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ARTICLE

Comparison of Blood Loss and Meat Quality Characteristics in Korean Black Goat Subjected to Head-Only Electrical Stunning or without Stunning

Allah Bakhsh[1], Ishamri Ismail[1], Young-Hwa Hwang[2], Jung-Gyu Lee[3], and Seon-Tea Joo[1,2,3,*]

[1]Division of Applied Life Science (BK21Plus), Gyeongsang National University, Jinju 52852, Korea
[2]Institute of Agriculture & Life Science, Gyeongsang National University, Jinju 52852, Korea
[3]Department of Animal Science, College of Agriculture & Life Science, Gyeongsang National University, Jinju 52852, Korea

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***Corresponding author** : Seon-Tea Joo
Division of Applied Life Science (BK21Plus), Gyeongsang National University, Jinju 52828, Korea
Tel: +82-55-772-1943
Fax: +82-55-772-1949
E-mail: stjoo@gnu.ac.kr

***ORCID**
Allah Bakhsh
0000-0002-7866-1736
Ishamri Ismail
0000-0003-4820-8292
Young-Hwa Hwang
0000-0003-3687-3535
Jung-Gyu Lee
0000-0002-2446-7348
Seon-Tea Joo
0000-0002-5483-2828

Abstract This study assessed the effects of non-stunning (NS) and head-only electrical stunning (HOES) slaughtering condition on meat quality traits of *longissimus lumborum* (LL) muscle from Korean black goat (KBG). Ten KBGs (18 months) were assigned into two groups and exposed to either NS or HOES treatments. Blood loss (BL) % was measured after exsanguination, and meat quality traits including muscle pH, meat color measurements (CIE L*, a*, b*, Chroma, and hue angle), water-holding capacity (WHC), Warner-Bratzler shear force (WBSF), and sarcomere length were measured at 24 h postmortem. Results indicated that NS and HOES had no significant difference on BL %, the rate of pH decline, meat color properties, and WHC ($p>0.05$). It has only a small effect on WBSF and sarcomere length values, but the difference was marginal. These results suggested that meat quality of LL muscle from goat might not be affected by slaughter methods because neither NS nor HOES did result in poor quality of meat.

Keywords goat meat, non-stunned, stunning, meat quality, slaughter method

Introduction

Slaughter processing is important for animal well-being, meat quality, safety, and public health in the 21st century (Sabow et al., 2016). In recent years, increased concern about animal welfare demands the researchers to elucidate the implications of animal handling, transportation, stunning and slaughtering on live animal stress and meat quality. Slaughter of food animals is normally a two-stage process i.e. stunning and bleeding (exsanguination). Stunning is deliberately induced process which lead to loss of consciousness and sensibility without pain and also reduces struggling through a more precise and immediate slaughtering process. Species specific slaughter legislation

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codes are available for slaughtering procedure. However, the appropriateness of generally used methods does not only depend on species but also the accessibility of services, consumer demands and/or acuities and economic reflections (Anil, 2012).

Slaughter of animals without stunning is the biggest animal welfare issue for the meat industry around the world (Grandin, 2017). Alterations in the slaughter techniques may not only effect animal welfare but also affects postmortem muscle metabolism (Bourguet et al., 2011). The traditional slaughter of animals without stunning is still a relevant method in this century. However, firm guidelines are followed throughout slaughtering sequences, i.e animal welfare, working environment, food cleanliness, and protection (Bergeaud-Blackler et al., 2007). Stunning animals before slaughter was not a legal requirement until 1902 in Finland, 1929 in Norway, 1937 in Sweden, 1947 in the UK, 1953 in Denmark (Metcalf, 1989), 1985 in the USA (USC, 1958), and 1974 in the EU (Council Directive, 1974). Studies have reported the impact of stunning and slaughtering methods on the meat quality. Majority of the studies were conducted on sheep and cattle (Anil et al., 2004, Onenc and Kaya, 2004; Sazili et al., 2013; Vergara et al., 2005). There are very little information existing on slaughter techniques and meat quality traits of goat meat. Therefore, the objective of the current study was to compare the physicochemical characteristics of *longissimus lumborum* (LL) muscle from goats exposed to stunning and without stunning.

