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# Effects of twenty-four hour transport or twenty-four hour feed and water deprivation on physiologic and performance responses of feeder cattle<sup>1</sup>

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**ABSTRACT:** The objective of this study was to compare the effects of 24-h road transport or 24-h feed and water deprivation on acute-phase and performance responses of feeder cattle. Angus × Hereford steers (n = 30) and heifers (n = 15) were ranked by gender and BW (217 ± 3 kg initial BW; 185 ± 2 d initial age) and randomly assigned to 15 pens on d -12 of the experiment (3 animals/pen; 2 steers and 1 heifer). Cattle were fed alfalfa–grass hay ad libitum and 2.3 kg/animal daily (DM basis) of a corn-based concentrate throughout the experiment (d -12 to 28). On d 0, pens were randomly assigned to 1 of 3 treatments: 1) transport for 24 h in a livestock trailer for 1,200 km (TRANS), 2) no transport but feed and water deprivation for 24 h (REST), or 3) no transport and full access to feed and water (CON). Treatments were concurrently applied from d 0 to d 1. Total DMI was evaluated daily from d -12 to d 28. Full BW was recorded before treatment application (d -1 and 0) and at the end of experiment (d 28 and 29). Blood samples were collected on d 0, 1, 4, 7, 10, 14, 21, and 28. Mean ADG was greater ( $P < 0.01$ ) in CON vs. TRANS and REST cattle but similar ( $P = 0.46$ ) between TRANS and REST cattle (1.27, 0.91, and 0.97 kg/d, respectively; SEM = 0.05). No treatment

effects were detected for DMI ( $P \geq 0.25$ ), but CON had greater G:F vs. TRANS ( $P < 0.01$ ) and REST cattle ( $P = 0.08$ ) whereas G:F was similar ( $P = 0.21$ ) between TRANS and REST cattle. Plasma cortisol concentrations were greater ( $P \leq 0.05$ ) in REST vs. CON and TRANS cattle on d 1, 7, 14, and 28 and also greater ( $P = 0.02$ ) in TRANS vs. CON cattle on d 1. Serum NEFA concentrations were greater ( $P < 0.01$ ) in REST and TRANS vs. CON cattle on d 1 and greater ( $P < 0.01$ ) in REST vs. TRANS cattle on d 1. Plasma ceruloplasmin concentrations were greater ( $P = 0.04$ ) in TRANS vs. CON cattle on d 1, greater ( $P = 0.05$ ) in REST vs. CON on d 4, and greater ( $P \leq 0.05$ ) in REST vs. TRANS and CON on d 14. Plasma haptoglobin concentrations were greater ( $P < 0.01$ ) in TRANS vs. CON and REST cattle on d 1 and greater ( $P \leq 0.05$ ) for REST vs. TRANS and CON cattle on d 7. In conclusion, 24-h transport and 24-h nutrient deprivation elicited acute-phase protein reactions and similarly reduced feedlot receiving performance of feeder cattle. These results suggest that feed and water deprivation are major contributors to the acute-phase response and reduced feedlot receiving performance detected in feeder cattle transported for long distances.

**Key words:** acute-phase response, feed and water deprivation, feeder cattle, performance, transport

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## INTRODUCTION

Cattle are inevitably exposed to psychological, physiological, and physical stressors associated with management procedures currently practiced within beef production systems (Carroll and Forsberg, 2007). Transporting, for example, is one of the most stressful events experienced by feeder calves (Swanson and Morrow-Tesch, 2001). Upon long transportation periods, cattle experience inflammatory and acute-phase

responses (Arthington et al., 2008; Cooke et al., 2011) that often lead to impaired health and productivity during feedlot receiving (Berry et al., 2004; Qiu et al., 2007; Araujo et al., 2010). These stress-induced immune responses may be elicited by several stressors that cattle are exposed to during road transport, including feed and water deprivation (Swanson and Morrow-Tesch, 2001).

