final report

Project code: V.RMH.0077

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Date published: 12 March 2019

PUBLISHED BY
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NORTH SYDNEY NSW 2059

An investigation into improving the product quality of hot boned beef

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Executive summary

This study tested post slaughter processing methods that can improve the tenderization of hot boned striploin. Because it is more economically beneficial, hot boning is commonly used for the grinding market as it often results in poorer meat quality and tenderness. The study tested a partial hot boning method where the short loin section was removed from the hot carcass and chilled. The striploin remained in the skeletal system. This cutting method could be a possible automation point, where hot boning plants could use DEXA systems to drive robots, allowing more benefit of DEXA than just lean meat yield values. This study also tested the tenderization benefit of dry aging in *Bos Indicus* cattle.

The partial hot boning treatment resulted in greater tenderization without aging compared to hot boned striploin, as measured by Warner Bratzer Shear force (WBSF). However, optimized electrical stimulation was a requirement for these improvements. These results also suggest that the partial cutting treatment produced better tenderization than the conventionally hung carcasses, likely due to the increased ability to manipulate pH/temp declines. After aging, for 14 and 28 days, all treatments improved, although the improvement in WBSF for the partial treatment was less as aging increased, suggesting that this method has the most benefit for short aging periods. No treatment impacted on sarcomere length, and the hot boned product was observed to have the least purge during aging. These results suggest that under conditions of optimised pH decline, some level of muscular restraint is required to optimise WBSF, which may be achieved without excessive moisture loss.

Dry aging of hot boned striploin resulted in further increases in tenderness at 28 days of aging compared to that of wet aged product. This treatment reduced shear force by 9N. Thus, the decrease in costs associated with hot boning could offset the cost of dry aging, while value adding to the striploin through improved tenderization. Dry aging is a process that results in a large volume of trim loss, especially in a striploin primal. Although the partial cutting treatment was not dry aged in the current study, it would likely be associated with less trim, since the surface area exposed to air is less.

Further research is required to test if these favourable WBSF values translate to improvements in consumer perception. With the current political climate looking as though live trade could slow down, many northern cattle producers could start looking at the viability of local slaughter. Since there is no increase in the domestic demand for ground product, yet a greater supply in cattle typically used for this market, options for value adding and improving eating quality will be sought. Alternatively, applying this scenario in a robotic system that automates the partial boning of the striploin should deliver meat with tenderness that matches that of conventionally hung carcases, however this would need to be tested in the commercial environment.

The key messages of this study were that partial hot boning of the striploin section (ie short-loin) improves tenderization compared to full hot boned striploins. This is a result of skeletal restraint and improved control of pH/temp declines. This cutting method could be a point of automation in abattoirs which results in improved tenderization and would be a further benefit of DEXA. Further work in this area includes the testing consumer eating quality of dry aged BI striploins. This could be a significant value adding point for northern cattle producers wanting to kill domestically. The application of DEXA systems to drive robots in commercial environments would also require further research.

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1 Background

During hot boning, primals are removed from the carcase about 1 hour post slaughter before the onset of rigor and immediately prior to the onset of chilling. By contrast during cold boning primals are removed after chilling. The advantages of hot boning include; ease of boning, reduced weight loss, ease of chilling due greater surface to volume ratios, and reduced requirements for chiller storage space as carcase chilling is eliminated (Pisula & Tyburcy, 1996). However, there are some negative aspects of HB including toughness due to a shorter sarcomere length (Pisula et al., 1996; White, O'Sullivan, Troy & O'Neill, 2006) and darker meat colour (Kastner, Morrison & Henrickson, 1973). The sarcomere shortening occurs due to a lack of skeletal restraint prior to the onset of rigor (Locker, 1960). Due to the sarcomere shortening and reduced tenderness, hot boned product is typically used for ungraded meat or for low quality beef that goes into ground product. Much of this product in Australia would come from Bos indicus cattle, which are associated with lower levels of tenderness development (Highfill, Esquivel-Font, Dikeman & Kropf, 2012; Shackelford, Wheeler & Koohmaraie, 1995).

