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Aqueous Chlorine Dioxide Treatment Decreases Microbial Contamination and Preserves Sensory Properties of Mackerel During Storage

-Research Note-

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Abstract

Effect of aqueous chlorine dioxide (ClO_2) treatment on quality change of mackerel during storage was examined. Mackerel treated with 0, 5, 10, and 50 ppm of ClO_2 solution, respectively was stored at 4°C. ClO_2 treatment decreased populations of aerobic bacteria in mackerel during storage. The number of total aerobic bacteria of mackerel treated with 50 ppm ClO_2 increased from 2.45 to 3.44 log CFU/g after 9 days of storage, while that of the control increased from 3.47 to 4.72 log CFU/g. The pH values of mackerel increased during storage, with no significant changes among treatments. Volatile basic nitrogen values of mackerel were decreased by ClO_2 treatment. Quality of mackerel treated with ClO_2 was better than that of the control during storage based on sensory evaluation. These results indicate that aqueous ClO_2 treatment could be useful for improving the microbial safety and qualities of mackerel.

Key words: mackerel, aqueous chlorine dioxide, microbial change, storage

INTRODUCTION

Deterioration of foods is generally caused by microbial contamination as well as physical factors such as temperature, loss of moisture content, and condition of packaging, etc. (1). Safety of foods is frequently impaired by the growth of microorganisms during the processing, storage, and transportation (1,2). Therefore, to enhance the safety of foods, various processing such as irradiation (3), washing with organic acids or sanitizers (4), chlorine (5,6), and ozone (7) treatment have been used to reduce bacterial counts and extend shelf life (8).

Regarding the use of chlorine as a sanitizer, there have been some health concerns due to the presence of trihalomethanes (THMs) generated in the presence of organic materials (9). Therefore, aqueous chlorine dioxide has been suggested as an effective alternative to chlorine (9,10). Chlorine dioxide has much higher oxidation capacity than chlorine (11), and does not generate toxic nitrogenous residuals such as chloramines or carcinogenic organic residuals. Food and Drug Administration has allowed the use of aqueous chlorine dioxide in washing fruits and vegetables. Recently, chlorine dioxide treatment has been commercially used in food industries such as apple packing and chicken processing. Andrews et al. (12) reported that aqueous chlorine dioxide treatment was more effective than aqueous chlorine in reducing aerobic bacteria in both shrimp and crawfish. Bae and Lee (13) also have reported that chlorine dioxide treatment effectively reduced major pathogenic bacteria such as *Vibrio anguillarum*, *Edwardsiella tarda*, and *Streptococcus* sp. in flounder.

Mackerel is one of the major fishes consumed in Korea, at over 100,000 tons annually. However, like other fishes, mackerel rapidly deteriorates due to autolysis and oxidation due to microbial action after death. Therefore, this study was conducted to examine the effect of aqueous chlorine dioxide treatment on the microbial growth, pH, VBN, and sensory evaluation of mackerel during storage, and to improve microbial safety and qualities of mackerel.

MATERIALS AND METHODS

Materials

Mackerel were purchased from a local market in Daejeon, Korea.

Chlorine dioxide preparation and treatment

Chlorine dioxide (ClO_2) was prepared by using a chlorine dioxide generating system (CH_2O Inc., Olympia, WA, USA) as described previously (14). Samples were treated by dipping into a solution of 0, 5, 10, and 50 ppm ClO_2 for 2 min, respectively, with concentrations conforming to the method of APHA (15). After ClO_2 treatment, samples were individually packaged and then stored at 4 ± 1°C.

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Microbiological analysis

After ClO_2 treatment, 5 g of mackerel flesh meat was removed using a sterile scalpel and then placed in 45 mL of peptone water (0.1% sterile peptone, w/v) in a sterile stomacher bag. Samples were then homogenized using a Stomacher (MIX 2, AES Laboratoire, France) for 3 min, filtered through a sterile cheese cloth, and diluted with peptone water for microbial count. Serial dilutions were performed in triplicate. Total bacterial counts were determined by plating appropriately diluted samples onto plate count agar (PCA, Difco Co., Detroit, MI, USA). Samples were evenly spread on the surface of the plates with a sterile glass rod. Plates were then incubated at 37°C for 48 hr.

pH measurement

5 g of mackerel was homogenized using a grinder (Model MCH600SI, Tong Magic Co., Seoul, Korea) with 45 mL of peptone water for 30 sec, centrifuged at 2000×*g* for 15 min, and pH measured using a pH meter (Corning Inc., Corning, NY, USA).

