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Effect of a beating process, as a means of reducing salt content in Chinese-style meatballs (kung-wan): A dynamic rheological and Raman spectroscopy study

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ABSTRACT

Chopping and beating processes were used as meat-cutting methods in preparing kung-wan to produce low-salt products while retaining or improving the emulsion stability, sensory evaluation, and physico-chemical properties of the standard high-salt formulation. Increased salt content improved emulsion stability and dynamic rheology. However, 3% salt content decreased the overall acceptance of kung-wan. Compared with the chopping process, beating resulted in higher emulsion stability, overall acceptance, and β-sheet content ($P < 0.05$). Additionally, the beating process formed more compact and continuous structures at the same salt content. Kung-wan produced by beating with 1% and 2% salt had similar emulsion stabilities, sensory evaluation, and secondary structures ($P > 0.05$). Therefore, this process allows reduction of salt content, suggesting that the kung-wan produced in this manner is healthier and has better texture.

1. Introduction

A wide range of emulsified meat products is available to consumers that provide various textures and flavors depending on the method of production. Different types of meat products generally originate from specific countries or regions, with tradition being the main contributor to product development. One such product is the Chinese-style meatball called kung-wan, which is primarily made of pork and is very popular in Mainland China, Taiwan, and other Chinese communities (Hsu & Chung, 1999).

The emulsification process is an important stage in manufacturing finely comminuted meat products (Banon, Diaz, Nieto, Castillo, & Alvarez, 2008). This process is crucial in decreasing fat and meat particle sizes, extracting salt soluble protein from the muscle, and influencing product texture and emulsion stability (Alvarez et al., 2007). The chopping method is widely used to produce frankfurters and other Western-style meatballs; bowl cutters with volume of 1200 L are typically used in the industrial production of fine sausages (Seydelmann, 2009; Weiss, Gibis, Schuh, & Salminen, 2010). However, kung-wan is produced using a distinct processing method, namely, beating (Kang et al., 2014). The qualities of kung-wan and frankfurters are different. Many consumers prefer frankfurters which are juicier and more tender, whereas other consumers prefer the harder, more elastic, and adequately juicy kung-wan products served in hot soup (Hsu & Chung, 1999).

Salt greatly influence the flavor, shelf life, texture, and emulsification stability of emulsified meat products (Sikes, Tobin, & Tume, 2009; Tobin, O'Sullivan, Hamill, & Kerry, 2012; Tobin, O'Sullivan, Hamill, & Kerry, 2013). Salt causes the swelling of myofibrillar proteins, the depolymerization of myofilaments, and the dissociation of the actomyosin complex (Xiong, 1997). However, excessive dietary salt intake can cause cardiovascular disease, osteoporosis, kidney disease, and asthma (Sacks, Svetkey, & Vollmer, 2001). Excessive salt intake is also associated with stomach cancer (Datta & Sablani, 2007). The salt content of emulsified meat products can be reduced by several methods, such as using salt substitutes, flavor enhancers, and masking agents, thus optimizing the physical form of salt and the processing technique (Desmond, 2006). However, aside from high-pressure processing of pre-rigor meat, few processing techniques can be employed to reduce salt content (Claus & Sorheim, 2006; Ma et al., 2012). Therefore, a new processing technique for decreasing salt content in emulsified meat products must be developed. This method should have widespread acceptability in commercial emulsified meat processing operations. This work aimed to study the effects of salt level and processing methods (chopping and beating) on the physico-chemical and sensory properties of kung-wan and to investigate a procedure for obtaining low-salt kung-wan of desirable texture.

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2. Materials and methods

2.1. Preparation of meatballs (kung-wan)

Meatballs (kung-wan) were prepared from lean pork meat (*semitendinosus*, *biceps femoris*, *mesoglutaeus*) using a number of different formulations and processing methods. Pork lean meat (24 h to 48 h postmortem, pH 5.78, 71.18% moisture, 20.47% protein, and 7.14% fat) and backfat (8.30% moisture, 1.68% protein, and 89.82% fat) were purchased from a local meat market (Nanjing, China). All visible fat and connective tissues were trimmed from the meat. The meat and backfat were separately passed through a grinder (MM-12, Guangdong, China), fitted with a 6 mm diameter plate. The ground meat (1.0 kg each) was packaged in double plastic (nylon/PE) bags and stored at −20 °C for 2 weeks prior to use. The base ingredients consisted of pork ham meat (1000 g), pork backfat (250 g), sucrose (40 g), sodium tripolyphosphate (3 g), and pepper (1 g). Meat emulsions were prepared by chopping or beating. For the chopping method, the products were prepared using the typical emulsification procedure in a vacuum bowl cutter (Stephan UMC-5C, Germany) described by Lin and Lin (2004), with slight modifications. The thawed ground meat was added with salt and sodium tripolyphosphate and chopped (1500 rpm) for 30 s, followed by a 3 min rest. After adding sugar, pepper, and pork backfat, the batter was chopped (1500 rpm) for 30 s, followed by a 3 min rest. The process was finished with high-speed (3000 rpm) emulsification for 60 s with a final temperature lower than 10 °C. For the beating method, the thawed ground meat was processed using a beating machine (MC-6, Shandong, China) according to the following procedure. The thawed ground meat was mixed with salt and sodium tripolyphosphate and beaten for 10 min (200 rpm). After adding sugar, pepper, and pork backfat, the batter was mixed (200 rpm) for 5 min with a final temperature of less than 10 °C. The processing conditions used were the same as those of a commercial operation. Then, the meat batters prepared by beating and chopping were shaped into meatballs with diameters of 30 mm and cooked in water at 80 °C for 20 min (internal temperature 72 °C). The cooked meatballs were cooled to room temperature, packed in laminated film (nylon/PE) bags, and stored separately in a stainless steel freezer at –20 °C for 2 weeks prior to sensory evaluation. All preparation methods were performed in random order and designated as follows: chopping with 0.5% (C1), 1% (C2), 2% (C3), and 3% (C4) NaCl; beating with 0.5% (T1), 1% (T2), 2% (T3), and 3% (T4) NaCl.

