astaxanthin and lipid oxidation (Sundararajan et al., 2011). The decrease in L*, a* and b* values on storage measured in this study are in agreement with data previously reported for MAP-treated pacific white shrimp (Zhang et al., 2015).

Shear strength: Storage time (days) at the refrigerated temperature had an effect on the shear force for all treatments. The force required to shear packed smoked oyster decreased with storage time for all MAP gas compositions (Fig. 2). However, smoked oyster packed in T50 required more shear force ($p \leq 0.05$) than samples from the other treatments. The TC sample showed the greatest decrease in the required shear as would be expected. It has been shown by other researchers that CO_2 acts as an antibacterial agent by displacement of some or all of the O_2 available for bacterial metabolism and CO_2 solubility and absorption in muscle where it is converted in carbonic acid leading to acidification and decrease of pH, thus reducing the growth rate of microorganisms. (Qian et al., 2013; Stamatis and Arkoudelos, 2007). Protein deterioration by bacterial enzymes was apparently decrease (Teerawut et al., 2014). The extension of the shelf life of fish products in MAP is dependent on the raw material, temperature, gas mixtures and packaging materials (McMillin, 2008).

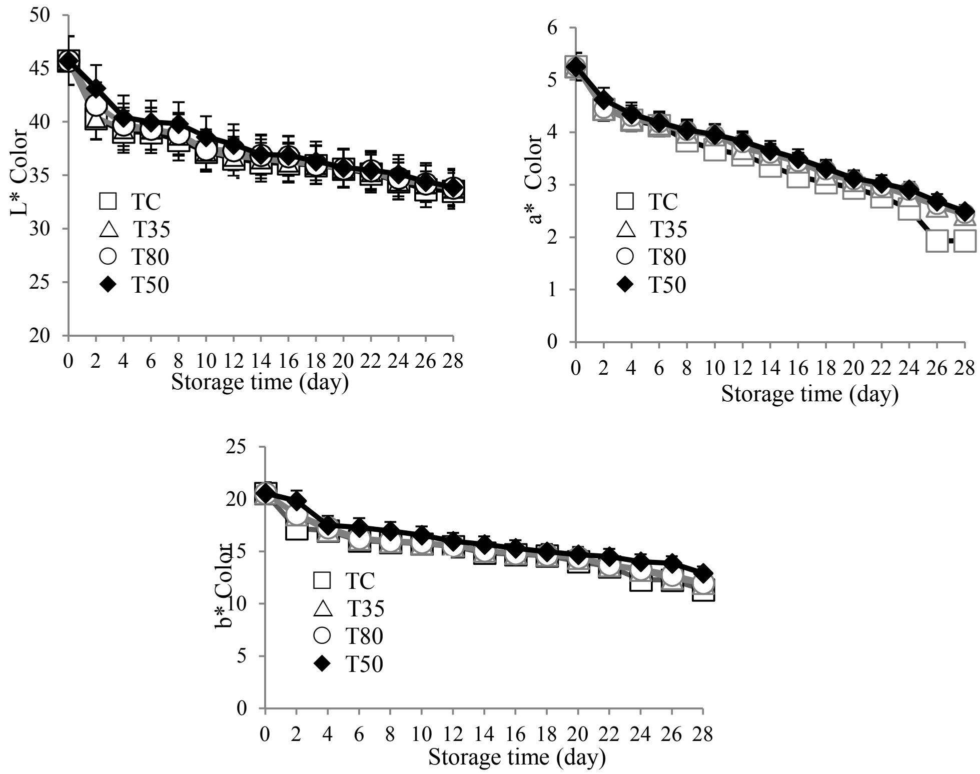

Fig. 1 Changes in colour of smoked oyster (*S. cucullata*) in control and MAP samples during refrigerated storage. (a) Colour L*, (b) Colour a*, (c) Colour b*

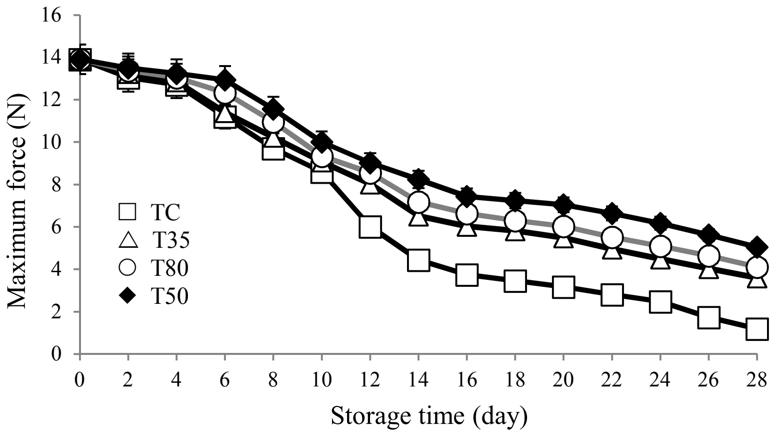

Fig. 2 Changes in shear strength (maximum force N g^{-1}) sample of smoked oyster (*S.cucullata*) in control and MAP samples during refrigerated storage.

