Evaluation of tropically adapted straightbred and crossbred beef cattle: Cortisol concentration and measures of temperament at weaning and transport^{1,2,3}

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ABSTRACT: The objective of this research was to evaluate circulating concentrations of plasma cortisol and measures of temperament at weaning in calves (steers and heifers) and at transport in steers. Calves ($n = 993$) were produced from a 3-breed diallel mating design that included calves from 3 consecutive years. Breed types of calves were straightbred Angus (A), Brahman (B), and Romosinuano (R) and all F_1 crossbred combinations (AB, BA, AR, RA, BR, and RB). At weaning (d 0) and at 24 and 72 h after weaning, blood was sampled from calves and the plasma was stored for later cortisol assay. Additionally, at each of these times, temperament was assessed as chute score, exit velocity, and pen score. About 1 mo later, steer calves ($n = 471$) were sampled before shipment, at arrival, and at 24 h, 72 h, 2 wk, and 4 wk after shipment (2,025 km; Brooksville, FL, to El Reno, OK). At each of these sampling times, blood was collected and plasma was stored for subsequent cortisol assay and temperament was assessed by measurement of exit velocity. At both weaning and transport, plasma concentrations of cortisol did not significantly differ ($P > 0.05$) among straightbreds or among crossbreds. Significant ($P < 0.05$) positive

genetic effects were observed for plasma concentration of cortisol at weaning (heterosis for BA and direct Romosinuano effect) and transport (heterosis for RA, BR, and BA; direct Romosinuano effect; and maternal Angus effect). Assessment of temperament using the objective measurement of exit velocity or the subjective measures of chute score or pen score (1 [lowest] to 5 [highest excitability] scale, based on behavior in chute and behavior in pen with human observer, respectively) generally provided similar results: Brahman was higher than Brahman crosses, which were higher than Angus, Romosinuano, and their reciprocal crosses. For exit velocity, however, Brahman did not differ from Brahman crosses and Angus did not differ from Romosinuano or Brahman crosses. At transport, sire breed and dam breed affected exit velocity of steers, with higher ($P < 0.05$) estimates for Brahman than for Romosinuano or Angus. These data suggest that weaned calves and shipped steers of various breed types show a similar response to stressors in cortisol concentration. In contrast, in assessing temperament or behavioral response to humans, Romosinuano and Angus had better temperaments and were less excitable than Brahman.

Key words: Brahman, cortisol, exit velocity, Romosinuano, temperament, weaning

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doi:10.2527/jas2017.1924

¹This research was conducted at the former USDA, Agricultural Research Service, Subtropical Agricultural Research Station, Brooksville, FL 34601.

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Received July 14, 2017.

Accepted October 16, 2017.

INTRODUCTION

Extensive use of tropically adapted breed types throughout the Southern United States has primarily been achieved through the use of purebred and crossbred American Brahman and Brahman-derivative breeds. Brahman crosses and the superiority of the F_1 Brahman cow in particular are at least partially attributable to maximizing heterosis; tolerance to heat, humidity, and parasites; and the ability to utilize poor quality forage resources. Increased interest in tropically adapted *Bos taurus* breeds for comparison with the Brahman breed has evolved over the last 30 yr. The Romosinuano is a “criollo” breed native to Colombia and is purported to be highly fertile under hot, humid tropical conditions (Molina et al., 1982; de Alba, 1987; Martinez Correal, 1995). Typically, breed type evaluations characterize animal performance through the major phases of beef production. Other factors such as stress response, that is, how an animal reacts to a stressor (e.g., weaning, transport to back grounding or finishing systems), and temperaments, that is, the response of an animal to handling by humans, are also important considerations in breed type evaluations.

Circulating concentrations of cortisol are commonly used as an indicator of stress response (Sapolsky et al., 2000). Assessment of temperament in cattle has been expanded by the addition of a tool to objectively measure flight speed or exit velocity (Burrow et al., 1988; Curley et al., 2006; Cooke, 2014). Exit velocity and subjective measures of temperament (e.g., chute score and pen score) have been used to assess temperament and have been related to production traits including feedlot gain (Voisinet et al., 1997b; Petherick et al., 2002; Vetter et al., 2013), carcass quality (Nkrumah et al., 2007; Vann et al., 2008; Cafe et al., 2011), and meat quality (Voisinet et al., 1997a; King et al., 2006). Others have used exit velocity as an indicator of temperament throughout various stages of the cow–calf production system (Cooke, 2014); however, an objective measure of temperament assessed around weaning may be a beneficial criterion for selection of replacement animals. The objective of this research was to determine the effect of stressors (weaning and transport) on plasma concentrations of cortisol and measures of temperament in Angus, Brahman, and Romosinuano straightbred and crossbred calves.

