Effects of temperament at feedlot arrival and breed type on growth efficiency, feeding behavior, and carcass value in finishing heifers

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ABSTRACT: Objectives were to evaluate the effects of temperament at feedlot arrival and breed type on productivity, feed efficiency, feeding behavior, and carcass quality traits in finishing beef heifers, and to examine interactions between temperament and breed type. Heifers (Angus, Braford, Brangus, and Simbrah, $N = 411$, BW = 280 kg) were fed a high-grain diet (ME = 3.0 Mcal/kg DM) in pens equipped with electronic feed bunks. Quality grade (**QG**), yield grade (**YG**), and Warner-Bratzler shear (**WBS**) force values (day 1 and 14 postmortem) were evaluated. Relative exit velocity (**REV**) at feedlot arrival was used as a covariate in mixed models to assess the effects of temperament and interactions with breed type, with means compared at ±1 SD from the mean initial REV. Calm heifers (mean REV minus 1 SD) had 4% greater ($P < 0.001$) initial BW, 12% greater ($P < 0.001$) ADG, 8% greater ($P < 0.001$) DMI, and 4% greater ($P < 0.02$) G:F than heifers with excitable temperaments (mean REV plus 1 SD). A temperament × breed interaction was detected ($P < 0.01$) for residual feed intake (RFI). Braford heifers had a more ($P < 0.05$) negative REV covariate slope (−1.49 ± 0.65) than the other breeds, such that excitable Braford heifers had lower ($P < 0.05$) RFI than the other breeds with excitable temperaments. Temperament × breed interactions were observed ($P < 0.001$) for DMI per $BW^{0.75}$ and bunk visit (**BV**) duration. Braford heifers had more ($P < 0.05$) negative REV covariate slopes for both traits than Angus, Brangus, and Simbrah heifers such that excitable Braford heifers consumed less ($P < 0.05$) DMI per $BW^{0.75}$ and had less BV duration compared to excitable Angus and Brangus heifers. Calm heifers had 9% greater ($P < 0.01$) meal duration, and consumed meals that were 22% longer ($P < 0.001$) and 17% larger ($P < 0.001$) compared to excitable heifers. Calm heifers had 12% more ($P < 0.001$) BV events per meal then excitable heifers. Carcasses from calm heifers were 4% heavier ($P < 0.05$) and had 7% greater ($P = 0.05$) backfat (BF) depth and tended to have 4% greater ($P = 0.07$) USDA YG than carcasses from excitable heifers. Additionally, loin steaks from calm heifers had 8% lower ($P < 0.05$) WBS force than steaks from excitable heifers. Based on a carcass grid with discounts and premiums for HCW, QG, YG, and tenderness, calm heifers returned $62 more ($P < 0.01$) revenue per animal than excitable heifers. These results demonstrate that heifers with divergent phenotypes for temperament on feedlot arrival differ in their performance, feed efficiency, and feeding behavior patterns, as well as carcass quality and revenue.

Key words: beef heifers, carcass traits, feed efficiency, feeding behavior, temperament, tenderness

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INTRODUCTION

Temperament has been defined as the reactive behavioral responses of an animal to close

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handling by humans (Burrow, 1997). Historically, calm cattle have been viewed as more economical, especially considering the additional damage and cost that housing and handling cattle with excitable temperaments can have on facilities, other animals, and humans (Burrow, 1997). Previous research has demonstrated that cattle with excitable temperaments have reduced performance, less favorable efficiency of gain, and leaner carcasses compared to calmer counterparts (Fordyce et al., 1988; Burrow and Dillon, 1997; Fox, 2004; Ferguson et al., 2006; Behrends et al., 2008). Although the root causes of the differences are not fully understood, many of the detrimental aspects observed in excitable cattle are thought to be associated with heightened basal levels of stress-related hormones (Curley et al., 2006; Llonch et al., 2016). *Bos indicus* cattle have been shown to have greater incidence of excitability compared to *Bos taurus* cattle (Voisinet et al., 1997b). However, the overall impacts of temperament on multiple supply chain components are not well understood, particularly between cattle of different biological types. Additionally, the extent that feedlot entry temperament might be used to identify potential management or outcome groups remains largely unknown. The objectives of this study were to evaluate the effects of temperament at feedlot arrival and breed type on feedlot growth performance, feed efficiency, feeding behavior, and carcass characteristics and value in finishing beef heifers.

MATERIALS AND METHODS

Animal Background and Management

All animal care and use procedures were in accordance with the guidelines for use of Animals in Agricultural Teaching and Research as approved by the Texas A&M University Institutional Animal Care and Use Committee (Protocol number 8-54).

Purebred Angus (n = 63), Braford (n = 116), Brangus (n = 122), and Simbrah (n = 110) heifers sourced from a single ranch were utilized in this study. Growth, feed intake, and feeding behavior data were collected during 3 trials that were conducted during consecutive years (n = 169, 118, and 124, respectively, with breeds equally distributed across years). Heifers were vaccinated for respiratory viral pathogens (Triangle 5; Boehringer Ingelheim Vetmedica, St. Joseph, MO; BHV-1, bovine viral diarrhea 1 and 2, bovine respiratory syncytial virus, parainfluenza-3), and for *Clostridial* diseases (Covexin 8; Merck, Madison, NJ) 4 to 5 wk prior to weaning and again upon weaning at approximately 8 mo of age. Thereafter, heifers were preconditioned on the ranch for 4 to 6 wk prior to being transported to the research facilities.

Upon arrival, heifers were fitted with passive, half-duplex radio frequency identification ear tags (**RFID** tags, Allflex USA Inc., Dallas, TX), administered Ivomec (Merial Ltd, Duluth, GA), and weighed. Heifers were stratified by breed and initial BW, and randomly assigned to 1 of 2 pens each equipped with 10 electronic feed bunks at the Texas A&M AgriLife Research Center in McGregor (TX), or to 1 of 4 pens each equipped with 4 electronic feed bunks at the Texas A&M AgriLife Beef Cattle Systems Research Center in College Station (TX). Heifers were adapted to a high-grain feedlot diet (Table 1) for 4 to 5 wk in pens equipped with electronic feed bunks (GrowSafe Systems, Ltd, Airdrie, AB) prior to the start of the trials. The feed bunks were equipped with load bars to measure feed disappearance, passive RFID antenna to record animal presence, and stanchion bars to prevent multiple animals from eating from the same feed bunk at a given time. The average initial BW and age of the heifers at the start of the trials were 280 ± 35 kg and 340 ± 35 d, respectively. Heifers were fed ad libitum twice daily, and individual animal feed intake and feeding behavior data collected daily for 70 d.

