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ORIGINAL ARTICLE

Effects of boning method and postmortem aging on meat quality characteristics of pork loin

Chunbao LI, Juqing WU, Nan ZHANG, Song ZHANG, Juan LIU, Jinping LI, Hongmin LI, Xianchao FENG, Yanqing HAN, Zhiyuan ZHU, Xinglian XU and Guanghong ZHOU*

Key Laboratory of Meat Processing and Quality Control, MOA
College of Food Science and Technology, Nanjing Agricultural University, Nanjing, China

ABSTRACT

This work investigated the effects of boning method and postmortem aging on pork loin color, shearing value and sensory attributes. Two experiments were assigned. In Experiment I, 30 Chinese native black pigs were slaughtered and their carcasses were divided into three groups: (i) hot-boning: carcasses were fabricated within 45 min postmortem just after dressing; (ii) cold boning at 24 h: carcasses were fabricated after chilling at 0°C for 24 h; (iii) cold boning at 36 h: carcasses were fabricated after chilling at 0°C for 36 h. In Experiment II, right sides of the second group in Experiment I were used and primal cuts were vacuum packed and aged for 1 day, 8 days and 16 days. Pork loins (*Longissimus lumborum*) were used for color measurement, shearing test, and sensory evaluation. Among three boning methods, cold-boning at 36 h postmortem had the advantages of giving muscles a better color, the lowest cooking loss and cooked shearing value, and the highest sensory tenderness, juiciness, flavor and overall liking. Postmortem aging could improve pork quality characteristics, but it is not the fact that the longer aging time is, the better pork quality would be. Eight days may be enough to obtain an acceptable sensory attribute. These results are meaningful for pork processing and pork consumption.

Key words: *aging, boning, palatability, pork, vacuum packaging.*

INTRODUCTION

Boning is one of the important procedures during pork processing that influences pork quality and safety. Hot-boning allows the whole carcass to be reduced to individual muscles or primal cuts before chilling but the muscles are still in the pre-rigor state. However, hot-boned meat has a short shelf life due to the action of microorganisms (Davey & Garnett 1980). Cold-boning involves the removal of primal cuts from the carcass after rigor mortis has set in. However, it has a potential detrimental impact on meat tenderness due to rigor mortis (Tornberg 1996). Previous studies have confirmed that aged pork had a better eating quality (Kristensen & Purslow 2001). Packaging, especially vacuum packaging, is widely used in aged meat because of its advantages: reduced weight losses, preserved visual appearance, improved hygiene control, and enhanced palatability (Seideman & Durland 1983).

Although people have accepted cold-boned, aged pork as a safer, more palatable food in America and Europe, many Asian consumers prefer hot-boned pork to cold-boned, aged pork because they think that hot-boned pork should be better (personal communication). The differences in consumer preference to pork between countries could be attributed mainly to their socio-demographic factors and eating habits (Ngapo *et al.* 2007). Most of previous studies have focused on a comparison of meat quality between aged and unaged pork (Channon *et al.* 2004), but few data are

Correspondence: Guanghong Zhou, Key Laboratory of Meat Processing and Quality Control, Ministry of Education, College of Food Science and Technology, Nanjing, Nanjing Agricultural University, Nanjing 210095, China. (Email: ghzhou@njau.edu.cn)
*Corresponding Author: Dr. G.H. Zhou. Email: ghzhou@njau.edu.cn. Tel: 8625 84395376.
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available on the differences between hot-boned pork and cold-boned pork. Rees *et al.* (2002) focused much on the comparison of pork quality between accelerated-boned pork at 30 min postmortem and conventionally boned pork at 1 day. However, hot-boned meat is usually consumed at least 10 h postmortem due to distribution and retail. It is maybe more useful to understand meat quality characteristics of hot-boned pork at 10 h postmortem.

In China, hot-boned pork is the predominate pork served. with cold-boned pork accounting for only 10% of fresh pork consumption (Kong 2004). For cold-boned pork, one part of carcasses are fabricated at 36 h and distributed directly to local retail markets, whilst the other parts of carcasses are fabricated at 24 h, and prime cuts are vacuum-packed, stored at 0°C to 4°C, and then distributed to long-distance retail markets. Long-term distribution, in fact, is concomitant to meat aging that improves meat palatability. It is critical to balance the improvement of meat quality and the shelf life of products. However, few such data are available.