Nutrient deprivation stimulates mobilization of body fat reserves (Cooke et al., 2007) as well as a neuroendocrine stress response modulated by the ACTH–cortisol axis (Ward et al., 1992; Henricks et al., 1994), which in turn have been shown to trigger acute-phase reactions in cattle (Cooke and Bohnert, 2011; Cooke et al., 2012). Feed and water deprivation may also disrupt the ruminal ecosystem and cause microbial death (Meiske, et al., 1958), resulting in the release of microbial endotoxins that also elicit the bovine acute-phase response (Carroll et al., 2009). Accordingly, our research group reported that water and feed deprivation for 24 h increased circulating concentrations of acute-phase proteins in beef steers (Cappelozza et al., 2011). Therefore, we hypothesized that feed and water deprivation is a major stimulant of the acute-phase response elicited by road transport. The objective of this experiment was to compare the effects of 24-h road transport or 24-h feed and water deprivation on circulating concentrations of cortisol, NEFA, acute-phase proteins, and feedlot receiving performance of feeder cattle.

## MATERIALS AND METHODS

This experiment was conducted at the Oregon State University – Eastern Oregon Agricultural Research Center (Burns station) from October to November 2011. All animals used were cared for in accordance with acceptable practices and experimental protocols reviewed and approved by the Oregon State University Institutional Animal Care and Use Committee.

### *Animals and Diets*

Forty-five Angus × Hereford steers ( $n = 30$ ) and heifers ( $n = 15$ ), which had been weaned 35 d before the beginning of the experiment (d –12), were ranked by gender and initial BW ( $217 \pm 3$  kg;  $185 \pm 2$  d initial age) and randomly allocated to 15 dry lot pens (3 animals/pen; 2 steers and 1 heifer; 7 by 15 m). From d –12 to 0, all pens were fed alfalfa–grass hay ad libitum and 2.3 kg/animal daily (DM basis) of a concentrate containing (as-fed basis) 84% cracked corn, 14% soybean meal, and 2% mineral mix, which was offered separately from hay at 0800 h. On d 0, pens were assigned to 1 of 3 treatments: 1) transport for 24 h in a double-deck commercial livestock trailer (Legend 50' cattle liner; Barrett LLC., Purcell, OK) for approximately 1,200

km (**TRANS**), 2) no transport but feed and water deprivation for 24 h (**REST**), or 3) no transport and full access to feed and water (**CON**). The TRANS and REST treatments were concurrently applied from d 0 to d 1, when REST cattle were maintained in a single pen (12 by 20 m) without feed and water troughs. Concurrently, CON cattle were individually allocated to the aforementioned dry lot pens (7 by 15 m) for individual feed intake evaluation (1 animal/pen). Upon completion of treatment application (d 1), all cattle were immediately returned to their original pens and received the same diet offered before treatment application. During treatment application, mean, maximum, and minimum temperatures ( $^{\circ}\text{C}$ ) were, respectively, 6.6, 16.7, and  $-3.9$ . Mean, maximum, and minimum humidity (%) were, respectively, 59, 96, and 22.