MATERIALS AND METHODS

Animals and Management

All procedures involving animals were approved by the USDA-ARS Subtropical Agricultural Research Station institutional animal care and use commit-

tee (weaning through shipment) and the USDA-ARS Grazinglands Research Laboratory institutional animal care and use committee (transport through backgrounding). Calves were born at the Subtropical Agricultural Research Station (28°37'34" N and 82°21'36" W) near Brooksville, FL. These calves were part of a larger project, an evaluation of Romosinuano that included Angus and Brahman for comparison and consisted of the evaluation of the 3 straightbreds and all F_1 combinations (i.e., reciprocals and 6 additional breed types). The overall breeding design and management criteria were previously reported (Riley et al., 2007). Straightbred and crossbred calves were born in spring from 2002 through 2004. Calves were tattooed on an ear and tagged within 24 h of birth, and bull calves were castrated at that time. Calves ($n = 993$) were weaned at approximately 7 mo of age in September of each year during a 3-wk period. Each week corresponded to the weaning of calves at 1 of 3 locations at the Subtropical Agricultural Research Station. Cow breeds and breed combinations of calves were balanced across locations. A total of 12, 11, and 15 Angus, Brahman, and Romosinuano bulls, respectively, sired calves, with an average of 28, 32, and 23 calves per Angus, Brahman, and Romosinuano sire, respectively. Weaned calves were provided a commercial preconditioning concentrate (medicated; 14% CP as-fed basis, cottonseed/soybean meal–based ration; 1.8 kg per calf per day) for 21 d and free-choice grass hay. Approximately 28 d after weaning, the steers ($n = 471$) were transported 2,025 km to the USDA-ARS Grazinglands Research Laboratory (35°33'43" N and 98°2'67" W) near El Reno, OK. Within each year, 2 truckloads of steer calves were loaded consecutively and transported. Each truckload was balanced with approximately the same numbers of calves and breed types as much as possible within weight restrictions.

Procedures

At weaning, calves entered the squeeze chute and were assigned a chute score of 1 to 5 during processing without their head restrained (1 = calm, no movement; 2 = restless shifting; 3 = squirming, occasionally shaking of device (squeeze chute or scale); 4 = continuous vigorous movement; and 5 = 4 and rearing, twisting, or violently struggling) as adapted from Grandin (1993). A blood sample was obtained through jugular venipuncture into a tube (9 mL) containing EDTA (Sarstedt, Inc., Newton, NC). Each tube containing blood was capped and inverted 3 times and placed in a rack on ice in an insulated cooler. All blood samples were centrifuged ($1750 \times g$ for 30 min at 4°C) on return to the laboratory, and plasma was stored at -20°C until assay for cortisol.

As an animal exited the squeeze chute, it passed through an infrared sensor that triggered a remote electronic counting apparatus to start the timer; as that animal progressed farther down the alley, it passed through a second infrared sensor (approximately 1.8 m) that triggered the remote electronic apparatus to stop the timer (FarmTek, Inc., North Wylie, TX; as described for flight speed by Burrow et al. [1988]). Exit velocity was calculated as the distance between light beams (1.8 m) divided by the elapsed time (seconds; i.e., m/s).

Calves continued through the chute and then were diverted from the alley into a pen that led to a second pen. A single observer assessed pen temperament score; each calf was usually assessed when the calf was by itself. Pen temperament scores were based on a 1 to 5 score as described previously (Hammond et al., 1996; 1 = nonaggressive [docile; walks slowly, can approach closely, not excited by humans or facilities]; 2 = slightly aggressive [runs along fences, will stand in corner if humans stay away, may pace fence]; 3 = moderately aggressive [runs along fences, head up and will run if humans move closer, stops before hitting gates and fences, avoids humans]; 4 = aggressive [runs, stays in back of group, head high and very aware of humans, may run into fences and gates even with some distance, will likely run fences if alone in pen]; and 5 = very aggressive [excited, runs into fences, runs over humans and anything else in path]) and adapted from Kunkle et al. (1986).

All of the aforementioned procedures were conducted on all calves at weaning, at 24 h after weaning, and at 72 h after weaning. Additionally, about 1 mo later, on only the steer calves ($n = 471$), a blood sample was collected and exit velocity was measured just prior to the steers being loaded on a commercial truck for shipment to El Reno, OK (2,025 km). Upon arrival, calves were unloaded and a blood sample was taken and exit velocity was measured (as previously described at weaning and shipment) and again at 24 and 72 h after arrival and at 2 and 4 wk after arrival. Also after arrival and initial processing, cattle were blocked by breed type and one-half of the steers of each breed type were randomly allotted to a second group (2 groups). During the 28-d receiving phase at El Reno, each group of calves was similarly managed and placed in drylot or in small grass pasture (dormant warm season grass). Calves had ad libitum access to hay (warm season grass hay) and were limit fed a 20% CP supplement to achieve an ADG of 0.9 kg.

Plasma Concentration of Cortisol

The concentration of cortisol in plasma samples was determined using a single-antibody RIA procedure

adapted from Willard et al. (1995). The cortisol antiserum cross-reacts with 60% corticosterone, 48% deoxycorticosterone, 0.01% progesterone, and 0.01% estradiol. The detection limit of the assay was 0.07 ng/mL, and the intra-assay CV was 8.12% and interassay CV was 11.88%.

