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THE EFFECT OF GENOTYPE, DURATION OF FEED WITHDRAWAL AND ELECTRICAL STIMULATION ON MEAT QUALITY

P.E Strydom* & L. Frylinck

Agricultural Research Council of South Africa, Private Bag X2, Irene, South Africa, 0062

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Introduction

Extrinsic factors, such as chilling rate, electrical stimulation and ageing, proved to have major influences on tenderness development of red meat (Ouali, 1990; Olsson *et al.*, 1994; Koohmaraie, 1996). The variation in tenderness, due to the development of *rigor* (peak toughness), is related to the conditions (pH and temperature) under which the muscle fibres enter *rigor* and, subsequently, settle into *rigor mortis* when all supplies of ATP are exhausted (Review: Hwang, Devine & Hopkins, 2003). Early and recent studies show that minimal shortening occurs above 12-15°C resulting in optimum tenderness (Locker & Hagyard, 1963; Tornberg, 1996). Below this temperature, pre-*rigor* contracture takes place until *rigor* is completed resulting in higher *rigor* toughness (Tornberg, 1996). The historical reason for the development of electrical stimulation was the acceleration of *post-mortem* glycolysis so that when the muscle entered rigor it was prevented from excessive shortening (Swatland, 1981). Further studies indicated that electrical stimulation may also contribute to the acceleration of proteolysis (Uytterhaegen, Claeys, & Demeyer, 1992). However, high temperature combined with low pH values could result into *rigor* contracture (termed heat shortening) has a concurrent reduction in ageing potential leading to less tender meat both at *rigor mortis* and when fully aged (Devine, Wahlgren & Tornberg, 1999). Stress, independent of ultimate pH seems to have a toughening effect on meat which is enhanced by electrical stimulation according to Morton, Bickerstaffe, Le Couteur & Keeley, (1997), although Geesink, Mareko, Morton & Bickerstaffe (2001), could not confirm these results.

Objectives

Considering an optimum pH/temperature ratio for maximum tenderness development, management of these ratios is not simple when animals with different muscle energy levels are slaughtered due to variation in pre-slaughter practice. In addition, differences in duration of stimulation together with different carcass sizes and therefore chilling rates enhance the problem of optimum rigor management further.

In the present study, the effect of breed, which also represented different carcass weights, and duration of stimulation and pre-slaughter stress on meat quality characteristics were investigated in order to find an optimum stimulation treatment for different types of carcasses and different levels of stress.

Methodology

From three groups sixty Simmental cross, Brahman cross and Nguni cross bulls raised under intensive conditions and aged 12 months, thirty animals were withdrawn from feed for 20 hours pre-slaughter. The remaining thirty of each breed cross were withdrawn from feed for only three hours pre-slaughter. Within each group of thirty animals, 10 carcasses were not stimulated while the remaining twenty were either stimulated (ES) for 15 (n=10) or 120 seconds (n=10) (400 V peak, 5 ms pulses at 15 pulses per second). Carcasses were chilled directly after dressing at room temperature before loading at 0 – 4°C. Sampling of the *M.longissimus* (LD) for measurement of Warner Bratzler shear force (WBS), sarcomere length and drip loss took place 24 hours *post mortem.* The pH and temperature of the LD were measured with a digital handheld meat pH meter (Sentron, Model 1001) between the 11^{th} and 12^{th} rib at 1, 2, 3, 4, 6, 8 and 20 hours *post* mortem. every hour for 4 hours *post-mortem,* and thereafter at 24 hours. LD of both sides were sampled. Samples destined for WBS were vacuum packaged and aged at 2°C ± 2 ºC for 1 days and 14 days *post-mortem.* The sarcomere lengths were measured by using a Video Image Analyser (Kontron, Germany) after preparation of a fresh sample (24 hours *post-mortem*), according the method of Hegarty & Naudé (1970), by using distilled water instead of Ringer Locke solution (Dreyer, van Rensburg, Naudé, Grouws, & Stiemie, 1979). Fifty grams of fresh meat (24 hours) sliced into cubes of 10 x 10 x 20 mm were suspended on a pin inside a sample bottle (200 ml. Duplicate samples were stored for three days at 4 ºC ± 2 ºC. The amount of drip was expressed as a percentage of the starting mass. LD aged for one or 14 days were processed into 30 mm steaks by means of a band saw before being thawed at 4°C for 24 h and prepared according to an oven-broiling method using direct radiant heat (AMSA, 1978). The steaks were broiled at 260°C (pre-set) to 70°C internal temperature. Core samples of 12.5 mm were removed along the fibre and sheared perpendicular to the fibre with a Warner Bratzler shear device attached to an Instron Universal Testing (Instron, 1990). Shear force was measured as the peak force (kg) average for eight cores per sample. The data were subjected to a three way analysis of variance. Means for the main effects and their were separated using Fisher's protected t-test least significant difference (LSD) at the 5% level (Snedecor & Cochran, 1980).

