LOW VOLTAGE ELECTRICAL STIMULATION, HOT BONING AND HIGH TEMPERATURE CONDITIONING OF *LONGISSIMUS LUMBORUM* MUSCLE FROM *BOS INDICUS*: DRIP AND COOKING LOSS, WATER HOLDING CAPACITY AND COLOUR

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Background

The interest in the technologies to accelerate conversion of muscle into meat remains. It is well established that electrical stimulation increases the rate of post-mortem glycolysis, allowing the use of hot boning and preventing that the meat becomes though (Hwang et al., 2003). Several studies demonstrated the flexibility of boning unchilled carcasses (hot boning) improving processing efficiency, functional properties, flavour, colour, juiciness, drip, and cooking loss (Henrickson, 1975; Kastner et al., 1973; Jeremiah et al., 1997). In a previous work, Cardoso et al. (2002) studied the influence of hot boning, high temperature conditioning, low voltage electrical stimulation, and aging on the rate of glycolysis, tenderness, and shear values of *longissimus dorsi* (*lumborum*). In this work were measured the effects of the same variables on water holding capacity, drip and cooking losses, and colour of *longissimus lumborum*.

Objectives

The purpose of the study was to demonstrate that hot boned *l. lumborum* from electrically stimulated *Bos indicus* carcasses can have drip and cooking loss, water holding capacity and colour, similar to those from conventionally boned meat.

Materials and methods

Forty Nelore (*Bos indicus*) pasture-fed steers with 30-36 months of age and average slaughter weights of approximately 450 kg were slaughtered at four different occasions over a three month period. Animals were stunned and bled. The beginning of bleeding was time zero for all treatments. Low voltage electrical stimulation (LVES) with a JARVIS BV 80 stimulator [20 V (rms); 60 Hz; 0.25 amps; for 90s alternating 5s on, 1s off] was applied immediately after exsanguination. Cattle were slaughtered at the Meat Technology Center of Institute of Food Technology in Campinas. Carcasses had an average weight of 250 kg. The animals were randomly assigned to five treatments (**Figure 1**) and two replications for each slaughtering session.

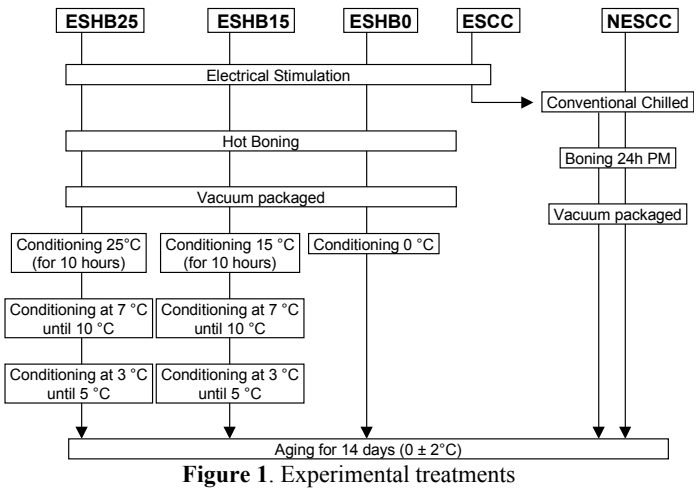

Figure 1. Experimental treatments

The *longissimus lumborum* (LL) was the muscle studied. The hot boned (HB) muscles were excised from the electrically stimulated carcasses after approximately 45 min post mortem (p.m) or conventionally chilled