Statistical Analysis

Data were analyzed using mixed linear models with the MIXED procedures of SAS (SAS Inst. Inc., Cary, NC). Data were grouped into 2 sets for separate analyses: 1) calves at weaning and 2) steers at shipment. Sampling time and the interaction of sampling time with breed type (sire breed $\times$ dam breed interaction) were fixed effects of special interest in analyses of both data sets. Calf sampling times included weaning, 24 h after weaning, and 72 h after weaning. There were 6 steer sampling time levels: shipment, arrival, 24 and 72 h after arrival, and 2 and 4 wk after arrival. Other fixed effects investigated included source of Angus sire (Riley et al., 2011), year of record, location (3 farms; approximately 10 km separated the 2 farthest), the age of the calf's dam in years (age 3 through 16 yr; ages 6 through 9 yr were combined into a single group and ages 13 yr and older were combined), age of calf as a linear covariate, and interactions. Sex of calf was included as a fixed effect in analyses of weaning data. Fixed effects with F ratios with $P < 0.05$ were kept for final analyses. Calf (or steer) and sire of calf (steer) within sire breed were random terms. Covariances between repeated records of animals across sampling times within each analysis were modeled investigating various structures using procedures described by Littell et al. (2002) and implemented as previously detailed (Qiu et al., 2007). Briefly, the investigated covariance structures included a single residual variance and then several structures with increasing complexity (compound symmetry, heterogeneous compound symmetry, and first order antedependence). Information criterion values generated by SAS were considered for selection of final covariance structures, but our intent was to primarily use Schwarz's Bayesian information criterion values to select the final structure because it incorporates penalties for inclusion of model effects that make it a conservative model assessment.

Similar models were applied separately to phenotypes of cows: exit velocity and chute temperament score (obtained at weaning). Residual values for each dam were produced from models that included year, location, age in years, breed, and sampling time. Sire of cow and cow were included in those models as random effects. Residual values for dam chute score were included in additional models of calf chute and pen temperament score as continuous variables. Residual

Table 1. Number of calves and records for mean cortisol concentration, mean exit velocity, and mean temperament scores at weaning by breed group¹

Breed group ²	Calves	Records	Cortisol, ng/mL	Exit velocity, m/s	Chute score	Pen score
Romosinuano	156	465	36.54 (1.112) ^{wx}	1.70 (0.070) ^w	1.58 (0.036) ^w	2.32 (0.058) ^w
Brahman	87	263	33.00 (1.513) ^{wx}	2.61 (0.092) ^y	2.42 (0.049) ^y	3.22 (0.076) ^z
Angus	79	237	30.71 (1.530) ^w	1.96 (0.093) ^{wx}	1.53 (0.050) ^w	2.13 (0.078) ^w
RA	97	290	38.25 (1.317) ^x	1.95 (0.081) ^w	1.70 (0.043) ^w	2.36 (0.068) ^w
AR	155	466	32.71 (1.245) ^{wx}	1.93 (0.077) ^w	1.67 (0.041) ^w	2.37 (0.063) ^{wx}
RB	83	249	36.66 (1.408) ^{wx}	2.27 (0.086) ^{xy}	2.01 (0.045) ^x	2.69 (0.072) ^y
BR	156	468	35.08 (1.334) ^{wx}	2.21 (0.082) ^x	2.02 (0.044) ^x	2.65 (0.066) ^{xy}
BA	89	266	37.89 (1.534) ^x	2.55 (0.093) ^{xy}	2.09 (0.050) ^x	2.81 (0.076) ^y
AB	91	272	32.80 (1.461) ^{wx}	2.46 (0.089) ^{xy}	2.18 (0.048) ^x	2.79 (0.073) ^y
Total ³	993	2,976				

^{w-z}Within a trait (column), means with different superscripts differ ($P < 0.05$).

¹Least squares means (SE).

²Straightbred breed groups are spelled out and crossbreds are indicated by pairs of letters that represent sire and dam, respectively: A = Angus; B = Brahman; R = Romosinuano.

³Total calves and records are depicted for cortisol concentration. For exit velocity, there were 1,002 calves and 2,999 records. For chute score, there were 1,003 calves and 3,000 records. For pen score, there were 1,002 calves and 2,987 records.

values of dam exit velocity were investigated as continuous variables in analyses of calf (and steer) exit velocity and cortisol values. Regression coefficients for these continuous variables were the only results summarized from these subsequent analyses.

