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Aqueous Chlorine Dioxide Treatment Improves the Shelf Life of *Panax ginseng* C.A. Meyer

– Research Note –

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Abstract

Effect of aqueous chlorine dioxide (ClO_2) treatment on the quality change of fresh ginseng during storage was examined. Fresh ginseng samples were treated with 0, 50, and 100 ppm of ClO_2 solution, respectively, and stored at 4°C. Microbiological data of the fresh ginseng after ClO_2 treatment revealed that the populations of total aerobic bacteria, and yeast and mold were significantly reduced with the increase of ClO_2 concentration. In particular, the populations of total aerobic bacteria, and yeast and mold in the fresh ginseng decreased by 2.1 and 1.2 log CFU/g at 100 ppm ClO_2 treatment, respectively. Aqueous ClO_2 treatment improved the color of the fresh ginseng during storage, but there was no significant difference in weight loss during storage among treatments. Sensory evaluation results represented that the qualities of the fresh ginseng treated with aqueous ClO_2 during storage were better than those of the control. These results clearly indicate that aqueous ClO_2 treatment could be useful in decreasing the microbial growth and extending the shelf life of fresh ginseng.

Key words: fresh ginseng, aqueous chlorine dioxide, microbial growth, storage

INTRODUCTION

Medicinal herbs have been widely used for health care (1). Korean ginseng (*Panax ginseng* C.A. Meyer) has been used as one of the most important medicinal herbs in Asia. Korean ginseng is generally cultivated for 4 to 6 years and harvested. However, fresh ginseng easily deteriorates within a week after harvest because it contains about 75% moisture. Therefore, it is difficult to supply high-quality fresh ginseng year-round (2). In particular, microbial contamination, dehydration, and physicochemical changes accelerate the deterioration of fresh ginseng (2,3).

To meet the market demand for good quality ginseng, it is necessary to enhance the postharvest quality of fresh ginsengs. Recently, prewashed fresh ginseng is being sold. However, if pathogenic microorganisms in fresh ginseng are not completely eliminated, fresh ginseng can become a vehicle for pathogen transmission (4). Therefore, various sanitizers such as organic acids (5), chlorine (6), and ozone (7) have been used to reduce the bacterial counts and to extend the shelf life of foods (8).

Regarding the use of chlorine, which is a typical sanitizing agent used in the food industry, there have been some health concerns due to the presence of trihalomethanes and chlorophenols generated during chlorination (9). Therefore, there have been many studies on chlorine dioxide as an effective alternative to chlorine (9,10). Because of its strong sterilizing power, chlorine dioxide can extend the shelf life of meats (11), seafood (12), and vegetables and fruits (13,14) by reducing the microbial counts. Aqueous chlorine dioxide treatment has been commercially used in food industries such as apple packing and chicken processing. Tsai et al. (15) reported that aqueous chlorine dioxide treatment was effective against the microorganisms on potatoes. Bae and Lee (16) also reported that chlorine dioxide treatment at 10 ppm effectively reduced the major pathogenic bacteria such as *Vibrio anguillarum*, *Edwardsiella tarda*, and *Streptococcus sp.* in flounder.

In this study, we focused on the processing method using an aqueous chlorine dioxide treatment, and determined the effectiveness of aqueous chlorine dioxide for controlling microbial growth as well as its effects on sensory qualities of fresh ginsengs during storage.

MATERIALS AND METHODS

Materials

Fresh ginseng (4 years old) was harvested in September, 2007 and provided by the Geumsan Ginseng Center (Geumsan, Korea).

Aqueous chlorine dioxide treatment

Aqueous chlorine dioxide (ClO_2) was prepared using

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the chlorine dioxide generating system (CH_2O Inc., Olympia, WA, USA) as described previously (17). Samples were treated by dipping in a solution of 0, 50, and 100 ppm ClO_2 solution for 30 min, respectively, where its concentration was determined according to the method of APHA (18). After ClO_2 treatment, samples were individually packaged and stored at $4 \pm 1^{o}C$.

Microbiological analysis

After ClO_2 treatment, samples (15 g) were placed in 135 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 6 min, filtered through a sterile cheese cloth, and diluted with peptone water for microbial counts. 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. Yeasts and molds were plated on potato dextrose agar (PDA, Difco Co., Detroit, MI, USA). Both plates were incubated at $37^{o}C$ for 48 hr. During storage at $4^{o}C$, changes in the populations of total bacteria, yeast and mold were determined. Each microbial count was the mean of three determinations, and it was expressed as log CFU/g.

Weight loss

Weight loss during storage was determined by weighing the initial and final weight of the samples. The value was expressed as a relative percentage.

