PE4.29 Explaining the variation in shear force using sarcomere length, the rate of rigor onset and pH 114.00

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***Abstract*—The temperature at pH6 has been found to impact on the tenderness and eating quality of sheep meat, particularly short aged product. Due to the expense, sarcomere length is not routinely measured as a variable to explain variation in shear force, but whether measures of the rate of rigor onset (e.g. the temperature at pH6) are as useful needs to be established. Using a sub-set of data from the Australian Sheep Industry Innovation CRC's Next Generation Meat Quality program, measures of rigor onset, including the temperature at pH6, have been evaluated in this study for their ability to explain some of the variation in shear force. Our results show that for 1 day aged product combinations of the temperature at pH6, the pH at 18 degrees and the pH at 24 hrs provided at least as large a reduction in total shear force variation as sarcomere length alone, with pH at 24 hrs being the single best measure. For 5 day aged product, pH at 18 degrees C was the single best measure. Inclusion of sarcomere length did represent some improvement, but the marginal increase would not be cost effective.**

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I. INTRODUCTION

THE measurement of the rate of decline in muscle pH post-mortem is a feature of the Meat Standards Australia (MSA) grading system for both beef [1] and sheep [2] carcases in Australia. This is because the temperature at nominal rigor (pH 6) has been shown to be an important determinant of tenderness and overall eating quality [3]. For example it has been shown that as the temperature at pH 6 increased (reflecting a faster rate of pH decline) the overall liking of lamb meat increased such that a 10°C increase would give a 4.3 improvement in the overall liking score (range 20-80) [4]. This effect is attributed to an acceleration of proteolysis and thus tenderisation [5]. Another factor that impacts on tenderness is the length of the sarcomere at rigor. Muscle with short sarcomeres at rigor will produce tougher meat [6], but there appears to be an interaction between the rate of rigor onset, sarcomere length and shear force (tenderness) [7]. These workers showed almost no relationship between sarcomere length (determined at 48 hours, with a range of 1.5 – 2.1 μm) and shear force values (for either aged (12 days) or non-aged muscle (48 hours)) in *longissimus* muscles that had undergone a rapid pH decline (i.e. pH < 6.3 at 3 hours), but a strong relationship (r = 0.84) for muscles which had undergone a slow rate of pH decline (i.e. pH > 6.3 at 3 hours). Further to this, the relationship between sarcomere length and shear force changes as meat ages. For example, a poor relationship was reported between shear force and sarcomere length of *longissimus* muscles that had been aged for 10-14 days [8]. For large scale experiments where the desire is to explain variation in shear force, the measurement of sarcomere length is prohibitive due to time and cost and so the question arises, can measurement of the rate of rigor onset be as useful for explaining the variation in shear force? As part of the CRC for Sheep Industry Innovation in Australia each year 2000 progeny are being evaluated for a wide range of meat production and consumer-relevant traits [9] which includes the temperature at pH6 (temp@pH6). This paper reports on a study, which uses as sub-set of these data, to compare whether the measurement of sarcomere length significantly improves the explanation of variation in shear force over and above determination of measures of rigor onset such as the temp@pH6.

II. MATERIALS AND METHODS

A. *Carcases*

Over four days, 261 lambs were slaughtered

representing both second cross lambs (Terminal sire x Border Leicester x Merino ewes) and first cross lambs (Terminal sire x Border Leicester or Terminal sire x Merino ewes) produced as part of the Information Nucleus for the CRC for Sheep Industry Innovation [10]. The lambs were slaughtered at 7-8 months of age. All carcases were electrically stimulated (800 milliamperes with variable voltage to maintain a constant current, for 25 seconds at 14 pulses/s, 1 millisecond pulse width) post-dressing with a mid-voltage unit [11]. Carcasses were trimmed according to the specifications of AUS-MEAT [12]. Carcasses were chilled at a mean temperature of 4–5°C over a 24 hr period.

B. *Measurements*

After the commencement of chilling, pH and temperature were measured in the left-hand portion of the m. *longissimus thoracis et lumborum* (LL) at the caudal end over the lumbar-sacral junction. A section of subcutaneous fat and the m. *gluteus medius* was cut away to expose the LL and after measurement the area was resealed with the overlaying tissue. pH was measured using WPS meters with temperature compensation (TPS, WP-80, PTS Pty Ltd) and a polypropylene spear-type gel electrode (Ionode IJ 44), calibrated at ambient temperature. Two measurements were taken as the pH declined, the first as soon as the carcases entered the chiller and the second after the temperature had dropped below 18°C. pH of the LL at 24 h post-mortem (LL_{24}pH) was measured in the caudal site used for repeat measures after calibrating the meter at chiller temperatures.

