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Article

Stress indicators in cattle in response to loading, transport and unloading practices

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Abstract:

Transporting of cattle can cause multiple physical and psychological stressors that may affect profitability. An evaluation was done of the effects of stress produced by management practices before, during and after cattle transport, based on changes in physiological indicators and weight prior to the finishing stage. Animals were 124 weaned calves transported to the State of Mexico from the states of Veracruz (500 km) and Chiapas (851 km), Mexico, for finishing in feedlots. Four treatments were used: 1) preloading reception management at place of origin (PRE); 2) PRE + preloading application of a β-blocker (PREβ); 3) reception management upon unloading at feedlot (POST); and 4) POST + preloading application of a β-blocker (POSTβ). The data were analyzed with the GLM procedure in the SAS program. The experimental design was a completely random 2 x 4 factorial arrangement (two transport distances and four treatments). Average live weight (LW) decreased 42 kg per animal (11.3 %) at unloading, but 10 days after unloading had

recovered by 35 kg. Live weight loss was lower in the PREβ treatment (37.6 kg) than in the PRE (47.5 kg) or POSTβ (44.5 kg) treatments. The PREβ did not differ (P>0.05) from the MD (38.7 kg). The most important stress indicators were changes in live weight, glucose and cortisol, with differences (P<0.05) identified by treatment and transport distance. No differences (P>0.05) were present in the other indicators (free fatty acids, β-hydroxybutyrate, total proteins, and sodium and potassium concentrations). The combination of preloading reception management and a β-blocker produced the least amount of stress in the animals. More attention is needed on the period between loading and unloading cattle for transport to finishing to establish optimum conditions.

Key words: Cortisol, Carazolol, Finishing, Transport.

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Introduction

Transport of cattle for finishing and slaughter subjects animals to multiple physical and psychological stressors[1,2], which can negatively impact health and productive behavior. Response to transport stress can vary according to different factors, such as nature of the trip, grouping of unknown animals, use of an electric sweeper, the presence of noise, high load density, vehicle type, driver skill, road conditions and trip duration, among others[1,3,4,5].

Behavioral, pathological and physiological indicators have been applied to assess the effects of transport stress on cattle[2,6]. Research on cattle stress during transport from finishing corral to slaughterhouse has shown increases in cortisol levels (5.2 to 14.3 $ng \cdot ml^{-1}$)[7], total blood serum proteins (67.7 to 74.4 $g \cdot l^{-1}$)[8], and blood glucose (>10% after 16 h transport)[9], as well as loss of live weight (7.9 to 10.5%)[10,11,12]. No evaluations have been done to date of the effects of transport from the breeding system to the finishing corral in a variety of conditions. In one study done in Chile of calves intended for grazing finishing[8], transport for more than 48 hours raised cortisol levels from 10 $ng \cdot ml^{-1}$ before loading to 15 $ng \cdot ml^{-1}$ at unloading, and caused 13% live weight loss.

Drugs such as allostatic modulators, sedatives and β-blockers have been tested to reduce the negative effects of cattle transport to the slaughterhouse[13]. Beta-blockers have been shown to lower stress levels in animals due to their antagonistic effect on β-adrenergic receptors

which decreases the effects of catecholamines, including their glycolytic action[14,15,16]. However, results have been variable and at times contradictory. Therefore, assessment is needed of the direct effects of transport stress on production parameters (e.g. live weight and recovery time) under specific situations.

In Mexico, it is common practice in cattle production to finish cattle acquired post-weaning from growth systems. No literature is currently available documenting the effects of cattle transport from growth systems to finishing corral. Commercial livestock carriers use various management practices when receiving animals for transport and at unloading, including application of drugs before transport to reduce adverse effects.

The present study objective was to evaluate the effect of use of reception management practices before or after transport and pre-loading application of a commercial β-blocker (Simpanorm®) in weaned calves on different stress indicators and live weight gain after transport to the finishing feedlot.

Material and methods

Study area and animals

Data were collected from July 2013 to July 2014 during commercial transport of calves from Acayucan, Veracruz (17°56' N; 94°54' W) and Pichucalco, Chiapas (17°31' N; 93°05' W) to finishing feedlots in Texcoco, State of Mexico (19°30' N; 98°52' W)[17]. Three trips were evaluated per place of origin (6 animals in the first trip, and 5 in the remaining two). The evaluated animals were 124 commercial cross (*Bos taurus* - *Bos indicus*) calves (from grazing systems) with a 375 ± 44 kg average weight. The animals from Acayucan were loaded directly at the growing facility and thus had not been transported previously. Those from Pichucalco had been transported a short distance from small production units to the collection point, although the conditions of this initial transport were unknown.