When hot boned striploins are not processed as ground product, processing techniques that improve the product tenderness are often incorporated, including, electrical stimulation, Slow chilling (White et al., 2006), high pressure processing (Morton, Pearson, Lee, Smithson, Mason & Bickerstaffe, 2017), moisture enhancement (Pivotto, Campbell, Swanson & Mandell, 2014), Smartstretch and Tenderbound (Pen, Kim, Luc & Young, 2012; Taylor, Toohey, van de Ven & Hopkins, 2013; Taylor, J.M. & Hopkins, 2011). The two latter methods use physical restraint to stretch the sarcomere. Loins that remain in the skeletal system do not shorten as much as hot boned striploins (Devine, Wahlgren & Tornberg, 1999) and thus the restraint from the skeletal system offers considerable tenderness advantages. However, it seems possible that partially boning the carcase, where the striploin would remain in the skeletal system and the remainder of the carcases is hot boned, may also prevent shortening. The remaining loin section would appear to be similar to the cut of the shortloin (AusMeat 1552; AusMeat (2005)), where the muscle is cut at both ends, then subsequently chilled. This would likely result in improved chilling while also providing skeletal restraint resulting in a further improvement of tenderness, allowing the striploin to be sold at a higher value.

The use of dry aging has been poorly studied in hot boned product as well as in *Bos indicus* cattle. Dry aging improves tenderness (Warren & Kastner, 1992), overall palatability (Campbell, Hunt, Levis & Chambers, 2001; Kim, Kemp & Samuelsson, 2016) and can produce desirable flavour attributes that could be compatible with meat from older animals (Warren et al., 1992). Dry ageing however reduces meat yield due to excess trimming and moisture loss during storage and thus is seen as an expensive process. Given the economic advantage of hot boning, dry ageing and hot boning may represent complementary techniques in producing a cost effective high quality product.

2 Project objectives

This study aimed to test two hypotheses

(1) Partial hot boning will prevent sarcomere shortening and reduce shear force (Warner Braztler Shear Force - WBSF) in beef striploin.

(2) Dry ageing will reduce shear force in hot boned beef striploin compared to wet aging.

3 Methodology

3.1 Sample collection and experimental design

Thirty six yearling Droughtmaster (Bos indicus) steers from the same consignment on the same day were slaughtered in a commercial abattoir. Steers were fed on grain for 70 days prior to consignment. Directly after slaughter the carcasses were subjected to one of 3 electrical stimulation treatments (no stimulation, low and high stimulation). The carcasses were stimulated with a low voltage nose to tail stimulation system (6ms pulse width, with 64ms pulse interval, 15.6 Hz, at 100V peak for 15 seconds averaging 1.14A 0-peak), and applied for 15 seconds in the high stimulation group and 5 seconds in the low stimulation group. Carcasses were split into sides and each side was allocated to one of 3 cutting treatments. The cutting treatments were

1. Conventional. The carcasses were hung by the Achilles and chilled as normal

2. Hot boned. The striploin were removed pre-rigor quartered at the 10th-11th rib and chilled on a rack.

3. Partial boning. Removal of short loin (AusMeat 1552; AusMeat (2005)) with the tenderloin removed and quartered at the 10th/11th rib, hung from the lumbar end and chilled as normal.

The cutting treatments were distributed to the left and right side of the carcass evenly as well as being balanced within a carcass and electrical stimulation groups. With this design there was 24 sides per cutting treatment with 8 sides across each electrical stimulation treatment within the cutting treatment.

At 72h post-slaughter the LL was removed from all carcasses in a commercial boning room. This included the removal of primals from the partial and conventional treatments (The hot boned were already removed as primals). The loins were packaged and transported back to Murdoch University where they were divided into Cranial and Lumbar ends of each loin. From each end section the loin was cut into 3 consistent blocks of around 80g each (weight recorded) and allocated to one of 3 aging treatments (5, 14 and 28 days), packaged in vacuum bags and stored at 2oC until the respective aging period had expired. An additional 1g slice was taken for sarcomere measurement. Approximately 1-1.5kg of the middle section of the loins from the Hot boned and Conventional cut loins were taken and set for dry aging for 28 days.

3.2 pH and Temperature

The pH was measured on both carcase sides over a period of 5 hours post slaughter in the m.longissimus lumborum (LL). The pH was measured using a TPS WP-80 pH meter (TPS Australia, Qld, Cat no: 121180) equipped with a glass-tipped Ionode pH electrode (Ionode Pty Ltd, Qld, Cat no: IJ 44) and a temperature probe (TPS Australia, Cat no: 121249) calibrated at ambient temperature using buffers at pH 4.0 and 7.0. The Ultimate pH (pHu) was measured 72 hours after slaughter.