Color measurement

Color of samples was analyzed using a colorimeter (CR-300 Minolta Chroma Meter, Minolta Camera Co., Osaka, Japan). Samples were placed on a white standard plate and Hunter values (L, a, b) were measured. Hunter L, a, and b values for the standard plate were $L = 98.34$, $a = -0.03$, $b = 1.62$, respectively. Five measurements were taken at different locations of each sample.

Sensory evaluation

Samples were analyzed for their freshness, texture, odor, color, and overall acceptability by 7 trained panelists (3 men; 4 women; age range, 22 to 27). Sensory qualities of samples were evaluated using a 5-point scoring method. Sensory scores were 5, very good; 4, good; 3, fair; 2, poor; and 1, very poor.

Statistical analysis

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

RESULTS AND DISCUSSION

Microbiological changes during storage

Initial populations of total aerobic bacteria, yeast and mold of fresh ginseng samples were 5.8 and 4.6 log CFU/g, respectively. Compared to other studies (19), our results are in good agreement with initial microbial loads of fresh ginseng. Therefore, these results indicate a need for the processing to ensure the microbial safety of fresh ginseng during storage. Fig. 1 shows that the populations of total aerobic bacteria in the fresh ginseng significantly decreased by ClO_2 treatment. Populations of the microorganisms on the samples treated with ClO_2 solution at 50 and 100 ppm were reduced by 1.3 and 2.1 log CFU/g, respectively. It has been known that ClO_2 causes protein denaturation, resulting in the death of the microorganisms by damaging cell membranes and inactivating mRNA (10).

Fresh ginseng samples showed an increase in the populations of total aerobic bacteria during storage at $4^{o}C$, reaching the populations in excess of 7 log CFU/g after 8 weeks of storage. Considering that 7 log CFU/g of the bacteria is the maximum allowable level of bacterial populations, these results indicate that the shelf life of fresh ginseng is less than 8 weeks when stored at $4^{o}C$. However, in comparison with the control, the populations of total bacteria on the samples treated with 50 and 100 ppm of ClO_2 were 6.0 and 5.5 log CFU/g after 8 weeks, respectively. Treatments of 50 and 100 ppm of ClO_2 extended the time required for total bacterial counts to reach 7 log CFU/g to more than 8 weeks. Thus, these results indicate that ClO_2 treatment is an efficient method to extend the shelf life of fresh ginseng by inhibiting the microbial growth.

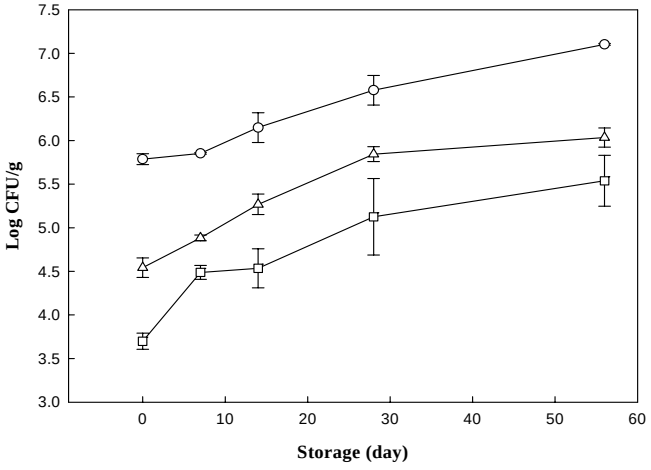

Fig. 1. Change in total aerobic bacteria populations of ClO_2-treated fresh ginseng during storage at $4^{o}C$. ○: control, △: 50 ppm, □: 100 ppm.

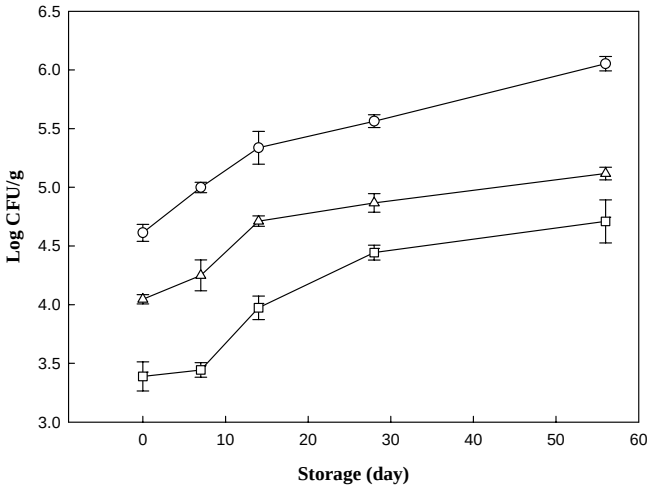

Fig. 2. Change in yeast and mold populations of ClO_2-treated fresh ginseng during storage at 4°C. ○: control, △: 50 ppm, □: 100 ppm.

