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Effect of beating processing, as a means of reducing salt content in frankfurters: A physico-chemical and Raman spectroscopic study

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ABSTRACT

Structural changes, L^*-value, cooking yield changes and textural properties of pork frankfurters containing 1% or 2% salt, produced by the two methods were studied by Raman spectroscopy and texture profile analysis. Increasing salt content from 1% to 2% increased the L^*-value, cooking yield and hardness, and decreased ($p < 0.05$) the C-H stretching and CH_2 and CH_3 bending vibrations, but did not affect the changes of secondary structures, tryptophan or tyrosine residues. Compared with the chopping, the beating increased L^*-value, cooking yield and hardness of the frankfurters in both salt concentrations. It also resulted in an increase in β-sheets, accompanied by a significant ($p < 0.05$) decrease in α-helix content, a greater exposure of tyrosine residues to the polar environment and a decrease in the C – H stretching and CH_2 and CH_3 bending vibrations. The results showed that the beating process enabled lowering of the salt content while improving the L^*-value, cooking yield and hardness of the frankfurters.

1. Introduction

Frankfurters are widely consumed meat products in certain sections of the global population (Delgado-Pando, Cofrades, Ruiz-Capillas, & Jimenez-Colmenero, 2010). The sausage batters could be classified three phases: a liquid continuous phase which includes water and soluble proteins, ions; a dispersed liquid phase and a dispersed solid phase which contain fat droplets and non-solvated muscle fiber particles, connective tissue, spices, respectively (Tintchev et al., 2013). Myofibrillar proteins determine the water- and fat- binding capacity, gel-forming capacity and textural characteristics of the meat batters (Whiting, 1988). The salt is a key factor in the solubilisation of the myofibrillar proteins, thus, its content is markedly affected of emulsion formation and stability of the emulsified meats (Sikes, Tobin, & Tume, 2009). However, some authors have reported that overconsumption of salt can raise hypertension and lead to cardiovascular disease, among other ailments (Hazen, 2010; Sacks, Svetkey, & Vollmer, 2001; Toldrá & Reig, 2011).

How to reduce salt without sacrificing product quality is a challenge for the meat industry (Desmond, 2006). For reducing the salt of frankfurters, some researchers have demonstrated the possible utilization methods, such as use of salt substitutes (Barbut, Maurer, & Lindsay, 1988), naturally brewed soy sauce (McGough, Sato, Rankin, & Sindelar, 2012a), natural flavor enhancers (McGough, Sato, Rankin, & Sindelar, 2012b), and transglutaminase (Colmenero, Ayo, & Carballo, 2005). Utilized processing techniques to reduce salt had few ways, such as high pressure and used pre-rigor meat, but they are limited in factory (Claus & Sorheim, 2006; Tintchev et al., 2013). Therefore, there is still a need to find a novel processing technique to decrease salt without sacrificing frankfurters quality. A novel processing technique, beating process, is the traditional way that kung-wan was produced in Asian communities. The qualities of kung-wan have a significant difference from frankfurter. Consumers prefer tender and juicier frankfurters, while they prefer harder, more elastic and juicy enough kung-wan products served in hot soup (Hsu & Chung, 1999). Kung-wans produced by the beating process could reduce NaCl content from 2% to 1%, and also had a better quality than the chopping with 2% NaCl (Kang et al., 2014). To our knowledge, no research that utilized the beating process to produce low-salt frankfurter was reported.

Raman spectroscopy is a non-invasive and direct technique, which can give information on peptide backbone conformations such as secondary and tertiary structures of meat proteins (Herrero, 2008a; Li-Chan, Nakai, & Hirotsuka, 1994; Tuma, 2005). The changes of Tryptophan residues and Tyrosine doublet bands could provide the information on protein unfolding and hydrogen bond, and they could affect the characteristics of meat batter (Herrero, 2008a; Herrero, 2008b; Shao, Zou, Xu, Wu, & Zhou, 2011). This method has been used to study the structural changes of meat systems during thermal gelation and used different processes such as high pressure (Pedersen, Morel, Andersen, & Engelsen, 2003; Schmidt, Scheier, & Hopkins, 2013; Tintchev et al., 2010). In emulsified meat systems, identification of the structural changes in meat proteins caused by salt during processing,

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and their interaction, may be beneficial for understanding the mechanisms, thereby improving the cooking yield and texture of frankfurter having a low-salt content. Therefore, the objective of this work was to determine protein structural differences and physico-chemical differences on frankfurters which were processed by beating or chopping the meat, and thereby to establish a procedure to obtain frankfurters of a desirable quality.

2. Materials and methods

2.1. Raw materials and ingredients

Pork leg lean meat (71.18% moisture, 20.47% protein, 7.14% fat and pH 5.78) and backfat (8.30% moisture, 1.68% protein and 89.82% fat, AOAC, 2000) were purchased from a local meat market (Nanjing, China). The purchased meat parts were randomly divided for the two batches, and they contained the muscles from the same pigs. All subcutaneous and intramuscular fat and visible connective tissues were removed from the pork meat. The lean meat and pork backfat were separately ground through a 6 mm plate (MM-12, Guangdong, China). The ground meat (1.0 kg each) was packaged in double plastic (nylon/PE) bags and store −20 °C until use within 2 weeks. The raw materials and other ingredients are shown in Table 1.

