PE4.15 Pre-rigor interventions: the effect on myofibrillar degradation and shear force 43.00

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Abstract— **The ability to consistently deliver a tender product efficiently is a challenge for the processing industry. The aim of this experiment was to evaluate the effect of three different hanging methods and two treatments using SmartStretch technology on myofibril degradation through Particle Size Analysis and shear force (SF) and to examine the relationship between the two variables. The three hanging methods evaluated were Achilles tendon (AT), tenderstretched (TS) and superstretched (SS). The two SmartStretch treatments were SmartStretch ice (SS-Ice) and SmartStretch chilled (SS-Chill). The SF and mean Particle Size (PS) results showed that there were significant ($P < 0.05$) differences between treatments and ageing, but no interactions. The 25% quartile for PS (LT25) indicated a significant interaction between treatment and ageing. The correlations between SF and mean PS or LT25 for each treatment were positive but not strong. Based on the results it is concluded that the pre-rigor interventions evaluated do have a positive effect on meat quality when compared with traditionally hung AT carcases.**

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***Index Terms*—Stretch, shear force, myofibrillar degradation**

I. INTRODUCTION

The ability to produce a tender product in a limited time while reducing inputs is a challenge for the processing industry. Meat tenderness is a function of production and processing factors [1] and is an attribute that is highly valued by the consumer. Methods to improve the tenderness of meat can be utilised during either the pre-rigor or post-rigor phases [2] and large improvements in meat tenderness can be made through such interventions at the processing stage. One such method of intervention is tenderstretching (where carcases are suspended from the obturator foramen or the aitch bone) which can substantially improve the tenderness in many muscles including m. *longissimus lumborum* [1]. Superstretching is an adaption to the tenderstretch method where carcases are suspended from the obturator foramen and a pulley system is used to draw the tenderstretched hind quarter towards the forequarter. Similar techniques have been used in the past where weights have been used to increase the stretch of tenderstretched carcases [3] and the results have shown that there were additional benefits in shear force when compared to tenderstretched carcases.

The method of boning is another post-slaughter intervention which can impact meat quality and processing speed. Carcases are most commonly boned cold, meaning they have been placed in a chiller for a period of time (usually around 24 hours) prior to boning. The process of hot boning is defined as the removal of muscles in a pre-rigor state shortly after slaughter [4]. There are a small number of processors in Australia who use the hot boning process, despite the tendency to be associated with poorer quality meat. One of the major constraints of hot boning is that muscles are disconnected from the skeletal framework which increases the risk of cold shortening in muscles [5]. To ensure hot-boned muscles are as tender as possible, their contraction needs to be restricted [4].

The many economic benefits for using hot boning include: increased meat yield, energy savings, chiller space minimisation, reduced labour and faster processing [6]. In addition, hot boning allows each muscle to be separated from the carcase pre-rigor and treated optimally according to its intrinsic properties [5], hence improving meat quality. Recent work has shown that if a combination of hot boning and a pre-rigor intervention (SmartStretch prototype) is used then tenderness could be improved by 46% at 0 days of ageing and 38% after 5 days of ageing [7].

The aim of this experiment was to evaluate the effect of different hanging methods Achilles tendon (AT), tenderstretched (TS), or superstretched (SS) and SmartStretch technology on myofibril degradation through Particle Size Analysis (PSA) and shear force and to examine the relationship between the two variables.

II. MATERIALS AND METHODS

A. Animals

The current study was based on 30 grain fed beef cattle. All the cattle were female, with a dentition score of 2 and originated from the same feedlot. Animals

were slaughtered under the normal practices of the cooperating abattoir, which included head stunning followed by low voltage stimulation.

B. Treatments and sampling

There were five post-slaughter treatments applied. Three were variations in hanging method: Achilles tendon (AT), tenderstretched (TS, where carcases are suspended from the obturator foramen), or superstretched (SS, carcases are suspended from the obturator foramen using a pulley system to draw the tenderstretched hind quarter towards the forequarter) and two using a meat stretching device including: SmartStretch chilled (SS-Chill) or SmartStretch ice (SS-Ice). One side of each carcase was randomly assigned to a SmartStretch treatment and the other was then randomly assigned to one of the three hanging methods.

For both the SmartStretch treatments the m. *longissimus lumborum* (striploin) (HAM 2140) [8] was removed from the hot carcase within 40 minutes post death. These samples were then trimmed of subcutaneous fat and processed through the SmartStretch prototype machine whilst still pre-rigor. The SmartStretch prototype (licensed as SmartStretch) under development by Meat & Livestock Australia and Meat & Wool New Zealand has a flexible inner sleeve. Once the striploins are placed in the sleeve, air pressure is applied to stretch and shape the meat. Samples were ejected from the SmartStretch machine into a tube packaging sleeve. After this, samples were either wrapped in two layers of bubble wrap and chilled on a rack in the same chiller as the other carcases (SS-Chill) or placed in an ice bath until samples reached 4º C and then chilled on the same rack as the other samples (SS-Ice). All other carcase sides were held in the chiller for approximately 24 hours and then the striploins were removed.

