Influence of Partial Replacement of NaCl with KCl on Formation of Volatile Compounds in Jinhua Ham during Processing

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Abstract The influence of partial replacement of NaCl with KCl on formation of volatile compounds during Jinhua ham processing was evaluated using 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 for both salt formulations, particularly at the end of the salting period. There were differences in volatile compound formation between formulations I and II after 45 days of processing. Contents of lipid-derived volatiles (hexanal) and Strecker aldehydes (2-methylbutanal and 3-methylbutanal) were higher in Jinhua hams treated with formulation II after 45 days of processing. Partial salt replacement of NaCl with KCl changed formation of volatile compounds in Jinhua hams and may have affected the flavor of finished products.

Keywords: ham, NaCl, replacement, KCl, flavor

Introduction

Dry-cured ham is a traditionally-cured meat product that is popular worldwide (1) and is well-known for flavor. Jinhua ham is a typical dry-cured ham produced in China with a unique flavor, a high sodium chloride content, and have an important impact on local economies. Sodium chloride, an essential curing agent for manufacture of cured meat products, preserves food quality, enhances food flavor, and provides the essential nutrient sodium (2). However, too much sodium can cause high blood pressure and many other human health problems (3). Dry-cured ham is a not recommended for hypertensive consumers due to a high sodium content of >5%. Consequently, different approaches have been used to reduce sodium levels in dry-cured hams for targeting of healthy diet markets, including reduction of the salting time, addition of less NaCl, and total or partial replacement of sodium with other salts, such as, KCl (2).

Development of salt substitutes for use with dry-fermented sausages and dry-cured ham has been studied (4), especially use of KCl to replace NaCl. Replacement of NaCl with a high level of KCl of > 40% affected the sensory characteristics of meat (5).

There is a close relationship in meat products between sensory quality and formation of volatile compounds. Two different pathways are responsible for formation of volatile compounds that influence dry-cured ham flavors during processing. The first pathway involves

enzymatic reactions, including both proteolysis and lipolysis, and the second involves chemical reactions, including lipid oxidation and Maillard and Strecker reactions (6). Enzymatic proteolysis contributes directly to flavor via formation of peptides and free amino acids, which are considered as flavor precursors and are involved in Maillard and Strecker reactions (7). Non-enzymatic lipid oxidation leads to formation of abundant volatile compounds in dry-cured ham via peroxidation products of unsaturated fatty acids (8). Effects of temperature on proteolysis, lipolysis, and flavor of Jinhua ham have been studied (9). However, the influence of replacing NaCl with KCl on generation of volatile compounds in Jinhua ham during processing remains unknown.

The objective of this study was evaluation of the influence of partial replacement of NaCl with KCl on formation of volatile compounds in Jinhua ham during processing. Results from this study should be useful for the processed ham industry for development of new ham products for a healthy diet without sacrificing traditional ham flavor.

Materials and Methods

Jinhua ham processing Jinhua ham processing was carried out at the Academy of Agricultural Sciences, Jiangsu Province, China in June of 2014. Forty-five green hams (raw ham) were purchased from Zhejiang Provincial Food Company (Hangzhou, Zhejiang Province,

China) of 6.8–7.8 kg each from Taihux Duroc× York crossbred pigs weighing 90 to 110 kg. Five hams were used for green ham measurements on day 1. The other 40 hams were randomly divided into 2 groups and subjected to a salting process for Jinhua hams (10). Hams were either salted with formulation I for control hams of 100% NaCl, or formulation II for treatment hams of 60% NaCl and 40% KCl. The total amount of salt was 6.5% (w/w) of the ham weight. The 60:40 ratio was used based on a report of Wu *et al.* (11) and preliminary experiments. Processing conditions reported by Zhang *et al.* (10) were used.

Salting was considered complete when no salt crystals were observed on the ham surface. During salting, hams were piled and placed in a chamber at 4±2°C and 85% relative humidity for 45 days during which piled hams were turned over 15 times. After salting, hams were soaked in water for 24 h, brushed, and dried for 3 days under the sun before the dry ripening process of aging in a loft chamber for 100 days with automatic temperature and humidity control. Mean values and ranges of temperature and relative humidity during dry-ripening are shown in Table 1.

Product sampling Both semimembranosus muscle (SM) and biceps femoris (BF) muscle (100 g) were sampled randomly from 5 hams from each formulation. Muscle samples were vacuum packed and stored at 40°C in freezer (BD-226W; Haier Company, Qingdao, China) prior to volatile analysis. Sampling times included green ham on day 1 of processing, at the end of salting, after 30 days of dry-ripening, after 60 days of dry-ripening, and after 100 days of dry-ripening.

Analysis of volatile compounds

Extraction: Jinhua ham volatile compounds formed during processing were extracted using an Eclipse 4660 purge and trap (PT) sample concentrator with a 4551A auto-sampler (OI Analytical Company, College Station, TX), a #10 trap filled with tenax silica gel charcoal sorbent (OI Analytical), and a 40 mL purge vial (12). The PT system was operated with 3.5 g of minced ham in a PT vial at 40°C for 30 min using a purge gas of high purity nitrogen at a flow rate of 40 mL/min at 60°C for 13 min. Tenax silica gel charcoal sorbent heated to 220°C with helium desorption for 2 min and direct transfer to a Thermo Finnigan GC/MS system (Thermo Electron Corporation, Waltham, MA, USA) followed. The trap was baked at 240°C for 30 min every time before use for removal of potential residues and/or contaminants.

Chromatographic method: Volatile compounds were identified using the method described by Huan *et al.* (13) with slight modification. Volatiles compounds were transferred to a GC/MS device (Thermo Electron Corporation) equipped with a DB-5MS capillary column (J & W Scientific, Folsom, CA, USA) (60 m×0.25 mm internal diameter, film thickness of 1 µm). GC/MS conditions were a helium carrier gas flow rate of 1.0 mL/min, an oven temperature program of 40°C for 3 min, increased at 5°C/min to 130°C, increased at 8°C/min to 200°C, increased at 12°C/min to 250°C, and kept isothermal for 7 min. The split ratio was 1:10. MS conditions were an ion source temperature

of 280°C, an ionization voltage of 70 eV, and a scan range of *m/z* 30–550. Volatiles were identified based on comparison of mass spectral data with the NISTDEMO, MAINLIB, WILEY, and REPLIB libraries based on matching of retention indices with reported values and standard alkanes (C6 to C20) (AccuStandard Inc., New Haven, CT, USA) for calculation of Kovats indices (12).

Sensory analysis Selected hams were assessed by a trained panel of 12 members using a quantitative-descriptive analysis method (QDA) (10) for evaluation of the influence of NaCl replacement with KCl on sensory characteristics. Panelists were trained and had participated in sensory evaluations of dry-cured hams for 2 years. Individual flavor and aroma recognition thresholds were used as a basis for selection of panelists, who had a total of 120 h of training in preparation for sensory analysis of ham.

Panel evaluations were held at 11:00 am, 3 h after breakfast. Three thin slices of 1 mm corresponding to semimembranosus muscle and Biceps femoris muscles of 8.0 g each were supplied. Product samples were presented with 3 digit codes in random order. Slices were obtained using a commercial slicing machine and were served immediately on glass plates with both the slices and the plates at room temperature of 20–23°C. A 100 mL glass of water at 12°C was provided for each panelist between evaluations. All sessions were conducted in a 6 booth sensory panel room at 22°C equipped with white fluorescent lighting at 220–230 V and 35 W.

