Effects of different cooking regimes on the microstructure and tenderness of duck breast muscle

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Abstract

BACKGROUND: Cooking has a great influence on meat tenderness, and we assumed that changes of tenderness in this process resulted from the liberation of actin and associated structural changes. Therefore, in this study, we investigated changes in the microstructure and tenderness when duck breast muscle were cooked to different internal endpoint temperatures (70, 80, 90, 95 °C) by three cooking regimes (conventional cooking, two-stage cooking and three-stage cooking).

RESULTS: When duck breast muscle was cooked to an internal endpoint temperature of 70 °C, the three-stage cooking significantly decreased the Meullenet–Owens razor shear force (MORSF) value (P < 0.05) and resulted in a longer sarcomere length (P < 0.05) compared with the conventional cooking. However, further improvement of the tenderness and an increase in sarcomere length did not occur at higher internal endpoint temperatures. The two-stage cooking regime, with a much longer cooking time below 55 °C, also resulted in a lower MORSF value (P > 0.05) and increased sarcomere length (P < 0.05) at an internal endpoint temperature of 70 °C compared with the conventional cooking. Significant liberation of actin was also observed in duck meat cooked between 50 and 60 °C.

CONCLUSION: The two- and three-stage cooking regimes with initial temperatures of 50–60 °C and endpoint temperature of 70 °C could improve tenderness of duck breast meat, which might be related to the liberation of actin. Three-stage cooking had the great advantages of improving meat tenderness and reducing cooking loss; therefore, this is to be recommended for further application and research.

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Keywords: duck breast muscle; staged cooking; tenderness; sarcomere length

INTRODUCTION

Cooking has a major influence on meat tenderness.1 Changes in tenderness is mainly associated with myofibrillar and connective tissue proteins (mainly collagen), which undergo several temperature- and time-dependent structural changes during cooking. It is generally considered that cooking causes denaturation of the myofibrillar component that results in toughening, whereas solubilisation of collagen results in tenderisation.2–4 The final tenderness of meat after cooking directly associates with the net effect of this tenderisation and toughening, which depends on the cooking conditions.

Both cooking temperature and time have a large effect on the physical properties of meat and the eating quality. In previous studies, a decrease in the shear force value was observed during the cooking of beef6 and rabbit meat6 at 50–60 °C. Furthermore, several studies have found that holding meat at a temperature between 50 and 60 °C for a certain time before cooking at a higher temperature could also significantly improve tenderness.2–4,7,8 However, the effect on these physical properties on meat heated at 50–60 °C is not clearly understood. Pietrasik et al.3 found that holding semi-membranosus and adductor muscles from either beef or bison at an internal temperature of 55 °C for 45 min or 90 min resulted in lower shear force values compared with those of the controls. This tenderisation was thought to be related to the beneficial effects of increased collagen solubilisation. Walsh et al.4 reported that forequarter beef muscles cooked in a water bath to 55 °C and held at this temperature for 2 h before heating to 72 °C significantly reduced the Warner–Bratzler shear force (WBSF) values; this has been attributed to changes in the collagen component which weakens the connective tissue network. Obuz et al.2 also reported a study on beef biceps femoris steaks cooked at 54 °C by a belt grill, further held them at 57 °C in a water bath for 15 min and subsequently reheated the steaks to 70 °C. It produced a 25% reduction in WBSF as compared to the control

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(cooking steaks directly to 70 °C without holding), which was attributed to increased collagen solubilisation with 15 min holding at 57 °C. When collagen of the surrounding connective tissue is heated, it undergoes physical changes. With extended heating in the presence of moisture, collagen is further hydrated and hydrolysed, thereby meat becomes tender. However, an increase in soluble collagen was not always detected with prolonged holding at the temperature between 50 and 60 °C, whereas a decrease of the shear force value could be observed after cooking at 50–60 °C in these studies; former studies attribute this phenomenon to the weakening and solubilisation of collagen at 50–60 °C. Furthermore, those studies only assessed beef and with different holding times at 50–60 °C. Obuz et al. also found that increasing the holding time from 15 to 30 min increased the WBPSF value. This is in contrast to another study which showed that increasing the cooking time of beef held at 50–60 °C increased the solubility of collagen.

