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The use of blood lactate concentration as an indicator of temperament and its impact on growth rate and tenderness of steaks from Simmental - Angus steers

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Abstract

The objective of this study was to evaluate the use of blood lactate concentration as an objective measure of beef cattle temperament and determine if the temperament of steers affected growth rate and tenderness of beef steaks. Angus × Simmental steers (n = 154) were evaluated for blood lactate (BL), exit velocity (EV) and chute score (CS), and humanely harvested. Carcass characteristics were assessed and loin samples were ob-tained for tenderness evaluation. All measures of the temperament were significantly correlated to each other (r = 0.14–0.47; P ≤ 0.04). Steaks from steers in the medium BL classification were significantly more tender than steaks from steers from the high BL classification. The steers with faster EV tended to result in steaks with higher shear force values (P = 0.07). The steers classified as fast growing resulted in steaks with lower shear force values (P = 0.02) compared to steaks from steers classified as slow growing. Results suggest that the temperament contributes to variations in growth rate, blood lactate, and tenderness.

1. Introduction

Variation in meat quality and tenderness is a challenge for the meat industry (Shook et al., 2008). Contributing to this variation is changes in rate of postmortem pH decline and extent of pH decline postmortem which affects tenderness and quality of meat (O'Halloran, Troy, & Buckley, 1997). Postmortem pH decline is influenced by numerous factors including temperature, genetics and anti-mortem stress. Apple et al. (1995) reported increased consumption of glycogen by muscle and altered pH decline postmortem in response to restraint of sheep. Neuroendocrine response to stress activates the hypothalamic–pituitary-axis (HPA) which results in secretion of steroid hormones from the adrenal gland (Matteri, Carroll, & Dyer, 2000) that increases the mobilization of energy by increased glycogenolysis, glycolysis, and proteolysis (Harvey, Phillips, Rees, & Hall, 1984). This response is similar to the response seen in exercise and leads to increased heart rate, respiration and to more anaerobic metabolic processes in the muscle and, subsequently, excessive lactate in the blood, similar to increased blood lactate reported in response to exercise in cattle (Holmes, Ashmore, & Robinson, 1972). Holmes et al. (1972) reported that heifers with excitable temperament had a greater increase in blood lactate concentration during exercise than heifers of calmer dispositions. Livestock that are more agitated when handled or have a more volatile temperament may result in chronic HPA activation causing metabolism to switch to anaerobic pathways more quickly especially during handling where there is movement (exercise) from a pen to handling facilities and thus resulting in more transport of lactate from the muscle into the blood.

Many researchers have developed simple methodologies to evaluate the temperament in an effort to measure stress response to handling on farm. Curley, Paschal, Welsh, and Randel (2006) reported that blood cortisol levels were related to how fast an animal left the handling chute. This suggested that the use of exit velocity was a viable tool to evaluate stress during livestock handling. Furthermore, Cafe et al. (2011) evaluated persistent assessments of temperament on productivity, carcass characteristics and meat quality traits (color and tenderness). They found that cattle with more excitable temperaments, as measured by exit velocities and chute speeds, had consistently lower feed intake and slower growth rates, resulting in smaller carcasses with less fat cover, darker longissimus lumborum muscle (LLM) color and increased muscle pH. Other researchers also reported decreased growth rates (average daily gain) in animals with more excitable temperaments (Behrends et al., 2009; Voisinet, Grandin, O'Connor, Tatum, & Deesing, 1997). Along with decreased growth rates, researchers reported that meat from animals possessing a more excitable temperament had higher shear force values (Cafe et al., 2011; King et al., 2006; Voisinet et al., 1997) and were more likely to produce carcasses that were borderline dark cutters (Voisinet et al., 1997). This relationship was seen to be stronger in *Bos indicus* (Brahman based cattle) breeds than *Bos taurus* breeds (Cafe et al., 2011; Voisinet et al., 1997). King et al. (2006) also reported a relationship between temperament and tenderness, speculating the effect on tenderness was mediated through reduced postmortem proteolysis. This was not, however, explained by a difference in calpastatin activity. This suggests that another mechanism is influencing the tenderness of the meat including the potential impact of animal temperament. The link between temperament and changes in growth rate and meat quality suggests a need for an objective and reliable, method to measure the temperament to help select animals with calmer temperaments. This will minimize predisposition to excitability and poor meat quality.

In lieu of various criteria subjectively used today (i.e. chute scores), an objective biomarker could enhance the potential for selecting animals with calmer temperaments. Edwards et al. (2010) used hand-held blood lactate meters to determine the concentration of lactate in blood at exsanguination. These researchers found that pre-slaughter handling of pigs resulted in elevated concentrations of lactate in the blood at exsanguination. Burfeind and Heuwiese (2012) showed that lactate concentrations measured with the small hand-held lactate meters were not different from lactate measured from serum in the laboratory for cattle. Therefore, the objective of this study was to determine if blood lactate concentration be used as an objective measurement of the temperament and if the temperament affected growth rate and tenderness of beef steaks.