Use of descriptor terms was based on previous reports of dry-cured ham (10). Eight sensory traits for Jinhua ham grouped as appearance (redness and yellowness), texture (hardness and juiciness), aroma (aroma intensity), and flavor (saltiness, bitterness, and after-taste) were assessed. Each attribute was scored in an unstructured line of 10 cm. Sensory traits, definitions, and extremes were based on the report of Ruiz *et al.* (14). Sensory evaluation was repeated in 3 sessions carried out on 3 different days. Final scores were averaged over all panelists.

Statistical analysis Five hams were used for each treatment at each sampling time point and each ham was analyzed in triplicate. Data were expressed as mean±standard deviation. A factorial analysis of variance (ANOVA) was used for data analysis. Mean values 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, USA) software package.

Results and Discussion

Volatile compounds Average amounts of volatile compounds extracted from SM and BF samples treated with either 100% NaCl or 60% NaCl plus 40% KCl at 5 different sampling points are shown in Table 2. Numbers of SM volatile compounds were 51 for formulation

Table 1. Sampling times, temperature, and relative humidity (RH)

Sampling stage	Green ham	End of salting	30 days of dry-ripening	60 days of dry-ripening	100 days of dry-ripening
Processing time (day)	1	45	79	110	150
Mean RH (%)	79.8	75.1	55.8	53.2	55
Highest/lowest RH (%)	80.2/78.5	85.2/74.9	65.2/45.3	55.2/50.7	55.6/53.2
Mean temp. (°C)	7.7	5.0	30.2	37.3	36.8
Highest/lowest temp. (°C)	8.5/7.0	9.0/3.7	32.2/26.0	37.8/35.3	38.1/35.9

I and 58 for formulation II after 100 days of dry ripening. Numbers of volatile compounds during processing for BF were 50 for 100% NaCl and 48 for 60% NaCl plus 40% KCl after 100 days of dry-ripening. Identified compounds were categorized into the 10 different chemical families of aldehydes, alcohols, ketones, esters, alkanes, alkenes, sulfur compounds, nitrogenous compounds, chloride compounds, and others.

Most of the volatile compounds identified in this study have been previously identified in dry-cured hams (7,15). The total number of volatiles was similar to a report of Du and Ahn (9) in which 35 compounds were identified and quantified. The number was different from a report of Huan *et al.* (13) for traditional Jinhua hams, perhaps due to different extraction methods and processing conditions.

Changes in amounts of volatile compounds in Jinhua ham treated with different salt formulations during processing, compared with no processing (green), are shown in Fig. 1 and 2. For the majority of volatile groups, levels increased after processing. Use of formulation II in SM samples resulted in release of more volatile compounds than use of formulation I, while formulation I resulted in more release of the key compounds hexanal and ethanol than formulation II in BF samples.

Aldehydes Aldehydes in dry-cured ham, dry-cured loin, and dry-cured sausage play vital roles in overall product flavor due to low perception thresholds (16,17), and contribute to the aroma of dry-cured meat products, even in trace amounts (18). In this study, aldehydes were the second most abundant chemical family in processed Jinhua ham, representing approximately 15% of the total chromatographic area in SM samples (Fig. 1A) and 45% in BF samples (Fig. 2A). Much higher relative levels of aldehydes were previously reported for dry-cured meat products (19).

The aldehyde content in Jinhua hams increased significantly ($p < 0.05$) during processing with both salt formulations, compared with controls. Significant ($p < 0.05$) differences in relative levels of aldehydes between the 2 formulations at the end of the salting period were identified. SM samples with both salt formulations and BF samples treated with formulation II exhibited significantly ($p < 0.05$) reduced aldehyde contents at the end of processing, compared with controls, in agreement with a report of Zhang *et al.* (20) probably due to conversion of aldehydes into other volatile or nonvolatile compounds during dry-ripening.

2-Methylbutanal and 3-methylbutanal, major methyl-branched

aldehydes detected in Jinhua hams in this study (Table 2), are products of proteolysis and Strecker degradation of the amino acids isoleucine and leucine (21). Content levels increased during processing time. Levels of 3-methylbutanal in formulation I samples were significantly ($p < 0.05$) higher than in formulation II samples at the end of processing; however, no ($p \geq 0.05$) significant differences in levels were observed during the first 30 days of dry-ripening stage. Sodium chloride can reportedly greatly restrain proteolytic activity (10). Substitution of KCl for NaCl probably enhanced proteolysis and resulted in increased Strecker degradation.

Hexanal was the most abundant straight-chain aliphatic aldehyde identified in dry-cured hams, regardless of salt formulation (Table 2). Hexanal has contributed to rancid odors of foods (22) and is a dominant breakdown product of lipid oxidation of n-6 fatty acids (15). In this study, the level of hexanal was significantly ($p < 0.05$) higher in hams dry-cured using formulation II than using formulation I, in agreement with a report of Armenteros *et al.* (23). However, the effect of KCl substitution was not the same as observed in other hams (8). Replacement of NaCl with KCl had a pro-oxidative effect on Jinhua hams in this study, resulting in increased lipid oxidation and formation of lipid-derived volatiles, such as hexanal.

At the end of the dry-ripening phase the hexanal content in ham treated with formulation I was significantly ($p < 0.05$) lower than in ham treated with formulation II, probably due to a reaction between hexanal and amino acids to form Maillard and Strecker compounds (6).

Alcohols Alcohols were the most abundant volatile compounds identified in Jinhua hams (Table 2), representing more than 50% of volatiles, regardless of sample type and salt formulation, in agreement with other reports (24).

Relative alcohol contents in Jinhua hams treated with the 2 different formulations are shown in Fig. 1B for SM and in Fig. 2B for BF. Alcohol levels increased significantly ($p < 0.05$) during processing, reaching the highest level after 100 days of dry-ripening. Formation and/or release of alcohols were significantly affected by salt formulations at the beginning of processing. However, no significant ($p > 0.05$) differences were found at the end of processing for formation and/or release of alcohols between the 2 formulations.

Ethanol, which is likely produced during carbohydrate fermentation by microorganisms (7), accounted for more than 30% of the total volatile fraction at the end of processing, in agreement with a previous report (25). The ethanol content was only 0.38% of total

Table 2. Contents of volatile compounds extracted from semi membranosus and biceps femoris tissues treated with 100% NaCl or 60% NaCl plus 40% KCl (percentage of the total area) at different sampling time points