Contrasts of least squares means were constructed to estimate breed direct, breed maternal, and heterosis effects for each trait (Dickerson, 1973). Maternal breed effects were estimated as the average difference between reciprocal crossbred groups: the Romosinuano maternal effect is $1/2[(AR - RA) + (BR - RB)]$, in which pairs of letters indicate calf breed group means, and the first and second letters indicate the breed of sire and dam of calves in the group, in which R, B, and A indicate Romosinuano, Brahman, and Angus, respectively. Direct breed effects for each breed were estimated as the purebred mean minus the maternal effect for that breed minus the average of the other 2 pure breeds; for example, Romosinuano direct breed effects were estimated by $RR - 1/2[(AR - RA) + (BR - RB)] - 1/2[(AA + BB)]$. Within a trait, the estimates of breed direct or maternal effects sum to 0. Estimates of heterosis for pairs of breeds for each trait consisted of a contrast between the averages of the crossbred and purebred groups; for example, the heterosis for Romosinuano and Brahman was estimated by $1/2[(RB + BR) - (RR + BB)]$. Pairwise differences of least squares means were assessed using *t*-tests with Bonferroni adjustments.

RESULTS

Number of calves and records at weaning (at weaning and at 24 and 72 h after weaning) for the mean plasma concentration of cortisol by breed type

are presented in Table 1. The mean plasma concentration of cortisol at weaning was affected by sire breed ($P < 0.005$), year ($P < 0.0001$), sex ($P < 0.0001$), sampling time ($P < 0.0001$), and weaning age ($P = 0.039$) and was influenced by the sire breed $\times$ dam breed interaction ($P = 0.038$). Location tended ($P = 0.062$) to affect the plasma concentration of cortisol near weaning. The mean plasma concentration of cortisol did not significantly differ among straightbred calves; however, numerically, plasma concentrations of cortisol were highest for Romosinuano calves, intermediate for Brahman calves, and lowest for Angus calves (Table 1). There were no significant differences in the plasma concentration of cortisol at weaning between or among reciprocal cross calves. Plasma concentrations of cortisol were numerically highest for RA and BA calves, which did not differ from one another, but both were higher ($P < 0.05$) than for Angus calves. Significant genetic effects for the mean plasma concentration of cortisol near weaning included a heterosis estimate of 3.49 ng/mL for BA, which was an 11% increase; a direct Romosinuano effect of 8.23 ng/mL; an Angus direct effect of -9.37 ng/mL; and a maternal Romosinuano effect of -3.56 ng/mL (Table 2).

Plasma concentrations of cortisol at weaning were influenced by day of sampling ($P < 0.0001$); the least ($P < 0.05$) concentrations were observed at weaning and the greatest concentrations were observed 24 h after weaning (Table 3). By 72 h, concentrations declined but not to levels observed at weaning. Heifers had higher ($P < 0.05$) plasma concentrations of cortisol than steers, but age of the calf's dam did not significantly affect cortisol concentrations. Age at weaning affected ($P = 0.039$) plasma concentrations of cortisol at weaning, and for

Table 2. Estimates of genetic effects for cortisol concentration, exit velocity, and temperament scores in calves at weaning^{1,2}

Effect	Cortisol, ng/mL	Exit velocity, m/s	Chute score	Pen score
Heterosis				
Romosinuano–Angus			0.13 (0.033) 8.4%	0.14 (0.054) 6.3%
Brahman–Romosinuano				–0.11 (0.055) –4%
Brahman–Angus	3.49 (1.162) 11%	0.23 (0.070) 10.1%	0.17 (0.037) 8.6%	0.13 (0.062) 2.4%
Direct				
Romosinuano	8.23 (2.505)	–0.54 (0.150)	–0.38 (0.083)	–0.34 (0.118)
Brahman		0.80 (0.171)	0.82 (0.010)	0.99 (0.136)
Angus	–9.37 (2.82)		–0.45 (0.092)	–0.65 (0.130)
Maternal				
Romosinuano	–3.56 (1.420)			
Brahman				
Angus				

¹Least squares means (SE). Heterosis also expressed as %. Should read “Least squares means (SE). Heterosis also expressed as %.

²Empty cells indicate effects that did not differ ($P > 0.05$) from 0.

each 1 d increase in age at weaning there was a 0.027 ± 0.013 ng/mL increase in plasma cortisol concentration. Subsequent analyses indicated that for each 1-unit increase in the residual value of exit velocity of the dam, there was a corresponding 7.39 ± 1.81 ng/mL increase in the plasma cortisol concentration in her calf. All information criterion values favored a compound symmetry structure to model the covariance among repeated records. Such a structure models a single variance term for all sampling dates, and the covariance structure is modeled by estimation of a single correlation value for records of a subject on all pairs of sampling days. This within-calf correlation modeled was 0.21.

Measures of temperament at weaning (i.e., exit velocity, chute score, and pen score) were affected by sire breed (all $P < 0.0001$) and dam breed (all $P < 0.0001$) and were influenced by the sire breed $\times$ dam breed interaction ($P = 0.008$ for exit velocity, $P < 0.0001$ for chute score, and $P = 0.002$ for pen score). In straightbred calves at weaning, measures of temperament were greater ($P < 0.05$) for Brahman than for Romosinuano or Angus (Table 1). No significant differences in temperament measurements were observed between Romosinuano and Angus calves. Measures of temperament also were consistent among reciprocal crosses; RA and AR had lower ($P < 0.05$) exit velocities, chute scores, and pen scores (except AR for pen score) than reciprocal Brahman crosses (RB, BR, BA, and AB). Furthermore, measures of temperament for RA and AR did not differ from those for Romosinuano and Angus and were lower ($P < 0.05$) than those for Brahman. In contrast, measures of temperament for reciprocal Brahman crosses for exit velocity did not differ from Angus and all except BR did not differ from Brahman. For chute and pen scores, reciprocal Brahman crosses did not differ from one another but differed ($P < 0.05$)

from all straightbreds. Therefore, the Brahman reciprocal crosses had higher ($P < 0.05$) chute and pen scores compared with Angus or Romosinuano calves but lower ($P < 0.05$) chute and pen scores than Brahman.