Sarcoplasmic proteins were considered as another cause of decreased toughness with temperatures elevated from 50 °C to 65 °C, because sarcoplasmic proteins denature, bind to the fibres which consequently clots the fibre bundles and thereby causes the meat to fracture more easily. Improved tenderness by cooking meat with a holding period at 50–60 °C also has been attributed to the activities of collagenase and cathepsin B + L, which still had activities up to 60 °C.

In recent years, liberation of actin was found when cooking bovine, porcine and chicken muscles at about 60 °C, which indicates the dissociation of thin filaments from thick filaments that may contribute to the tenderising of meat. This also may be, at least in part, a potential cause for tenderisation of meat either cooked at 50–60 °C or held at 50–60 °C for a period before being cooked at a higher temperature. It is supposed that the liberation of actin weakens the structural integrity of myofibrils and may restrict the shrinkage of the sarcomere, and thereby restricts the toughening of meat cooking at 50–60 °C or reheating to even higher temperatures.

There is no information available describing the effect of the cooking process with a holding range between 50 and 60 °C on the tenderness of duck meat, nor the liberation of actin in duck meat cooked between 50 and 60 °C. The aim of this study was to investigate the effects of different cooking treatments with a holding range between 50 and 60 °C on tenderness and microstructure, as well as the liberation of actin in duck meat cooked between 50 and 60 °C.

MATERIALS AND METHODS

Sample preparation

Skinless, de-boned breast fillets (pectoralis major) of 41-day-old Cherry Valley ducks were obtained from a local continuous processing plant. The deboning time was 3 h after slaughter. The breast fillets with similar weights were selected and placed in plastic bags individually and then vacuum sealed. The breast fillets were packed on ice for transportation to the laboratory. The breast fillets were aged for 24 h at 4 °C then frozen at −20 °C and used within 1 month.

Cooking treatment

Forty-eight frozen breast fillets were thawed overnight at 4 °C and weighed accurately. The average weight was 96.9 ± 8.3 g. The samples were placed in vacuum bags (unsealed) and opened at room temperature to adjust the internal meat temperature to 20 °C prior to cooking treatments. A total of three cooking regimes were applied for cooking samples to four different final internal meat temperatures of 70, 80, 90 and 95 °C. The breast fillets were randomly assigned to each treatment; each treatment was repeated four times. The fillets were sealed in vacuum bags individually. The treatment regimes were as follows:

- **Treatment for conventional cooking**: Samples were cooked directly until the final internal meat temperature reached 70, 80, 90 and 95 °C in a water bath of 97 °C.
- **Treatment for two-stage cooking**: Samples were first cooked in a 57 °C water bath at 55 °C internal meat temperature for 15 min, then transferred to another water bath of 97 °C until the final internal meat temperature of 70, 80, 90 and 95 °C was reached.
- **Treatment for the three-stage cooking**: Samples were first cooked in a 97 °C water bath until the internal meat temperature reached 54 °C, then transferred to another water bath of 57 °C for 15 min, and then transferred back to the 97 °C water bath until the final internal meat temperature increased to 70, 80, 90 and 95 °C.

Upon reaching the designated internal temperatures, samples were immediately transferred to iced water until the internal temperature decreased to 25 °C. After cooling, samples were removed from the iced water, wiped with a paper towel to remove excess water, and weighed and used for subsequent analyses. During each cooking treatment, thermocouples (CENTER 309; Center Corp., Taipei, Taiwan) were used to monitor the temperatures of the sample centre and the water baths. The thermocouples were inserted into the geometric core of each fillet to monitor the internal temperature.

Razor blade shear force

Following overnight storage at 4 °C, the tenderness of the cooked fillets was determined through the application of the Meullenet–Owens razor shear (MORS) test, using a texture analyser (TVT-300XP; TexVol Instruments, Viken, Sweden) as described by Meullenet et al. and Cavitt et al. with slight modifications. A razor blade with a height of 24 mm and a width of 8.9 mm set to a penetration depth of 24 mm. The cross-head speed was set at 2 mm s⁻¹, and the test was triggered by a 10 g contact force. The shear was perpendicular to the axis of muscle fibres. In each treatment, the MORS test value was determined in triplicate at predetermined locations on each of the fillets.

Cooking loss

Each breast fillet was weighed accurately prior to cooking. After cooking, the breast fillets were cooled and wiped with blotting paper to remove excess water and weighed immediately. The measurements were conducted in four replications. Cooking loss was calculated as: cooking loss (%) = [(raw weight – cooked weight)/raw weight] × 100.