(CC) and boned 24 h p.m. The LL muscle were cut in three pieces of the same size (10,16cm) and all pieces were vacuum packaged in CRYOVAC® shrinkable bags and placed into 536X235X162 mm cardboard boxes. Water holding capacity and drip loss: Muscles samples for water holding capacity (WHC) measurements, were 24 h p.m., at the 7th and 14th days p.m. For WHC determination, triplicate samples of 500 mg of muscle were placed on a filter paper (Whatmann n.2) and pressed between two plexiglass plates for 5 minutes at 500kg/cm2 on the ram of a laboratory press, following the procedure of Hoffmann et al. (1982). Results were expressed as the ratio between the areas of the liquid infiltrated (External Area=eA) and meat spot (Internal Area=iA) measured with a planimeter. The drip loss of the vacuum packaged cuts was determined by weighing the muscles before packaging and after unpacking on the 2nd, 7th and 14th days p.m. Results were expressed as percentages (%) of losses. Cooking and cooking loss: Three 2.54cm LL slices per treatment were cooked at 2nd, 7th and 14th days p.m.. The LL steaks were cooked according to AMSA (1995) guidelines, in an electrical grill SIRMAN PDL model with both plates heated, till their internal temperature reached 74°C. Temperatures were monitored using a digital thermometer NOVUS 51 with thermocouples (K type) inserted into the center of each steak. Cooking loss measurements were obtained by recording sample weights before and after cooking. Results were expressed as percentages (%) of losses. Color Analysis: Color readings were taken in the L* a* b* color space on the cross section of the LL muscle using a Minolta Spectrophotometer CM 508-d with D_{65} illuminant and 10° observer angle. Color was measured after deboning and on the 7th and 14th days p.m. with five replications. At 7 and 14 days p.m. the readings were made 30 min after unpacking and air exposure of the steaks. The mean of five replications was used as final result for reading and expressed in *L (lightness), a*(redness) and b* (yellowness) values. Statistical analysis: The results were statistically analyzed using the Statistical Analysis System program version 8.0. Analysis of variance was used to test for significance of slaughter period, treatment, ageing time and interaction treatment/ageing time effects. The mean values were compared pairwise with Duncan's Multiple Range. The significance level of 5% was used in all analysis.

Results and discussion

The drip loss, cooking loss and water holding capacity values are shown on Table 1. The drip losses of the LL were not significantly different ($p>0.05$) in relation to the treatments up to 7 days post mortem. In the 14th day of ageing the muscles of treatments ESHB15 and ESHB0 had significantly ($p<0.05$) lower values of drip losses: 1.08 and 1.22% respectively than those of the NESCC treatment (1.9%) but not significantly different ($p>0.05$) from the muscles of ESHB25 (1.35%) and ESCC (1.53%). However ageing had a significant ($p<0.05$) influence on drip losses with the higher values being reached with the higher values been reached after 7 days for all treatments except the ESHB25 one which had its highest values after 14 days of storage.

Table 1. Water holding capacity, drip and cooking losses of M. *longissimus lumborum* submitted postmortem to different treatments.

Measurement	TREATMENTS									
	ESHB25		ESHB15		ESHB0		ESCC		NESCC	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Drip loss (%)										
2 days p.m.	0.70^{y}	± 0.06	0.60^{y}	± 0.07	0.69^{y}	± 0.07	0.38^{y}	± 0.04	0.79^{y}	± 0.32
7 days p.m.	0.89^{y}	± 0.15	0.85^{xy}	± 0.11	0.98^{xy}	± 0.11	1.05^{x}	± 0.23	1.34^{xy}	± 0.28
14 days p.m.	$1.35^{ab;x}$	± 0.23	$1.08^{b;x}$	± 0.17	$1.22^{b;x}$	± 0.23	$1.53^{ab;x}$	± 0.35	$1.91^{a;x}$	± 0.23
Cooking loss (%)										
2 days p.m.	$26.27^{ab;x}$	± 1.23	$25.03^{b;x}$	± 0.79	$26.19^{ab;x}$	± 0.52	$29.40^{a;\ x}$	± 1.07	$26.90^{ab;x}$	± 1.48
7 days p.m.	28.38^{x}	± 0.54	27.50^{x}	± 1.10	27.91^{x}	± 0.33	28.67^{x}	± 0.98	28.35^{x}	± 0.65
14 days p.m.	27.04^{x}	± 0.97	27.82^{x}	± 0.06	27.80^{x}	± 1.19	28.79^{x}	± 0.89	27.63^{x}	± 0.88
WHC(eA/iA)**										
24 hours p.m.	$0.47^{b;x}$	± 0.02	$0.47^{b;x}$	± 0.02	$0.50^{ab;x}$	± 0.01	$0.51^{ab;x}$	± 0.02	$0.52^{a;x}$	± 0.02
7 days p.m.	$0.43^{c;x}$	± 0.02	$0.44^{bc;y}$	± 0.02	$0.51^{a;x}$	± 0.02	$0.46^{abc;y}$	± 0.01	$0.48^{ab;xy}$	± 0.02
14 days p.m.	$0.47^{ab;x}$	± 0.01	$0.40^{c;z}$	± 0.01	$0.48^{a;x}$	± 0.03	$0.43^{bc;y}$	± 0.01	$0.44^{abc;y}$	± 0.02