2. Materials and methods

Data was collected in compliance with Montana State University Agriculture Animal Care and Use Committee under the Animal Care approval number 2013-AA02. One hundred and fifty four Simmental × Angus calves were evaluated for temperament using traditional chute scores (Table 1), blood lactate concentrations, and chute exit velocities at four time periods. All the steers were born at the same ranch and were part of the American Simmental Association's Carcass Merit Program (Simmental × Angus steer calves). The steers received the same feed, environment, and handling throughout their lifespan in an attempt to eliminate confounding variables. Initial temperament and weight measurements were made on the ranch at weaning (Time 1) with the second measurement occurring 2 weeks later when vaccine boosters were administered (Time 2). After vaccine boosters were administered, the steers were transported to the Chappell Feedlot in Chappell, NE. The steers were allowed a 7 day acclimation period and then processed into the feedlot where temperament measurements were conducted (Time 3). The final temperament measurement was completed 3 days after ultrasound was performed to determine harvest days for steers (USDA Choice endpoint, mid-way through feed lot, Time 4).

Table 1
Docility score (Chute score) descriptions.[a]

Chute score	Definition and interpretation
Score 1	Docile, mild disposition, gentle and easily handled. Stands and moves slowly during processing. Undisturbed, settled, somewhat dull. Does not pull on head gate when in chute. Exits chute calmly.
Score 2	Restless. Quieter than average, but may be stubborn during processing. May try to back out of chute or pull back on head gate. Some flicking of tail. Exits chute promptly.
Score 3	Nervous. Typical temperament is manageable, but nervous and impatient. A moderate amount of struggling, movement and tail flicking. Repeated pushing and pulling on head gate. Exits chute briskly.
Score 4	Flighty (wild). Jumpy and out of control, quivers and struggles violently. May bellow and froth at the mouth. Continuous tail flicking. Defecates and urinates during processing. Frantically runs fence line and may jump when penned individually. Exhibits long flight distance and exits chute wildly.
Score 5	Aggressive. May be similar to score 4, but with added aggressive behavior, fearfulness, extreme agitation, and continuous movement which may include jumping and bellowing while in chute. Exits chute frantically and may exhibit attack behavior when handled alone.
Score 6	Very aggressive. Extremely aggressive temperament. Thrashes about or attacks wildly when confined in small, tight places. Pronounced attack behavior.

[a] Beef Improvement Federation http://www.bifconference.com/bif2012/proceedings-pdf/05Randel.pdf.

Following a thirty-day step-up period in the feedlot, the steers were fed a 94% concentrate ration consisting of rolled corn, beet pulp, dried distillers grains, protein supplement, corn silage, and ground hay (dry matter basis: 14.58% CP and 0.61 Mcal/lb net energy for gain). During this stage, the steers were implanted with Component TE-S (120 mg of trenbolone acetate, 24 mg of estradiol ESP and 29 mg of tylosin tartrate). Average daily gains (ADG) were calculated using adjusted 205 day weaning weights (weaning weight − birth weight/days of age × 205) and weight at mid-way through the finishing phase or Time 4 (Time 4 weight − adjusted 205 adjusted weaning weight)/ 140 days in feedlot).

Blood lactate concentrations (mmol/L) were determined using a blood lactate analyzer (Lactate Pro, Arkray Inc., Minami-Ku, Kyoto, Japan) using test strips requiring 5–25 μL of blood. Burfeind and Heuwiese, 2012 indicated that hand-held blood lactate meters were consistent with bench top concentrations. The steers were caught in a head gate as they were processed through the chute to be either weighed or vaccinated. A 16 gauge needle was used to pierce the ear vein on the back of the ear to obtain a drop of blood that was placed on the lactate test strip, and analyzed in 60 s with the Lactate Pro meter. Following the determination of blood lactate and body weight, animals were allowed to leave the chute and the exit velocities were obtained with a FarmTek infrared timer system (FarmTek, Inc., Wylie, TX). The initial infrared photocell was placed 1.824 m in front of the chute, perpendicular to the path of the animals and the final timer was placed 1.824 m beyond the initial photocell, 3.648 m in front of the chute. The exit speed was recorded and the velocity was calculated (meters per second) for statistical analysis (Curley et al., 2006). The chute scores, ranging from 1 to 6, were assigned by a single individual at all handling times (Table 1) while in the chute prior to the chute exit.

The steers were transported for harvest when the ultrasound predicted that they would grade USDA Choice. The steers were transported from Chappell, NE to Fort Morgan, CO. The steers selected for further tenderness research were all harvested on the same day in a federally inspected harvest facility. Carcass data (carcass weight, ribeye area (REA), 12th rib back fat thickness, internal fat percentage (KPH), intramuscular fat score (marbling) for USDA quality grade) were collected on all 154 steers using a USDA assisted camera grading system. A subsample of 15 steers with a low average daily gain (ADG, 0.86–1.28 kg/day) and a subsample of 15 steers with high average daily gain (ADG, 1.75–1.89 kg/day) were chosen and strip loins collected from each carcass from the designated steers. The loin samples were collected 36 h after slaughter from the carcasses, and transported to Montana State University (4 °C), where loins were cut into steaks and the steaks aged for 3, 7, 14, and 21 days postmortem, prior to being frozen. Following aging, the samples were frozen for further analyses to evaluate shear force tenderness, myofibrillar fragmentation index, and protein degradation using SDS-PAGE (data not shown for protein degradation).