Significant genetic effects were observed for temperament traits at weaning (Table 2). Estimated heterosis for BA for exit velocity was 10.1%. Direct effects for exit velocity were negative for Romosinuano and positive for Brahman. For chute score, estimates of heterosis were 8.4% for RA and 8.6% for BA. Direct effects for chute score for Romosinuano and Angus were negative and were positive for Brahman. For pen score, estimates of heterosis were 6.3% for RA, –4% for BR, and 2.4% for BA. The heterosis estimate of –4% for pen score for BR is the only negative or favorable significant genetic effect noted for Brahman. Direct effects for pen score were negative for Romosinuano and Angus and positive for Brahman.

At weaning, time of sampling affected exit velocity ($P < 0.0001$), chute score ($P = 0.007$), and pen score ($P < 0.0001$). Exit velocity and chute score did not differ between weaning and 24 h after weaning, but exit velocity declined ($P < 0.05$) and chute score increased ($P < 0.05$) by 72 h after weaning (Table 3). Pen score was highest ($P < 0.05$) at weaning, declined ($P < 0.05$) 24 h after weaning, and continued to decline ($P < 0.05$) at 72 h after weaning. Calf sex affected exit velocity ($P = 0.0008$), chute score ($P < 0.0001$), and pen score ($P < 0.0001$) at weaning. Heifers had higher exit velocity ($P < 0.05$), chute score ($P < 0.05$), and pen score ($P < 0.05$) than steers. Age of dam affected calf exit velocity ($P = 0.03$) and pen score ($P = 0.04$). The highest exit velocity was recorded for calves from 11-yr-old dams, but it did not differ ($P > 0.05$) for calves from 3-, 4-, 5-, 12-, and 13-yr-old and older dams. No differences ($P > 0.05$) in age of dam were observed for pen score.

Table 3. Means for cortisol concentration, exit velocity, and temperament scores in calves at weaning as affected by sampling time, calf sex, and cow age¹

Item	Cortisol, ng/mL	Exit velocity, m/s	Chute score	Pen score
Sampling time				
Weaning	32.89 (0.722) ^w	2.19 (0.043) ^w	1.89 (0.024) ^w	2.73 (0.035) ^w
Weaning + 24 h	36.59 (0.722) ^x	2.23 (0.043) ^w	1.90 (0.024) ^w	2.56 (0.035) ^x
Weaning + 72 h	35.07 (0.720) ^y	2.13 (0.043) ^x	1.95 (0.024) ^x	2.49 (0.035) ^y
Calf sex				
Steers	32.28 (0.722) ^w	2.11 (0.046) ^w		2.49 (0.038) ^w
Heifers	37.42 (0.708) ^x	2.25 (0.045) ^x		2.70 (0.037) ^x
Cow age, yr				
3		2.16 (0.058) ^{wx}		2.55 (0.049)
4		2.20 (0.066) ^{wx}		2.66 (0.056)
5		2.18 (0.059) ^{wx}		2.58 (0.050)
6 through 9		2.17 (0.047) ^w		2.57 (0.039)
10		2.04 (0.101) ^w		2.38 (0.087)
11		2.48 (0.096) ^x		2.74 (0.083)
12		2.14 (0.111) ^{wx}		2.63 (0.096)
13 and older		2.09 (0.103) ^{wx}		2.65 (0.089)

^{w-y}Within an item and trait (column), means with different superscripts differ ($P < 0.05$).

¹Least squares means (SE).

Additionally, at weaning, exit velocity was affected by location ($P < 0.0001$) and year ($P < 0.0001$) but not age at weaning ($P = 0.26$), chute score was affected by location ($P < 0.0001$) and year ($P < 0.0001$) but not age at weaning ($P = 0.62$), and pen score was affected by age at weaning ($P = 0.0015$) but not by location ($P = 0.11$) or year ($P > 0.05$). For each 1-d increase in age at weaning, there was a -0.002 ± 0.001 unit decrease in pen score. Subsequent analyses indicated that for each 1-unit increase in residual value of exit velocity of the dam, there was a corresponding 0.34 ± 0.109 m/s increase in exit velocity of her calf. Similarly, for each 1-unit increase in residual value for dam chute score, there was a corresponding 0.216 ± 0.058 unit increase in chute score ($P = 0.0002$) and 0.19 ± 0.10 unit increase in pen score ($P = 0.0017$) of her calf. The residual covariances among records of calves for the different sampling times were best modeled with a compound symmetry structure, and the correlations modeled were 0.52 for exit velocity, 0.14 for chute score, and 0.44 for pen score.