Compounds	K ⁽³⁾	Semimembranosus muscle						Biceps femoris					
		Green ham	End of salting	30 days of dry-ripening	60 days of dry-ripening	100 days of dry-ripening	Green ham	End of salting	30 days of dry-ripening	60 days of dry-ripening	100 days of dry-ripening		
Aldehydes													
Acetaldehyde	377	I	0.29±0.01 ^{1)(a2)}	1.33±0.07 ^{bcA}	2.11±0.04 ^{abA}	3.77±0.99 ^{aA}	1.39±0.34 ^{bcB}	0.29±0.01 ^{dA}	1.86±0.49 ^{cA}	7.60±0.01 ^{aA}	2.99±0.23 ^{ba}		
		II	0.29±0.01 ^{cA}	1.98±0.47 ^{bA}	1.98±0.19 ^{bA}	3.37±0.57 ^{bA}	6.09±0.62 ^{aA}	0.29±0.01 ^{bA}	1.23±0.01 ^{abA}	0.53±0.07 ^{abB}	2.80±1.45 ^{aA}		
3-Methylbutanal	663	I	0.21±0.12 ^{bA}	4.54±0.11 ^{aA}	2.07±0.23 ^{abA}	5.70±2.34 ^{aA}	2.36±0.21 ^{abB}	0.21±0.12 ^{cA}	14.48±2.92 ^{bA}	17.43±0.39 ^{abA}	17.44±1.17 ^{abA}		
		II	0.21±0.12 ^{dA}	7.91±1.03 ^{aA}	2.77±0.35 ^{cA}	5.07±0.17 ^{bA}	4.07±0.26 ^{bcA}	0.21±0.12 ^{aA}	16.25±0.50 ^{aA}	15.47±10.75 ^{aA}	5.79±3.25 ^{ab}		
2-Methylbutanal	674	I	0.00±0.00 ^{bA}	1.21±0.29 ^{bA}	0.00±0.00 ^{BB}	2.81±0.83 ^{aA}	1.26±0.07 ^{bA}	0.00±0.00 ^{bA}	0.64±0.14 ^{BB}	3.29±0.00 ^{aA}	3.83±0.21 ^{aA}		
		II	0.00±0.00 ^{cA}	1.55±0.03 ^{aA}	0.93±0.14 ^{bA}	1.08±0.04 ^{bA}	1.52±0.05 ^{aA}	0.00±0.00 ^{cA}	1.96±0.04 ^{abA}	1.05±0.13 ^{bcB}	3.64±1.04 ^{aA}		
Pentanal	708	I	0.00±0.00 ^{dA}	3.14±0.28 ^{aA}	1.67±0.08 ^{BB}	0.89±0.03 ^{cA}	0.83±0.03 ^{CB}	0.00±0.00 ^{bA}	0.65±0.17 ^{aA}	0.26±0.01 ^{BB}	0.36±0.13 ^{abA}		
		II	0.00±0.00 ^{dA}	2.81±0.83 ^{bA}	4.35±0.00 ^{aA}	0.93±0.11 ^{cdA}	1.65±0.06 ^{bcA}	0.00±0.00 ^{cA}	2.13±0.35 ^{aA}	1.48±0.04 ^{abA}	1.00±0.52 ^{bcB}		
Hexanal	800	I	2.12±1.09 ^{cA}	35.51±5.17 ^{aA}	18.72±1.27 ^{BB}	4.07±0.17 ^{cA}	2.95±0.11 ^{CB}	2.12±1.09 ^{bA}	4.22±1.24 ^{BB}	1.08±0.18 ^{BB}	0.99±0.06 ^{BB}		
		II	2.12±1.09 ^{dA}	18.40±3.12 ^{BB}	29.93±0.43 ^{aA}	6.36±0.54 ^{cA}	8.32±0.24 ^{cdA}	2.12±1.09 ^{cA}	16.14±1.00 ^{aA}	7.42±1.43 ^{BA}	3.33±0.20 ^{bcA}		
Heptanal	901	I	0.09±0.02 ^{bA}	0.96±0.28 ^{aA}	0.39±0.03 ^{BB}	0.14±0.01 ^{BA}	0.08±0.01 ^{BB}	0.09±0.02 ^{bA}	0.15±0.01 ^{BB}	0.06±0.01 ^{BA}	0.04±0.01 ^{BA}		
		II	0.09±0.02 ^{BA}	0.84±0.11 ^{aA}	0.68±0.05 ^{aA}	0.16±0.00 ^{BA}	0.21±0.01 ^{BA}	0.09±0.02 ^{bcA}	0.59±0.06 ^{aA}	0.30±0.07 ^{bA}	0.19±0.11 ^{bcA}		
2-Heptenal	959	I	0.00±0.00 ^{bA}	0.00±0.00 ^{bA}	0.02±0.00 ^{aA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{bA}	0.02±0.00 ^{aA}	0.00±0.00 ^{BB}	0.00±0.00 ^{BA}		
		II	0.00±0.00 ^{cA}	0.00±0.00 ^{cA}	0.06±0.01 ^{aA}	0.03±0.01 ^{BA}	0.00±0.00 ^{CA}	0.00±0.00 ^{cA}	0.06±0.01 ^{aA}	0.03±0.01 ^{BA}	0.00±0.00 ^{BA}		
Benzaldehyde	971	I	0.00±0.00 ^{cA}	0.00±0.00 ^{cA}	0.00±0.00 ^{CA}	0.08±0.01 ^{aA}	0.05±0.00 ^{BB}	0.00±0.00 ^{CA}	0.00±0.00 ^{CA}	0.08±0.01 ^{aA}	0.05±0.00 ^{BB}		
		II	0.00±0.00 ^{bA}	0.00±0.00 ^{bA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.11±0.01 ^{aA}	0.00±0.00 ^{bA}	0.00±0.00 ^{CA}	0.00±0.00 ^{BB}	0.11±0.01 ^{aA}		
Octanal	1005	I	0.04±0.01 ^{bA}	0.58±0.26 ^{aA}	0.17±0.01 ^{abA}	0.08±0.01 ^{BA}	0.06±0.01 ^{BB}	0.04±0.01 ^{BA}	0.07±0.00 ^{BB}	0.03±0.01 ^{BA}	0.00±0.00 ^{BA}		
		II	0.04±0.01 ^{BA}	0.63±0.16 ^{aA}	0.25±0.06 ^{bA}	0.07±0.00 ^{BA}	0.13±0.01 ^{BA}	0.04±0.01 ^{CA}	0.29±0.02 ^{aA}	0.17±0.04 ^{bA}	0.13±0.04 ^{bcA}		
Benzeneacetaldehyde	1054	I	0.01±0.00 ^{aA}	0.09±0.01 ^{aA}	0.17±0.01 ^{aA}	1.54±1.00 ^{aA}	0.08±0.00 ^{AB}	0.01±0.00 ^{dA}	1.62±0.05 ^{cA}	6.04±0.72 ^{aA}	2.96±0.04 ^{BA}		
		II	0.01±0.00 ^{cA}	0.08±0.02 ^{bcA}	0.09±0.04 ^{BA}	0.06±0.01 ^{bcA}	0.21±0.01 ^{aA}	0.01±0.00 ^{BA}	0.12±0.04 ^{BB}	0.21±0.16 ^{BB}	0.96±0.38 ^{AB}		
2-Octenal	1062	I	0.00±0.00 ^{bA}	0.03±0.01 ^{aA}	0.03±0.00 ^{aA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.03±0.01 ^{aA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}		
		II	0.00±0.00 ^{bA}	0.00±0.00 ^{bA}	0.05±0.01 ^{aA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{bA}	0.05±0.01 ^{aA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}		
Nonanal	1108	I	0.03±0.00 ^{dA}	0.36±0.00 ^{BB}	0.17±0.00 ^{bA}	0.12±0.01 ^{bcA}	0.08±0.03 ^{cdA}	0.03±0.00 ^{bA}	0.08±0.01 ^{BB}	0.04±0.00 ^{BA}	0.03±0.00 ^{BA}		
		II	0.03±0.00 ^{dA}	0.51±0.01 ^{aA}	0.18±0.00 ^{BA}	0.07±0.01 ^{CA}	0.09±0.00 ^{CA}	0.03±0.00 ^{bcA}	0.22±0.02 ^{aA}	0.12±0.02 ^{abCA}	0.15±0.06 ^{abA}		
2-Decenal	1269	I	0.01±0.00 ^{bA}	0.08±0.01 ^{aA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BB}	0.01±0.00 ^{abA}	0.03±0.01 ^{aA}	0.02±0.00 ^{abB}	0.00±0.00 ^{BA}		
		II	0.01±0.00 ^{bA}	0.09±0.01 ^{aA}	0.00±0.00 ^{CA}	0.03±0.00 ^{BA}	0.03±0.00 ^{BA}	0.01±0.00 ^{BA}	0.00±0.00 ^{bA}	0.05±0.01 ^{aA}	0.07±0.01 ^{aA}		
1328		I	0.00±0.00 ^{bA}	0.06±0.02 ^{aA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}		
		II	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}		
2-Undecenal	1372	I	0.00±0.00 ^{bA}	0.10±0.02 ^{aA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}		
		II	0.00±0.00 ^{bA}	0.04±0.00 ^{aA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{BA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}		