All GrowSafe system default settings were used in this study, apart from the parameter setting for maximum duration of time between consecutive RFID recordings to end an uninterrupted bunk visit (BV) event. For these studies, a parameter setting of 100 s was used, as recommended by Mendes

Table 1. Feed ingredient composition and chemical analysis of experimental diet

Item	
Ingredient	As-fed basis %
Dry rolled corn	73.7
Chopped sorghum-sudan hay	6.0
Cottonseed meal	6.0
Cottonseed hulls	6.0
Molasses	5.0
Mineral premix[1]	2.5
Urea	0.8
Chemical composition	Dry matter basis
Dry matter, %	90.2
CP, % DM	12.6
NDF, % DM	20.3
ME, Mcal/kg DM	3.0

[1]Mineral premix contained minimum 15.5% Ca, 2,800 ppm Zn, 1,200 ppm Mn, 12 ppm Se, 14 ppm Co, 3 ppm I, 45,400 IU/kg Vit-D, 726 IU/kg Vit-E, 1,200 ppm Tylan.

et al. (2011). Feed intakes and feeding behavior data were omitted for 27, 3, and 2 d for trials 1, 2, and 3, respectively, due to power outage, equipment malfunction, and(or) when the proportion of assigned feed disappearance (**AFD**) was less than 95%. The average AFD for the feed intake data included in the analyses were 98.9%, 99.4%, and 98.1% for trials 1, 2, and 3, respectively. Estimates for missing feed intake data were derived from linear regression of the feed intake on the day of the trial as recommended by Hebart et al. (2004).

Temperament was evaluated by measuring exit velocity (**EV**) upon feedlot arrival, and on days 0 and 70 of each trial. Exit velocity was measured as time to traverse a fixed distance of 1.8 m upon exiting a squeeze chute using infrared sensors (Farm Tec, Inc., North Wylie, TX). Exit velocity data were transformed to relative EV (**REV**) as the difference of each animal's EV from the mean divided by the mean EV for each day. Initial REV was computed as the average of REV measured at feedlot arrival and on day 0 of the trial. During the trials, heifers were monitored twice daily for clinical signs of illness. Heifers deemed to be morbid were administered antimicrobial therapy (Draxxin, Zoetis, Parsippany, NJ) if rectal temperature exceeded 40.5 °C, and returned to their home pen after treatment. During the 3 trials, 4 heifers were removed due to morbidity associated with bovine respiratory disease.

Diet samples were collected weekly and composited by weight at the end of each trial. Moisture analyses were conducted by drying the samples in a forced-air oven for 48 h at 105 °C. Chemical analyses of the feed samples were conducted by an independent laboratory (Cumberland Valley Analytical Services Inc., Hagerstown, MD). Metabolizable energy concentration of the diet was computed using the Large Ruminant Nutrition System (https://nutritionmodels.tamu.edu/models/lrns/), based on the Cornell Net Carbohydrate and Protein System. Cattle were weighed at 14-d intervals, and ultrasound measurements of subcutaneous backfat (**BF**) depth, intramuscular fat (**IMF**) percentage, and loin muscle area (**LMA**) collected on days 0 and 70 of each trial by a certified ultrasound technician using an ALOKA 500-V instrument with a 17 cm, 3.5 MHz transducer (Corometrics Medical Systems Inc., Wallingford, CT). Images were analyzed by the Centralized Ultrasound Processing Laboratory (Ames, IA).

For each trial, heifers were slaughtered at Kane Beef (Corpus Christi, TX) in 2 groups that were 4 to 6 wk apart when they reached a targeted BF depth endpoint of approximately 1.4 cm. At 48 h postmortem, carcasses were ribbed between the 12th and 13th rib interface, and HCW, 12th rib BF depth, estimated percentage of kidney, pelvic, and heart fat (**KPH**), USDA quality grade (QG), yield grade (YG), and LMA were determined as defined by the USDA (USDA, 1997). Two 2.5-cm thick steaks were cut from the 13th rib, vacuum packaged, and placed in a 4 °C cooler for 14 d to determine Warner-Bratzler shear (**WBS**) force. At 1- and 14-d postmortem aging, WBS force measurements were collected. The steaks were cooked on a Faberware Open-Hearth grill (Faberware Co., Bronx, NY) until the internal temperature reached 70 °C. Steaks were allowed to cool at room temperature for 4 h prior to obtaining six 1.27-cm diameter core samples. The core samples were sheared with a Universal Testing Instrument (Model SSTM-500, United Calibration Corp., Huntington Beach, CA) equipped with a V-notch Warner-Bratzler blade, and a 50-kg compression load cell with a crosshead speed of 200 mm/min, as described by AMSA (2015). The average force required to segment the 6 cores was recorded for each steak.

Carcass value ($/kg) was determined using a standard marketing grid based on 3-yr (2014–2016) average premiums and discounts for USDA YG, QG, and HCW (**Grid 1**; USDA (2017)). Carcass value was also determined with a marketing grid (Grid 2) that included premiums and discounts for tenderness based on the difference consumers were willing to pay between guaranteed tender (≤3.0 kg WBS, 14-d postmortem aging) and tough (>3.0 kg WBS, 14-d postmortem aging) steaks (Miller et al., 2001). The premium and discount values derived from Miller et al. (2001) were adjusted for inflation ($1 USD 2001 = $1.40 USD 2017; BLS, 2017) and converted to a carcass basis for inclusion in Grid 2.

Computations

Growth rates of individual heifers were modeled using linear regression of BW on day of test using PROC GLM (SAS Inst., Cary, NC), with the regression coefficients used to compute initial and final BW, ADG, and mid-test $BW^{0.75}$. Moisture analyses of the diet ingredients were used to compute daily DMI from feed intake data.

Residual feed intake (**RFI**) was calculated as the difference between actual DMI and expected DMI to meet growth and maintenance energy requirements (Koch et al., 1963). Expected DMI was based on linear regression of DMI on ADG and mid-trial $BW^{0.75}$ using PROC GLM procedure of

SAS, with year and pen included as fixed effects. Residual gain (**RG**) was calculated as actual ADG minus expected ADG based on DMI and mid-trial $BW^{0.75}$, with expected ADG based on linear regression of ADG on DMI and mid-trial $BW^{0.75}$ using PROC GLM (SAS), with year and pen included as fixed effects. Gain:feed ratio was calculated as the ratio of ADG to daily DMI.