Materials and Methods

Animals and muscle samples

A total of ten Korean black goats (KBGs) (yielding 20 muscle left and right side) with age of 18 months were attained from a commercial farm. Goats were raised under same environments and nourished with same diets. Goats were transferred from the commercial farm to slaughter house one day before the experiment, and were rested for 18 h with free watering but no food before slaughtering.

The goats were separated into two groups and slaughtered by two different methods. For the non-stunned method (NS, n=10), slaughtering was carried out by license slaughter man for halal slaughtering with following method. The head of each animal was dragged dorsally and stretch toward the neck for the purpose of exsanguinations. Transverse section was accomplished using a piercing knife. Without removing the head a sharp and swift cut was carried on neck served the major veins, arties, and nerves.

The head-only electrical stunning method (HOES, n=10) was carried out before slaughtering and similar procedure as earlier described in NS slaughtering. Animals were stunned electrically using the head only technique at a constant of 1 A, 50 Hz for 3 s, the head electrodes were positioned between the eyes and the ears on both edges. The procedure was carried out using electrical stunning transformer type CS-1 system (Karl Schermer, Ettlingen, Germany) linked to double-electrode scissor type dry stunning tongs (Z3, Karl Schermer, Ettlingen, Germany). Instantly after stunning, the goats were bled to eliminate extra blood from the carcass. The regular stun-to-stick interval was 8.61±0.11 s, and the interval of 2–3 min was adopted between slaughter and dressing.

After slaughter, all carcasses were stored in cold room at 4℃ for 24 h. The muscle pH was measured with 3 g meat sampled at 1, 2, 3, 6, 12, and 24 h postmortem from carcass. The LL muscle was excised at 24 h postmortem to investigate meat quality traits.

Determination of blood loss

Blood loss % was determined as the difference of goat weight between pre-slaughter weight (pre-SW) and post-slaughter

weight (post-SW) as followed:

$$\text{Blood loss } \% = [(\text{pre-SW} - \text{post-SW})/\text{pre-SW}] \times 100$$

Muscle pH

The pH of the LL muscle was measured using a portable pH meter (Mettler Toledo, MP 230, Switzerland). A total of 3 g of meat from each group was chopped and homogenized (IKA T25 ULTRA-TURRAX Germany) in 27 mL of distilled water for 30 s. The pH meter was first calibrated on 7, 4.01, and 9.21 before evaluation of pH.

Color measurements

Minolta Chromameter (Minolta CR-300, Japan) was used for determination of meat color. Before measuring the color values, the Minolta Chromameter was calibrated with white plate (Y=93.5, X=0.3132, y=0.3198) the different color values was evaluated by measuring L* (lightness), a*(redness/greenness) and b* (yellowness/blueness) hue (h°) and Chroma (C). For statistical analysis, an average value from different positions from each sample surface was carried out.

Water-holding capacity

Water-holding capacity (WHC) of meat was determined by drip loss percentage and cooking loss percentage. Drip loss percentage was measured based on the method as described by Honikel (1998). A sample weight of approximately 25–30 g was weighed and suspended on a supporting wire and then placed within the container. Samples were stored at 4℃ chilling room for 24 h and again weighed after dry. Drip loss % was calculated as a percentage of the initial weight.

For cooking loss %, the LL muscle was cut into 4×3×3 cm (L×H×W) dimension with weight 25–30 g and packed in a low-density polyethylene bag. Samples were cooked at 75℃ for 30 min and chilled immediately in the ice flake for 10 min. Cooking loss % was determined by weight difference before and after cooking.

Warner-Bratzler shear force

Warner-Bratzler shear force (WBSF) was carried out on the cooked sample based on AMSA (1995) guideline. Samples core (1.0 cm-diameter) were inserted parallel to the myofiber direction of the cooked sample. The cores were sheared perpendicular to the myofibers position using an Instron tensile testing machine (Model 4443, Instron Corp., USA) with a V-shaped shear blade. Peak force was obtained using 100 N load cell tension applied at a crosshead speed of 250 mm/min and the full-scale load was 50 kg. Shear force was reported as maximum peak force recorded during the test. For each sample group average of five measurements were recorded.