Effect of MAP on sensory properties of smoked oyster during refrigerated storage

Appearance: There was a progressive decrease in the appearance score levels with length of time during refrigerated storage ($p \leq 0.05$) (Fig. 3a). Smoked oyster appearance changed to a darker colour because unsaturated fatty acids in the oyster underwent lipid oxidation,that accelerated discolouration. Caglak et al. (2008) reported the appearance score of mussel (*Mytilus galloprovincialis*) stored under modified atmosphere packaging decreased during storage. This study also found significant differences between the MAP and control smoked oyster samples. However, smoked oyster packed in T50 had a higher appearance score than the other MAP samples. Sample T35 still contains O_2 so some aerobic bacteria growth was expected. T80 gas contained CO_2 thus promoting protein denaturation (Qian et al., 2013). Similar results were reported by Arvanitoyannis et al. (2011) and Cakli et al. (2006) reported the sensorial score of mussel shrimps (*Melicertus kerathurus*) and smoked rainbow trout (*Onchoryncus mykiss*) store under MAP at 80% CO_2 lower than the other MAP conditions.

Odour: Odour is one of the most important quality criteria in fishery products. The odour score of all MAP and control samples decreased with the time of refrigerated storage (Fig. 3b). It could be related to the presence of some volatile compounds produced by bacterial deterioration, including trimethylamine (TMA) derived from the bacterial reduction of trimethyl-aminoxide (TMAO). TMA has a very characteristic "fishy" smell (Huss, 1995). Lipid oxidation leads to unpleasant odour, rancid taste and discolouration (Gram and Dalgaard, 2002). Similar odour score decreases were reported in sardines and steam-cooked rainbow trout stored by chilling (Özogul et al., 2004, Kaba et al, 2014). It is important to emphasise that the

T50 sample showed significantly the highest values during 28 days of storage. Apart from the unpleasant odour, CO_2 suppresses the respiration of many microorganisms by inhibiting growth of spoilage microorganisms and delay of enzymatic spoilage (Qian et al., 2013). However, a high concentration of CO_2 as in T80 may cause quality deterioration through lipid and protein oxidation (Cakli et al., 2006). Similar results have been reported in steam-cooked rainbow trout (Kaba and Corapci, 2014).

Taste and texture: The taste acceptability scores of all packaged samples decreased gradually with the time of refrigerated storage with a relatively similar decrease rate as the texture scores (Fig. 3c and 3d). Lipid oxidation causes undesirable rancid off-flavours and increased protein deterioration, leading to the qualitative deterioration of fish (Eymard et al., 2005). Similar results were reported by Ozogul et al. (2004) and Teerawut et al. (2014). High CO_2 concentrations near to 100% as in T80 may affect promotion of protein denaturation and decrease water retention capacity, which causes free amino acid protein function loss as sweetness taste leading to the obvious off-taste (Arvanitoyannis et al., 2011). However, sample T50 had the highest taste and texture scores, which is in agreement with Cakli et al. (2006) and Kaba and Corapci (2014).

Overall: The changes in overall likeness score are presented in Fig. 3e. Overall likeness scores for the T50 sample was the highest and it is noteworthy that T50 imparted desirable and pleasant odor and taste in smoked oyster samples until day 28 of storage, attributes well appreciated by the panelists. It has already been reported that CO_2 has an important effect on microbial growth, exerting a selective inhibitory action on aerobic microorganisms (McMillin, 2008). Therefore MAP delays the spoilage of smoked oyster. This is in agreement with the results by for Cakli et al. (2006) for hot smoked rainbow trout under MAP with 50% CO_2 : 50% N_2 gas. Results of the present work show that the limit of sensory acceptability (based on the odour attribute score was lower than 5) was reached for smoked oyster samples, on day 14 (TC), day 20 (T35), day 26 (T80) and on day 28 (T50).

