TITLE PAGE

- Food Science of Animal Resources -

Upload this completed form to website with submission

ARTICLE INFORMATION	Fill in information in each box below
Article Type	Research article
Article Title	Evaluation of Peroxidized Acetic Acid Disinfectant Proper Use Concentration and its Effect on Chicken carcasses Quality
Running Title (within 10 words)	Evaluation of Peroxidized Acetic Acid Disinfectant Proper Use Concentration
Author	Kang Heung Kim1, Byong Kon Lee2, Ji Yeon Chun3, Jeong Hun Nam2, Soo Ah Lee2, Jin Man Kim1
Affiliation	1 Department of Food Marketing and Safety, Konkuk University, Seoul 05029, the Republic of Korea 2 Cherrybro Co., Okcheon-gun 29051, the Republic of Korea 3 Department of Food Bioengineering, Jeju National University, Jeju 63243, the Republic of Korea
Special remarks – if authors have additional information to inform the editorial office	
ORCID (All authors must have ORCID) https://orcid.org	Kang Heung Kim (https://orcid.org/0009-0002-1853-2155) Byong Kon Lee (https://orcid.org/0000-0001-9749-8455) Ji Yeon Chun (https://orcid.org/0000-0002-4336-3595) Jeong Hun Nam (https://orcid.org/0009-0004-9255-5691) Soo Ah Lee (https://orcid.org/0009-0009-2665-3804) Jin Man Kim (https://orcid.org/0000-0002-2887-8195)
Conflicts of interest List any present or potential conflict s of interest for all authors. (This field may be published.)	The authors declare no potential conflict of interest.
Acknowledgements State funding sources (grants, funding sources, equipment, and supplies). Include name and number of grant if available. (This field may be published.)	
Author contributions (This field may be published.)	Conceptualization: Kim KH. Data curation: Lee BK. Formal analysis: Chun JY. Methodology: Nam JH. Software: Lee SA. Validation: Lee BK. Investigation: Lee BK, Kim JM. Writing - original draft: Kim KH, Kim JM. Writing - review & editing: Kim KH, Lee BK, Chun JY, Nam JH, Lee SA, Kim JM.
Ethics approval (IRB/IACUC) (This field may be published.)	This article does not require IRB/IACUC approval because there are no human and animal participants.

CORRESPONDING AUTHOR CONTACT INFORMATION

For the corresponding author (responsible for correspondence, proofreading, and reprints)	Fill in information in each box below
First name, middle initial, last name	Jin Man Kim
Email address – this is where your proofs will be sent	jinmkim@konkuk.ac.kr
Secondary Email address	
Postal address	Department of Food Marketing and Safety, Konkuk University, Seoul 05029, Korea.

Cell phone number	+82-2-450-3688
Office phone number	+82-2-450-3688
Fax number	

Evaluation of Peroxidized Acetic Acid Disinfectant Proper Use Concentration and its Effect on Appearance of Chicken carcasses

ABSTRACT

With the increase in consumer interest in food safety, in this study, we aimed to investigate the antibacterial effect of 50, 100, 150, and 200 ppm of peracetic acid (peracetic acid A, peracetic acid B, and peracetic acid) and sodium hypochlorite disinfectants on chicken carcasses and contaminated water, respectively, and changes in the appearance of chicken carcasses. Considering the antibacterial effect of each disinfectant concentration, the most significant antibacterial efficacy was observed for general bacteria and *E. coli* at 200 ppm regardless of disinfectant type. Considering the disinfectant type at 200 ppm, sodium hypochlorite was the least effective, and peracetic acid A showed the highest antibacterial efficacy at all concentrations. In chicken carcasses, 200 ppm of peracetic acid A exhibited the highest bacterial reduction rates of 92.7 and 89.3% for general bacteria and *E. coli*, respectively; in contaminated water, 200 ppm of peracetic acid A exhibited a significantly higher reduction rate ($p<0.05$). Salmonella was negative throughout the experiment, and discoloration of the neck and tip was observed for peracetic acid A and peracetic acid (Daesung) at 100 ppm and peracetic acid B at 150 ppm. Sodium hypochlorite did not cause discoloration at any concentration. Flavor analysis indicated that 100 ppm of peracetic acid A exhibited olfactory characteristics similar to those of 100 or 150 ppm of sodium hypochlorite. In conclusion, 50 ppm of peracetic acid A was adequate for use in poultry processing plants.

Keyword: Chicken carcasses, Peroxidized Acetic acid, Sodium hypochlorite, Acetic acid, Octanoic acid.

Introduction

Many poultry processing plants currently use disinfectants to control microorganisms after slaughter. In particular, sodium hydrochlorite-based disinfectants have most commonly been used for more than 100 years owing to their low cost and high antibacterial efficacy (White, 1998; Northcutt & Jones, 2004; Rutala & Weber, 1997; Hidalgo et al., 2002). However, their disadvantages include the possibility of decreased antibacterial efficacy depending on the environment (Northcutt & Lacy, 2000) and the risk of hypochlorous acid breakdown with decreasing pH of the disinfectant, which can increase the risk of corrosion of equipment and fixtures (Korea Health Industry Development Institute, 2003; European Union, 2017). As presented in Table 1, chlorine-based disinfectants produce toxic chlorine gas when mixed with acids (Fukuzaki, 2006) and react with certain organic substances during the disinfection process to produce the environmental pollutant trihalomethane (THM) (Pavón et al., 2008; Cantor et al., 1978; Morris et al., 1992; Bull et al., 1995; King & Marrct, 1996).

Recently, studies have been conducted on disinfectants that can be used safely and effectively as an alternative to chlorine-based disinfectants, with peracetic acid-based disinfectants garnering increasing attention (Kim & Huang, 2020). Peracetic acid (peroxyacetic acid) is a peroxide of acetic acid, produced by making acetic acid react with hydrogen peroxide in the presence of sulfuric acid as a catalyst. At a pH of 5.5-8.2, spontaneous decomposition occurs, primarily by acetic acid and oxygen (Block, 1991; Gehr et al., 2002), wherein acetic acid, hydrogen peroxide, oxygen, and water are produced as decomposition products (Lefevre et al., 1992; Gehr et al., 2002; Wagner et al., 2002).

Peracetic acid is a colorless liquid with a pungent vinegar-like odor that is known for its antibacterial properties against a wide range of microorganisms (US Environmental Protection Agency, 2012; Kim & Kim, 2015; Zhang, 2022). In the United States (US), it was approved by the US Food and Drug Administration in 1986 for use as a disinfectant solution and subsequently approved by the US Environmental Protection Agency (EPA) and US Department of Agriculture. It is currently used in a variety of industries, including food, medicine, agriculture, alcoholic beverages, institutional horticulture facilities and equipment, animal housing, the dairy industry, and water treatment (Dychdala, 1988; Baldry, 1983; Block, 2001; Kitis, 2004; Luukkonen & Pehkonen, 2017). However, to date, domestic research on the use and appropriate concentration of peracetic acid-based disinfectants in poultry processing plants is limited.

In this study, we examined the antibacterial efficacy of peracetic acid as a replacement for chlorine-based disinfectants currently used in poultry processing plants; investigated the effect of peracetic acid disinfectant on the appearance of chicken meat by evaluating the quality of chicken meat using an electronic tongue and electronic nose, and established the optimal concentration and safe-use level to meet the food hygiene safety requirements of chicken meat. Among peracetic acid-based disinfectants, there is no difference in the components of samples peracetic acid A and B used in this experiment, but it is thought that applying a small mixture of octane compared to general peracetic acid will protect the chicken's appearance from discoloration compared to peracetic acid and increase the product satisfaction of final consumers This is expected to minimize the spoiled appearance of chicken meat that can occur when using peracetic acid-based disinfectants and improve end-user product satisfaction by preventing industrial hazards, thereby increasing its usability and profitability in the poultry industry.