2.2. Preparation of frankfurters

The meat batters were prepared by either chopping or beating process. For the chopping method, the batters were prepared using a typical emulsification procedure in a vacuum cutter bowl (Stephan UMC-5C, Germany) as described by Lin and Lin (2004) and modified: the thawed ground meat was chopped (1500 rpm) with salt, sodium tripolyphosphate and 1/3 ice for 30 s, followed by a 3 min rest; the pork backfat, spices and 2/3 ice were added and chopped (1500 rpm) for 30 s, followed by a 3 min rest; then finished with a high speed (3000 rpm) emulsification for 60 s (final temperature less than 10 °C). For the beating method, the thawed ground meat was processed using a beating machine (MC-6, Shandong, China; Capacity: 3 L) according to the processing in below: the thawed ground meat was beat with salt, sodium tripolyphosphate and 1/3 ice for 10 min (200 rpm); followed by the pork backfat, spices and 2/3 ice were mixed (200 rpm) to the batter for 5 min (final temperature less than 10 °C). Immediately after chopping and beating, the batter was stuffed by a vacuum stuffer (VF608, Germany), in 24 mm diameter edible collagen sausage casings (Shenguan Holdings (Group) Limited, China). Frankfurters were hand linked at 18 cm intervals, weighed, heat processed in smokehouse (T1900 El619, Germany) according to the following processing cycle: drying for 15 min at 50 °C and 60% relative humidity (RH), and steam cooking for 25 min at 80 °C and 100% relative humidity (RH) to an internal temperature of 72 °C, then showered for 15 min and drying for 10 min at 30 °C and 60% RH; removed from the smokehouse and chilled at 2 °C overnight. Each product was prepared in four replications and twenty sausages were used for each replicate.

Table 1
Formulation (%) of frankfurters when produced by chopping (C) or beating (T) process with various amounts of added salts.

Ingredient (g)	C1	C2	T1	T2
Lean pork	1500	1500	1500	1500
Backfat	480	480	480	480
Ice	408	408	408	408
Polyphosphate	7.2	7.2	7.2	7.2
Salt	24	48	24	48
Spices	15.6	15.6	15.6	15.6

C1, T1: 1% NaCl; C2, T2: 2% NaCl.

2.3. Cooking yield

After cooling at 2 °C overnight, the frankfurters were weighed and the percentage weight yield was calculated using the following formula:

$$\text{Cooking yield\%} = \text{eight of sausage after cooking/weight of sausage before cooking} \times 100.$$

2.4. Color measurement

The color of frankfurter was measured using a Minolta chromameter (CR-40, Minolta Camera Co., Japan), calibrated with a white plate ($L^* = 96.86$, $a^* = -0.15$, $b^* = 1.87$). Five samples from each formulation or processing method were evaluated for internal color (L^*-value, Lightness) of the frankfurters, and each fresh slice was measured three times within 1 min.

2.5. Hardness

After cooling at 2 °C overnight, the frankfurters were stay at room temperature for 2 h. The hardness attributes of the frankfurter was determined using a texture analyzer (TA-XT. plus, Stable Micro system Ltd., Surry, UK) at room temperature. Hardness parameters were determined using five cooked cores (each diameter 20 mm, height 20 mm). The conditions were as follows: test speed 2.0 mm/s; strain 50%, time 5.0 s; and trigger force 5 g. The cylinder probe (P/50, 50 mm stainless cylinder) of the texture analyzer mold was used. Attributes were calculated as follows: hardness, the peak force (N) required for the first compression (Bourne, 1978).

2.6. Raman spectroscopic

Raman experiments were determined using a modified procedure of Shao et al. (2011). Raman experiments were conducted with a HR800 spectrometer (Horiba/Jobin. Yvon, Longjumeau, France). Each spectrum of fresh sausage slice was obtained under the following conditions: 3 scans, 30 s exposure time, 2 cm^{-1} resolution, a sampling speed of 120 cm^{-1}/min with data collected every 1 cm^{-1}. The time required for the acquisition of 1 spectrum was about 2 min. Spectra were smoothed, baselines corrected and normalized against the phenylalanine band at 1003 cm^{-1} (Herrero, 2008b) using Labspec version 3.01c (Horiba/Jobin. Yvon, Long-jumeau, France). The secondary structures of the cooked kung-wans proteins were determined as percentages of α-helix, β-sheet, β-turn, and random coil or unordered conformations (Alix, Pedanou, & Berjot, 1988). With this aim, the water spectrum was subtracted from the spectra by following the same criteria as that described previously (Alix et al., 1988; Herrero, Carmona, Pintado, Jimenez-Colmenero, & Ruiz-Capillas, 2011).

2.7. Statistical analysis

Data were analyzed using the statistical software package SPSS v.18.0. The data was analyzed using the one-way ANOVA program. The difference between means was considered significant at $p < 0.05$. Significant differences between means were identified by the LSD procedure.

3. Results and discussion

3.1. Cooking yield

Both the chopping and beating processes and salt content had significant effects ($p < 0.05$) on cooking yields (Fig. 1). The beating treatment with 2% NaCl (T2) gave the highest cooking yield, followed by that with 1% NaCl (T1) and both were significantly ($p < 0.05$) higher than with