Published November 10, 2015

Impacts of temperament on Nellore cattle: physiological responses, feedlot performance, and carcass characteristics[1]

C. L. Francisco,*[2] F. D. Resende,† J. M. B. Benatti,† A. M. Castilhos,‡ R. F. Cooke,§ and A. M. Jorge*

*Faculdade de Medicina Veterinária e Zootecnia, UNESP, Univ Estadual Paulista, Campus de Botucatu, Departamento de Produção Animal, Botucatu, SP, Brazil, 18618-000; †Agência Paulista de Tecnologia dos Agronegócios (Apta), Colina, SP, Brazil, 14770-000; ‡Faculdade de Medicina Veterinária e Zootecnia, UNESP, Univ Estadual Paulista, Campus de Botucatu, Departamento de Melhoramento e Nutrição Animal, Botucatu, SP, Brazil, 18618-000; §Oregon State University, Eastern Oregon Agricultural Research Center, Burns, OR 97720

ABSTRACT: Forty-four feedlot-finished Nellore cattle were used to evaluate the impacts of temperament on performance, meat and carcass traits, and serum concentrations of hormones, proteins, enzymes, and immunoglobulins. Individual temperament was assessed at feedlot entry (d 0), 67 d, and 109 d, utilizing chute score (CS; 5-point scale) and exit velocity (EV). Temperament scores were calculated averaging CS and EV scores, and cattle were subsequently classified according to their temperament (an average of ≤3 = adequate temperament [ADQ], or an average of >3 = excitable temperament [EXC]). At the end of the experiment (d 109), all 44 animals were slaughtered, and 16 were randomly selected for final empty body weight (EBW) estimation. Blood samples were collected at 0, 67, and 109 d and analyzed for serum variables (cortisol, insulin, haptoglobin, total protein, lactate, creatinine kinase [CK], lactate dehydrogenase [LDH], and IgA). The incidence of carcass bruises was verified immediately after the hide was removed. Carcass pH was obtained at 0 and 24 h postmortem. Samples of the LM were collected for meat quality analyses. Cattle classified as ADQ had greater final BW ($P = 0.03$), final EBW ($P = 0.02$), metabolic weight ($P = 0.03$), ADG ($P = 0.02$), feed efficiency ($P = 0.03$), HCW ($P = 0.02$), cold carcass weight ($P = 0.02$), and LM area ($P < 0.01$) compared to that of the EXC cohorts. Cattle classified as ADQ tended to have a lower percentage of cooler shrink ($P = 0.06$) compared to that of EXC cattle. No temperament effects were detected for initial BW ($P = 0.70$), DMI ($P = 0.14$), cold dressing percentage ($P = 0.98$), or backfat thickness ($P = 0.29$). Cattle classified as ADQ had greater marbling ($P = 0.02$) and meat fat content ($P = 0.05$) compared with that of EXC cattle. No temperament effects ($P > 0.05$) were detected for unsaturated fatty acid (UFA), SFA, MUFA, PUFA, and n-6:n-3 ratio. For blood parameters, EXC cattle had greater values of cortisol ($P = 0.04$) and haptoglobin ($P = 0.05$) and tended ($P = 0.06$) to have reduced serum insulin concentration compared with ADQ cattle. Both temperament groups had similar serum concentrations of IgA ($P = 0.25$) and total protein ($P = 0.84$). Cattle classified as EXC presented greater amounts ($P = 0.05$) of carcass bruises. In conclusion, an EXC temperament impaired feedlot performance, carcass characteristics, and meat quality traits in finishing Nellore cattle.

Key words: acute-phase protein, beef cattle, bruises, cortisol, meat quality, performance

 J. Anim. Sci. 2015.93:5419–5429
doi:10.2527/jas2015-9411

INTRODUCTION

Research has shown that cattle temperament traits, such as excitability and level of motor activity during human handling, persist throughout their productive lives (Grandin, 1993; Burrow and Dillon, 1997; Cafe et al., 2011a). Moreover, temperament impacts growth, performance, feeding efficiency, carcass characteristics, and meat quality

[1]Appreciation is expressed to São Paulo Research Foundation, FAPESP (grant number 2010/16170-4, research support; and grant number 2010/09516-1, doctoral scholarship) and to the National Council for Scientific and Technological Development, CNPq (grant number 47.8769/2010-5) for financial support. The opinions, hypotheses, conclusions, or recommendations contained in this material are the responsibility of the authors and do not necessarily reflect FAPESP's vision.

[2]Corresponding author: carolinelimafrancisco@gmail.com

Received June 10, 2015.
Accepted September 2, 2015.

in beef cattle. Cattle with excitable (**EXC**) temperaments also have altered physiology, such as variations in hormonal and (Curley et al., 2008; Cooke et al., 2009a) immunological responses (Murata and Miyamoto, 1993; Murata, 1997; Earley et al., 2012), that are associated with the immediate response to the stressor, resulting in performance losses (Petherick et al., 2009; Francisco et al., 2012) and negatively impacting production systems (Grandin, 1997; Cooke et al., 2009b; Hall et al., 2011). Cattle with EXC temperaments are also more difficult to handle, present carcasses with greater incidence of injuries (McNally and Warriss, 1996), and have inferior meat quality traits compared with those of calmer cohorts (Voisinet et al., 1997; Ferguson et al., 2006; Vann, 2006).

Excitable temperament is detected more frequently in *B. indicus* cattle compared with that in *B. taurus* and *B. taurus* crosses (Fordyce et al., 1988; Voisinet et al., 1997), and studies evaluating temperament and its consequences to productivity in *B. indicus* breeds, such as Nellore cattle, are still limited. Hence, we hypothesized that the temperament of Nellore cattle results in alterations on physiology, performance, and meat and carcass traits. To test this hypothesis, this study evaluated the impacts of temperament of Nellore cattle on feedlot performance, blood variables, and carcass and meat characteristics.

MATERIAL AND METHODS

The experimental procedures were reviewed and approved by the Ethics Animal Use Committee (protocol number 139/2010-CEUA) of the Faculdade de Medicina Veterinaria e Zootecnia, Universidade Estadual Paulista (**FMVZ-UNESP**), Botucatu, SP, Brazil.

Location, Animals, Facilities, and Experimental Period

The experiment was conducted at the Regional Pole of Technological Development of Agribusiness, located in Colina, SP, Brazil, whose geographical coordinates are 20°43´ S lat and 48°32´ W long, at an altitude of 588 m above sea level, and average annual temperature of 24°C. Forty-four Nellore bulls (initial BW = 387.9 ± 22.4 kg; 22 ± 1.4 mo of age) previously reared in *Brachiaria brizantha* cv. Marandu pasture were utilized. The animals were assigned randomly to individual half-covered pens (8 m^2/pen) and were provided with individual concrete feeding troughs and automatic water troughs.

During the experimental period, cattle were fed ad libitum a balanced diet (Table 1), formulated according to the Cornell Net Carbohydrate and Protein System (**CNCPS**, v. 5.0), and with a concentrate:forage ratio of 90:10 on a DM basis. The diet was offered twice daily at 0800 and 1500 h, and the amount of feed offered was adjusted so that the orts were from 5 to 10% of the initial provision. The provided fresh feed and orts were collected daily, weighed, and sampled for DM determination to calculate daily DMI.

