SARCOMERE LENGTHS AND GOAT MEAT TENDERNESS AFTER APPLYING TWO "IDEAL" POST SLAUGHTER PROCEDURES

Pamela Pophiwa[1,*], Edward C. Webb[1] and Lorinda Frylinck[2]

[1]Department of Animal and Wildlife Sciences, University of Pretoria, Hatfield, 0028, South Africa

[2]Animal Production Institute, Agricultural Research Council of South Africa, Irene, 0062, South Africa

*Corresponding author email: Pamela.Pophiwa@tuks.co.za

Abstract – Two "ideal" post slaughter procedures namely, electrical stimulation (220V for 30 seconds, then chilling at 4 ^{0}C) and delayed chilling without electrical stimulation (10-15 ^{0}C for 6 hours, 4 ^{0}C until 24 hours) were tested on Boer and South African indigenous goats (n =10 goats /breed). Temperature and pH profiles, sarcomere lengths and Warner Bratzler shear force (WBSF) values were evaluated on samples of the *m. longissimus thoracis et lumborum* and *m. semimembranosus*. Both electrical stimulation and delayed chilling resulted in sarcomeres longer than 1.9 µm, therefore there were no cold shortening effects. The *m. semimembranosus* samples of electrical stimulation treatment had lower ($P < 0.01$) WBSF values (more tender) than the corresponding samples of delayed chilling treatment. This study confirms that electrical stimulation has a higher potential than delayed chilling in improving goat meat tenderness.

Key Words – Cold shortening, Delayed chilling, Electrical stimulation

I. INTRODUCTION

Meat tenderness is rated the most important eating quality by consumers [1]. However, the commercial chilling conditions are not "ideal" for optimum goat meat tenderness. Goat carcasses are generally small and have thin subcutaneous fat. These characteristics permit rapid dissipation of heat in early *post mortem*, which may lead to cold shortening and subsequent muscle toughening.

Earlier studies have shown that control of pH/temperature combinations prior to the onset of *rigor mortis* is crucial for optimal meat tenderness [2]. Ideally, pH should drop to 6 while carcass temperature is between 14 ^{0}C and 19 ^{0}C [3]. Temperatures below 12 ^{0}C or above 35 ^{0}C, at the onset of *rigor mortis* can cause excessive sarcomere shortening, thus affecting meat tenderness. The present study assess "ideal" slaughter conditions for optimum goat meat tenderness.

II. MATERIALS AND METHODS

Twenty castrated goats, representative of Boer and South African indigenous goats (n = 10/breed), of A –age class were used in this study. The goats were slaughtered according to standard procedures at the abattoir of the Agricultural Research Council, Irene, South Africa. The dressed carcasses were split into two halves, along the vertebra column. The left sides were immediately electrically stimulated for 30 seconds using 220 V at 9.5 pulses/sec and then rapidly chilled at ±4 ^{0}C for 24 hours (electrical stimulation treatment). The right sides were held at 10-15 ^{0}C for 6 hours and then chilled at ±4 ^{0}C until 24 hours (delayed chilling treatment). Temperature and pH readings of the *m. longissimus lumborum* (between the 4th and 5th lumbar vertebra) and the *m. semimembranosus* (close to the posterior end) were recorded within 30 minutes of slaughter (0 h) and at 1, 3, 6 and 24 hours *post mortem*, using a portable pH meter (Eutech Instruments, Cyber Scan pH 11). At 24 hours *post mortem*, the *m. longissimus thoracis et lumborum* and *m. semimembranosus* were dissected from both carcass sides. Fresh meat samples weighing ~50 g were kept at 4 ^{0}C for determination of sarcomere lengths. Meat samples of ~200 g were vacuum packed and kept frozen at -20 ^{0}C for determination of Warner Bratzler shear force (WBSF) values.