2.1. Shear force

Shear force was determined following the procedures of Boles, Boss, Neary, Davis, and Tess (2009). Briefly, steaks were thawed at 4 °C for 24 h, weighed and two copper constantan thermocouple (Omega Engineering, Stamford, CT) were inserted into the geometric center of each steak and placed under (10 cm from element) an electric broiler and cooked to a final internal temperature of 70 °C turning when the samples reached 35 °C. Five to eight samples (1.27 × 1.27 × 2.54 cm) from each steak were sheared perpendicular to the fiber direction with a TMS 30 Food Texturometer (Food Technology Corp., Rockville, MD) fitted with a Warner–Bratzler shear attachment. The maximum shear force of cores from each steak was averaged for statistical analysis.

2.2. Myofibril fragmentation index

Myofibril fragmentation index was determined following the procedures reported by Culler, Parrish, Smith, and Cross (1978), as modified by Hopkins, Littlefield, and Thompson (2000). Two samples per steer, coupled with duplicate samples, yielded four measurements per steer. The average of the MFI (myofibrillar fragmentation index) for each sample was calculated, and the average was used for statistical analyses.

2.3. Statistical analyses

The experimental units were the individual steers. Growth and carcass data were collected on each individual steer harvested with analyses conducted on the original 154 steers. Tenderness data were obtained from the loins of thirty subsampled steers. The General Linear Model of SAS Statistical Software (SAS, Cary, NC) was used to analyze differences in growth and carcass data, where the independent variables were the individual animals, growth rate, chute score, exit velocity, and blood lactate concentration classifications of each animal. The dependent variables were average daily gain and carcass characteristics. To identify the growth, exit velocity, and blood lactate classifications, means and standard deviations were calculated using 154 animals for all temperament measurements. The means plus one standard deviation were designated "high" growth ($n = 19$), "fast" speed ($n = 23$) or "high" blood lactate ($n = 29$), and the mean minus one standard deviation represented "low" growth ($n = 25$), "slow" speed ($n = 23$) or "low" blood lactate ($n = 21$). The remainder were designated as medium for the classification (growth, $n = 107$; speed, $n = 108$; blood lactate, $n = 104$). The GLM procedure of SAS was also used to analyze tenderness data (MFI and shear force). The classifications described above were used along with days aged as the independent or class variables, and dependent variables were shear force and MFI values. Interactions between days of aging and growth, speed and lactate classification were also tested. LSMEANS procedures were employed due to unequal number of observations upon which to compare differences between variables. Dunnett's tests were used to separate the means because of the unbalanced representation of the temperament and growth classification variables. Pearson product–moment correlations were calculated on all data. Statistical significance was determined a priori at the ≥ 0.05 level. A trend was considered when the P-value was greater than 0.05 but less than 0.1.

3. Results and discussion

3.1. Relationship between different temperament variables

As shown in Table 2, average chute scores and exit velocities indicated that the animals tended to be restless to nervous when handled. Very few were wild with only one animal evaluated as being aggressive at one evaluation period. Chute scores did not seem to change over time. Cafe et al. (2011), however, observed a slight reduction (1.6–1.4) in average crush score of Angus steers as the number of handling experiences increased.

The exit velocities reported here were slightly lower than those reported by Behrends et al. (2009) and the chute scores and exit velocity reported here are similar to the numbers reported by Cafe et al. (2011) for the Brahman cattle. These researchers also indicated that the *Bos taurus* steers had consistently slower exit speeds than the *Bos indicus* steers. The exit velocities reported here were reduced as the number of handling times increased, indicating a possible "learning" effect or increased comfort with the process (Table 2). Cafe et al. (2011) also indicated that the general response of the cattle to handling as measured by flight speed declined over the duration of their experiment.

Table 2
Simple means of temperament measurements and growth data.

Variable	N	Mean	Maximum	Minimum	Std dev
Chute score					
Time 1	154	2.44	4.00	1.00	0.88
Time 2	153	2.58	5.00	1.00	0.81
Time 3	153	2.25	4.00	1.00	0.85
Time 4	154	2.65	4.00	1.00	0.64
CSAVG[a]	154	2.48	3.75	1.25	0.51
Exit Velocity					
Time 1	120	3.24	5.36	0.94	0.86
Time 2	142	3.33	6.42	0.97	0.98
Time 3	152	2.80	7.17	0.66	1.06
Time 4	153	2.30	4.93	0.24	0.87
EVAVG[a]	154	2.88	4.99	1.04	0.77
Blood Lactate					
Time 1	125	2.61	7.8	0.80	1.51
Time 2	152	3.06	9.1	0.80	1.63
Time 3	154	2.92	11.30	0.80	1.73
Time 4	154	2.59	10.20	0.80	1.76
BLAVG[a]	154	2.81	7.72	1.00	1.09
ADG [b]	151	1.55	2.0	0.90	0.21

[a] Average blood lactate (BLAVG), average exit velocity (EVAVG), and average chute score (CSAVG) are the average of the four measurements taken at weaning, re-vaccination, feedlot entrance, and midway feedlot.
[b] Average daily gain = (mid-way feedlot weight − adjusted 205 weaning weight)/140 days.