Microstructure

The microstructure of meat samples were determined using a scanning electron microscope (SEM) and a transmission electron
microscope (TEM) according to Chang et al. and Kong et al. with slight changes.

Procedure for the scanning electron microscopy analysis
Pieces (1 × 1 × 0.5 cm) were excised from muscle samples and fixed in 2.5% glutaraldehyde in 0.1 mol L\(^{-1}\) phosphate buffer (pH 7.3) at room temperature. The specimens were then rinsed with 0.1 mol L\(^{-1}\) phosphate buffer (pH 7.3) and dehydrated for 15 min in 50%, 70%, 80% and 90% ethanol, respectively, and three times in absolute ethanol for 30 min each. The specimens were freeze dried, mounted on aluminium stubs and coated with gold for SEM examination and photographing (S-3000 N; Hitachi High-Technologies Corporation, Tokyo, Japan). The micrographs were taken at 1000-fold magnification to examine changes of the perimysium connective tissue.

Procedure for the transmission electron microscopy analysis
Pieces (1 × 1 × 2 mm) were excised from raw and cooked muscle samples and fixed in 2.5% glutaraldehyde in 0.1 mol L\(^{-1}\) phosphate buffer (pH 7.3) followed by a secondary fixation with 2% osmium tetroxide at room temperature. The specimens were then dehydrated in 50%, 70%, 80% and 90% ethanol, respectively, for 15 min in each solution and 30 min in absolute ethanol three times. The samples were embedded in epoxy resin (Durcupan) for 15 min in each solution and 30 min in absolute ethanol three times. The resin was allowed to cure at 70 °C for 24–48 h. The cured resin blocks were cut in an ultra cut ultra-microtome. The ultra cuts were stained using a solution of 4% uranyl acetate in ethanol for 10 min followed by an aqueous solution of Reynolds’ lead (7 min). The micrographs were taken at 2500-fold magnification for longitudinal sections by transmission electron microscopy (H-7650; Hitachi). One micrograph from each sample was taken and 10 measurements of sarcomere length on each sample were made.

Actin extraction and SDS-PAGE analysis
Four grams of minced duck breast muscle (unheated) was weighed and placed in a vacuum bag. The minced muscle in the bag was sliced into a 2 mm thick sheet and then heated in a thermostatically controlled water bath (50 °C and 60 °C). After heating for 1, 10, 30 and 60 min, respectively, the minced muscle was cooled with iced water and used for actin extraction.

The method for actin extraction was performed according to Okitani et al., with slight modifications. To extract actin, 1 g of heated minced meat was mixed with 10 mL modified Weber-Edsall solution (0.6 mol L\(^{-1}\) NaCl/0.04 mol L\(^{-1}\) NaHCO\(_3)/0.01 mol L\(^{-1}\) Na\(_2\)CO\(_3\); pH 9.2) and homogenised twice at 17 000 rpm for 1 min (with a 30 s break). The homogenate was transferred to a beaker and stirred for 16 h; the stirred homogenate was mixed with two volumes of distilled water to lower the NaCl concentration to 0.2 mol L\(^{-1}\). The diluted homogenate was centrifuged at 12 000 × g for 20 min; the supernatant was collected for sodium dodecyl sulfate–polyacrylamide gel electrophoresis (SDS-PAGE) analysis.

SDS-PAGE was carried out by the method of Laemmli using 5% stacking and 12% separating polyacrylamide gels. The supernatants were mixed with the sample buffer at a ratio of 1:2 (v/v) and boiled for 3 min. The samples (5 μL) loaded on each well were subjected to electrophoresis at a constant voltage of 200 V using a Mini PROTEAN Tetra cell (Bio-Rad Laboratories, Hercules, CA, USA). Supernatant extracted from raw minced meat was used as control. After electrophoresis, the gels were stained with Coomassie brilliant blue R250. Images of the gels were captured and then the intensities of actin band in each lane were quantified using Quantity One software (Bio-Rad Laboratories). The relative value of the actin band intensity was calculated as intensity of the actin band in each lane in comparison to the control lane.

Statistical analysis
All data were analysed by one-way analysis of variance (ANOVA) using SPSS 18.0 statistical package (SPSS, Chicago, IL, USA). Duncan’s multiple-range test was carried out to determine the significant differences among cooking treatment means. Correlation analyses were also performed among shear force, cooking loss and sarcomere length. Effects were considered significant at \(P < 0.05\).

