THE USE OF PLASMA-TREATED WATER AS A SOURCE OF NITRITE FOR CURING HAM

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Abstract – The objective of this study was to produce the cured ham by replacing nitrite or nitrate with plasma-treated water (PTW). To produce the PTW, distilled water was treated by plasma and injected to the pork loin. The hams cured with PTW (HCP) showed lower total aerobic bacteria (log CFU/g) and residual nitrite concentration, but higher a^*-value compared to hams cured with sodium nitrite solution (HCN). There were no significant differences in sensory evaluation between HCP and HCN.

Key Words – Cured ham, Plasma, Nitrite

I. INTRODUCTION

Nitrites in meat products reduced to nitric oxide then interact with myoglobin to produce nitric oxide myoglobin responsible for characteristic pink color of cured meat [1]. Nitrite can also improve the flavour and inhibit the growth of food spoilage bacteria, especiallly, *Clostridium botulinum* [2]. Sodium and potassium nitrite have been used for years in the preparation of cured meats for many purposes [3]. However, consumer demands the natural curing agent added meat products theese days. Meat industries continues to find an alternative of sodium or potassium nitrite. However, up to date, no replacement for synthetic nitrite has been discovered that effectively maintain the color characteristics of nitrite cured meat products [4].

Plasma, electrically energized matter in the gaseous state, can be generated by electrical discharge of gas and contain abundant chemically active free radicals, such as excited atoms and molecules, charged particles, reactive oxygen and nitrogen species, and UV photons [5]. Thus, atmospheric pressure plasma (APP) has been investigated as a non-thermal pasteurization technique in food processing.

Oehmigen et al. [6] proposed that biological as well as chemical effects of plasma in liquids are a result of complex interactions resulting in generation of reactive oxygen and nitrogen species including nitrate (NO_3^-) and nitrite (NO_2^-) in liquid. Therefore, the purpose of this study was to compare the quality of ham cured by plasma treated water and traditional sodium nitrite in order to assess the possibility of plasma treated water as a nitrite replacer in meat industry.

II. MATERIALS AND METHODS

Preparation of plasma-treated water (PTW)

Fig. 1(a) illustrated a plasma device for providing air discharge consists of a pair of powered electrode and ground electrode, and an alumina plate between two electrodes. Figure 1(b) shows real images of ground electrode involving patterns (3 x 3 mm). A bipolar square waveform with 15 kHz was applied to powered electrode and the average power is 3.14 W with 200 W of peak power. To produce air discharge irradiated solution, 500 mL distilled water containing 1% sodium pyrophosphate (w/v) was irradiated by a surface dielectric barrier discharge for 4 hr.

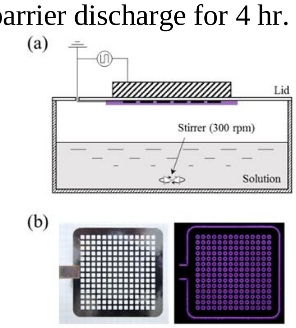

Fig. 1. Schematic drawing of plasma apparatus (a), real images of ground electrode (b).

Manufacture of Cured ham

Cured ham was manufactured using pork loin obtained from a commercial butcher (Seoul, Korea). Two brine solutions were formulated (HCP, ham cured with PTW; HCN, ham cured with sodium nitrite solution to compare with HCP) and those were injected at a 40% addition to the meat product weight. The concentration of nitrite ion in both solutions was maintained at 70 mg/kg. Then, the ham was tumbled for 48 h at 4°C and smoked until internal temperature of the sausage reached 78°C. After cooling in freezer, the cooked hams were vacuum-packaged. The properties of cured hams were analyzed during 2 weeks storage at refrigerator temperature (4°C).

Total aerobic bacterial counts

Cured hams sample (5 g) was blended with sterile saline (45 mL) for 2 min and then serially diluted in sterile saline. Each diluent (100 μL) was spread on the tryptic soy agar (Difco Laboratories, Detroit, MI, USA) and the agar plates were incubated at 37 °C for 48 h. The microbial counts were expressed as log CFU/g.