Measurement of volatile basic nitrogen (VBN)

VBN was determined according to the micro-diffusion method (16). Samples (5 g) were ground with 45 mL of distilled water for 30 sec, and after centrifugation at 2,000×*g* for 20 min, the supernatant was filtered through Whatman No 1, and 1 mL of filtrate was put in the left outside of Conway dish. One mL of 0.01 N H_3BO_3 and 50 μL of Conway reagent (0.066% methyl red, 0.066% bromocresol green) was added to the dish. In the right outside of the dish, 1 mL of saturated K_2CO_3 was added and the lid was closed. After reaction with the sample in the left outside at 37°C, samples were left for 2 hr, and then titrated with 0.02 N H_2SO_4.

Sensory evaluation

Samples were analyzed for their freshness, texture, odor, spoilage, and overall acceptability by 9 trained panelists (5 men and 4 women; age range, 23 to 27). Sensory qualities of samples were evaluated using a five point hedonic scale.

Statistical analysis

Analysis of variance and Duncan's multiple range tests were performed to analyze the results using a SAS program (SAS Institute, Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Microbiological changes

Microbial growth is one of the most important factors in determining the quality of mackerel during storage. Chlorine dioxide treatment significantly decreased total aerobic bacteria counts. After ClO_2 treatment, populations of bacteria in mackerel were 3.47, 3.15, 2.87, and 2.45 log CFU/g with 0, 5, 10, and 50 ppm of chlorine dioxide treatment, respectively (Fig. 1). Fifty ppm ClO_2 treatment reduced total aerobic bacteria by one log CFU/g. After 9 days of storage, the control reached 4.72 log CFU/g, while populations of total aerobic bacteria of samples treated with 5, 10 and 50 ppm of ClO_2 had 4.26, 3.84, and 3.44 log CFU/g, respectively. These results clearly indicate that microbial growth during storage of mackerel is inhibited proportionally as chlorine dioxide concentration increases.

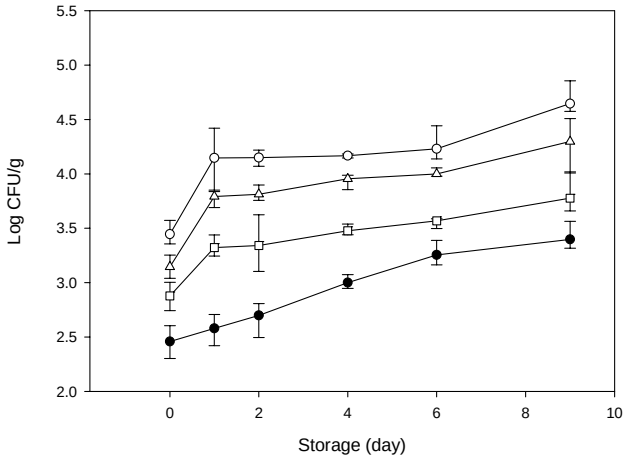

Fig. 1. Changes in total aerobic bacteria of ClO_2 treated mackerel during storage. ○: control, △: 5 ppm, □: 10 ppm, ●: 50 ppm.

Kim et al. (17) reported that 40 ppm chlorine dioxide treatment reduced microorganisms in salmon and red grouper fillets by 0.3 and 0.6 log CFU/g, respectively. Youm et al. (14) reported that *Escherichia coli* O157:H7, *Salmonella* Typhimurium, *Listeria monocytogenes* treated with 5 ppm chlorine dioxide for 5 min were reduced by 1.5, 1.8, and 0.98 log CFU/g, respectively. Lin et al. (18) also reported a similar bactericidal effects in ClO_2-treated fish model systems, resulting in 50～60% decreases in *Listeria monocytogenes* populations. The effect of chlorine dioxide treatment in this study was in good agreement with other results reported in the literature (14,17,18). These results suggest that aqueous chlorine dioxide treatment should delay the increase in populations of total aerobic bacteria in mackerel, and 50 ppm of chlorine dioxide treatment should enhance the quality and microbial safety of mackerel.

