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The impact of beef cattle temperament assessed using flight speed on muscle glycogen, muscle lactate and plasma lactate concentrations at slaughter

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ABSTRACT

This study evaluated the effect of animal temperament measured using flight speed (FS) on plasma lactate, muscle glycogen and lactate concentrations at slaughter plus ultimate pH in 648 lot finished cattle of mixed breed and sex. Muscle samples were collected at slaughter from the *m. semimembranosus*, *m. semitendinosus* and *m. longissimus thoracis* (LT) for analysis of glycogen and lactate concentration. Blood was collected after exsanguination and analysed for plasma lactate concentration and ultimate pH of the LT was measured. FS had no effect on muscle glycogen concentration in any muscle or ultimate pH of the LT ($P > 0.05$). As FS increased from 1 to 5 m/s, plasma and muscle lactate concentration increased by 54% and 11.4% ($P < 0.01$). The mechanisms through which temperament contributes to variation in glycogen metabolism remain unclear. The risk of dark cutting was not impacted by temperament, indicating that other production and genetic factors have a greater impact on the incidence of dark cutting.

1. Introduction

Dark cutting beef is one of the most prominent meat quality issues worldwide. Dark cutting beef has a reduced shelf life, bland flavour, and variable levels of tenderness, rendering it unacceptable for retailers, food service and consumers alike (Ferguson et al., 2001). These negative impacts on meat quality have led to its exclusion from the Meat Standards Australia (MSA) grading system (Grunert, Bredahl, & Brunsø, 2004; Thompson, 2002; Watson, Polkinghorne, & Thompson, 2008).

Dark cutting beef is defined by MSA as any muscle tissue with an ultimate pH greater than 5.7 (Thompson, 2002) or an AUSmeat meat colour greater than 3 (AUS-MEAT, 2005; Watson et al., 2008). The major determinant of ultimate pH is the concentration of muscle glycogen at slaughter, which in the anaerobic conditions of the muscle post-mortem, is metabolised through glycolysis to form lactate. The formation of lactate and the production of hydrogen ions lower the intracellular pH of the muscle from a pH of around 7, which is standard in a living animal (Tarrant, 1989), down to a pH_u of around 5.4 to 5.7 during the first 24 to 48 h post-mortem (Maltin, Balcerzak, Tilley, & Delday, 2003). However, if there is insufficient muscle glycogen concentration at slaughter, there will only be limited formation of lactate post-mortem, and thus a pH_u of less than 5.7 will not be reached and dark cutting will result.

Muscle glycogen concentration at slaughter is a function of glycogen synthesised 'on-farm' through nutrition, minus the glycogen mobilised for muscle energy during the pre-slaughter period in response to stress or muscle contraction (McGilchrist, Alston, Gardner, Thomson, & Pethick, 2012). One factor which may impact both glycogen synthesis and mobilisation is temperament, a notion supported by Voisinet, Grandin, O'Connor, Tatum, and Deesing (1997). Cattle with flighty temperaments have been shown to have consistently lower feed intakes and growth rates relative to calm cattle (Busby, 2010; Cafe et al., 2011; Fell, Colditz, Walker, & Watson, 1999; Petherick, Holroyd, Doogan, & Venus, 2002; Vann, Parish, & McKinley, 2008; Voisinet, Grandin, Tatum, O'Connor, & Struthers, 1997). This indicates that flighty cattle may have a reduction in substrate available for glycogen synthesis, lowering their muscle glycogen concentrations prior to the pre-slaughter period.

In addition, it is well established that flighty cattle have higher basal concentrations of catecholamines and cortisol than calm cattle (Burdick, Carroll, Hulbert, Dailey, Willard, et al., 2010; Curley, 2004; Vann, Burdick, Lyons, Welsh, & Randel, 2010). Catecholamines and cortisol are released in the event of stress and directly stimulate glycogen mobilisation. Furthermore, muscle contractions also stimulate glycogen mobilisation, and as cattle with 'excitable' or 'flighty' temperaments are more active than cattle with 'calm' temperaments during routine handling practices (Grandin, 1993) it is reasonable to expect that 'flighty'

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cattle will have increased muscle contractions during the pre-slaughter period and a greater mobilisation of glycogen during this period, thus less muscle glycogen at slaughter. Given the likely increase in stimulation of the catecholamine, cortisol and contraction linked mechanisms of glycogen mobilisation in flighty cattle, it can be assumed that they will also have elevated levels of muscle and plasma lactate, as lactate is the end product of mobilised glycogen under anaerobic conditions. Therefore, the combination of these factors is likely to result in reduced muscle glycogen at slaughter and a higher incidence of dark cutting in flighty cattle. However no study to date has measured the effect of temperament on glycogen concentration within muscle which maybe a more sensitive measure of potential risk to dark cutting.

This study aims to identify whether a relationship exists between cattle temperament measured using flight speed and muscle glycogen concentration. We hypothesise that cattle with flighty temperaments and high flight speeds will have higher muscle and plasma lactate concentrations, higher ultimate pH and lower muscle glycogen concentrations at slaughter.

