RATE OF PH DECLINE IN BOVINE MUSCLE POST-MORTEM – A BENCHMARKING STUDY.

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BACKGROUND

There is evidence that the post-mortem glycolytic rate in bovine muscle varies widely between and within slaughter groups (Kahn & Ballantyne, 1973). Electrical stimulation is used to control the rate of post-mortem glycolysis so that myofibre shortening is minimised and protease activity or ageing potential is maximised, thus producing more tender meat. However, despite the use of stimulation variation still exists resulting in meat quality problems associated with excessively fast or slow rates of pH decline. This means that within groups, carcases at the extremes of the distribution may be at risk of heat shortening or cold shortening. This variation within groups of carcases is poorly understood with a combination of animal, management and processing factors potentially impacting on pH fall. To minimise this variation, the impact of production traits on glycolytic rate needs to be quantified so that appropriate electrical inputs can be used during processing to match their potential. In an attempt to achieve this, a benchmarking study to quantify sources of variation in glycolytic rate under commercial conditions was carried out.

OBJECTIVES

To quantify the factors influencing the rate of pH decline in post-mortem bovine muscle and to examine the variability in rate of pH decline, both within and between different classes of cattle.

METHODS

Data collection: Over a 6 month period, data was collected from a commercial abattoir in Southern Queensland, Australia. During each visit, 6 to 12 groups of approximately 15 to 20 head of cattle were selected based on availability, pre-slaughter background and origin. Body number, slaughter time and electrical inputs were recorded on the kill floor following slaughter. All carcases received electrical inputs during immobilisation and from the rigidity probe during hide removal. As the operation of these inputs was not automated, the electrical inputs could have varied between animals. Low voltage electrical stimulation was also applied to some groups of cattle, namely pasture-fed animals (≈ 10 secs) and all vealers, regardless of finishing regime (≈ 25 secs). Grain-fed animals were not stimulated.

Upon entry to the chiller, (ca. 40 mins post-mortem), a small area of subcutaneous fat was removed from each carcase to expose the *m. longissimus dorsi* (LD) at the 10th/11th rib quartering site (beef) or the 12th/13th rib quartering site (veal). pH and temperature values for the LD were recorded on all carcases every hour for 7 to 12 hours post-mortem using a TPS pH meter with an Ionode glass probe. Two tissue samples for laboratory analysis of ultimate pH and muscle glycogen and lactate concentrations were collected from the LD approximately 7 hours post-mortem. The pH tissue samples were kept chilled to allow ultimate pH to be reached. The glycogen samples were frozen immediately (-20°C). Frozen samples were assayed for glycogen and lactate concentrations according to the enzymatic methods of Kunst *et al* (1983) and Marbach and Weil (1967).

The following pre-slaughter details were recorded for all groups: vendor, age, sex, breed, type and plane of nutrition, days on grain finishing where applicable, curfew type and length, consignment type, method of transport, weather conditions during transit and lairage, distance travelled, number of times unloaded during transit, time in transit, lairage conditions at abattoir and temperament, both on farm and at the abattoir.

Analysis: Prior to analysis, all pH readings were adjusted to 10°C using the function described by Briskey & Wismer-Pedersen (1961):

$$pH_{adjusted} = pH_{unadjusted} + (Temp_{actual} - 10) * 0.01$$

pH/temperature data was analysed as 2 relationships; pH as a function of time post-mortem and pH as a function of muscle temperature. pH as a function of time was described by predicting pH at 1.5 hours post-mortem for each animal, as this is the time of greatest variation in pH/time curves. pH as a function of temperature was described by predicting muscle temperature when pH 6, the assumed point of rigor, was reached. Both pH at 1.5 hours post-mortem and temperature at pH 6 were predicted using the exponential function described by Bruce *et al* (2001):

$$y_t = a_u + (a_i - a_u)e^{-akt}$$

where y_t is pH, or temperature, as a function of time, a_u is ultimate pH, or temperature, a_i is initial pH, or temperature, a_k is the rate of pH or temperature fall and t is time, which was fitted to the data using PROC NLIN in SAS.

Animals within the non-stimulated (domestic grain-fed) or stimulated (domestic pasture-fed and veal) groups were analysed separately. The effect of pre- and post-slaughter factors on pH at 1.5 hours post-mortem and temperature at pH 6 were analysed using a mixed model which contained fixed effects for vendor and dentition, covariates for slaughter data (pHu, carcase weight and P8 fat depth) and muscle glycogen level (as linear and curvilinear effects) and a random animal term.

