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Influence of electrical stimulation on carcass and meat quality of Kosher and conventionally slaughtered cattle

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Abstract

In a previous study regarding the effects of Kosher and conventional slaughter techniques on carcass and meat quality of cattle, it was speculated that electrical stimulation may have affected some of the meat qualities. Therefore, the objective of this study was to investigate the effects of electrical stimulation (ES) and non-electrical stimulation (NES) on key carcass and meat quality attributes of cattle slaughtered by Kosher vs. conventional slaughter methods. Carcass pH and temperature profiles over a 24 h *post mortem (pm)* period, meat shear force and water holding capacity were investigated in feedlot type cattle of comparable weights and breed types. Results showed that the combined effects of slaughter methods did not influence the meat quality attributes, but there were differences within the slaughter groups. The effect of ES on carcass pH lasted longer within the conventionally slaughtered group (12 h), than in the Kosher slaughter group (6 h). Muscle samples from the ES groups for both slaughter methods were more tender. Electrical stimulation also had a significant effect on the cooking loss from Kosher meat, while there was no significant difference in meat from the conventional slaughter methods. The results show that ES influences certain meat and carcass quality attributes of cattle, based on the way cattle were slaughtered.

Keywords: Carcass pH, cooking loss, drip loss, electrical stimulation, shear force, slaughter technique
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Introduction

There has been little or no studies directed at the effect of electrical stimulation on carcass and meat quality attributes of cattle slaughtered either conventionally (pre-stunned before the cut) or by the Kosher technique (without a pre-cut stun). This study forms part of a broader study in which the influence of Kosher and conventional slaughter techniques on carcass and meat quality attributes of cattle was evaluated. During this study it was speculated that electrical stimulation may have played a part in some of the results obtained. Consequently, it was decided to investigate the effects of ES on carcass pH and temperature decline (within 24 h *post mortem (pm)*), shear force of the meat and water holding capacity of meat, in terms of cooking and drip loss.

Electrical stimulation is known to accelerate *post mortem* glycolysis and the onset phase of rigor, so that rapid cooling/freezing may be done soon after slaughter, without the risk of cold shortening of the muscles (Carse, 1973; Davey *et al*., 1976). Electrical stimulation has also been adopted as a means of meat tenderisation in beef, lamb and goat carcasses (Chrystall & Hagyard, 1976; Savell *et al*., 1977; Geesink *et al*., 1994). Tenderisation of muscle is achieved by enhancing the rate of proteolysis, which is stimulated by the release of Ca^{2+} at higher temperatures (Savell *et al*., 1981). Electrical stimulation then also reduces variation in tenderness, compared to what is achieved in unstimulated meat (Rosenvolt *et al*., 2008; Devin *et al*., 2009; Agbeniga & Webb, 2013).

However, it has been reported that electrical stimulation, especially with a high voltage/high frequency of about 60 Hz wavelength, produced myofibrillar damage in the muscle tissue, which has been described as areas of super contractions and associated areas of myofibrillar stretching (Marsh, 1986; Takahashi *et al*., 1987). The work of Hwang *et al*. (2003) also supported the theory of physical disruption of the muscle fibres. It is widely recognised that the contracture is ATP dependent, and its extent decreases with muscle pH (Honikel *et al*., 1983). In addition to the accelerated glycolysis caused by electrical stimulation to lower the pH of carcasses after slaughter, stress before or at slaughter could also play a part in lowering the pH and stimulating proteolysis and gluconeogenesis by the secretion of corticosteroid hormones. Carcasses from

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stressed cattle would also not be prone to cold shortening if the ability to regenerate ATP has been reduced by the stress (Gregory, 1998). This could particularly be beneficial for meat from Kosher slaughtered cattle, in terms of tenderness (Agbeniga & Webb, 2013). Catecholamine levels were also found to be significantly higher in cattle slaughtered by Schechita (Kosher) than in cattle slaughtered conventionally, according to a study conducted by Petty *et al*. (1994).

Stress at slaughter, especially acute stress, could result in the depletion of glycogen or increased metabolic conversion of glycogen to lactic acid, which lowers the muscle pH (Mobergh & Mench, 2000). Stress at slaughter or before slaughter could also result in a high muscle temperature and when this combines with the low pH, it disrupts the muscle proteins (denaturation) (Kinsman *et al*., 1994). Recent work by Mellor *et al*. (2009) revealed that consciousness and the ability to perceive pain and experience distress after incision in animals killed without stunning may persist for 60 seconds or more in cattle. This was performed by quantitative analysis of the electro-encephalogram (EEG), which allows the experience of pain to be assessed more directly. The experience of pain invariably translates to stressful conditions. In essence, a combination of these stressful conditions with electrical stimulation could bring about quicker glycogen depletion, faster pH decline and the attainment of rigor which could also bring about meat tenderisation or a reduction in cold shortening (Agbeniga & Webb, 2013).