However, Burdick et al. (2011) reported an increase in exit velocity as the days of age increased in Brahman calves from 21 days of age through 56 days postweaning and that the more "temperamental" calves had a larger increase in exit velocity over the time measured. The differences seen between the experiments could indicate that the exit velocity response to handling plateaus at a certain age and does not vary much beyond a specific age and the animals evaluated by Cafe et al. (2011) and here had reached the plateau so the increase was not as great.

The blood lactate concentration ranged from below detectable limits (0.8 mmol/L) to 11.3 mmol/L. The average blood lactate concentration suggested the majority of the animals when handled had blood lactate concentrations between 2.5 mmol/L and 3.0 mmol/L (Table 2). The mean blood lactate concentration was higher than the values reported by Burfeind and Heuwiese (2012) when evaluating the blood lactate concentration in dairy cows (0.5–2.0 mmol/L). However, many maximal values we obtained were much higher than those reported by Holmes et al. (1972) indicating that normal beef heifers had blood lactate concentrations averaging 3.14 mmol/L in response to exercise. This confirms that there are times that animals have transient high levels of blood lactate during handling.

Even though our chute scores were based on the 1–6 Beef Improvement Federation chute score system (Table 1), our maximum score for all animals except one was only 4 with only one animal at one time period exhibiting aggressive behavior. Although this scoring system is used by various breed associations to calculate estimated progeny differences between animals, the lack of variation within our sample raises the question of whether or not the chute scores are a valid measurement of the temperament. Curley et al. (2006) also suggested that subjective scores like the chute score were not as good at predicting the temperament as exit velocity. Our results indicate that exit velocity and lactate measurements may be better predictive measures of the temperament.

Simple correlation coefficients between the chute score (CS), exit velocity (EV), blood lactate concentration and ADG at the four handling times are displayed in Table 3. The correlations between the temperament measurements and blood lactate concentration were low (EV $r- = 0.26 - 0.31$; CS $r = 0.14 - 0.31$) but significant ($P \leq 0.0014$) at all the measurement times. However, the relationship between the

Table 3
Simple correlation coefficients (P-value) between chute scores, exit velocity and blood lactate concentrations measured at four times and average daily gain (ADG) over the period between weaning and mid feedlot measurement.

	Chute score	Exit velocity	Lactate	ADG
Time 1				
Chute score	1.0			
Exit velocity	0.47 (<0.0001)	1.0		
Blood lactate	0.32 (0.0002)	0.31 (0.0007)	1.0	
ADG[a]	−0.06 (0.43)	−0.1 (0.88)	−0.11 (0.21)	1.0
Time 2				
Chute score	1.0			
Exit velocity	0.31 (0.0002)	1.0		
Blood lactate	0.14 (0.08)	0.27 (0.001)	1.0	
ADG[a]	−0.002 (0.97)	−0.03 (0.73)	−0.04 (0.63)	1.0
Time 3				
Chute score	1.0			
Exit velocity	0.65 (<0.0001)	1.0		
Blood lactate	0.17 (0.04)	0.26 (0.0014)	1.0	
ADG[a]	0.04 (0.63)	0.08 (0.35)	−0.04 (0.62)	1.0
Time 4				
Chute score	1.0			
Exit velocity	0.05 (0.50)	1.0		
Blood lactate	0.15 (0.05)	0.26 (0.0014)	1.0	
ADG[a]	−0.04 (0.63)	0.04 (0.60)	−0.15 (0.06)	1.0

[a] ADG = (mid-way feedlot weight − 205 day weaning weight)/140 days.

two objective measurements, blood lactate concentration and exit velocity was stronger at each time period and did not seem to be affected as much by the number of times handled. The correlation coefficients between the exit velocity and chute score reported here for the measurements made at time 1 and time 2 are similar to those reported by Cafe et al. (2011). The correlations between average daily gain and measurements of the temperament or blood lactate concentration were not significant at any of the times measured. This disagrees with information reported by other researchers (Behrends et al., 2009; Cafe et al., 2011; Voisinet et al., 1997) who all reported a reduction in average daily gain with more excitable animals (increased chute score or increased exit velocity). The correlation coefficients between the blood lactate concentration and chute score were low (0.15–0.32) but significant ($P = 0.0002 - 0.05$, except at time 2 $P = 0.08$) and the relationship between the chute score and blood lactate concentration was highest the first time the animals were handled ($r = 0.32$) and was less the more times animals went through the handling process ($r = 0.14$, 0.17 or 0.15) (Table 3). Cafe et al. (2011) also observed a reduction in the strength of the relationship between the exit speed and chute scores with multiple measurements. This suggests two different avenues of interpretation. One would be that increased exposure to handling made the animal more comfortable with the environment resulting in less stress response. The second option is that the steers learn to fight the head chute less resulting in lower subjective scores that are not sensitive enough to reveal the anaerobic stress and concomitant increase in lactic acid production the animal is actually experiencing. The latter option is supported by the correlation between the chute scores and lactate levels being lower than the correlation between the chute score and exit velocity at all times measured, especially at the third and fourth measurements.

