PE1.13 Alternative methods for determining the temperature at pH 6 113.00

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***Abstract*—Measurement of pH decline post-mortem is used in grading schemes for both beef and sheep in Australia. The temperature at pH6 has been found to impact on the eating quality of beef and sheep meat, particularly short aged product. In Australia, the Sheep CRC's Next Generation Meat Quality program is undertaking the slaughter, sampling and testing of carcases and meat for a range of traits. Each year 2000 progeny are being evaluated for a wide range of meat production and consumer-relevant traits including the temperature at pH6. Obtaining this data is labour intensive and thus restrictive for large slaughter experiments and so a study was undertaken to determine whether collection of 3 measures of pH and temperature during the post-mortem period would provide a reliable indication of the temperature at pH6 as opposed to the usual collection of 5-6 measures. Six measures of pH and temperature were taken on each of 53 lamb carcases during the post-mortem period. Determination of the temperature at pH6 was based on non-linear and linear modeling. This showed that measurement of lamb carcases to derive a predicted temperature at pH6 using linear modeling based on 3 measurement time points during the onset of rigor was comparable to 6 time point measurements and the use of non-linear modeling. However, use of linear modeling based on 3 measurement time points and a measurement at 24 hours is not recommended as it overestimates the number of carcases meeting the threshold.**

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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 the overall liking of lamb meat increased such that a 10°C increase would give a 4.3 increase in the overall liking score [4]. To establish the impact of the temperature at pH 6 (temp@pH6) on eating quality traits repeated pH and temperature measurements have been taken on carcases during the onset of rigor [4]. Using this approach the rate of pH decline relative to time from the first measurement post-mortem for each carcase was modelled using a non-linear procedure previously described [5]. The non-linear procedure was also used to describe temperature decline relative to chilling time and from this the temp@pH6 was derived, as the predicted temperature at the time when the predicted pH was 6.0. This approach is labour intensive and thus restrictive for large slaughter experiments. 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 [6] which includes temp@pH6. In some studies linear modelling to derive temp@pH6 has been applied [7], but a comparison of the approaches has not been reported. Linear modelling based on fewer measurement points offers the potential to obtain predictions of temp@pH6 on larger numbers of carcases. This paper reports a study to compare the 2 approaches.

II:MATERIALS AND METHODS

A. *Carcases*

The 53 carcases used in this study were derived from second cross lambs (Terminal sire x Border Leicester x Merino ewes) produced as part of the CRC for Sheep Industry Innovation. The lambs were slaughtered at 7 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) using a post-dressing mid-voltage unit [8]. Carcasses were trimmed according to the specifications of AUS-MEAT [9]. Carcasses were chilled at a mean temperature of 4–5°C over a 24 hr period.

B. *Measurements*

At regular intervals (approximately hourly) 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. Five measurements were taken as the pH declined. 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.

C. *Statistical analysis*

The rate of pH decline relative to time from the first measurement post-mortem for each carcase was described using data for the 6 different sample points using the following non-linear equation and a non-linear procedure [10]:

$$pH_t = pH_\infty + (pH_0 - pH_\infty)\exp^{-k_1 t}$$

where pH_t = pH at time t, pH_∞ = the ultimate pH, pH_0 = the pH at t = 0, k_1 = rate constant of pH decline and t = the time in hours.

The same procedure was used to describe temperature decline relative to chilling time;

$$Temp_t = Temp_\infty + (Temp_0 - Temp_\infty)\exp^{-k_2 t}$$

Where $Temp_t$ = Temperature at time t, $Temp_\infty$ = the final temperature, $Temp_0$ = temperature at t = 0, k_2 = rate constant of temperature decline and t = the time in hours. Non-linear curves of pH against time post-stimulation and of temperature against time post-stimulation were fitted for each carcase and model parameters were obtained and used to determine the time to reach pH 6.0. Using this time a predicted temperature at pH 6 (temp@pH6) was calculated.

Linear modeling of temperature versus pH was undertaken to derive temp@pH6lin using 3 data points (initial post-mortem pH measure, second pH measure and a third measure when the temperature was less than 18°C) with temperature being the independent variable. A similar approach was used to derive the pH at 18°C (pH@18degrees) in which case pH was the independent variable. The modeling was repeated using the 3 data points and $LL_{24}pH$ (temp@pH6linu) with temperature being the independent variable. The models were fitted for each carcase. Given that the minimum recommended temp@pH6 is 18°C [2] the distribution of the carcases based on the different methods of determining temp@pH6 was compared using a Chi-square test and the means were compared using a two tailed t-test.