Concerning drip loss, the rapid rigor brought about by electrical stimulation produces inevitable drip loss (Devine, 2009). This could be attributed to a more rapid decline in pH, which has also been suggested by other researchers (Stoier *et al*., 2001). The stress that is experienced before and at slaughter can then also affect the water holding capacity of meat in terms of drip and cooking losses (Cheng & Sun, 2008). Generally, the changes that occur in water-binding during the conversion of muscle to meat depend on the rate and extent of the pH drop and the amount of protein denatured (Forrest *et al*., 1975). These two conditions can be brought about by electrical stimulation and stress, emanating from the way the animals were slaughtered. Due to the complex interrelationships of slaughter methods, electrical stimulation and carcass and meat quality attributes, it was deemed necessary to undertake these investigations.

Materials and Methods

The trial was conducted in a high throughput abattoir towards the end of the winter month of July. A total of 123 carcasses were analysed for the effects of slaughter methods and electrical stimulation on pH and temperature decline (within 24 h *post mortem*), shear force and meat water-holding capacity in terms of drip and cooking losses. Pre-slaughter conditions were assessed to ensure that the animals were not unnecessarily stressed, as this may affect meat and carcass qualities (Gregory, 1998). The animals had about 12 hours of lairage time, with access to water but not feed. The animals were randomly selected and were typical crossbred feedlot cattle weighing an average live weight of 400 kg. The cattle were mainly steers, representative of the “A” and “AB” age groups, which represents more than 80% of feedlot cattle slaughtered in South Africa.

Kosher slaughter was carried out by a Rabbi using the American Society for Prevention of Cruelty against Animals (ASPCA) specially designed box in which animals stand in an upright position. The box was fitted with a hydraulic chin lift that lifts the head upwards and extends the neck for the cut, a belly plate to raise the animal for stability and a rear pusher to reduce the struggle of the animal with a firm restraint (Grandin & Regenstein, 1994; Shragge & Price, 2004). The Shochet (i.e. the Rabbi) then stabs the animal with a sharp knife of approximately 40 cm long. The cut is made upwards and across the ventral part of the neck within a second, in accordance with Talmudic standards (Levinger, 1995). Twenty seconds after the cut, the animals were stunned with a 0.22 calibre penetrative captive bolt gun to render them unconscious according to the present South African slaughter regulations. The carcasses were then hoisted by the hind leg and allowed to bleed out for about eight minutes, before being electrically stimulated. After the stimulation, evisceration and carcass splitting procedures were carried out before the carcasses enter the chillers. In total, 57 animals were assigned to this treatment.

Conventional slaughter was done with the aid of a pneumatic captive bolt gun which utilises compressed air (Anil *et al*., 2002). Here, 66 animals were assigned to this treatment. The animals were restrained in a v-shaped metal box with an open top and with a rear gate to prevent the animals from struggling or trying to get out of the box. Cattle were restrained in an upright position, while the shot was delivered to the forehead. Cattle were then released from the box, hoisted and cut to bleed on the bleeding rail for approximately 8 minutes, before being electrically stimulated. After the stimulation, carcasses were eviscerated and split, before entering the chillers.

Electrical stimulation was carried out after the animals had lost about 90% of their blood on a rail connected to an electrical input by metal shackles, which were inserted on the neck of each animal. Out of the 57 animals assigned to the Kosher slaughter, 40 were electrically stimulated (ES) while 17 were not stimulated (NES). Out of the 66 animals assigned to conventional slaughter, 46 were electrically stimulated,

while 20 were not stimulated. High voltage electrical stimulation of 810 volts at a current of 5 Amperes was used and it lasted approximately one minute for each carcass.

Following carcass splitting and organ removal, the carcasses were moved to a compartment where warm and cold carcass weight, sex and conformation grade were recorded. After this, carcasses were moved to the chilling rooms where the initial temperature was 4 ºC and air velocity 1.5 m/s.

The muscle pH and carcass temperature measurements were recorded with a portable pH meter (Hanna Instruments, code- H18424N), using a temperature probe and a special glass electrode (visc smicrokynar electrode, code FC 200B), especially designed for measuring meat pH. The pH was taken at the 10^{th} and 11^{th} rib, on the *longissimus dorsi*. Measurements were taken at 45 min, 3 h, 6 h, 12 h and 24 h *pm*.