Table 1. Nutritional composition of ingredients of diet based on DM

Item	DM, %	CP	Ash	NDF	Ether extract	Diet, %
Sugarcane bagasse	74.84	2.56	10.25	86.49	3.24	10.00
Crushed corn	89.45	8.44	2.21	14.35	8.88	73.60
Cottonseed	90.25	20.54	3.02	56.56	19.26	6.40
Soybean bran	88.75	51.11	7.30	18.03	6.63	6.40
Mineral mix[1]	90.00	70.00	–	–	–	3.60
Diet	88.35	14.02	6.37	37.61	6.59	–

[1]Basic composition of the mineral mix: iron sulfate, copper sulfate, cobalt sulfate, calcium iodate, corn gluten, sodium chloride (common salt), calcitic lime, sodium selenite, bicalcium phosphate, manganese monoxide, zinc oxide, and potassium chloride. Levels of product assurance: 7.4% corn gluten, 14.8% iodized salt, 36.9% calcitic lime, 7.4% bicalcium phosphate, 22.1% urea, 0.9% microminerals, 3.1% sulfur, and 7.4% potassium chloride.

Shrunk BW was recorded at 0 (beginning of the experiment), 67, and 109 d (final day of the experiment) after 12 h of feed and water withdrawal. Individual total gain was determined by the difference between the final shrunk BW (109 d) and the initial shrunk BW (0 d). Individual ADG was calculated by individual total gain divided by the number of days on the trial (109 d), and the G:F was determined as the ratio of ADG to daily DMI.

Evaluation of Animal Temperament

Animal temperament was evaluated on d 0, 67, and 109 using 2 distinct evaluation methods (chute score and exit velocity) according to the methodology described by Cooke et al. (2011a). Chute score of each animal was determined as soon as chute handling started, utilizing a 5-point scale in which 1 = calm with no movement, 2 = restless movements, 3 = frequent movement with vocalization, 4 = constant movement, vocalization, and shaking of the chute, and 5 = violent and continuous struggling. Infrared sensors (FarmTek Inc., Wylie, TX, USA) were set up 2 m apart and were strategically placed at the exit of the squeeze chute to measure exit velocity. The animals were divided in quintiles according to their exit velocity and assigned a score from 1 to 5 (1 = slowest steer; 5 = fastest steer). The individual temperament score was calculated averaging chute score and exit velocity. According to their temperament score (type of temperament), the animals were classified as adequate (**ADQ** = temperament score of ≤3) or EXC (temperament score of >3) as described by Cooke et al. (2011a).

Slaughter and Data Collection

On d 109, all cattle were transported 24.3 km (approximately 60 min) in a commercial livestock trailer to a commercial packing facility (Minerva, Barretos, SP, Brazil). The slaughter was randomly performed with a captive bolt stunning gun and slitting of the jugular vein. The time intervals between stunning and bleeding were measured using a portable timer (West Bend, Focus Electrics, LLC, West Bend, WI) to ensure that there was standardization during the procedure among the temperament groups. Carcasses were evaluated to verify the presence of lesions (contusions/bruises) while in the slaughter line system after removal of the hide. The final empty body weights (**EBW**) of 16 randomly selected animals (EXC temperament = 8; ADQ temperament = 8) were obtained, and the EBW-to-BW ratio was utilized to estimate the EBW of all animals in the experiment. After chilling (4°C for 24 h), the left half-carcass of each animal was sectioned between the 12th-rib and 13th-rib to obtain the LM area (**LMA**) using surface tracings made with acetate paper for posterior measurement by computerized planimetry. The backfat thickness (**BFT**) was measured at three-fourths the distance from the medial border of the LM by digital paquimeter (Digimess Instrumentos de Precisão Ltda, São Paulo, SP, Brazil).

Blood Samples and Laboratory Analyses

Blood samples were collected at 0 d (beginning of the experiment) and 67 d via jugular venipuncture using vacuum tubes without anticoagulant (Vacutainer, 10 mL; Becton Dickinson, Franklin Lakes, NJ; 2 tubes for each animal). Blood samples were also collected in sterile containers at the packing plant during exsanguination (109 d) and immediately transferred to 10-mL vacuum tubes without anticoagulant. All blood samples were preserved in ice for less than 2 h, subsequently centrifuged at 2,500 × *g* for 30 min at 4°C for serum harvest, and stored at −20°C.

Serum cortisol and insulin concentrations were analyzed using commercial RIA kits (Coat-a-Count; Siemens Healthcare Diagnostics Inc., Los Angeles, CA), and the radioactivity was measured using an automatic gamma counter (Cobra II Auto-Gamma; Packard Instrument Company, Meriden, CT). Concentrations of total serum protein were determined by biuret method (Gornall et al., 1949) utilizing a commercial biochemical kit (Katal Biotecnológica Ind. Com. Ltda, Belo Horizonte, MG, Brazil). For the analyses of creatine kinase (**CK**), lactate, and lactate dehydrogenase (**LDH**), commercial biochemical kits were used (Lactate and LDH, Katal Biotecnológica Ind. Com. Ltda; CK, Doles Reagentes e Equipamentos para Laboratórios Ltda, Goiânia, GO, Brazil). Total serum protein, CK, lactate, and LDH readings were performed using an automated Cobas Mira Plus spectrophotometer (Biotécnica Ind. e Com. Ltda, Varginha, MG, Brazil). Serum IgA concentrations were determined according to the methodology proposed by Weber and Osborn (1969). Sodium dodecyl sulfate polyacrylamide gel electrophoresis (**SDS-PAGE**) was utilized, and protein bands were identified by comparing them to the utilized standard band (20 to 200 kDa for the molecular weight of proteins; SigmaMarker, St. Louis, MO; catalog S8445) according to the values of the molecular weight known for IgA (165 kDa). Afterward, the results of total serum protein concentration analyses were used to calculate the estimated immunoglobulin concentration (mg/dL) according to its corresponding peak in the gel measured by densitometry. Concentrations of haptoglobin were determined according to the methodology described by Cooke and Arthington (2013), and results are expressed as arbitrary units from the absorption reading at 450 nm × 100.

Meat Analysis

During carcass chilling, pH values were measured (1 and 24 h after slaughter) in the LM between the 12th and 13th ribs by a portable digital pH meter (model PM 603; Analion Aparelhos e Sensores, São Paulo, SP, Brazil) with a puncture electrode (model V-627).

During deboning procedures in an experimental cooler room for carcass handling, samples of LM were collected between the 10th and 13th ribs, individually vacuum packaged, and frozen at −20°C until subsequent analyses. One LM steak (2.54 cm thick) was utilized to measure color, marbling, cooking loss, and shear force. After a 30-min exposure to air, the sample was measured for color parameters using a Minolta portable colorimeter (model CR 410; D_{65} illuminator; 10° observer; Konica Minolta Sensing Americas, Inc., Osaka, Japan) calibrated against a standard white tile before data collection. Three readings were taken on each sample and meat color was expressed using the CIELAB color space (L* = lightness, a* = redness, and b* = yellowness) according to the CIE system. Subjective marbling measurement was performed according to the methodology described by USDA Quality Grade (USDA, 1997). Cooking loss was determined according to the technique proposed by Abularach et al. (1998). Shear force was measured according to the method described by Wheeler et al. (1995) to prepare samples and using a TAX-T2 plus texture analyzer (Texture Technologies Corp, Scarsdale, NY) equipped with a Warner-Bratzler shear blade (3.38 mm thick) with 50 kg of capacity and a sectioning speed of 20 cm/min.

Water holding capacity (**WHC**) was determined according to the methodology proposed by Hamm (1960)

in which three 0.5-g LM samples were cut in cubes, placed between 2 layers of filter paper and posteriorly between 2 plaques of acrylic, and individually submitted to 10 kg of pressure for 5 min. The WHC was calculated by %WHC = {[Wi − (Wi − Wf)]/Wi} × 100, where Wi is the initial weight of the sample before pressure, and Wf is the final weight of the sample after pressure.