Therefore, the objectives of the present study were: (i) to compare the differences in pork quality characteristics among hot-boned pork, cold-boned pork at 24 h and 36 h; (ii) to track the changes of quality characteristics of vacuum-packed pork during aging.

MATERIALS AND METHODS

Meat sampling

Two experiments were arranged in the present study. Experiment I was designed to compare pork quality characteristics among hot-boned pork, cold-boned pork at two times (24 h and 36 h). Experiment II was designed to observe the changes of pork quality characteristics during a 16-day aging.

Experiment I: In a pig slaughter-line, 30 pork carcasses were selected. Ten carcasses were boned at 45 min and then the meat was put i in PVC film at room temperature (18°C to 20°C) for 10 h (Hot-boning). Another 10 carcasses were transferred to a 0°C chiller till 24 h, and then fabricated (Cold-boning at 24 h). The remaining 10 carcasses were chilled at 0°C for 36 h till fabrication (Cold-boning at 36 h). At each time, left sides of each carcass were fabricated and three 2.54-cm thick loin pieces (*longissimus lumborum*) were obtained for meat color measurement, shearing test and sensory evaluation, respectively. All the carcasses came from castrated Chinese native black pigs (live weight: 95 kg to 100 kg). Before dressing, animals were rested with *ad libitum* access to water but not food, at a commercial pork processing plant for about 20 h. Animals were electrically stunned by a head-only automatic stunner for 3 s (voltage: 180 V, current: 1.3 A), exsanguinated and scalded at 62°C for 3 min. Cleaning and evisceration of the carcasses were completed within 45 min postmortem.

Experiment II: The corresponding right sides of the 10 carcasses of the second group in Experiment I were used. Before entering into the chiller, initial carcass temperature and pH of pork loin were measured using a portable needle-tipped combination electrode (HI 9025; HANNA, Woonsocket, Italy) combined with a portable needle-tipped thermometer (HI145; HANNA). During chilling, carcass temperature and pH were tracked at 4 h, 8 h, 12 h, 16 h and 20 h, respectively. Finally, at 24 h, the whole right loin was removed from each carcass and divided into three roasts. Roasts were individually vacuum packed using Cryovac BB4 bags, and randomly assigned to one of the three aging points: 0 days, 7 days and 15 days (actual aging periods: 1 day, 8 days and 16 days, respectively). After vacuum packaging, the packs were dipped in an 80°C water bath for 5 s to shrink. At each aging point, each roast was further divided into three 2.54-cm thick pieces: one for meat color measurement, one for shearing test and the third for sensory evaluation.

Meat color measurement (CIE L*a*b*)

Before measurement, loin pieces were bloomed in the air for 10 min to 15 min. Five measurements were performed on each loin piece. Color parameters were determined using a Minolta colorimeter (CR-300; Minolta Camera Co., Osaka, Japan) with illuminant D65, a 0° viewing angle and an 8 mm port/viewing area. Before use, the colorimeter was standardized with a white tile (mod CR-A43). The following color coordinates were determined: lightness (L*), redness (a*) and yellowness (b*). Here, L* represents lightness, ranging from 0 to 100. The a* value represents red or green, where a positive value is red, and a negative value is green. The larger the value in either direction, the stronger the color. Similar is true for yellow/blue represented by the b* value.

Shearing test of raw meat

According to Ruiz de Huidobro *et al.* (2005), shearing value of raw meat was a good predictor of sensory juiciness and the number of chewings. Therefore, a shearing test was performed on the raw meat. The measurement was performed on the same loin pieces on which meat color was determined. Six 1.27-cm-diameter cylindrical cores parallel to the muscle fiber orientation were obtained from each loin piece. A single, peak shear force measurement was recorded for each core using a Warner-Bratzler meat shear machine (Salter 235; Manhattan Kansas, USA).

Cooking loss and shearing test of cooked meat

Loin pieces were individually placed inside polyethylene bags and cooked in a water bath at 80°C until an internal temperature of 70°C was reached. During cooking, the internal temperature was tracked by the above-mentioned portable needle-tipped thermometer. The cooked pieces were cooled at 4°C for 16 h (overnight), taken from the bags, dried with filter paper and then weighed. The cooking loss was expressed as the percentage weight change before and after cooking. And then six 1.27-cm-diameter cylindrical cores parallel to the muscle fiber orientation were removed from each piece. A single, peak shear force measurement was obtained for each core using a Warner-Bratzler meat shear machine (Salter 235; Manhattan Kansas, USA).