Materials and methods

Preparation of sample and materials

The experimental chickens were Arbor Acres Plus breed and sampled from the Cherrybro poultry processing plant. The contaminated water used for disinfection and verification of sterilization was mixed with 5 kg of meat and 15 L of water and stored in an incubator at 30 ℃ for 48 h. The deteriorated contaminated water was filtered through a mesh net. Peracetic acid was used from Daesung C&S (Oxyacid) as present in Table 2, and the peracetic acid sample was a mixture of peracetic acid (POAA), peroxyoctanoic acid (POOA), hydrogen peroxide, acetic acid, and octanoic acid, as presented in Table 3. The composition of peracetic acid A and B for the treatment groups was the same. For comparison, 13-15% of commercially available sodium hypochlorite was used.

Preparing disinfectants

The disinfectants used in the experiments were prepared, as presented in Tables 4 and 5, and their concentrations were determined by reading the test paper on a dedicated instrument. The tap water used in the experiment was 10 to 15 degrees of water at pH 6 to 7, and the residual chlorine present in the tap water was considered to have no effect on the experimental results. The concentration of each disinfectant was based on the commonly used product (40-60% acetic acid, 15-20% peracetic + peroxyoctanoic acid, 2.5-10% hydrogen peroxide).

Applying disinfectants to carcasses

At each concentration of the four disinfectants, 21 carcasses were immersed for 5 min (based on the time required to pass through the combination chiller during the conventional poultry processing process) and subsequently placed in a refrigerator below 5 ℃ for 1 h (based on the time required to pass through the air chiller for 1 h during the conventional poultry processing process), and the test was conducted according to the bacteriological test method for meat according to the Food Code.

Applying contaminated water to carcasses

We collected contaminated water 12 times (10 mL each) to be used as raw samples. The experimental samples were prepared by creating 321 samples of 9 mL of raw contaminated water samples and dispensing 1 mL of each concentration in four disinfectants (peracetic acid (Dae sung), peracetic acid A, peracetic acid B, and sodium hypochlorite), diluting them with a vortex mix for 30 s, and subsequently vortexing for 30 min.

For *Salmonella*, 22.5 mL of raw contaminated water sample was prepared, treated with four disinfectants (peracetic acid, peracetic acid A, peracetic acid B, and sodium hypochlorite) at 50, 100, 150, and 200 ppm each in a 2.5-mL aliquot (applied by 10%), diluted with a vortex mixer for 30 s, and stabilized for 30 min prior to use.

Experimental methods

For the general bacterial count experiment, the experimental solution was re-homogenized with a vortex mixer, and the samples were taken in 1 mL aliquots with a micropipette and diluted in 9 mL of 0.85% sterile PBS to concentrations of 10^4, 10^5, and 10^6; subsequently, they were incubated in a general dry-film medium to measure the bacterial count. The resulting red colonies were counted and multiplied by the dilution factor to determine the general bacterial count. The reduction rate (%) calculated dividing (Initial bacterial count – Count of bacteria after 10 minutes) by initial bacterial count and multiplying 100.

For the count experiment of *E. coli*, the dilutions prepared the same way as those for the general bacterial count experiment were incubated on *E. coli* dry-film medium, and the bubbles formed around the colonies after incubation were counted and multiplied by the dilution factor to determine the *E. coli* count. The Salmonella test was conducted by adding sterilized buffered peptone water (BPW) to the prepared test solution for primary growth, and the culture was harvested and sub-cultured in Rappaport-Vassiliadis (RV) medium for secondary growth. The cultures from the second round of growth were then sub-cultured onto xylose lysine deoxycholate (XLD) agar and Brilliant Green (BG) Sulfa Agar, with XLD agar and BG Sulfa Agar being considered positive when black and red colonies occurred, respectively, and the test was finally confirmed to be positive when all media showed positive results. The reduction rate (%) calculated dividing (Initial bacterial count – Count of bacteria after 10 minutes) by initial bacterial count and multiplying 100.

Heracles II Electronic Nose (Alpha MOS, Toulouse, France) was used to analyze the flavor components of the samples, and the measurement results were expressed as the rate of change of the resistance value of the volatile components (R_{gas}) of the samples with respect to the resistance value of air (R_{air}) using Alpha Soft software (Alpha MOS, Toulouse, France) for flavor principal component analysis (PCA); the sensitivity of each sensor was expressed as delta (R_{gas}/R_{air}). The measured flavor components were represented in a PCA plot, and the first (PC1) and second principal component (PC2) values were obtained to distinguish the flavor patterns. For comparison of peracetic acid and sodium hypochlorite acid, set peracetic A as control and sodium hypochlorite acid as treatment. (C-100 = peracetic A 100ppm; C-150 = peracetic A 150ppm; T-100 = sodium hypochlorite acid 100ppm; T-150 = sodium hypochlorite acid 150ppm)

Statistical processing

All experiments were conducted with at least three replicates and the results were expressed as the mean and standard deviation. Statistical analysis was conducted using Minitab 18 (Minitab Inc.). One-way analysis of variance (ANOVA) was used to test the significance ($p<0.05$) of each sample, and Tukey's multiple range test was used for the post-hoc test.

Results and discussion

Antibacterial efficacy by disinfectant concentration

Table 6 presents the antibacterial efficacy of peracetic acid (Daesung) on carcasses and contaminated water. The reduction of general bacteria in the carcasses was not significantly different at 50, 100, and 150 ppm but tended to be the lowest (60.2%) at 100 ppm. At 200 ppm, the bacterial count significantly reduced from 5350.0 before treatment to 388.5 after treatment ($p<0.05$). For E. coli, no significant differences were observed, with reduction rates of 63.8 and 66.7% at 50 and 100 ppm, respectively, but E. coli decreased significantly by 71.3 and 89.3% at 150 and at 200 ppm, respectively ($p<0.05$). When applied to contaminated water, the highest and lowest decreases in the number of general bacteria were 63.5 and 46.5% at 200 and 50 ppm, respectively ($p<0.05$). Similar to general bacteria, E. coli showed the highest reduction at 200 ppm, with an 82.4% reduction from 3.6×10^7 to 6.3×10^6, but significance was not identified.

Table 7 presents the antibacterial efficacy of peracetic acid A on carcasses and contaminated water. When applied to carcasses, the largest decrease in the number of general bacteria in contaminated water was 98.4% at 200 ppm, whereas the reduction rate was significantly lower (88.8%) at 50 ppm ($p<0.05$), showing no significant differences at other concentrations. For E. coli, no significant difference was observed at all concentrations, but the lowest reduction rate was 91.6% at 50 ppm, and the antibacterial efficacy tended to increase in a concentration-dependent manner. When applied to contaminated water, general bacteria decreased by 58.6% at 50 ppm, 64.3% at 100 ppm, and 72.8% at 150 and 200 ppm, showing a significantly higher antibacterial efficacy ($p<0.05$). For E. coli, the antibacterial efficacy was the highest at 200 ppm, with a reduction in the count of E. coli from 3.6×10^7 to 2.7×10^6 ($p<0.05$), followed by those at 100 (88.0%) and 150 ppm (84.0%), with no significant difference between them; 50 ppm of peracetic acid A showed the lowest reduction rate, namely, 79.1% ($p<0.05$).

Table 8 presents the antibacterial efficacy of peracetic acid B on carcasses and contaminated water. When applied to carcasses, the reduction in general bacteria was lowest at 50 ppm, with no significant difference from that at 100 ppm. The highest reduction was observed at 200 ppm, with a significant reduction of 92.5% ($p<0.05$). For E. coli, the largest reduction was 92.2% at 200 ppm ($p<0.05$), followed by 85.0% at 150 ppm, and no significant reduction at 100 and 50 ppm. When applied to contaminated water, the bacterial reduction was higher in general bacteria with increasing disinfectant concentration, but no significant difference was observed between them. For E. coli, the largest reduction was 82.9% at 200 ppm, and the reduction rate was significantly lower (61.4%) at 50 ppm ($p<0.05$), with no significant difference between concentration of 100 and 150 ppm.