In transported steers (sampled just prior to shipment, at arrival, and at 24 h, 72 h, 2 wk, and 4 wk after arrival), mean plasma concentrations of cortisol were affected by sire breed ($P = 0.004$), dam breed ($P = 0.049$), year ($P < 0.0001$), sampling time ($P < 0.0001$), and weaning age ($P = 0.0227$) and were influenced by the sire breed $\times$ dam breed interaction ($P < 0.0001$). Mean plasma concentrations of cortisol in transported steers did not significantly differ among straightbreds but were numerically highest for Romosinuano, intermediate for Brahman, and lowest for Angus (Table 4). In reciprocal crosses at transport, RA steers had higher ($P < 0.05$) plasma con-

centrations of cortisol than AR steers but did not differ from Brahman-reciprocal crosses. Plasma concentration of cortisol for RA steers was higher ($P < 0.05$) than for Brahman or Angus steers but did not differ ($P > 0.05$) from Romosinuano steers. Significant genetic effects for plasma concentration of cortisol in transported steers included heterosis estimates (mean and as % heterosis) of 3.51 ng/mL (12.6%) for RA, 2.54 ng/mL (8.7%) for BR, and 5.48 ng/mL (20.5%) for BA (Table 5). There was a positive Romosinuano direct effect and a negative Angus direct effect on cortisol concentration in plasma of transported steers. Maternal effects were negative for Romosinuano and positive for Angus for plasma cortisol concentrations of transported steers.

Time of sampling affected ($P < 0.0001$) concentrations of cortisol in transported steers. Plasma concentrations of cortisol in steers were highest ($P < 0.05$) just after arrival compared with all other sampling times (Table 6). Just prior to shipment and 24 h after arrival, concentrations of cortisol did not differ ($P > 0.05$) between times and were higher ($P < 0.05$) than at 72 h, 2 wk, and 4 wk after arrival. Plasma cortisol concentrations in steers declined ($P < 0.05$) from 72 h after arrival to 2 wk after arrival but then increased ($P < 0.05$) at 4 wk after arrival, which did not differ ($P > 0.05$) from 72 h after arrival (Table 6). For each 1-d increase in age at weaning, there was a corresponding increase of 0.029 ± 0.013 ng/mL cortisol in transported steers.

Exit velocity of transported steers was affected by sire breed ($P < 0.0001$), dam breed ($P < 0.0001$), year ($P = 0.0007$), and sampling time ($P < 0.0001$). The sire breed $\times$ dam breed interaction was not significant

Table 4. Number of steers transported and records for mean cortisol concentration by breed group and for exit velocity by sire breed and dam breed¹

Breed group	Steers	Records	Cortisol, ng/mL	Exit velocity, m/s ²	
				Sire breed	Dam breed
Romosinuano	75	419	30.32 (1.027) ^{wxy}	1.76 (0.054) ^w	1.81 (0.042) ^w
Brahman	42	238	28.19 (1.381) ^{wx}	2.30 (0.064) ^x	2.14 (0.053) ^x
Angus	37	207	25.24 (1.463) ^w	1.80 (0.060) ^w	1.91 (0.055) ^w
RA	44	243	34.36 (1.293) ^y		
AR	80	444	28.23 (1.072) ^{wx}		
RB	36	205	31.87 (1.431) ^{xy}		
BR	74	402	31.72 (1.155) ^{xy}		
BA	35	195	33.90 (1.546) ^{xy}		
AB	48	272	30.49 (1.304) ^{wxy}		
Total ³	471	2,625			

^{w-y}Within a trait (column), means with different superscripts differ ($P < 0.05$).

¹Least squares means (SE).

²The interaction of sire and dam breeds was not retained ($P = 0.101$) in the final model for exit velocity. Means presented are for the significant main effects of sire breed and dam breed.

³Total steers and records are depicted for cortisol concentration. For exit velocity, there were 471 steers with 2,618 records.

($P > 0.10$). For exit velocity of transported steers, the effect of sire breed was greater ($P < 0.05$) for Brahman than for Romosinuano or Angus (Table 4). The effect of dam breed was greater ($P < 0.05$) for Brahman than for Romosinuano or Angus. Sire breed effects and dam breed effects for exit velocity did not differ ($P > 0.10$) between Romosinuano and Angus, respectively.

Time of sampling ($P < 0.0001$) affected exit velocity in transported steers (Table 6). The greatest ($P < 0.05$) exit velocity occurred just prior to shipment compared with all other sampling times. Exit velocity was similar ($P > 0.05$) at arrival and through 72 h after arrival. Exit velocity was least ($P < 0.05$) at 2 and 4 wk after arrival.

Additional analyses indicated that for each 1-unit increase in residual value for exit velocity of the dam, there was a corresponding 0.48 ± 0.14 m/s increase ($P = 0.0006$) in exit velocity of her calf near transport. Also, for each 1-unit increase in residual value for exit velocity, there was a corresponding 4.6 ± 2.15 ng/mL increase in plasma cortisol concentration.