Shear force, drip and cooking loss measurements were determined using approximately 450 g of *m. longissimus dorsi* samples excised between the 9^{th} and 12^{th} rib of the left side of each carcass after the 24 h muscle pH and carcass temperature readings had been taken. For drip loss measurement, about 30 g of the meat samples that had been cut at right angles to the fibre direction from the *m. longissimus dorsi* were used 36 h *pm*. Each sample was suspended with a thin wire from the lid of a sealed, transparent plastic container. This was done by drilling two thin holes through the lid and passing the thin wire through the meat and through the holes to suspend the meat without touching the container. By doing so, the meat was able to release the drip directly onto the floor of the container. The samples were then stored at 4 ºC for 24 h. After 24 h, the samples were taken from the containers, gently blotted dry and weighed (Honikel, 1998). The drip loss was then expressed as a percentage of the initial weight:

$$\% \text{ drip loss} = \frac{\text{weight loss after drip}}{\text{Initial sample weight}} \times \frac{100}{1}$$

Cooking loss was done on meat samples of 200 g to 300 g, cut from the big *longissimus* samples. The samples were taken approximately 36 h *pm* at 4 ºC and had an average pH of 5.5. Each sample was cut in a rectangular shape of 8 cm x 6 cm x 5 cm. Samples were then placed in thin-walled, transparent plastic bags and placed in a boiling water bath. The samples were boiled for one hour at 80 ºC, while the internal meat temperature reached 70 ºC. After boiling, the bags were removed from the water bath and cooled in a bath of ice-cold water. Samples were then stored in a refrigerated condition at 4 ºC for 12 h. The samples were later blotted dry and weighed (Honikel, 1998). Cooking loss was expressed as a percentage of initial weight:

$$\% \text{ cooking loss} = \frac{\text{weight loss after cooking}}{\text{Initial sample weight}} \times \frac{100}{1}$$

Meat shear force measurements were performed on the same samples used for cooking loss determinations. A hollow metal probe of 1.27 cm diameter and 8 cm length was used to take 10 samples from each block of meat along the length of the fibre arrangement. An Instron shear force apparatus was attached to an Instron machine (model 1101) and 10 shear force values were recorded for each core sample obtained from each block of meat. The shear measurement was taken perpendicular to the fibre arrangement (Honikel, 1998) and an average of 10 values from each sample was then calculated to record a mean shear force value. The standard deviation of each mean sample was also determined.

Statistical analysis was done by analyses of variance using the general linear model (GLM) procedure. Data processing was done using SAS (version 9.2) (SAS, 2008). Fisher's protected t-test and the least significant difference (LSD) at a 5% level of probability were used. Most of the data were transformed using special statistical procedures to facilitate easy analyses. This was done due to the data not being normally distributed.

Results and Discussion

As expected, there were significant differences between the stimulated and unstimulated carcasses in terms of pH decline (Table 1). The rate of pH decrease for the electrically stimulated carcasses for both slaughter groups were different (P <0.05) and faster than the non-stimulated carcasses. Significant differences were recorded between the ES and NES for both slaughter groups for a period of at least 6 h. However, the major difference between the two slaughter groups in terms of ES was that the effect of electrical stimulation lasted longer - up to 12 h in the conventionally slaughtered carcasses. There was also a significant difference between the ES and NES groups, in terms of pH decline for up to 12 h *pm*, compared to 6 h in the Kosher slaughtered carcasses.

A possible reason for the shorter effect of ES in the Kosher slaughter group was the acute stress at slaughter suffered by Kosher slaughtered cattle. The animals were left in agony for 20 seconds after sticking

(i.e. the cut) before being stunned by captive bolt. This could result in glycogen depletion and increased metabolic conversion of glycogen to lactic acid, which significantly lowers the muscle pH at a faster rate (Immonen *et al*., 2000; Mobergh & Mench, 2000). This was more evident in the NES group (5.77) in the Kosher slaughtered group than the NES (5.85) in the conventionally slaughtered group at 12 h *pm*.

In terms of the effect of ES on carcass temperature decline, there were no differences (P >0.05) between the ES and the NES groups for both slaughter methods, although the temperature of the conventionally slaughtered carcasses decreased faster than the Kosher slaughtered carcasses. Electrical stimulation showed no significant effect in terms of temperature decline, irrespective of the slaughter method.

Table 1 Effects of electrical stimulation on muscle pH decline for different slaughter methods in cattle

Treatment		pH 45 min Mean ± SD	pH 3 hrs Mean ± SD	pH 6 hrs Mean ± SD	pH 12 hrs Mean ± SD	pH 24 hrs Mean ± SD
K	ES	6.24^{a} ± 0.28	5.77^{a} ± 0.43	5.62^{a} ± 0.43	5.61 ± 0.43	5.55 ± 0.44
	NES	6.28^{b} ± 0.22	6.57^{b} ± 0.26	6.01^{b} ± 0.28	5.77 ± 0.25	5.50 ± 0.22
C	ES	6.08^{a} ± 0.23	5.68^{a} ± 0.33	5.52^{b} ± 0.26	5.59^{a} ± 0.32	5.54 ± 0.25
	NES	6.89^{b} ± 0.23	6.42^{b} ± 0.31	6.00^{b} ± 0.30	5.85^{b} ± 0.35	5.61 ± 0.19

^{ab} Means in the same column with different superscript differ significantly (P <0.05).
K = Kosher slaughter; C = conventional slaughter; ES = electrical stimulation; NES = non-electrical stimulation.

