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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

Zhuang-Li Kang; Peng Wang¹; Xing-Lian Xu*; Chao-Zhi Zhu; Yu-Feng Zou; Ke Li;
Guang-Hong Zhou

Key Lab of Meat Processing and Quality Control, College of Food Science and
Technology, Nanjing Agricultural University, Nanjing, 210095, PR China

*Corresponding author: Xing-Lian Xu

¹Peng Wang contributed equally to this work and should be considered co-first
authors

Address: College of Food Science and Technology, Nanjing Agricultural University,
Nanjing, 210095, PR China

Tel.: + 86 25 843 95730

Fax: + 86 25 843 95939

E-mail address: xlxu@njau.edu.cn (Xing-Lian, Xu).
**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.

**Keywords:** Chopping, Beating, Emulsion stability, Dynamic rheological, Raman spectroscopy

**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 and Chung, 1999).
The emulsification process is an important stage in manufacturing finely comminuted meat products (Banon et al., 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 et al., 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 and Chung, 1999).

Salt greatly influence the flavor, shelf life, texture, and emulsification stability of emulsified meat products (Tobin et al., 2013; Tobin et al., 2012; Sikes et al., 2009). 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 et al., 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 and 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-yan and to investigate a procedure for obtaining low-salt kung-yan of desirable texture.

2. Materials and methods

2.1 Preparation of meatballs (kung-yan)

Meatballs (kung-yan) were prepared from lean pork meat (*semitendinosus, biceps femoris, mesoglutaes*) 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 wk 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 wk 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 15000 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 et al. (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, Fischer 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 (Auton 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 δ) 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-3000N, 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 et al. (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 et al., 1988) by subtracting the water spectrum from the spectra following the described criteria (Alix et al., 1988; Herrero et al., 2011).

2.7 Sensory evaluation

The eight members of the sensory panel were selected and trained according to Meilgaard et al. (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 and Lin, 2011).

2.8 Statistical analysis

The experiment was designed as a completely randomized block with four replications, and 20 samples were used for each replicate. The data were analyzed using one-way ANOVA. The difference between the means was considered significant at P < 0.05. Significant differences between the means were identified by least significant difference procedure using the statistical software package SPSS v.18.0 (SPSS Inc., USA) for Windows.

3. Result and discussion

3.1 pH and emulsion stability

Table 1 shows the pH values and the salt level of different batters produced by either chopping or beating. The pH values were not significantly different (P > 0.05). A
similar finding stating that salt concentration did not affect the pH values of pork sausages has been reported (Puolanne et al., 2007).

Salt level and processing method had significant effects (P < 0.05) on the emulsion stability (Table 1). The emulsion stability of the raw meat batters increased with increasing salt content. Among the samples, those with 3% salt had the lowest TR, WR, and FR, whereas 0.5% salt batters had the highest TR, WR, and FR. Schmidt (1984) showed that meat batters with reduced salt (0.58%) had larger capillaries in their gel structure compared with high-salt batters (2.82%), and low-salt meat batters had less stable gel structures. In a previous study (Kang et al., 2014), the salt-soluble protein (SSP) concentration in uncooked kung-kan was found to increase with increasing salt content from 0.5% to 3% when produced by either chopping or beating. Increasing the salt level from 0 g/100 g to 3 g/100 g resulted in an overall increase in cooking yield in poultry meat batters because higher salt content allowed greater protein extraction (Somboonpanyakula et al., 2007). Tobin et al. (2013) reported that increasing salt content from 0.8% to 2.4% increased the cooking yield and water binding of pork breakfast sausage. These results are consistent with those reported by Hand et al. (1982) and Saricoban et al. (2009), in which low salt levels reduced the ionic strength of the batters, the protein extraction, and the water binding. At 1.0% and 2.0% salt content, the emulsion prepared by beating had significantly (P < 0.05) lower TR, WR, and FR compared with the emulsions prepared by chopping; such discrepancies were caused by the different effects of the chopping and beating processes on the meat proteins (Kang et al., 2014).
3.2 Dynamic rheological properties