Sensory evaluation

The sensory panel design allowed for the evaluation of 30 loin pieces and thus of 150 cores in Experiments I and II, respectively. A total of 15 consumers were recruited to take part in each sensory test. Each consumer was given 10 coded 1 cm × 1 cm × 1 cm cores per sitting (providing 5 consumer responses per muscle).

Loin pieces were cooked according to the most common cooking method in Chinese households – water boiling. The procedure was as follows: Loin pieces were heated in boiling water for about 15 min to achieve an internal temperature of approximately 70°C. After cooking, pieces were cut into 1 cm^3 cubes prior to individual presentation to consumers. Sensory evaluation was performed according to the procedure of Channon *et al.* (2004) with a small modification. Briefly, all consumers were provided with water and biscuit to cleanse their palates between samples. Consumers were asked to use a continuous line scale to assess quality of loin pieces. The scores used for flavor and overall liking were: 0 = dislike extremely to 10 = like extremely, with the mid-point designated as 'neither like nor dislike'. The scores used for tenderness were: 0 = very tough and 10 = very tender. Juiciness was scored using: 0 = very dry to 10 = very juicy.

Statistical analysis

In Experiment I, the effect of boning method on meat color, shear force value, cooking loss and sensory scores were evaluated by a simple analysis of variance (ANOVA) technique where these determinants were dependent variables and boning method the independent variable. A Duncan's multiple-range test was performed to compare the averages of meat color, shear force value, cooking loss and sensory scores among three boning treatments.

In Experiment II, the pH and temperature decline of chilled pork carcasses were evaluated using ANOVA and Duncan's multiple-range test. The similar procedures were performed on evaluating the effect of aging period on the above variables.

All statistical analyses were performed by SAS 8e (SAS Institute. Inc. Cary, NC, USA, 2001).

RESULTS AND DISCUSSION

Effect of boning method

As shown in Table 1, boning method had a significant effect on meat color, shearing value and sensory scores.

Meat color

Compared with hot-boned loin, cold-boned loin at 24 h had a lower L* value and a * value ($P < 0.0001$), whereas cold-boned loin at 36 h had a slightly higher L* value and a 2.5-fold b* value. It indicates that cold-boning may result in a darker appearance when operating at 24 h postmortem or a slightly lighter appearance at 36 h, which could be associated with the rate of rigor attainment and the pattern of blooming (Young *et al.* 1999). Young *et al.* (1999) found that color coordinate L* value was positively affected by the temperature during rigor attainment within the first-hour blooming. In the present study, all the blooming time was less than 1 h. Hot-boned pork loin that entered rigor more quickly at approximately 20°C became expectedly more reflective, whereas cold-boned pork loin may attain the maximum rigor at 24 h and thus was less reflective at the same blooming time. At 36 h, the rigor of chilled pork loin was partially resolved and its blooming time was similar to that of

Table 1 A comparison of meat quality characteristics among hot-boned, cold-boned at 24 h and 36 h pork loins (mean ± standard error)†‡

Items	Hot-boning at 45 min	Cold-boning at 24 h	Cold-boning at 36 h	*P* value
Color attributes				
L*	50.39 ± 0.27[b]	46.05 ± 0.28[c]	51.54 ± 0.45[a]	<0.0001
a*	11.97 ± 0.13[a]	6.87 ± 0.15[b]	11.92 ± 0.54[a]	<0.0001
b*	2.18 ± 0.09[c]	2.91 ± 0.09[b]	5.36 ± 0.13[a]	<0.0001
Shearing value (N)				
Raw meat	18.51 ± 0.38[b]	24.89 ± 0.58[a]	23.68 ± 0.99[a]	<0.0001
Cooked meat	41.96 ± 0.65[a]	32.54 ± 0.53[b]	32.78 ± 0.81[b]	<0.0001
Cooking loss (%)	22.40 ± 0.70[a]	20.58 ± 0.60[a]	14.25 ± 1.08[b]	<0.0001
Sensory score				
Tenderness	4.46 ± 0.16[b]	4.75 ± 0.18[b]	5.40 ± 0.12[a]	<0.0001
Flavor	4.65 ± 0.16[a]	4.76 ± 0.18[a]	5.11 ± 0.12[a]	0.0556
Juiciness	4.24 ± 0.17[b]	4.31 ± 0.18[b]	4.94 ± 0.12[a]	0.0008
Overall liking	4.55 ± 0.15[b]	4.67 ± 0.16[b]	5.29 ± 0.11[a]	<0.0001

†Means include those measured at 10 h (hot boned), 24 h and 36 h post-mortem. ‡Means with different superscripts in the same row differ significantly.

hot-boned pork. The differences in a* value between hot-boned pork loin at 10 h and cold-boned pork loin at 24 h could be attributed to their different oxygen-consuming capacity due to the residue activities of oxygen-reducing system to myoglobin/ metmyoglobin in meat.