Table 2. Continued

Compounds	Kl ⁽³⁾	Semimembranosus muscle					Biceps femoris				
		Green ham	End of salting	30 days of dry-ripening	60 days of dry-ripening	100 days of dry-ripening	Green ham	End of salting	30 days of dry-ripening	60 days of dry-ripening	100 days of dry-ripening
Alcohols											
Ethanol	548	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}	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 ^{abB}	34.14±8.46 ^{abA}	40.86±22.19 ^{aA}	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}
Isopropanol	552	I 0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.98±0.09 ^{ba}	2.50±0.01 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.98±0.09 ^{ba}	2.50±0.01 ^{aA}
	II	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.47±0.07 ^{ab}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.47±0.07 ^{ab}	0.00±0.00 ^{ba}
1,3-Butanediol	556	I 0.00±0.00 ^{ba}	1.09±0.20 ^{aA}	0.01±0.01 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	1.09±0.20 ^{aA}	0.01±0.01 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
	II	0.00±0.00 ^{aA}	0.00±0.00 ^{ba}	1.37±0.03 ^{aA}	0.65±0.12 ^{ba}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ba}	1.37±0.03 ^{aA}	0.65±0.12 ^{ba}	0.00±0.00 ^{aA}
1-Propanol	557	I 0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	1.80±1.11 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	1.8±1.11 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}
	II	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}
2-Butanol	604	I 0.00±0.00 ^{da}	0.00±0.00 ^{da}	0.48±0.04 ^{aA}	0.59±0.02 ^{ba}	0.69±0.00 ^{aA}	0.00±0.00 ^{da}	0.00±0.00 ^{da}	0.48±0.04 ^{aA}	0.59±0.02 ^{ba}	0.69±0.00 ^{aA}
	II	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.17±0.01 ^{ab}	0.12±0.01 ^{ab}	0.51±0.42 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.17±0.01 ^{ab}	0.12±0.01 ^{ab}	0.51±0.42 ^{aA}
1-Butanol	667	I 0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	1.00±0.09 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	1.00±0.09 ^{aA}
	II	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.75±0.11 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.75±0.11 ^{aA}	0.00±0.00 ^{ba}
1-Penten-3-ol	693	I 0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}
	II	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.19±0.02 ^{aA}	0.11±0.06 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.19±0.02 ^{aA}	0.11±0.06 ^{aA}	0.00±0.00 ^{ba}
3-Methyl-1-butanol	738	I 0.09±0.01 ^{ba}	8.89±1.80 ^{aA}	2.51±0.03 ^{ba}	7.45±0.13 ^{aA}	8.24±0.64 ^{aA}	0.09±0.01 ^{ba}	1.98±0.08 ^{abA}	1.93±0.19 ^{abA}	3.31±1.26 ^{aA}	0.49±0.01 ^{ba}
	II	0.09±0.01 ^{ba}	0.24±0.00 ^{ba}	12.45±0.05 ^{aA}	1.58±0.57 ^{ba}	2.37±1.43 ^{ba}	0.09±0.01 ^{aA}	2.90±0.49 ^{aA}	1.52±0.27 ^{ba}	0.92±0.19 ^{baA}	1.59±0.16 ^{ba}
2-methyl-1-butanol	742	I 0.00±0.00 ^{aA}	1.21±0.00 ^{aA}	0.55±0.00 ^{ba}	1.55±0.06 ^{aA}	1.25±0.22 ^{aA}	0.00±0.00 ^{da}	0.00±0.00 ^{da}	0.50±0.00 ^{ba}	1.03±0.03 ^{aA}	0.13±0.01 ^{cb}
	II	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	1.80±0.00 ^{aA}	0.47±0.18 ^{ba}	0.61±0.36 ^{ba}	0.00±0.00 ^{aA}	0.54±0.06 ^{aA}	0.46±0.00 ^{abB}	0.32±0.00 ^{ba}	0.33±0.02 ^{ba}
1-Pentanol	766	I 0.04±0.01 ^{ba}	0.37±0.08 ^{aA}	0.08±0.03 ^{ba}	0.03±0.00 ^{ba}	0.09±0.01 ^{ba}	0.04±0.01 ^{ba}	0.37±0.08 ^{aA}	0.08±0.03 ^{ba}	0.03±0.00 ^{ba}	0.09±0.01 ^{ba}
	II	0.04±0.01 ^{ba}	0.04±0.01 ^{ba}	0.97±0.04 ^{aA}	0.33±0.16 ^{ba}	0.15±0.08 ^{ba}	0.04±0.01 ^{ba}	0.04±0.01 ^{ba}	0.97±0.04 ^{aA}	0.33±0.16 ^{ba}	0.15±0.08 ^{ba}
1-Hexanol	865	I 0.00±0.00 ^{aA}	0.52±0.10 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.26±0.08 ^{ba}	0.00±0.00 ^{ba}	0.31±0.01 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
	II	0.00±0.00 ^{ba}	0.02±0.00 ^{abB}	0.00±0.00 ^{ba}	0.12±0.06 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.34±0.08 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
1-Octen-3-ol	979	I 0.00±0.00 ^{ba}	0.18±0.01 ^{aA}	0.01±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.13±0.04 ^{aA}	0.16±0.00 ^{aA}	0.04±0.00 ^{ba}	0.02±0.00 ^{ba}
	II	0.00±0.00 ^{ba}	0.02±0.01 ^{ba}	0.15±0.02 ^{aA}	0.06±0.00 ^{ba}	0.05±0.00 ^{ba}	0.00±0.00 ^{aA}	0.18±0.08 ^{abA}	0.21±0.01 ^{aA}	0.04±0.00 ^{baA}	0.10±0.00 ^{abA}
Ketones											
1-methoxy-1-propanone	492	I 0.00±0.00 ^{aA}	0.63±0.16 ^{aA}	0.00±0.00 ^{aA}	9.12±1.17 ^{aA}	6.49±0.02 ^{ba}	0.00±0.00 ^{aA}	0.63±0.16 ^{aA}	0.00±0.00 ^{aA}	9.12±1.17 ^{aA}	6.49±0.02 ^{ba}
	II	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	9.64±0.23 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	9.64±0.23 ^{aA}
Acetone	493	I 1.57±0.37 ^{ba}	17.60±1.49 ^{aA}	15.46±1.09 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	1.57±0.37 ^{ba}	17.60±1.49 ^{aA}	15.46±1.09 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
	II	1.57±0.37 ^{ba}	8.32±6.60 ^{abA}	21.51±1.20 ^{aA}	5.99±5.95 ^{ba}	0.00±0.00 ^{ba}	1.57±0.37 ^{ba}	8.32±6.60 ^{abA}	21.51±1.20 ^{aA}	5.99±5.95 ^{ba}	0.00±0.00 ^{ba}
2,3-Butanedione	590	I 0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}
	II	0.00±0.00 ^{aA}	0.35±0.07 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.11±0.01 ^{ba}	0.00±0.00 ^{aA}	0.35±0.05 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.11±0.01 ^{ba}
2-Butanone	600	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 ^{ba}	0.00±0.00 ^{ba}	1.52±0.25 ^{aA}	1.67±0.03 ^{aA}	1.54±0.57 ^{aA}	0.00±0.00 ^{ba}
	II	0.00±0.00 ^{aA}	1.16±0.13 ^{ba}	1.56±0.02 ^{aA}	1.08±0.11 ^{ba}	1.21±0.01 ^{ba}	0.00±0.00 ^{aA}	1.16±0.13 ^{ba}	1.56±0.02 ^{aA}	1.08±0.11 ^{ba}	1.21±0.01 ^{ba}
2-Pentanone	697	I 0.00±0.00 ^{da}	0.66±0.01 ^{ba}	0.07±0.01 ^{ba}	1.26±0.04 ^{aA}	0.29±0.03 ^{aA}	0.00±0.00 ^{aA}	0.55±0.08 ^{aA}	0.37±0.00 ^{ba}	0.41±0.02 ^{ba}	0.32±0.01 ^{ba}
	II	0.00±0.00 ^{ba}	0.11±0.01 ^{ba}	0.25±0.01 ^{abA}	0.29±0.01 ^{abB}	0.48±0.18 ^{aA}	0.00±0.00 ^{aA}	0.52±0.03 ^{ba}	0.75±0.11 ^{aA}	0.38±0.02 ^{ba}	0.49±0.03 ^{ba}