The effects of different salt levels (1% and 2%) and processing methods of raw meat batters on changes in G' during the heating process were determined (Fig. 1). C2 and C3 had similar heating curves. Three phases were evident in G' during the heating process of raw meat batters because of protein denaturation. The first phase showed a slight increase in G' as the temperature increased from 43 °C to 53 °C because gelation was initiated after the protein-protein interactions (Xiong and Brekke, 1990). This phase was immediately followed by the second phase in which G' slightly decreased as the temperature increased from 54 °C to 58 °C. This decrease resulted from the denaturation of the myosin tails (Wu et al., 2009; Tornberg, 2005), causing a sharp increase in fluidity and a possible disruption of the protein network that had previously formed at lower temperatures. Finally, in the third phase, G' rapidly increased as the temperature increased to 80 °C because of the transformation of the viscous sol into an elastic gel network (Alvarez, 2012). C3 showed higher values of G' than C2 during heating from 20 °C to 80 °C. Given that protein aggregation or coagulation is stronger at high-salt concentrations, G' increased or decreased more significantly with increasing salt concentration in the peak region (Hermansson et al., 1986). Egelandsdal and Martinse (1995) also demonstrated that G' was greatly affected by salt at both high and low temperatures.

T2 and T3 also involved three phases during the heating process. In the first phase, G' exhibited a moderate decline as the temperature increased from 20 °C to 32 °C, because the beating process resulted in a great number of unfolded myofibrillar
proteins in the solution at 30 °C to 32 °C, when the unfolding of myofibrillar proteins in solution starts (Tornberg, 2005). In the second phase, G' exhibited a moderate increase as the temperature increased from 33 °C to 50 °C in T2 and from 33 °C to 54 °C in T3. The coordination of salt content and beating process could reveal whether SSP (myosin and actin) exists in monomeric or filament form and could influence the temperature of protein–protein association and gelation (Tornberg, 2005). In the beating process, the addition of 2% salt increased protein–protein association and gelation during heating. The second phase was immediately followed by the third phase where G' decreased as the temperature increased from 50 °C to 58 °C in T2, followed by a smaller reduction in temperature from 55 °C to 57 °C in T3. A rapid increase in G' occurred at approximately 58 °C as the temperature approached 80 °C.

Tan δ refers to the relative distribution of "viscosity" compared with "elasticity" during the formation of protein gel matrix in meat or meat products. A smaller value of tan δ corresponds to more elastic behavior (Ferry, 1980; Korhonen et al., 2001). Figure 2 shows the changes in tan δ of raw batters during heating from 20 °C to 80 °C. C2 and C3/T2 and T3 had similar heating curves. The tan δ value of C2 and C3 exhibited a moderate increase as the temperature increased from 33 °C to 44 °C, followed by a slight decrease as the temperature increased from 45 °C to 48 °C, followed by a moderate increase as the temperature increased from 49 °C to 52 °C. Subsequent heating from 53 °C to 80 °C resulted in a drop in tan δ. When produced by beating, the tan δ value of T2 and T3 decreased sharply with increasing
temperature up to 49 °C, followed by a moderate increase as the temperature increased from 50 °C to 54 °C. Subsequent heating from 55 °C to 80 °C resulted in a drop in tan δ. The differences were caused by the different processing methods. Compared with the chopping process, the beating process caused greater protein denaturation (Kang et al., 2014). The results demonstrated that the beating process could decrease the pre-gel effects generated by the denaturation of myosin tails; such effects disrupt the protein network previously formed at lower temperatures (Tornberg, 2005).