Fat, moisture, and protein were determined by spectrometry of near-infrared transmittance (**NIT**; 850 to 1,050 nm) using FoodScan Lab equipment (Foss Electric A/S, Hillerød, Denmark). Samples of LM were used, and the analysis procedures consisted of removing the subcutaneous fat of the samples and processing them in a meat multiprocessor. Subsequently, approximately 180 g of ground meat samples was placed in a 14-cm round sample dish for immediate reading in the FoodScan. The results (grams per 100 g of sample) were obtained in 45 s. Ash was determined by AOAC (1990).

One LM steak (1 cm thick) from each one-half carcass was divided into 2 equal parts, individually vacuum packaged, and frozen at −20°C for subsequent analysis of lipid oxidation. At 2-d intervals, one-half of the samples were thawed in a biochemical oxygen demand (**BOD**; 4.5 to 5°C) incubator on d 1, and the remaining one-half was thawed 2 d later to simulate retail display conditions and home storage, respectively. The lipid oxidation was performed according to the methodology described by Pikul et al. (1989), estimated as thiobarbituric acid-reactive substances (**TBARS**) and expressed as milligrams of tetramethoxypropane (**TMP**) per kilogram of sample.

The analysis of fatty acids (**FA**) of meat were performed according to a modified method of Hara and Radin (1978), using hexane:isopropanol 3:2 (vol/vol), followed by methylation and transesterification, according to methods described by Christie (1982) and modifications cited by Chouinard et al. (1999). Gas chromatography was performed using Thermo Finnigan equipment (Trace; Thermo Fisher Scientific Inc., Wayne, MI) with a flame ionization detector (**FID**) and fused silica capillary column (SP-2560; Supelco, Bellefonte, PA) containing helium at 1.2 mL/min as the carrier gas. A temperature gradient of 70 to 250°C was used to identify of FA peaks. The retention times were compared to standard times (CRM-164; Commission of the European Communities, Community Bureau of Reference, Brussels, Belgium). The concentrations are expressed as a percentage of the total FA recovered (grams FA per 100 g of total FA).

Statistical Analysis

The descriptive statistics of the characteristics used to calculate temperament score was analyzed with the MEANS procedure of SAS (SAS Inst. Inc., Cary, NC). Data were tested for normality using the UNIVARIATE procedure (SAS Inst. Inc.) with normality of distributions determined by the Shapiro-Wilk (**W**) test, obtaining probability values greater than 0.90. Animal was considered the experimental unit. All data were analyzed using the MIXED procedure (SAS Inst. Inc.) and the Satterthwaite approximation to determine the denominator degrees of freedom for the tests of fixed effects. The model statement for the temperament score, performance parameters, carcass, and meat traits included temperament type effect (EXC or ADQ). The model statement used for serum protein evaluations and lipid oxidation contained the effects of temperament type (EXC or ADQ), day, and the resulting interactions. The term day was used for repeated measurements in the evaluations of serum protein and lipid oxidation, and animal (temperament) was utilized as the subject. All data were analyzed using animal (temperament) as random variable. Because interactions (temperament × day) were not detected, the results are reported as least squares means (LSMEANS) and according to temperament. For all analyses, significance was set at $P \leq 0.05$ and tendencies were determined if $P > 0.05$ and $P \leq 0.10$.

RESULTS AND DISCUSSION

Data related to the assessment of animal temperament at feedlot entry day (d 0) are presented in Table 2. The animal percentage for each temperament type in the herd (31.82 and 68.18% for EXC and ADQ, respectively) is similar to values presented in previous studies with *Bos indicus* (Cooke et al., 2011a) and *Bos taurus* (Francisco et al., 2012), where the same methodology was used to evaluate this characteristic. Temperament classification was constant for both groups during the experiment, and a temperament × day interaction was detected ($P < 0.01$; Fig. 1), i.e., the animals that were initially classified as EXC or ADQ remained within the same classification at the end of the experimental period. Supporting our results, other studies with cattle have shown that temperament characteristics are inherited (Morris et al., 1994; Burrow and Corbet, 2000; Hoppe et al., 2010) and persist for a long time (Grandin, 1993; Burrow and Dillon, 1997; Cafe et al., 2011a). Moreover, during this study, there was no mortality or any disease that could affect the evaluations of the measured characteristics.

Studies on beef cattle showed associations between temperament and performance traits (Voisinet et al., 1997; Petherick et al., 2009). In our study, EXC and ADQ cattle had similar initial BW ($P = 0.69$; Table 3), which was expected because cattle selected for this experiment had similar initial age and BW to focus on performance differences among groups during the

Table 2. Descriptive statistics of exit velocity, exit velocity score, chute score, and temperament score of Nellore cattle classified according to temperament (excitable or adequate) at entry day in feedlot (d 0)

Description	Average	SEM	Minimum	Maximum
Excitable[1] (n = 14)				
Exit velocity, m/s	2.20	0.16	1.36	3.19
Exit velocity score	4.67	0.13	4	5
Chute score	3.44	0.14	3	4
Temperament score	4.06	0.04	4	4.5
Adequate[1] (n = 30)				
Exit velocity, m/s	0.98	0.06	0.26	1.81
Exit velocity score	2.39	0.21	1	5
Chute score	2.17	0.15	1	4
Temperament score	2.28	0.13	1	3

[1]Calculated by temperament score (excitable temperament, temperament score of >3; adequate temperament, temperament score of ≤3). The temperament score was calculated by the average of the chute score (Cooke et al., 2011a) and the exit velocity score. The exit velocity score was calculated by dividing the exit velocity results in quintiles and classifying the animals in a 1-to-5 score (velocity score: 1 = slowest animals, 5 = fastest animals).

Table 3. Least squares means of the productive performance of Nellore cattle finished in feedlot and classified according to excitable or adequate temperament

	Temperament[1]			
Item	Excitable (n = 14)	Adequate (n = 30)	SEM	P-value
Initial BW, kg	387.20	390.11	7.68	0.70
Final BW, kg	502.36	531.70	12.81	0.03
Final EBW[2], kg	463.22	492.20	11.94	0.02
MW[3], kg^{0,75}	106.06	110.68	2.02	0.03
ADG[4], kg/d	1.06	1.30	0.10	0.02
DMI[5], kg/cattle daily	8.85	9.36	0.34	0.14
G:F[6], g/kg	119	139	0.08	0.03

[1]Calculated by the temperament score (excitable temperament, temperament score of >3; adequate temperament, temperament score of ≤3). The temperament score was calculated by averaging chute score (Cooke et al., 2011a) and exit velocity score. The exit velocity score was calculated by dividing the exit velocity score results in quintiles and classifying the animals in a 1-to-5 score (velocity score: 1 = slowest animals, 5 = fastest animals).

[2]Final empty body weight. Calculated using a subsample of animals (excitable temperament = 8; adequate temperament = 8).

[3]Metabolic weight (MW = final BW$^{0.75}$).

[4]ADG = (final BW − initial BW)/109 d.

[5]DMI = total DMI/109 d.

[6]Feed efficiency [G:F = (final BW − initial BW)/total DMI].

finishing phase. A temperament effect for final BW was detected (P = 0.03; Table 3). Cattle classified as ADQ were approximately 29 kg heavier compared to EXC cohorts. When evaluated by final EBW, which does not consider the weight of gastrointestinal contents for the calculation, the effect (P = 0.02; Table 3) still favored ADQ cattle; this result was also observed for metabolic weight (**MW**; P = 0.03; Table 3). The variation of ruminants' gastrointestinal content is still the greatest error factor when measuring BW gains (Lofgreen et al., 1962); therefore, to accurately measure BW of animals from the same herd, the evaluation of EBW is recommended. However, it is known that this practice is only possible in research studies and that this tool does not reflect the reality of industrial routines.