Samples of hay and concentrate ingredients were collected weekly, pooled across all weeks, and analyzed for nutrient content by a commercial laboratory (Dairy One Forage Laboratory, Ithaca, NY). All samples were analyzed by wet chemistry procedures for concentrations of CP (method 984.13; AOAC, 2006), ADF (method 973.18 modified for use in an Ankom 200 fiber analyzer; Ankom Technology Corp., Fairport, NY; AOAC, 2006), and NDF (Van Soest et al., 1991; modified for use in an Ankom 200 fiber analyzer; Ankom Technology Corp.). Calculations for TDN used the equation proposed by Weiss et al. (1992) whereas  $\text{NE}_m$  and  $\text{NE}_g$  were calculated with the equations proposed by the NRC (1996). Hay nutritional profile was (DM basis) 58% TDN, 57% NDF, 38% ADF, 1.18 Mcal/kg of  $\text{NE}_m$ , 0.60 Mcal/kg of  $\text{NE}_g$ , and 12.5% CP. Based on the nutritional analysis of ingredients, concentrate nutritional profile was (DM basis) 85% TDN, 9.0% NDF, 4.6% ADF, 2.12 Mcal/kg of  $\text{NE}_m$ , 1.46 Mcal/kg of  $\text{NE}_g$ , and 14.5% CP. The mineral mix (Cattleman's Choice; Performix Nutrition Systems, Nampa, ID), contained 14% Ca, 10% P, 16% NaCl, 1.5% Mg, 3,200 mg/kg of Cu, 65 mg/kg of I, 900 mg/kg of Mn, 140 mg/kg of Se, 6,000 mg/kg of Zn, 136,000 IU/kg of vitamin A, 13,000 IU/kg of vitamin D<sub>3</sub>, and 50 IU/kg of vitamin E. Water was offered for ad libitum consumption throughout the experiment, except to TRANS and REST cattle during treatment application.

All cattle were vaccinated against clostridial diseases (Clostrishield 7; Novartis Animal Health; Bucyrus, KS) and bovine virus diarrhea complex (Virashield 6 + Somnus; Novartis Animal Health) at approximately 30 d of age. At weaning, cattle were vaccinated against clostridial diseases and *Mannheimia haemolytica* (One Shot Ultra 7; Pfizer Animal Health, New York, NY), infectious bovine rhinotracheitis, bovine viral diarrhea complex, and pneumonia (Bovi-Shield Gold 5 and TSV-2; Pfizer Animal Health) and administered an anthelmintic (Dectomax; Pfizer Animal Health). No incidences of mortality or morbidity were observed during the entire experiment.

## Sampling

Individual full BW was recorded and averaged over 2 consecutive d before treatment application (d -1 and 0) and at the end of experiment (d 28 and 29) for ADG calculation. Individual BW was also collected on d 1, immediately after treatment application, to evaluate BW shrink as percentage change from the average BW recorded on d -1 and 0. Concentrate, hay, and total DMI were evaluated daily from d -12 to 28 from each pen by collecting and weighingorts daily. Samples of the offered and nonconsumed feed were collected daily from each pen and dried for 96 h at 50°C in forced-air ovens for DM calculation. Hay, concentrate, and total daily DMI of each pen were divided by the number of animals within each pen and expressed as kilograms per animal per d. Total BW gain and DMI of each pen from d 1 to 28 were used for feedlot receiving G:F calculation.

Blood samples were collected on d 0 (before treatment application), 1 (immediately at the end of treatments), 4, 7, 10, 14, 21, and 28 via jugular venipuncture into commercial blood collection tubes (Vacutainer; 10 mL; Becton Dickinson, Franklin Lakes, NJ) with or without 158 United States Pharmacopeia (USP) units of freeze-dried sodium heparin for plasma and serum collection, respectively. Blood samples were collected before concentrate feeding, except for d 0 when REST and TRANS cattle were not fed hay and concentrate after blood collection. All blood samples were placed immediately on ice, centrifuged ( $2,500 \times g$  for 30 min; 4°C) for plasma or serum harvest, and stored at -80°C on the same day of collection. Plasma concentrations of cortisol were determined using a bovine-specific commercial ELISA kit (Endocrine Technologies Inc., Newark, CA). Plasma concentrations of ceruloplasmin and haptoglobin were determined according to colorimetric procedures previously described (Demetriou et al., 1974; Cooke and Arthington, 2012). Serum concentrations of NEFA were determined using a colorimetric commercial kit (HR Series NEFA - 2; Wako Pure Chemical Industries Ltd. USA, Richmond, VA) with the modifications described by Pescara et al. (2010). The intra- and interassay CV were, respectively, 6.6 and 7.4% for cortisol, 1.9 and 2.2% for NEFA, 9.2 and 10.7% for ceruloplasmin, and 4.1 and 8.8% for haptoglobin.

