LIPID OXIDATION OF DRY-CURED BACONS AS AFFECTED BY THE PARTIAL SUBSTITUTION OF NACL WITH KCL

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Abstract –This study investigated the influence of partial substitution of NaCl with KCl on lipid oxidation and antioxidant enzyme activities in dry-cured bacons during processing. The partial substitution was 0% KCl (I), 40% KCl (II), and 70% KCl (III). Compared with 0% KCl (I), the substitution of 40% NaCl with KCl did not significantly influence the lipid oxidation and antioxidant enzyme activities. The bacons that were treated with 70% KCl treatment (III) showed increased lipid oxidation and antioxidant enzyme GSH-Px activity, whereas samples treated with formula I and II showed higher antioxidant enzyme catalase activity. These results demonstrate that the substitution of NaCl with KCl by more than 40% may significantly affects lipid oxidation and that for the substitution of NaCl in further processed meat products with other chloride salts, salt content is very important for control of lipid biochemical changes in finished products.

Key Words –Potassium chloride, Substitution, lipid oxidation.

I. INTRODUCTION

Sodium chloride (NaCl) is an essential ingredient in dry-cured meat products. NaCl functions as a preserving agent, improves flavor of products, and provides dietary sodium [1]. However, in spite of these essential roles in producing dry-cured meat, over-consumption of sodium could lead to the propensity to develop hypertension, stroke, and coronary heart disease [2].

Potassium chloride has been the most widely tested salt substitute to reduce the sodium chloride content in dry-cured meat products. Lately, Wu et al. [3] reported no adverse effects on sensory properties in dry-cured bacon by substitution of sodium chloride up to 40% with potassium chloride. However, it is still of interest to see if the partial substitution of NaCl with KCl has impacts on lipid oxidation and antioxidant enzyme activities of dry-cured bacon during processing. The aim of this study was to determine the influence of substitution of NaCl with KCl at different levels on lipid oxidation and antioxidant enzyme activities and relationship between the oxidation and antioxidant activities in dry-cured meat.

II. MATERIALS AND METHODS

Fresh bacon was treated with 0% KCl (100% NaCl Control or treatment I), 40% KCl plus 60% NaCl (treatment II), or 70% KCl plus 30% NaCl (treatment III) (wt/wt). The amount of added salt mixture was 3% of the total weight of muscle samples. The partial substitution ratio was selected based on the results published by Wu et al. [3] and our preliminary experiments. The processing conditions were adopted from those published by Wu et al. [4]. The extent of lipid oxidation was evaluated by the 2-thiobarbituric acid-reactive substances (TBARS) assay. The thiobarbituric-reactive substances (TBARS) values were determined following the method of Du et al. [5] and Jin et al. [6].

The enzyme extract solution was prepared according to the method described by Hernández et al. [7]. Catalase activity assay was performed following the method of Jin et al. [8]. GSH-Px activity was measured by a modification of the method of Paglia et al. [9].

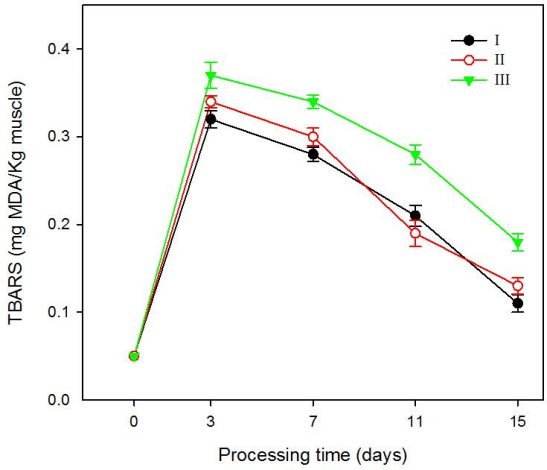
Factorial ANOVA was used for statistic analysis of data. The means were compared using Duncan's multiple-range test and differences were considered significant at $P< 0.05$. All statistical analysis was performed using the SPSS® 19.0 for windows (SPSS Inc., Chicago, IL) software package.

III. RESULTS AND DISCUSSION

Fig. 1 shows the changes in TBARS values during dry-curing. TBARS values significantly ($P < 0.05$) increased during the salting stage and then decreased ($p < 0.05$) during the drying/ripening period regardless of treatment. The TBARS values were in the range 0.11 to 0.18 mg MDA/kg muscle at the end of ripening stage, which was lower than those reported in dry-cured ham [10]. These differences between the TBARS values might be due to variations in the process conditions for different meat products and methods for the TBARS assay.