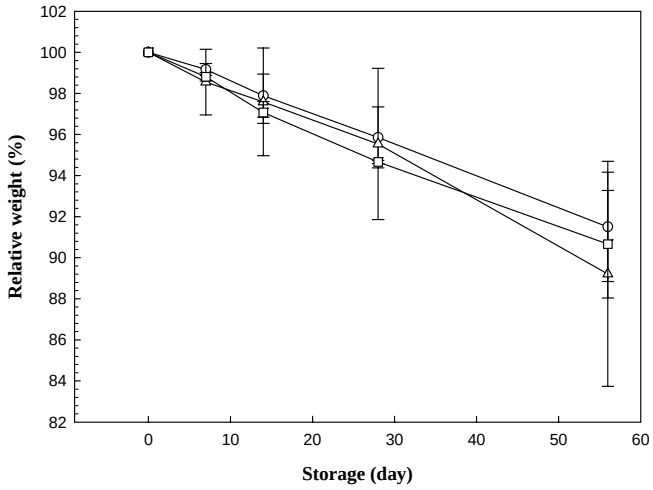

Fig. 3. Change in weight loss of ClO_2-treated fresh ginseng during storage at 4°C. ○: control, △: 50 ppm, □: 100 ppm.

Populations of yeast and mold increased in a similar pattern as did total aerobic bacteria (Fig. 2). Populations of yeast and mold in the fresh ginseng treated with 50 and 100 ppm of ClO_2 were reduced to 4.0 and 3.4 log CFU/g right after the treatment, compared to 4.6 log CFU/g for the control. In addition, after 4 weeks of storage, the control reached 5.6 log CFU/g, while populations of yeast and mold for the samples treated with 50 and 100 ppm of ClO_2 were 4.9 and 4.4 log CFU/g, respectively. After storage for 8 weeks, the control reached populations of yeasts and molds in excess of 6 CFU/g, while the samples treated with 50 and 100 ppm of ClO_2 had 5.1 and 4.7 log CFU/g, respectively.

The oxidizing power of chlorine dioxide has been reported to be 2.5 times that of chlorine (20). Kraiber et al. (21) reported that treatment of carrots with 100 ppm chlorinated water decreased the total aerobic bacteria by 1.4 log cycle, and that ozonated water treatment was less effective than the chlorinated water. Therefore, compared with the results of other studies (20,21) using chlorine or ozonated water, ClO_2 treatment was better in terms of microbial decontamination. Wu and Kim (22) reported that treatment of blueberries with 15 ppm ClO_2 decreased yeasts and molds by 2.86 log cycle. Singh et al. (13) also reported that *Escherichia coli* O157:H7 on shredded lettuce and baby carrot were significantly reduced by ClO_2 treatment. Thus, the effect of ClO_2 treatment in this study was comparable with other results reported in the literature (13,22). Therefore, these results suggest that aqueous chlorine dioxide treatment should delay the increase in the populations of total aerobic bacteria and yeast and mold in the fresh ginseng, and 100 ppm of chlorine dioxide treatment could extend the shelf life for 8 more weeks by inhibiting the microbial growth of the fresh ginseng.

Change in weight loss

Fig. 3 showed that the weight loss of the fresh ginseng increased during storage, and had about 10% weight loss after 8 weeks. Relative weight percentages of the fresh ginseng after 8 weeks of storage were 91.5, 89.2, and 90.7 at 0, 50, and 100 ppm treatment, indicating that there was a negligible difference among treatments.

Change in color change

Hunter L, a, and b values of the fresh ginseng treated with ClO_2 solution are shown in Table 1. There were significant differences among Hunter's L, a, and b values of the samples after storage. In particular, after 4 weeks, Hunter L value of the control decreased more than the samples treated with 50 and 100 ppm of ClO_2. In addition, compared to the samples treated with 50 and 100 ppm of ClO_2, it should be noted that Hunter a and b values of the control increased more during storage. Therefore, our results clearly indicate that ClO_2 treatment improves the color of the fresh ginseng. These results are comparable with other studies (15).

Sensory evaluation

Sensory evaluation of the fresh ginseng during storage is shown in Table 2. Sensory qualities such as freshness, texture, decay, and odor were examined among samples during storage. After 8 weeks of storage, ClO_2-treated fresh ginseng had better sensory scores than the control. The sensory evaluation results indicate that ClO_2 treatment could extend the shelf life of the ginseng for at least 4 more weeks.