The time to pH6 (independent of pHu) for each individual sample was predicted by fitting the following exponential function:

$yt = xu + (xi - xu)-xkt$

where yt is pH as a function of time, xu is pH reached at 4 hours, xi is initial pH, xk is the rate of pH decline and t is time, and this function was fitted to the data using a PROC NONLIN in SAS (SAS Institute, 2001). This enabled us to set a value for time and temperature at pH 6 as an indicator of rate of PH decline.

Temperature of the hot boned primals will be measured throughout the trial until the temperature was permanently under 7oC. The time-temperature data being used to calculate the refrigeration index (which is a regulatory requirement for export establishments). All samples reached a refrigeration index with the lowest predicted microbial growth.

3.3 Dry Ageing

A walk in cool room provided the facility for dry ageing. The air in the cool room had a temperature of 1.80±0.041°C and relative humidity of 86.95 ±0.245% for the duration of the dry ageing period.

3.4 Meat Quality measurements

Once the respective ageing period was completed, loins were removed from the packaging and reweighed to calculate the purge loss during aging, which was the percentage of loss from initial weight pre-storage. The samples were then repackaged in vacuum bags, frozen and stored at -20oC until required for Warner-Bratzler Shear Force (WBSF) measurements.

The samples were then cooked from frozen in vacuum bags in a water bath preheated to 70°C until an internal temperature of 70°C was attained (Approximately 30 minutes). Each sample was suspended from a metal rack and cooked in a water bath. Samples were then cooled in iced water for 30 minutes. Samples were dried and weighed to determine cook loss (expressed as a percentage of weight lost due to cooking; total moisture loss was also determined and expressed as the percentage weight lost from pre-storage to after cooking) and then stored at 4oC for 24 hours. From each sample, five 1 cm2 replicate samples were cut parallel to the orientation of muscle fibres and WBSF was measured using a Warner Bratzler shear blade fitted to a Lloyd Texture Analyser with a 1000N load cell (TA-2, United Kingdom). Values are reported in newton's (N).

Sarcomere length was determined by sectioning five thin subsamples parallel to muscle fibres. Sections were removed from each sample of frozen LL muscle. The method for the determination of Sarcomere length was the same as previously described by Bouton, Fisher, Harris and Baxter (1973).

3.5 Data analysis

The software package SAS® was used for all statistical analyses (SAS Institute, 2001). The sarcomere length, pHu, Temp at pH6 and time to pH 6 were all analysed as dependent variables using a general linear model with the fixed effects cutting and stimulation included as independent variables. The meat quality measures of BWSF, Purge, Cookloss and total moisture loss were also analysed using a general linear model. Along with stimulation and cutting treatments, aging was included in the model as well as all interactions (See table 4 for full models). Animal was used as a random term. The model was regressed to remove non-significant interactions. Temp and Time to pH6, were used as covariates but had no impact on any objective meat quality measures. Therefore stimulation was included in the model as a fixed effect instead.

This study involved two main experimental phases, first to establish the basic relationships between DEXA and chemical fat, lean and bone composition for tissues of varying thickness, and second to apply these relationships to the determination of carcase composition as measured by computed tomography (CT). This series of experiments were conducted at the NUCTECH research facilities in Beijing.

4 Results

4.1 Carcase data

For a summary of carcase data, see Table 1. There was no difference in carcase weight of fat depth for any treatment group. The mean carcase weight was 226.31kg ±11.41 (SD) hot standard carcase weight, with a P8 fat score of 7.72 ± 2.85 (SD).

Table 1. A description of the hot standard carcase weight (kg) and fat depth (mm) measured at the x site for each electrical stimulation treatment (High, low and no) and deboning treatment (HB, PHB, Cold) .