3.2. Effect of temperament and growth classification on carcass characteristics

When raw data was used to develop classifications for exit velocity, blood lactate concentration and growth a significant effect was observed for selected carcass characteristics. The ADG in each growth classification was significantly ($P < 0.0001$) different, indicating that our method of classification was successful at separating the three groups. As expected, faster growing animals resulted in significantly ($P < 0.0001$) larger carcasses, with a tendency ($P = 0.08$) for a larger ribeye area, than did either the medium or slow growing animals (Table 4). This is supported by data reported by Karlsson et al. (1993), who reported that faster growing animals resulted in larger carcass weights. Exit velocity classification significantly ($P = 0.01$) affected average daily gain and showed a trend ($P = 0.06$) to impact carcass weights. The animals that were in the classification that left the chute more slowly possessed the lower ADG and lower carcass weights than the steers in the fast or medium rate classification. This disagrees with data reported by other researchers (Voisinet et al., 1997; Behrends et al., 2009; Cafe et al., 2011; Black et al., 2013) who found that a fast exit speed of individual animals resulted in reduced average daily gain. The relationship between the temperament and ADG has been suggested to be because of altered feeding behavior, increased metabolic demand or heightened activity (Turner et al., 2011). Vetters, Engle, Ahola, and Grandin (2013) reported that when a category system was used similar to the approach used in this experiment to evaluate the effect of temperament on animal performance the best performance was in the category 2 not 1 or 3 which were not the docile or flighty animals. These researchers suggested that the docile animals may not exert enough energy to ensure adequate intake and actually have reduced performance. This could also be part of the explanation as to why our information is different from previous research reported. Another possible difference is much of the research reported where significant differences were found were evaluating *Bos indicus* steers alone or in comparison to *Bos taurus* steers. Cafe et al. (2011) indicated that increased flight speed during backgrounding and finishing were strongly related to average daily gain in *Bos indicus* steers but the relationship

Table 4
Effect of growth rate, exit velocity, and blood lactate on carcass characteristics (least squares means).

Classification	ADG[1]	Carcass weight (kg)	Marbling score[2]	Ribeye area (cm^2)	Fat thickness (cm)	Yield grade
Growth rate[3]						
Fast	1.84[a]	398.7[a]	488.4	88.3	0.9[b]	2.8[a]
Medium	1.58[b]	384.0[b]	511.5	84.0	1.3[a]	3.2[a]
Slow	1.20[c]	371.2[c]	485.8	83.2	1.1[ab]	2.9[b]
P-value	<0.0001	<0.0001	0.41	0.08	<0.0001	0.002
Exit velocity[3]						
Fast	1.59[a]	386.8	502.9	85.0	1.1	3.0
Medium	1.55	390.2	494.1	85.7	1.1	3.0
Slow	1.14[b]	376.9	488.7	84.9	1.1	2.9
P-value	0.01	0.06	0.75	0.90	0.63	0.82
Blood lactate[3]						
High	1.54	386.2	507.8	85.1	1.0	3.0
Medium	1.54	386.1	495.6	86.9	1.1	2.9
Low	1.50	381.5	482.3	83.4	1.2	3.1
P-value	0.39	0.69	0.67	0.16	0.50	0.47

[a,b,c] Means within a column with different superscripts are significantly different $P < 0.05$.
[1] ADG = (feedlot weight − 205 adjusted weaning weight)/140.
[2] Marbling scores: 300 = slight, 400 = small, 500 = modest, 600 = moderate.
[3] Classifications for growth rate, exit speed and blood lactate are based on ± one standard deviation from the mean. Plus one standard deviation is fast growth rate (n = 19), fast exit velocity (n = 23) or high blood lactate concentration (n = 29) and minus one standard deviation is slow growth (n = 25), slow exit velocity (n = 23) or low blood lactate concentration (n = 21). The rest of the steers were classified as medium (growth rate, n = 107; exit velocity, n = 108; blood lactate concentration, n = 104).

was not as strong when evaluating *Bos taurus*. Furthermore, Turner et al. (2011) reported a relationship between the temperament and ADG during the finishing phase but none of the temperament measurements evaluated in this research were related to lifetime ADG in Angus Limousin steers. This suggests that responses to stress as measured by exit velocity and chute scores may be different in *Bos indicus* when compared to *Bos taurus* animals.