Overall, this study clearly indicated that aqueous ClO_2 treatment significantly decreased the populations of the

Table 1. Change in Hunter color values of ClO_2-treated fresh ginseng during storage at 4°C

Color parameter[1)]	ClO_2 treatment (ppm)	Storage period (week)				
		0	1	2	4	8
L	0	76.23±3.71[a]	78.32±2.47[a]	76.96±1.08[b]	70.80±5.64[b]	69.31±2.59[b]
	50	79.90±0.95[a]	80.26±1.31[a]	79.55±1.32[a]	78.39±1.28[a]	73.12±2.89[a]
	100	79.59±1.18[a]	79.32±0.62[a]	79.72±0.36[a]	78.73±0.23[a]	76.63±0.36[a]
a	0	1.75±0.72[a]	-0.76±1.46[a]	0.65±0.30[a]	2.35±1.79[a]	6.30±1.56[a]
	50	-0.03±0.87[a]	-1.21±0.71[a]	0.56±0.79[a]	-0.83±0.75[b]	1.67±1.09[b]
	100	-0.64±1.14[a]	-0.11±0.52[a]	-0.45±0.16[a]	-1.06±0.58[b]	-0.26±0.63[c]
b	0	33.72±3.85[a]	34.28±3.11[a]	38.55±0.63[a]	40.95±3.09[a]	38.91±0.35[a]
	50	34.36±2.53[a]	34.71±2.80[a]	33.18±1.64[b]	33.23±2.30[b]	35.99±0.79[b]
	100	33.98±1.61[a]	34.29±3.97[a]	31.24±1.78[b]	32.39±2.99[b]	29.72±0.45[c]

[1)]L: degree of whiteness (0 black～100 White), a: degree of redness (-80 greenness～100 redness), b: degree of yellowness (-80 blue～70 yellowness). [a-c]Any means in the same column followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.

Table 2. Sensory evaluation of ClO_2-treated fresh ginseng during storage at 4°C

Organoleptic parameter	ClO_2 treatment (ppm)	Storage period (week)				
		0	1	2	4	8
Freshness	0	5.00±0.00[a]	5.00±0.00[a]	3.86±0.38[b]	3.00±0.58[b]	2.00±0.58[a]
	50	5.00±0.00[a]	5.00±0.00[a]	4.00±0.00[b]	3.86±0.38[a]	2.50±0.79[a]
	100	5.00±0.00[a]	5.00±0.00[a]	4.86±0.38[a]	4.29±0.76[a]	3.00±1.15[a]
Texture	0	5.00±0.00[a]	5.00±0.00[a]	4.57±0.54[a]	4.14±0.90[a]	3.29±0.49[a]
	50	5.00±0.00[a]	5.00±0.00[a]	4.71±0.49[a]	4.14±0.69[a]	3.83±0.49[a]
	100	5.00±0.00[a]	5.00±0.00[a]	4.86±0.38[a]	4.29±0.76[a]	3.71±0.49[a]
Decay	0	5.00±0.00[a]	5.00±0.00[a]	3.90±0.90[a]	3.29±0.95[a]	2.29±0.49[b]
	50	5.00±0.00[a]	5.00±0.00[a]	4.40±0.80[a]	3.86±0.38[a]	2.83±0.69[ab]
	100	5.00±0.00[a]	5.00±0.00[a]	4.70±0.50[a]	3.86±0.38[a]	3.14±0.38[a]
Odor	0	5.00±0.00[a]	5.00±0.00[a]	4.43±0.53[a]	3.86±0.69[a]	3.00±0.58[a]
	50	5.00±0.00[a]	5.00±0.00[a]	4.86±0.38[a]	4.00±0.58[a]	3.33±0.90[a]
	100	5.00±0.00[a]	5.00±0.00[a]	4.86±0.38[a]	4.14±0.69[a]	3.50±0.76[a]
Overall	0	5.00±0.00[a]	5.00±0.00[a]	3.67±0.82[b]	3.00±0.58[b]	2.14±0.38[b]
	50	5.00±0.00[a]	5.00±0.00[a]	4.67±0.82[a]	3.86±0.38[a]	2.83±0.38[a]
	100	5.00±0.00[a]	5.00±0.00[a]	4.83±0.41[a]	4.28±0.49[a]	3.29±0.49[a]

[a,b]Any means in the same column followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.

microorganisms in the fresh ginseng during storage, and was effective in maintaining the quality of the fresh ginseng. Therefore, aqueous ClO_2 treatment can extend the shelf life for more than 4 weeks based on the microbial results and sensory evaluation of the ginseng during storage.

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