All 60 striploin samples were cut into three 7 cm long samples, which were randomly allocated to one of three ageing treatments: 1, 7 or 21 days. Samples were frozen at -20º C after their respective ageing period. From these samples, a full range of meat quality traits were assessed including: pH and temperature, shear force, cooking loss, sarcomere length, colour stability, thaw loss and particle size analysis. However, the current study only reports results for shear force, particle size analysis and the relationship between the two.

C. Particle Size Analysis (PSA)

Particle size analysis was conducted on 2 g samples as previously described [9].

D. Shear force

The Warner-Braztler shear force results were determined using an adapted method from that previously described [10]. These modifications include the dimension size of samples (4x4x5 cm); cooking time (35 minutes) and samples were cooked from a frozen state.

E. Statistical methods

Analysis of the data was performed in two stages. For the first stage the results for shear force (SF), mean particle size (PS) and the 25% quartile for particle size (LT25) were analysed separately, using a linear mixed model (LMM). Models were fitted using ASREML [11]. The model contained fixed effects for stretch treatment at five levels (AT, SS-Chill, SS-Ice, SS and TS), ageing as a linear covariate, ageing as a factor with three levels (1, 7 and 21 days) and the interaction of treatment and ageing. Random terms used in the model were date of test, animal, side within animal and finally a random error. All random terms were included as uncorrelated effects. The variances of the random errors were initially allowed to differ across treatments.

The second stage of the analysis focused on estimation of the correlations between: SF and mean PS; and SF and log (LT25). Bi-variate analyses (LMM) were performed with the pairs of dependent variables, taking as PS results the average of the duplicate results of each sample. The bi-variate model included fixed effects for each combination of treatment and ageing for each trait. The random effects included: test date effect for each test; trait × animal effects (correlated across traits but uncorrelated across animals); uncorrelated animal × side effects for the SF trait; and residual effects which were correlated across traits but uncorrelated across samples. The variance–covariance matrix for the residuals was allowed to differ for treatment = AT, for treatment = SS-Chill & SS-Ice, and for treatment = SS & TS.

III. RESULTS AND DISCUSSION

The mean PS differed significantly ($P < 0.05$) across stretch treatments and across levels of ageing, with no significant interaction between the two factors. There was an estimated decline of 66.6 µm (se 5.44 µm) in mean PS for 7 day aged loin compared to 1 day

aged loin. There was an estimated decline of 108.2 µm (se 5.39 µm) in mean PS for 21 day aged loin compared to 1 day aged loin. Mean PS results may reflect increased fragility in the sarcomere due to increased sarcomere length and/or the degradation of myofibrillar proteins. However in a previous study [7] where a stretch treatment was compared to no stretch in sheep topsides, the mean PS results showed there was no difference between stretch treatments but there was an aging effect; the sarcomere length results showed that there was a significant difference between stretch treatments but no ageing effect. Based on this it could be concluded that the higher mean PS (i.e. larger particles) of the AT treatment in the current study could be due to the physical restraint and this may be better explained by the variance in sarcomere length which is not presented in the current findings. The ageing changes within treatments however are indicative of increased protein degradation (Table 1), an outcome supported by previous studies [9]. In addition Table 1 shows that at 1, 7 and 21 days of ageing, SS-Chill was not significantly different to any other treatment. However at 1, 7 and 21 days aged, SS-Ice had a significantly higher mean PS than TS and SS. The AT treatment also had a significantly higher mean PS than SS. This higher mean PS signifies that there was potentially less myofibrillar degradation and it could be concluded that the SS-Ice treatment resulted in a slower proteolysis rate due to the low temperature and/or shorter sarcomere length. Adjustment of mean PS results for sarcomere length across treatments would shed additional light on the important mechanism causing change in sarcomere structure.

Table 1. Predicted means, standard error (SE) and LSD ranking for mean PS (µm) and PS (LT25) for the various treatments

	AT		SS-Ice		SS-Chill		TS		SS	
Days Aged	**Predicted value**	**LSD Rank**	**Predicted value**	**LSD Rank**	**Predicted value**	**LSD Rank**	**Predicted value**	**LSD Rank**	**Predicted value**	**LSD Rank**
					PS Mean					
1	273(7.5)	i j	273(6.7)	j	262(7.0)	h i j	258(7.8)	h i	250(7.7)	h
7	206(7.3)	f g	206(6.7)	g	195(6.6)	e f g	192(7.4)	e f	184(7.5)	d e
21	165(7.4)	b c d	165(6.8)	c	154(6.7)	a b c	150(7.6)	a b	142(7.4)	a
					PS (LT25)					
1	79(3.2)	g h	84(2.7)	h	77(2.8)	g h	74(3.8)	d g f	73(3.4)	d e g
7	65(3.0)	b c e f	72(2.6)	d g	66(2.5)	c d	69(3.1)	c d	67(3.1)	c d
21	68(3.0)	c d	65(2.8)	b c e	64(2.8)	b c	58(3.2)	a b	51(3.1)	a

Means within a trait having no letter in common under LSD Rank are significantly different ($P = 0.05$).