	Carcase weight (9kg)				Fat depth (mm)			
Stimulation	Mean	STD	Min	Max	Mean	STD	Min	Max
				Cold				
No	229.28	10.37	212.2	240.2	7.25	3.09	4	12
Low	221.68	10.24	204.0	236.0	7.50	2.83	4	12
High	225.25	7.17	217.8	241.8	7.13	1.96	5	10
				Partial				
No	227.05	10.03	207.8	239.4	9.38	2.53	5	12
Low	228.55	15.75	204.8	251.0	7.75	3.04	4	12
High	225.30	9.21	216.4	241.8	7.75	3.26	5	15
				Hot Boned				
No	230.38	12.54	207.8	240.2	8.13	2.90	4	12
Low	225.23	16.67	204.0	251.0	7.50	2.31	4	10
High	224.05	6.64	216.4	238.2	7.13	3.48	5	15

4.2 pH

The pH data can been seen in Table 2. Cutting and stimulation treatments affected the temperature and time to pH 6 (P<0.001; Table 2). In general, the pH of the non-stimulated loin reached pH 6 at a later time and lower temperature (P<0.001) compared to low stimulation. In contrast, the high stimulation loin reached pH 6 in less time and at a higher temperature (P<0.001) compared to low stimulation.

There was an interaction between stimulation and cutting method for the time to reach pH 6. Across all electrical stimulation treatments, the conventional cutting treatment reached pH6 faster and at a higher temperature (P<0.001) than other cutting treatments. The largest impact was observed in the non-stimulated carcases where the conventionally hung sides reached pH 6 at least 2 hours before the other cutting treatments. The temperature at pH 6 in these sides was 10.8 and 6.4oC higher than the hot bone and partial treatments (P<0.001).

The distribution of the pH temperature window (pH6 between 35 and 15oC) achieved in the LL from each treatment can be seen in Table 3. The cutting method was not the main effect of reaching the pH temperature window, with 42% of hot boned loin reaching the window and 54% of Conventional and Partial loins reaching the window. Stimulation was the main driver of the pH temperature window with 75% of all low stimulated LL muscles being inside the pH temperature window, while only 42% and 33% of the No stimulation and high stimulation LL muscles reached this window. Furthermore, all Partial/Low sides reached the window, while only one Partial/High sides reach the window, with the remaining 7 in the zone of heat toughening.

The rate of pH decline had no impact on the sarcomere length (data not shown). There was neither an impact of Cutting or Stimulation treatment on sarcomere length (Table 2).

Table 2. The ultimate pH (pHu), temperature (°C) and time (hours) to pH6 and sarcomere length for each the cutting treatment (Hot bone, Conventional and Partial) by high, low and no electrical stimulation. Values are means predicted from the model .The statistical significance of individual terms and the interaction is also presented.

		Cutting								
		HotBone		**Conventional**		**Partial**		**Cutting**	**Stim**	**Cutting x Stim**
	Stim	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**P Value**		
pHu	**No**	5.56	0.024	5.47	0.024	5.52	0.024	***	ns	ns
	Low	5.59	0.024	5.49	0.024	5.58	0.024			
	High	5.55	0.024	5.48	0.024	5.55	0.024			
Temp @ pH6 (ºC)	**No**	9.98	2.309	20.82	2.309	14.37	2.309	***	***	***
	Low	23.52	2.309	28.92	2.309	26.64	2.309			
	High	35.14	2.309	34.96	2.309	37.18	2.309			
Time to pH6 (Hours)	**No**	8.16	0.730	5.34	0.730	8.02	0.730	***	***	***
	Low	2.98	0.730	2.41	0.730	2.69	0.730			
	High	1.04	0.730	1.49	0.730	1.27	0.730			
Sarco (µm)	**No**	1.95	0.042	1.92	0.042	1.90	0.042	ns	ns	ns
	Low	1.90	0.042	1.97	0.042	2.00	0.042			
	High	1.88	0.042	1.97	0.042	1.91	0.042			

*** denotes P <0.001; ns – not significant.

Table 3. The numbers of carcase sides within pH temperatures categories (> pH 6 when temperature was in the range of 35 to15 °C) considered optimal for sarcomere length

Stim	Cutting	Temperature when pH = 6.			% of carcases in window
		>35°C	15-35°C	<15°C	
High	**Hot Bone**	4	4		50%
	Conventional	5	3		37.5%
	Partial	7	1		12.5%
	Subtotal	16	8	0	33%
Low	**Hot Bone**	2	4	2	50%
	Conventional	2	6		75%
	Partial		8		100%
	Subtotal	4	18	2	75%
No	**Hot Bone**		2	6	25%
	Conventional	1	4	3	50%
	Partial		4	4	50%
	Subtotal	1	10	13	42%

4.3 Cutting method, stimulation and ageing

The statistical outputs for Purge, cook and total moisture loss, as well as WBSF values can be seen in Table 4, and their associated least square means are reported in Table 5.