## Statistical Analysis

Data were analyzed using animal as the experiments unit, given that animals were equally exposed to treatments, with the PROC MIXED procedure (SAS Inst. Inc., Cary, NC) and Satterthwaite approximation to determine the denominator degrees of freedom for the tests of fixed effects. The model statement used for BW shrink from d 0

to d 1 and ADG contained the effects of treatment, gender, and the treatment  $\times$  gender interaction. Data were analyzed using animal(treatment  $\times$  pen) as random variable. The model statement used for DMI and G:F contained the effects of treatment, day, the treatment  $\times$  day interaction, and average feed intake from d -12 to -1 as covariate for DMI only. Data were analyzed using pen(treatment) as the random variable. The model statement used for blood variables contained the effects of treatment, day, gender, all resultant interactions (treatment  $\times$  gender, treatment  $\times$  day, and treatment  $\times$  gender  $\times$  day), and values obtained on d 0 as covariate. Data were analyzed using animal(treatment  $\times$  pen) as the random variable. The specified term for the repeated statements was day and pen(treatment) or animal(treatment  $\times$  pen) as subject for DMI or blood variables, respectively, and the covariance structure used was based on the Akaike information criterion. Results are reported as least square means as well as covariately adjusted least square means for DMI and blood variables and were separated using the probability of differences option (PDIF). Significance was set at  $P \leq 0.05$  and tendencies were determined if  $P > 0.05$  and  $\leq 0.10$ . Results are reported according to main effects if no interactions were significant or according to the highest-order interaction detected.

## RESULTS AND DISCUSSION

No interactions containing the effects of treatment and gender were detected ( $P \geq 0.33$ ) for the variables analyzed and reported herein; therefore, results are reported across steers and heifers. Hay, concentrate, and total DMI from d 0 to 1 in CON cattle were  $5.5 \pm 0.3$ ,  $1.7 \pm 0.1$ , and  $7.2 \pm 0.3$  kg/d, respectively. Hence, all cattle assigned to CON consumed the expected amount of feed, in addition to ad libitum access to water, as TRANS and REST cohorts were receiving their assigned treatments.

A treatment effect was detected ( $P < 0.01$ ) for BW shrink from d 0 to 1. Shrink was greater ( $P < 0.01$ ) for both TRANS and REST compared with CON cattle but also greater for TRANS compared with REST cattle (Table 1). Hence, BW after treatment application (d 1) was greater ( $P \leq 0.03$ ) for CON cattle compared with TRANS and REST cohorts (Table 1). Supporting our findings, other research studies reported substantial BW loss in feeder cattle upon 24-h road transport or feed and water deprivation (Cole and Hutcheson, 1985; Arthington et al., 2008). In addition, Phillips et al. (1991) also documented greater BW loss in steers assigned to road transport for 48 h compared with nontransported cohorts subjected to 48-h feed and water deprivation. Transported cattle are exposed to additional factors during road transport to which fasted cattle are not exposed, such as loading and unloading, that may further stimulate urina-

**Table 1.** Feedlot receiving performance (28 d) of cattle submitted to transport for 24 h in a livestock trailer for 1,200 km (TRANS; n = 15), no transport but feed and water deprivation for 24 h (REST; n = 15), or no transport and full access to feed and water (CON; n = 15)<sup>1</sup>