3.3. Relationship of temperament measures to carcass characteristics

As would be expected with the significant effect of the growth rate on carcass weight, ADG was significantly correlated with carcass weight ($P < 0.0001$). Furthermore, the carcass weight was significantly related to the ribeye area ($P < 0.0001$) but not fat thickness or yield grade (Table 5). Boles et al. (2009) also found an increased hot carcass weight with an increased ribeye area in Simmental steers. As expected, carcass characteristics that are used to calculate yield grade were significantly correlated to the yield grade and fat thickness was positively correlated to the marbling scores. Additionally, our results showed that the growth rate was not related to marbling ($P = 0.909$). This data is in contrast to Purchas, Burnham, and Morris (2002) who concluded that faster growth rate was associated with more intramuscular fat ($P < 0.05$).

The temperament measurements were not correlated with most carcass characteristics with the exception of a trend for fat thickness to be negatively correlated with average blood lactate concentration ($P = 0.06$) and exit velocity ($P = 0.08$). This indicated that as the average blood lactate concentration and exit velocity increased, fat thickness decreased. There could be several explanations for these trends. One explanation could be that animals that are more "temperamental" are more active and burn more energy thus, less fat is deposited as stored energy (Vetters et al., 2013). Another potential explanation is that temperamental cattle may have higher or more frequent peaks of cortisol (Curley et al., 2006) that alter metabolism resulting in less energy stored as fat (Matteri et al., 2000).

3.4. Effect of growth, exit speed and blood lactate classification on MFI and shear force values

Growth classification had a significant ($P = 0.02$) effect on the shear force values but there was no effect on MFI (Table 6). The steers from the faster growth rate classification resulted in steaks with significantly lower shear force values (Table 6). Oddy, Harper, Greenwood, and McDonagh (2001), and Purchas et al. (2002) reported that the rapid growth over the lifetime of an animal often resulted in lower shear force values. This could be explained by a more rapid growth rate resulting in differences in structural and cross linking of the collagen matrix, along with altered proteolytic activity which influences the rate of protein accretion. However, there were no obvious differences in the banding pattern on 5% and 10% gels comparing, growth rate (fast vs slow), tenderness (tough vs tender) and blood lactate concentration (high vs low) (data not shown).

Blood lactate classification also significantly affected the shear force values ($P = 0.02$). The steaks from the steers in the high blood lactate classification were significantly more tender than the steaks from the steers from the medium blood lactate classification but was not different from the steaks from the steers classified as low blood lactate. Even though meat pH was not measured, the high blood lactate concentration antemortem reflected an increase in anaerobic metabolism which may have subsequently enhanced upregulation of monocarboxylate transporter (MCTs) mediated transport of lactate possibly altering the rate of postmortem pH decline in muscle enough to impact tenderness. Multiple researchers have reported that altered rates of pH decline postmortem can affect the tenderness of steaks (Hwang & Thompson, 2001; O'Halloran et al., 1997; Shackelford, Koohmaraie, & Savell, 1994; Silva, Patarata, & Martins, 1999; Voisinet et al., 1997; Yu & Lee, 1986).

Table 6
Effect of growth, exit velocity and blood lactate classification on myofibrillar fragmentation index (MFI) and shear force values (least squares means).

Class	MFI	Shear
Growth rate[1]		
Fast	41.4	55.7[b]
Slow	37.4	66.0[a]
P-value	0.16	0.02
Exit velocity[1]		
Fast	39.6	69.3
Medium	42.1	60.5
Low	36.5	55.7
P-value	0.27	0.07
Blood lactate[1]		
High	39.5	57.1[b]
Medium	39.7	67.9[a]
Low	39.5	60.5[ab]
P-value	0.97	0.02

[a,b] means within a column with different superscripts are significantly different $P < 0.05$.
[1] Classifications for growth rate, exit velocity and blood lactate are based on ± one standard deviation from the mean. Plus one standard deviation is a fast growth rate ($n = 19$), fast exit velocity ($n = 23$) or high blood lactate concentration ($n = 29$) and minus one standard deviation is slow growth ($n = 25$), slow exit velocity ($n = 23$) or low blood lactate concentration ($n = 21$). The rest of the steers were classified as medium (growth rate, $n = 107$; exit velocity, $n = 108$; blood lactate concentration, $n = 104$).

Table 5
Simple correlations coefficients between (P-value) between average chute score, average exit velocity and average blood lactate concentration and carcass measurements. ($n = 154$).

	Carcass weight	Marbling	Fat thickness	Ribeye area	Yield grade	ADG[1]	CSAVG[2]	EVAVG[2]	BLAVG[2]
Carcass weight	1	0.15 (0.07)	−0.10 (0.21)	0.42 (<0.0001)	0.01 (0.9)	0.34 (<0.0001)	0.14 (0.08)	0.13 (0.11)	0.07 (0.42)
Marbling		1	0.21 (0.01)	0.08 (0.32)	0.10 (0.20)	−0.01 (0.91)	0.04 (0.62)	−0.02 (0.82)	0.02 (0.80)
Fat thickness			1	−0.32 (<0.0001)	0.74 (<0.0001)	0.05 (0.55)	−0.13 (0.12)	−0.14 (0.08)	−0.15 (0.06)
Ribeye area				1	−0.78 (<.0001)	0.08 (0.37)	0.03 (0.78)	0.05 (0.59)	0.05 (0.57)
Yield grade					1	0.09 (0.24)	−0.03 (0.71)	−0.06 (0.47)	−0.09 (0.26)
ADG[1]						1	0.08 (0.35)	0.05 (0.56)	−0.10 (0.21)
CSAVG[2]							1	0.66 (<0.0001)	0.48 (<0.0001)
EVAVG[2]								1	0.38 (<0.0001)
BLAVG[2]									1

[1] ADG = (mid-way feedlot weight − 205 day weaning weight)/140 days.
[2] Average blood lactate (BLAVG), average exit velocity (EVAVG), and chute score (CSAVG) are the average of the four measurements taken.