Information criterion values favored a heterogeneous compound symmetry structure to model covariances among repeated records on calves across the 6 sampling times. With this structure, a unique variances was modeled for each sampling day in analyses of both cortisol and exit velocity in steers near transport. Variances were numerically largest just prior to transport for exit velocity and at arrival for cortisol and then declined to numerically lowest values at 2 wk after arrival for cortisol and 4 wk after arrival for exit velocity (data not shown). The within-animal residual correlation of records on different sampling dates was modeled as 0.196 for cortisol and 0.478 for exit velocity.

DISCUSSION

Cortisol concentration in calves near weaning and in steers before and after transport did not significantly differ among straightbred groups or among the crossbred groups. Cortisol concentration is commonly used as an indicator of stress or stress response. In this research, a lack of significant difference in plasma cortisol among straightbreds and among crossbreds would suggest that these breed types responded similarly to the stressors associated with weaning and transport. Additionally, estimates of heterosis for plasma concentrations of cortisol were, however, significant and greater than 0 for Brahman–Angus crossbred calves at weaning and for transported steers. In one study, Angus $\times$ Hereford steers had lower baseline concentrations of cortisol than Angus $\times$ Brahman or Hereford $\times$ Brahman steers (Zavy et al., 1992). In another study, it was reported that Angus steers had lower cortisol values than Brahman $\times$ Angus steers when the data were averaged across treatments (Blecha et al., 1984). Angus heifers were reported to have lower plasma concentrations of cortisol than Brahman heifers (Hammond et al., 1996). Consistent with this study are others that reported no statistical difference between cortisol concentrations in Brahman vs. *B. taurus* bulls (Berardinelli et al., 1992; Chase et al., 1995) and steers (Browning and Leite-Browning, 2013), and in cows, Angus had greater cortisol concentrations than Brahman (Stahlinger et al., 1994). These latter studies were conducted with mature animals whereas the former studies used weaned to yearling cattle, as did the present study.

In a previous study, at summer sampling, there was no difference in cortisol concentrations between

Table 5. Estimates of genetic effects for cortisol concentration in transported steer calves^{1,2}

Effect	Cortisol, ng/mL
Heterosis	
Romosinuano–Angus	3.51 (1.109) 12.6%
Brahman–Romosinuano	2.54 (1.141) 8.7%
Brahman–Angus	5.48 (1.291) 20.5%
Direct	
Romosinuano	6.74 (2.085)
Brahman	
Angus	–8.78 (2.400)
Maternal	
Romosinuano	–3.14 (1.271)
Brahman	
Angus	4.77 (1.369)

¹Least squares means (SE). Heterosis also expressed as %.

²Empty cells indicate effects that did not differ ($P > 0.05$) from 0.

Brahman and Romosinuano, whereas at the winter sampling, Romosinuano tended to have lower cortisol concentrations than Brahman (Hammond et al., 1996). Previous studies using Romosinuano and Angus showed no difference in basal cortisol concentrations; however, following lipopolysaccharide stimulation, cortisol concentrations were greater in Angus steers than in Romosinuano steers (Carroll et al., 2011), whereas in another study, lipopolysaccharide-stimulated cortisol concentrations were greater for Romosinuano heifers than for Angus heifers (Carroll et al., 2013).

Weaning and transport elicited an increase in plasma concentrations of cortisol in the present study. The highest concentrations of cortisol were observed 24 h after weaning in calves and just after arrival from shipment in steers. Plasma concentrations of cortisol in calves 72 h after weaning declined to values found between 24 and 0 h after weaning. Cortisol concentrations in transported steers 72 h after arrival declined from a high at arrival to a concentration lower than that observed just prior to shipment. In agreement with the present study, others have reported an increase in concentration of cortisol in calves weaned and/or transported (Crookshank et al., 1979; Blanco et al., 2009). Likewise, in older bulls, steers, and cows, increased cortisol has been associated with various stressors (Chase et al., 1995; Browning and Leite-Browning, 2013). In contrast, others have shown no apparent increase in cortisol concentration after weaning and/or transport in calves (Blecha et al., 1984; Zavy et al., 1992). Lefcourt and Elsasser (1995) reported an increase in catecholamines in calves separated from their dams, but the slight increase in cortisol was not significant. They suggested that the lack of response in cortisol may be due to differing perceptions of

Table 6. Mean cortisol concentration and exit velocity in transported steers as affected by sampling time¹

Sampling time	Cortisol, ng/mL	Exit velocity, m/s
Shipment	32.8 (0.764) ^y	2.31 (0.046) ^y
Arrival	42.73 (0.918) ^z	1.93 (0.041) ^x
Arrival + 24 h	35.06 (0.736) ^y	1.99 (0.040) ^x
Arrival + 72 h	26.16 (0.689) ^x	1.95 (0.040) ^x
Arrival + 2 wk	20.41 (0.652) ^w	1.8 (0.040) ^w
Arrival + 4 wk	25.73 (0.738) ^x	1.75 (0.039) ^w

^{w–z}Within a trait (column), means with different superscripts differ ($P < 0.05$).