Item	CON	REST	TRANS	SEM	P-value
BW, <sup>2</sup> kg					
Initial	219	218	219	5	0.98
Posttreatment	219 <sup>a</sup>	201 <sup>b</sup>	199 <sup>b</sup>	6	0.03
Final	257	246	246	6	0.37
Shrink, <sup>3</sup> %	0.07 <sup>a</sup>	8.1 <sup>b</sup>	9.6 <sup>c</sup>	0.7	<0.01
ADG, <sup>4</sup> kg/d	1.27 <sup>a</sup>	0.97 <sup>b</sup>	0.91 <sup>b</sup>	0.05	<0.01
DMI, <sup>5</sup> kg/d					
Hay	5.5	4.9	5.4	0.3	0.32
Concentrate	2.30	2.29	2.26	0.05	0.52
Total	7.9	7.2	7.8	0.4	0.25
G:F, <sup>6</sup> g/kg	163 <sup>a</sup>	143 <sup>ab</sup>	127 <sup>b</sup>	7	0.03

<sup>a-c</sup>Within rows, values with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>Treatments were concurrently applied from d 0 to 1.

<sup>2</sup>Initial = average of BW recorded on d -1 and 0; Posttreatment = BW recorded immediately after the end of treatment application (d 1); Final = average of BW recorded on d 28 and 29.

<sup>3</sup>Based on BW loss from d 1 to 0.

<sup>4</sup>Calculated using Initial and Final BW.

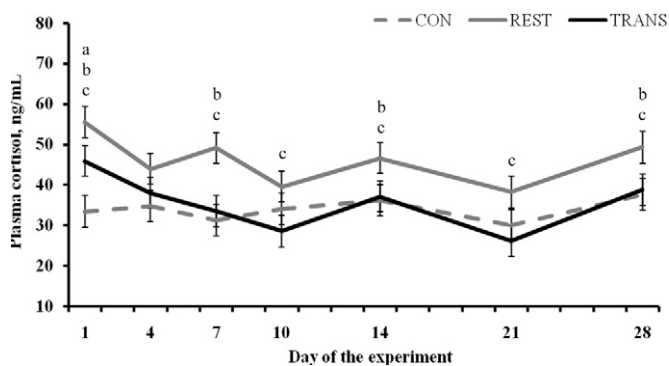
<sup>5</sup>Calculated from each pen, but divided by the number of cattle within each pen and expressed as kilograms per animal/day. Means covariately adjusted to average hay, concentrate, and total DMI recorded before treatment application (d -12 to d 0; significant covariates,  $P < 0.05$ ).

<sup>6</sup>Calculated using total DMI and BW gain of each pen d 0 to d 28.

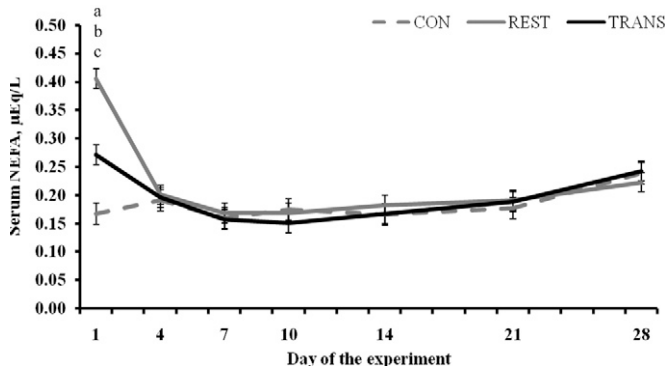
tion, defecation, and consequent BW shrink (Swanson and Morrow-Tesch, 2001). A treatment effect was also detected ( $P < 0.01$ ) for ADG (Table 1). Cattle assigned to CON had greater ( $P < 0.01$ ) ADG compared with TRANS and REST cohorts whereas ADG was similar between ( $P = 0.46$ ) TRANS and REST cattle. Accordingly, Arthington et al. (2003) reported reduced feedlot receiving ADG in transported cattle compared with nontransported cohorts whereas Phillips et al. (1991) reported similar 28-d ADG in steers assigned to road transport for 48 h and nontransported cohorts subjected to 48-h feed and water deprivation. Nevertheless, treatment effects detected on ADG were not sufficient to impact ( $P = 0.37$ ) cattle BW at the end of the experimental period. No treatment ( $P \geq 0.25$ ) effects were detected on hay, concentrate, and total DMI (Table 1) although other authors reported depressed feed intake in cattle upon road transport (Hutcheson and Cole, 1986) or feed and water deprivation (Cole and Hutcheson, 1985), particularly due to impaired ruminal function and altered endocrine or metabolic patterns (Cole, 2000). Nevertheless, a treatment effect was detected ( $P = 0.03$ ) for G:F because CON had greater G:F compared with TRANS ( $P < 0.01$ ) and tended to have greater G:F compared with REST cattle ( $P = 0.08$ ) whereas G:F was similar ( $P = 0.21$ ) between TRANS and REST cattle (Table 1). Hence, REST