A trend ($P = 0.07$) was noted for exit speed classification to affect shear values. On average, steaks from animals in the fast exit speed classification, tended to have higher shear force values than steaks from steers in the medium or slow velocity classification. This is consistent with the work of Cafe et al. (2011), Voisinet et al. (1997), and Behrends et al. (2009), all of which indicated that steaks from cattle with more excitable temperaments as measured by the chute score and exit velocity, had higher shear force values along with a concomitant increase in the number of carcasses that had a dark, dry and firm texture to the lean which indicates an altered ultimate pH.

3.5. Relationships between carcass characteristics and tenderness and temperament measurements and tenderness

There was a significant negative correlation between the carcass weight and shear force after 3 ($P = 0.02$) and 7 days ($P = 0.05$) of postmortem aging and a negative correlation between ADG and shear force after 3 days of postmortem aging (Table 7). This may suggest faster growing animals with larger carcasses will be more tender (lower shear force values) especially with less postmortem aging.

Temperament measurements were not strongly correlated to tenderness (Table 8). However, a significant positive correlation ($P = 0.04$) was observed between the average exit speed and the shear force values after 3 days of postmortem aging. This suggested that the steers with a faster exit speed resulted in meat with higher shear force values. Additionally, exit speed was correlated to the chute scores ($P = 0.001$) and lactate concentrations. This was supported by Voisinet et al. (1997) who found that as temperament increased from calm to excitable, Warner-Bratzler shear force values increased therefore, concluding temperament had a significant effect on tenderness.

As expected, a significant correlation ($P \leq 0.02$) was seen between MFI and shear force values after 7, 14 and 21 days of postmortem aging (Tables 7 & 8). No significant interaction was found between postmortem aging time and the different temperament or growth classifications. However, the correlations between the shear force values at different aging times indicated that if the shear force was higher after 7 days of aging, it was higher after 21 days of aging. This suggests that even if the shear force values become more similar with postmortem aging, if they are higher initially they will be higher after aging contributing to a variation in the samples in the marketplace.

4. Conclusions

The relationship between the different accepted measures of the temperament and blood lactate concentration were significant but not high. The low relationship would suggest that the measures are related, but other factors are contributing to differences. Furthermore, the growth rate and blood lactate classifications indicated that tenderness was impacted by different physiological conditions that occur during the growing phase of animals such as muscle protease activity or metabolic processes that would affect collagen cross-linkages. Combining the temperament data with the tenderness data reported here indicate that if an animal is temperamental based upon exit velocity and blood lactate concentrations before harvest, this, could set the stage for postmortem processes that affect the tenderness of the final product. The impact of temperament or other forms of stress could lead to some of the variation in tenderness observed in the marketplace. Utilizing a simple objective measure of the temperament like the lactate meter could possibly lead to decreasing variations in the temperament within a producers' herd and could lead to less variation in the tenderness a consumer will encounter. Currently, the most common measurement of temperament is subjective chute scores. Our data indicates that the chute score is not as good a predictor of tenderness as the exit speed. However, the hardware required to measure the exit speeds is expensive and would, therefore, not be used in a normal production setting. The significant correlation between the exit speed and blood lactate concentration, however, suggests that this simple objective measurement can be used to sort animals into categories. However, more research is warranted to determine what the optimum blood lactate concentration would be as the steaks from steers with high lactate concentration were more tender than were the steaks from steers with medium blood lactate concentrations. Providing the producer with an objective measurement of temperament would enhance livestock selection

Table 7
Simple correlations coefficients between (P-value) carcass and tenderness measurements (n = 30).