Table 9 presents the antibacterial efficacy of sodium hypochlorite on carcasses and contaminated water. When applied to carcasses, the antibacterial efficacy was significantly higher at 200 ppm (78.3%; $p<0.05$), followed by those at 150 and 100 ppm; it then decreased to 47.3% at 50 ppm. For E. coli, the largest reduction was found at 200 ppm ($p<0.05$), and the antibacterial efficacy decreased in a concentration-dependent manner, but no significant difference was observed among them. When applied to contaminated water, the largest decrease in the number of general bacteria was 56.3% at 200 ppm, and the lowest reduction rates were 29.4 and 35.0% at 50 and 100 ppm, respectively ($p<0.05$). The reduction rates for E. coli were 56.3, 48.3, 35.0, and 29.4% at 200, 150, 100, and 50 ppm, respectively, with no significant differences between those at each concentration.

Referred to results of table 6-9, based on the results in section 200 ppm was set as the optimal concentration for each disinfectant in this study. The comparison of the antibacterial efficacy of each disinfectant at the optimal (200ppm) concentration is presented in Table 10.

Before applying disinfectant to treatment, all treatment have no statistically significance in result of antibacterial efficacy. All disinfectants except sodium hypochlorite showed a bacterial reduction rate of 90% when applied to carcasses ($p<0.05$). In particular, when applied to carcasses, peracetic acid A showed a significant reduction of 99.4% in E. coli levels from 6941.7 before treatment to 44.2 after treatment compared with that in the control ($p<0.05$). When applied to contaminated water, peracetic acid A showed the highest significant reduction among all disinfectants, with a reduction rate of approximately 80% ($p<0.05$). However, no significant difference was observed in antibacterial efficacy between peracetic acid (Daesung) and peracetic acid B. The average reduction from the control was the highest for peracetic acid A, peracetic acid B, peracetic acid (Daesung), and sodium hypochlorite, with sodium hypochlorite showing the lowest reduction among all disinfectants, regardless of concentration ($p<0.05$).

The tests of antibacterial efficacy on sample carcasses revealed that the peracetic acid series had higher antibacterial efficacy than sodium hypochlorite at the same concentration. This result is consistent with the trends observed in other previous studies (Kim et al., 2010; Lee et al., 2006; Lee, 2020). Considering the peracetic acid series, peracetic acid A showed an antibacterial efficacy of more than 90% at 50 ppm and a reduction rate consistently exceeding 90% at other concentrations, which are considered to be the highest among all disinfectants ($p<0.05$).

The antibacterial efficacy tests on contaminated water revealed that the peracetic acid-based disinfectants had a significantly higher reduction rate than sodium hypochlorite at the same concentration ($p<0.05$). When comparing peracetic acid-based disinfectants, peracetic acid A had the highest reduction rate at all concentrations, distinguishing it from the other disinfectants ($p<0.05$), whereas peracetic acid B and peracetic acid (Dae sung) had similar effects.

The effect of each disinfectant on the appearance of chicken

The changes in the appearance of chicken are shown in Figures 1 to 4. Discoloration was observed on the neck and tips with peracetic acid and peracetic acid A at 100 ppm and peracetic acid B at 150 ppm, whereas no discoloration was observed with sodium hypochlorite at any concentration.

Meat color are subjective characteristic of meat that perceived by consumer. And, consumers tend to favor chicken meat that closely resembles the color of the meat they typically consume (Manjankattil et al., 2021). Various organic acids have been studied for application in poultry processing plant including acetic, citric, and lactic acid. (Mulder et al., 1987; Dickens et al., 1994). It has been reported that these acids, while effective as antimicrobials, may result in negative flavor and color alterations (Blankenship et al., 1990). In current experiment, discoloration was observed on the neck and tips with peracetic acid and peracetic acid A at 100 ppm and peracetic acid B at 150 ppm. However, no discoloration was observed with sodium hypochlorite at any concentration. These results disagree with Bauermeister et al. (2008), as there were no differences in the lightness values of the 0.01% and 0.015% peracetic acid levels and sodium hypochlorite. The reason for these inconsistent results in appearances may be due to the different analysis methods of meat color. In our experiment, we simply analyze changes in appearances, therefore, a precise analysis method is needed for further study such as Hunter L*a*b* color system.

Analysis results of *Salmonella*

Salmonella was not detected in all samples at each concentration, as presented in Table 11.

Electronic nose analysis results

Figure 5 shows the PCA results of the electronic nose. In the PCA section of the sample, the values of PC1 and PC2 were 99.992 and 0.005517%, respectively, and the differences between treatments were mainly distinguished by PC1. Along the x-axis, C-100, T-100, and T-150 did not show a significant change in position among treatment groups, with C-150 being the furthest to the right and clearly distinguishable from the other treatment groups. C-100, T-100, and T-150 seemed to exhibit similar flavors, whereas C-150 exhibited a different flavor profile from the other treatment groups. Therefore, the olfactory characteristics after disinfection with sodium hypochlorite at 100 or 150 ppm is expected to be similar to those after disinfection with peracetic acid A at 100 ppm.

Conclusions

In this study, we evaluated the antibacterial efficacy of three peracetic acid-based disinfectants and a sodium hypochlorite disinfectant applied to carcasses and contaminated water to determine the effect of peracetic acid on chicken meat. In the results of antibacterial efficacy tests, peracetic acid-based disinfectants had a significantly higher reduction rate than sodium hypochlorite. Increasing concentration of peracetic A had higher reduction rate than others at the same concentration. However, discoloration was observed on the neck and tips with peracetic acid A at 100 to 200. In conclusion, considering both reduction rate of bacteria and appearance, 50ppm of peracetic acid A was adequate for use in poultry processing plants.

References

1. Kim C, Kim B. 2015. Development of sterilant for the prevention of infection of the medical institution interior space. J Korean Soc Mech Technol 17(1):153-160.
2. Jang B. 2022. The disinfectant effect of peroxyacetic acid on vegetables and chicken

carcasses. Master’s thesis, Konkuk University Graduate School, Korea.

3. Lee J. 2020. Treatment of peroxyacetic acid to reduce Salmonella Thompson in chicken meat. Master’s Thesis, Chung-Ang University Graduate School, Seoul, Korea.
4. Son H, Bae W, Ji K. 2022. Enhanced antibacterial activity of sodium hypochlorite under acidic pH condition. Microbiology and Biotechnology Letters 50(2):211-217.
5. Korea Health Industry Development Institute. 2003. Evaluation of Disinfectant Safety and Efficacy (II)(2023-62). Available from: https://scienceon.kisti.re.kr/commons/util/originalView.do?cn=TRKO200400000079&dbt=TRKO&rn=. Accessed at 11 30. 2023.
6. Bae Y, Heo S, Lee S. 2009. Inhibitory Effect of Dry-heat treatment and chemical sanitizers against foodborne pathogens contaminated on the surfaces of materials. J Korean Soc Food Sci Nutr 38(9):1265-1270.
7. Kim H, Park S, Kwak I, Sung J, Lim H, Kim H, Kim S. 2010. Efficacy of sanitizers due to the changes of contact time and temperature. J Food Hyg Saf 25(4):325-332.
8. Lee H, Hong S, Kim D, Son S. 2006. [P4-01] Comparison of the Microbial Control Effectiveness of Hypochlorous Acid and Peracetic Acid Treatments on Sliced Cabbage. Conference Proceedings of the Korean Society of Food, Seoul, Korea. pp 238-238.
9. Kim J, Huang CH. 2020. Reactivity of peracetic acid with organic compounds: a critical review. Acs Es&T Water 1(1):15-33.
10. Choi TY. 2008. Biocidal effect of a sanitizer/disinfectant, foodsafe against bacteria, yeast, and mycobacteria. Korean J Clin Microbiol 11(2):117-122.
11. Jeong MI, Park SY, Ha SD. 2018. Effects of sodium hypochlorite and peroxyacetic acid on the inactivation of murine norovirus-1 in Chinese cabbage and green onion. LWT 96:663-670.
12. Nanny MA. 1999. Handbook of Chlorination and Alternative Disinfectants. 4th ed.