Feeding behavior traits were based on the frequency and duration of BV events, meal frequency and duration, head-down (**HD**) duration, and time for an animal to approach the feed bunk following feed delivery (time-to-bunk; **TTB**). A BV event began when an animal was detected at a feed bunk, and ended when the time between the previous 2 recordings exceeded 100 s, or when the RFID tag was detected at another feed bunk. Bunk visit duration was defined as the sum of the lengths of all BV events recorded each day, and HD duration as the number of RFID recordings each day multiplied by the scanning rate of the GrowSafe system. Bunk visit eating rate (g/min) was computed as daily DMI divided by daily BV duration. The subroutine of GrowSafe 4000E software was used to calculate daily feed intake.

The longest nonfeeding interval considered to be part of the meal event is referred to as meal criterion. To compute meal data, a 2-pool Gaussian–Weibull distribution model was fitted to log-transformed nonfeeding interval data, and the intercept of the 2 distributions used to define meal criterion (Bailey et al., 2012). Meal criterion was used to compute individual animal meal frequency, meal duration, and meal size. For this study, meal eating rate (g/min) was equal to daily DMI divided by daily meal duration.

Statistical Analysis

Data were analyzed using a mixed model (PROC MIXED; SAS Inst., Cary, NC) that included breed as a fixed effect, initial REV as a linear covariate, the interaction of breed × initial REV covariate, and trial and pen within trial as random effects. Least square mean differences among breeds were evaluated using the Tukey's post hoc test. To examine the possible interactive effects between breed and temperament, an unequal slope model was fit for those dependent variables with significant ($P < 0.05$) breed × initial REV covariate interactions, with differences in slope for Braford, Brangus, and Simbrah compared to that of Angus. Additionally, breed subclass means of heifers with calm and excitable temperaments were compared at mean initial REV minus 1 SD and mean initial REV plus 1 SD, respectively, using PDIFF option of SAS. Pearson correlation coefficients among traits were determined using the CORR procedure of SAS.

Chi-analyses were conducted using PROC FREQ to examine the effects of temperament classification on the proportion of heifers with tender (≤3.0 kg WBS) or tough (>3.0 kg WBS) carcasses, and with carcasses grading USDA Choice QG or higher. For the analysis of categorical carcass characteristics, heifers were classified as having calm, intermediate, or excitable temperaments based ± 0.5 SD from the mean initial REV (0.0 ± 0.21 SD m/s). Additionally, the normal distribution of heifers with calm, intermediate, or excitable temperaments within breed was analyzed using PROC FREQ.

RESULTS AND DISCUSSION

Effect of Breed on Temperament

There were no significant differences among the 4 breeds evaluated in this study for initial ($P = 0.79$) or final ($P = 0.14$) REV. Further, chi-square analysis revealed that the proportion of heifers within each temperament classification (±0.5 SD from mean initial REV) were similar within breed ($P = 0.37$; data not shown). The absence of temperament differences between breed types is in contrast with most studies that have examined subjective (Hearnshaw and Morris, 1984; Voisinet et al., 1997b) and objective (Cafe et al., 2011; Thomas et al., 2012) temperament traits among *B. indicus* and *B. taurus* cattle. Cafe et al. (2011) found that Angus cattle had consistently calmer temperaments based on EV and subjective chute score (**CS**) than Brahman cattle. Hearnshaw and Morris (1984) demonstrated that differences in temperament scores between *B. taurus* and Brahman-influenced cattle increased as the percentage of Brahman inheritance increased, suggesting Brahman genetics had an additive effect on temperament. Voisinet et al. (1997b) found that *B. taurus* feedlot cattle had calmer temperaments than cattle with Brahman inheritance. However, in that study, the cattle were sourced from multiple locations; therefore, environmental factors during calfhood may have contributed to the observed breed differences in temperament. The lack of breed effect on temperament in the current study may reflect the relatively low proportion of Brahman inheritance in the American breeds used in this study.

Effect of Temperament and Breed on Feedlot Performance

Initial REV was a significant covariate for initial BW, but not age, such that calm heifers had greater initial BW at a similar age compared to heifers with excitable temperaments (±1.0 SD from mean initial REV; Table 2). Whereas Burrow and Dillon (1997) reported no difference in initial BW due to temperament in their study, Tulloh (1961), Cafe et al. (2011), and Reinhardt et al. (2009) reported that cattle with calm temperaments exhibited greater initial BW than cattle with excitable temperaments. Likewise, Francisco et al. (2012) reported that weaning BW were heavier in calm calves than excitable calves, with temperament classification based on both EV and a subjective score while restrained in a chute (EV + CS).

Heifers with calm temperaments had greater ($P < 0.001$) ADG than heifers with excitable temperaments (Table 2), which is consistent with results from previous studies in growing cattle (Burrow and Dillon, 1997; Voisinet et al., 1997b; Nkrumah et al., 2007; Cafe et al., 2011; Francisco et al., 2015; Bruno et al., 2016; Llonch et al., 2016; Braga et al., 2018). Initial REV was moderately correlated with ADG ($r = -0.30$, $P < 0.05$). Burrow and Dillon (1997) found that ADG was 43% greater in calm than excitable animals, and proposed that the greater ADG of calm animals was likely a function of greater DMI. In the current study, the greater ADG in calm heifers was associated with an 8% greater ($P = 0.001$) DMI compared to excitable heifers. Likewise, Nkrumah et al. (2007), Cafe et al. (2011), Bruno et al. (2016), and Llonch et al. (2016) found that calm cattle consumed more feed than excitable cattle, and had corresponding greater ADG. Nkrumah et al. (2007) reported negative correlations of −0.35 and −0.26, respectively, between EV and DMI and ADG. Differences in DMI and ADG due to temperament may be associated with increased susceptibility to stress in excitable cattle (Turner et al., 2011), which would reduce intake and repartition nutrients away from growth. However, the mechanisms associated with this reduction in DMI and ADG due to excitable temperament have not been fully explained.

Temperament impacted feed efficiency as measured by G:F ratio and RG (Table 2), such that calm heifers had more ($P < 0.05$) favorable G:F and RG than their excitable counterparts. The effect of temperament on G:F and RG was independent of breed (temperament × breed interactions; $P > 0.10$). The effects of the initial REV covariate on G:F and RG were not unexpected, given the magnitude of the phenotypic correlations with ADG ($r = 0.46$ and 0.71, respectively; $P < 0.001$). Although G:F was affected by temperament in this study, Llonch et al. (2016) found that temperament (EV + CS) classification did not affect F:G, even though excitable steers consumed less DMI and tended to have lower ADG than calm steers. In a study with *B. indicus* cattle, Petherick et al. (2002) reported that steers with calm temperaments had greater ADG and more favorable F:G than steers with excitable temperaments, even though feed intake was not affected by temperament.