Table 2. Continued

Compounds	KI ⁽³⁾	Semimembranosus muscle						Biceps femoris			
		Green ham	End of salting	30 days of dry-ripening	60 days of dry-ripening	100 days of dry-ripening	Green ham	End of salting	30 days of dry-ripening	60 days of dry-ripening	100 days of dry-ripening
3-methyl-2-pentanone	755	I	0.00±0.00 ^{ba}	0.13±0.01 ^{aA}	0.12±0.00 ^{ab}	0.00±0.00 ^{bb}	0.00±0.00 ^{ba}	0.17±0.01 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
		II	0.00±0.00 ^{aA}	0.08±0.00 ^{da}	0.29±0.01 ^{aA}	0.12±0.00 ^{ba}	0.00±0.00 ^{ba}	0.01±0.00 ^{ab}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
3-Heptanone	884	I	0.00±0.00 ^{ba}	0.08±0.01 ^{aA}	0.00±0.00 ^{bb}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.10±0.01 ^{aA}	0.01±0.00 ^{bb}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
	II	0.00±0.00 ^{ca}	0.04±0.00 ^{bb}	0.05±0.00 ^{aA}	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.00±0.00 ^{ba}	0.00±0.00 ^{bb}	0.02±0.00 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
2-Heptanone	888	I	0.01±0.00 ^{da}	0.15±0.01 ^{ab}	0.07±0.00 ^{bb}	0.06±0.00 ^{bca}	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 ^{da}	0.18±0.00 ^{ca}	0.24±0.01 ^{ba}	0.05±0.00 ^{da}	0.31±0.03 ^{aA}	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}
2,3-Octanedione	983	I	0.00±0.00 ^{ba}	0.36±0.10 ^{aA}	0.38±0.00 ^{aA}	0.00±0.00 ^{bb}	0.00±0.00 ^{ba}	0.27±0.03 ^{aA}	0.00±0.00 ^{bb}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
	II	0.00±0.00 ^{ba}	0.21±0.10 ^{aA}	0.26±0.01 ^{ab}	0.09±0.00 ^{aba}	0.12±0.01 ^{aba}	0.00±0.00 ^{ba}	0.04±0.00 ^{bb}	0.23±0.03 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
Acetophenone	1077	I	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.00±0.00 ^{cb}	0.02±0.00 ^{aA}	0.00±0.00 ^{ba}	0.15±0.01 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
	II	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.06±0.01 ^{ba}	0.02±0.01 ^{bca}	0.26±0.04 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{bb}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.14±0.04 ^{aA}
Esters											
Ethyl Acetate	613	I	0.00±0.00 ^{da}	0.00±0.00 ^{da}	0.20±0.01 ^{ca}	0.48±0.02 ^{ba}	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 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{bb}	0.45±0.16 ^{aba}	0.74±0.26 ^{aA}	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}
Ethyl 2-methylpropanoate	758	I	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{bb}	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}
	II	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.17±0.05 ^{aba}	0.39±0.17 ^{aA}	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}
Methyl 3-methylbutanoate	776	I	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{bb}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{bb}	0.05±0.00 ^{ab}
	II	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.10±0.01 ^{aA}	0.10±0.01 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.10±0.01 ^{aA}	0.10±0.01 ^{aA}
Ethyl 2-methylbutanoate	846	I	0.00±0.00 ^{da}	0.00±0.00 ^{db}	0.16±0.01 ^{ca}	0.56±0.02 ^{ba}	0.00±0.00 ^{da}	0.00±0.00 ^{da}	0.16±0.01 ^{ca}	0.56±0.02 ^{ba}	0.65±0.01 ^{ab}
	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}	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}
Ethyl 3-methylbutanoate	851	I	0.00±0.00 ^{ea}	0.13±0.01 ^{da}	0.37±0.03 ^{ca}	1.26±0.01 ^{ba}	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}
	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}	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}
Ethyl hexanoate	997	I	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.00±0.00 ^{cb}	0.04±0.01 ^{ba}	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.00±0.00 ^{cb}	0.04±0.01 ^{ba}	0.08±0.00 ^{ab}
	II	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.03±0.00 ^{ba}	0.04±0.00 ^{ba}	0.23±0.01 ^{aA}	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.03±0.00 ^{ba}	0.04±0.00 ^{ba}	0.23±0.01 ^{aA}
Ethyl octanoate	1195	I	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.03±0.00 ^{aA}
	II	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}
Ethyl decanoate	1393	I	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.03±0.00 ^{aA}
	II	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}
Alkanes and alkenes											
Hexane	600	I	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	4.71±0.05 ^{aA}
	II	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}	0.00±0.00 ^{ab}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}
Heptane	700	I	0.32±0.15 ^{aba}	0.55±0.14 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.32±0.15 ^{aba}	0.55±0.14 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
	II	0.32±0.15 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.32±0.15 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
2-Octene	808	I	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.08±0.01 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.08±0.01 ^{aA}	0.00±0.00 ^{ba}
	II	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.08±0.01 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.08±0.01 ^{aA}	0.00±0.00 ^{ba}
Styrene	896	I	0.00±0.00 ^{ca}	0.22±0.01 ^{aA}	0.13±0.01 ^{ba}	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.22±0.01 ^{aA}	0.13±0.01 ^{ba}	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}
	II	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}	0.00±0.00 ^{ab}	0.02±0.01 ^{aA}	0.06±0.01 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}	0.00±0.00 ^{ab}	0.02±0.01 ^{aA}	0.06±0.01 ^{aA}