George Clifford White (ed). John Wiley & Sons, Inc., New York, Chichester, Weinheim, Brisbane, Singapore, and Toronto. pp xxi+ 1569.

13. Northcutt JK, Jones DR. 2004. A survey of water use and common industry practices in commercial broiler processing facilities. J Appl Poult Res 13(1):48-54.

14. Northcutt JK, Lacy MP. 2000. Odor problems associated with chlorine usage in poultry processing plants. Poult Sci 78:47.

15. European Union. 2017. Commission Implementing Regulation (2017/1273). Available from: https://www.legislation.gov.uk/eur/2017/1273. Accessed at 28 08.2024

16. Kitis M. 2004. Disinfection of wastewater with peracetic acid: a review. Environ Int 30(1):47-55.

17. Baldry MGC. 1988. Disinfection with peroxygens. Industrial biocides; Critical reports on applied chemistry 23:91-116.

18. Monarca S, Feretti D, Zerbini I, Zani C, Alberti A, Richardson SD, et al. 2002. Studies on mutagenicity and disinfection by-products in river drinking water disinfected with peracetic acid or sodium hypochlorite. Water Sci Technol Water Supply 2(3):199-204.

19. Monarca S, Richardso SD, Feretti D, Grottolo M, Thruston Jr AD, Zani C, et al. 2002. Mutagenicity and disinfection by-products in surface drinking water disinfected with peracetic acid. Environ Toxicol Chem: An International Journal 21(2):309-318.

20. U.S. Environmental Protection Agency. 2012. Alternative Disinfection Methods Fact Sheet: Peracetic Acid. (832-F-12-030). Available from: https://www.epa.gov/sustainable-water-infrastructure/peracetic-acid-alternative-disinfection-methods-fact-sheet. Accessed at 26 08.2024

21. Dychdala GR. 1988. New hydrogen peroxide-peroxyacetic acid disinfectant. Proceedings of the 4th Conference on Progresses in Chemical Disinfection, Binghamton, New York, USA, pp 315-342.

22. Block SS. (Ed.). 2001. Disinfection, sterilization, and preservation. 5th ed. Lippincott Williams & Wilkins, Philadelphia, PA.

23. Luukkonen T, Pehkonen SO. 2017. Peracids in water treatment: A critical review. Crit Rev Environ Sci Technol 47(1):1-39.

24. Baldry MGC. (1983). The bactericidal, fungicidal and sporicidal properties of hydrogen peroxide and peracetic acid. J Appl Bacteriol 54(3):417-423.

25. Lefevre F, Audic JM, Ferrand F. 1992. Peracetic acid disinfection of secondary effluents discharged off coastal seawater. Water Sci Technol 25(12):155-164.

26. Gehr R, Cochrane D. 2002. Peracetic acid (PAA) as a disinfectant for municipal wastewaters: encouraging performance results from physicochemical as well as biological effluents. Water Environment Federation. pp 182-198.

27. Wagner M, Brumelis D, Gehr R. 2002. Disinfection of wastewater by hydrogen peroxide or peracetic acid: development of procedures for measurement of residual disinfectant and application to a physicochemically treated municipal effluent. Water Environ Res 74(1):33-50.

28. Yuan Z, Ni Y, Van Heiningen ARP. 1997. Kinetics of peracetic acid decomposition: part I: spontaneous decomposition at typical pulp bleaching conditions. Can J Chem Eng 75(1):37-41.

29. Liberti L, Notarnicola M. 1999. Advanced treatment and disinfection for municipal wastewater reuse in agriculture. Water Sci technol 40(4-5):235-245.

30. Leaper S. 1984. Synergistic killing of spores of Bacillus subtilis by peracetic acid and alcohol. Int J Food Sci Tech 19(3):355-360.

31. Deng J, Wang H, Fu Y, Liu Y. 2022. Phosphate-induced activation of peracetic acid for diclofenac degradation: Kinetics, influence factors and mechanism. Chemosphere 287:132396.

32. Jian L. 2019. Degradation of Antibiotics in Water by Advanced Oxidation Technologies Based on the Application of Peroxide. Master's Thesis, Suzhou University of Science and Technology, Suzhou, China.

33. Rudd T, Hopkinson LM. 1989. Comparison of disinfection techniques for sewage and sewage effluents. J Inst Water Environ Manag 3:612-8.

34. Rutala WA, Weber DJ. 1997. Uses of inorganic hypochlorite (bleach) in health-care facilities. Clin Microbiol Rev 10(4):597-610.

35. Hidalgo E, Bartolome R, Dominguez C. 2002. Cytotoxicity mechanisms of sodium hypochlorite in cultured human dermal fibroblasts and its bactericidal effectiveness. Chem Biol Interact 139(3):265-282.

36. Fukuzaki S. 2006. Mechanisms of actions of sodium hypochlorite in cleaning and disinfection processes. Biocontrol Sci 11(4):147-157.

37. Ogata N, Sakasegawa M, Miura T, Shibata T, Takigawa Y, Taura K, et al. 2016. Inactivation of airborne bacteria and viruses using extremely low concentrations of chlorine dioxide gas. Pharmacology 97(5-6):301-306.

38. Girard M, Mattison K, Fliss I, Jean J. 2016. Efficacy of oxidizing disinfectants at inactivating murine norovirus on ready-to-eat foods. Int J Food Microbiol 219:7-11.

39. Ma JW, Huang BS, Hsu CW, Peng CW, Cheng ML, Kao JY, et al. 2017. Efficacy and safety evaluation of a chlorine dioxide solution. Int J Hyg Environ Health 14(3):329.

40. Rutala WA, Weber DJ. 1997. Uses of inorganic hypochlorite (bleach) in health-care facilities. Clin Microbiol Rev 10(4):597-610.

41. Pavón JLP, Martín SH, Pinto CG, Cordero BM. 2008. Determination of trihalomethanes in water samples: a review. Anal Chim Acta 629(1-2):6-23.

42. Cantor KP, Hoover R, Mason TJ, McCabe LJ. 1978. Associations of cancer mortality with halomethanes in drinking water. J Natl Cancer Inst 61(4):979-985.

43. Morris RD, Audet AM, Angelillo IF, Chalmers TC, Mosteller F. 1992. Chlorination, chlorination by-products, and cancer: a meta-analysis. Am J Public Health 82(7):955-963.

44. Bull RJ, Birnbaum L, Cantor KP, Rose JB, Butterworth BE, Pegram REX, Tuomisto J. 1995. Water chlorination: essential process or cancer hazard? Toxicol Sci 28(2):155-166.

45. King WD, Marrett LD. 1996. Case-control study of bladder cancer and chlorination by-products in treated water (Ontario, Canada). Cancer Causes Control 7:596-604.

46. Ruddy M, Kibbler CC. 2002. Endoscopic decontamination: an audit and practical review. J Hosp Infect 50(4):261-268.

47. Kingsley DH, Vincent EM, Meade GK, Watson CL, Fan X. 2014. Inactivation of human norovirus using chemical sanitizers. Int J Food Microbiol 171:94-99.

48. Luukkonen T, Pehkonen SO. 2017. Peracids in water treatment: A critical review. Crit Rev Environ Sci Technol 47(1):1-39.

49. Alonso-Hernando A, Capita R, Prieto M, Alonso-Calleja C. 2009. Adaptation and cross-adaptation of *Listeria monocytogenes* and *Salmonella enterica* to poultry decontaminants. J Microbiol 47(2):142-146.