4.4 Purge, cook and total moisture loss

Purge and total moisture loss increased with aging, but mostly from day 5 to day 14 but not 14 to 28. Aging did not impact cook loss (Table 4). The Conventional treatment had the greatest purge and total moisture loss compared to the other cutting treatment from the respective aging periods (Table 5: P<0.001). Cookloss was only weakly impacted by cutting method, with the hot boned treatment losing about 1% more weight during cooking than the other treatments (data not shown). This effect was largest in the Hot bone/Low treatment, in which about 5% more weight was lost during cooking compared to the other cutting treatments in the same stimulation group at 5 days aging (P<0.05; Table 5).

Overall, Stimulation did not impact on Purge, cook or total moisture loss. However, an interaction between cutting and stimulation was observed for Purge and total moisture loss. For Purge loss, this was driven by an increase in purge loss in the Partial/No stim treatment (P<0.001). Higher levels of total Moisture loss were also observed in the no stimulation treatment of the partial cuts at 14 days, while the Hot boned/No treatment had less total moisture loss than the other stimulation treatments (within the Hot boned treatment) at 5 days only.

Cuts from the cranial end of the LL had less purge loss compared to the Lumbar end, but no other impact of End of the LL was observed (Table 4).

Table 4. The numerator degrees of freedom (NDF), denominator degrees of freedom (DDF), F values s of the models applied to the date to test WBSF, Total Moisture loss, purge and cookloss.

	WBSF			**Total Moisture loss**			**Purge**			**CookLoss**		
Effect	NDF;DDF	F Value	P value	NDF;DDF	F Value	P value	NDF;DDF	F Value	P value	NDF;DDF	F Value	P value
Cutting	2;380	10.02	***	2;380	4.59	*	2;387	21.72	***	2;388	5.82	**
Aging	2;380	35.24	***	2;380	15.5	***	2;387	75.25	***	2;388	0.02	ns
End	2;380	0.03	ns	2;380	2.58	ns	2;387	11.71	***	2;388	0.03	ns
STIM	1;380	0.64	ns	1;380	0.22	ns	1;387	0.59	ns	1;388	0.9	ns
Cutting*STIM	4;380	3.25	*	4;380	2.67	*	4;387	6.53	***			
Cutting*Aging	4;380	3.08	*	4;380	2.44	*						

*** denotes P<0.001; ** P<0.01; * P<0.05; ns not significant

Table 5. The least square means for WBSF, purge, cook and total moisture loss, from the LL of high, low and non-stimulated carcases from different cutting treatments, over 5,14 and 28 days of aging.

		Conventional			Partial			Hot Bone			
	Age **Treatment**	**5**	**14**	**28**	**5**	**14**	**28**	**5**	**14**	**28**	**SEM**
							Purge (% weight lost)				
Stimulation treatment	**No**	7.57^{b}	11.05^{b}	11.32^{b}	7.29^{b}	10.95^{by}	12.48^{by}	5.17^{a}	7.82^{a}	8.61^{a}	
	Low	7.75^{b}	11.13^{b}	12.03^{b}	5.55^{a}	7.16^{ax}	9.01^{ax}	6.06^{ab}	9.01^{a}	9.72^{a}	0.77
	High	7.58^{b}	11.19^{b}	10.43^{b}	6.29^{ab}	8.55^{ax}	9.97^{abx}	5.87^{a}	8.76^{a}	8.52^{a}	
							Cookloss (% weight lost)				
	No	25.56	28.26	25.59	25.98	26.16	26.33	26.93^{x}	27.47	27.6	
	Low	26.12^{a}	26.74	26.14	25.67^{a}	25.98	26.11	30.91^{by}	26.6	27.52	1.07
	High	26.89	27.51	27.92	25.62	26.14	27.74	28.54^{xy}	28.25	27.16	
							Total Moisture loss (% weight lost)				
	No	31.18	36.19	33.98	31.3	34.18^{y}	35.54	30.78^{x}	33.23	33.89	
	Low	31.91^{a}	34.93^{b}	35.05	29.63^{a}	31.15^{ax}	32.86	35.05^{by}	33.28^{ab}	34.61	1.13
	High	32.5	35.68^{b}	35.54	30.33	32.47^{axy}	34.98	32.63^{xy}	34.47^{ab}	33.3	
							WBSF (N)				
	No	53.09^{ab}	46.41	40.75^{a}	50.16^{a}	48.50^{y}	47.01^{by}	58.23^{b}	50.53	39.57^{a}	
	Low	47.89^{a}	42.87^{ab}	38.91^{ab}	42.04^{a}	37.17^{ax}	35.99^{ax}	55.28^{b}	48.73^{b}	43.99^{b}	3.68
	High	50.13^{b}	49.46	40.33	42.66^{a}	41.56^{xy}	38.23^{xy}	56.18^{b}	49.71	43.05	

