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Effect of pre-emulsified soy oil with soy protein isolate in frankfurters: A physical-chemical and Raman spectroscopy study

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ABSTRACT

In this study, the changes of protein structure, proximate composition and physico-chemical attributes of frankfurters (1% NaCl) with pre-emulsified soy oil used in the beating processing were investigated. Three samples were prepared: C, with pork backfat; T1, with pre-emulsified soy oil (soy protein isolate (SPI): soy: water was 1:10:10); T2, with pre-emulsified soy oil (SPI: soy: water was 1:5:5). The energy and fat content decreased while the protein content, L^* value, cooking yield and textural properties of frankfurters increased when substituting backfat with pre-emulsified soy oils. The microstructure of C showed a spongy appearance with numerous cavities, then T1 and T2 showed more cavity formation and SPI dispersed around the oil globules. There were significantly ($p < 0.05$) affected the secondary and tertiary structures of protein, an increase of β-sheet, β-turn and random coil content accompanied by a decrease of α-helices content, and formed more hydrophobic interactions were found. However, there was no significantly ($p > 0.05$) changes for the secondary structures of protein in T1 and T2. The results showed that replaced pork backfat with pre-emulsified soy oil enabled to produce low-salt and low-fat frankfurters.

1. Introduction

Recent years, more and more consumers require healthier meat products. Frankfurters as one of a type of frequently consumed meat products have been widely accepted by consumer in certain sections of the global population (Delgado-Pando, Cofrades, Ruiz-Capillas, Solas, & Jimenez-Colmenero, 2010a). But traditional frankfurters have high salt level, which could contain up to 30% fat with an industrial average of about 20% (Keeton, 1994). Excessive dietary salt and fat intake however can cause overweight, raise blood pressure, then increase the risk of cardiovascular disease (He & MacGregor, 2002; McNeill & Elswyk, 2012). Salt and fat are key factors affecting the frankfurters characters, such as water holding capacity, texture, juice, color, flavor and shelf life (Sikes, Tobin, & Tume, 2009; Tobin, O'Sullivan, Hamill, & Kerry, 2012). Thus, how to decline salt and fat without lowering frankfurters quality is a challenge.

Soy protein isolate (SPI) is a commonly useful vegetable protein in the meat industry, which has a good water and fat holding capacity, excellent gelling and structuring behaviour (Berghout, Boom & Goot, 2015; Kotula & Berry, 1986). Some researchers have reported that used pre-emulsified plant oil with SPI for animal fat replacement, which can decrease fat content and energy of meat products. Gao, Huang, and Gao (2013) reported that added pre-emulsified sunflower oil with SPI, which decreased fat content and energy of sika deer frankfurters. Jimenez-Colmenero, Herrero, Pintado, Solas, and Ruiz-Capillas (2010) observed that used olive oil-in-water emulsion with SPI to replace pork backfat decreased fat content in beef patties. Kayaardi and Gok (2003) found that replacement of beef fat with pre-emulsified olive oil with SPI could increase protein content and decreased total fat content in Turkish soudjouk.

The beating processing is a novel processing technique, there is the traditional way that kung-wan was produced in China and other Asian communities. The processing could reduce NaCl content of kung-wans and frankfurters from 2% to 1%, and had a better quality than the chopping with 2% NaCl (Kang et al., 2014a, b). To our knowledge, no research that utilized the beating process and

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pre-emulsified soy oil with SPI to produce low-salt and low-fat frankfurter has been reported. Therefore, the objective of the present study was to determine protein structural and physicochemical differences of frankfurters which were produced by beating processing with pre-emulsified soy oils, and thereby to establish a procedure to obtain low-salt and low-fat frankfurters with desirable quality.

2. Materials and methods

2.1. Raw materials and ingredients

40 kg pork leg lean meat (after 24–48 h of slaughtering, pH, 5.74, 72.32% moisture, 19.85% protein, 6.63% fat) and 10 kg backfat (7.95% moisture, 1.73% protein and 90.16% fat, AOAC, 2000) were purchased four times in two days from a local meat market (Xinxiang, China). All subcutaneous and intramuscular fat and visible connective tissues were removed from the lean meat. The lean meat and backfat were passed through a grinder (JR-120, Shandong, China) fitted with a plate having 6 mm diameter holes. The ground meat and backfat (1.0 kg each) was vacuum packaged in nylon/PE bags and store at −20 °C until use within 2 weeks. SPI (91.5% protein) was provided by Shandong Shansong Soy Foods co., Ltd (China). Soy oil (Shanghai Standard Foods co., Ltd, China), tripolyphosphate, salt and spices was purchased from a local market (Xinxiang, China).