Animals classified as ADQ presented greater ADG (P = 0.02; Table 3) compared to that of EXC cohorts. These results are consistent with others studies in which ADG was also associated with animal temperament type and in which animals with ADQ temperaments presented greater ADG compared to animals with EXC temperaments (Voisinet et al., 1997; Fell et al., 1999; Turner et al., 2011). On the other hand, these results are divergent from reports in the literature that attribute the difference in BW gain to greater DMI (Nkrumah et al., 2007). In the present study, this fact was not evident because ADQ and EXC cattle had similar DMI (P = 0.14; Table 3). Thus, from the G:F calculation, ADQ cattle were more efficient (P = 0.03), which resulted in greater BW gain per kilogram of DMI compared to EXC cattle. In studies conducted with *B. indicus*, Petherick et al. (2002) reported that the animals with ADQ temperaments were more efficient than cohorts with EXC temperaments, supporting the results presented in this study.

A temperament effect was detected for the incidence of carcass bruising. The carcasses from EXC cattle presented a greater (P = 0.05) amount of bruises compared to ADQ cohorts (Fig. 2). Studies have shown a strong relationship among the injury incidence in carcasses, animal welfare, and stress and

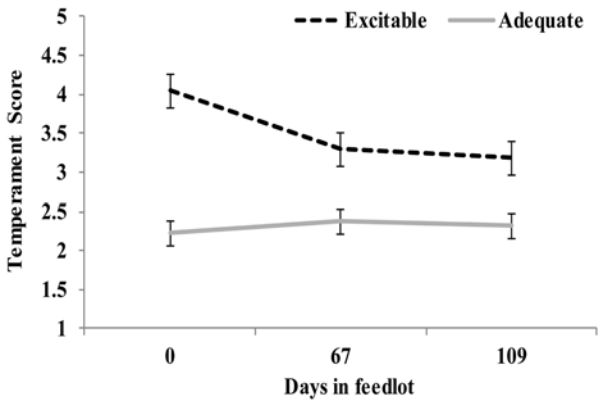

Figure 1. Temperament score during the trial period in feedlot (0 to 109 d) of Nellore cattle classified according to excitable or adequate temperament. Temperament was assessed by the temperament score (excitable temperament, temperament score of >3; adequate temperament, temperament score of ≤3). The temperament score was calculated by averaging chute score (Cooke et al., 2011a) and exit velocity score. The exit velocity score was calculated by dividing the exit velocity score results in quintiles and classifying the animals in a 1-to-5 score (velocity score: 1 = slowest animals, 5 = fastest animals). A temperament × day interaction was detected (P < 0.01).

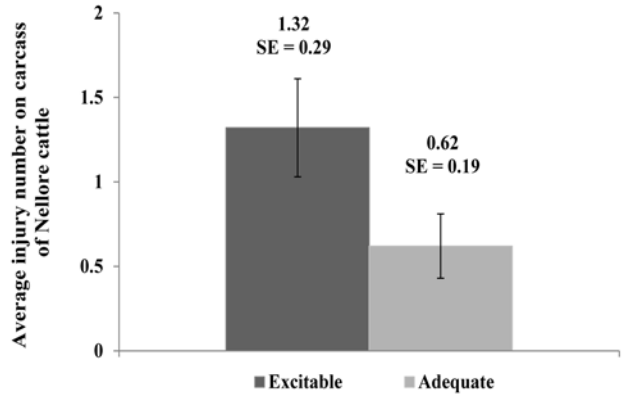

Figure 2. Incidence of injuries on carcass of Nellore cattle (*Bos indicus*) classified according to excitable or adequate temperament. Temperament was assessed by the temperament score (excitable temperament, temperament score of >3; adequate temperament, temperament score of ≤3). The temperament score was calculated by averaging chute score (Cooke et al., 2011a) and exit velocity score. The exit velocity score was calculated by dividing the exit velocity score results in quintiles and classifying the animals in a 1-to-5 score (velocity score: 1 = slowest animals, 5 = fastest animals; $P = 0.05$).

Table 4. Least squares means of the carcass traits of Nellore cattle finished in feedlot and classified according to excitable or adequate temperament

	Temperament[1]			
Item	Excitable ($n = 14$)	Adequate ($n = 30$)	SEM	P-value
HCW, kg	276.04	296.21	8.52	0.02
Cold carcass weight, kg	273.32	294.10	8.29	0.02
Hot dressing percentage[2], %	59.59	60.18	0.66	0.83
Cold dressing percentage[3], %	59.41	59.43	0.65	0.98
Cooler shrink[4], %	0.96	0.70	0.13	0.06
LM area, cm^2	68.17	78.64	2.96	<0.01
Backfat thickness, mm	4.38	4.93	0.51	0.29

[1]Calculated by the temperament score (excitable temperament, temperament score of >3; adequate temperament, temperament score of ≤3). The temperament score was calculated by averaging the chute score (Cooke et al., 2011a) and exit velocity score. The exit velocity score was calculated by dividing the exit velocity score results in quintiles and classifying the animals in a 1-to-5 score (velocity score: 1 = slowest animals, 5 = fastest animals).

[2]Hot dressing percentage = (HCW/final empty body weight) × 100.

[3]Cold dressing percentage = (Cold carcass weight/final empty body weight) × 100.

[4]Cooler shrink = (HCW − cold carcass weight) × 100/HCW.

have reported that management improvements of the ranch, transportation, and preslaughter may contribute to reduce production loss (McNally and Warriss, 1996; Paranhos da Costa et al., 2012). In our study, assessments regarding the exact time that bruising occurred were not conducted. Nevertheless, it was evident that temperament type was associated with the number of bruises occurrences in Nellore cattle.

There was no difference ($P = 0.49$) in the time interval between stunning and bleeding (89 vs. 84 s for EXC and ADQ temperaments, respectively; SEM = 7.65; data not shown). Thus, carcass and meat quality traits among temperament types were not influenced by this outcome. Results regarding the carcass characteristics are presented in Table 4. Cattle with ADQ temperaments obtained greater HCW and cold carcass weight ($P = 0.02$) as well as greater daily carcass gain ($P < 0.01$) when compared with that of the EXC cohorts. The greater body development of ADQ cattle was also evident by the greater LM area ($P < 0.01$) compared to that of the EXC cohorts. Other studies have shown associations between temperament and carcass characteristics in beef cattle, reporting that cattle with ADQ temperaments have greater values for characteristics such as HCW (Francisco et al., 2012) and LM area (Behrends et al., 2009) compared with those of animals with EXC temperaments. No effects of temperament were detected for hot dressing percentage ($P = 0.83$) and cold dressing percentage ($P = 0.98$). However, the carcasses of ADQ cattle tended to have reduced cooler shrink ($P = 0.06$) compared with that of the carcasses of the EXC cohorts. The cooler shrink is commonly influenced by the amount of subcutaneous fat covering the carcass because it functions as an insulator and avoids dehydration losses (Smith and Carpenter, 1973; Savell et al., 2005). Nevertheless, in our study, temperament type did not impact ($P = 0.29$) backfat thickness. Therefore, other biological factors such as preslaughter stress (Traore et al., 2012) or structural, as in the carcass spacing and alignment in the chill cooler (Allen et al., 1987), may have contributed to greater cooler shrink in EXC cattle.