Sarcomere length

Sarcomere length was determined by the method of Cross et al. (1981). Samples (3.0×3.0×2.0 cm) were run longitudinally and put in vials comprising solution A (0.1 M KCl, 0.39 M boric acid, and 5 mM ethylene-diaminetetra acetic acid in 2.5% glutaraldehyde) for 2 h. Samples were then relocated to fresh vials comprising solution B (0.25 M KCl, 0.29 M boric acid, and 5 mM ethylene-diaminetetra acetic acid in 2.5% glutaraldehyde) for 17–19 h. On the next day, individual fibers were torn into fragments and placed onto microscope slides with a droplet of solution B. The slide was placed straight in the path of a

vertically oriented laser beam to give a display of diffraction bands on a screen. Sarcomere length (μm) was calculated using the following equation.

$$\mu = (632.8 \times 10^{-3} \times D \times \left[\sqrt{\left(\frac{T}{D}\right)^2} + 1\right])/T$$

Where D is a distance from specimen to diffraction pattern screen (D=98 mm) and T is the separation (mm) between zero and the first maximum band.

Statistical Analysis

The data obtained were analyzed using analysis of variance (ANOVA) using SPSS (SPSS 16.0, Chicago, IL, USA) and variances between mean values were obtained by Student *t*-test. Significance was defined at a level of $p<0.05$. The results were stated as the least square mean values of three independent replications, except for WBSF has recorded the average for five measurements.

Results and Discussion

The blood loss (BL) results are shown in the Table 1 in which goats were assigned to slaughtering technique, i.e. NS and HOES slaughter. There was no significant difference ($p>0.05$) in BL % between NS and HOES. However this was not statistical difference but the BL of NS was somewhat higher than that of HOES. The probable reason could be the outcome of Tachycardia of the heart instantly after slaughter in NS group than HOES group. Contrasting result have been observed on different studies which is carried out on slaughter method and BL. Results of our experiment are similar with Anil et al. (2004, 2006) who reported no effect of slaughter methods including stunning and no stunning on BL in sheep and cattle. Anil et al. (2004) reported approximately 3.98% and 3.78% of BL for sheep slaughtered with or without stunning, respectively. On the other hand, Velarde et al. (2003) also assessed the effect of two slaughtering methods (NS and HOES) on lambs. They found that the amount of BL was much lower as relative to the body weight in non-stunned as compared to head stunned animal in which the BL was significantly higher.

The postmortem pH decline pattern of LL muscle from goats slaughtered with NS or HOES are shown in Fig. 1. The pH values for both groups were almost identical throughout the monitoring period ($p>0.05$). Our results agree with Velarde et al. (2015) and Wong et al. (2003) but contradict to findings obtained by (Kadim et al., 2010; King et al., 2004). According to Devine et al. (1984) and Velarde et al. (2003), electrical stunning is one of the main reason for the increased rate of

Table 1. Pre-slaughter body weight, post-bleeding body weight and blood loss in goats in subjected to different slaughtering methods

Parameters	Non-stunning (NS)	Head-only electrical stunning (HOES)
Pre-slaughter body weight (kg)	52.8±1.66	53.4±1.24
Post-bleeding body weight (kg)	50.7±0.45	51.3±0.71
Blood loss (kg)	2.14±0.03	2.11±0.04
Blood loss (%)	4.05±0.09	3.95±0.07

Data is mean±SD.

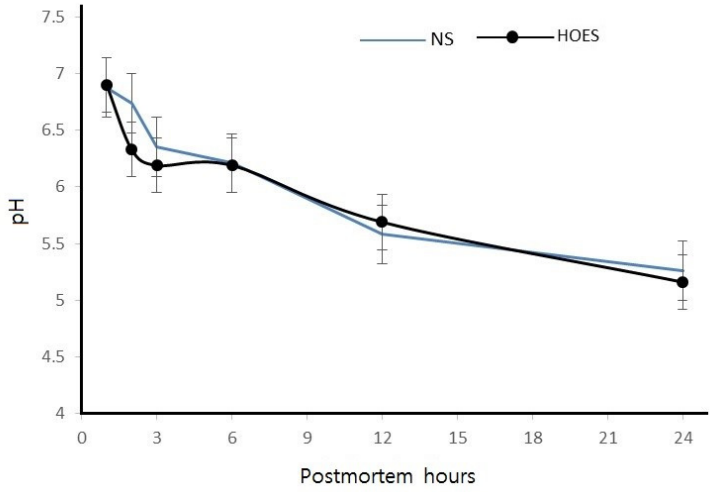

Fig. 1. The muscle pH decline rate during 24 hours of postmortem. Error bar represent standard error. NS, non-stunning slaughter; HOES, head-only electrical stunning.

postmortem glycolysis. However, our results showed that the changes in pH during postmortem muscle glycolysis was not different from that observed in non-stunned goats. This might be due to the conditions in pre-stunning that resulted in these outcomes. Since the very minor and short stun-stick interval can reduce the rate of postmortem glycolysis (Velarde et al., 2003), in the present study, the postmortem pH decline pattern was not much affected by slaughtering methods.