^{ab} Denotes differences between cutting treatments within stimulation and aging treatments;

^{xy} Denotes differences between Stimulation treatments within Cutting and Aging treatments.

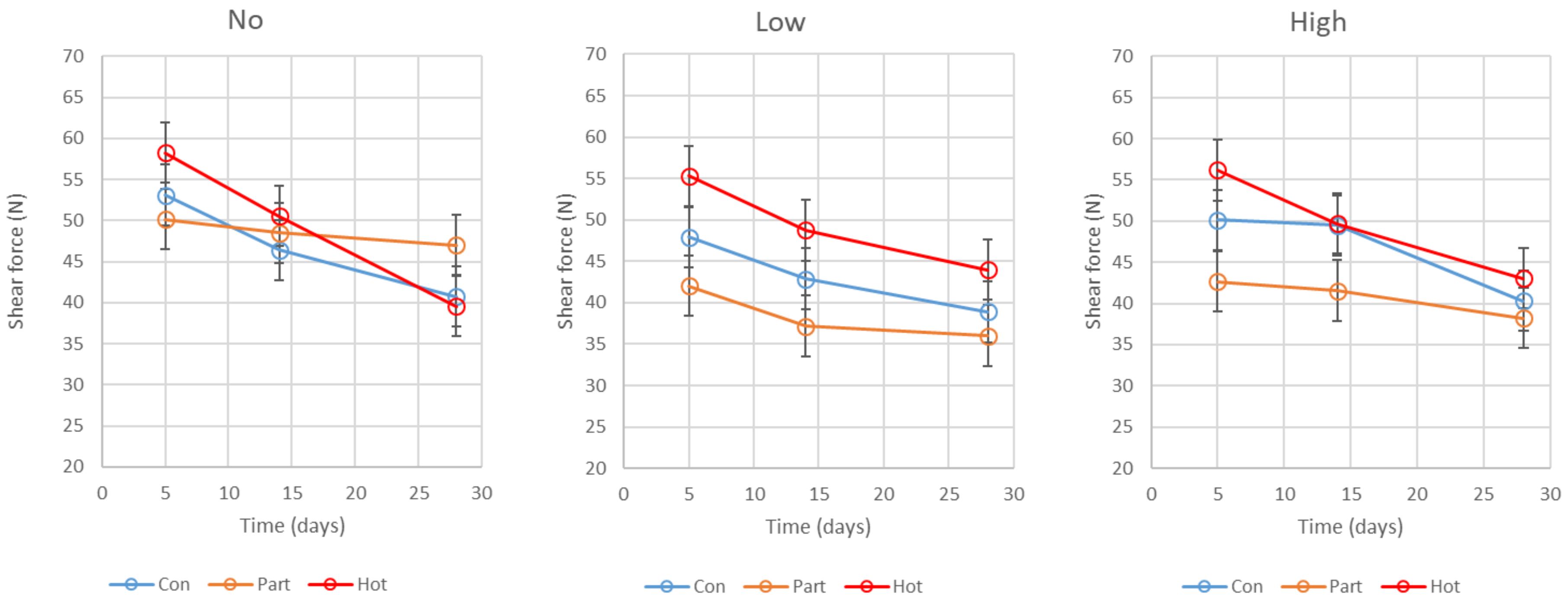

Figure 1. The Warner Bratzler shear force (N) values of beef LL muscle aged over 28 days from non, low and high stimulated beef carcases, conventionally (Con) boned, partial boned (Part) and Hot boned (Hot). Errors are expressed as standard error of the mean.