From the loin (Product identification number HAM 4910; [13]) the right loin muscle was removed at 24 h post-mortem and divided into 2 portions (cranial and caudal) for shear force testing (aged for 1 day or 5 days) respectively. Chilled 5 day samples were vacuum packed and held chilled (4-5°C) until preparation and freezing on day 5. Samples of LL were prepared into 65 g blocks and frozen (–20°C) at either 1 or 5 days of ageing for subsequent shear testing. Samples for shear testing were cooked from frozen for 35 min in plastic bags at 70°C in a water bath before being tested using a Lloyd (Model LRX, Lloyd Instruments, Hampshire, UK) with a Warner-Bratzler shear blade fitted as previously described [14]. A thin (1-2 mm) slice of frozen LL muscle (-20°C) from each 1 day aged portion was used for determination of sarcomere length using laser light diffraction [15].

C. *Statistical analysis*

Linear modeling of temperature versus pH was undertaken to derive temp@pH6 using 3 data points which included the first measurement, second measurement and LL_{24}pH with temperature being the dependent variable. A similar approach was used to derive the pH at 18°C (pH@18degrees) in which case pH was the dependent variable. The models were fitted for each carcase.

A linear mixed model (LMM) was fitted using ASREML [16] for shear force including as fixed effects all possible linear combinations of temp@pH6, pH@18deg, LL_{24}pH and sarcomere length, with random effects for slaughter day, cooking day of shear force samples and shear force cooking batch (within cook day). The models were fitted separately for days of ageing.

III. RESULTS AND DISCUSSION

The summary statistics for the various measures are given in Table 1. The base model for shear force data within each period of aging comprised an overall mean effect, no covariates and random effects for slaughter day, cooking day, cooking batch and random error. The total variance (sum of the variance components) for the base models were 66.8 and 35.4 for meat aged 1 and 5 days respectively, with most of the variance attributed to random error in both cases. In Table 2 the decreases in total shear force variance (expressed as a percentage relative to the base model) are shown when various fixed covariates are included in the model.

It was readily apparent that of the single traits LL_{24}pH was the most useful measure for decreasing variance in shear force predictions, although the value of this measure was less for 5 day aged product. Including sarcomere length with LL_{24}pH did improve the reduction in variance, but a similar level was achieved by combining temp@pH6, pH@18deg and LL_{24}pH. In fact this combination gave a better result for 5 day aged product. For cost effectiveness measurement of these three traits is better than measuring just LL_{24}pH and sarcomere length. Indeed based on related results [17], the usefulness of temp@pH6 can be improved further by the measurement of three pH and temperature measures and this could well increase the reduction in shear force variance when included as a fixed effect along with pH@18deg and LL_{24}pH. The extra expense of including sarcomere length over and above the

measures of rigor onset and muscle pH appears unjustified, particularly for 5 day aged product.

IV. CONCLUSION

For large scale measurement of lamb carcases to derivation of predicted temperature at pH6 for use as a covariate for shear force analysis appears more useful when combined with other measures such as pH@18deg and LL_{24}pH, than measurement of sarcomere length, particularly for 5 day aged product. Inclusion of sarcomere length did represent some improvement, but the marginal increase would not be cost effective.

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REFERENCES

[1]Thompson, J.M. (2002). Managing meat tenderness. Meat Science, 62, 295-308.

[2]Anon. (2007). Producing quality sheep meat. Meat Technology Update, 6/07, Food Science Australia.

[3]Thompson, J.M., Hopkins, D.L., D¡¦Sousa, D., Walker, P.J., Baud, S.R., & Pethick, D.W. (2005). The impact of processing on sensory and objective measurements of sheep meat eating quality. Australian Journal of Experimental Agriculture, 45, 561-573.

[4]Hopkins, D.L., Stanley, D.F., Toohey, E.S., Gardner, G.E., Pethick, D.W., & van de Ven, R. (2007). Sire and growth path effects on sheep meat production. 2. Meat and eating quality. Australian Journal of Experimental Agriculture, 47, 1219¡V1228.