cattle experienced similar decrease in feedlot receiving performance compared with TRANS cohorts, supporting that feed and water deprivation are major causes for the reduced performance of feeder cattle transported for 24 h (Swanson and Morrow-Tesch, 2001)

Treatment  $\times$  day interactions were detected for plasma cortisol ( $P = 0.03$ ), haptoglobin ( $P = 0.02$ ), ceruloplasmin ( $P = 0.05$ ), and serum NEFA ( $P < 0.01$ ). Plasma cortisol concentrations were greater ( $P \leq 0.05$ ) in REST compared with CON and TRANS cattle on d 1, 7, 14, and 28, greater ( $P \leq 0.04$ ) in REST compared with TRANS cattle on d 10 and 21, and greater ( $P = 0.02$ ) in TRANS compared with CON cattle on d 1 (Figure 1). Other studies also reported increasing circulating cortisol concentrations in cattle exposed to road transport (Crookshank et al., 1979; Cooke et al., 2011) or fasting (Ward et al., 1992; Henricks et al., 1994). Serum NEFA concentrations were greater ( $P < 0.01$ ) in REST and TRANS compared with CON cattle on d 1 as well as greater ( $P < 0.01$ ) in REST compared with TRANS cattle on d 1 (Figure 2), demonstrating that fasting and road transport stimulate fat tissue mobilization and increase circulating NEFA concentration in cattle (Earley and O'Riordan, 2006; Cooke et al., 2007). Plasma ceruloplasmin concentrations were greater ( $P = 0.04$ ) in TRANS compared with CON cattle on d 1, greater ( $P = 0.05$ ) for REST compared with CON on d 4, and greater ( $P \leq 0.05$ ) for REST compared with TRANS and CON on d 14 (Figure 3). Plasma haptoglobin concentrations were greater ( $P < 0.01$ ) for TRANS compared with CON and REST cattle on d 1 whereas REST cattle had greater ( $P \leq 0.05$ ) plasma haptoglobin compared with TRANS and CON cattle on d 7 (Figure 4). Similarly, previous research also documented an acute-phase protein reaction



**Figure 1.** Plasma cortisol concentration in cattle submitted to transport for 24 h in a livestock trailer for 1,200 km (TRANS; n = 15), no transport but feed and water deprivation for 24 h (REST; n = 15), or no transport and full access to feed and water (CON; n = 15). Treatments were concurrently applied from d 0 to 1. Values obtained before treatment application (d 0) served as covariate ( $P < 0.01$ ) but did not differ ( $P = 0.66$ ) among treatments (35.9, 35.9, and 30.7 ng/mL for CON, REST, and TRANS, respectively; SEM = 4.8). Therefore, results reported are covariately adjusted least squares means. A treatment  $\times$  day interaction was detected ( $P = 0.03$ ). Within days, letters indicate the following treatment differences; a = TRANS vs. CON ( $P = 0.02$ ), b = REST vs. CON ( $P \leq 0.05$ ), and c = TRANS vs. REST ( $P \leq 0.04$ ).