*SEM=Standard Error of Mean, n=8 replications for treatments; Same superscript letters in the same row or column among means (^{a,b,c}:rows=treatments; ^{x,y,z}:columns=ageing) indicate no significant difference by Duncan test ($p < 0.05$)

These results indicated that the drip loss is not affected greatly by the exposition of the meat immediately post-mortem to high temperatures (15-25ºC), and nor by the electrical stimulation, contrary to the results of Smith (1985), and agreeing with the results of West (1982) who found that drip loses of non-stimulated vacuum-packed *l. dorsi* stored at 0 ± 2ºC was 2.7% against 3.0 and 3.1% for low and high voltage

electrically stimulated muscles. George et al., (1980) reported drip losses for vacuum packed LL stored at 1ºC for two days p.m. of 2.2% for stimulated muscle, and 2.5% for non-stimulated muscle. These reported values were much larger than those observed in the present study. Butchers et al. (1998) reported drip losses for LL in the range of 0.65 - 1.30% when kept 1ºC for 48 h, showing statistical evidence that the electrical stimulation increased the drip losses, contrary to the results of the present work.

After 2 days of aging significant differences ($p<0.05$) in total cooking losses due to different treatments were found. The muscles from the ESCC presented significantly higher losses (29.40%) than the ones from the ESHB15 (25.03%) treatment but both treatments showed no differences in relation to the other treatments. After 7 and 14 days of storage no significant differences ($p>0.05$) among treatments were found regarding cooking losses, that ranged from 27.50 to 28.79%. These results indicate that the treatments studied have no great effect on cooking loss.

Water holding capacity (WHC) in this work is the ability of meat to retain its own water. Twenty four hours post mortem the LL of the ESHB25 and ESHB15 treatments had the lower means for WHC values (0.47) that were only significantly different ($p<0.05$) from the value determined for the meat of the NESCC treatment (0.52). After 14 days of storage at 0 ± 2ºC the lower means for WHC were of treatments ESHB15, ESCC and NESCC, respectively 0.40, 0.43, 0.44. the storage time reduced significantly ($p<0.05$) the WHC means for the treatments ESHB15, ESCC and NESCC but had no influence on the WHC values for ESHB25 (0.47) and ESHB0 (0.48) treatments.

Meat colour is the primary criterion by which consumers evaluate meat quality and acceptability. Consumers prefer bright-red fresh meat. In Table 2 is presented the means of the L*, a* and b* color parameters of LL measured after boning, at 7 and 14 days post mortem. Immediately after hot boning treatments (ESHB25, ESHB15 and ESHB0) had significantly lower L* values than those measured on ESCC and NESCC muscles. The ESCC L* values were also significantly higher than those of the NESCC muscles. After 7 days of ageing the means of L* values of ESCC muscles had significantly higher (34.77) than the values of the muscles of the other treatments with the exception of the ESHB25 (32.30). The L* values of ESCC treatment also showed the greatest variability as indicated by a standard error of mean (SE) that was more than double the values observed for the other treatments. The means L* value of muscles of ESHB0 treatment were the lowest (28.72) but was not significantly different from the others treatments. After 14 days of ageing the muscles of ESCC treatment presented the highest means L* value (34.38) and the ESHB0 the lowest value (30.85) both not significantly different ($p>0.05$) from the other treatments. Ageing time caused a significant increase in L* values for all treatments except for the ESCC muscles that showed no significant increase during the ageing period. For the LL of the ESHB25 and ESHB0 treatments there were significant increases in L* values from values observed immediately after boning and those measured after 7 days of ageing, but not significant increases from 7 to 14 days of ageing. For the ESHB15 muscles the L* values increased from boning to the 14th day of ageing. The NESCC muscles showed L* values increase from the 7th to the 14th day of ageing.

Table 2. L*, a* and b* values of M. *longissimus lumborum* submitted postmortem to different treatments