50. Mulder, R. W. A. W., M. C. van der Hulst, and N. M. Bolder. 1987. Salmonella decontamination of broiler carcasses with lactic acid, L. cysteine, and hydrogen peroxide. Poult. Sci. 66:1555–1557.

51. Blankenship, L. C., B. G. Lyon, and C. E. Lyon. 1990. Efficacy of acid treatment plus freezing to destroy Salmonella contaminants of spice-coated chicken fajita meat. Poult. Sci. Symp. 69:20. (Abstr.)

52. Dickens, J. A., B. G. Lyon, A. D. Whittemore, and C. E. Lyon. 1994. The effect of an acetic acid dip on carcass appearance, microbiological quality, and cooked breast meat texture and flavor. Poult. Sci. 73:576–581.

53. Manjankattil, S., D. V. T. Nair, C. Peichel, S. Noll, T. J. Johnson, R. B. Cox, A. M.

Donoghue, and A. K. Johny. 2021. Effect of caprylic acid alone or in combination with peracetic acid against multidrug-resistant Salmonella Heidelberg on chicken drumsticks in a soft scalding temperature-time setup. Poult. Sci. 100:101421.

54. Bauermeister, L. J., Bowers, J. W. J., Townsend, J. C., & McKee, S. R. (2008). The microbial and quality properties of poultry carcasses treated with peracetic acid as an antimicrobial treatment. Poultry Science, 87(11), 2390-2398.

Table 1. By-products after disinfection

Volatiles	Surface water limit[1)]	Peraceticacid	Chlorination / Dechlorination
Bromodichloromethane (μg/L)	22	<0.6	56.82
Bromoform(μg/L)	360	<0.6	19.62
Chloroform (μg/L)	470.8	<0.64	21.55
Dibromochloromethane (μg/L)	34	<0.75	72.71
Total Trihalomethane (μg/L)	-	<0.6	170.71

1) Florida Department of Environmental Protection surface water limit for Class III marine waters

Table 2. Peracetic acid product information

Classification	Peracetic acid **(Oxyacid, Daesung C&S)**
Appearance	A colorless, transparent liquid
Scent	Strong acetic acid scent
Foamy	None
pH (Undiluted)	About 1
pH (2%)	3.3
Specific gravity	1.13
Hydrogen peroxide (Hydrogen peroxide dioxide)	<6%
Peracetic acid(Peroxy acetic acid)	10-25%
Acetic acid(Clacial acetic acid)	25-50%
COD (conc.), mgO_2/L	110,000
COD (4%), mgO_2/L	4,400

Table 3. Preparation of the peracetic acid mixtures

Classification	Peracetic acid A	Peracetic acid B
POAA[1)]+POOA[2)]	16%	17.30%
H_2O_2	5.50%	5.00%
Acetic acid	47.50%	49.00%
Octanoic acid	1.0-4.0%	1.0-4.0%

1) POAA: peracetic acid

2) POOA: peroxyoctanoic acid.

Table 4. Preparation of the peracetic acid disinfectants

1) The tap water was 10 to 15 degrees of water at pH 6 to 7

Concentration	Tab water[1)]	Peracetic acid (Daesung, A, and B)
50ppm	60L	19.8g
100ppm	60L	39.6g
150ppm	60L	59.4g
200ppm	60L	79.2g

Table 5. Preparation of the sodium hypochlorite disinfectant

Concentration	Tab water[1)]	12% sodium hypochlorite
50ppm	60L	45g
100ppm	60L	90g
150ppm	60L	165g
200ppm	60L	180g

1) The tap water was 10 to 15 degrees of water at pH 6 to 7

Table 6. Antibacterial efficacy of peracetic acid (Daesung) on carcasses and contaminated water[1)]

Classification			50ppm	100ppm	150ppm	200ppm	SEM	p-value
Before treatment	Carcasses	General bacteria	5350	5350	5350	5350	13.4	0.98
		E. coli	925.8	925.8	925.8	925.8	18.74	0.97
	Contaminated water	General bacteria	3.6×10^{8}	3.6×10^{8}	3.6×10^{8}	3.6×10^{8}	1.4×10^{7}	0.97
		E. coli	3.8×10^{7}	3.6×10^{7}	3.6×10^{7}	3.6×10^{7}	1.7×10^{6}	0.98
After treatment	Carcasses	General bacteria	1731.5^{b}	2127.5^{b}	980.5^{b}	388.5^{b}	415.06	0.06
		E. coli	335.0^{b}	308.5^{b}	266.0^{b}	98.6^{b}	60.28	0.08
	Contaminated water	General bacteria	$1.9\times10^{8\ b}$	$1.7\times10^{8\ b}$	$1.5\times10^{8\ ab}$	$1.3\times10^{8\ a}$	1.71×10^{8}	<0.05
		E. coli	$9.7\times10^{6\ a}$	$8.7\times10^{6\ ab}$	$6.8\times10^{6\ a}$	$6.3\times10^{6\ c}$	1.8×10^{5}	<0.05
Redution rate (%)[2)]	Carcasses	General bacteria	67.6^{b}	60.2^{b}	81.7^{b}	92.7^{a}	17.46	<0.05
		E. coli	63.8^{c}	66.7^{c}	71.3^{b}	89.3^{a}	11.46	<0.05
	Contaminated water	General bacteria	46.5^{b}	52.4^{b}	58.5^{ab}	63.5^{a}	7.37	<0.05
		E. coli	74.5^{b}	75.7^{ab}	81.1^{a}	82.4^{a}	3.92	<0.05

1) Each values are mean ±SD of at least three repeated experiments.

2) Redution rate(%) : (Initial bacterial count – Count of bacteria after 10 minutes)/Initial bacterial count*100

Table 7. Antibacterial efficacy of peracetic acid A on carcasses and contaminated water[1)]

Classification			50ppm	100ppm	150ppm	200ppm	SEM	p-value
Before treatment	Carcasses	General bacteria	18816	18816	18816	18816	19.7	0.99
		E. coli	6941.7	6941.7	6941.7	6941.7	41.45	0.96
	Contaminated water	General bacteria	3.6×10^{8}	3.6×10^{8}	3.6×10^{8}	3.6×10^{8}	1.4×10^{7}	0.97
		E. coli	3.8×10^{7}	3.6×10^{7}	3.6×10^{7}	3.6×10^{7}	1.7×10^{6}	0.98
After treatment	Carcasses	General bacteria	2113.0^{b}	1110.5^{c}	884.0^{b}	292.0^{b}	288.26	<0.05
		E. coli	585.5^{ab}	139.0^{b}	122.0^{b}	44.2^{b}	56.98	<0.05
	Contaminated water	General bacteria	$1.5\times108^{\ b}$	$1.3\times10^{8\ b}$	$9.8\times10^{7\ b}$	$9.8\times10^{7\ a}$	1.6×10^{7}	<0.05
		E. coli	$7.9\times10^{6\ a}$	$4.3\times10^{6\ b}$	$5.8\times10^{6\ a}$	$2.7\times10^{6\ b}$	3.4×10^{6}	<0.05
Redution rate (%)[2)]	Carcasses	General bacteria	88.8^{c}	94.1^{b}	95.3^{b}	98.4^{a}	1.46	<0.05
		E. coli	91.6^{bc}	98.0^{b}	98.2^{b}	99.4^{b}	3.53	<0.05
	Contaminated water	General bacteria	58.6^{b}	64.3^{b}	72.8^{a}	72.8^{a}	6.92	<0.05
		E. coli	79.1^{c}	88.0^{b}	84.0^{b}	92.4^{a}	5.66	<0.05

1) Each values are mean ±SD of at least three repeated experiments.

