AROMA-ACTIE COMPOUNS OF JINHUA HAM AS AFFECTED BY PARTIAL SUBSTITUTION OF NACL WITH KCL

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Abstract –The influence of partial replacement of NaCl with KCl on aroma-active compounds during Jinhua ham processing was evaluated using a headspace purge and trap GC/MS system. Jinhua ham was treated with either 100% NaCl (I) or 60% NaCl and 40% KCl (II). Formation of volatile compounds increased in Jinhua hams during processing regardless of salt formulation, particularly at the end of salting. There were also significant differences in volatile compound formation between formulation I and II after 45 days of processing. Contents of lipid-derived volatiles (hexanal) and Strecker aldehydes (2-methylbutanal and 3-methylbutanal) were significantly ($p< 0.05$) higher in Jinhua hams treated with formulation II than those treated with formulation I after 45 days of processing. The data demonstrated that partial salt replacement of NaCl with KCl changed the formation of volatile compounds in Jinhua hams and thereafter might have affected the flavor of finish products.

Key Words – Potassium chloride, Substitution, Flavour.

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 formation of volatile compounds in Jinhua ham in the same samples, even though several laboratories have studied the flavor effects of changing NaCl contents in the further processed meat [4,5]. The aim of this study was to determine the influence of the partial substitution of NaCl with KCl on the volatile formation or profiles of Jinhua ham.

II. MATERIALS AND METHODS

Hams were either salted with formulation I: Control, 100% NaCl or formulation II: 60% NaCl, 40% KCl. The total amount of salt was 6.5% (w/w) of the weight of hams. The 60:40 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 Zhang et al. [6].

In order to evaluate the influence of the replacement of NaCl with KCl on sensory characteristics, the selected hams were assessed by a trained panel of 12 members, using a quantitative-descriptive analysis method (QDA) [7].

Volatile compounds of Jinhua ham during processing were extracted using Eclipse 4660 Purge and Trap (PT) Sample Concentrator with 4551A auto-sampler (OI Analytical Company, USA), a #10 trap filled with Tenax-Silica Gel-Charcoal sorbent (OI Analytical Company, USA), and a 40 ml purge vial [8]. Volatile compounds were identified using the method described by Huan et al. [9]. Volatiles compounds were transferred to the GC/MS (Trace GC/MS, Finnigan) equipped with a DB-5MS capillary column (J&W Scientific; 60 m ×0.25 mm internal diameter, 1 μm of film thickness).

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

The results of the sensory analysis of Jinhua hams salted with two types of salt are presented in Table 1. The substitution did not affect any of the sensory characteristics in the Biceps femoris muscles ($P > 0.05$) except saltiness. The findings are not in line with previous work by Armentero which reported that the replacement of NaCl by KCl could be 50% without affecting their sensory attribute [10]. This difference could be due to the fact that the replacement of NaCl with 40% KCl results in a less salty taste in the dry-cured hams and a less salty taste is sometimes positively valuated by the assessors.

Table 1 Sensory traits of Jinhua hams with different salt formulations:I: Control, 100% NaCl; II: 60% NaCl, 40% KCl.

Sensory traits	Biceps femoris	
	I	II
Redness	5.81 ± 0.41^{A}	5.31 ± 0.29^{A}
Yellowness	3.12 ± 0.27^{A}	3.22 ± 0.09^{A}
Hardness	4.44 ± 0.37^{A}	4.87 ± 0.22^{A}
Juiciness	5.33 ± 0.16^{A}	5.31 ± 0.30^{A}
Aroma intensity	4.64 ± 0.24^{A}	4.35 ± 0.45^{A}
Saltiness	5.72 ± 0.43^{A}	4.60 ± 0.35^{B}
Bitterness	1.29 ± 0.37^{A}	1.28 ± 0.46^{A}
After-taste	4.65 ± 0.44^{A}	4.48 ± 0.22^{A}

A-B: Means in the same row with different superscripts differ significantly for Biceps femoris ($p < 0.05$).

The average contents of some aroma-active compounds extracted from Biceps femoris (BF), which were treated with either 100% NaCl or 60% NaCl plus 40% KCl, at five different sampling points are showed in Table 2.

2-methylbutanal and 3-methylbutanal were major methyl-branched aldehydes detected in Jinhua hams in present study (Table 2). They are the products of proteolysis and Strecker degradation of amino acids isoleucine and leucine [11]. Their contents increased during the processing time. 3-methylbutanal in formulation I was significantly higher than that in formulation II ($P < 0.05$) at the end of processing, however, no significant differences were observed during the first dry-ripening stage (30 days of drying-ripening) ($P \geqslant 0.05$). It has been reported that sodium chloride could greatly restrain the proteolysis activity [3].The substitution of NaCl with KCl might enhance proteolysis and result in increased Strecker degradation.

At the end of drying-ripening phase, hexanal content in the ham treated with formulation I was significantly lower that treated with formulation II. This could be due to the reaction between hexanal and amino acids to form Maillard and Strecker compounds [12].