In contrast to ADG, G:F, and RG, there was a significant temperament × breed interaction for RFI (Fig. 1), with Braford heifers having a more ($P < 0.05$) negative REV covariate slope (−1.49 ± 0.65) than Angus, Brangus, and Simbrah heifers (range from −0.02 to 0.50). For

Table 2. Effects of temperament and breed on feedlot performance, dry matter intake, and feed efficiency in finishing heifers

	Temperament[2]			Breed[3]					*P*-value		
Item[1]	Calm	Excitable	SE	Angus	Braford	Brangus	Simbrah	SE	Temp	Breed	Temp × breed
Performance traits											
Initial age, d	332	331	5	335[a]	330[ab]	327[b]	332[ab]	3	0.87	0.05	0.18
Initial BW, kg	280.0	267.9	7.0	265.8[a]	269.7[b]	277.5[bc]	282.8[c]	4.7	0.001	0.001	0.85
Final BW, kg	391.6	367.8	9.2	383.6[a]	361.1[b]	384.5[a]	389.4[a]	6.2	0.001	0.001	0.6
ADG, kg/d	1.60	1.43	0.06	1.68[a]	1.31[b]	1.53[c]	1.53[c]	0.04	0.001	0.001	0.46
DMI, kg/d	9.41	8.72	0.30	9.52[a]	8.36[b]	9.25[a]	9.12[a]	0.20	0.001	0.001	0.09
DMI, g/MBW$^{0.75}$	119.9	115.4	3.4	124.0[a]	111.5[b]	118.1[c]	116.9[c]	2.3	0.001	0.001	0.01
Feed efficiency traits											
G:F	0.172	0.165	0.006	0.179[a]	0.159[b]	0.168[c]	0.168[c]	0.001	0.02	0.001	0.11
RFI, kg/d	0.044	−0.009	0.205	0.162	−0.077	0.036	−0.053	0.139	0.34	0.32	0.003
RG, kg/d	0.021	−0.104	0.085	0.143[a]	−0.098[b]	0.008[c]	0.010[c]	0.032	0.002	0.001	0.19

[a–c]Means in the same row with unlike superscripts differ at $P < 0.05$.

[1]RFI = residual feed intake; RG = residual gain.

[2]Calm and excitable temperament means were computed at mean initial REV (0.0 ± 0.21 SD m/s) minus and plus 1 SD, respectively.

[3]Angus (n = 63), Braford (n =116), Brangus (n = 122), and Simbrah (n =110).

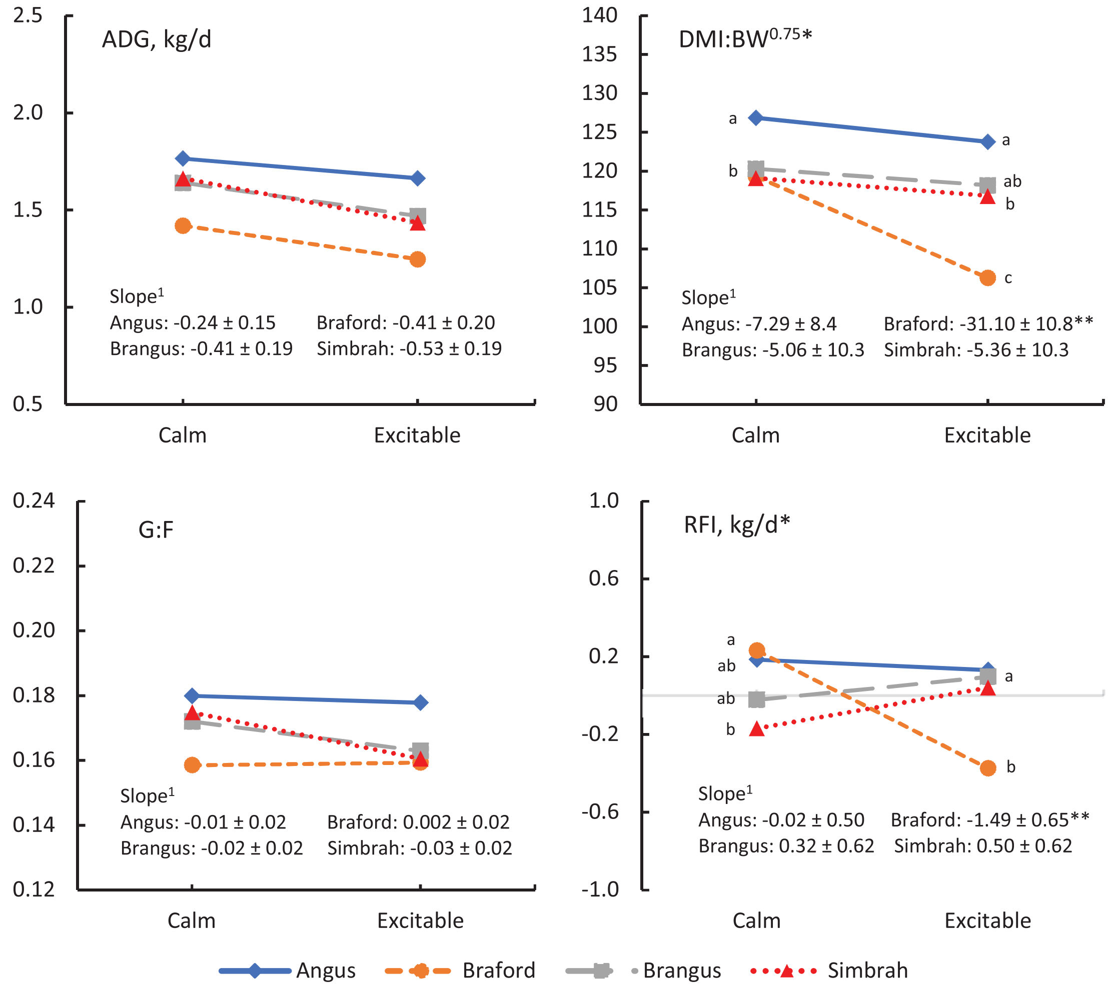

Figure 1. Effects of temperament and breed on ADG, DMI:BW$^{0.75}$, G:F, and RFI. *Indicates that there was an initial REV × breed ($P < 0.01$). [1]Slope = slope of initial REV covariate ± SE for each breed. **Slopes of Braford, Brangus, or Simbrah differed ($P < 0.05$) from Angus. [a–c]Indicate differences ($P < 0.05$) between subclass breed means.