3.3 Microstructure

Micrographs of the raw meat batters showed that salt content (1% and 2%) and processing method (chopping or beating process) affected several properties of the emulsion structure (Fig. 3). The raw batters of C2 presented a coarse, loose structure, and several myofibrils were found. Consequently, the content of extracted SSP was low (Kang et al., 2014). Raw batters with high salt content (C3) showed a dense and compact matrix. Myofibrillar proteins are vital in producing the desirable texture and water binding in comminuted meat products (Chin et al., 2009). Salt alters the protein structure and increases hydration, consequently improving water-holding capacity. Salt also increases the binding properties of proteins and the viscosity of batters. Moreover, salt facilitates the incorporation of fat to form stable batters (Desmond, 2006). The raw batters of T2 and T3 had similar structures, which were more compact and continuous compared with C3. Analysis of all micrographs of the batters showed that the size of the fat particles of the beaten products (T2 and T3) were larger than
those of the chopped products (C2 and C3). These differences in microstructure provide insight into the effects of the chopping and beating processes on the properties of the batters.

3.4 Raman spectroscopic analysis

The secondary structures of cooked kung-wan were affected by salt content and processing method, as shown in Table 2. For the same processing method, salt content had no significant effect (P > 0.05) on α-helical, β-sheet, β-turns, and random coil contents. Heating induces the denaturation and aggregation of muscle proteins, followed by gel formation in kung-wan, suggesting that heating is an important process for heat-induced gelation of protein. As the temperature increased, α-helix content decreased, whereas β-sheet content increased (Li-Chan and Nakai, 1991; Nonaka et al., 1993; Li-Chan et al., 1994). Liu et al. (2008) reported that the unfolding of α-helix and the formation of β-sheets favored the gelation of porcine myosin. Processing method had a significant effect (P < 0.05) on α-helix and β-sheet contents. Compared with kung-wan prepared by chopping, the α-helix contents of kung-wan prepared by beating were lower, and β-sheet contents were higher. The β-turn were not significantly different (P > 0.05) except in C2. The β-sheet structure is the base on which protein aggregates and gel forms (Wang & Damodaran, 1991). In the present study, kung-wan prepared by beating had better texture and higher G' at 80 °C compared with that prepared by chopping at the same salt content. These results are in agreement with Liu et al. (2010) who reported that the high β-sheet and β-turn fractions present prior to heating could improve G’ of fish myosin at 90 °C. Herrero
(2008) reported that in meat systems, the increase in proportions of $\beta$-sheet and $\beta$-turn structures were accompanied by increases in hardness, springiness, and cohesiveness. Consequently, kung-wan produced by beating had better texture than kung-wan produced by chopping at the same salt content (Kang et al., 2014).

3.5 Sensory evaluation

Results of sensory evaluation (Table 3) showed that salt content and processing method influenced the sensory attributes of kung-wan. Consumers prefer kung-wan with a brighter appearance (Hsu and Chung, 1998; Hsu and Yu, 2002). In the present study, appearance scores showed that C1, C2, and T1 were less acceptable for this attribute. C1, C2, and T1 had lower emulsion stabilities compared with other samples because greater amounts of water and fat were lost during cooking, resulting in a paler appearance. The juiciness scores exhibited a trend similar to that of the appearance scores, that is, the scores decreased with decreasing salt content. The low-salt beaten product (T2) had the same SSP concentration as C4 and T3 (Kang et al., 2014). Consequently, T2, T3, and C4 have similar appearance and juiciness scores. Hsu and Chung (1998) reported that texture was the most important property of kung-wan, and consumers preferred a harder texture. Thus, hardness and elasticity were regarded as important desirable qualities for kung-wan. The high-salt beaten product (T4) had lower hardness scores compared with C3, C4, and T2, with T4 having a rubber-like texture. These results were consistent with those reported by Hsu and Yu (2002) and Hsu and Sun (2006), where an extremely hard texture was found to have a negative effect on the sensory qualities of kung-wan. The springiness scores for the products
were similar to the parameters of texture profile analysis (Kang et al., 2014), indicating that consumers prefer a more elastic texture provided an acceptable level of hardness is achieved. Panelists found that the addition of 3% salt to kung-wan resulted in excessive saltiness, causing C4 and T4 to have low scores for overall acceptance. Given that all preparations of kung-wan contained 3% sugar, the low-salt products (1.0%) showed similar acceptability as those containing high-salt content (2.0%). This finding is in agreement with Hsu and Chung (1998) who reported that maximum odor preference was related to the sugar levels in the testing range (3% to 5%). Among all samples, T2 and T3 had the highest scores for overall acceptance because they had suitable color, texture, juiciness, and odor. Therefore, this study demonstrates that by employing the beating process, high-quality kung-wan product with low-salt (1.0%) content can be produced.