Ethanol is likely derived from carbohydrate fermentation by microorganisms [11]. There was significant difference in ethanol content between two salt formulations ($P < 0.05$) at the end of salting stage in BF muscles. Hams salted with formulation II showed higher levels of ethanol than those with formulation I. It is deduced that a partial replacement of NaCl by KCl could somehow enhance microbial growth and generate more ethanol.

2-methylbutanol and 3-methylbutanol are derivatives from reduction of 2-methylbutanal and 3-methylbutanal, respectively [13]. There was no significant difference in 2-methylbutanol and 3-methylbutanol content between two salt formulations ($P < 0.05$) at the end of salting stage. This is probably attributed to less chemical reductions of the corresponding branched aldehydes by microbial enzymes cause low microbial counts found inside the hams, the conditions that are unfavorable for microbial growth and low microbial enzyme activity levels [14].

Hams salted with formulation II produced more ketones. 2-ketones are considered to have a great effect on meat and they are believed to be the products of autoxidation or β-oxidation of fatty acids [11]. Our results suggest that replacement of NaCl by KCl may promote the oxidation of fatty acid.

Ethyl acetate, 2-methyl-ethyl ester accounted for most esters in Jinhua hams [9]. Its content in the hams salted with formulation II was significantly higher than those with formulation I. It is deduced that the substitution of NaCl with KCl in hams might have accelerated the proteolysis, generated more alcohols, and then formed more esters by reacting with free fatty acid [15].

Table 2. Contents of some aroma-active compounds extracted from Biceps femoris treated with 100% NaCl or 60% NaCl plus 40% KCl

Compounds		Biceps femoris				
		Green ham	End of salting	30 days of ripening	60 days of ripening	100 days of ripening
Aldehydes						
3-methylButanal	I	0.21±0.12^{cA}	20.93±1.41^{aA}	14.48±2.92^{bA}	17.43±0.39^{abA}	17.44±1.17^{abA}
	II	0.21±0.12^{aA}	0.70±0.04^{aB}	16.25±0.50^{aA}	15.47±10.75^{aA}	5.79±3.25^{aB}
2-methylButanal	I	0.00±0.00^{bA}	3.42±0.40^{aA}	0.64±0.14^{bB}	3.29±0.00^{aA}	3.83±0.21^{aA}
	II	0.00±0.00^{cA}	0.00±0.00^{cB}	1.96±0.04^{abA}	1.05±0.13^{bcB}	3.64±1.04^{aA}
Hexanal	I	2.12±1.09^{bA}	9.97±3.01^{aA}	4.22±1.24^{bB}	1.08±0.18^{bB}	0.99±0.06^{bB}
	II	2.12±1.09^{cA}	1.69±0.04^{cA}	16.14±1.00^{aA}	7.42±1.43^{bA}	3.33±0.20^{bcA}
Alcohols						
Ethanol	I	0.25±0.13^{bA}	8.81±1.17^{bA}	35.76±12.71^{aA}	34.01±0.16^{aA}	33.83±0.78^{aA}
	II	0.25±0.13^{bA}	0.93±0.48^{abB}	19.45±0.47^{abA}	34.14±8.46^{abA}	40.86±22.19^{aA}
1-Butanol,3-methyl-	I	0.09±0.01^{bA}	1.98±0.08^{abA}	1.93±0.19^{abA}	3.31±1.26^{aA}	0.49±0.01^{bB}
	II	0.09±0.01^{cA}	2.90±0.49^{aA}	1.52±0.27^{bA}	0.92±0.19^{bcA}	1.59±0.16^{bA}
1-Butanol,2-methyl-	I	0.00±0.00^{dA}	0.00±0.00^{dB}	0.50±0.00^{bA}	1.03±0.03^{aA}	0.13±0.01^{cB}
	II	0.00±0.00^{cA}	0.54±0.06^{aA}	0.46±0.00^{aB}	0.32±0.00^{bB}	0.33±0.02^{bA}
Ketones						
2-Butaneone	I	0.00±0.00^{bA}	1.52±0.25^{aA}	1.67±0.03^{aA}	1.54±0.57^{aA}	0.00±0.00^{bB}
	II	0.00±0.00^{cA}	1.16±0.13^{bA}	1.56±0.02^{aA}	1.08±0.11^{bA}	1.21±0.01^{bA}
2-Pentanone	I	0.00±0.00^{cA}	0.55±0.08^{aA}	0.37±0.00^{bA}	0.41±0.02^{bA}	0.32±0.01^{bB}
	II	0.00±0.00^{cA}	0.52±0.03^{bA}	0.75±0.11^{aA}	0.38±0.02^{bA}	0.49±0.03^{bA}
2-Heptanone	I	0.01±0.00^{cA}	0.31±0.00^{aA}	0.02±0.01^{bcA}	0.02±0.00^{bA}	0.02±0.01^{bA}
	II	0.01±0.00^{bA}	0.02±0.00^{abB}	0.09±0.02^{aA}	0.05±0.01^{abA}	0.06±0.04^{abA}
Esters						
Ethyl Acetate	I	0.00±0.00^{dA}	0.15±0.03^{cA}	0.50±0.01^{bA}	0.58±0.04^{bA}	1.48±0.04^{aA}
	II	0.00±0.00^{dA}	0.19±0.01^{cA}	0.27±0.01^{cB}	0.55±0.03^{bA}	1.12±0.05^{aB}
Propanoic acid,2-	I	0.00±0.00^{dA}	0.00±0.00^{dA}	0.20±0.00^{cA}	0.48±0.04^{bA}	0.65±0.01^{aA}
methly-,ethyl ester	II	0.00±0.00^{dA}	0.00±0.00^{dA}	0.28±0.03^{cA}	0.47±0.01^{bA}	0.63±0.03^{aA}
Butanoic acid,2-	I	0.00±0.00^{dA}	0.00±0.00^{dB}	0.16±0.01^{cA}	0.56±0.02^{bA}	0.65±0.01^{aB}
methyl-,ethyl ester	II	0.00±0.00^{dA}	0.03±0.00^{dA}	0.26±0.06^{cA}	0.52±0.01^{bA}	0.89±0.01^{aA}
Butanoic acid,3-	I	0.00±0.00^{eA}	0.13±0.01^{dA}	0.37±0.03^{cA}	1.26±0.01^{bA}	1.60±0.02^{aB}
methyl-,ethyl ester	II	0.00±0.00^{dA}	0.08±0.02^{dA}	0.70±0.15^{cA}	1.20±0.01^{bA}	2.27±0.04^{aA}