Transport conditions

Exact transport time depended on the conditions specific to each of the three trips; those from Acayucan (500 km) lasted 16, 16 and 13 h, while those from Pichucalco, Chiapas (821 km) lasted 18, 17 and 25 h[17]. Transport was done on paved roads and a toll highway, in tractor-

trailer rigs equipped with cattle cages (14.2 m [48 ft.] long, six internal sections). The effects of section were partially mitigated by transporting the evaluated animals in the two lowest sections of the trailer; the resulting allocated space per animal was 0.83 m^2 in the trailers from Acayucan and 0.86 m^2 in those from Chiapas.

Environmental conditions during transport were temperatures from 10 to 32 °C in the trips from Pichucalco; and from 12 to 31 °C in those from Acayucan. Temperatures were highest at the place of origin in both cases.

Treatments and response variables

The evaluated animals (n= 124) were randomly and evenly distributed among four treatments based on routine practices used by the participating commercial carriers: 1) preloading reception management at the place of origin (PRE); 2) PRE + administration of β-blocker before loading (PREβ); 3) post-unloading reception management at finishing feedlot (POST); and 4) POST + application of β-blocker before loading (POSTβ).

Data for the response variables were collected during two periods: P1) loading to unloading (i.e. values at loading minus values at unloading); and P2) unloading to 10 d after arrival in finishing feedlot (i.e. unloading values minus values 10 d after unloading). Analyses were done of eight variables: live weight (LW); glucose (GLU); β-hydroxybutyrate (βHB); free fatty acids (FFA); total proteins (TP); cortisol (COR); sodium (Na); and potassium (K).

Fieldwork

Before loading, the animals were weighed individually on a livestock scale (max. capacity 5,000 kg), marked for identification and assigned to the treatments, applying the corresponding reception management (i.e. PRE, PREβ, POST or POSTβ). Data were also collected on each animal's breed (i.e. Zebu, European or cross) based on external phenotypic characteristics, and the presence of horns.

Reception management in all four treatments consisted of deworming (Ivomec F®, Merial ivermectin 1 ml 50 kg^{-1} LW); vaccinating (Protector 5®, Lapisa, Michoacán, Mexico, and Blacklegol®, Bayer, North Rhine-Westphalia, Germany); vitamin supplementation (Synt ADE®, Zoetis, New Jersey, United States); and a growth promoter implant (Revalor, MSD, New Jersey, United States; one implant per animal: 140 mg trenbolone acetate plus 20 mg

17ß estradiol). A β-blocker was administered in the PREβ and POSTβ treatments. This consisted of carazolol hydrochloride (Simpanorm®, Schütze-Segen, Mexico City, Mexico) and was applied by intramuscular injection at 0.02 ml kg^{-1} LW, 30 min before loading into the cattle trailer.

For all the evaluated trips the animals were loaded in the afternoon (1600-1900 h), after an eight-hour fast. Time elapsed and temperature inside the trailer were recorded during transport. Temperature readings were taken using a digital thermometer (Mod. 445702, Extech, Hong Kong, China) at eight times during the trip within each of the two divisions (indicated as 1 and 2) inside the trailer where the evaluated animals were kept.

At the feedlot, the animals were transferred to cargo trucks with steel railing for transfer to the finishing corrals (approximate travel time= 15 min, space per animal= 1.1 m^2). Reception management for the animals in the POST and POSTβ treatments was done at the feedlot. Once in the finishing corrals, the evaluated animals from each trip were kept together to begin adaptation. For the first 1 to 2 d, hay-only forage (barley straw) was provided, followed by feed concentrate (PC = 14%; ME = 2.8 MCal) which was gradually increased by 15 % of total daily ration. Water was freely available.

The variables LW, GLU and βHB were measured three times: upon loading, at unloading, and 10 days after arrival in the finishing corral. For GLU and βHB, a drop of blood was taken from the coccygeal vein and analyzed using a glucometer (Mod. Optium Xceed, Abbott Laboratories, Chicago, United States), which used strips specific to each test. The βHB strips contain the enzyme hydroxybutyrate dehydrogenase which oxidizes to acetoacetate, with simultaneous reduction of NAD^+ to NADH; this is proportional to the βHB concentration. The system is valid for concentrations of 0 to 6 mmol l^{-1}[18].