heifers with calm temperaments, RFI was greater ($P < 0.05$) for Braford than Simbrah, with Angus and Brangus being intermediate, whereas among heifers with excitable temperaments, Braford had a lesser ($P < 0.05$) RFI than Angus, Brangus, and Simbrah. Similar to RFI, the temperament × breed interaction was significant for DMI per unit of metabolic mid-trial body size (**DMI:BW$^{0.75}$**), such that Braford heifers had a more ($P < 0.05$) negative REV covariate slope (−31.1 ± 10.8) than Angus, Brangus, and Simbrah heifers (range from −5.06 to −7.29). As initial REV increased in Braford heifers, the magnitude of the reduction in DMI:BW$^{0.75}$ was greater than the corresponding reduction in ADG, which resulted in the excitable Braford heifers having lower ($P < 0.05$) RFI then Angus, Brangus, or Simbrah heifers with excitable temperaments (Fig. 1).

The biological basis for this breed interaction with temperament is not apparent, as most studies have found that temperament is not associated with RFI (Nkrumah et al., 2007; Llonch et al., 2016). Llonch et al. (2016) reported that temperament classification did not affect RFI, and concluded that lack of an effect of temperament on RFI was due to the fact that similar reductions in both DMI and ADG were observed in excitable vs. calm cattle. Likewise, in the present study, RFI was not affected by initial REV in Angus, Brangus, and Simbrah heifers as the magnitude of the reductions in DMI:BW$^{0.75}$ and ADG between calm and excitable heifers were similar.

Initial REV was negatively correlated ($P < 0.05$) with initial BW (−0.17), ADG (−0.30), DMI (−0.24), G:F (−0.14), and RG (−0.19). However, REV measured on day 70 of the trials was not correlated with ADG, DMI, or either of the feed efficiency traits. The actual mean EV ± SD at feedlot arrival, and days 0 and 70 of the trials were 3.19 ± 1.02, 3.19 ± 0.72, and 2.29 ± 1.29 m/s, respectively. These results are similar to the results of Behrends et al. (2008), who found that temperament measured at weaning had greater relationships with performance than temperament measured at feedlot entry. This was likely due to the effects of repeated handling, and the authors suggest that early-life temperament scores may be more predictive of performance than scores measured after cattle have the opportunity to acclimate to human handling. Therefore, evaluation of temperament earlier in life, near to weaning, likely reflected future performance more accurately than measurements taken later in life. However, Burrow (1997) reported in a review of temperament that animal age and experience did not always result in a calmer temperament, and other factors, such as sex, may play a role.

Angus heifers had more favorable ($P < 0.02$) G:F and RG than Braford heifers, with Brangus and Simbrah heifers being intermediate (Table 2). These breed differences in G:F and RG largely reflect the breed type differences noted in ADG (Table 2). In a study comparing bulls from several Continental and British breeds, Schenkel et al. (2004) reported that the leaner Continental breeds (Blonde d' Aquitaine and Limousin) had more favorable F:G than Angus and Simmental bulls that tended to be fatter. Elzo et al. (2009) reported that ADG and F:G decreased as the percentage of Brahman genetic influence increased, which supports results from the current study.

In this study, breed type did not effect RFI, which is in agreement with Nkrumah et al. (2004), who found no effect of sire breed on RFI among bulls and steers. Crowley et al. (2010) found that Limousin- and Charolais-sired cattle had lower RFI than purebred Angus, Hereford, and Simmental bulls. Schenkel et al. (2004) found Blonde d' Aquitaine, Limousin, Charolais, and Simmental bulls had more favorable RFI than Angus and Hereford cattle. However, when RFI was adjusted for variation in carcass BF depth, Hereford bulls were more similar to Blonde d' Aquitaine and Limousin bulls. Elzo et al. (2009) suggested that the differences in RFI between *B. indicus*-influence and *B. taurus* breeds may be larger than the differences between *B. taurus* breeds, although few studies have directly compared RFI between *B. indicus* and *B. taurus* breeds.

Effect of Temperament and Breed on Feeding Behavior

The effects of temperament and breed type on feeding behavior traits are presented in Table 3. Temperament × breed type interactions were significant for both HD duration and BV duration (Fig. 2). Braford heifers had a more ($P < 0.05$) negative REV covariate slope (−27.4 ± 11.5) for HD duration than Angus, Brangus, and Simbrah heifers (range from −9.5 to 4.0). Likewise, for BV duration, the REV covariate slope was more negative for Braford heifers (−32.8 ± 13.1) than for Angus, Brangus, and Simbrah heifers (range from −17.3 to 1.8). Although the REV covariate slopes for HD and BV durations in Simbrah heifers did not differ ($P > 0.1$) from Angus heifers, they were numerically more negative than in Angus and Brangus heifers. In heifers with calm temperaments, HD and BV durations of Braford did not differ from Angus, Brangus, or Simbrah. However, in heifers with excitable temperaments, Braford and Simbrah had lower ($P < 0.05$) HD and BV durations than Angus and Simbrah. The magnitude of the reductions in HD and BV duration in Braford heifers as initial REV increased was similar to that observed in DMI:BW$^{0.75}$ (Fig. 1). Although the temperament × breed type interaction was not significant ($P < 0.1$) for meal duration, there was a greater numerical reduction in meal duration of Braford and Simbrah heifers than for Angus and Brangus heifers as initial REV increased. Thus, in Braford heifers, the greater reduction in DMI:BW$^{0.75}$ as initial REV increased was due at least in part to less time spent at the feed bunk compared with Angus, Brangus, and Simbrah heifers.

There was a temperament × breed interaction noted for meal eating rate (Fig. 2), such that Simbrah heifers had a more ($P < 0.05$) positive REV covariate slope (20.6 ± 11.9) for meal eating rate than Angus, Brangus, and Simbrah heifers (range from −11.4 to −1.8). In heifers with calm temperaments, meal eating rate was not affected by breed type, whereas excitable Simbrah heifers had greater meal eating rates then Angus, Brangus, and Braford heifers with excitable temperaments. The increase in meal eating rate of Simbrah heifers as initial REV increase occurred as the magnitude of the reduction in time spent consuming meals was greater than the reduction in DMI:BW$^{0.75}$ compared to the other 3 breeds.