4.5 WBSF

The Partial/Low treatment had the lowest WBSF across all aging periods, while WBSF improved with aging time (Table 4, Figure 1; P<0.001). Initially, at 5 days aging, the Partial and the Conventional treatments had lower WBSF compared to the hot boned product (Figure 1). By 14 days this difference had mostly disappeared, apart from the low stimulation treatment, where the Partial/Low cuts required 11.57 N less force (Almost 25%) to shear compared to the respective hot boned cuts. By 28 days, there was no impact of individual stimulation and cutting terms. The partial cutting treatment was observed to result in the best WBSF during the aging periods tested, however, stimulation was required.

4.6 Sarcomere length

Sarcomere length had no impact on any eating quality measurement. However, sarcomere length was different between ends of the LL (P>0.001), with the Lumbar end being longer (1.98±0.019) than the Cranial end (1.88±0.019). This was the only differences observed in sarcomere lengths.

4.7 Dry ageing

The statistical output and least square means for dry aging can be seen in Table 6. Dry aging further improved the WBSF of loins when compared to wet aging for the same length of time (P<0.001; Table 6). Dry aged Beef LL had WBSF values 8.93N less than when wet aged for 28 days (P<0.001; Table 6). Stimulation or cutting type did not impact on WBSF values. Dry aged product lost 8.4% more weight during storage than the wet aged product, but lost 4.25% less weight during cooking (P<0.001; Table 6).

Table 6. The least square means data for WBSF, purge and cookloss for hot boned and conventional boned LL after dry aging or wet aging for 28 days. The F values and the P value significance for each individual term are included.

	Cutting				**Aging type**					
	HotBone		**No cutting**		**DryAGE**		**WET**		**Cutting**	**Aging type**
	Mean	sem	Mean	sem	Mean	sem	Mean	sem	F value	F value
WBSF	37.42	1.83	35.69	1.83	32.09	1.87	41.02	1.70	1.22^{ns}	43.51***
Purge	13.31	0.33	15.25	0.33	18.48	0.37	10.08	0.28	20.7***	396.58***
CookLoss	25.47	0.39	24.27	0.39	22.74	0.45	26.99	0.33	5.25*	64.25***

*** denotes P<0.001; ** P<0.01; * P<0.05; ns not significant

5 Discussion

5.1 Cutting method

Partial hot boning improved the WBSF values compared to hot boning, but there were no differences in sarcomere lengths between any of the treatments. Thus supporting the WBSF component but not supporting the sarcomere component of our initial hypothesis. Furthermore, partial hot boning coupled with the low stimulation treatment, reached an ideal pH/Temperature window during chilling (Thompson, 2002), and was more likely to reach this window than conventionally hung carcases. This demonstrates that in a hot boning plant with optimized electrical stimulation, the partial removal of the striploin can result in a more tender product across all aging periods. Previous work has established the importance of electrical stimulation in improving proteolysis and is therefore particularly important for tenderness in Bos indicus cattle (Ferguson, Jiang, Hearnshaw, Rymill & Thompson, 2000). The benefit of cutting treatment on WBSF was mostly observed in the early aging periods. Since optimized electrical stimulation creates ideal conditions for calpain activation and thus tenderization in the early aging periods (Ferguson et al., 2000; Hwang, Devine & Hopkins, 2003), this impact could be primarily due to the pH/Temp window being reached. Thus the partial treatment, with a greater surface to volume ratio enabling more rapid chilling, is more suited for tenderness development without aging. Therefore, it is plausible that the WBSF benefit observed for the partial cutting treatments is due to pH/temp decline.

The lack of difference in Sarcomere length between cutting treatments contradicts our expectations which were based on several previous studies, where hot boning shortened sarcomere length in comparison to conventionally hung carcases (Locker, 1960; Pisula et al., 1996; White et al., 2006). Although no observed shortening occurred in the current study, it would be remiss to rule out the benefit of skeletal restraint. Mechanical stretching, through pre-rigor stretching and restraint, are designed to mimic skeletal restraint (Hopkins, 2017) and to lengthen the muscle. Methods such as Tenderstretch, Smartstretch and Tenderbound have been shown to increase the total length of the muscle but not the sarcomere length (Pen et al., 2012; Taylor, J. et al., 2013; Taylor, J.M. et al., 2011). In these studies the benefit of WBSF was nullified with aging, in agreeance with the current results and providing evidence that the WBSF benefit is likely linked to skeletal restraint.