Blood samples and laboratory analysis

Blood samples were taken upon loading, at unloading and 10 d after arrival at the finishing corral. The coccygeal vein was punctured using vacuum tubes without anticoagulant (20 ml per animal). The samples were allowed to coagulate at room temperature and centrifuged at 3,500 rpm for 15 min. The serum was separated from the clotted blood to avoid hemolysis, deposited in storage tubes and transported to the laboratory in coolers (temperature no higher than 4 °C). Cortisol levels (COR) were quantified by the ELISA (enzyme-linked immunoabsorbant essay) technique using rabbit antibody and horseradish peroxidase as an antigen (Cat. No. 6101-17, Diagnostic Automation, Inc., Calabazas, California, United States). Readings were done at a 410 µm wavelength and two replicates done of all

measurements. Free fatty acids (FFA) were quantified by enzymatic colorimetry with acyl-CoA oxidase (ACOD) (Randox kit, Mod. FA115, Crumlin, County Antrim, Ireland), in two replicates.

Total proteins (TP) were measured by the refractometry technique using an ATAGO® refractometer and deionized water as a blank[19]; three replicates were done of each measurement. Electrolytes (Na and K) were measured by atomic absorption spectrophotometry[20].

Statistical analysis

Analysis of changes in the stress indicator variables was done with a completely randomized experimental design using a 2 x 4 factorial arrangement. Four treatments (PRE, PREβ, POST and POSTβ) and two transport distances (500 and 851 km) were used as well as the interaction of these effects. With the purpose of removing variability due to other effects reported as important in similar studies[3,21,22], other independent variables were considered such as cattle breed group based on external phenotype traits (Zebu, European or cross); presence of horns (yes or no); transport time per trip (covariate); average ambient temperature inside trailer during transport; initial value (upon loading) of response variable (covariate); and animal position inside trailer during transport (section one or two). These effects and their simple interactions were initially included in the analysis of each variable and the non-significant ones ($P>0.05$) removed from the final analyses.

Under the present study conditions, in P1 the variables removed from the final analyses for all response variables were breed and presence of horns. Transport time was removed from the final models for changes in LW and βHB; while the initial value for this variable was excluded only for changes in FFA. Ambient inside trailer temperature was only considered for changes in GLU and TP; while position within the trailer was used only for changes in LW and FFA. In P2, only the presence of horns variable was excluded from all the models in all response variables. Transport time was removed only for changes in βHB, Na and K. Animal breed was only considered in the final models for changes in FFA and COR, while inside trailer temperature was only included for changes in GLU, COR and TP. Variable initial value was used only for changes in GLU and TP, and position inside trailer only for changes in LW and TP.

The data were analyzed by period: P1 (loading to unloading) and P2 (unloading to 10 days in corral). The response variable complied with the assumptions of normality (Shapiro-Wilk W test), so the GLM SAS procedure and a Tukey test were used to compare the means[23].

Results

Descriptive statistics by sampling period

As expected, stress indicator variability values were high (CV between 12 and 84%) due to the influence of the various factors (e.g. treatments, transport distance, etc.) (Table 1).

Table 1: Overall averages ± standard deviations (coefficient of variation, %) of stress indicators during calf transport at loading, unloading and 10 days after unloading (10dUL).

Indicator	Loading	Unloading	10d UL
Live weight, kg	375 ± 44.3 (12)	333 ± 45.5 (14)	368 ± 51.2 (14)
Glucose, mg·dl^{-1}	78 ± 21.1 (27)	91 ± 21.3 (23)	69 ± 12.5 (18)
βHB, mmol·l^{-1}	0.39 ± 0.21 (55)	0.38 ± 0.23 (61)	0.28 ± 0.18 (65)
FFA, mmol·l^{-1}	0.58 ± 0.36 (63)	0.71 ± 0.22 (31)	0.23 ± 0.18 (78)
TP, g·dl^{-1}	8.05 ± 1.32 (16)	8.83 ± 1.08 (12)	7.94 ± 0.92 (12)
Cortisol, pg·dl^{-1}	3.33 ± 2.12 (64)	3.79 ± 2.48 (65)	2.47 ± 2.07 (84)
Na, mg·dl^{-1}	4407 ± 1747 (40)	4718 ±2075 (44)	5020 ± 2126 (42)
K, mg·dl^{-1}	147 ± 32 (22)	145 ± 34 (23)	162 ± 37 (23)

βHB= β-hydroxybutyrate; FFA= free fatty acids; TP= total proteins; Na= sodium; K= potassium.