Table 2. Continued

Compounds	Kl ⁽³⁾	Semimembranosus muscle						Biceps femoris			
		Green ham	End of salting	30 days of dry-ripening	60 days of dry-ripening	100 days of dry-ripening	Green ham	End of salting	30 days of dry-ripening	60 days of dry-ripening	100 days of dry-ripening
Sulfur compounds											
Methanethiol	415	I	0.00±0.00 ^{ba}	0.38±0.14 ^{ba}	11.59±1.89 ^{aA}	0.00±0.00 ^{bb}	0.00±0.00 ^{ba}	0.38±0.14 ^{ba}	11.59±1.89 ^{aA}	0.00±0.00 ^{bb}	0.00±0.00 ^{bb}
		II	0.00±0.00 ^{da}	0.00±0.00 ^{da}	0.07±0.01 ^{cb}	1.73±0.02 ^{aA}	0.95±0.03 ^{ba}	0.00±0.00 ^{da}	0.00±0.00 ^{da}	0.07±0.01 ^{cb}	1.73±0.02 ^{aA}
Dimethyl disulfide	751	I	0.00±0.00 ^{ba}	0.47±0.01 ^{abA}	0.41±0.03 ^{abA}	0.83±0.52 ^{aA}	0.00±0.00 ^{ba}	0.47±0.01 ^{abA}	0.41±0.03 ^{abA}	0.83±0.40 ^{aA}	0.95±0.06 ^{aA}
		II	0.00±0.00 ^{ba}	0.24±0.06 ^{ba}	1.85±0.40 ^{aA}	0.41±0.02 ^{ba}	0.00±0.00 ^{bb}	0.00±0.00 ^{ba}	0.24±0.06 ^{ba}	1.85±0.40 ^{aA}	0.00±0.00 ^{bb}
Dimethyl trisulfide	982	I	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.08±0.00 ^{aA}	0.07±0.01 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.08±0.00 ^{aA}	0.07±0.01 ^{aA}
		II	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}	0.00±0.00 ^{ab}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}	0.00±0.00 ^{ab}
Benzothiazole	1252	I	0.01±0.00 ^{ca}	0.20±0.03 ^{aA}	0.07±0.01 ^{ba}	0.07±0.01 ^{ba}	0.04±0.00 ^{bca}	0.01±0.00 ^{ca}	0.20±0.03 ^{aA}	0.07±0.01 ^{ba}	0.04±0.00 ^{bca}
		II	0.01±0.00 ^{ca}	0.14±0.02 ^{aA}	0.10±0.02 ^{abA}	0.05±0.01 ^{bca}	0.04±0.00 ^{ca}	0.01±0.00 ^{ca}	0.14±0.02 ^{aA}	0.10±0.02 ^{abA}	0.04±0.00 ^{ca}
Nitrogenous compounds											
Trimethylamine	421	I	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.61±0.09 ^{ba}	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.61±0.09 ^{ba}	1.95±0.26 ^{aA}
		II	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}	0.00±0.00 ^{ab}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}	0.00±0.00 ^{ab}
Dimethylamine	520	I	0.00±0.00 ^{ba}	0.42±0.03 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.42±0.03 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}
		II	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ab}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}
2,4-Dimethyl pyrimidine	915	I	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.01±0.00 ^{ba}	0.02±0.00 ^{aA}	0.00±0.00 ^{ca}	0.00±0.00 ^{ca}	0.01±0.00 ^{ba}	0.02±0.00 ^{aA}
		II	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{bb}	0.04±0.01 ^{aA}	0.00±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{bb}	0.04±0.01 ^{aA}
Chloride compounds											
1,4-Dichlorobenzene	1027	I	0.01±0.00 ^{ca}	0.18±0.03 ^{aA}	0.09±0.01 ^{ba}	0.05±0.01 ^{bca}	0.02±0.00 ^{cb}	0.01±0.00 ^{ca}	0.18±0.03 ^{aA}	0.09±0.01 ^{ba}	0.02±0.00 ^{cb}
		II	0.01±0.00 ^{da}	0.25±0.01 ^{aA}	0.11±0.01 ^{ba}	0.04±0.00 ^{ca}	0.03±0.00 ^{ca}	0.01±0.00 ^{da}	0.25±0.01 ^{aA}	0.11±0.01 ^{ba}	0.04±0.00 ^{ca}
Aromatic and cyclic hydrocarbons											
Toluene	771	I	0.05±0.00 ^{da}	0.23±0.02 ^{aA}	0.11±0.01 ^{cb}	0.15±0.01 ^{ba}	0.10±0.00 ^{ca}	0.05±0.00 ^{da}	0.23±0.02 ^{aA}	0.11±0.01 ^{cb}	0.10±0.00 ^{ca}
		II	0.05±0.00 ^{ca}	0.05±0.01 ^{cb}	0.25±0.01 ^{ba}	0.16±0.02 ^{bca}	0.45±0.10 ^{aA}	0.05±0.00 ^{ca}	0.05±0.01 ^{cb}	0.25±0.01 ^{ba}	0.16±0.02 ^{bca}
p-Xylene	873	I	0.03±0.01 ^{ca}	0.21±0.00 ^{aA}	0.06±0.01 ^{bb}	0.00±0.00 ^{db}	0.00±0.00 ^{da}	0.03±0.01 ^{ca}	0.21±0.00 ^{aA}	0.06±0.01 ^{bb}	0.00±0.00 ^{db}
		II	0.03±0.01 ^{ca}	0.02±0.00 ^{cb}	0.16±0.01 ^{aA}	0.05±0.00 ^{bca}	0.09±0.04 ^{ba}	0.03±0.01 ^{ca}	0.02±0.00 ^{cb}	0.16±0.01 ^{aA}	0.05±0.00 ^{bca}
Ethylbenzene	864	I	0.03±0.00 ^{ba}	0.00±0.00 ^{ca}	0.00±0.00 ^{cb}	0.06±0.01 ^{aA}	0.04±0.00 ^{abB}	0.03±0.00 ^{ba}	0.00±0.00 ^{da}	0.05±0.00 ^{aA}	0.00±0.00 ^{ca}
		II	0.03±0.00 ^{ca}	0.00±0.00 ^{da}	0.24±0.01 ^{aA}	0.04±0.01 ^{ca}	0.10±0.01 ^{ba}	0.03±0.00 ^{ba}	0.00±0.00 ^{ba}	0.00±0.00 ^{bb}	0.09±0.04 ^{aA}
Styrene	896	I	0.00±0.00	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ca}	0.34±0.01 ^{aA}	0.08±0.01 ^{ba}	0.00±0.00 ^{ca}
		II	0.00±0.00	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{ba}	0.02±0.00 ^{bb}	0.09±0.01 ^{aA}	0.00±0.00 ^{ca}
Biphenyl	1407	I	0.02±0.00 ^{ca}	0.09±0.01 ^{aA}	0.09±0.00 ^{aA}	0.07±0.01 ^{abA}	0.05±0.00 ^{ba}	0.02±0.00 ^{ba}	0.06±0.01 ^{aA}	0.02±0.00 ^{ba}	0.02±0.00 ^{ba}
		II	0.02±0.00 ^{ca}	0.05±0.00 ^{ba}	0.08±0.00 ^{aA}	0.07±0.01 ^{ba}	0.06±0.00 ^{ba}	0.02±0.00 ^{ba}	0.02±0.00 ^{bb}	0.08±0.03 ^{abA}	0.06±0.02 ^{abA}
Acenaphthylene	1492	I	0.01±0.00 ^{da}	0.07±0.01 ^{aA}	0.06±0.00 ^{ba}	0.03±0.01 ^{ca}	0.02±0.00 ^{cdA}	0.01±0.00 ^{bca}	0.05±0.01 ^{aA}	0.02±0.00 ^{bb}	0.00±0.00 ^{ca}
		II	0.01±0.00 ^{da}	0.05±0.01 ^{aA}	0.03±0.01 ^{bb}	0.02±0.00 ^{cdA}	0.02±0.00 ^{bca}	0.01±0.00 ^{ba}	0.01±0.00 ^{bb}	0.04±0.00 ^{abA}	0.06±0.02 ^{aA}
Dibenzofuran		I	0.01±0.00 ^{ca}	0.20±0.04 ^{aA}	0.08±0.00 ^{ba}	0.05±0.01 ^{bca}	0.03±0.00 ^{bca}	0.01±0.00 ^{ba}	0.12±0.02 ^{aA}	0.02±0.00 ^{bb}	0.01±0.00 ^{ba}
		II	0.01±0.00 ^{ca}	0.12±0.01 ^{aA}	0.06±0.01 ^{bb}	0.03±0.01 ^{ca}	0.03±0.00 ^{ca}	0.01±0.00 ^{ba}	0.02±0.00 ^{bb}	0.06±0.01 ^{abA}	0.08±0.03 ^{aA}
Fluorene		I	0.01±0.00 ^{ba}	0.12±0.03 ^{aA}	0.04±0.00 ^{ba}	0.04±0.01 ^{ba}	0.03±0.00 ^{ba}	0.01±0.00 ^{ba}	0.07±0.01 ^{aA}	0.01±0.00 ^{bb}	0.01±0.00 ^{ba}
		II	0.01±0.00 ^{ca}	0.06±0.00 ^{aA}	0.05±0.01 ^{abA}	0.03±0.01 ^{bca}	0.02±0.00 ^{bcb}	0.01±0.00 ^{ba}	0.01±0.00 ^{ba}	0.03±0.00 ^{abA}	0.07±0.03 ^{aA}