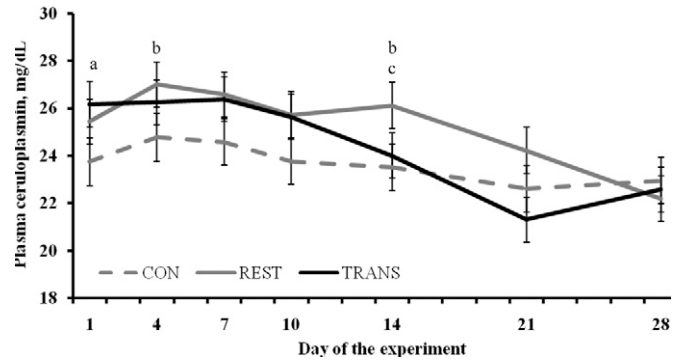


**Figure 2.** Serum NEFA concentration in cattle submitted to transport for 24 h in a livestock trailer for 1,200 km (TRANS;  $n = 15$ ), no transport but feed and water deprivation for 24 h (REST;  $n = 15$ ), or no transport and full access to feed and water (CON;  $n = 15$ ). Treatments were concurrently applied from d 0 to 1. Values obtained before treatment application (d 0) served as covariate ( $P = 0.03$ ) but did not differ ( $P = 0.89$ ) among treatments (0.163, 0.169, and 0.159  $\mu\text{Eq/L}$  for CON, REST, and TRANS, respectively; SEM = 0.017). Therefore, results reported are covariately adjusted least squares means. A treatment  $\times$  day interaction was detected ( $P = 0.01$ ). Within days, letters indicate the following treatment differences; a = TRANS vs. CON ( $P < 0.01$ ), b = REST vs. CON ( $P < 0.01$ ), and c = TRANS vs. REST ( $P < 0.01$ ).

in beef cattle upon 24-h road transport (Arthington et al., 2008; Araujo et al., 2010) or feed and water deprivation (Phillips et al., 1991; Cappellozza et al., 2011).

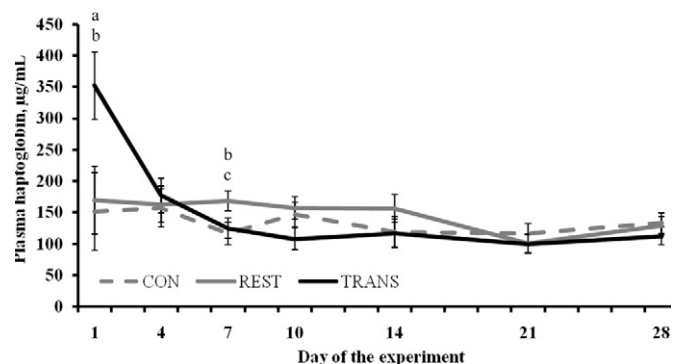
Supporting our main hypothesis, TRANS and REST elicited a neuroendocrine stress response (Sapolsky et al., 2000), stimulated mobilization of body reserves (Ellenberger et al., 1989), and induced an acute-phase protein reaction (Carroll and Forsberg, 2007) that impaired feedlot receiving ADG and G:F. Accordingly, circulating concentrations of acute-phase proteins in transported feeder cattle have been negatively associated with feedlot receiving performance (Berry et al., 2004; Qiu et al., 2007; Araujo et al., 2010), and such outcome can be attributed to altered basal metabolism, increased tissue catabolism, and reduced feed efficiency during an acute-phase response (Johnson, 1997). Recent research from our group demonstrated that the bovine acute-phase response is triggered by stressful situations, such as road transport or feed and water deprivation, via neuroendocrine reactions that stimulate breakdown of body reserves and activate acute-phase and inflammatory processes (Cooke and Bohnert, 2011; Cooke et al., 2012). Moreover, severe feed and water deprivation result in death of rumen microbes and subsequent release of endotoxins (Meiske et al., 1958), which may be absorbed through the ruminal wall and small intestine, incorporated into the circulation (Chin et al., 2006), and elicit neuroendocrine and acute-phase reactions (Carroll et al., 2009). Hence, the acute-phase protein reaction detected in TRANS and REST cattle can be attributed to the increase in circulating cortisol and NEFA as well as impaired ruminal function and health after treatment application.

