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

Yingyang Zhang¹, Haizhou Wu, Jing Tang, Mingming Huang, Jianying Zhao, and Jianhao Zhang*

National Center of Meat Quality and Safety Control, Synergetic Innovation Center of Food Safety and Nutrition, College of Food Science and Technology, Nanjing Agricultural University, Nanjing, Jiangsu Province, 210095, China
¹School of Food Science and Technology, Changzhou University, Changzhou, Jiangsu Province, 213164, China

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 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 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.

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, 210000, China).
China) of 6.8-7.8 kg each from Taihu× 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 NIST DEMO, MAINLIB, WILEY, and REPULB 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...