On average, heifers with excitable temperaments had 9% shorter HD duration, 8% shorter BV duration, and tended ($P = 0.08$) to have longer TTB than heifers with calm temperaments. The longer TTB for heifers with excitable temperaments would suggest that these heifers were more reluctant to approach the feed bunk following feed delivery then calm heifers. Bunk visit frequency and BV eating rate were similar between calm and excitable heifers. As BV eating rate is derived from DMI and BV duration, the lack of significance between BV eating rate and the initial REV covariate indicates

Table 3. Effects of temperament and breed on feeding behavior traits in finishing heifers

Item[1]	Temperament[2]			Breed[3]					*P*-value		
	Calm	Excitable	SE	Angus	Braford	Brangus	Simbrah	SE	Temp	Breed	Temp × breed
Bunk visit traits											
Head-down duration, min	40.4	36.7	3.6	42.5[a]	35.0[b]	42.6[a]	34.0[b]	2.4	0.05	0.001	0.01
BV frequency, events per day	66.39	64.26	3.05	63.88	64.42	65.21	67.76	2.05	0.11	0.15	0.47
BV duration, min/d	65.41	59.89	4.04	70.49[a]	57.50[b]	66.61[a]	55.95[b]	2.74	0.003	0.001	0.01
BV eating rate, g/min	160.2	162.0	11.7	143.4[a]	162.9[a]	153.0[a]	185.2[b]	7.9	0.79	0.001	0.26
Time-to-bunk, min	134.0	150.6	13.5	134.5	145.3	144.5	145.2	9.0	0.09	0.69	0.28
Meal traits											
Meal frequency, events per day	10.17	10.57	0.76	9.34[a]	10.92[b]	10.97[b]	10.25[ab]	0.51	0.23	0.01	0.98
Meal duration, min/d	138.7	126.8	7.5	136.9[bc]	123.0[a]	141.6[b]	129.3[c]	5.0	0.002	0.001	0.06
Meal length, min per event	17.77	14.57	1.95	18.61[a]	13.53[b]	19.20[a]	16.32[a]	1.31	0.001	0.001	0.09
Meal size, kg per event	1.32	1.12	0.12	1.44[a]	1.03[b]	1.14[bc]	1.28[ac]	0.08	0.001	0.001	0.06
Meal eating rate, g/min	72.68	74.30	3.88	73.6[ab]	79.9[ab]	70.9[a]	76.5[b]	2.6	0.83	0.07	0.02
BV per meal, events per meal	7.58	6.77	0.61	7.61[a]	6.58[b]	6.69[b]	7.81[a]	0.41	0.001	0.00	0.58

[a–c]Means in the same row with unlike superscripts differ at $P < 0.05$.

[1]BV = bunk visit.

[2]Calm and excitable temperament means were computed at mean initial REV (0.0 ± 0.21 SD m/s) minus and plus 1 SD, respectively.

[3]Angus (*n* = 63), Braford (*n* =116), Brangus (*n* = 122), and Simbrah (*n* =110).

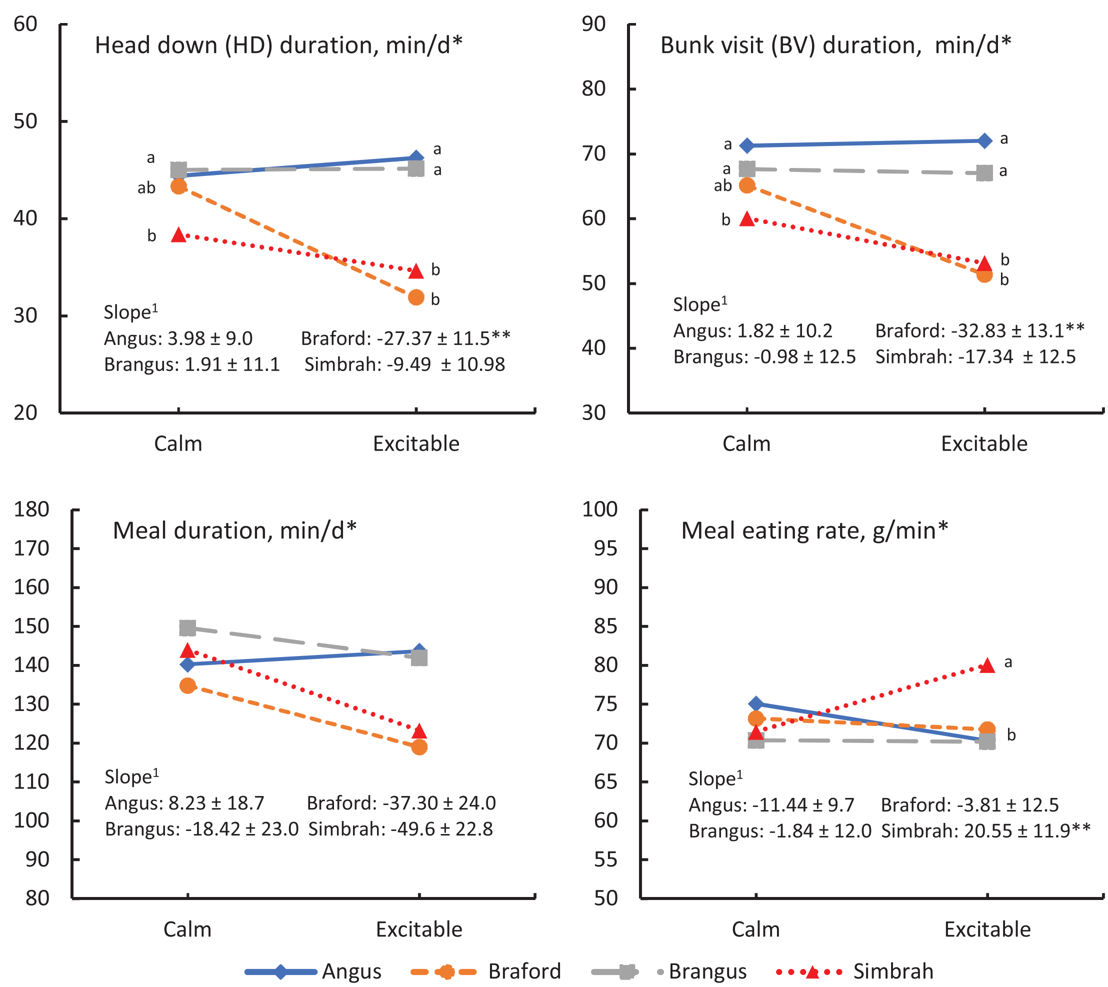

Figure 2. Effects of temperament and breed on HD, BV duration, meal duration, and meal eating rate. *Indicates that there was an initial REV × breed ($P < 0.05$). [1]Slope of initial REV covariate ± SE for each breed. **Slopes of Braford, Brangus, or Simbrah differed ($P < 0.05$) from Angus. [a–c]Indicate difference ($P < 0.05$) between breed subclass means.