2) Redution rate(%) : (Initial bacterial count – Count of bacteria after 10 minutes)/Initial bacterial count*100

Table 8. Antibacterial efficacy of peracetic acid B on carcasses and contaminated water[1)]

Classification			50ppm	100ppm	150ppm	200ppm	SEM	p-value
Before treatment	Carcasses	General bacteria	4525.0	4525.0	4525.0	4525.0	9.71	0.99
		E. coli	665.0	665.0	665.0	665.0	17.21	0.97
	Contaminated water	General bacteria	3.6×10^{8}	3.6×10^{8}	3.6×10^{8}	3.6×10^{8}	1.4×10^{7}	0.97
		E. coli	3.8×10^{7}	3.6×10^{7}	3.6×10^{7}	3.6×10^{7}	1.7×10^{6}	0.98
After treatment	Carcasses	General bacteria	1051.5[b]	996.5[c]	774.0[b]	341.0[b]	195.14	<0.05
		E. coli	247.5[b]	224.0[b]	100.0[b]	51.7[b]	44.04	<0.05
	Contaminated water	General bacteria	1.8×10^{8} [b]	1.7×10^{8} [b]	1.3×10^{8} [b]	1.2×10^{8} [a]	2.4×10^{7}	0.07
		E. coli	1.5×10^{7} [a]	1.1×10^{7} [b]	9.5×10^{6} [a]	6.1×10^{6} [b]	3.6×10^{6}	<0.05
Redution rate (%)[2)]	Carcasses	General bacteria	76.8[bc]	78.6[b]	82.9[b]	92.5[a]	7.00	<0.05
		E. coli	62.8[b]	66.3[b]	85.0[ab]	92.2[a]	14.27	<0.05
	Contaminated water	General bacteria	51.2[b]	52.9[b]	62.9[b]	66.0[b]	7.31	0.06
		E. coli	61.4[b]	69.2[ab]	73.4[ab]	82.9[a]	8.97	<0.05

1) Each values are mean ±SD of at least three repeated experiments.

2) Redution rate(%) : (Initial bacterial count – Count of bacteria after 10 minutes)/Initial bacterial count*100

Table 9. Antibacterial efficacy of sodium hypochlorite on carcasses and contaminated water[1)]

Classification			50ppm	100ppm	150ppm	200ppm	SEM	p-value
Before treatment	Carcasses	General bacteria	8791.7	8791.7	8791.7	8791.7	23.61	0.99
		E. coli	1877.5	1877.5	1877.5	1877.5	32.17	0.97
	Contaminated water	General bacteria	3.6×10^{8}	3.6×10^{8}	3.6×10^{8}	3.6×10^{8}	1.4×10^{7}	0.97
		E. coli	3.8×10^{7}	3.6×10^{7}	3.6×10^{7}	3.6×10^{7}	1.7×10^{6}	0.98
After treatment	Carcasses	General bacteria	4633.0^{a}	3638.5^{a}	3343.0^{a}	1909.0^{a}	749.07	0.08
		E. coli	1246.5^{a}	1100.0^{a}	1000.0^{a}	640.5^{a}	581.91	0.06
	Contaminated water	General bacteria	$2.5\times10^{8\ a}$	$2.3\times10^{8\ a}$	$1.9\times10^{8\ a}$	$1.6\times10^{8\ a}$	3.7×10^{7}	0.06
		E. coli	$1.6\times10^{7\ a}$	$1.5\times10^{7\ a}$	$1.3\times10^{7\ a}$	$1.3\times10^{7\ a}$	3.7×10^{6}	0.07
Redution rate (%)[2)]	Carcasses	General bacteria	47.3^{b}	58.6^{b}	62.0^{ab}	78.3^{a}	12.80	<0.05
		E. coli	33.6^{b}	41.4^{b}	46.7^{b}	65.9^{a}	13.75	<0.05
	Contaminated water	General bacteria	29.4^{b}	35.0^{b}	48.3^{a}	56.3^{a}	12.26	<0.05
		E. coli	57.2^{a}	59.2^{a}	63.3^{a}	63.0^{a}	2.99	0.09

1) Each values are mean ±SD of at least three repeated experiments.

2) Redution rate(%) : (Initial bacterial count – Count of bacteria after 10 minutes)/Initial bacterial count*100

Table 10. Comparison of antibacterial efficacy at the optimal concentration[1)]

Classification			Peracetic acid (Daesung)	Peracetic acid A	Peracetic acid B	Sodium hypochlorite	SEM	p-value
Before treatment	Carcasses	General bacteria	5350.0	18816.0	4525.0	8791.7	611.17	0.14
		E. coli	925.8	6941.7	665.0	1877.5	589.74	0.12
	Contaminated water	General bacteria	3.6×10^{8}	3.6×10^{8}	3.6×10^{8}	3.6×10^{8}	1.4×10^{7}	0.97
		E. coli	3.6×10^{7}	3.6×10^{7}	3.6×10^{7}	3.6×10^{7}	1.7×10^{6}	0.98
After treatment	Carcasses	General bacteria	388.5^{b}	292.0^{b}	341.0^{b}	1909.0^{a}	328.89	<0.05
		E. coli	98.6^{b}	44.2^{b}	51.7^{b}	640.5^{a}	129.68	<0.05
	Contaminated water	General bacteria	$1.3\times10^{8\ a}$	$9.8\times10^{7\ a}$	$1.2\times10^{8\ a}$	$1.6\times10^{8\ a}$	1.5×10^{7}	0.05
		E. coli	$6.3\times10^{6\ c}$	$2.7\times10^{6\ b}$	$6.1\times10^{6\ b}$	$1.3\times10^{7\ a}$	7.8×10^{5}	<0.05
Reduction rate (%)[2)]	Carcasses	General bacteria	92.7^{ab}	98.4^{a}	92.5^{ab}	78.3^{b}	8.90	<0.05
		E. coli	89.3^{b}	99.4^{a}	92.2^{ab}	65.9^{c}	14.51	<0.05
	Contaminated water	General bacteria	63.5^{b}	72.8^{a}	66.0^{b}	56.3^{b}	6.81	<0.05
		E. coli	82.4^{b}	92.4^{a}	82.9^{b}	63.0^{c}	12.35	<0.05

1) Each values are mean ±SD of at least three repeated experiments.

2) Redution rate(%) : (Initial bacterial count – Count of bacteria after 10 minutes)/Initial bacterial count*100

Table 11. *Salmonella* test results

1) N = Negative

Classification			Completion	50ppm	100ppm	150ppm	200ppm
Peracetic acid (Daesung)	Carcasses	General bacteria	N[1)]	N	N	N	N
		E. coli	N	N	N	N	N
	Contaminated water	General bacteria	N	N	N	N	N
		E. coli	N	N	N	N	N
Peracetic acid A	Carcasses	General bacteria	N	N	N	N	N
		E. coli	N	N	N	N	N
	Contaminated water	General bacteria	N	N	N	N	N
		E. coli	N	N	N	N	N
Peracetic acid B	Carcasses	General bacteria	N	N	N	N	N
		E. coli	N	N	N	N	N
	Contaminated water	General bacteria	N	N	N	N	N
		E. coli	N	N	N	N	N
Sodium hypochlorite	Carcasses	General bacteria	N	N	N	N	N
		E. coli	N	N	N	N	N
	Contaminated water	General bacteria	N	N	N	N	N
		E. coli	N	N	N	N	N