Although feedlot receiving performance was similar



**Figure 3.** Plasma ceruloplasmin concentration in cattle submitted to transport for 24 h in a livestock trailer for 1,200 km (TRANS;  $n = 15$ ), no transport but feed and water deprivation for 24 h (REST;  $n = 15$ ), or no transport and full access to feed and water (CON;  $n = 15$ ). Treatments were concurrently applied from d 0 to 1. Values obtained before treatment application (d 0) served as covariate ( $P < 0.01$ ) but did not differ ( $P = 0.26$ ) among treatments (22.6, 25.1, and 23.0 mg/dL for CON, REST, and TRANS, respectively; SEM = 1.2). Therefore, results reported are covariately adjusted least squares means. A treatment  $\times$  day interaction was detected ( $P = 0.05$ ). Within days, letters indicate the following treatment differences; a = TRANS vs. CON ( $P = 0.04$ ), c = REST vs. CON ( $P = 0.05$ ), and c = TRANS vs. REST ( $P \leq 0.05$ ).

between TRANS and REST cattle, it is important to note that the increase in plasma cortisol and serum NEFA concentrations upon treatment application was greater in REST compared with TRANS cattle. Similarly, plasma cortisol, ceruloplasmin, and haptoglobin concentrations remained elevated for a longer period in REST compared with TRANS cattle upon treatment application. These results suggest that the treatment-induced neuroendocrine stress response was more severe in REST cattle (Sapolsky et al., 2000), which caused or resulted from the greater mobilization of body tissues (Abbas and Lichtman, 2007) and yielded more persistent ceruloplasmin and haptoglobin responses compared with that observed in TRANS cohorts (Cooke et al., 2012). The



**Figure 4.** Plasma haptoglobin concentration in cattle submitted to transport for 24 h in a livestock trailer for 1,200 km (TRANS;  $n = 15$ ), no transport but feed and water deprivation for 24 h (REST;  $n = 15$ ), or no transport and full access to feed and water (CON;  $n = 15$ ). Treatments were concurrently applied from d 0 to 1. Values obtained before treatment application (d 0) served as covariate ( $P = 0.01$ ) but did not differ ( $P = 0.63$ ) among treatments (101.6, 125.9, and 112.6  $\mu\text{g/mL}$  for CON, REST, and TRANS, respectively; SEM = 17.7). Therefore, results reported are covariately adjusted least squares means. A treatment  $\times$  day interaction was detected ( $P = 0.03$ ). Within days, letters indicate the following treatment differences; a = TRANS vs. CON ( $P < 0.01$ ), b = TRANS vs. REST ( $P \leq 0.05$ ), and c = REST vs. CON ( $P = 0.03$ ).

reasons for these outcomes are unknown and deserve further investigation, particularly because TRANS cattle also experienced a 24-h feed and water deprivation during transport whereas nutrient withdrawal is only one of the several stressors to which cattle are exposed during road transport (Swanson and Morrow-Tesch, 2001).

In conclusion, 24-h road transport and 24-h feed and water deprivation stimulated breakdown of fat reserves, elicited neuroendocrine and acute-phase protein responses, and similarly reduced performance of feeder cattle. Therefore, feed and water deprivation are major contributors to the acute-phase response and reduced feedlot receiving performance detected in feeder cattle transported for long distances. These results help elucidate some of the mechanisms responsible for the immune challenges experienced by transported feeder cattle that often lead to impaired health and productivity during feedlot receiving (Berry et al., 2004; Qiu et al., 2007; Araujo et al., 2010). This knowledge can be used in the development of strategies that lessen the magnitude of the transport-induced acute-phase reaction and benefit the productivity and overall efficiency of feeder cattle.

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