Samples for sarcomere lengths were prepared according to Hegarty and Naudé [4]. A few drops of the homogenate were mount on a slide and covered with a cover slip. The slides were viewed

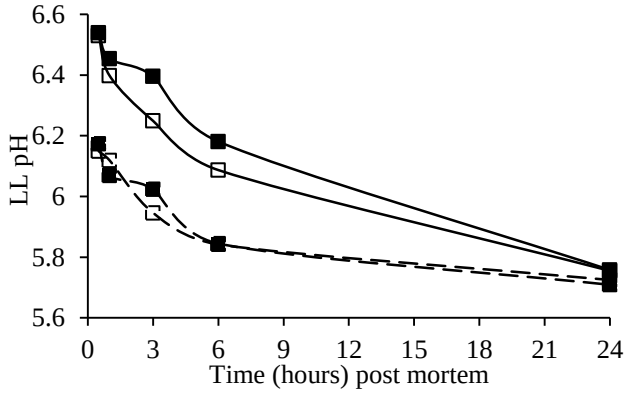
under an Olympus B340 microscope system, attached to CC12 video camera (Olympus, Tokyo, Japan). Fifty sarcomeres were measured per sample and mean lengths were used for statistical analysis.

Frozen meat samples for determination of WBSF values were thawed at 4 ^{0}C for 24 hours. The thawed samples were broiled in an oven (Miele H 217) pre-set at 190 ^{0}C, to an internal temperature of 70 ^{0}C. The cores were sheared across the fibres, using a Warner Bratzler shear device mounted on a Universal Instron apparatus (Model 4301). The toughness of meat was measured as the average peak force (N) required to shear through the six cores per sample.

The effects of breed, carcass treatment and their interaction on pH and temperature values, sarcomere lengths and WBSF values were analyzed using General Linear Model procedure for Multivariate Analysis of Variance in SPSS 23.0. Muscle pH and temperature values at 0, 1, 3, 6 and 24 hours *post mortem* were analyzed as repeated measurements. Significances between means were assessed using the LSD procedure at $P < 0.05$.

III. RESULTS AND DISCUSSION

The rate of muscle pH decline was faster ($P < 0.001$) for electrical stimulation than delayed chilling treatment (Fig. 1). Earlier studies have reported a similar trend in pH decline following electrical stimulation of goat carcasses [5, 6]. Electrical stimulation accelerated the onset of *rigor mortis*, reducing the risk of cold shortening in goat carcass sides that were rapidly chilled. Although, the rate of muscle pH decrease was slower for delayed chilling treatment, carcass sides of this treatment were not at risk of cold shortening (Fig. 2). Similar results were reported for lamb carcasses held at 12 ^{0}C for 7 hours before chilling at 2 ^{0}C [7]. In fact, the measured sarcomeres for muscle samples of delayed chilling treatment were longer than 2 µm (Fig. 3), confirming that cold shortening did not occur under these conditions [8]. Therefore, the cold shortening phenomenon was ruled out in both slaughter procedures.



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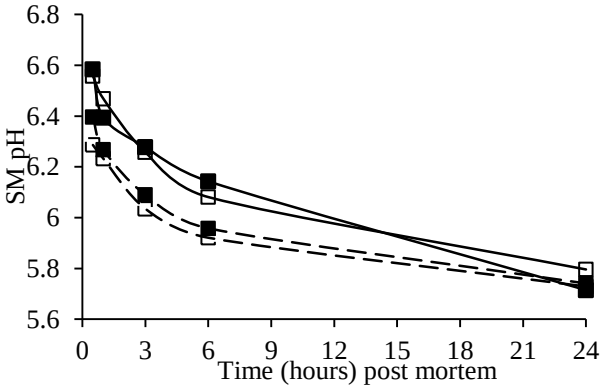
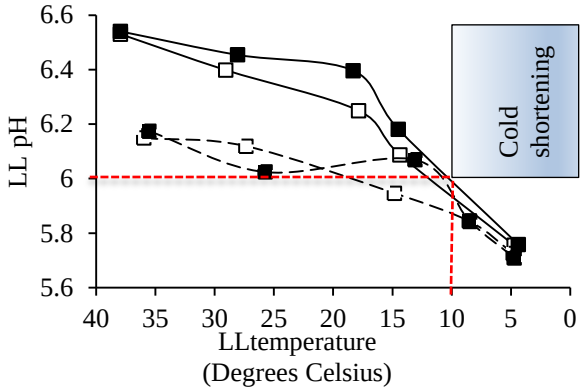


B.

Figure 1. The pH profiles for (A) *m. longissimus lumborum* (LL) and (B) *m. semimembranosus* (SM) of goats (Boer goats; electrical stimulation —□— or delayed chilling —□— :Indigenous goats; electrical stimulation —■— or delayed chilling—■—).