Shearing value and cooking loss

For raw meat, both cold-boned loins at 24 h and 36 h had higher shearing values than hot-boned meat ($P < 0.0001$). A 4.86% decrease in shearing value occurred when cold-boning at 36 h, compared to cold-boning at 24 h. The higher shearing value of cold-boned loin could be attributed to the maximum rigor mortis at 24 h and then a slight resolution of rigor at 36 h. However, cold-boned loins, especially at 36 h, had lower cooking losses and shearing values of cooked meat than hot-boned loin ($P < 0.0001$).

Sensory score

Sensory evaluation showed that cold-boned loin at 36 h had higher sensory tenderness, juiciness and overall liking scores than hot-boned loin and cold-boned loin at 24 h. The latter two loins had similar sensory scores. There was no statistically significant difference in the sensory flavor scores ($P = 0.0556$). As known, sensory tenderness was mainly determined by the state of myofibrillar protein and intramuscular connective tissue of cooked meat, whilst sensory juiciness and flavor were determined by moisture content and/or intramuscular fat content retained within cooked meat (Lawrie & Ledward 2006). Although Ruiz de Huidobro *et al.* (2005) showed a good relationship between shearing value of raw meat and sensory juiciness and the number of chewings, in the present study the shearing value of raw meat could not correspond to that of cooked meat or any of sensory attributes (data not shown). This could be attributed to the different states of raw meat, where hot-boned loin lay in a relaxing state but cold-boned loin in a shortening state. It is speculated that during cooking, the relaxing meat shrink stronger than the shortening meat, release more juice, and thus have higher cooking loss and cooked shearing value, and lower sensory attributes. A further study is needed to confirm this.

Therefore, among three boning methods, cold-boning at 36 h postmortem had the advantages of given muscles a better appearance, the lowest cooking loss and cooked shearing value, and the highest sensory tenderness, juiciness, flavor and overall liking.

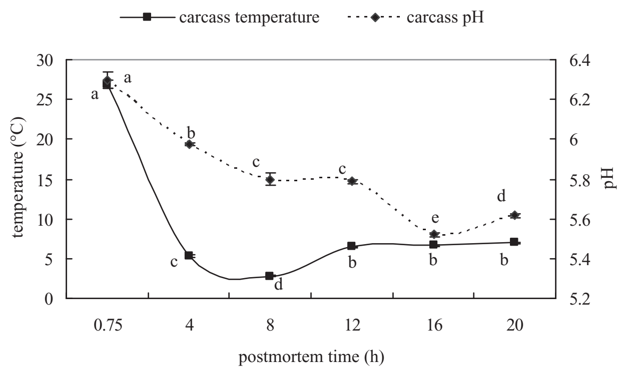

Figure 1 Change of carcass temperature and pH value at 4°C within 20 h during postmortem chilling. Solid line shows the change of carcass temperature. Means with different letters under solid line indicate significant change occurred in temperature ($P < 0.05$). Dash line shows the change of carcass pH value. Means with different letters above dash line indicates pH changes significantly ($P < 0.05$).

Carcass pH and temperature decline

As shown in Figure 1, carcass pH declined gradually within the first 16 h and then returned by 0.3 pH unit within the next 4 h ($P < 0.05$). It is no doubt that the pH decline within the 16 h resulted from muscle glycolysis. The increase in pH value between 16 h and 20 h could be due to the release of peptides and amino acids by proteolysis (Lawrie *et al.* 1961). Carcass temperature declined rapidly within the first 4 h ($P < 0.05$), and then gradually within the second 4 h ($P < 0.05$), but it had a small increase between 8 h and 12 h ($P < 0.05$), and then kept constant.

Effect of aging

As shown in Table 2, postmortem aging had a significant influence on meat color, shearing values, cooking loss, and sensory score.

Meat color

L* value increased with aging period, but a* and b* values increased only between day 1 and day 8. That is to say, pork loin became brighter during storage. The resolution of rigor and the degradation of myofibrillar protein during aging could contribute to the shortening of blooming time and thus make pork loin more reflective at 8 days and 16 days. Tikk *et al.* (2008) reported the occurrence of meat discoloration during postmortem aging, but the present study showed that the first 8 days of aging improve meat color attributes.