There was also no consistent effect of any of the stimulation treatments on purge, moisture loss, or cook loss. Indeed the only differences observed were across cutting treatments. None-the-less these effects were small and inconsistent. There have been very few studies that show a negative impact of electrical stimulation in beef (Warner, 2017), and since there were also no sarcomere length differences these impacts are difficult explain. There was however a consistent impact of cutting treatment on purge, where hot boned product almost always had less purge than that of the conventionally hung carcasses. This is supported by literature where only very fast chilled hot boned product resulted in greater purge loss (Pinto Neto, Beraquet & Cardoso, 2013). Therefore under the conditions of this study, this suggests that hot boning does not lead to great levels of moisture loss.

In conclusion, these results suggest that under conditions of optimised pH decline, some level of muscular restraint is required to optimise WBSF, which may be achieved without excessive moisture loss. Alternatively, applying this scenario in a robotic system that automates the partial boning of the striploin should deliver meat with tenderness that matches that of conventionally hung carcases.

5.2 Dry aging

Aligning with our second hypothesis, dry aging further reduced the WBSF values of hot boned striploin when compared to the hot boned product wet aged for the same period of time. Thus proving our second hypothesis. This improvement was not only observed in hot boned loin but also in the conventionally hung carcases. Dry aging is known to improve the palatability in beef cuts (Campbell et al., 2001; Kim et al., 2016), and the large decrease in WBSF values in the current study would likely result in an increase in consumer tenderness scores compared to wet aged product. However, these cuts would need to be tested in a consumer taste panel to evaluate the palatability, particularly since there are no known studies of dry aging taste panels dealing with *Bos indicus* cattle breeds. Since *Bos Indicus* are well known to have a decreased eating quality, mainly due to the lack of tenderisation (Shackelford et al., 1995), dry aging could be a way to value add to the striploin from these cattle. Since hot boning did not negatively impact the WBSF values in the dry aged product, it could be beneficial to pair these two processing methods, the increase in cost associated with dry aging offsetting the reduced costs of hot boning. Although not currently investigated, the added benefit of the partially hot boned striploin combined with dry aging may result in further economic improvement, since there would be less muscle surface area exposed to air, thus less trim required. This will need further investigation.

In Australia, most of the lower quality cattle, which are predominantly *Bos indicus*, are either processed through small abattoirs, or exported through live trade. In the current social climate, the export of live animals from Australia may decline, and thus more cattle will need to be processed through local abattoirs. Since there is no increase domestically in the demand for ground product, yet an increase in total low quality cattle supply, abattoirs may need to incorporate practices that will improve eating quality. With the incorporation of more automation in Australian abattoirs, the preparation of partially cut sections of beef carcasses could be driven by robotics thus allowing for greater ease and reduced cost of fabrication. While hot boning is cost effective for lower value animals, keeping the high value cuts, such as the loin, and value adding through dry aging could result in improved eating quality.

6 Conclusions/recommendations

6.1 Future work

There are several items to address in future experimental work. This includes:

a) The application of robotic automation in removing the partial boned striploin section and the subsequent tenderisation and chilling optimization

b) Testing of the consumer eating quality of wet and dry aged striploin from hot boned, partial hot boned and conventionally hung carcasses.

c) Investigating alternative markets for locally slaughtered and value added *Bos Indicus* cattle.

6.2 Conclusions

Partial Hot boning of beef striploin was shown to produce more tender meat than striploin from either hot boned or conventionally hung carcases. Partial Hot boning of the loin could be a cost effective option in adding value to lower quality carcasses, such as *Bos indicus*, as long as this is coupled with optimized electrical stimulation and chilling. Furthermore, the application of dry aging to hot boned Bos indicus striploins showed increases in tenderness development and thus seems to be a further value adding alternative. However, further investigation into value adding and eating quality is required.

Further work in this area includes the testing consumer eating quality of dry aged BI striploins. This could be a significant value adding point for northern cattle producers wanting to kill domestically. The application of DEXA systems to drive robots in commercial environments would also require further research.

7 Key messages

- Partial hot boning of the striploin section improves tenderization compared to full hot boned striploins. This is a result of skeletal restraint and improved control of pH/temp declines.

- The partial cutting method could be a point of automation in abattoirs, which results in improved tenderization.

- Dry aging of hot boned *Bos Indicus* striploin has significant improvements in tenderness as measured by shear force.

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