Measurement	TREATMENTS									
	ESHB25		ESHB15		ESHB0		ESCC		NESCC	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
L*										
After boning	$24.34^{c;y}$	± 0.50	$25.16^{c;z}$	± 0.67	$23.13^{c;y}$	± 0.36	$31.22^{a;x}$	± 0.84	$28.68^{b;y}$	± 1.46
7 days p.m.	$32.30^{ab;x}$	± 0.74	$30.66^{b;y}$	± 0.66	$28.72^{b;x}$	± 0.85	$34.77^{a;x}$	± 2.09	$30.81^{b;xy}$	± 1.00
14 days p.m.	$33.82^{ab;x}$	± 0.71	$33.14^{ab;x}$	± 0.91	$30.85^{b;x}$	± 1.16	$34.38^{a;x}$	± 0.37	$32.83^{ab;x}$	± 1.26
a*										
After boning	$9.85^{c;y}$	± 0.39	$9.77^{c;y}$	± 0.30	$10.69^{bc;y}$	± 0.52	$11.99^{ab;y}$	± 0.21	$12.21^{a;y}$	± 0.75
7 days p.m.	16.03^{x}	± 0.79	16.22^{x}	± 0.82	15.10^{x}	± 0.55	14.48^{x}	± 0.34	15.46^{x}	± 0.76
14 days p.m.	16.44^{x}	± 0.40	15.99^{x}	± 0.63	15.91^{x}	± 0.72	15.61^{x}	± 1.03	14.97^{x}	± 0.76
b*										
After boning	$-4.40^{b;y}$	± 0.37	$-3.92^{b;y}$	± 0.56	$-4.96^{b;y}$	± 0.47	$1.38^{a;y}$	± 0.94	$0.06^{a;y}$	± 0.38
7 days p.m.	$6.02^{a;x}$	± 0.86	$5.03^{ab;x}$	± 0.67	$3.37^{b;x}$	± 0.71	$6.93^{a;x}$	± 1.32	$5.92^{a;x}$	± 0.92
14 days p.m.	$6.61^{ab;x}$	± 0.34	$5.97^{abc;x}$	± 0.89	$3.85^{c;x}$	± 0.57	$6.94^{a;x}$	± 1.01	$4.29^{bc;x}$	± 1.01

*SEM=Standard Error of Mean, n=8 replications for treatments; Same superscript letters in the same row or column among means (^{a,b,c}:rows=treatments; ^{x,y,z}:columns=ageing) indicate no significant difference by Duncan test ($p < 0.05$)

In relation to a* values only immediately after boning significant differences were found among the treatments. The LL of ESCC treatment had a significantly higher a* value (11.99) than hot boned treatments except the ones from the ESHB0 (10.69).

In relation to the b* values, immediately after boning they were negative for the hot boning treatments, in the blue region and significantly different than the positive values situated in the yellow region observed for the ESCC and NESCC treatments. When using hot boning, the oxygen consumption rate by mitochondria is very rapid and reduced myoglobin (purple colour) is more intense (Renerre a& Bonhomme, 1991). After 7 days of ageing, the lowest value of b* was observed for muscles from the ESHB0 (3.37) treatment which was not significantly different from the ESHB15 (5.03) treatment. After 14 days of ageing the lowest mean value was still observed for the ESHB0 treatment, significantly lower than the value observed for the muscles of the ESCC treatment.

Immediately after boning, the hot boned cuts presented a darker red-bluish color. Tang & Henrickson (1980) demonstrated that electrically stimulated carcasses presented greater oximioglobina percentage, the reason for having a lighter color. Page et al., (2001) established that parameters L *, a* and the b* are inversely correlated to pH. This explains the darker color of the muscles not electrically stimulated (pH_{24}=5.91) in relation to the stimulated ones (pH_{24}=5.48) (Cardoso et al, 2002). In accordance with Page et al., (2001) a muscle with pH_{24}=5,91 would be inside the category of "dark cutting meat", as these authors established as limit for maximum normal meat pH of 5.87. The observed values of L* in this study were compatible to those measured in *longissimus dorsi* with minimum degree of maturity of the skeleton, in accordance with the classification of the USDA given by Wulf & Wise (1999) that would be of 33.70. The same applies in relation to the values of a* and b* given by the authors of 16.6 and 5.3 respectively. The values of a* in this work were in the range of 14.97-16.44 while those of b* were between 3.85-6.61.

Conclusions

1. Up to the 7th day of storage at 0 ± 2ºC the treatments studied showed no significant effect on drip losses. After 14 days of storage, non-stimulated conventionally chilled LL presented highest drip loss not significantly different ($p>0.05$) from the stimulated control.
2. The treatments did not affect cooking losses after 7 and 14 days of storage.
3. The range of WHC values observed for the different treatments at different storage times was small between 0.40-0.52 in spite of statistical differences being observed between treatments.
4. L*, a* and b* values showed that, immediately after boning, cold-boned cuts were significantly lighter and between cold boned cuts the electrically stimulated ones were lighter. Up to 7 days of storage, storage time also turned the hot boned cuts lighter.

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