4. Conclusions
This study showed that salt level and processing method significantly influenced the properties of raw batters and kung-wan, with the exception of pH. Improved emulsion stability and texture were obtained with increasing salt content. Compared with the chopping process, the coordination of salt content and beating process could decrease the effect of denaturation of the myosin tails, thereby forming better texture. The micrographs reveal that raw batters with 1% and 2% salt produced by beating had a smoother and more uniform microstructure compared with batters produced by chopping. The changes in the secondary structures of the meat proteins in kung-wan generated by beating were stronger. Higher β-sheet content can be observed in
kung-wan produced by beating than that produced by chopping. This higher β-sheet content improved the sensory evaluation scores. The results indicate that the beating process can produce low-salt (1.0%) kung-wan with the desirable sensory qualities of good appearance, hardness, and elasticity.

Acknowledgments

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Reference


using Raman spectroscopy. *Food Research International*, 44, 2955-2961.


Fig 1. Changes in dynamic storage modulus ($G'$, Pa) with increasing temperature ($T$, °C) for different meat formulations. C2: chopping with 1% salt; C3: chopping with 2% salt; T2: beating with 1% salt; T3: beating with 2% salt.
Fig. 2. Changes in loss tangent (tanδ) with increasing temperature ($T$, °C) for different meat formulations.
C2: chopping with 1% salt; C3: chopping with 2% salt; T2: beating with 1% salt; T3: beating with 2% salt.
**Fig. 3.** Scanning electron micrographs of raw meat batters.
C2: chopping with 1% salt; C3: chopping with 2% salt; T2: beating with 1% salt; T3: beating with 2% salt.
Figure captions:

Fig 1. Changes in dynamic storage modulus (G', Pa) with increasing temperature (T, °C) for different meat formulations.
C2: chopping with 1% salt; C3: chopping with 2% salt; T2: beating with 1% salt; T3: beating with 2% salt.

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Fig. 3 Scanning electron micrographs of raw meat batters.
C2: chopping with 1% salt; C3: chopping with 2% salt; T2: beating with 1% salt; T3: beating with 2% salt.
Table 1. pH and emulsion stability (TR, WR, FR) of raw batters produced by chopping or beating product with various amounts of added salt.

<table>
<thead>
<tr>
<th>Sample</th>
<th>pH</th>
<th>Emulsion stability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TR (%)</td>
<td>WR (%)</td>
</tr>
<tr>
<td>C1</td>
<td>6.32±0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.21±0.40&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>C2</td>
<td>6.30±0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.89±0.44&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>C3</td>
<td>6.29±0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.00±0.13&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>C4</td>
<td>6.29±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.97±0.12&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>T1</td>
<td>6.29±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.66±0.11&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>T2</td>
<td>6.30±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.34±0.13&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>T3</td>
<td>6.30±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.23±0.07&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>T4</td>
<td>6.30±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.84±0.04&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

TR: total fluid release; WR: water released component (% of the initial sample weight); FR: fat released component (% of the initial sample weight).

<sup>a-f</sup> Different superscripts in the same column indicate significant differences (P < 0.05).

C1: chopping with 0.5% salt; C2 1% salt; C3: 2% salt; C4 3% salt; T1: beating with 0.5% salt; T2: 1% salt; T3: 2% salt; T4: 3% salt. Which were also used for Table 2, 3.
Table 2. Percentages of protein secondary structures α-helix, β-sheet, β-turns, random coil of the cooked kung-wan analyzed by chopping or beating process with various amounts of added salt.