RESULTS AND DISCUSSION
Cooking time
The typical heating profiles and cooking times of duck breast fillets were recorded during heating of the samples as shown in Table 1. It took a longer time when muscle samples cooked to a higher internal endpoint temperature ranging from 70 to 95 °C. Both two- and three-stage cooking regimes took a much longer time compared to the conventional cooking regime at the same internal endpoint temperatures (\(P < 0.05\)). The two-stage cooking regime took even longer time than the three-stage cooking regime (\(P < 0.05\)); this was largely caused by a lower temperature of the water bath in the first stage of the cooking process (57 °C for the two-stage cooking regime in comparison to 97 °C for three-stage cooking regime).

![Table 1. Cooking time of duck breast muscles cooked to different internal endpoint temperatures by different cooking regimes](https://example.com/table1.png)

<table>
<thead>
<tr>
<th>Variable</th>
<th>70 °C</th>
<th>80 °C</th>
<th>90 °C</th>
<th>95 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>I</td>
</tr>
<tr>
<td>Mean (min)</td>
<td>7.7(^{c})</td>
<td>32.0(^{a})</td>
<td>22.2(^{b})</td>
<td>8.8(^{c})</td>
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<tr>
<td>Standard error</td>
<td>0.7</td>
<td>1.0</td>
<td>0.8</td>
<td>0.4</td>
</tr>
<tr>
<td>N</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

\(^{a,b,c}\)Means with differing superscripts in the same row within the same internal endpoint temperature are significantly different (\(P < 0.05\)).

The duck breast fillets had a uniform shape and the average weight was 96.9 ± 8.3 g. The initial core temperature was 20 °C. Regimes I, II and III represent conventional cooking, two-stage cooking, and three-stage cooking, respectively.
Changes in tenderness

Changes in Meullenet–Owens razor blade shear force (MORSF) value of duck breast muscle cooked to different internal endpoint temperatures by different regimes are shown in Fig. 1. A gradual increase in cooking loss with increased internal endpoint temperature from 70 to 95 °C by each cooking regime was observed. At 90 °C, the three-stage regime significantly decreased cooking loss (9.76%, \( P < 0.05 \)) compared to the conventional regime. Collagen solubilisation was usually inferred to be the reason for this phenomenon; however, an increase in soluble collagen content with prolonged holding time between 50 and 60 °C has not always been detected.\(^2\)–\(^4\),\(^7\),\(^8\) It was concluded that the increased tenderness by staged cooking was more related to the total insoluble fraction collagen than Ringer’s soluble collagen.\(^8\) Improved tenderness by cooking meat with a holding range between 50 and 60 °C also has been attributed to the activity of collagenase\(^10\) and cathepsin B + L,\(^1\) which still had activity up to 60 °C.

Duck breast muscles cooked by the two-stage regime had a higher (\( P < 0.05 \)) MORSF value at the internal endpoint temperatures 80, 90 and 95 °C compared to the conventional cooking regime. However, the three-stage cooking regime significantly (\( P < 0.05 \)) reduced MORSF value at internal endpoint temperature of 80 and 90 °C compared to the two-stage cooking regime. This might probably be caused by the longer cooking time in the two-stage cooking. The two-stage regime allowed longer time at an internal temperature below 55 °C, which has been reported to result in the onset of heat shrinkage of the connective tissue (mainly collagen) before collagen solubilisation took place.\(^5\),\(^17\)