Meat quality traits are shown in Table 5. No temperament effect were detected on initial pH ($P = 0.32$) or final pH ($P = 0.43$). Similar to our findings, other studies failed to report a relationship between cattle temperament and carcass pH (Fordyce et al., 1988; Petherick et al., 2002; Del Campo et al., 2010). A tendency for temperament effect ($P = 0.09$) was detected for L* values; however, no temperament effects were detected for others color parameters ($P = 0.60$ and $P = 0.11$ for a* and b* values, respectively). Although others associated meat color variation with EXC temperament (Kadel et al., 2006; Turner et al., 2011), in the present study, the absence of this effect was expected due to the results obtained in the pH evaluation and considering that there is a close relationship between the color characteristic and the final pH values of the meat (Mancini and Hunt, 2005). Water holding capability and cooking loss were similar among temperament types ($P = 0.11$ and $P = 0.98$, respectively). Contrary to our results, the literature reports association of the temperament with cooking loss (Cafe et al., 2011b), attributing greater loss to animals with EXC temperaments. However, in that same study, Cafe et al. (2011b) report-

Table 5. Least squares means of quality meat traits evaluated at the LM (12th/13th rib interface) of feedlot-finished Nellore cattle categorized for excitable or adequate temperament

	Temperament[1]			
Item	Excitable (n = 14)	Adequate (n = 30)	SEM	P-value
Initial pH, 1 h	7.00	7.08	0.08	0.32
Final pH, 24 h	5.75	5.79	0.05	0.43
Color[2]				
L*	38.25	38.97	0.42	0.09
a*	17.77	18.01	0.46	0.60
b*	6.08	6.56	0.29	0.11
WHC[3], %	59.51	61.01	0.89	0.11
Cooking loss, %	23.42	23.37	1.87	0.98
Shear force, kg/cm^2	7.53	7.33	0.51	0.69
Protein, g/100g of meat	24.17	24.29	0.20	0.53
Moisture, g/100g of meat	73.17	72.76	0.21	0.07
Ash, %	1.16	1.18	0.03	0.60
Fat, g/100g of meat	2.28	2.66	0.19	0.05
Marbling[4]	1.62	2.18	0.23	0.02
TBARS[5], mg tetramethoxypropane/kg of sample	1.53	1.46	0.06	0.24
Sum, g/100 g of total fatty acids				
SFA	42.19	43.23	1.08	0.34
UFA[6]	54.73	53.61	1.12	0.32
MUFA	45.53	46.21	1.22	0.58
PUFA	9.20	7.40	1.15	0.13
Ratio				
UFA:SFA	1.30	1.25	0.05	0.33
MUFA:SFA	1.08	1.07	0.04	0.88
PUFA:SFA	0.22	0.17	0.03	0.12
n-6:n-3	3.43	3.60	0.20	0.40

[1]Calculated by the temperament score (excitable temperament, temperament score of >3; adequate temperament, temperament score of ≤3). The temperament score was calculated by averaging the chute score (Cooke et al., 2011a) and exit velocity score. The exit velocity score was calculated by dividing the exit velocity score results in quintiles and classifying the animals in a 1-to-5 score (velocity score: 1 = slowest animals, 5 = fastest animals).

[2]Color obtained by CIELAB (L* = lightness; a* = redness; b* = yellowness), utilizing a Minolta colorimeter.

[3]Water holding capacity.

[4]Subjective marbling (slight = 0; small = 1; modest = 2; moderate = 3; slightly abundant = 4; moderately abundant = 5) obtained according to the methodology described by USDA (1997).

[5]Thiobarbituric acid-reactive substances.

[6]UFA = sum of unsaturated fatty acids.

ed alterations in the final pH of meat, reporting values close to 6. There was no effect of temperament type (P = 0.69) on meat shear force. Contrary to our findings, previous research reported a relationship between these 2 variables, attributing a less tender meat to cattle with EXC temperaments. However, these studies also relate these results to additional characteristics such as preslaughter handling (Gruber et al., 2010), breed (Del Campo et al., 2010), sex (Hall et al., 2011), and meat pH (King et al., 2006). Therefore, it can be speculated that the adequate handling of the animals in this study likely contributed to reduced animal stress, including during the preslaughter period. Thus, there was likely not enough use of the muscle glycogen reserve that would affect the process of muscle transformation into meat and, consequently, lead to pH reduction inefficiently, inducing alterations in the assessed physical characteristics (Immonen et al., 2000).

There was no effect of temperament type on the parameters of meat protein and ash (P = 0.53 and P = 0.60, respectively), and a tendency (P = 0.07) was detected for meat moisture; however, there was an effect on the meat fat analyzed by near infrared reflectance spectrometry (**NIRS**) and subjective marbling scores (Table 5). Meat from ADQ cattle had greater fat content (P = 0.05) and marbling (P = 0.02) compared with that of the meat of EXC cohorts. It is important to point out that the meat samples evaluated by NIRS were ground and contained no subcutaneous fat that could overestimate the results. Supporting our results, Hall et al. (2011) reported that animals with EXC temperaments have less available energy for the intramuscular fat reserve, resulting in the low marbling score.

Although there was an effect of temperament type for the amount of fat in meat, no effect was detected (P = 0.24) for lipid oxidation measured by the amount of TBARS (Table 5). Studies show that the FA profile influences the lipid oxidation capacity, and PUFA are more easily oxidized than SFA (Zhang et al., 2007; Mello et al., 2012). Nevertheless, in the present study, no temperament effect ($P \geq 0.12$) was detected for total PUFA content or for unsaturated FA (**UFA**), SFA, MUFA, and n-6:n-3 ratio (Table 5). However, a temperament type effect was observed for nervonic acid (C24:1; $P < 0.01$; data not shown) and dihomo-γ-linolenic acid (C20:3 n-6; P = 0.03; data not shown). Concentrations of these FA were greater in EXC cattle compared with those in ADQ cohorts (0.005 vs. 0.001 for C24:1 and 0.31 vs. 0.20 for C20:3 n-6 for EXC and ADQ, respectively; data not shown). These outcomes demonstrate that temperament may impact the FA profile in Nellore meat, but it is important to note that other physiological mechanisms that may alter the tissue FA profile, such as enzymatic activity and plasma FA concentrations (Archibeque et al., 2005; Scholljegerdes et al., 2007; Cooke et al., 2011b), were not properly evaluated in the present study. Therefore, this subject deserves further investigation because it is unknown how these changes may occur as well as the physiological pathway associated with the ruminal biohydrogenation mechanisms and their relationship with animal temperament.

For blood parameters, EXC cattle had greater concentrations of cortisol (P = 0.04), haptoglobin (P = 0.05), and tended (P = 0.06) to have a lower concen-

Table 6. Blood parameters of Nellore cattle finished in feedlot and evaluated according to excitable or adequate temperament

	Temperament[1]			
Item	Excitable (n = 14)	Adequate (n = 30)	SEM	P
Cortisol, ng/mL	19.6	16.7	0.14	0.04
Insulin, IU/mL	12.7	19.4	3.56	0.06
Haptoglobin, 450 nm × 100	3.38	2.20	0.58	0.05
IgA, mg/dL	183.03	195.81	10.98	0.25
Total serum protein, g/dL	8.05	8.08	0.17	0.84
CK[2], U/L	417.36	410.60	54.15	0.90
LDH[3], U/L	1,663.01	1,699.21	70.66	0.61
Lactate, mmol/L	6.23	5.79	0.44	0.33

[1]Calculated by the temperament score (excitable temperament, temperament score of >3; adequate temperament, temperament score of ≤3). The temperament score was calculated by averaging the chute score (Cooke et al., 2011a) and exit velocity score. The exit velocity score was calculated by dividing the exit velocity score results in quintiles and classifying the animals in a 1-to-5 score (velocity score: 1 = slowest animals, 5 = fastest animals).