<table>
<thead>
<tr>
<th>Sample</th>
<th>α-helix (%)</th>
<th>β-sheet (%)</th>
<th>β-turns (%)</th>
<th>Random coil (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>58.99±4.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.56±3.13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.60±0.64&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>10.04±0.25&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>C2</td>
<td>63.21±5.83&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.33±4.47&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>13.94±0.91&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>9.78±0.36&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>C3</td>
<td>56.72±5.63&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.31±4.31&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.96±0.88&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>10.18±0.34&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>C4</td>
<td>59.46±4.77&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.21±3.65&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.53±0.75&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>10.01±0.29&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>T1</td>
<td>53.97±2.37&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>20.42±1.82&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.39±0.37&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.35±0.15&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T2</td>
<td>54.84±3.23&lt;sup&gt;b&lt;/sup&gt;</td>
<td>19.75±2.48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.26±0.51&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.30±0.20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T3</td>
<td>52.05±1.65&lt;sup&gt;c&lt;/sup&gt;</td>
<td>21.89±1.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.69±0.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.47±0.10&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T4</td>
<td>54.84±3.24&lt;sup&gt;b&lt;/sup&gt;</td>
<td>19.75±2.48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.26±0.51&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.30±0.20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>,<sup>c</sup> Different superscripts in the same column indicate significant differences (P < 0.05).
Table 3. Comparisons of sensory quality indices of kung-wan preparations by chopping or beating process with various amounts of added salt.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Appearance</th>
<th>Hardness</th>
<th>Springiness</th>
<th>Juiciness</th>
<th>Overall acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>5.13±0.25c</td>
<td>3.88±0.31f</td>
<td>4.43±0.36f</td>
<td>4.30±0.52e</td>
<td>4.38±0.39f</td>
</tr>
<tr>
<td>C2</td>
<td>6.13±0.26b</td>
<td>5.20±0.33d</td>
<td>5.85±0.32d</td>
<td>6.40±0.31c</td>
<td>5.65±0.28d</td>
</tr>
<tr>
<td>C3</td>
<td>6.75±0.17e</td>
<td>6.16±0.34e</td>
<td>6.61±0.26e</td>
<td>6.78±0.18b</td>
<td>6.60±0.29bc</td>
</tr>
<tr>
<td>C4</td>
<td>6.73±0.21a</td>
<td>6.78±0.27a</td>
<td>6.84±0.18b</td>
<td>6.90±0.25a</td>
<td>6.49±0.20c</td>
</tr>
<tr>
<td>T1</td>
<td>6.07±0.29b</td>
<td>4.89±0.26e</td>
<td>5.26±0.2e</td>
<td>5.13±0.38d</td>
<td>5.30±0.44e</td>
</tr>
<tr>
<td>T2</td>
<td>6.66±0.36a</td>
<td>6.75±0.25a</td>
<td>6.89±0.22ab</td>
<td>6.97±0.18a</td>
<td>6.98±0.26a</td>
</tr>
<tr>
<td>T3</td>
<td>6.75±0.32a</td>
<td>6.84±0.24a</td>
<td>6.92±0.22ab</td>
<td>7.00±0.16a</td>
<td>7.05±0.30a</td>
</tr>
<tr>
<td>T4</td>
<td>6.75±0.26a</td>
<td>6.52±0.23b</td>
<td>7.03±0.17a</td>
<td>6.63±0.25b</td>
<td>6.72±0.26b</td>
</tr>
</tbody>
</table>

a-f Different superscripts in the same column indicate significant differences (P < 0.05).
Highlights

- Beating process allowed for production of lower salt and higher quality products.
- Compared with chopping, beating improved emulsified stability.
- Beating resulted in better sensory evaluation than chopping.
- Beating could decrease the effect of denaturation of myosin tails.
- Beating changed the secondary structures, especially β-sheet and β-turns.