Changes in cooking loss

Changes in cooking loss of duck breast muscle cooked to different internal endpoint temperatures by different regimes are shown in Fig. 2. A gradual increase in cooking loss with increased internal endpoint temperature from 70 to 95 °C by each cooking regime was observed. At 90 °C, the three-stage regime significantly decreased cooking loss (9.76%, \( P < 0.05 \)) compared to the conventional regime. The results were similar to those of Powell et al.\(^8\) who reported that holding beef semitendinosus roasts at 55 °C for 60 min followed by cooking to an internal temperature of 71 °C had no significant effect on cooking yield compared to conventional cooking. Pietraski et al.\(^3\) also reported that staged cooking at 55 °C had no significant effect on the cooking yield of beef semi-membranous muscle. Previously studies have also found a decrease of cooking loss during staged cooking. Obuz et al.\(^2\) found that holding steaks for longer times (15 or 30 min) followed by reheating to an internal temperature of 70 °C increased cooking loss. Walsh et al.\(^4\) reported that beef muscles cooked in a water bath to 55 °C and held at this temperature for 2 h before heating to 72 °C decreased cooking yield. Shortening of sarcomeres with increasing internal endpoint temperature is likely to contribute, at least in part, to the increased cooking losses with increasing internal endpoint temperatures itself, as there was a moderate correlation between cooking loss and sarcomere length (\( -0.444, P < 0.05 \)). Collagen shrinkage, the driving force of fluid loss, as well as possible heat-induced damage to the sarcolemma may also contribute to cooking loss.\(^2\)

At 80 °C, the two-stage regime significantly increased cooking loss (35.31%, \( P < 0.05 \)) compared to the conventional regime. However, the three-stage regime significantly decreased (\( P < 0.05 \)) cooking loss at 80 and 90 °C (23.82% and 12.95%, respectively) compared to the two-stage regime. The two-stage cooking that allowed a longer time for meat holding below 55 °C might induce more shrinkage of connective tissue,\(^5\),\(^17\) which forced out fluids. Moisture has been considered to help ensure a more consistent, juicy and tender product.\(^18\) The higher cooking loss in the two-stage regime caused a tougher meat.
Changes in sarcomere length

Changes in sarcomere length of duck breast muscle cooked to different internal endpoint temperatures by different regimes are shown in Fig. 3. Sarcomere length decreased with increasing internal endpoint temperatures ranging from 70 to 95 °C in each regime. The sarcomere length of duck breast muscle cooked by both staged regimes were longer ($P < 0.05$) at an internal endpoint temperature of 70 °C compared to that cooked by the conventional cooking. These results are consistent with that of Christensen et al.\textsuperscript{5} who reported that the increase of whole meat toughness at temperatures above 60 °C was associated with an increased breaking strength of single muscle fibres. Wattanachant et al.\textsuperscript{19} also reported that the shrinkage of muscle fibres was primarily paralleled to the fibre axis at 70–100 °C. Palka and Daun\textsuperscript{20} found that sarcomere length decreased continuously from 50 to 121 °C. The results indicated that cooking duck breast muscle to an internal endpoint temperature of 70 °C by both staged cooking regimes could avoid shrinkage of muscle sarcomere. The longer sarcomere length may have contributed to the MORSF value when cooking duck breast muscle to internal endpoint temperature of 70 °C by both staged cooking regimes.

Changes in microstructure

Changes in microstructures of duck breast muscle cooked to different internal endpoint temperatures by different regimes are shown in the SEM photographs of Fig. 4. At an internal endpoint temperature of 70 °C, apparent gaps were found between perimysium and muscle fibre bundles. In muscles treated by conventional cooking (Fig. 4,A1), structural changes occurred and the destruction of perimysium was visible. The granulation of the perimysium was also observed. Similar changes were observed by Li et al.\textsuperscript{21} These changes were probably caused by the reduction of the water content, cellular membrane destruction, aggregation and gel formation of sarcoplasmatic proteins and the shortening and solubilisation of the connective tissue.\textsuperscript{20,22} The phenomenon of granulation and destruction of perimysium was more obvious in muscles cooked by the three-stage regime (Fig. 4,A3). At an internal endpoint temperature of 80 °C, gaps between perimysium and muscle fibres were still visible. Structural integrity of the perimysium was destroyed, the granulation of the perimysium intensified, collagen fibres were melted as well. In muscles cooked by the conventional regime, a part of the perimysium portion was still present and collagen fibres were still visible, however, the perimysium almost granulated and began to fill in the space between the fibres and perimysium tubes in muscles cooked by the three-stage regime. At internal endpoint temperatures of 90–95 °C, obvious structural changes were visible. The integrity of perimysium portion was almost destroyed, and the sheet structure of the perimysium almost disappeared. The perimysium melted and the intensified granulation filled up the space between perimysium and fibres.