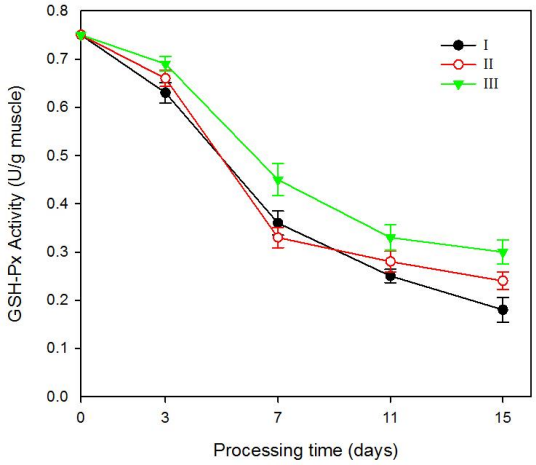
At the end of ripening stage, the TBARS value in treatment III samples was a significantly higher ($p < 0.05$) than those in the other two treatments (Fig. 1). The same relationships were also noticed for hexanal in our preliminary experimental results [4], in which the level of hexanal was significantly higher in bacons treated with formula III than those in the other two treatments. These could be attributed to the differences in NaCl contents in salt mixtures. NaCl is a pro-oxidant in meat and meat products when its content was less than 2% [11]. However, Rhee et al. [12] showed the pro-oxidant effect of NaCl was decreased and/or inhibited as its concentration was over 3% in muscle foods. In this study, in the presence of KCl, pro-oxidant activity of NaCl at a lower concentration could further be enhanced.

Fig. 1. TBARS change during dry-cured bacon processing using three types of salt.



At the end of ripening stage, GSH-Px activity in bacons treated with formula I was the lowest among three treatments (Fig. 2). Replacement with KCl increased GSH-Px activity. This finding was consistent with the results published by Hernández et al., who observed a higher GSH-Px activity in longissimus dorsi salted by KCl than that salted by NaCl [7].

Fig. 2. Changes of glutathione peroxidase (GSH-Px) activity during dry-cured bacon processing using three types of salt.

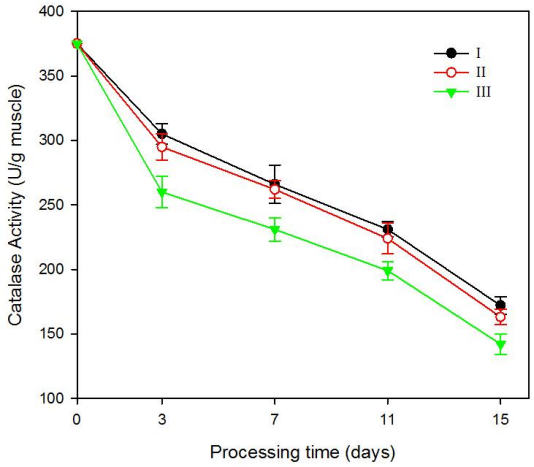


In general, oxidation of lipids is affected by both pro-oxidant and antioxidant factors [11]. Antioxidant enzymes can inhibit lipid oxidation in meat systems [8]. Hernández et al. attributed the low oxidative stability of salted muscle foods to the inhibitory activity of NaCl against antioxidant enzymes [7]. Taking this into consideration, we would have expected higher TBARS value in bacons salted with treatment I, which had lower GSH-Px activity, than those salted with treatment II or III. However, exactly the opposite results were observed. This demonstrates that in vivo lipid oxidation and GSH-Px activity do not always negatively correlated [11]. Similar results have been reported by Sárraga et al. who found that higher level of GSH-Px activity was accompanied by higher level of TBARS value in dry-cured Longissimus dorsi [13].

In this study, the catalase activity decreased significantly ($p < 0.05$) during processing regardless of treatment (Fig. 3). This indicates that, as GSH-Px, the catalase in muscle samples was also unstable during salting and drying-

ripening. This could be mainly due to the effect of salt on catalase. Similarly to GSH-Px, catalase can be inhibited by NaCl, and increased NaCl content results in reduced catalase activity [7]. At the end of salting, treatment III showed a significantly lower ($p < 0.05$) catalase activity compared with treatment I and treatment II. These results agree with the results obtained by Hernández et al. who reported a lower catalase activity in Boston butt salted by KCl than that salted by NaCl during refrigerated storage [7]. In addition, the differences in the catalase activity between three treatments were reduced at the end of the ripening stage (15 days). This can be attributed to rising temperature during drying/ripening. Rising temperature accelerates the moisture loss and changes the environment of catalysis, resulting in reduced catalase activity [8]. In the present study, reduced catalase activity in bacons treated with formula III might be partially responsible for the relatively higher TBARS values.