Table 2. Continued

Compounds	Kl ⁽³⁾	Semimembranosus muscle					Biceps femoris				
		Green ham	End of salting	30 days of dry-ripening	60 days of dry-ripening	100 days of dry-ripening	Green ham	End of salting	30 days of dry-ripening	60 days of dry-ripening	100 days of dry-ripening
Others											
Pyruvic acid	I	0.10±0.01 ^{cA}	0.53±0.10 ^{aA}	0.44±0.05 ^{aBA}	0.39±0.02 ^{aBA}	0.30±0.01 ^{bA}	0.10±0.01 ^{bA}	0.29±0.03 ^{aA}	0.12±0.01 ^{BB}	0.14±0.01 ^{bA}	0.11±0.01 ^{bA}
	II	0.10±0.01 ^{dA}	0.38±0.03 ^{aBA}	0.43±0.01 ^{aA}	0.33±0.04 ^{b,cA}	0.29±0.01 ^{cA}	0.10±0.01 ^{bA}	0.11±0.01 ^{BB}	0.31±0.04 ^{bA}	0.30±0.08 ^{bA}	0.71±0.18 ^{aA}
Pinene	I	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{bA}	0.06±0.00 ^{aA}	0.00±0.00 ^{bA}	0.00±0.00 ^{bA}	0.00±0.00 ^{bA}
	II	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aB}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}	0.00±0.00 ^{aA}
2-Pentyl furan	I	0.02±0.01 ^{bA}	0.00±0.00 ^{BB}	0.08±0.02 ^{aA}	0.00±0.00 ^{BB}	0.02±0.01 ^{BB}	0.02±0.01 ^{bA}	0.32±0.03 ^{aA}	0.04±0.00 ^{bA}	0.00±0.00 ^{BB}	0.00±0.00 ^{bA}
	II	0.02±0.01 ^{cA}	0.27±0.03 ^{aA}	0.13±0.03 ^{bA}	0.02±0.00 ^{cA}	0.05±0.00 ^{cA}	0.02±0.01 ^{b,cA}	0.00±0.00 ^{CB}	0.11±0.02 ^{aA}	0.05±0.00 ^{bA}	0.05±0.01 ^{bA}
D-Limonene	I	0.04±0.00 ^{bA}	0.17±0.06 ^{aA}	0.09±0.01 ^{aBA}	0.08±0.01 ^{aBA}	0.00±0.00 ^{bA}	0.04±0.00 ^{bA}	0.17±0.06 ^{aA}	0.09±0.01 ^{aBA}	0.08±0.01 ^{aBA}	0.00±0.00 ^{bA}
	II	0.04±0.00 ^{aA}	0.02±0.01 ^{aA}	0.04±0.00 ^{aB}	0.09±0.08 ^{aA}	0.13±0.10 ^{aA}	0.04±0.00 ^{aA}	0.02±0.01 ^{aA}	0.04±0.00 ^{aB}	0.09±0.08 ^{aA}	0.13±0.09 ^{aA}

¹⁾Values are mean±standard error (n=5).

²⁾a-e Means in the same row with different superscripts differ significantly (p<0.05). A-e Means in the same compound batch with different superscripts differ significantly (p<0.05).

³⁾Kl, Kovats index calculated for DB-5MS column analysis (60 m, 0.25 mm id, film thickness of 1 µm) installed on a gas chromatograph equipped with a mass-selective detector.

volatiles in green ham and the high ethanol content in ham products was most likely due to processing. There was a significant ($p < 0.05$) difference in ethanol contents between the 2 salt formulations at the end of both the salting and ripening stages for SM, and only at the end of the salting stage for BF samples. Hams salted with formulation II showed significantly ($p < 0.05$) higher levels of ethanol than hams salted with formulation I. Partial replacement of NaCl with KCl probably enhanced microbial growth and generated more ethanol, which contributed little to the overall flavor of dry-cured ham because of a high odor threshold value (25).

2-Methylbutanol and 3-methylbutanol, derivatives of 2-methylbutanal and 3-methylbutanal reduction, respectively (24), are probably important volatile compounds of dry-cured ham due to relatively low odor threshold values (24). Compared with formulation I, treatment with formulation II resulted in significantly ($p < 0.05$) increased formation of these 2 methyl alcohols. Thus, KCl substitution had a significant ($p < 0.05$) effect for increasing formation of 2-methylbutanol and 3-methylbutanol, compared with controls (Table 2). However, a significant ($p > 0.05$) difference was not observed for BF samples, compared with controls, probably due to reduced levels of chemical reduction of corresponding branched aldehydes by microbial enzymes because of low microbial counts in hams, conditions that are unfavorable for microbial growth, resulting in (26) low microbial enzyme activity levels (27).

The secondary alcohol 1-octen-3-ol derived from linoleic acid oxidation provided a mushroom note (25,28). For SM samples, no significant ($p \geq 0.05$) difference was found during processing between the 2 salt formulations, except at the end of processing. However, for BF samples, formulation II significantly ($p < 0.05$) increased formation of 1-octen-3-ol during processing, compared with controls. Thus, NaCl may not have exerted a salting out effect due to release 1-octen-3-ol, as reported by Flores *et al.* (19) for Spanish Serranot dry-cured hams.

Ketones Ketone contents increased significantly ($p < 0.05$) after salting, compared with controls (Fig. 1C and 2C), similar to a previous report (9). Nevertheless, variation in ketone contents between the 2 different salt formulations was observed during processing (Table 2). The maximum percentage of total ketones appeared at the end of the salting stage for formulation I, while the highest level was reached after 30 days of dry-ripening for formulation 2. Nine ketones were identified, including 2-pentanone, 2-hexanone, 2-heptanone, 2,3-butanedione, 2,3-octanedione, and acetone, which was the most common ketone identified in this study. Hams salted with formulation II produced significantly ($p < 0.05$) more ketones, compared with controls. 2-Ketones are considered to have a great effect on meat (22) and are believed to be products of autoxidation or β -oxidation of fatty acids (29). Replacement of NaCl with KCl apparently promoted oxidation of fatty acids.

Esters Changes in ester levels during ham processing are shown in

Fig. 1D and 2D. Effects of both salt formulations on ester contents in SM samples were significant ($p < 0.05$) for all processing times. No significant ($p > 0.05$) difference was observed in BF samples until the final stage of dry-ripening. No esters were detected in green hams. Differences between the 2 sample types may have been due to differences in penetration speeds of different salts, which affected formation of volatile compounds during processing (23). Ethyl 2-methylbutanoate accounted for most esters in Jinhua hams (13), the content of which in hams salted with formulation II was significantly ($p < 0.05$) higher than in hams salted using formulation I. The same relationship was observed for the ethyl 3-methylbutanoate content. Substitution of KCl for NaCl in hams might have accelerated proteolysis (6), generated more alcohols, and formed more esters in reactions with free fatty acids. The esters ethyl 2-methylbutanoate and ethyl acetate were also identified in cured hams (13,15). Ethylesters were formed by combination of ethyl alcohol and acids during processing (16). Formation of methyl-branched, short-chain esters was found to be positively related to aging of meat (30).