Liberation of actin

An image of the SDS-PAGE and relative values of liberated actin in duck breast muscle cooked at temperatures of 50 and 60 °C are shown in Fig. 5. A very thin band of actin was observed in unheated duck breast muscle (Fig. 5A). When the muscle was heated at 50 °C, the density of the actin band increased after 1 min, and was significantly increased at 10 min ($P < 0.05$) compared with the density of actin band from unheated muscle. Up to 60 °C, the density of the actin band significantly increased ($P < 0.05$) compared with the density of the actin band from the unheated control sample. The density of actin band reached its maximal level at 10 min at 50 °C and 60 °C; the actin band decreased but was still present at longer holding times of up to 1 h. It seems that longer holding times caused some insolubilisation of the liberated actin. When duck breast muscle was cooked at temperatures higher than 70 °C, no actin band was observed by SDS-PAGE (data not shown), and these results were consistent with data shown by Okitani et al.\textsuperscript{11} These results suggested that cooking duck breast muscle between 50 and 60 °C could lead to the dissociation of actomyosin. At higher temperatures, most of the actomyosin appears to be transferred to a heat-denatured form without dissociation.\textsuperscript{11}

Liberation of actin (dissociation of actomyosin), which occurred at temperatures of 50–60 °C, may relate to the longer sarcomere of duck breast muscle cooked to an internal endpoint temperature of 70 °C by both staged regimes. The liberation of actin between 50 and 60 °C weakened the structural integrity of the myofibrils; thereby the shrinkage of sarcomere between 60 and 70 °C was restricted, and restricted finally also the toughening of duck meat cooked to an internal endpoint temperature of 70 °C by the staged cooking regime.

Correlation

Correlation coefficients for duck breast muscle cooked to different internal endpoint temperatures by different regimes are shown in Table 2. The sarcomere length and cooking loss were both moderately correlated to MORSF values of the duck breast muscle ($-0.456$ and $0.635$, $P < 0.05$). Sarcomere length was also moderately correlated with cooking loss ($-0.444$, $P < 0.05$). Similarly, Wattanachant et al.\textsuperscript{19} reported strong correlations between shear force value and cooking loss, sarcomere length, as well as a strong correlation between sarcomere length and cooking loss. The results suggested that changes in myofibril structure might influence the texture and cooking loss of cooked duck breast muscle.
Table 2. Correlation coefficients for duck breast muscle cooked to different internal endpoint temperatures by different regimes

<table>
<thead>
<tr>
<th>Variable</th>
<th>MORSF value (kg)</th>
<th>Cooking loss (%)</th>
<th>Sarcomere length (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MORSF value (kg)</td>
<td>1</td>
<td>0.635&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.456&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cooking loss (%)</td>
<td>—</td>
<td>1</td>
<td>-0.444&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sarcomere length (µm)</td>
<td>—</td>
<td>—</td>
<td>1</td>
</tr>
</tbody>
</table>

<sup>a</sup> Correlation is significant at the 0.05 level (two-tailed).

MORSF, Meullenet–Owens razor shear force.

CONCLUSIONS

With an increased internal endpoint temperature ranging from 70 to 95 °C, the shear force value and cooking loss of duck breast muscle gradually increased. During cooking, collagen denaturation and solubilisation occurred, and the perimysium was destroyed and granulated. The sarcomere length also shortened with an increasing internal endpoint temperature. At an internal endpoint temperature of 70 °C, duck breast muscle cooked by the staged cooking regime at 50–60 °C had a significantly decreased shear force value and shrinkage of the sarcomere, without apparent negative effects on the cooking yield compared to that by conventional cooking regime. This might be, at least partly, related to the liberation of actin (dissociation of actomyosin) at temperatures between 50 and 60 °C, which may restrict the shrinkage of the sarcomere. The findings of the present study suggest that the three-stage cooking regime could improve the tenderness of duck breast muscle at the temperature of 70 °C, therefore this regime is recommended for further application and research.

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Tenderness of cooked duck meat

Figure 5. Liberation of actin in duck breast meats cooked at 50 and 60 °C as shown by (A) SDS-PAGE together with the relative values (B). Lane LA represents the control (unheated); lanes LB–LE represent the samples held at 50 °C for 1, 10, 30 and 60 min, respectively; lanes LF–LI represent the samples held at 60 °C for 1, 10, 30 and 60 min, respectively. The relative value of the actin band was calculated as the intensity of the actin band in each lane over that in the control lane. Data are representative of three independent experiments and bars indicate standard errors of means. a–e Bars with different letters differ significantly (P < 0.05).

REFERENCES