Change in pH

The pH value of fish usually decreases after death, mainly due to degradation of ATP and production of lactic acid. After decreasing to pH 5.5, it increases up to pH 8.0 because of basic components produced by decay

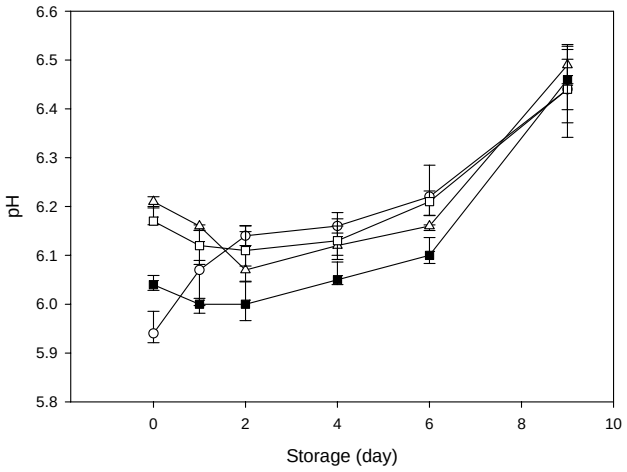

Fig. 2. Changes in pH of ClO_2 treated mackerel during storage. ○: control, △: 5 ppm, □: 10 ppm, ●: 50 ppm.

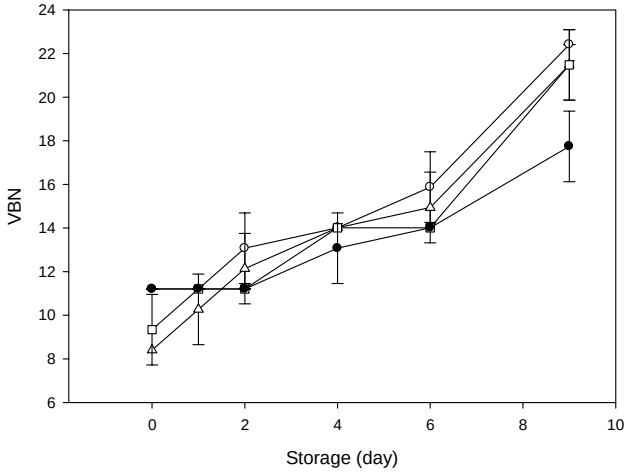

Fig. 3. Changes in VBN of ClO_2 treated mackerel during storage. ○: control, △: 5 ppm, □: 10 ppm, ●: 50 ppm.

(19). Fig. 2 shows the pH of mackerel treated with ClO_2 solution during storage. Initial pH values for mackerel were 5.95, 6.21, 6.18, and 6.04 after treatment with 0, 5, 10, and 50 ppm chlorine dioxide, respectively, and then increased during storage. However, there were no significant differences in changes among treatments. These results are similar to those of sardine (20), and the result of Byun et al. (19), where mackerel, croaker, and saury samples increased pH during storage.

Change in VBN

VBN value is an indicator of the degree of deterioration obtained by determining amine and ammonia contents in foods (21). VBN values of mackerel increased during storage, and initial VBN values after treatment with 0, 5, 10, and 50 ppm of ClO_2 solution were 11.21, 8.4, 9.3, and 11.21 mg%, respectively (Fig. 3). However, after 6 days of storage, all samples except for 50 ppm showed rapid increases in VBN values. In particular, after 9 days, samples treated with 0, 5, 10, and 50 ppm reached 22.4, 21.4, 21.4, and 17.7 mg%, respectively. The control increased 11.2 mg% of VBN value, while 50 ppm treatment increased only 6.5 mg% after 9 days of storage, demonstrating that ClO_2 treatment reduced VBN values during storage.