Results & Discussion

Carcasses with pH values higher than 6 were excluded from the analysis. Furthermore, no combination of breed, feed withdrawal or ES treatment resulted in muscle temperatures lower than 12 °C before pH values reached 6. Therefore, cold shortening according to the rule of thumb (Tornberg, 1996) was not likely to take place. However, pH values declined faster for stimulated carcasses than for non-stimulated ones and initially faster for longer stimulation times (data not presented). For the latter, the unfavourable temperature/pH ratio coincided with shorter sarcomeres (Table 1) probably indicating some heat shortening (Devine, Wahlgren & Tornberg, 1999).pH decline was also faster for shorter feed withdrawal times.

Meat tenderness was significantly influenced by breed, feed withdrawal and ES ($P<0.05$)(Table 1). These effects occurred at both one day and 14 days *post mortem*. Breed, feed withdrawal and ES also interacted at day one ($P=0.044$)(Figure 1) and day 14 ($P=0.08$)(Not shown). On average, the Simmental had the tougher meat than the Nguni and Brahman ($P<0.05$), which is in contrast with the findings of Shackelford *et al.*, (1995) showing a decrease in tenderness as percentage *Bos indicus* inheritance increased. On the other hand, De Bruyn (1991) reported tougher meat for Simmental compared to other breeds such as the Bonsmara, Charolais and Hereford. The difference between breeds was most evident for long feed withdrawal periods combined with no ES. The general effect of ES was also more pronounced with longer feed withdrawal periods. These patterns were still the same even after prolonged ageing. Regarding stress (duration of feed withdrawal in the present trial) and ES the results of the present trial contradict the findings of Morton *et al.*, (1997). They report a toughening effect of stress on sheep meat which was enhanced by electrical stimulation. Morton *et al.* (1997) concluded that μ-calpain worked less efficiently when ES is applied to stressed animals, hence the tougher meat. With regard to sarcomere length, the shorter sarcomere length (in general) of the Nguni does not reflect its low shear force values. However, sarcomere length of the Simmental was less than 1.6 μm (not shown) when animals were on long feed withdrawal and not stimulated, which could partly explain the high shear force values. Improvement in shear force due to ES was reflected by longer sarcomere lengths but could also have been due to an enhanced rate of proteolysis (Uytterhaegen, Claeys, & Demeyer, 1992). Longer feed withdrawal coincided with higher shear force values in general, although it was more evident for non-stimulated carcasses. Longer feed withdrawal also coincided with higher final pH values for Nguni carcasses in particular ($pH>5.8$). Purchas (1990) reported high shear force values for ultimate pH values between 5.8 and 6.2 (mildly stressed), which could explain the higher shear force values of the Nguni (1 and 14 days) with long feed withdrawal, but does not explain why ES improved the tenderness.

Despite the benefit of ES with regard to tenderness, the amount of drip loss increased by ~0.5 of a percent between no stimulation and 15 seconds stimulation and a further 0.9 of a percent with 120 seconds stimulation (Table 1). Conditions of low pH and high temperatures in *post-mortem* muscle reduce the water binding capacity of meat, an effect attributed to the denaturation of muscle proteins, particularly myosin (Offer & Knight, 1988, Offer, 1991). Electrical stimulation, by accelerating pH decline, contributes to reduced water binding capacity in beef, though the magnitude of the effect depends on the chilling rate (Babiker & Lawrie, 1983). As the pH decline of the 120 second ES was initially faster than that of the 15 second ES treatment, the differences in drip loss was expected. Drip loss was significantly higher for the Brahman compared to the other two breeds. The lower rate of pH decline and faster chilling rate of the Nguni could explain the difference in drip loss between the Nguni and Brahman. The carcass weights of the Simmental and Brahman was almost 70 kg higher than that of the Nguni. A shorter duration of feed withdrawal was associated with a faster rate of pH decline and higher drip loss.