Meat color properties of the LL muscles subjected to NS and HOES are presented in Table 2. As expected, no significant differences in lightness (L*), redness (a*), yellowness (b*), color saturation (C), and hue angle (h°) values were observed between NS and HOES sample groups. The similar color properties of stunned (HOES) and non-stunned (NS) sample groups can be associated with the pH values with having no difference after 24 h postmortem. These findings were agreed with Velarde et al. (2003) and Vergara et al. (2005) who reported that stunned sheep showed no significant difference in L*, a* and b* values as associated to non-stunned sheep meat. However, the meat of NS seemed to be brighter (higher L* values), redder (higher a* values), and lower discoloration (lower h° values) than those of the HOES sample, although the difference was not significant.

In the present study, WHC was measured as drip loss and cooking loss (Fig. 2). Different slaughtering condition had no effect on cooking loss and drip loss ($p>0.05$). Although the numerical difference was marginal, however, slightly high drip loss % and cooking loss % were observed in NS goat meat compared to HOES goat meat. This might be due to the small changes in pH after cooking loss and drip loss procedure, even though the pH values were not significantly different between

Table 2. Meat color parameters of *longissimus lumborum* muscle in goats subjected to NS and HOES slaughtering conditions

Variables	Non-stunning (NS)	Head-only electrical stunning (HOES)
Lightness (L*)	36.05±2.16	32.46±2.69
Redness (a*)	16.37±3.39	15.58± 3.25
Yellowness (b*)	10.44±3.92	11.87±0.47
Chroma (C)	19.41±3.31	19.59±2.84
Hue (h°)	32.53±1.43	37.30±1.68

Data is mean±SD.

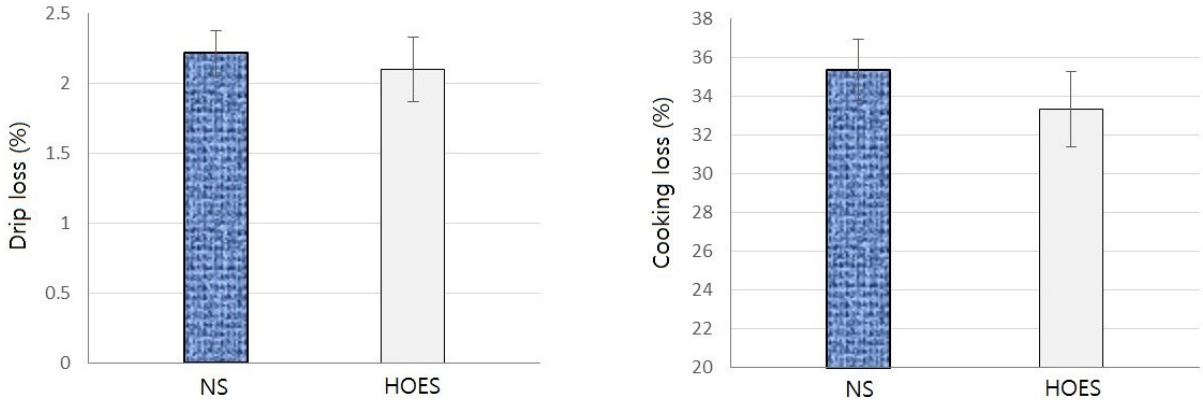

Fig. 2. The relationship between drip loss % and cooking loss % of *longissimus lumborum* muscle in goats subjected to NS and HOES slaughtering condition. Error bar represent standard error. NS, non-stunning; HOES, head-only electrical stunning.

NS and HOES groups after 24 h postmortem. Corroborating the present observation, this result agrees with Lokman et al. (2017), and Onenc and Kaya (2004) in WHC with no difference recorded among method of slaughter in goat and cattle, respectively. However, in contrast to Wong (2015) who described that non-stunned animals shows a lower cooking loss than stunned animals. This author defined the effect of protein denaturation caused by heat from cooking in the stunning samples were higher and thus resulting in a higher loss than non-stunned samples.