Table 1. Sensory evaluation of mackerel treated with aqueous ClO_2 during storage

Organoleptic parameter	ClO_2 (ppm)	Storage time (day)					
		0	1	2	4	6	9
Freshness	0	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.89 ± 0.33^{a}	2.33 ± 0.50^{b}	1.44 ± 0.53^{a}	1.00 ± 0.00^{a}
	5	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.89 ± 0.33^{a}	2.67 ± 0.50^{ba}	1.67 ± 0.50^{a}	1.11 ± 0.33^{a}
	10	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.89 ± 0.33^{a}	3.00 ± 0.00^{a}	1.89 ± 0.33^{a}	1.33 ± 0.50^{a}
	50	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.89 ± 0.33^{a}	3.00 ± 0.00^{a}	1.89 ± 0.33^{a}	1.56 ± 0.52^{a}
Texture	0	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.67 ± 0.50^{a}	2.67 ± 0.50^{a}	1.44 ± 0.53^{b}	1.11 ± 0.33^{b}
	5	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.67 ± 0.50^{a}	2.89 ± 0.33^{a}	1.78 ± 0.44^{ba}	1.11 ± 0.33^{b}
	10	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.67 ± 0.50^{a}	3.11 ± 0.33^{a}	2.00 ± 0.00^{a}	1.67 ± 0.50^{a}
	50	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.67 ± 0.50^{a}	3.11 ± 0.33^{a}	2.00 ± 0.00^{a}	1.89 ± 0.33^{a}
Decay	0	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.67 ± 0.50^{a}	3.00 ± 0.00^{a}	1.44 ± 0.53^{b}	1.11 ± 0.33^{a}
	5	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.67 ± 0.50^{a}	3.00 ± 0.00^{a}	1.78 ± 0.44^{ba}	1.11 ± 0.33^{a}
	10	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.67 ± 0.50^{a}	3.33 ± 0.50^{a}	2.00 ± 0.00^{a}	1.44 ± 0.53^{a}
	50	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.78 ± 0.50^{a}	3.44 ± 0.53^{a}	2.00 ± 0.00^{a}	1.67 ± 0.50^{a}
Odor	0	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.33 ± 0.71^{a}	3.00 ± 0.00^{a}	1.00 ± 0.00^{b}	1.00 ± 0.00^{a}
	5	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.33 ± 0.71^{a}	3.00 ± 0.00^{a}	1.11 ± 0.33^{b}	1.11 ± 0.33^{a}
	10	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.44 ± 0.53^{a}	3.00 ± 0.00^{a}	1.22 ± 0.44^{b}	1.11 ± 0.33^{a}
	50	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.67 ± 0.50^{a}	3.00 ± 0.00^{a}	1.89 ± 0.33^{a}	1.44 ± 0.53^{a}
Total	0	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.56 ± 0.53^{a}	2.78 ± 0.44^{a}	1.11 ± 0.33^{c}	1.00 ± 0.00^{b}
	5	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.56 ± 0.53^{a}	2.89 ± 0.33^{a}	0.56 ± 0.53^{b}	1.00 ± 0.00^{b}
	10	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.56 ± 0.53^{a}	3.00 ± 0.00^{a}	2.00 ± 0.00^{a}	1.44 ± 0.53^{ba}
	50	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.78 ± 0.44^{a}	3.00 ± 0.00^{a}	2.00 ± 0.00^{a}	1.78 ± 0.44^{a}

[a-c]Any means with different letters within a column are significantly different ($p<0.05$).

Sensory evaluation

Sensory evaluations of mackerel during storage are shown in Table 1. The effect of storage time on freshness, texture, decay, and odor of the samples was evaluated. After 4 days of storage, ClO_2 treated mackerel had better sensory scores than the control.

In conclusion, this study clearly indicated that ClO_2 treatment significantly decreased the populations of microorganisms in mackerel during storage. In addition, ClO_2 treatment was effective in maintaining the qualities of mackerel. Therefore, ClO_2 treatment can extend the shelf life and improve the microbial safety of mackerel during storage.

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