2.2. pH

Approximately 10 g of each sample was homogenized with 40 mL of pre-cooled distilled water using a Polytron homogenizer at 15,000 rpm for 10 s. The pH was then determined using a digital pH meter (Hanna, Italy). All analyses were performed in triplicate.

2.3. Emulsion stability

Emulsion stability was determined using the procedure proposed by Fernández-Martín, López-lópez, Cofrades, and Colmenero (2009). Raw batter (25 g) was placed in a 50 mL centrifuge tube and centrifuged at 500 *g* for 15 min at 3 °C (Model 225, Fisher Scientific, Pittsburgh, Pa., U.S.A.) to eliminate air bubbles. Each tube was heated in an 80 °C water bath for 20 min and then immediately removed. The tubes were uncapped and left inverted on paper towels at room temperature for 50 min to release any exudate. The exudate, or total fluid release (TR), was expressed as the percentage of the initial sample weight. Higher TR corresponds to lower emulsion stability. The percentage of water released (WR, percentage of initial sample weight) was determined from the dry weight content of TR after heating at 105 °C for 16 h. Any minor protein or salt component was ignored in determining the percentage of fat released (FR, percentage of the initial sample weight), which was regarded as the difference between TR and WR. Four determinations (four tubes) were performed for each formulation per batch.

2.4. Dynamic rheological measurement

Dynamic rheological studies were performed using an MCR301 dynamic rheometer (Anton Paar Ltd., Austria). A 50 mm parallel steel plate geometry with 0.5 mm gap was used. The raw batter was placed between the flat parallel plates, with the perimeter coated with a thin layer of silicone oil to prevent dehydration. The samples were heated from 20 °C to 80 °C at 2 °C/min. During the heating process, the samples were continuously sheared in an oscillatory mode at a fixed frequency of 0.1 Hz. Changes in storage modulus (G') and loss tangent ($\tan\delta$) were measured during processing with increasing temperature. Each sample was measured in triplicate.

2.5. Scanning electronic microscopy

The microstructure of the raw meat batters was determined using scanning electron microscopy (SEM, Hitachi-S-3000 N, Hitachi High Technologies Corp., Tokyo, Japan) according to the procedure of Haga and Ohashi (1984) with slight modifications. Cubic samples (3 mm × 3 mm × 3 mm) obtained from the raw meat batters were fixed for 24 h at 4 °C in 0.1 M phosphate buffer (pH 7.0) containing 2.5% glutaraldehyde. The fixed samples were washed in 0.1 M phosphate buffer (pH 7.0) for 10 min and then post-fixed for 5 h in the same buffer with 1% osmium tetraoxide. The post-fixed samples were washed three times with 0.1 M phosphate buffer (pH 7.0) for 10 min and dehydrated in incremental concentrations of ethanol (50%, 60%, 70%, 80%, 90%, 95%, and three times with 100%) with 10 min for each solution.

2.6. Raman spectroscopy

Raman experiments were performed using a modified version of the procedure of Shao, Zou, Xu, Wu, and Zhou (2011). The spectra were obtained in the range of 400 cm^{-1} to 3600 cm^{-1}. Each spectrum of cooked kung-wan was obtained under the following conditions: three scans, 30 s exposure time, 2 cm^{-1} resolution, sampling speed 120 cm^{-1}/min, and data collection every 1 cm^{-1}. The spectra were smoothed, baseline corrected, and normalized against the phenylalanine band at 1003 cm^{-1} (Herrero, 2008) using Labspec version 3.01c (Horiba/Jobin Yvon, Longjumeau, France). The secondary structures of the cooked kung-wan proteins were determined as percentages of α-helix, β-sheet, β-turn, and random coil conformations (Alix, Pedanou, & Berjot, 1988) by subtracting the water spectrum from the spectra following the described criteria (Alix et al., 1988; Herrero, Carmona, Pintado, Jimenez-Colmenero, & Ruiz-Capillas, 2011).

2.7. Sensory evaluation

The eight members of the sensory panel were selected and trained according to Meilgaard, Civille, and Carr (1991). After one week in frozen storage, the meatballs were assessed by the panel. The meatballs were removed from the package and heated in water at 100 °C for 10 min (internal temperature 75 °C). The meatballs were served warm to the panelists for assessment of appearance, springiness, hardness, juiciness, and overall acceptability using a nine-point hedonic scale (9, extremely desirable; 1, extremely undesirable) (Wu & Lin, 2011).