Table 2 A comparison of meat quality characteristics among aged pork loins at 1 day, 8 days and 16 days (mean ± standard error)†

Items	Aging period (days)			
	1	8	16	*P* value
Color attributes				
L*	47.23 ± 0.19[c]	53.55 ± 0.27[b]	54.64 ± 0.25[a]	<0.0001
a*	6.47 ± 0.34[b]	12.31 ± 0.26[a]	11.33 ± 0.26[a]	<0.0001
b*	3.21 ± 0.09[b]	8.08 ± 0.21[a]	7.66 ± 0.17[a]	<0.0001
Shearing value (N)				
Raw meat	24.16 ± 0.37[a]	23.18 ± 0.68[a]	18.93 ± 0.73[b]	<0.0001
Cooked meat	32.78 ± 0.43[a]	25.83 ± 0.73[b]	27.05 ± 0.88[b]	<0.0001
Cooking loss (%)	19.98 ± 0.73[b]	16.29 ± 0.77[c]	25.90 ± 1.17[a]	<0.0001
Sensory score				
Tenderness	4.86 ± 0.17[b]	6.19 ± 0.20[a]	6.23 ± 0.15[a]	<0.0001
Flavor	4.67 ± 0.17[b]	5.40 ± 0.18[a]	5.59 ± 0.16[a]	<0.0001
Juiciness	4.18 ± 0.17[b]	5.39 ± 0.20[a]	5.23 ± 0.17[a]	<0.0001
Overall liking	4.79 ± 0.16[b]	5.67 ± 0.18[a]	5.81 ± 0.13[a]	<0.0001

†Means with different superscripts in the same row differ significantly.

Vacuum packaging combined with heat shrinkage could contribute to this change.

Shearing value and cooking loss

Postmortem aging led to the decline in shearing value of raw pork loin ($P < 0.0001$). But the first decrease between day 1 and day 8 was so small that there was no significant difference ($P > 0.05$). The change in shearing value of raw meat could reflect the degradation of myofibrillar components (Eikelenboom *et al.* 1998) in the earlier period and structural weakening of intramuscular connective tissue in the latter period (Nishimura & Hattori 1995). For cooked pork loin, shearing value decreased significantly between day 1 and day 8 ($P < 0.0001$), which could be because of the proteolysis of cytoskeleton (Eikelenboom *et al.* 1998). A longer period of aging did not decrease the shearing value further ($P > 0.05$). The absence of aging effect on WBSF of cooked meat between 8 days and 16 days could be attributed to the cooking effect on muscular structure that causes the low sensitivity of the Warner Bratzler test to detect myofibrillar changes at 16 days (Campo *et al.* 2000). Cooking losses had a slight decrease between 1 day and 8 days, but had a great increase between 8 days and 16 days ($P < 0.0001$). In a study of Boakye and Mittal (1993), cooking loss has been shown to be the same from 2 days of ageing until 12 days, but with an increase at 16 days. The change in cooking losses may result from the change of water-holding capacity of muscle. In the present study, the degradation of the cytoskeleton and thus the improvement of the water-holding capacity during aging could be attributed to the decrease in cooking losses within the first 8 days. During subsequent aging, the cell structure could become more liable to destruction by heat and thus cooking losses increased between 8 days and 16 days.

Sensory test

All the sensory attributes were improved by postmortem aging, especially within the first 8 days, but varied little between 8 days and 16 days. Channon *et al.* (2004) also found that aging of pork loin steaks for 7 days improved sensory tenderness and overall liking scores by 4.7 units and 3.0 units, respectively, on a 100 point scale compared with pork aged for only 2 days post-slaughter. It is therefore enough to refrigerate pork for 8 days to obtain an acceptable palatability.

Implications

Boning methods influenced pork quality characteristics. In spite of a good appearance, hot-boned pork loin was not preferable due to its lower cooking yield and discounted sensory attributes. For chilled pork carcasses, boning time should be dependent on the target market: operating at 24 h if prime cuts would be distributed long distance, otherwise operating at 36 h. Postmortem aging could improve pork quality characteristics, but it is not the fact that the longer aging time is, the better pork quality would be. Eight days may be enough to obtain an acceptable sensory attributes. If a longer-time storage is inevitable, it is essential to choose vacuum packaging, combined with heat shrinkage if budget permits.

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