2.2. Preparation of pre-emulsified soy oils

Preparation of pre-emulsified soy oils were based on the procedure as follows: briefly, the ratio of SPI: soy oil: water was 1:10:10 and 1:5:5, respectively. SPI and ice water were placed in a chilled bowl cutter (Stephan UMC-5C, German) at 2 °C. After homogenizing at 1500 rpm for 50s, the soy oil was added slowly while homogenization continued for 60s. Finally, the mixture was homogenized for an additional 2 min and poured into nylon/PE bags. These were stored at 4 °C overnight pending product manufacture. The emulsions were passed through a grinder fitted with a plate having 6 mm diameter holes and remained stable when they are used to form frankfurter.

2.3. Preparation of frankfurter

Three different frankfurters were prepared with four replications at different occasions. The control (C) was prepared with pork meat 1000 g, backfat 320 g, ice water 272 g, sodium tripolyphosphate 4.8 g, salt 16 g, spices 10.5 g; T1 was prepared with pork meat 1000 g, emulsion (SPI: soy oil: water was 1:10:10) 320 g, ice water 272 g, sodium tripolyphosphate 4.8 g, salt 16 g, spices 10.5 g; T2 was prepared with pork meat 1000 g, emulsion (SPI: soy oil: water was 1:5:5) 320 g, ice water 272 g, sodium tripolyphosphate 4.8 g, salt 16 g, spices 10.5 g. The preparation of frankfurter was as described by Kang et al. (2014b). Pork meat were thawed (overnight at 4 °C) prior to use. The thawed ground meat was processed using a beating machine according to the processing in below: the thawed meat was beat with NaCl, sodium tripolyphosphate and 1/3 ice for 10 min (200 rpm); followed by the backfat/pre-emulsified soy oils, spices and 2/3 ice were mixed (200 rpm) to the batter for 5 min (final temperature less than 10 °C). Then, the batter was stuffed by a vacuum stuffer (GZY3500, China), 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% RH to an internal temperature of 72 °C, then showered for 15 min, dried for 10 min at 30 °C and 60% RH, removed from the smokehouse and chilled at 2 °C overnight.

2.4. Proximate analysis

Protein content was determined by an automatic Kjeldahl nitrogen analyzer (Kjeltec 2300 Analyzer Unit, Sweden). Total fat content was determined by Sohxlet extraction with diethyl ether according to Bligh and Dyer (1959). Moisture and ash contents were determined according to Association of Official Analytical Chemists methods (AOAC, 2000). Each product was analyzed in representative duplicate samples at the same time, then repeated four times. The energy content of the frankfurters was determined based on 17 kJ/g for protein, 16 kJ/g for carbohydrate and 37 kJ/g for fat (Southgate & Durnin, 1970).

2.5. Color measurement

The color of frankfurter was measured using a Minolta chromameter (CR-40, Minolta Camera Co., Japan), calibrated with a white plate ($L^* = 96.86$, $a^* = -0.15$, $b^* = 1.87$). Six replicates were performed for internal color of each treatment group.

2.6. Cooking yield

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

Cooking yield% = weight of sausage after cooking/weight of sausage before cooking × 100.

2.7. Texture profile analysis (TPA)

After cooling at 2 °C overnight, the frankfurters were stay at room temperature for 2 h. The TPA attributes of the frankfurter was determined using a texture analyzer (TA-XT.plus, Stable Micro system Ltd., Surry, UK) at room temperature. TPA parameters were determined using five frankfurter cores (each diameter 20 mm, height 25 mm). The conditions were as follows: pre-text speed 2.0 mm/s; test speed 2.0 mm/s; post-text speed 5.0 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 mould was used. Attributes were calculated as follows: hardness, the peak force (N) required for first compression; cohesiveness, the ratio of active work done under the second compression curve to that done under the first compression curve (dimensionless); springiness, distance (mm) of sample recovery after the first compression; and chewiness, hardness × cohesiveness × springiness (N mm) (Bourne, 1978). Five replicates were performed for internal color of each treatment group.

2.8. Scanning electronic microscopy

Microstructure of frankfurters was determined using scanning electron microscopy (Hitachi-S-3000N, Hitachi High Technologies Corp., Toyoko, Japan), with slight adaption to the procedure reported by Haga and Ohashi (1984). Cubic samples ($3 \times 3 \times 3$ mm^3) obtained from frankfurters were fixed for 24 h at 4 °C in a 0.1 mol/L phosphate buffer (pH 7.0) containing 2.5% glutaraldehyde. The fixed samples were washed in 0.1 mol/L phosphate buffer (pH 7.0) for 10 min, and then post-fixed for 5 h in the same buffer containing 1% osmium tetroxide. The post-fixed samples were washed three times with 0.1 mol/L phosphate buffer (pH 7.0) for 10 min, and then dehydrated in a graded series of 50%, 70%, 90%, 95%, 100% ethanol