a–e Means in the same row with different superscripts differ significantly ($p < 0.05$). A–B Means in the same compound batch with different superscripts differ significantly ($p < 0.05$).

IV. CONCLUSION

The partial replacement (40%) of NaCl with KCl has a great influence on aroma-active compounds throughout the processing of dry-cured hams in Biceps femoris muscles. An increased formation and/or release of volatile compounds were found during Jinhua ham processing, particularly during salting and the first ripening stage. The most pronounced differences were detected at the end of the salting phase. Particularly, formulation II (60% NaCl, 40% KCl) promoted the formation of lipid-derived aldehydes, Strecker aldehydes, alcohols and methyl-branched aldehydes from amino acid. The results demonstrate that the replacement of NaCl with could significantly influence the aroma of Jinhua ham. However, sensory analysis of the final products indicated it was possible to reduce NaCl by 40% in dry-cured ham without adverse effects on sensory properties. This fits with consumer demands and health requirements. How to confirm whether partial replacement of NaCl with KCl will affect the safety and overall acceptability of the final product will be conducted in further study.

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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. Corral, S., Salvador, A., & Flores, M. (2013). Salt reduction in slow fermented sausages affects the generation of aroma active compounds. Meat science, 93(3), 776-785.
5. Armenteros, M., Toldrá, F., Aristoy, M. C., Ventanas, J., & Estévez, M. (2012). Effect of the partial replacement of sodium chloride by other salts on the formation of volatile compounds during ripening of dry-cured ham. Journal of agricultural and food chemistry, 60(31), 7607-7615.
6. Zhang, J., Jin, G., Wang, J., & Zhang, W. (2011). Effect of intensifying high-temperature ripening on lipolysis and lipid oxidation of Jinhua ham. LWT-Food Science and Technology, 44(2), 473-479.
7. Ruiz, J., Ventanas, J., Cava, R., Timón, M. L., & Garcıa, C. (1998). Sensory characteristics of Iberian ham: influence of processing time and slice location. Food Research International, 31(1), 53-58.
8. Yuan, B., Xu, D., Li, F., & Fu, M. L. (2013). Removal efficiency and possible pathway of odor compounds (2-methylisoborneol and geosmin) by ozonation. Separation and Purification Technology, 117, 53-58.
9. Huan, Y., Zhou, G., Zhao, G., Xu, X., & Peng, Z. (2005). Changes in flavor compounds of dry-cured Chinese Jinhua ham during processing. Meat science, 71(2), 291-299.
10. Armenteros, M., Aristoy, M. C., Barat, J. M., & Toldrá, F. (2009). Biochemical and sensory properties of dry-cured loins as affected by partial replacement of sodium by potassium, calcium, and magnesium. Journal of agricultural and food chemistry, 57(20), 9699-9705.
11. Sabio, E., Vidal-Aragón, M. C., Bernalte, M. J., & Gata, J. L. (1998). Volatile compounds present in six types of dry-cured ham from south European countries. Food Chemistry, 61(4), 493-503.
12. 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.
13. Wang, J., Jin, G., Zhang, W., Ahn, D. U., & Zhang, J. (2012). Effect of curing salt content on lipid oxidation and volatile flavour compounds of dry-cured turkey ham. LWT-Food Science and Technology, 48(1), 102-106.
14. Fadda, S., Sanz, Y., Vignolo, G., Aristoy, M. C., Oliver, G., & Toldrá, F. (1999). Characterization of muscle sarcoplasmic and myofibrillar protein hydrolysis caused by Lactobacillus plantarum. Applied and Environmental Microbiology, 65(8), 3540-3546.
15. Toldrá, F., & Flores, M. (1998). The role of muscle proteases and lipases in flavor development during the processing of dry-cured ham. Critical Reviews in Food Science, 38(4), 331-352.