2. Material and methods

2.1. Animals

Data were collected on cattle at two sites in Western Australia. Cattle at site A comprised of 547 feedlot steers (n = 313) and heifers (n = 234) of both *Bos taurus* (Angus, Murray Grey, Limousin, Charolais and Simmental) and *Bos indicus* (Brahman, Santa Gertrudis, Droughtmaster) descent. Cattle were sourced from sale yards and direct from producers. Cattle at site A ranged in age from 9 months (weaning age) to 18 months at the time of induction into the feedlot. The source of each herd was recorded as the 'origin' of the cattle. At site A, the cattle came from 10 different origins, and there were between 1 and 4 breeds of cattle from each origin. Cattle were inducted into the commercial feedlot over a period of three months and were assigned to 'lots' in the feedlot according to their origin and/or weight at induction. Cattle from each origin were of similar age. Lots were formed by cattle from 1 or more origins. Lots were A1 to A8 for the cattle from site A. Upon induction into the feedlot, live weight (kg) and hip height (cm) measurements were recorded. All cattle were introduced to grain feeding using a 'step up' ration program where energy levels in the diet were increased over a 21 day period, after which time they were placed on the finisher ration. The finisher ration contained 12.6 MJ/kg dry matter of metabolisable energy and 11% crude protein on a dry matter basis and had a digestibility of 82.8%. Cattle were harvested based on liveweight (minimum 420 kg) after a minimum of 70 days in the feedlot, targeting a carcass weight of 220 to 320 kg.

Cattle at site B consisted of Angus steers (n = 101) which were inducted on a single date. Cattle were penned in groups of 10 or 11 and were not mixed with other cattle between induction and slaughter. These cattle were assigned to a single lot for analysis called B1. Live weight and hip height measurements were recorded monthly over the period of feeding. These cattle were also introduced to grain feeding using a 'step up' ration programme, with the finisher ration containing 10.6 MJ/kg dry matter of metabolisable energy and 19% crude protein on a dry matter basis and a digestibility of 73.2%. Cattle were harvested after 111 days on feed, when the average weight was 450 kg.

Cattle at site A were selected for slaughter 0 to 48 h before departure from the feedlot, and cattle from different lots were transported in separate pens on the trucks to fill a consignment of cattle which met market specifications. Cattle were sent for slaughter on a weekly basis to either processor 'H' or processor 'W' which were 2 commercial export licensed processing plants. Each consignment was referenced as a 'slaughter group' (H1 to H10 and W1 to W3), to identify cattle by the date and location of slaughter.

The use of cattle at site A was approved by the Murdoch University Animal Ethics Committee (Permit No. O2391/11). The use of cattle at site B was approved by the Department of Agriculture and Food Western Australia Animal Research Committee (Permit No. 6-10-44).

2.2. Temperament assessment

Temperament was assessed using flight speed (FS) (Burrow, Seifert, & Corbet, 1988). FS measures the speed at which cattle exit the crush, with high flight speeds indicative of poor or 'flighty' temperaments (Burrow & Corbet, 2000). At site A, FS measurement was taken during induction into the feedlot on all cattle and 46% of cattle at site A had FS measured again 3 weeks later when the cattle were re-weighed for assessment of performance. For the 46% of cattle with 2 FS measurements, average FS of cattle at Site A was calculated for each animal. At site B, FS measurements were taken once at weaning time (7 months) and twice at the beginning of their time in the feedlot (9 months of age). Average FS for cattle at site B was the average of the 3 FS measurements.

Burrow and Corbet (2000) stated that the use of an average flight speed score substantially increased heritability of the trait (0.50) when compared with the use of a single flight speed score, which is why an average was used for all cattle at site B and 46% of cattle at site A. Burrow and Corbet (2000) also noted that the heritability of single flight speed scores was in the moderate range (0.29 to 0.39), with heritability decreasing with age from weaning to 18 months of age, which is why at site A, FS was recorded at the time of induction. Cafe et al. (2011) state that the correlations between 8 different FS measures were moderate to high and all were significant in Brahman cattle and 90% of correlations were significant in Angus cattle when measured at the same location, which is the case with cattle at sites A and B for this experiment.

Cattle were individually confined in a weighing chute before being released. Upon release from the weighing chute the cattle entered into a wide straight race and flight speed was measured over a distance of 1.7 to 2.2 m at both sites using dual laser beams. The time required to travel the measured distance was divided by the distance to calculate FS in meters per second (m/s) for analyses.

2.3. Plasma and muscle sampling

At slaughter, muscle samples from the *m. semimembranosus* (SM) and *m. semitendinosus* (ST) were taken on the slaughter floor immediately after the hide was peeled back from the hind leg (~10 min post-slaughter), while the *m. longissimus thoracis* (LT) sample was taken after the carcasses had been split and was entering the chiller (~60 min post-slaughter). The sample of LT was obtained from the superficial (dorsal) region of the muscle, adjacent and caudal to the 12th rib. Samples of SM and ST were obtained from dorsal, proximal regions of each muscle. Immediately after each sample was taken, visible fat was removed and samples were frozen in liquid nitrogen and later stored at −20 °C for glycogen and lactate analysis.

Blood samples were collected from 275 head only. Blood was collected post-slaughter after exsanguination using K_3 EDTA vacutainers™ (Becton Dickinson, Franklin Lakes, NJ, Cat. No. 366457). Blood was collected from slaughter groups H6, H7, H8, H9 and H11. The blood tubes were placed on ice, centrifuged at 3000 ×*g* for 15 min at 5 °C and the harvested plasma was frozen at −20 °C for later laboratory determination of lactate.

2.4. Ultimate pH measurement

Ultimate pH is measured in the rib eye muscle (*longissimus thoracis*) of the chilled carcass at the quartering site approximately 20 h post-mortem. The ultimate pH of all cattle slaughtered at processing plant H was measured. Temperature and pH were measured using a Meat Standards Australia approved TPS MC-80 or TPS WP-80M pH meter (TPS Pty Ltd., Springwood, Brisbane, QLD 4127, Australia). pH and temperature probes were calibrated to pH 4 and 7 at 25 °C. The probes were