[2]Creatine kinase.

[3]Lactate dehydrogenase.

tration of insulin when compared to that of the ADQ temperament cohorts (Table 6). Supporting our results, studies showed that cortisol levels increase according to the animal's excitability (King et al., 2006; Curley et al., 2008; Cafe et al., 2011b) and that this increase also elicits inflammatory reactions such as the acute-phase protein response (Cooke and Bohnert, 2011). Contrary to cortisol, insulin reduces mediators (IL-1 and IL-6) that stimulate acute-phase protein production (Campos and Baumann, 1992); therefore, they have lower concentration in the blood. This hormone induces glucose capture from the peripheral tissues, resulting in increased lipogenesis or reduction in lipolysis (Schoonmaker et al., 2003; Rhoades et al., 2007). Hence, insulin is related to fat synthesis (Trenkle, 1970) and positively correlated to muscle and carcass adiposity (Trenkle and Topel, 1978). Diets with greater starch content, such as the diet utilized herein, promote greater intramuscular fat deposition compared with subcutaneous fat (Choat et al., 2003; Schoonmaker et al., 2004). This allows us to verify that ADQ cattle tended to have greater insulin concentrations and also presented the greatest values of marbling and muscle fat but did not differ regarding subcutaneous fat when compared to EXC cohorts.

A positive correlation (r = 0.38; P = 0.02) between cortisol concentration and temperament score was observed. Studies report a positive correlation between cortisol concentrations and temperament evaluations (Curley et al., 2006; Cooke et al., 2009a), indicating that the EXC temperament can be identified reliably through measurements such as exit velocity and chute score (Curley et al., 2006; Cooke et al., 2009a; Vetters et al., 2013). Moreover, a negative correlation was detected between the concentrations of haptoglobin and ADG (r = −0.47; P < 0.01). Supporting our results, studies report the association of acute-phase proteins like haptoglobin with productive performance of cattle (Arthington et al., 2005; Araujo et al., 2010; Marques et al., 2012) as well as the relationship of this protein with animal temperament, showing that animals with EXC temperaments have an increase in haptoglobin concentrations (Cooke et al., 2009b; Cooke et al., 2012; Francisco et al., 2012).

There was no effect of the temperament type on the concentrations of IgA and total serum protein ($P \geq 0.25$; Table 6). Similarly to our results, studies showed that temperament did not affect immunoglobulin concentration, like IgA, in *B. indicus* (Burdick et al., 2009) and *B. taurus* (Fell et al., 1999) calves. According to Butler (1969), the values of IgA concentration in cattle range from 80 to 800 mg/L, and they are elevated when in young cattle because of the passive transfer of this Ig after birth. Although IgA is broadly studied in humans and rats, Snoeck et al. (2006) reported that the function of IgA in the immunological response of production and commercial animals has not been totally elucidated; however, it has been indicated that it could be related to a secondary defense line and act to eliminate pathogens instead of being related to stressing factors. Temperament type did not affect serum concentrations of CK (P = 0.90), lactate (P = 0.33), and LDH (P = 0.61; Table 6). Accordingly, Miranda-de la Lama et al. (2013) evaluated bulls from different breeds and did not observe differences between serum concentrations of CK and lactate according to the level of animal dominance, demonstrating that behavioral traits may not influence these blood metabolites. Regarding the elevated concentrations of CK, lactate, and LDH found in the serum for both temperaments, it is suggested that the transportation up to the commercial packing plant contributed to an increase in these characteristics. Gruber et al. (2010) evaluated the blood concentrations of CK and lactate in heifers and steers after the animals were transported to the packing plant where blood was harvested during bleeding, and they reported increased concentrations of these parameters. However, these authors found a positive correlation between CK and lactate concentrations and temperament, which was not found in our study.

Considering the objectives and results reported herein, temperament impacted feedlot finishing performance and postslaughter carcass traits in Nellore cattle. Temperament was associated with alterations on the physiology, performance, and carcass characteristics of Nellore cattle finished in a feedlot system. It was verified that cattle temperament did not affect serum concentrations of enzymes related to the muscle metabolism (CK and LDH) but influenced other se-

rum proteins, meat quality traits such as marbling, and incidence of carcass bruising. Therefore, it is advisable to utilize temperament evaluation as a tool for selection strategies. Additional studies are warranted on different production systems, including forage-based scenarios, to further understand the extent of the temperament effect on the productivity of Nellore cattle.

LITERATURE CITED

Abularach, M. L. S., C. E. Rocha, and P. E. Felício. 1998. Características de qualidade do contrafilé (m. *L. dorsi*) de touros jovens da raça Nelore. Ciênc. Tecnol. Aliment. 18:205–210.

Allen, D. M., M. C. Hunt, A. Luchiari Filho, R. J. Danler, and S. J. Goll. 1987. Effects of spray chilling and carcass spacing on beef carcass cooler shrink and grade factors. J. Anim. Sci. 64:165–170.

AOAC. 1990. Official methods of analysis. 15th ed. Assoc. Off. Anal. Chem., Arlington, VA.

Araujo, D. B., R. F. Cooke, G. R. Hansen, C. R. Staples, and J. D. Arthington. 2010. Effects of rumen-protected polyunsaturated fatty acid supplementation on performance and physiological responses of growing cattle following transportation and feedlot entry. J. Anim. Sci. 87:4125–4132.

Archibeque, S. L., D. K. Lunt, C. D. Gilbert, R. K. Tume, and S. B. Smith. 2005. Fatty acid indices of stearoyl-CoA desaturase do not reflect actual stearoyl-CoA desaturase enzyme activities in adipose tissues of beef steers finished with corn-, flaxseed-, or sorghum-based diets. J. Anim. Sci. 83:1153–1166.

Arthington, J. D., J. W. Spears, and D. C. Miller. 2005. The effect of early weaning on feedlot performance and measures of stress in beef calves. J. Anim. Sci. 83:933–939.

Behrends, S. M., R. K. Miller, F. M. Rouquette, Jr., R. D. Randel, B. G. Warrington, T. D. A. Forbes, T. H. Welsh, H. Lippke, J. M. Behrends, G. E. Carstens, and J. W. Holloway. 2009. Relationship of temperament, growth, carcass characteristics and tenderness in beef steers. Meat Sci. 81:433–438.

Burdick, N. C., J. P. Banta, D. A. Neuendorff, J. C. White, R. C. Vann, J. C. Laurenz, R. D. Welsh, Jr., and T. H. Randel. 2009. Interrelationships among growth, endocrine, immune, and temperament variables in neonatal Brahman calves. J. Anim. Sci. 87:3202–3210.

Burrow, H. M., and N. J. Corbet. 2000. Genetic and environmental factors affecting temperament of zebu and zebu-derived beef cattle grazed at pasture in the tropics. Aust. J. Agric. Res. 51:155–162.

Burrow, H. M., and R. D. Dillon. 1997. Relationships between temperament and growth in a feedlot and commercial carcass traits of *Bos indicus* crossbreds. Aust. J. Exp. Agric. 37:407–411.

Butler, J. E. 1969. Bovine immunoglobulins: A Review. J. Dairy Sci. 52:1895–1909.