	CWT[1]	MARB[1]	FAT[1]	REA[1]	YG[1]	ADG[1]	MFI3[1]	MFI7[1]	MFI14[1]	MFI21[1]	SHR3[1]	SHR7[1]	SHR14[1]	SHR21[1]
CWT[1]	1	0.05 (0.81)	−0.34 (0.04)	0.29 (0.11)	−0.02 (0.93)	0.60 (0.0005)	0.06 (0.74)	0.20 (0.30)	0.06 (0.76)	0.25 (0.19)	−0.41 (0.02)	−0.36 (0.05)	0.02 (0.92)	−0.16 (0.39)
MARB[1]		1	0.28 (0.13)	0.05 (0.78)	0.09 (0.62)	0.18 (0.34)	−0.12 (0.51)	−0.20 (0.29)	−0.06 (0.75)	−0.01 (0.98)	−0.12 (0.52)	0.18 (0.33)	−0.007 (0.96)	0.40 (0.02)
FAT[1]			1	−0.42 (0.02)	0.61 (0.0003)	−0.003 (0.99)	0.11 (0.55)	−0.11 (0.55)	−0.08 (0.96)	−0.01 (0.96)	0.03 (0.86)	0.10 (0.59)	0.05 (0.81)	0.09 (0.63)
REA[1]				1	0.90 (<0.0001)	0.22 (0.25)	0.04 (0.85)	0.004 (0.98)	−0.008 (0.96)	−0.16 (0.39)	0.02 (0.93)	−0.01 (0.94)	0.11 (0.55)	−0.14 (0.45)
YG[1]					1	0.04 (0.83)	−0.33 (0.86)	0.02 (0.91)	−0.02 (0.92)	−0.01 (0.95)	−0.15 (0.44)	−0.08 (0.68)	−0.05 (0.77)	0.11 (0.58)
ADG[1]						1	0.07 (0.70)	−0.02 (0.89)	−0.10 (0.60)	0.01 (0.94)	−0.38 (0.04)	−0.20 (0.28)	−0.10 (0.60)	−0.11 (0.56)
MFI3[1]							1	0.30 (0.10)	−0.24 (0.20)	0.07 (0.70)	−0.32 (0.09)	0.005 (0.98)	−0.32 (0.09)	0.33 (0.08)
MFI7[1]								1	0.28 (0.13)	0.42 (0.02)	−0.29 (0.11)	−0.41 (0.02)	−0.56 (0.001)	−0.38 (0.04)
MFI14[1]									1	0.62 (0.0003)	0.05 (0.81)	0.02 (0.92)	−0.19 (0.34)	−0.03 (0.90)
MFI21[1]										1	−0.14 (0.46)	−0.11 (0.53)	−0.33 (0.08)	−0.22 (0.23)
SHR3[1]											1	0.69 (<0.0001)	0.31 (0.10)	0.39 (0.03)
SHR7[1]												1	0.33 (0.07)	0.53 (0.002)
SHR14[1]													1	0.26 (0.17)
SHR21[1]														1

[1] CWT = hot carcass weight, MARB = USDA marbling score (300 = slight, 400 = small, 500 = modest, 600 = moderate), FAT = 12th rib fat thickness, REA = ribeye area, YG = calculated yield grade, ADG = average daily gain, MFI = myofibrillar fragmentation index, aged postmortem 3, 7, 14 and 21 days, SHR = shear force value, aged postmortem 3, 7, 14 and 21 days.

Table 8
Simple correlations coefficients between (P-value) average chute scores, exit velocity and blood lactate of steers and carcass tenderness measurements. (n = 30).

	CSAVG[1]	EVAVG[1]	BLAVG[1]	MFI3[1]	MFI7[1]	MFI14[1]	MFI21[1]	SHR3[1]	SHR7[1]	SHR14[1]	SHR21[1]
CSAVG[1]	1	0.57 (0.001)	0.59 (0.0006)	0.26 (0.16)	−0.04 (0.82)	−0.25 (0.18)	0.25 (0.20)	0.15 (0.44)	−0.11 (0.58)	−0.10 (0.61)	−0.24 (0.20)
EVAVG[1]		1	0.46 (0.01)	0.12 (0.53)	−0.10 (0.61)	0.36 0.17	−0.11 (0.57)	0.38 (0.04)	0.10 (0.60)	0.14 (0.45)	−0.04 (0.84)
BLAVG[1]			1	0.23 (0.22)	−0.09 (0.62)	−0.09 (0.65)	−0.06 (0.73)	0.16 (0.39)	0.005 (0.97)	−0.005 (0.98)	−0.12 (0.53)
MFI3[1]				1	0.30 (0.10)	−0.24 (0.20)	−0.07 (0.70)	−0.32 (0.09)	−0.41 (0.02)	−0.32 (0.09)	−0.33 (0.08)
MFI7[1]					1	0.28 (0.13)	0.41 (0.02)	−0.30 (0.11)	0.43 (0.02)	−0.56 (0.001)	0.38 (0.04)
MFI14[1]						1	0.62 (0.0003)	0.05 (0.81)	0.02 (0.92)	−0.19 (0.32)	−0.02 (0.89)
MFI21[1]							1	−0.14 (0.46)	−0.12 (0.54)	−0.32 (0.08)	−0.22 (0.23)
SHR3[1]								1	0.70 (<0.0001)	0.31 (0.09)	0.39 (0.03)
SHR7[1]									1	0.33 (0.07)	0.53 (0.002)
SHR14[1]										1	0.26 (0.17)
SHR21[1]											1

[1] CSAVG = average docility score, EVAVG = average exit velocity measurement, BLAVG = average blood lactate, MFI = myofibrillar fragmentation index, aged postmortem 3, 7, 14 and 21 days, SHR = shear force value, aged postmortem 3, 7, 14 and 21 days.

resulting in more consistent tenderness of steaks in the marketplace, and culminating in greater consumer satisfaction at the table.

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