RESULTS AND DISCUSSIONS

A total of 73 groups (1083 animals) were monitored during the benchmarking study. The average group mean pH at 1.5 hours post-mortem was 6.2 with a variance of 0.2. The average group mean temperature, at which pH 6 was reached, was 28.4°C with a standard deviation of 4.5°C. Overall, the pH/temperature fall of the carcases was close to the optimal range of 29°C to 30°C at pH 6 as described by Hwang & Thompson (2001), however the values demonstrated substantial variance between groups. There was also considerable variation within groups of cattle with an average within group standard deviation, for pH at 1.5 hours and temperature at pH 6, of 0.1 and 4.3°C respectively.

pH as a function of time: The relationship between pH decline and time was assessed as pH at 1.5 hours post-mortem, within stimulation treatments. In the non-stimulated group, carcase weight ($P<0.05$) was significant and there was a trend for a curvilinear relationship for glycogen concentration ($P=0.0701$) to affect pH at 1.5 hours. Increased carcase weight resulted in an increase in pH at 1.5 hours. Within the

stimulated group, the curvilinear terms for glycogen were significant (P<0.05) along with a trend (P = 0.0586) for ultimate pH to influence pH at 1.5 hours. Carcases which had a higher ultimate pH also had a higher pH at 1.5 hours. Overall it was evident that pH at 1.5 hours in both stimulated and non-stimulated groups was related to glycogen concentration in the muscle, but was not affected by vendor. The relationship between pH at 1.5 hours and muscle glycogen concentration was a decreasing curvilinear function.

A number of factors impacted on the variance in pH at 1.5 hours with significant results for both total distance travelled to slaughter (P<0.05) and curfew length (P<0.05). Variance in pH at 1.5 hours decreased with greater distance travelled in contrast to longer curfew times, which caused an increase in variance. Nutrition type was also significant (P<0.05) with milk fed veal having the lowest variance (SD = 0.09), followed by grain and mixed nutrition (SD = 0.13), with pasture-fed domestic cattle having the highest variance (SD =0.20). This may be associated with the more variable production systems from which pasture-fed cattle are sourced.

Temperature at pH 6: There was no effect of vendor on temperature at pH 6 in either the stimulated or non-stimulated treatments, even when partitioned into consignment type, nutrition type, distance travelled and curfew time. In the non-stimulated group, P8 fat (P<0.05) and curvilinear terms for muscle glycogen concentration (P<0.05) were significant, with the fatter carcases tending to have a higher temperature at pH 6. Glycogen concentration (P<0.05) was also significant in the stimulated animals, but as they were generally leaner (i.e. pasture-fed and veal) the effect of P8 fat on temperature at pH 6 was not evident. Again it was apparent that the level of glycogen within the muscles was the major factor influencing the muscle temperature at pH 6 (Fig. 1), regardless of electrical inputs or vendor. This supports the theory that the size of the glycogen depot, and therefore substrate availability, may be a factor determining glycolytic rate.

Consignment type (P<0.05) had a significant effect on variance in temperature at pH 6 with direct consignment groups having approximately half the variance of saleyard groups (SD = 2.8°C vs 5.0°C, respectively). In addition there was a trend (P=0.06) for total distance travelled to have an effect, with longer distances resulting in a lower variation in temperature at rigor.

CONCLUSIONS

Results of this benchmarking study showed that post-mortem glycolytic rate in the carcase was a function of glycogen concentration within the muscles. The primary implication of this relationship between muscle glycogen levels and rate of pH fall is that greater electrical stimulation would be required by carcases with low glycogen concentrations in order to achieve optimum rates of post-mortem glycolysis and in turn reach pH 6 at an optimum temperature. In contrast, those carcases with higher glycogen levels would require less stimulation. This study also showed that production traits, nutrition type, consignment type, curfew type and total distance travelled to slaughter, influence the amount of variation in post-mortem glycolytic rate, evident within a group of carcases.

PERTINENT LITERATURE

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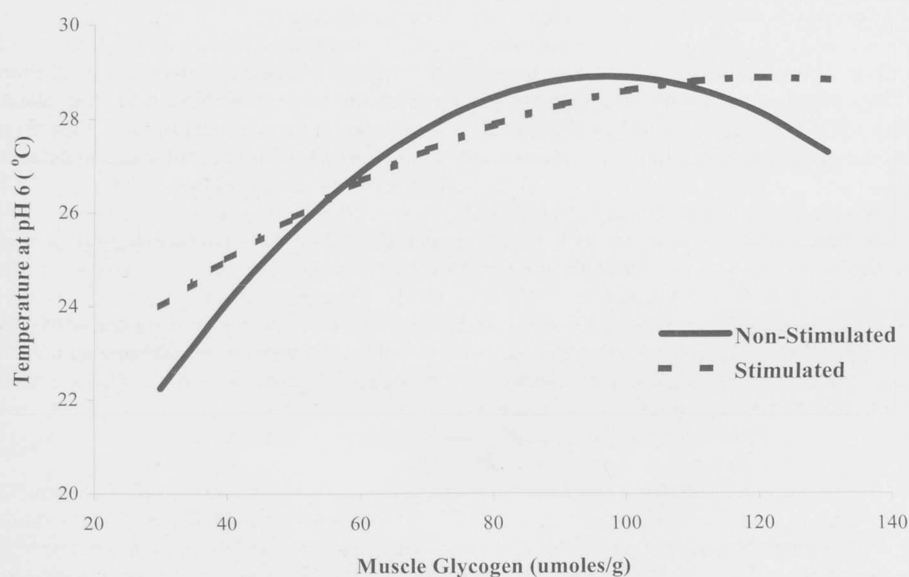

Figure 1. The relationship between muscle glycogen level (μmoles/g) and temperature at pH 6 (°C).