that excitable heifers were consuming less feed, in shorter BV events, than calm heifers. Nkrumah et al. (2007) found that EV was not significantly correlated with any of the feeding behavior traits measured (BV duration and frequency, and HD duration) among Angus-, Charolais-, and Hybrid-sired steers. However, consistent with the current study, Nkrumah et al. (2007) found that DMI decreased as EV increased, suggesting that excitable calves in their study consumed feed at a faster rate than calm calves.

Although meal frequency was not affected by temperament or temperament × breed interaction ($P > 0.05$), the length of meal events was 18% shorter and size of meals 15% smaller in excitable heifers compared to calm heifers (Table 3). As such, daily meal duration was 9% shorter and DMI 7% less in excitable heifers compared to calm heifers. Additionally, calm heifers had a greater ($P < 0.001$) frequency of BV events per meal than excitable heifers.

Breed affected several of the feeding behaviors including HD duration, BV duration, and BV eating rate. Angus and Brangus heifers had greater ($P < 0.05$) HD duration and BV durations than Braford and Simbrah heifers, and BV eating rate was greater ($P < 0.05$) for Simbrah heifers than the other 3 breeds. Kayser and Hill (2013) also reported breed differences in feeding behavior traits between Angus and Hereford bulls. In their study, Angus bulls had greater HD duration than Hereford bulls even though BV frequency did not differ between the 2 breeds. Breed also affected ($P < 0.001$) meal frequency, duration, length, and size, such that Angus heifers had fewer meal events per day than either Braford or Brangus, and Simbrah heifers were intermediate. Further, length of individual meal events was shorter for Braford cattle than for the other 3 breeds, consistent with the lesser DMI observed in the Braford heifers.

Effect of Temperament and Breed on Ultrasound Carcass and Slaughter Carcass Traits

The effects of temperament and breed on ultrasound carcass traits, carcass characteristics, and carcass value and income are presented in Table 4. Initial REV was a significant covariate ($P < 0.05$) for final ultrasound BF depth and percentage IMF, such that calm heifers had 8% greater BF depth and 3% greater percentage IMF than excitable heifers. Temperament did not interact ($P > 0.1$) with breed to impact carcass ultrasound traits. Nkrumah et al. (2007) reported that EV was not correlated with ultrasound BF depth and IMF, although EV was positively correlated ($r = 0.22$) with LMA among Angus-, Charolais-, and Hybrid-sired steers. These differences in ultrasound carcass composition suggest that temperament altered rate as well as composition of gain during this study. Breed affected final ultrasound LMA, such that LMA was greater ($P < 0.05$) in Brangus then Braford heifers, with Brangus and Simbrah heifers being intermediate ($P < 0.001$). Final ultrasound BF depth was less ($P < 0.05$) in Simbrah heifers than the other 3 breeds ($P < 0.001$), and final ultrasound IMF was less ($P < 0.05$) in Simbrah than Angus heifers, with Braford and Brangus heifers being intermediate.

Excitable heifers had 4% lighter ($P < 0.001$) HCW, 6% less ($P < 0.05$) BF depth, and tended ($P = 0.09$) to have 2% greater LMA than calm heifers (Table 4). However, there was no temperament × breed interactions among these or other carcass traits. Previous studies have also reported finding that cattle with calm temperaments produced heavier carcasses then excitable cattle (Burrow and Dillon, 1997; Nkrumah et al., 2007; Reinhardt et al., 2009; Cafe et al., 2011; Francisco et al., 2015). The LMA tended ($P = 0.09$) to be higher, and YG tended ($P = 0.07$) to be lower in calm vs. excitable heifers. Both Behrends et al. (2008) and Cafe et al. (2011) reported significant increases in LMA of calm cattle compared to excitable cattle, and Café et al. (2011) found that carcasses from calm cattle had greater BF depth than those from excitable cattle.

Marbling scores were not affected by the initial REV covariate ($P = 0.17$), despite the fact that calm cattle had greater BF depth. Likewise, lean and bone maturity scores (data not shown) and USDA QG ($P = 0.15$) were not affected by initial REV. The proportion of carcasses grading USDA Choice or higher was numerically greater ($P = 0.18$) in heifers classified as having calm temperaments (63.5%) compared to heifers with excitable temperaments (55.5%; data not shown). Francisco et al. (2015) reported that calm Nellore cattle had greater marbling scores than excitable Nellore cattle. Furthermore, Reinhardt et al. (2009) found that feedlot cattle with more excitable temperaments produced a lower proportion of carcasses grading choice or higher than cattle with calm temperaments.

Breed differences in LMA and BF depth largely reflect the differences noted in carcass ultrasound traits, except that Simbrah heifers had larger LMA than Angus heifers. Simbrah heifers also produced carcasses with the least BF depth, and consequently had the highest-yielding ($P < 0.05$) carcasses

Table 4. Effects of temperament and breed on carcass ultrasound traits, carcass characteristics, and economic value in finishing heifers