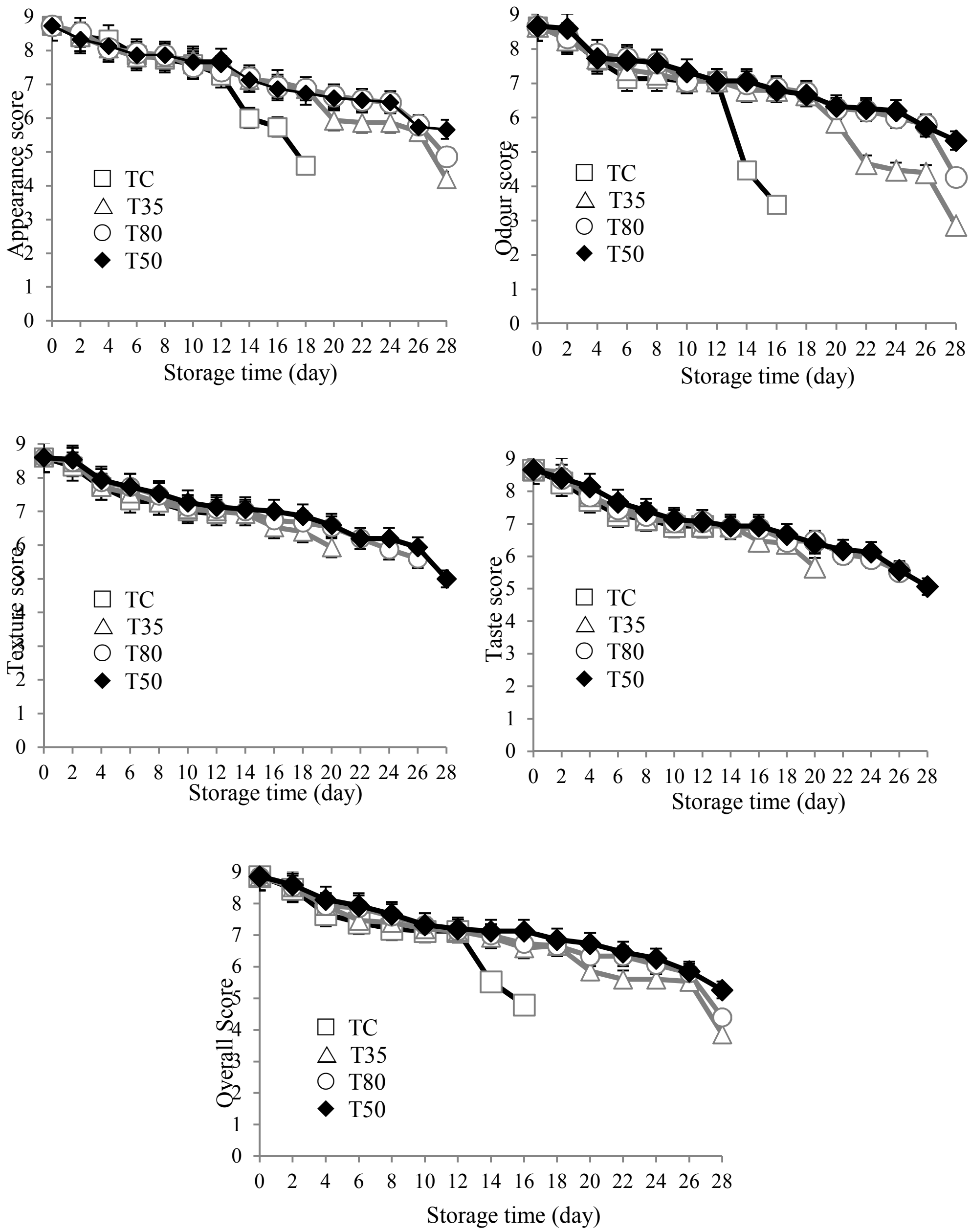

Fig. 3 Changes in sensory score of smoked oyster (*S.cucullata*) for control and MAP samples during refrigerated storage. (a) Appearance score, (b) Odour score, (c) Taste score, (d) Texture score, (e) Overall score

CONCLUSIONS

Various MAP treatments were evaluated for the loss of quality smoked oyster during refrigerated storage. When compared with its counterparts, the MAP batch with the gas composition 50% CO_2: 50% N_2 (T50) exerted a more significant inhibitory effect on deterioration, as monitored by parameters such as texture and color properties and also for sensorial scores. Based on sensory analyses data, the shelf-life of the T50 (50% CO_2: 50% N_2) smoked oyster during refrigerated storage was approximately 28 days, while the T80 and T35 samples were 26 and 20 days respectively, compared to smoked oyster without MAP of 14 days. The present results support the hypothesis that the decrease in physical quality and sensory properties of smoked oyster is retarded by MAP.

ACKNOWLEDGEMENT

The authors gratefully acknowledge financial support by Burapha University through the National Research Council of Thailand.

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