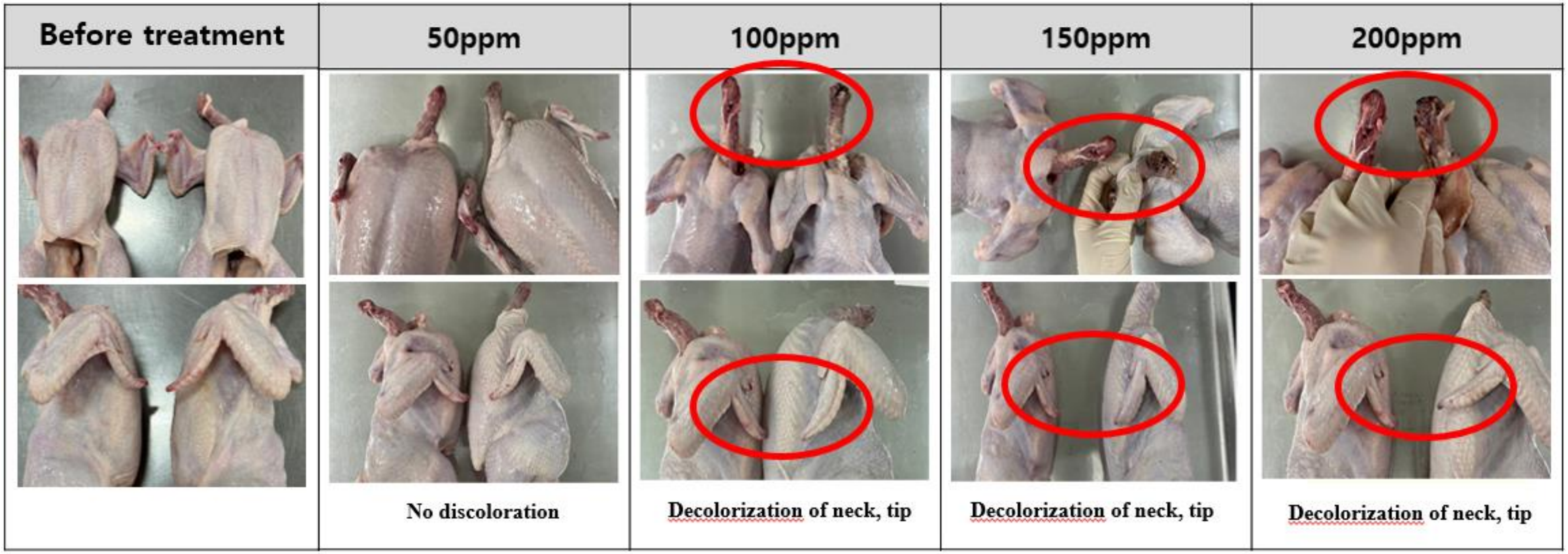
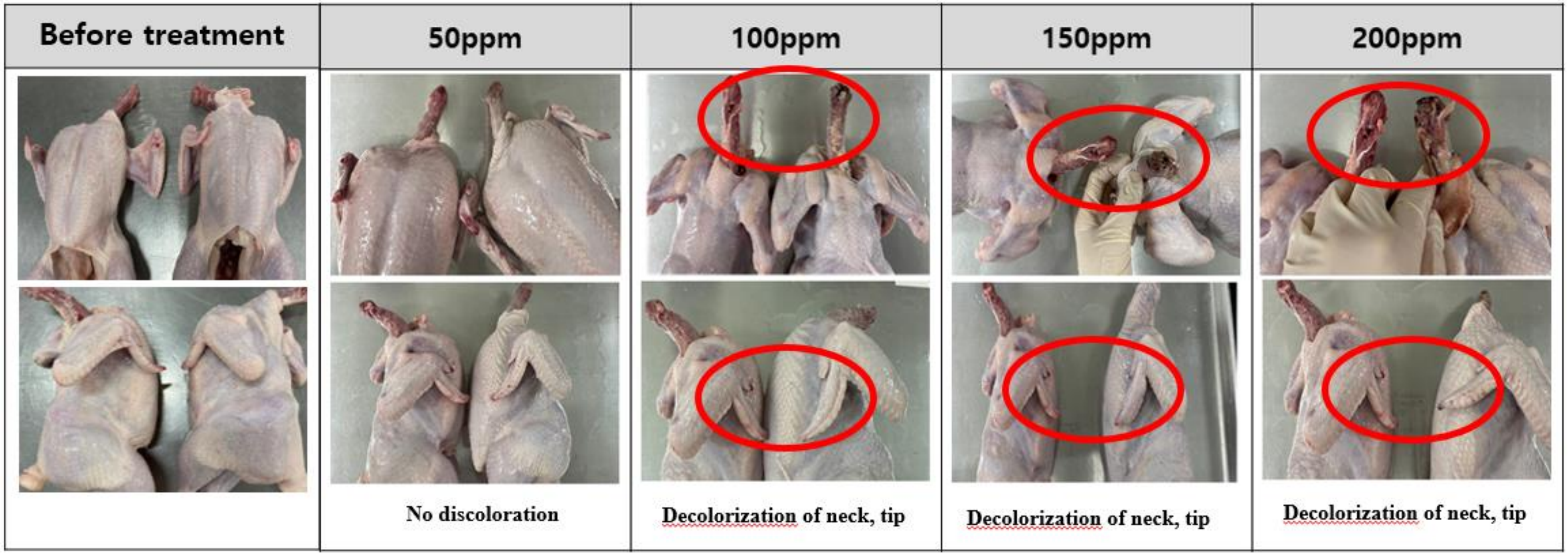


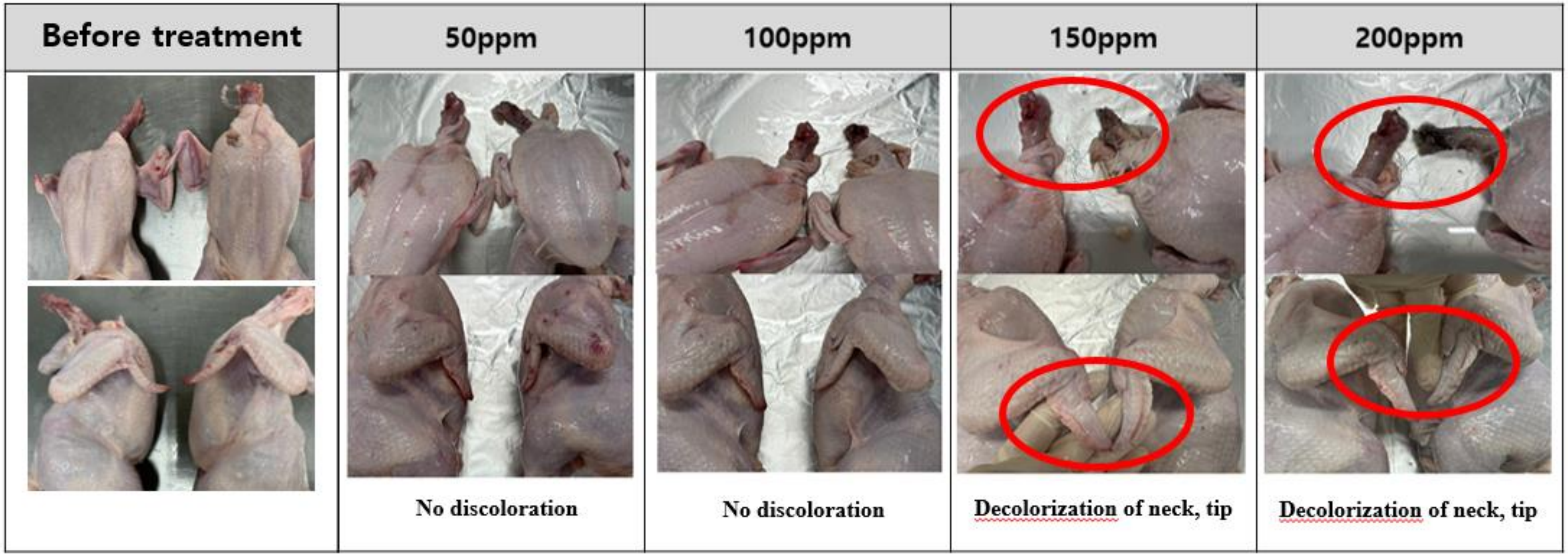
Figure 1. Discoloration of chicken meat by peracetic acid (Daesung) at each concentration