The results obtained for shear force and sarcomere length are shown in Fig. 3. The values obtained for both NS and HOES samples were not significantly different, but NS samples showed slightly lower WBSF values than HOES samples. Interestingly, data in sarcomere length shown that pre-stunning induced HOES samples were slightly lower than NS samples. It is well recognized that when sarcomere length is increased, the overlap of actin and myosin filament is also decreased, which in turn results in the tenderness of cooked meat (Kannan et al., 2006). However, sarcomere length could not be concluded to be the main factor for meat tenderness, because some previous studies had found that sarcomere length did not influence meat tenderness (Tschirhart-Hoelscher et al., 2006; Wheeler et al., 2000). Also, Lokman et al. (2017) found that different methods of slaughtering either with or without stunning had no effect on sarcomere length, rather it had affected by the postmortem storage or duration of aging (Pen et al., 2012).

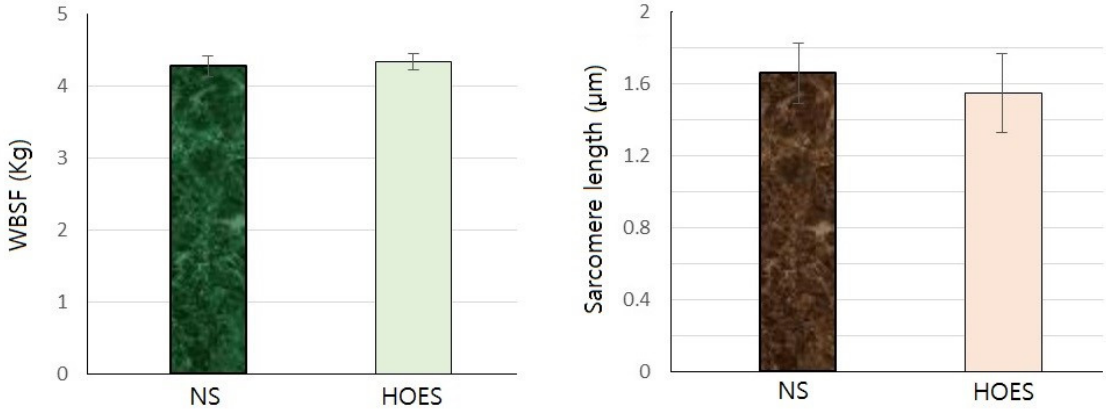

Fig. 3. Warner-Bratzler shear force (WBSF) and sarcomere length of *longissimus lumborum* muscle in goats subjected to NS and HOES slaughtering Conditions. Error bar represent standard error. NS, non-stunning; HOES, head-only electrical stunning.

Conclusion

The current study suggests that meat quality traits of LL muscle from KBGs subjected to NS or HOES slaughtering are not significantly different. The slaughtering methods has no effects on BL %, muscle pH decline pattern, meat color measurements, and WHC, but a little effect on shear force and sarcomere length. Consequently, results in this study imply that NS slaughtering does not result in poor quality of goat meat.

Conflicts of Interest

The authors declare no potential conflict of interest.

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References

AMSA. 1995. Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat. Chicago, IL: American Meat Science Association in Cooperation with National Live Stock and Meat Board. p 8.

Anil MH, Yesildere T, Aksu H, Matur E, McKinstry JL, Erdogan O, Hughes S, Mason C. 2004. Comparison of religious slaughter of sheep with methods that include pre-slaughter stunning, and the lack of differences in exsanguination, packed cell volume and meat quality parameters. Anim Welf 13:387-392.

Anil MH, Yesildere T, Aksu H, Matur E, McKinstry JL, Weaver HR, Erdogan O, Hughes S, Mason C. 2006. Comparison of halal slaughter with captive bolt stunning and neck cutting in cattle: Exsanguination and quality parameters. Anim Welf 15:325-330.

Anil MH. 2012. Effects of slaughter method on carcass and meat characteristics in the meat of cattle and sheep. A Divison of the Agriculture and Horticulture Development Board, UK.

Bergeaud-Blackler F. 2007. New challenges for Islamic ritual slaughter: A European perspective. J Ethn Migr Stud 33:965-980.