There was a trend towards shorter ($P < 0.05$) sarcomeres for muscle samples of electrical stimulation treatment compared than the corresponding samples of delayed chilling treatment (Fig. 3). Muscles with longer sarcomeres have been reported to be more tender than those with shorter sarcomeres [9]. In contrast, meat samples of electrical stimulation treatment were more tender despite having shorter ($P < 0.01$) sarcomeres (Fig. 4). Since all sarcomeres measured were longer than 1.9 µm, it is possible that meat tenderness was independent of muscle shortening The improved tenderness associated with electrical stimulation may be attributed to increased proteolysis and /or physical disruption of muscle fibres [10].



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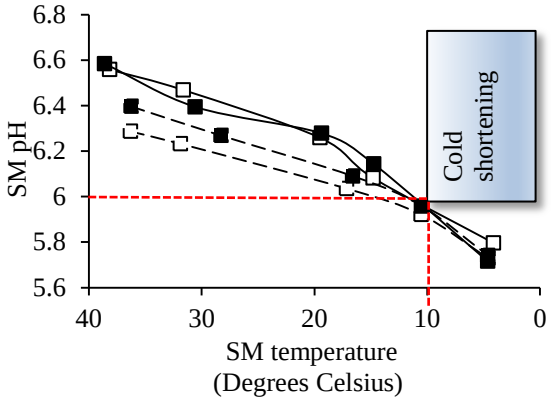
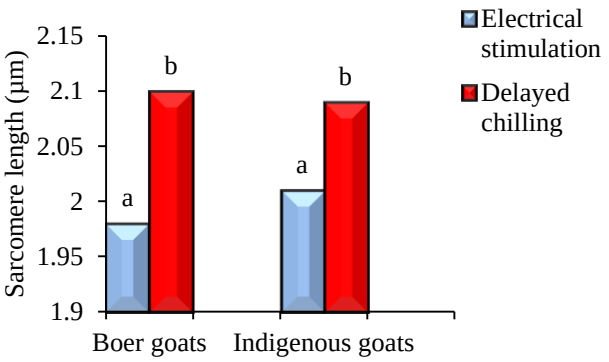


B.

Figure 2 Illustrations of pH/temperature profiles for (A) *m. longissimus lumborum* (LL) and (B) *m. semimembranosus* (SM) of goats (Boer goats; electrical stimulation —□— or delayed chilling —□— :Indigenous goats; electrical stimulation —■— or delayed chilling —■—).

Warner Bratzler shear force values of *m. longissimus thoracis et lumborum* samples were not different ($P > 0.05$) between the electrical stimulation and delayed chilling treatment. The *m. longissimus thoracis et lumborum* samples of both slaughter procedures were tender at 1 day *post mortem*, considering that these muscles had no added advantage of an ageing period(Fig. 4). Tenderness of the *m. longissimus* can be ascribed to its lower insoluble collagen content compared to *m. semimembranosus* [11], or the efficiency of both slaughter procedures in preventing cold shortening of goat carcasses. Electrical stimulation may have caused some proteolytic differences between genotypes [12], since the *m. semimembranosus* samples of Boer goats responded better to electrical stimulation (Fig. 4).



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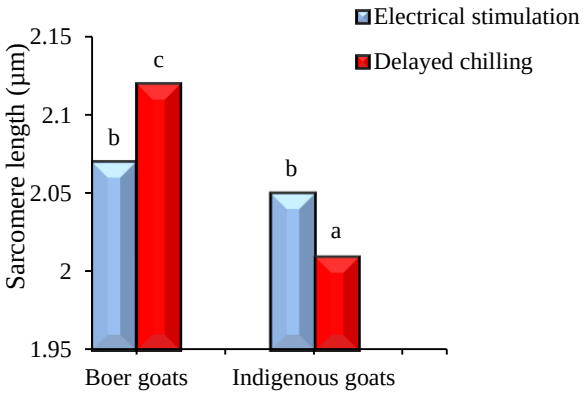

B.

Figure 3 Mean sarcomere lengths for (A) *m. longissimus thoracis et lumborum* (B) *m. semimembranosus* of Boer and South African indigenous goats, as influenced by electrical stimulation and delayed chilling of carcasses. Means with different letters (a, b, c) are different ($P < 0.05$).

IV. CONCLUSION

This study confirms that both electrical stimulation and delayed chilling without electrical stimulation are useful procedures in reducing the risk of cold shortening in goat carcasses. Electrical stimulation has a higher potential than delayed chilling in improving goat meat tenderness.