Conclusions

Electrical stimulation was beneficial for LD tenderness even after 14 days of ageing when compared to no stimulation. Electrical stimulation had a greater advantage when the LD had a high inherent toughness and when animals were moderately stressed due to long feed withdrawal periods. Stimulation for fifteen seconds and two minutes had equally favourable effects on tenderness, but the longer stimulation time had a detrimental effect on drip loss.

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Tables and Figures

Table 1. The effect of breed, feed withdrawal period and electrical stimulation treatment on shear force resistance, sarcomere length and driploss.

Breed	**Brahman**	**Nguni**	**Simmental**	**SEM[2]**	**P-value**
Shear force day 1 (kg)	6.9[ab]	6.7[a]	7.3[b]	0.1627	0.027
Shear force day 14 (kg)	4.3[a]	4.4[a]	4.9[b]	0.1266	<0.001
Sarcomere length (µm)	1.72[b]	1.65[a]	1.70[b]	0.0152	0.005
Drip loss (%)	2.7[b]	1.8[a]	1.9[a]	0.1146	<0.001
Feed withdrawal	**18 hours**	**4 hours**		**SEM[2]**	**P-value**
Shear force (kg)	7.3[a]	6.7[b]		0.1329	0.004
Shear force day 14 (kg)	4.8[a]	4.3[b]		0.1034	<0.001
Sarcomere length (µm)	1.66[a]	1.72[b]		0.0124	0.003
Drip loss (%)	2.0	2.2		0.0936	0.096
Electrical stimulation	**None**	**15 sec.**	**120 sec.**	**SEM[2]**	**P-value**
Shear force (kg)	8.7[b]	6.3[a]	6.0[a]	0.1627	<0.001
Shear force day 14 (kg)	5.4[b]	4.0[a]	4.1[a]	0.1266	<0.001
Sarcomere length (µm)	1.66[a]	1.74[b]	1.68[a]	0.0152	<0.001
Drip loss (%)	1.5	2.0	2.9	0.1146	0.001

[a,b] Means within a row with different superscripts differ significantly (P<0.05)

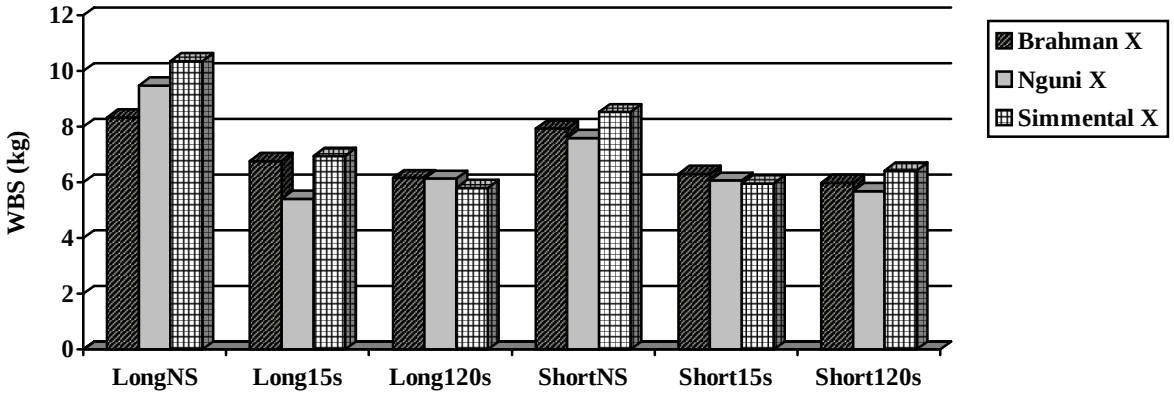

Figure 1: Interaction between breed, feedwithdrawal and electrical stimulation with regard to tenderness (1 day post mortem)

(Long and short – feed withdrawal period; NS, 15s and 120 s – no stimulation, 15 seconds and 120 seconds stimulation respectively; WBS – Warner Bratzler shear force)