III. RESULTS AND DISCUSSION

For the non-linear modeling of pH and temperature against time the R^2 was 0.8 and 0.99 respectively. For the linear modeling based on 3 data points the R^2 was 0.61 and when the model included $LL_{24}pH$ the R^2 was 0.77. For determining the pH at 18°C the R^2 was 0.72 based on 3 data points from linear modeling

The summary statistics for the various measures are given in Table 1. There was no significant difference ($P > 0.05$) between the mean values for temp@pH6 and temp@pH6lin, or between temp@pH6 and temp@pH6linu and temp@pH6lin and temp@pH6linu ($P > 0.05$). Of the measures temp@pH6linu had the lowest variance, but it also gave the largest difference for the mean when compared to the mean temp@pH6. The method based on 3 data points (temp@pH6lin) has one limitation which occurs when the decline in pH is very slow as the model consequently predicts a negative temperature as happened for one carcase in this study. At 24 hours post-mortem, however, the pH had dropped below 6 in this carcase allowing estimates of temp@pH6 and temp@pH6linu.

The results of an analysis of the distribution of the measures based on being below or above 18°C are outlined in Table 2. Using the Chi-squared test statistic and testing for no association, it is concluded there was a significant level of association ($P < 0.001$) between temp@pH6 (exponential) and temp@pH6lin, with 48 of the 53 carcases allocated to the same class. The p-value for the test statistic here, and below, is obtained using Monte Carlo simulation. Using the same test statistic for temp@pH6 (exponential) and temp@pH6linu indicates no significant association ($P = 0.20$). For temp@pH6 (exponential) and pH@18degrees, with 50 carcases allocated to the same class, there was a significant level of association ($P < 0.001$). Overall 42 carcases were above 18°C when the pH was 6 or less based on temp@pH6 (exponential), 43 based on temp@pH6lin and 52 based on temp@pH6linu. For pH@18degrees there were 41 of the 53 carcases classified to be acceptable (e.g. with a pH below 6).

These results clearly indicate that a linear model based on the inclusion of $LL_{24}pH$ overestimates the number of carcases meeting the threshold for temperature at pH6 and for this reason is not recommended. Given that pH@18degrees has been shown as useful for explaining the variation in shear force as temp@pH6 based on 2 measurement points plus $LL_{24}pH$ when derived from a linear model [11], this measure is suggested a viable option to the determination of temp@pH6. Determination of pH@18degrees also does not rely on all values having a pH less than 6.

IV. CONCLUSION

For large scale measurement of lamb carcases to derive a predicted temperature at pH6 the use of 3 measurement time points during the onset of rigor is recommended. It is preferable if the third time point is when the temperature is less than 18°C. From such data either the temperature at pH 6 or the pH at 18°C can be derived.

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TABLE 1: Mean (±s.e.) and standard deviation (s.e.) for traits along with the number of measures per trait.

Trait	Mean ± s.e.	s.d.	Number
Temp@pH6 (exponential)	22.7 ± 0.81	5.93	53
Temp@pH6lin (linear, 3 data points)	22.9 ± 0.68	4.93	52
Temp@pH6linu (linear, 3 data points, plus LL_{24}pH)	23.7 ± 0.41	3.02	53
pH@18degrees	5.88 ± 0.02	0.16	53

TABLE 2: Distribution of measures according to temperature thresholds.

		Temp@pH6lin	
		Number > 18°C	**Number < 18°C**
Temp@pH6 (exponential)	**Number > 18°C**	**40**	**2**
	Number < 18°C	**3**	**8**
		Temp@pH6linu	
		Number > 18°C	**Number < 18°C**
Temp@pH6 (exponential)	**Number > 18°C**	**42**	**0**
	Number < 18°C	**10**	**1**
		pH@18degrees	
		Number > pH6	**Number < pH6**
Temp@pH6 (exponential)	**Number > 18°C**	**2**	**40**
	Number < 18°C	**10**	**1**