Concerning the effect of ES on shear force (SF) of both slaughter methods, as anticipated, there were significant differences between the ES and NES groups. The meat samples from the ES groups were lower in shear force values than the NES groups for both slaughter methods. However, when comparing the effect of ES and NES between the two slaughter methods, the NES group from conventional slaughter group had a higher (P <0.05) shear force value (64.74), compared to the NES carcasses in the Kosher slaughter group (56.94). Likewise, the ES group for the conventionally slaughtered carcasses recorded a higher (P <0.05) shear force value (48.67) than the Kosher slaughter group (37.06).

Table 2 Effects of electrical stimulation on drip loss (DL), cooking loss (CL) and shear force (SF) of meat for both slaughter methods

Treatment		% DL Mean ± SD	% CL Mean ± SD	SF (N) Mean ± SD
K	ES	2.51 ± 0.20	17.48^{a} ± 0.66	37.06^{a} ± 1.73
	NES	2.12 ± 0.30	19.75^{b} ± 1.00	56.94^{b} ± 2.66
C	ES	2.84 ± 0.19	22.30^{ab} ± 0.61	48.67^{ab} ± 1.61
	NES	2.40 ± 0.28	21.67^{ab} ± 0.93	64.74^{bc} ± 2.45

$^{a, b, c, d}$ Means in the same column with different superscript letter differ (P <0.05).
K = Kosher slaughter; C = conventional slaughter; DL = drip loss; CL = cooking loss; SF = shear force (Newton); ES = electrical stimulation; NES = non-electrical stimulation.

The reason for the significant difference in shear force could be attributed to the stress at slaughter in the Kosher slaughter group, which led to higher muscle temperature, combined with a faster rate of proteolysis which enhances tenderisation (Savell *et al*., 1981). As stated earlier, carcasses from stressed cattle would not be prone to cold shortening, if the ability to regenerate ATP has been reduced by the stress (Gregory, 1998). This could then be beneficial to meat from Kosher slaughter, in terms of tenderness (Agbeniga & Webb, 2013).

In terms of drip loss, ES did not show any significant difference between the two slaughter groups. However, meat samples from the ES carcasses in the conventionally slaughtered group showed a higher drip loss (2.84%) than the meat samples from the Kosher slaughter group (2.51%). Likewise, the NES

carcasses in the conventional slaughter group showed a higher drip loss (2.41%) than the NES in the Kosher slaughter group (2.12%), as set out in Table 2.

In terms of cooking loss, ES also recorded a significant difference between the two slaughter groups (Table 2). The ES group in the conventional group lost more water (P <0.05) as cooking loss (22.30%) than the ES group of the Kosher slaughtered cattle (17.48%). Likewise, the NES group (21.67%) for the conventional slaughter group lost more water (P <0.05) as cooking loss than the Kosher slaughter group (19.75%). This phenomenon is difficult to explain, but a possible explanation is the redistribution of water to the viscera organs and skeletal muscles and brain caused by the stun in the conventional slaughter method, which is known, due to the stress experienced at stunning (Ferguson & Warner, 2008). It is also worth noting that during the Kosher slaughter, the animals are bled, without prior stunning. Hence, the cattle lost more water and blood before the stun (20 seconds later) than with the conventional slaughter procedure, in which the animals were stunned before bleeding. This means there is less water to lose as drip and cooking loss in the meat samples of the Kosher slaughtered carcasses. This is also reflected in the results. The Kosher group had lower drip loss and cooking loss percentages than the conventional slaughter group.

Conclusion

In terms of pH decline, it may be concluded that the effects of electrical stimulation lasted significantly longer (between ES and NES groups) in the conventionally slaughtered carcasses than in the Kosher slaughtered animals. Regarding shear force, it could be concluded that slaughter without prior stunning (Kosher slaughter), combined with ES, brought about a significantly lower meat shear force than with conventional slaughter. Regarding the drip and cooking losses, although values were numerically higher and significant losses recorded in the ES vs NES groups for both slaughter methods, the use of electrical stimulation for both slaughter methods is still highly recommended, as the advantages outweigh the disadvantages. More studies are needed to better understand the effects of lower voltage stimulation and stunning duration in relation to the different slaughter methods and the resultant carcass and meat quality traits.

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