Bourguet C, Deiss V, Tannugi CC, Terlouw EMC. 2011. Behavioral and physiological reactions of cattle in a commercial abattoir: Relationships with organizational aspects of the abattoir and animal characteristics. Meat Sci 88:158-168.

Council Directive. 1974. Council Directive No 74/577 on the protection of animals at the time of slaughter or killing. Official Journal of the European Union, European Communities, Brussels, Belgium.

Cross HR, West RL, Dutson TR. 1981. Comparison of methods for measuring sarcomere length in beef semitendinosus muscle. Meat Sci 5:261-266.

Devine C, Ellery S, Wade L, Chrystall BB. 1984. Differential effects of electrical stunning on the early post-mortem glycolysis in sheep. Meat Sci 11:301-309.

Grandin T. 2017. On-farm conditions that compromise animal welfare that can be monitored at the slaughter plant. Meat Sci 132:52-58.

Honikel KO.1998. Reference methods for the assessment of physical characteristics of meat. Meat Sci 49:447-457.

Kadim IT, Mahgoub O, Al-Marzooqi W, Khalaf S, Al-Sinawi SS, Al-Amri I. 2010. Effects of transportation during the hot season, breed and electrical stimulation on histochemical and meat quality characteristics of goat *longissimus* muscle. Anim Sci J 81:352-361.

Kannan G, Gadiyaram K M, Galipalli S, Carmichael A, Kouakou B, Pringle TD, McMillin KW, Gelaye S. 2006. Meat quality in goats as influenced by dietary protein and energy levels, and postmortem aging. Small Rumin Res 61:45-52.

King DA, Voges KL, Hale DS, Waldron DF, Taylor CA, Savell JW. 2004. High voltage electrical stimulation enhances muscle tenderness, increases aging response, and improves muscle color from cabrito carcasses. Meat Sci 68:529-535.

Lokman NS, Sabow AB, Abubakar AA, Adeyemi KD, Sazili AQ. 2017. Comparison of carcass and meat quality in goats subjected to preslaughter head-only electrical stunning or slaughtered without stunning. CYTA J Food 15:99-104.

Metcalf MF. 1989. Regulating slaughter: Animal protection and antisemitism in Scandinavia, 1880-1941. Patterns Prejudice 23:32-48.

Onenc A, Kaya A. 2004. The effects of electrical stunning and percussive captive bolt stunning on meat quality of cattle processed by Turkish slaughter procedures. Meat Sci 66:809-815.

Pen S, Kim YHB, Luc G, Young OA. 2012. Effect of pre rigor stretching on beef tenderness development. Meat Sci 92:681-686.

Sabow AB, Zulkifli I, Goh YM, Ab Kadir MZA, Kaka U, Imlan JC, Abubakar AA, Adeyemi KD , Sazili AQ. 2016. Bleeding efficiency, microbiological quality and oxidative stability of meat from goats subjected to slaughter without stunning in comparison with different methods of pre-slaughter electrical stunning. PLOS ONE 11:1-18.

Sazili AQ, Norbaiyah B, Zulkifli I, Goh YM, Lotfi M, Small AH. 2013. Quality assessment of *longissimus* and *semitendinosus* muscles from beef cattle subjected to non-penetrative and penetrative percussive stunning methods. Asian-Australas J Anim Sci 26:723-731.

Tschirhart-Hoelscher TE, Baird BE, King DA, McKenna DR, Savell JW. 2006. Physical, chemical, and histological characteristics of 18 lamb muscles. Meat Sci 73:48-54.

USC [United States Congress]. 1958. Humane Slaughter Act 1958, USA 1, 7 USC 1901-1907.

Velarde A, Gispert M, Diestre A, Manteca X. 2003. Effect of electrical stunning on meat and carcass quality in lambs. Meat Sci 63:35-38.

Vergara H, Linares MB, Berruga MI, Gallego L. 2005. Meat quality in suckling lambs: Effect of pre-slaughter handling. Meat Sci 69:473-478.

Wheeler TL, Shackelford SD, Koohmaraie M. 2000. Variation in proteolysis, sarcomere length, collagen content, and tenderness among major pork muscles. J Anim Sci 78:958-965.

Wong MM. 2015. The Effect of non-stunned and stunned halal slaughter method on broiler breast meat quality. MOJ Food Process Technol 1:56-63.