Color measurements

Surface color measurement of cured ham was performed using a spectrophotometer CM 3500d (Konica Minolta Censing Inc., Japan) and L* (lightness), a* (redness), and b* (yellowness) were determined.

Residual nitrite content

Residual nitrite in cured ham was measured according to AOAC method 973.31 (AOAC, 1990).

Sensory evaluation

Cured hams were cut into a similar size pieces and served to the sensory panel. The semi-trained sensory panels consist of ten panelists, who had at least 2 years of experience in meat sensory analysis. The scoring of each sample was done on a single sheet using a 9-point hedonic scale (1 = extremely dislike, 9 = extremely like). The sensory parameters scored were appearance, color, flavor, taste, juiciness, chewiness, off-odor, and acceptability.

Statistical analyses

Statistical analysis was performed by One-way Analysis of Variance (ANOVA). When significant differences were detected, the differences among the mean values were determined by the Duncan's multiple comparison test at a confidence level of p<0.05.

III. RESULTS AND DISCUSSION

Total aerobic bacterial counts

The number of total aerobic bacteria in cured ham is shown in Table 1. HCP had lower number of total aerobic bacteria than HCN (p<0.05) on 0 week of storage. Oehmigen et al. [6] proposed that treatment of distilled water by surface-DBD in atmospheric air resulted in bactericidal effect on the liquid itself.

Surface color

The L^*, a^*, and b^*-value reflects the change in the lightness, redness, and yellowness of the spectrum. During the storage weeks, L^*-values were increased in HCP (p<0.05). The a^*-values of HCP were significantly lower than those of HCN and there were no differences in b^*-values (Table. 2). Distinct red or pink color is one of the characteristic of meat product cured by nitrite [1]. Vegetable juice powder and a starter culture containing *Staphylococcus carnosus* have been identified the red color similar to traditional cured products [7].

Residual nitrite

Residual nitrite concentrations appeared to be decreased throughout the storage time for all treatments (Table 3). Also, the residual nitrite concentration was greater in the HCN during the storage compared to HCP (P<0.05). Residual nitrite is important for maintaining the quality of cured meat products during storage [8]. However, many consumers are interested in less residual nitrite level due to the potential relationship of nitrite with nitrosamines and cancer [9].

Sensory evaluation

The scores of appearance, color, flavor, taste, juiciness, chewiness, off-odor, and acceptability for HCP and HCN have no significant differences (Table 4). Sindelar et al. [7] proposed that ham cured by vegetable concentrate increase the undesirable sensory properties with increase their concentration. Therefore, this method using PTW for curing may have advantage in the sensory quality.

Table 1. The number (log CFU/g) of total aerobic bacteria in cured hams

Treatment	Storage weeks			SEM[1)]
	0	1	2	
HCP	3.88[cy]	6.14[b]	6.52[a]	0.047
HCN	4.21[cx]	6.25[b]	6.68[a]	0.055
SEM[2)]	0.053	0.039	0.058	

[1)]Standard error of the means (n=9), [2)](n=6)
[a-c]Values with different letters within the same row differ significantly (*P*<0.05).
[x,y]Different letters within same column differ significantly (*P*<0.05).

Table 2. Surface color of cured hams

Treatment	Storage weeks			SEM[1)]
	0	1	2	
L^*-value				
HCP	71.51[ab]	70.55[b]	73.23[ax]	0.549
HCN	71.03	71.00	71.08[y]	0.354
SEM[2)]	0.466	0.406	0.507	
a^*-value				
HCP	7.28[x]	7.40[x]	7.10[x]	0.159
HCN	6.65[y]	6.50[y]	6.35[y]	0.147
SEM[2)]	0.080	0.187	0.171	
b^*-value				
HCP	9.50	9.64	9.39	0.182
HCN	9.64	9.57	9.57	0.092
SEM[2)]	0.214	0.110	0.065	

[1)]Standard error of the means (n=9), [2)](n=6)
[a-c]Values with different letters within the same row differ significantly (*P*<0.05).
[x,y] Different letters within same column differ significantly (*P*<0.05).