¹Least squares means (SE).

stress that result in different response patterns of adrenal stress hormones as proposed by Henry (1993). This differential response to perceived stress may also explain why in some studies at weaning, there is little response in cortisol, whereas in others, there is an increase.

Measures of temperament in this research included chute score, exit velocity, and pen score. Chute score and pen score are subjective measures whereas exit velocity is an objective measure. Breed type differences, in general, appeared to be consistent among the measures of temperament. Measures of temperament were generally highest for Brahman followed by Brahman crosses and were lowest for Romosinuano and Angus and their crosses. In agreement with these observations are those from heifers of similar breed types with temperament data (exit velocity and chute score) collected monthly after weaning to about 19 mo of age (Riley et al., 2010). Others have reported higher temperament measures for Brahman or Brahman crosses compared with *B. taurus* or *B. taurus* crosses (Voisinet et al., 1997b; Cafe et al., 2011). Most researchers, however, have focused on within-breed or among similar breed type comparisons. Temperament has been related to production traits including feedlot gain (Voisinet et al., 1997b; Petherick et al., 2002; Vettters et al., 2013), carcass quality (Nkrumah et al., 2007; Vann et al., 2008; Cafe et al., 2011), and meat quality (Voisinet et al., 1997a; King et al., 2006). Others have used exit velocity as an indicator of temperament throughout various stages of the cow–calf production system (Cooke, 2014) and, likewise, for Brahman cattle (Curley et al., 2006; Burdick et al., 2009; Price et al., 2015).

Heterosis estimates were significant for all temperament measures for Brahman–Angus crossbred calves at weaning and in transported steers. Combined with the significant heterosis observed for plasma concentration of cortisol in Brahman–Angus weaned calves and transported steers, heterosis for Brahman–Angus was significant for all traits (cortisol and temperament) that were measured. These heterosis estimates were greater than 0, which, for these particular traits, may not be favorable for Brahman–Angus; however,

these data demonstrate the unique heterotic advantage of Brahman–Angus crosses for even nongrowth traits (cortisol and temperament).

In the present research, considering the data from the 3 methods of temperament assessment, each of the methods provided some separation among the breed types; however, there were differences among methods. Exit velocity of Brahman did not differ from Brahman crosses (BA, AB, and RB) and Brahman crosses (BA, AB, and RB) did not differ from Angus. In contrast, for the subjective measures of chute score and pen score, Brahman had greater scores than Brahman crosses and Brahman crosses had greater scores than Angus. In addition to the objective vs. subjective differences among the temperament measures, it may also be important to consider what behavior each test actually assesses or measures. In the present study, the modeled within-calf residual correlations (weaning) were larger for exit velocity and pen score than for chute score for records of calves, and that correlation modeled for steer exit velocity near transport was of approximately the same magnitude (0.48). This may suggest that exit velocity and pen score were more consistent than chute score, which is in agreement with others (Curley et al., 2006; Vann et al., 2008). In the present study, other analyses indicated that for each 1-unit increase in residual value for exit velocity of the dam, there was a corresponding 0.34 m/s increase in exit velocity of her calf at weaning and 0.48 m/s increase in exit velocity of her transported steer calf.

There was evidence for acclimation effects on exit velocity in transported steers, with significantly lower exit velocity at 2 and 4 wk compared with just prior to transport or on arrival. In similar breed types of heifers, Riley et al. (2010) reported no evidence for acclimation effects on exit velocity measured monthly after weaning for 13 mo. Realizing the differences between 4 wk and 13 mo of measurements, perhaps there are some acclimation effects in the short term but not in the long term. In some situations, this may be important, for example to determine the number and timing of evaluations to adequately assess an animal's exit velocity (i.e., temperament) while minimizing the number of evaluations.

In conclusion, Romosinuano, Angus, and Brahman straightbred and F_1 reciprocal crossbred calves were sampled near weaning and steer calves were sampled near transport. Near weaning and transport, plasma concentrations of cortisol were increased relative to the event (weaning or transport); however, there were no statistical differences in cortisol concentrations among straightbreds or among crossbreds. At weaning, measures of temperament (exit velocity, chute score, and pen score) in general indicated that Brahman and Brahman crosses had more excitable temperaments compared with Angus and Romosinuano and their crosses. Near

transport, exit velocity was increased when Brahman was the sire and/or dam breed compared with Angus or Romosinuano as the sire and/or dam breed. Within-calf residual correlations were greater for exit velocity and pen score compared with chute score, and within-calf residual correlations for exit velocity observed in calves near weaning were consistent with those observed in steers near transport. The results suggest that for the assessment of temperament across diverse breed types, criteria designed for that purpose, specifically exit velocity (and perhaps pen score), provided more meaningful information on temperament, per se, than did circulating concentrations of cortisol.

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