Analysis of LT25 indicated a significant interaction (P = 0.03) between treatment and ageing (Table 1), the variation of the random error was not significantly different across treatments. The significant interaction between treatment and levels of ageing for PS LT25 is seen for example, between 7 and 21 days of ageing there was no significant change for AT and SS-Chill treatments while they different to other treatments. This was different to the results found for mean PS for AT and SS-ice treatments.

The shear force results showed there was a significant difference across stretch treatments and a linear trend with the period of ageing as shown in Figure 1. From the coefficients SF declined by 0.47 Newton's (s.e. 0.09) for each day of ageing (up to 21 days).

The significant difference between treatments was such that the AT had a significantly higher shear force value at 1, 7 and 21 days when compared to all other treatments. This result supports previous studies which have shown that carcases hung by the Achilles tendon have a significantly higher shear force when compared to tenderstretched and superstretched carcases [3]. This result also indicates that the hot boned samples were restrained and muscles were prevented from contracting when treated through the SmartStretch prototype, which is supported by previous work with the same prototype where mutton topsides had an improved shear force at both 0 and 5 days of ageing [7]. The SS-Ice treatment had a significantly lower shear force than AT, but higher than all other treatments, indicating that during rapid chilling of the muscles in an ice bath, the packaging did not completely prevent cold-shortening. Also, based on the mean PS results the muscle from the SS-ice treatment exhibited less myofibril degradation having higher absolute values than all other treatments except the AT treatment. There was no significant difference between SS-Chill, SS or TS at 1, 7 or 21 days aged and

no significant ($P > 0.05$) interaction effect between ageing and treatments.

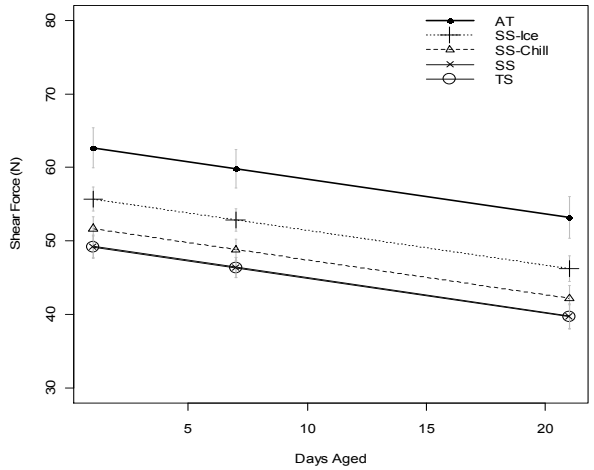

Figure 1. Predicted shear force (N) means with standard errors

Table 2 reports the estimates of the correlations between SF and each of the two variables (PS Mean and LT25). These correlations are for a single result obtained for both the SF and the PS test, with the sample tested given the same treatment and aged for the same duration. The correlations are derived from samples within the same animal, but not necessarily the same side, nor necessarily tested on the same day. Estimates of the standard errors of the correlation estimates are also given and a 95% confidence interval provided for the estimate. The latter values were obtained using Monte Carlo simulation.

Table 2. Estimates of the correlations, standard error (SE) and 95% confidence interval (95% CI) between Shear Force and each of the two variables (PS Mean and LT25)

Traits	Treatment	Correlation	SE	95% CI
SF & PS Mean	AT	0.28	0.16	(-0.06, 0.54)
	SS - Ice	0.16	0.09	(-0.02, 0.32)
	SS - Chill	0.16	0.09	(-0.02, 0.32)
	TS	0.08	0.12	(-0.13, 0.30)
	SS	0.08	0.12	(-0.13, 0.30)
SF & LT25	AT	0.09	0.17	(-0.26, 0.40)
	SS - Ice	0.20	0.08	(0.03, 0.36)
	SS - Chill	0.20	0.08	(0.03, 0.36)
	TS	0.08	0.11	(-0.14, 0.30)
	SS	0.08	0.11	(-0.14, 0.30)

Shear force was positively correlated with the two PS traits (Mean and LT25), but the correlations are not strong (Table 2). These low correlations do not differ from recent studies where the correlation was examined between mean PS, LT25 PS and shear force [9]. This suggests that myofibril degradation does not describe well the variation in meat tenderness in the current study.

IV. CONCLUSION

The pre-rigor interventions examined in the current study had a positive effect on meat tenderness, with traditionally hung AT carcases having a higher shear force when compared to all other treatments. The hot boned meat samples used for the SmartStretch prototype treatments, in particular the SS-Chill treatment, proved to be an acceptable alternative method of processing when compared to the conventionally chilled AT, SS and TS treatments. Particle size varied between the various processing interventions with AT and SS-Ice exhibiting a larger particle sizes than other treatments and the lack of stretch and low temperature respectfully may have attributed to the lack of degradation. The weak correlations between shear force and each of the two variables (PS Mean and LT25) suggests that particle size did not describe the variation in meat tenderness well in the current study.

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