IV. CONCLUSION

Ham cured by PTW shows more red (pink) color, lower number of total aerobic bacteria, and lower concentration of residual nitrite content compared to ham cured by nitrite (70 mg/kg) without affecting the sensory characteristics. We concluded that PTW can be used as possible replacer for synthetic nitrites.

Table 3. Residual nitrite of cured hams

Treatment	Storage weeks			SEM[1)]
	0	1	2	
HCP	24.68[ax]	23.30[ax]	20.38[bx]	0.503
HCN	14.96[ay]	13.93[aby]	10.36[by]	0.866
SEM[2)]	0.834	0.409	0.801	

[1)]Standard error of the means (n=9), [2)](n=6)
[a,b]Values with different letters within the same row differ significantly (*P*<0.05).
[x,y]Different letters within same column differ significantly (*P*<0.05).

Table 4. Sensory evaluation of cured hams

Sensory parameter	HCP	HCN	SEM[1)]
Appearance	5.97	5.37	0.377
Color	5.77	5.37	0.340
Flavor	5.73	5.30	0.214
Taste	5.63	5.47	0.227
juiciness	5.27	5.33	0.355
Chewiness	5.33	5.27	0.312
Off-odor	2.37	2.80	0.381
Acceptability	6.10	5.67	0.290

[1)]Standard error of the means (n=20)

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REFERENCES:

1. Honikel, K. O. (2008). The use and control of nitrate and nitrite for the processing of meat products. Meat science 78: 68-76.
2. Ahn, H. J., Kim, J. H., Jo, C., Lee, C. H., & Byun, M. W. (2002). Reduction of Carcinogenic N-Nitrosamines and Residual Nitrite in Model

System Sausage by Irradiation. Journal of food science 67: 1370-1373.
3. Cammack, R., Joannou, C. L., Cui, Y., Martinez, C.-T., Maraj, S. R., & Hughes, M. N. (1999). Nitrite and nitrozyl compounds in food preservation. Biochimica et Biophysica Acta 1411: 475-488.
4. Zhang, X., Kong, B., & Xiong, Y. L. (2007). Production of cured meat color in nitrite-free Harbin red sausage by *Lactobacillus* fermentum fermentation. Meat Science 77: 593-598.
5. Kim, H. J., Yong, H. I., Park, S., Choe, W., & Jo, C. (2013). Effects of dielectric barrier discharge plasma on pathogen inactivation and the physicochemical and sensory characteristics of pork loin. Current Applied Physics 13: 1420-1425.
6. Oehmigen, K., Winter, J., Hähnel, M., Wilke, C., Brandenburg, R., Weltmann, K. D., & von Woedtke, T. (2011). Estimation of possible mechanisms of *Escherichia coli* inactivation by plasma treated sodium chloride solution. Plasma Processes and Polymers 8: 904-913.
7. Sindelar, J. J., Cordray, J. C., Sebranek, J. G., Love, J. A., & Ahn, D. U. (2007). Effects of varying levels of vegetable juice powder and incubation time on color, residual nitrate and nitrite, pigment, pH, and trained sensory attributes of ready-to-eat uncured ham. Journal of Food Science 72: 388-395.
8. Fernandez-Lopez, J., Sendra, E., Sayas-Barbera, E., Navarro, C., & Perez-Alvarez, J. A. (2008). Physico-chemical and microbiological profiles of "salchichon" (Spanish dry-fermented sausage) enriched with orange fiber. Meat Science 80: 410-417.
9. Pourazrang, H., Moazzami, A. A., & Fazly Bazzaz, B. S. (2002). Inhibition of mutagenic N-nitroso compound formation in sausage samples using L-ascorbic acid and atocopherol. Meat Science 62: 479-483.