Cafe, L. M., D. L. Robinson, D. M. Ferguson, G. H. Geesink, and P. L. Greenwood. 2011a. Temperament and hypothalamic-pituitary-adrenal axis function are related and combine to affect growth, efficiency, carcass, and meat quality traits in Brahman steers. Domest. Anim. Endocrinol. 40:230–240.

Cafe, L. M., D. L. Robinson, D. M. Ferguson, B. L. McIntyre, G. H. Geesink, and P. L. Greenwood. 2011b. Cattle temperament: Persistence of assessments and associations with productivity, efficiency, carcass and meat quality traits. J. Anim. Sci. 89:1452–1465.

Campos, S. P., and H. Baumann. 1992. Insulin is a prominent modulator of the cytokine-stimulated expression of acute-phase plasma protein gene. Mol. Cell. Biol. 12:1789–1797.

Choat, W. T., C. R. Krehbiel, G. C. Duff, R. E. Kirksey, L. M. Lauriault, J. D. Rivera, B. M. Capitan, D. A. Walker, G. B. Donart, and C. L. Goad. 2003. Influence of grazing dormant native range or winter wheat pasture on subsequent finishing cattle performance, carcass characteristics, and ruminal metabolism. J. Anim. Sci. 81:3191–3201.

Chouinard, P. I., L. Corneau, D. M. Barbano, L. E. Metzger, and D. E. Bauman. 1999. Conjugated linoleic acids alter milk fatty acid composition and inhibit milk fat secretion in dairy cows. J. Nutr. 129:1579–1584.

Christie, W. W. 1982. A simple procedure for rapid transmethylation of glycerolipids and cholesteryl esters. J. Lipid Res. 23:1072–1075.

Cooke, R. F., and J. D. Arthington. 2013. Concentrations of haptoglobin in bovine plasma determined by ELISA or a colorimetric method based on peroxidase activity. J. Anim. Physiol. Anim. Nutr. 97:531–536.

Cooke, R. F., J. D. Arthington, D. B. Araujo, and G. C. Lamb. 2009a. Effects of acclimation to human interaction on performance, temperament, physiological responses, and pregnancy rates of Brahman-crossbred cows. J. Anim. Sci. 87:4125–4132.

Cooke, R. F., J. D. Arthington, B. R. Austin, and J. V. Yelich. 2009b. Effects of acclimation to handling on performance, reproductive, and physiological responses of Brahman crossbred heifers. J. Anim. Sci. 87:3403–3412.

Cooke, R. F., and D. W. Bohnert. 2011. Bovine acute-phase response after corticotrophin-release hormone challenge. J. Anim. Sci. 89:252–257.

Cooke, R. F., D. W. Bohnert, B. I. Cappellozza, C. J. Mueller, and T. Delcurto. 2012. Effects of temperament and acclimation to handling on reproductive performance of *Bos taurus* beef females. J. Anim. Sci. 90:3547–3555.

Cooke, R. F., D. W. Bohnert, M. Meneghetti, T. C. Losi, and J. L. M. Vasconcelos. 2011a. Effects of temperament on pregnancy rates to fixed-timed AI in *Bos indicus* beef cows. Livest. Sci. 142:108–113.

Cooke, R. F., D. W. Bohnert, P. Moriel, B. W. Hess, and R. R. Mills. 2011b. Effects of polyunsaturated fatty acid supplementation on ruminal in situ forage degradability, performance, and physiological responses of feeder cattle. J. Anim. Sci. 89:3677–3689.

Curley, K. O., Jr., D. A. Neuendorff, A. W. Lewis, J. J. Cleere, T. H. Welsh, Jr., and R. D. Randel. 2008. Functional characteristics of the bovine hypothalamic-pituitary-adrenal axis vary with temperament. Horm. Behav. 53:20–27.

Curley, K. O., Jr., J. C. Paschal, T. H. Welsh, Jr., and R. D. Randel. 2006. Technical note: Exit velocity as a measure of cattle temperament is repeatable and associated with serum concentration of cortisol in Brahman bulls. J. Anim. Sci. 84:3100–3103.

Del Campo, M., G. Brito, J. Soares de Lima, P. Hernández, and F. Montossi. 2010. Finishing diet, temperament and lairage time effects on carcass and meat quality traits in steers. Meat Sci. 86:908–914.

Earley, B., M. Murray, D. J. Prendiville, B. Pintado, C. Borque, and E. Canali. 2012. The effect of transport by road and sea on physiology, immunity and behaviour of beef cattle. Res. Vet. Sci. 92:531–541.

Fell, L. R., I. G. Colditz, K. H. Walker, and D. L. Watson. 1999. Associations between temperament, performance and immune function in cattle entering a commercial feedlot. Aust. J. Agric. Res. 39:795–802.

Ferguson, D. M., D. Johnston, M. H. Burrow, and A. Reverter. 2006. Relationships between temperament, feedlot performance and beef quality. In: Australian Beef–the Leader! The impact of science on the beef industry, Beef CRC, Armidale, NSW, Australia. p. 161–165.

Fordyce, G., J. R. Wythes, W. R. Shorthose, D. W. Underwood, and R. K. Shepherd. 1988. Cattle temperaments in extensive beef herds in northern Queensland. 2. Effect of temperament on carcass and meat quality. Aust. J. Exp. Agric. 28:689–693.

Francisco, C. L., R. F. Cooke, R. S. Marques, R. R. Mills, and D. W. Bohnert. 2012. Effects of temperament and acclimation to handling on feedlot performance of *Bos taurus* feeder cattle originated from a rangeland-based cow-calf system. J. Anim. Sci. 90:5067–5077.

Gornall, A. G., C. J. Bardawill, and M. M. David. 1949. Determination of serum proteins by means of the biuret reaction. J. Biol. Chem. 177:751–766.

Grandin, T. 1993. Behavioral agitation during handling of cattle is persistent over time. Appl. Anim. Behav. Sci. 36:1–9.

Grandin, T. 1997. Assessment of stress during handling and transport. J. Anim. Sci. 75:249–257.

Gruber, S. L., J. D. Tatum, T. E. Engle, P. L. Chapman, K. E. Belk, and G. C. Smith. 2010. Relationships of behavioral and physiological symptoms of preslaughter stress to beef longissimus muscle tenderness. J. Anim. Sci. 88:1148–1159.

Hall, N. L., D. S. Buchanan, V. L. Anderson, B. R. Ilse, K. R. Carlin, and E. P. Berg. 2011. Working chute behavior of feedlot cattle can be an indication of cattle temperament and beef carcass composition and quality. Meat Sci. 89:52–57.

Hamm, R. 1960. Biochemistry of meat hydration. Adv. Food Res. 10:435–443.

Hara, A., and N. S. Radin. 1978. Lipid extraction of tissues with a low-toxicity solvent. Anal. Biochem. 90:420–426.

Hoppe, S., H. R. Brandt, S. König, G. Erhardt, and M. Gauly. 2010. Temperament traits of beef calves measured under field conditions and their relationships to performance. J. Anim. Sci. 88:1982–1989.

Immonen, K., M. Ruusunen, K. Hissa, and E. Puolanne. 2000. Bovine muscle glycogen concentration in relation to finishing diet, slaughter and ultimate pH. Meat Sci. 55:25–31.

Kadel, M. J., D. J. Johnson, H. M. Burrow, H. U. Graser, and D. M. Ferguson. 2006. Genetics of flight time and other measures of temperament and their value as selection criteria for improving meat quality traits in tropically adapted breeds of beef cattle. Aust. J. Agric. Res. 57:1029–1035.