Fig. 3. Changes of catalase (CAT) activity during dry-cured bacon processing using three types of salt.



IV. CONCLUSION

The results showed that compared with 100% NaCl, the substitution of 40% NaCl with KCl did not markedly influence the oxidative stability in dry-cured bacon during processing, as measured by lipid oxidation (TBARS), glutathione peroxidase (GSH-Px) activity, and catalase (CAT) activity. However, the substitution of 70% NaCl with KCl would lead to increased lipid oxidation and reduced protein oxidation, indicating that the high level of KCl (70%) may result in significantly changes in lipid and protein biochemistry in dry-cured bacons. These results demonstrate that based on biochemical analysis of lipids and proteins, NaCl can be partially substituted with other chloride salts for dry-cured meat products without negative effects on quality. However, the substituting level is critical for the success.

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REFERENCES

1. Ruusunen, M., & Puolanne, E. (2005). Reducing sodium intake from meat products. Meat science, 70(3), 531-541.
2. Doyle, M. E., & Glass, K. A. (2010). Sodium reduction and its effect on food safety, food quality, and human health. Comprehensive Reviews in Food Science and Food Safety, 9(1), 44-56.
3. Wu, H., Zhang, Y., Long, M., Tang, J., Yu, X., Wang, J., & Zhang, J. (2014). Proteolysis and sensory properties of dry-cured bacon as affected by the partial substitution of sodium chloride with potassium chloride. Meat science, 96(3), 1325-1331.
4. Wu, H., Zhuang, H., Zhang, Y., Tang, J., Yu, X., Long, M., & Zhang, J. (2015). Influence of partial replacement of NaCl with KCl on profiles of volatile compounds in dry-cured bacon during processing. Food chemistry, 172, 391-399.
5. Du, M., Nam, K. C., Hur, S. J., Ismail, H., & Ahn, D. U. (2002). Effect of dietary conjugated linoleic acid, irradiation, and packaging conditions on the quality characteristics of raw broiler breast fillets. Meat Science, 60(1), 9-15.
6. Jin, G., Zhang, J., Yu, X., Zhang, Y., Lei, Y., & Wang, J. (2010). Lipolysis and lipid oxidation in bacon during curing and drying-ripening. Food Chemistry, 123(2), 465-471.
7. Hernández, P., Park, D., & Soon Rhee, K. (2002). Chloride salt type/ionic strength, muscle site and refrigeration effects on antioxidant enzymes and lipid oxidation in pork. Meat

Science, 61, 405-410.
8. Jin, G., He, L., Yu, X., Zhang, J., & Ma, M. (2013). Antioxidant enzyme activities are affected by salt content and temperature and influence muscle lipid oxidation during dry-salted bacon processing. Food Chemistry, 141(3), 2751-2756.
9. Paglia, D. E., & Valentine, W. N. (1967). Studies on the quantitative and qualitative characterization of erythrocyte glutathione peroxidase. The Journal of Laboratory and Clinical Medicine, 70(1), 158-169.
10. Andrés, A., Cava, R., Ventanas, J., Muriel, E., & Ruiz, J. (2004). Lipid oxidative changes throughout the ripening of dry-cured Iberian hams with different salt contents and processing conditions. Food Chemistry, 84(3), 375-381.
11. Min, B., & Ahn, D. (2005). Mechanism of lipid peroxidation in meat and meat products–A review. Food Science and Biotechnology, 14(1), 152-163.
12. Rhee, K., Smith, G., & Terrell, R. (1988). Enzymic and nonenzymic catalysis of lipid oxidation in muscle foods. Food Technology, 42(6), 127-132.
13. Sárraga, C., Carreras, I., & Regueiro, J. A. G. a. (2002). Influence of meat quality and NaCl percentage on glutathione peroxidase activity and values for acid-reactive substances of raw and dry-cured Longissimus dorsi. Meat Science, 62(4), 503-507.