* The changes in the appearance of chicken after leaving in conductors in disinfectant for 1 hour
* Discoloration was observed on the neck and tips at 100 ppm



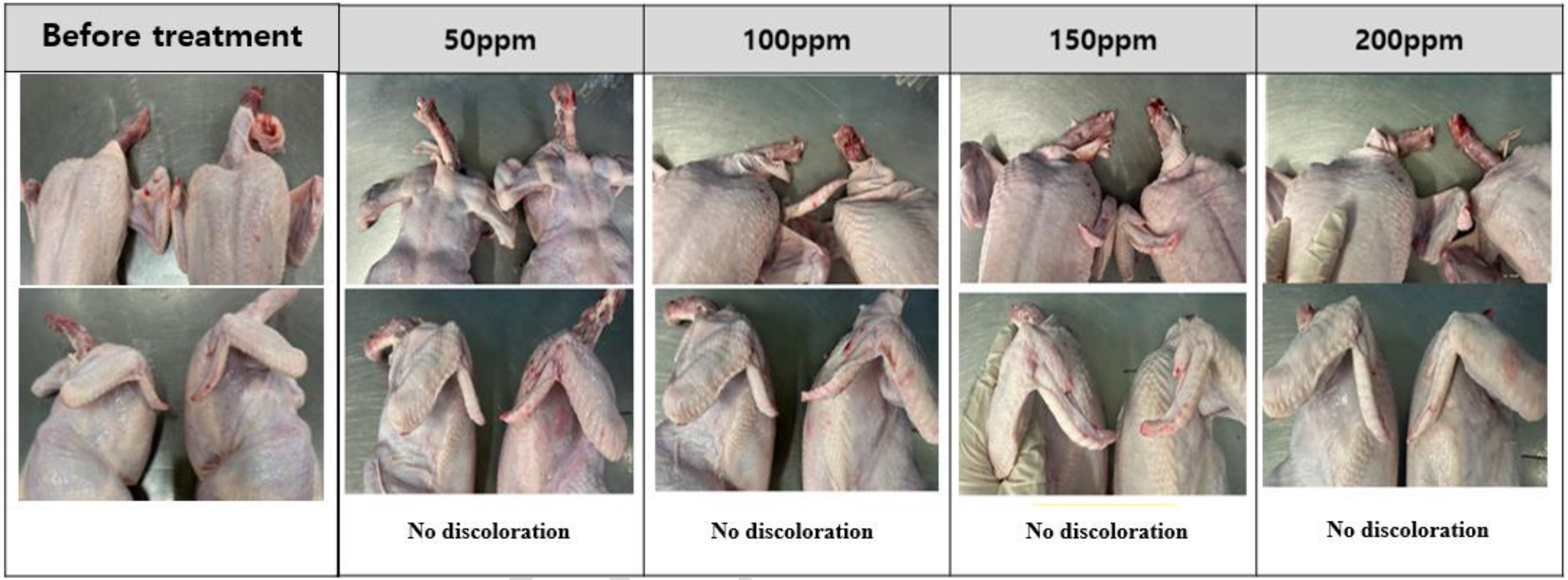
* The changes in the appearance of chicken after leaving in conductors in disinfectant for 1 hour
* Discoloration was observed on the neck and tips at 100 ppm

Figure 2. Discoloration of chicken meat by peracetic acid A at each concentration



* The changes in the appearance of chicken after leaving in conductors in disinfectant for 1 hour
* Discoloration was observed on the neck and tips at 150 ppm

Figure 3. Discoloration of chicken meat by peracetic acid B at each concentration



* The changes in the appearance of chicken after leaving in conductors in disinfectant for 1 hour
* no discoloration was observed at any concentration.

Figure 4. Discoloration of chicken meat by sodium hypochlorite at each concentration

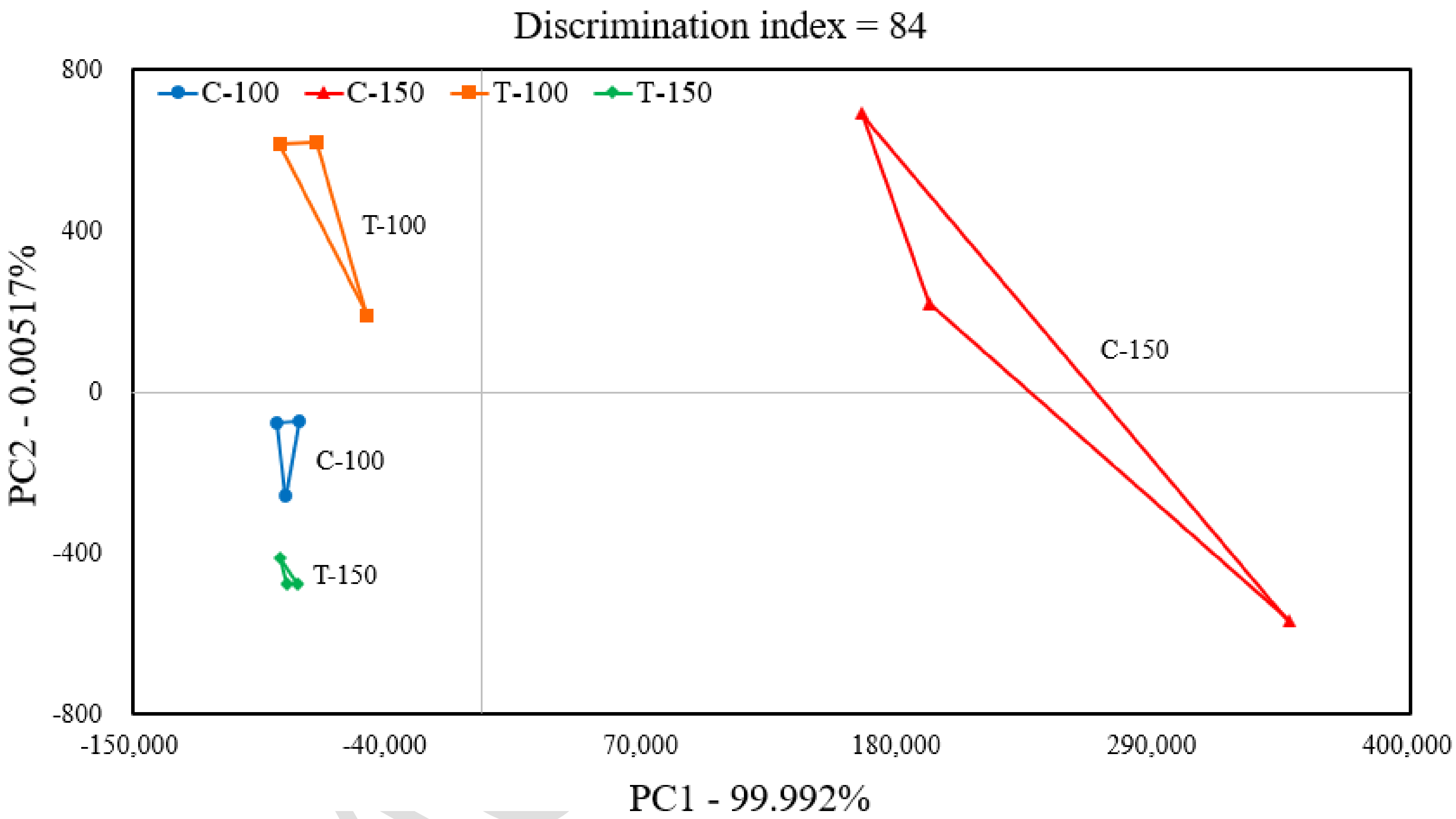


Figure 5. Principal component analysis (PCA) results of chicken skin treated with sodium hypochlorite and peracetic acid A by concentration. *C-100: peracetic acid A, 100 ppm; C-150: peracetic acid A, 150 ppm; T-100: sodium hypochlorite, 100 ppm; T-150: sodium hypochlorite, 150 pp