Alkanes and alkenes Changes in formation of alkanes and alkenes in processed hams during processing are shown in Fig. 1E and 2E. Levels of alkanes and alkenes increased significantly ($p < 0.05$) in processed hams using both formulations, compared with controls, by the end of the salting period. However, a sharp decrease was observed in BF samples during the ripening stage for both salt formulations. On the contrary, alkane levels significantly ($p < 0.05$) increased during processing in SM samples using formulation II, compared with controls. However, with formulation I, alkane levels first decreased, then sharply increased at the end of dry-ripening, perhaps attributable to differences in degradation and intermolecular rearrangement of fatty acids and amino acids in different ham parts (9). Since alkanes and alkenes have relatively high odor threshold levels, both have almost no contribution to overall aromas of dry-cured hams (31).

Sulfur compounds Sulfur compounds mainly originate from methionine, cysteine, and cystine via Strecker degradation of thiols (20). Changes in levels of volatile sulfur compounds during Jinhua ham processing are shown in Fig. 1F and 2F. The 4 sulfur compounds identified in this study were methanethiol, dimethyl disulfide, dimethyl trisulfide, and benzothiazole, in agreement with results reported by Huan *et al.* (13). Both salting formulations affected the content of methanethiol in BF samples during dry-ripening. Hams treated with 100% NaCl exhibited a significantly ($p < 0.05$) higher methanethiol content, compared with controls. Relatively low sulfur compound levels provided important contributions to the overall flavor of hams because of low threshold values, lower than for other volatile compounds.

Nitrogenous compounds Only trace levels of nitrogenous compounds were detected throughout processing (Fig. 1G and 2G). A continued

Fig. 1. Evolution of volatile compounds (A, Aldehydes; B, Alcohols; C, Ketones; D, Esters; E, Alkanes and alkenes; F, Sulfur compounds; G, Nitrogenous compounds; H, Chloride compounds) in semi membranous muscle tissues during Jinhua ham processing. (▲) Formulation I of 100% NaCl, and (○) formulation II of 60% NaCl and 40% KCl. Error bars indicate standard error for each mean value. Different letters indicate significant differences between the 2 salt formulations ($p < 0.05$).

Fig. 2. Evolution of volatile compounds (A, Aldehydes; B, Alcohols; C, Ketones; D, Esters; E, Alkanes and alkenes; F, Sulfur compounds; G, Nitrogenous compounds; H, Chloride compounds) in Biceps femoris muscle tissues during Jinhua ham processing, ($\blacktriangle$) formulation I of 100% NaCl, and ($\bigcirc$) formulation II of 60% NaCl and 40% KCl. Error bars indicate standard error for each mean value. Different letters indicate significant differences between the 2 salt formulations ($p < 0.05$).

Table 3. Mean values of sensory traits of semi membranous and biceps femoris muscle tissues from Jinhua hams prepared using different salt formulations: I: Control, 100% NaCl; II: 60% NaCl and 40% KCl

Sensory traits	Semimembranosus		Biceps femoris	
	I	II	I	II
Redness	6.24±0.85 ^{a1)}	6.01±0.32 ^a	5.81±0.41 ^{A2)}	5.31±0.29 ^A
Yellowness	3.03±0.45 ^a	3.01±0.11 ^a	3.12±0.27 ^A	3.22±0.09 ^A
Hardness	5.45±0.29 ^a	5.85±0.46 ^a	4.44±0.37 ^A	4.87±0.22 ^A
Juiciness	4.41±0.31 ^a	4.25±0.26 ^a	5.33±0.16 ^A	5.31±0.30 ^A
Aroma intensity	4.59±0.23 ^a	4.14±0.31 ^a	4.64±0.24 ^A	4.35±0.45 ^A
Saltiness	5.09±0.27 ^a	4.01±0.41 ^b	5.72±0.43 ^A	4.60±0.35 ^B
Bitterness	1.10±0.22 ^a	1.14±0.29 ^a	1.29±0.37 ^A	1.28±0.46 ^A
After-taste	4.55±0.21 ^a	4.24±0.33 ^a	4.65±0.44 ^A	4.48±0.22 ^A

¹⁾a-b: Means in the same row with different superscripts differ significantly for Semimembranosus ($p<0.05$) ($n=30$).

²⁾A-B: Means in the same row with different superscripts differ significantly for Biceps femoris ($p<0.05$) ($n=30$).

significant ($p<0.05$) increase in nitrogenous compound levels was detected in Jinhua ham throughout processing, compared with controls. Generally, pyrazine is a typical product of Maillard reactions during meat cooking (13). Numbers and content levels of nitrogenous compounds in this study were lower than reported by Huan *et al.* (13), probably due to a relative short ripening time in this study, compared with traditional Jinhua ham processing of approximately 300 ripening days. In this study, the nitrogenous compounds trimethylamine and dimethylamine were identified in cured BF samples, which were not previously reported (25). There was no significant ($p\geq 0.05$) difference in formation of 2,4-dimethyl pyrimidine between the 2 salt formulations and also during processing (Table 2).

Chloride compounds Changes in chloride compound levels during processing are shown in Fig. 1H and 2H. Methylene chloride, a major volatile chloride compound, was only found in green ham. Du and Ahn (9) concluded that chloride volatiles in hams did not originate from meat products but did originate from packaging materials or from pesticide residues ingested by pigs.

Others 2-Pentyl-furan, which is supposedly an oxidation product of linoleic acid, is usually found in dry-cured hams (19). In this study, use of formulation II resulted in significantly ($p<0.05$) higher levels of 2-pentyl furan in Jinhua hams than use of formulation I, in agreement with the aforementioned results for 1-octen-3-ol, which is also considered to be a derivative of linoleic acid oxidation.

Sensory analysis Sensory analytical study of dry-cured hams salted using the 2 formulations are shown in Table 3. Substitution of KCl for NaCl did not significantly ($p>0.05$) affect any sensory characteristics for both SM and BF samples, compared with controls, except saltiness. This implies that a significant effect was in disagreement with a report of Armentero *et al.* (32) that replacement of NaCl with up to 50% KCl did not affect sensory attributes (32). Replacement of NaCl with 40% KCl probably resulted in a reduced salty dry-cured ham taste that was evaluated positively by assessors (26). Moreover, salt

is not the only factor determining a salty taste, which can also be influenced by amino acids and nucleotides (16).

In conclusion, 40% replacement of NaCl with KCl had an influence on formation of volatile compounds throughout processing of dry-cured hams in both SM and BF muscle tissues. Increased formation and/or release of volatile compounds was observed 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. Formulation II of 60% NaCl and 40% KCl promoted formation of lipid-derived aldehydes, Strecker aldehydes, alcohols, and methyl-branched aldehydes from amino acids. Thus, replacement of NaCl with 40% KCl influenced the aroma of Jinhua ham. However, sensory analysis of final products indicated that it was possible to reduce the NaCl content by 40% in dry-cured ham without adverse effects on sensory properties to satisfy consumer demands and health requirements. Confirmation of whether partial replacement of NaCl with KCl will affect the safety and overall acceptability of final products will require further study.

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