	Temperament[5]			Breed[6]					*P*-value		
Item[1]	Calm	Excitable	SE	Angus	Braford	Brangus	Simbrah	SE	Temp	Breed	Temp × breed
Carcass ultrasound traits											
Final LMA, cm²	64.33	63.96	1.70	64.52^{ac}	60.70^{b}	66.92^{a}	64.44^{c}	1.14	0.34	0.001	0.8
Final BF thickness, cm	0.66	0.61	0.05	0.72^{a}	0.67^{a}	0.67^{a}	0.49^{b}	0.03	0.02	0.001	0.98
Final IMF, %	3.91	3.68	0.17	4.69^{a}	3.61^{b}	3.84^{b}	3.05^{c}	0.12	0.001	0.001	0.37
Carcass characteristics											
Hot carcass weight, kg	289.1	278.0	6.2	284.0^{a}	268.6^{b}	285.5^{a}	296.1^{c}	4.2	0.001	0.001	0.18
BF depth, cm	1.23	1.16	0.08	1.34^{a}	1.30^{a}	1.25^{a}	0.88^{b}	0.06	0.05	0.001	0.72
LMA, cm	75.06	73.74	1.67	74.87^{a}	69.83^{b}	74.81^{a}	78.07^{c}	1.13	0.09	0.001	0.74
KPH, %	2.29	2.27	0.13	2.25	2.22	2.32	2.35	0.09	0.55	0.299	0.29
USDA yield grade	2.86	2.76	0.13	2.92^{a}	3.00^{a}	2.87^{a}	2.45^{b}	0.09	0.07	0.001	0.69
Marbling[2]	450	439	21	510^{a}	406^{b}	443^{c}	418^{bc}	11	0.17	0.001	0.25
USDA quality grade[3]	408	402	10	433^{a}	387^{b}	405^{c}	395^{bc}	7	0.15	0.001	0.19
Warner-Bratzler shear (WBS) force											
WBS force (1 d), kg	3.42	3.70	0.22	3.35^{a}	3.75^{b}	3.44^{ab}	3.70^{b}	0.15	0.002	0.02	0.26
WBS force (14 d), kg	2.25	2.41	0.13	2.25	2.41	2.31	2.34	0.90	0.003	0.33	0.44
Carcass value											
Carcass value, \$/kg (Grid 1)[4]	4.61	4.58	0.05	4.69^{a}	4.48^{b}	4.60^{c}	4.62^{ac}	0.03	0.15	0.001	0.16
Income, \$ per animal (Grid 1)	1,334	1,278	40	$1{,}337^{ab}$	$1{,}208^{c}$	$1{,}306^{a}$	$1{,}373^{b}$	27	0.001	0.001	0.19
Carcass value, \$/kg (Grid 2)[4]	4.67	4.63	0.05	4.75^{a}	4.53^{b}	4.65^{c}	4.68^{ac}	0.03	0.08	0.001	0.11
Income, \$ per animal (Grid 2)	1,354	1,292	38	$1{,}352^{ab}$	$1{,}223^{c}$	$1{,}330^{a}$	$1{,}388^{b}$	25	0.001	0.001	0.17

[a–c]Means in the same row with unlike superscripts differ at $P < 0.05$.

[1]LMA = loin muscle area; BF = back fat; IMF = intramuscular fat; KPH = kidney, pelvic, and heart fat.

[2]300 = Slight[00]; 400 = Small[00]; 500 = Modest[00]; 600 = Moderate[00].

[3]300 = Select[00]; 400 = Choice[00]; 500 = Prime[00].

[4]Grid 1 was based on 3-yr average premiums and discounts for carcass weight, and USDA YG and QG; Grid 2 was the same, with additional premiums or discounts for tenderness.

[5]Calm and excitable temperament means were computed at mean initial REV (0.0 ± 0.21 SD m/s) minus and plus 1 SD, respectively.

[6]Angus (n = 63), Braford (n =116), Brangus (n = 122), and Simbrah (n =110).

(Table 4). Angus heifers had higher ($P < 0.001$) quality carcasses, with 86% grading USDA QG of Choice or higher (data not shown) compared to 51% in Braford heifers, with Brangus and Simbrah being intermediate.

Consumer acceptance of beef products is impacted by tenderness, and consumers are willing to pay premiums for beef products which are more likely to be tender. Warner-Bratzler shear force was 8% lower ($P < 0.05$; Table 4) in calm vs. excitable heifers at day 1 of postmortem aging, and 7% lower ($P < 0.003$) at day 14 postmortem aging. As with other carcass traits, temperament did not interact ($P > 0.1$) with breed to impact carcass WBS force. Ninety-three percent of heifers classified as calm temperament had WBS force less than 3.0 kg at day 14 postmortem aging compared ($P < 0.05$) to 80% of heifers classified as excitable temperament (data not shown). Similarly, Fordyce et al. (1988), King et al. (2006), Behrends et al. (2008), and Voisinet et al. (1997a) reported that carcasses from cattle with more excitable temperaments had greater WBS force values than carcasses from calm cattle. Among Angus, Angus-cross, and Bonsmara-sired steers, King et al. (2006) reported that excitable steers had tougher steaks with shorter sarcomeres than calm steers. Petherick et al. (2002) reported a small negative correlation between carcass pH and temperament among *B. indicus*-cross steers, and that 12% more carcasses from excitable steers were subject to heat shortening than carcasses from calm steers. Petherick et al. (2002) suggested that cattle with excitable temperaments might be more susceptible to heat shortening due to antemortem stress levels, which could explain some of the difference in tenderness among temperament groups in the current study.

Miller et al. (2001) reported that consumers were willing to pay a premium of \$1.08/kg for steaks with WBS force values less than 3 kg, compared to steaks with WBS force greater than 4.9 kg. Similarly, Boleman et al. (1997) found that consumers were able to differentiate between 3 toughness levels, and would be willing to pay premiums for more tender beef. Carcass value ($/kg) was not affected by temperament based on Grid 1, although the initial REV covariate tended (P = 0.08) to be significant for carcass value based on Grid 2 (Table 4). However, carcass income ($ per animal) was affected ($P < 0.001$) by the initial REV covariate based on both Grid 1 and 2, with carcass income being 4% to 5% higher for calm than excitable heifers. Few studies have examined the effects of temperament on carcass value, and further research could be performed to elucidate the impact that temperament has on overall profitability of feedlot cattle and resulting carcasses.

On day 1 postmortem aging, WBS force scores were lower ($P < 0.05$) for Angus heifers than Braford and Simbrah heifers, with Brangus heifers being intermediate. However, at day 14 postmortem aging, breed differences in WBS force were no longer detected. Among steers and heifers representing multiple *B. indicus* and *B. taurus* breeds, O'Connor et al. (1997) reported that the SD of WBS force values decreased with increasing postmortem aging time, which implied that aging reduced tenderness variation between and within breeds. Breed significantly impacted carcass value based on both grids, such that Angus heifers generated $0.21 more per kg of HCW ($P < 0.001$; Table 4) than Braford heifers, with Simbrah and Brangus heifers being intermediate.

Results from this study demonstrate that there were considerable differences in performance, production efficiency, feeding behavior, and carcass merit between cattle with divergent temperament phenotypes. Further research is warranted to investigate the use of management systems that sort and manage feeder calves based on feedlot-arrival temperament to reduce variation in growth efficiency and carcass quality, thereby improving predictability of feedlot performance and consistency of beef quality.

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