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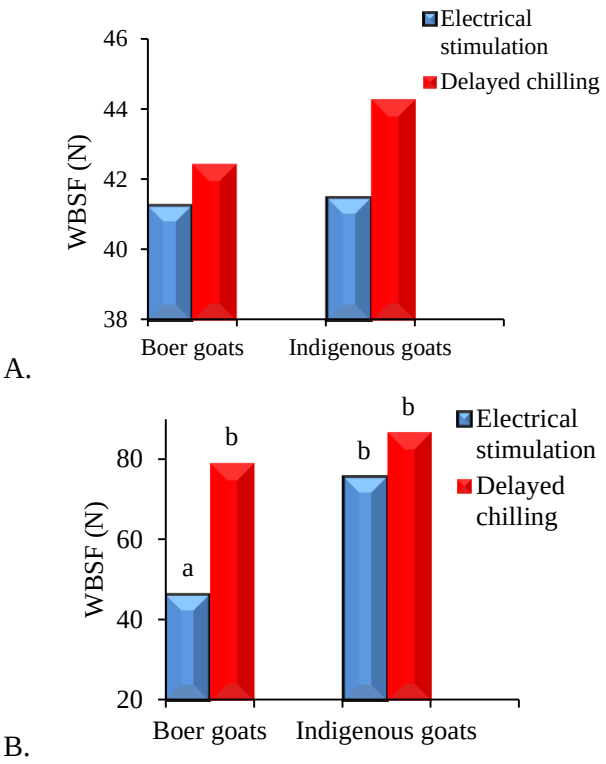

Figure 4 Warner Bratzler shear force values for (A) *m. longissimus thoracis et lumborum* (B) *m. semimembranosus* of Boer and South African indigenous goats, as influenced by electrical stimulation and delayed chilling of carcasses. Means with different letters (a, b) are different ($P < 0.05$).

REFERENCES

1. Troy, D.J. & Kerry, J.P. (2010). Consumer perception and the role of science in the meat industry. Meat Science 86: 214-226.

2. Hannula, T. & Puolanne, E. (2004). The effect of cooling rate on beef tenderness: The significance of pH at 7 °C. Meat Science 67: 403-408.

3. Locker, R.H. & Hagyard, C.J. (1963). A cold shortening effect in beef muscles. Journal of the Science of Food and Agriculture 14: 787-793.

4. Hegarty, P.V.J. & Naudé, R.T. (1970). The accuracy of measurement of individual skeletal muscle fibres separated by a rapid technique. Laboratory Practice: 19, 161-163.

5. Cetin, O., Bingol, E. B., Colak, H. & Hampikyan, H. (2012). Effects of Electrical Stimulation on Meat Quality of Lamb and Goat Meat. The Scientific World Journal Article ID574202: 9 pages.

6. King, D.A., Voges, K.L., Hale, D.S., Waldron, D.F, Taylor, C. & Savell, J.W. (2004). High voltage electrical stimulation enhances muscle tenderness, increases aging response, and improves muscle color from cabrito carcasses. Meat Science 68: 529-535.

7. Fernández, A.M. & Vieira, C. (2012). Effect of chilling applied to suckling lamb carcasses on hygienic, physicochemical and sensory meat quality. Meat Science 92: 569-574.

8. Veiseth, E., Shackelford, S.D, Wheeler, T.L. & Koohmaraie, M. (2004). Factors regulating lamb longissimus tenderness are affected by age at slaughter. Meat Science 68: 635-640.

9. Gadiyaram, K.M., Kannan, G., Pringle, T.D., Kouakou, B., McMillin, K.W. & Park, Y.W. (2008). Effects of postmortem carcass electrical stimulation on goat meat quality characteristics. Small Ruminant Research 78: 106-114.

10. Hwang, I.H., Devine, C.E. & Hopkins, D.L. (2003). The biochemical and physical effects of electrical stimulation on beef and sheep meat tenderness. Meat Science 65: 677-691.

11. Torrescano, G., Sanchez-Escalante, A., Gimenez, B., Roncales, P. & Beltrán, J.A. (2003). Shear values of raw samples of 14 bovine muscles and their relation to muscle collagen characteristics. Meat Science 64: 85-91.

12. Ferguson, D.M., Jiang, S.-T., Hearnshaw, H., Rymill, S.R. & Thompson, J.M. (2000). Effect of electrical stimulation on protease activity and tenderness of M. longissimus from cattle with different proportions of Bos indicus content. Meat Science 55: 265-272.