[5]Hopkins, D.L., & Geesink, G.H. (2009). Protein degradation post mortem and tenderisation. In Ed Du, M. & R McCormick, Applied Muscle Biology and Meat Science, (in press). CRC Press.

[6]Penny, I.F., & Dransfield, E. (1979). Relationship between toughness and troponin T in conditioned beef. Meat Science, 3, 135-141.

[7]Smulders, F.J.M., Marsh, B.B., Swartz, D.R., Russell, R.L., & Hoenecke, M.E. (1990). Beef tenderness and sarcomere length. Meat Science, 28, 349-363.

[8]Culler, R.D., Parrish, F.C. Jr., Smith, G.C., & Cross, H.R. (1978). Relationship of myofibril fragmentation index to certain chemical, physical and sensory characteristics of bovine longissimus muscle. Journal of Food Science, 43, 1177-1180.

[9]Hopkins, D.L., Jacob, R.H., Ball, A.J., & Pethick, D.W. (2009). The CRC for Sheep Industry Innovation ¡V measurement of new and novel meat traits. In Proceedings 55th International Congress of Meat Science and Technology. Copenhagen, Denmark. In press.

[10]Fogarty, N.M., Banks, R.G., van der Werf, J.H.J., Ball, A.J., & Gibson, J.P. (2007). The Information Nucleus ¡V a new concept to enhance sheep industry genetic improvement. Proceedings of the Association for the Advancement of Animal Breeding and Genetics, 17, 29-32.

[11]Toohey, E.S., & Hopkins, D.L. (2006). Rate of pH and temperature decline in lamb carcases using mid voltage electrical stimulation. Australian Society of Animal Production 26th Biennial Conference, (Short communication No. 5).

[12]AUS-MEAT AUS-MEAT language. 4th edn. AUS-MEAT, Sydney, Australia.

[13]Anon. (1998) ¡¥Handbook of Australian meat.¡¦ 6th edn. Authority for Uniform Specification Meat and Livestock: Brisbane.

[14]Hopkins, D.L., & Thompson, J.M. (2001). The relationship between tenderness, proteolysis, muscle contraction and dissociation of actomyosin. Meat Science 57, 1-12.

[15]Bouton, P.E., Fisher, A.L., Harris, P.V., & Baxter, R.I. (1973). A comparison of the effects of some post-slaughter treatments on the tenderness of beef. Journal of Food Technology 8, 39¡V49.

[16]Gilmour, A.R., Gogel, B.J., Cullis, B.R., & Thompson, R. (2006). ASReml User Guide Release 2.0. VSN International Ltd, Hemel Hempstead, HP1 1ES, UK

[17]Hopkins, D.L., Lamb, T.A., Kerr, M.J., & G. Refshauge (2009). Alternative methods for determining the temperature at pH 6. In Proceedings 55th International Congress of Meat Science and Technology. Copenhagen, Denmark. In press.

TABLE 1: Summary statistics for shear force, rate of pH decline, sarcomere length and pH at 24 hours post-mortem.

Trait	Mean	s.d.	Min	Max
Shear force 1 day aged (N)	36.8	8.1	21.6	73.9
Shear force 5 day aged (N)	23.0	5.9	11.7	47.0
Temp@pH6.0	16.3	3.6	7.4	27.0
pH@18°C	6.09	0.16	5.70	6.60
Sarcomere length (μm)	1.73	0.07	1.52	1.94
$LL_{24}pH$	5.52	0.09	5.22	5.86

TABLE 2: Relative decrease (in %) in total shear force variance, relative to the base model, when combinations of fixed effects are added to base model.

Fixed effects	Aged 1 day	Aged 5 days
Temp@pH6.0	0.7	2.4
pH@18 deg	0.7	3.0
$LL_{24}pH$	5.6	1.8
Sarcomere length	4.2	0.6
Temp@pH6.0 + pH@18 deg	0.4	2.2
Temp@pH6.0 + $LL_{24}pH$	4.2	0.3
pH@18 deg + $LL_{24}pH$	4.7	3.0
Temp@pH6.0 + Sarcomere length	5.6	3.3
pH@18 deg + Sarcomere length	6.1	4.4
$LL_{24}pH$ + Sarcomere length	8.1	1.3
Temp@pH6.0 + pH@18 deg + $LL_{24}pH$	8.2	5.2
Temp@pH6.0 + pH@18 deg + $LL_{24}pH$ + Sarcomere length	11.8	5.5