King, D. A., C. E. S. Pfeiffer, R. D. Randel, T. H. Welsh, Jr., R. A. Oliphint, B. E. Baird, K. O. Curley, Jr., R. C. Vann, D. S. Hale, and J. W. Savell. 2006. Influence of animal temperament and stress responsiveness on the carcass quality and beef tenderness of feedlot cattle. Meat Sci. 74:546–556.

Lofgreen, G. P., J. L. Hull, and K. K. Otagaki. 1962. Estimation of empty body weight of beef cattle. J. Anim. Sci. 21:20–24.

Mancini, R. A., and M. C. Hunt. 2005. Current research in meat color. Meat Sci. 71:100–121.

Marques, R. S., R. F. Cooke, C. L. Francisco, and D. W. Bohnert. 2012. Effects of twenty-four hour transport or twenty-four hour feed and water deprivation on physiologic and performance responses of feeder cattle. J. Anim. Sci. 90:5040–5046.

McNally, P. W., and P. D. Warriss. 1996. Recent bruising in cattle at abattoirs. Vet. Rec. 138:126–128.

Mello, S. A., Jr., C. R. Calkins, B. E. Jenschke, T. P. Carr, E. M. R. Dugan, and G. E. Erickson. 2012. Beef quality of calf-fed steers finished on varying levels of corn-based wet distillers grains plus solubles. J. Anim. Sci. 90:4625–4633.

Miranda-de la Lama, C. G., M. Pascual-Alonso, A. Guerrero, P. Alberti, S. Alierta, P. Sans, J. P. Gajan, M. Villarroel, A. Dalmau, A. Velarde, M. M. Campo, F. Galindo, M. P. Santolaria, C. Sañudo, and G. A. María. 2013. Influence of social dominance on production, welfare and the quality of meat from beef bulls. Meat Sci. 94:432–437.

Morris, C. A., N. G. Cullen, R. Kilgour, and K. J. Bremner. 1994. Some genetic factors affecting temperament in Bos *taurus* cattle. N. Z. J. Agric. Res. 37:167–175.

Murata, H. 1997. Effects of burdizzo castration on peripheral blood lymphocyte variables in calves. Vet. J. 153:229–231.

Murata, H., and T. Miyamoto. 1993. Bovine haptoglobin as a possible immunomodulator in the sera of transported calves. Br. Vet. J. 149:277–283.

Nkrumah, J. D., D. H. Crews, Jr., J. A. Basarab, M. A. Price, E. K. Okine, Z. Wang, C. Li, and S. S. Moore. 2007. Genetic and phenotypic relationships of feeding behavior and temperament with performance, feed efficiency, ultrasound, and carcass merit of beef cattle. J. Anim. Sci. 85:2382–2390.

Paranhos da Costa, M. J. R., S. M. Huertas, C. Gallo, and O. A. Dalla Costa. 2012. Strategies to promote farm animal welfare in Latin America and their effects on carcass and meat quality traits. Meat Sci. 92:221–226.

Petherick, J. C., V. J. Doogan, B. K. Venus, R. G. Holroyd, and P. Olsson. 2009. Quality of handling and holding yard environment, and beef cattle temperament: 2. Consequences for stress and productivity. Appl. Anim. Behav. Sci. 120:28–38.

Petherick, J. C., R. G. Holroyd, V. J. Doogan, and B. K. Venus. 2002. Productivity, carcass and meat quality of lot-fed *Bos indicus* cross steers grouped according to temperament. Anim. Prod. Sci. 42:389–398.

Pikul, J., D. E. Leszczynski, and F. A. Kummerow. 1989. Evaluation of tree modified TBA methods for measuring lipid oxidation in chicken meat. J. Agric. Food Chem. 37:1309–1313.

Rhoades, R. D., J. E. Sawyer, K. Y. Chung, M. L. Schell, D. K. Lunt, and S. B. Smithet. 2007. Effect of dietary energy source on in vitro substrate utilization and insulin sensitivity of muscle and adipose tissues of Angus and Wagyu steers. J. Anim. Sci. 85:1719–1726.

Savell, J. W., S. L. Mueller, and B. E. Baird. 2005. The chilling of carcasses. Meat Sci. 70:449–459.

Scholljegerdes, E. J., S. L. Lake, T. R. Weston, D. C. Rule, G. E. Moss, T. M. Nett, and B. W. Hess. 2007. Fatty acid composition of plasma, medial basal hypothalamus, and uterine tissue in primiparous beef cows fed high-linoleate safflower seeds. J. Anim. Sci. 85:1555–1564.

Schoonmaker, J. P., M. J. Cecava, D. B. Faulkner, F. L. Fluharty, H. N. Zerby, and S. C. Loerch. 2003. Effects of source of energy and rate of growth on performance, carcass characteristics, ruminal fermentation, and serum glucose and insulin of early-weaned steers. J. Anim. Sci. 81:843–855.

Schoonmaker, J. P., F. L. Fluharty, and S. C. Loerch. 2004. Effect of source and amount of energy and rate of growth in the growing phase on adipocyte cellularity and lipogenic enzyme activity in the intramuscular and subcutaneous fat depots of Holstein steers. J. Anim. Sci. 82:137–148.

Smith, G. C., and Z. L. Carpenter. 1973. Postmortem shrinkage of lamb carcasses. J. Anim. Sci. 36:862–867.

Snoeck, V., I. R. Peters, and E. Cox. 2006. The IgA system: A comparison of structure and function in different species. Vet. Res. 37:455–467.

Traore, S., L. Aubry, P. Gatellier, W. Przybylski, D. Jaworska, K. Kajak-Siemaszko, and V. Santé-Lhoutellier. 2012. Higher drip loss is associated with protein oxidation. Meat Sci. 90:917–924.

Trenkle, A. 1970. Plasma levels of growth hormone, insulin and plasma protein-bound iodine in finishing cattle. J. Anim. Sci. 31:389–393.

Trenkle, A., and D. G. Topel. 1978. Relationship of some endocrine measurements to growth and carcass composition of cattle. J. Anim. Sci. 46:1604–1609.

Turner, S. P., E. A. Navajas, J. J. Hyslop, D. W. Ross, R. I. Richardson, N. Prieto, and M. Bell. 2011. Associations between response to handling and growth and meat quality in frequently handled *Bos taurus* beef cattle. J. Anim. Sci. 89:4239–4248.

USDA. 1997. United states standards for grades of carcass beef. Agricultural Marketing Service, USDA, Washington, DC.

Vann, R. C. 2006. Relationships between carcass quality and temperament in beef cattle. In: Proc. Beef Improv. Fed, Chocktaw, MS. p. 69–72.

Vetters, M. D. D., T. E. Engle, J. K. Ahola, and T. Grandin. 2013. Comparison of flight speed and exit score as measurements of temperament in beef cattle. J. Anim. Sci. 91:374–381.

Voisinet, B. D., T. Grandin, J. D. Tatum, S. F. O'Connor, and J. J. Struthers. 1997. Feedlot cattle with calm temperaments have higher average daily gains than cattle with excitable temperaments. J. Anim. Sci. 75:892–896.

Weber, K., and M. Osborn. 1969. The reliability of molecular weight determinations by dodecyl sulfate-polyacrylamide gel electrophoresis. J. Biol. Chem. 244:4406–4412.

Wheeler, T. L., M. Koohmaraie, and S. D. Shackelford. 1995. Standardized Warner-Bratzler shear force procedures for meat tenderness measurement. Clay Center, USDA, Washington, DC.

Zhang, W. H., B. Shi, and J. Shi. 2007. A theoretical study on autoxidation of unsaturated fatty acids and antioxidant activity of phenolic compounds. J. Am. Leather Chem. Assoc. 102:99–105. (Abstr.)