Transport resulted in weight loss with an average 42 kg (11.3%) drop in LW per animal at unloading, followed by a 35 kg recovery after 10 days in the feedlot. The COR and βHB levels remained within normal biological ranges (COR = 0-20 ng·ml^{-1}; βHB = 0.02-0.46 mmol·L^{-1})[24,25], although COR levels did vary widely (CV> 63%). Average GLU values were above the normal range (50-70 mg·dl^{-1})[24] during loading and unloading, but returned to normal values after 10 days in the feedlot. Total protein (TP) values were above the normal value (6.8 g·dl^{-1})[26] at all sampling times. Sodium (Na) values were generally higher than the proposed normal biological range (3,105-3,405 ppm)[27], and increased by 311 ppm after transport. In contrast, K levels were low during loading and unloading, even lower than the normal range (160-200 ppm)[27].

Stress indicators during transport (P1)

During P1 the most important stress indicators were changes in LW, GLU and COR, since differences (P<0.05) occurred due to treatment (Table 2) and transport distance (Table 3). No differences were observed in the other stress indicators (P>0.05). Differences were present between treatments (P<0.05) for changes in LW (Table 2), with 26.3% less (P<0.05) loss of LW in the PREβ treatment than in the PRE (21%) or POSTβ (16%) treatments; PREβ did not differ from POST (P>0.05). Average loss of LW in the animals not in the PREβ treatment during P1 was 9.9 kg per animal. Transport distance was one of the main factors affecting weight loss during transport (P<0.05; Table 3): those that traveled 500 km lost less weight than those that traveled 851 km. In addition, the animals that traveled 851 km had COR levels 2.5 times higher than those that traveled 500 km (P<0.05).

Table 2: Least squared means ± standard errors for changes in stress indicators due to the treatments in P1 (loading to unloading).

Indicators	Treatments			
	PRE	**PREβ**	**POST**	**POSTβ**
Live weight, kg	-47.5 ± 3.0 ^{b}	-37.6 ± 2.5 ^{a}	-38.7 ± 1.9 ^{ab}	-44.5 ± 3.8 ^{b}
Glucose, mg·dl^{-1}	15.1 ± 5.2 ^{ab}	20.1 ± 5.9 ^{a}	8.8 ± 4.3 ^{b}	7.2 ± 6.8 ^{b}
βHB, mmol·l^{-1}	-0.03 ± 0.08	-0.01 ± 0.06	-0.02 ± 0.05	-0.01 ± 0.06
FFA, mmol·l^{-1}	0.04 ± 0.80	0.13 ± 0.70	0.25 ± 0.60	0.05 ± 0.70
TP, g·dl^{-1}	0.71 ± 0.30	0.64 ± 0.18	0.67 ± 0.20	0.82 ± 0.28
Cortisol pg·dl^{-1}	0.75 ± 0.53	1.01 ± 0.56	0.11 ± 0.36	0.28 ± 0.63
Na, mg·dl^{-1}	496 ± 487	186 ± 457	556 ± 680	-32 ± 457
K, mg·dl^{-1}	-12.2 ± 9.1	-5.2 ± 6.8	12.2 ± 7.8	-3.0 ± 11.8

PRE= preloading reception management at point of origin; PREβ= PRE + β-blocker; POST= reception management after unloading at feedlot; POSTβ= POST + β-blocker at loading; βHB= β-hydroxybutyrate; FFA= free fatty acids; TP= total proteins; Na= sodium; K= potassium.

^{ab} Different letter superscripts in the same row indicate significant difference (P<0.05).

Table 3: Least squared means ± standard errors for changes in stress indicators due to place of origin in P1 (loading to unloading)

Indicators	Transport distance (km)	
	500	851
Live weight, kg	-39.2 ± 1.8 [a]	-45.1 ±2.1 [b]
Glucose, mg·dl^{-1}	25.6 ± 3.3 [a]	-3.0 ± 3.5 [b]
βHB, mmol·l^{-1}	0.05 ± 0.06	-0.03 ± 0.04
FFA, mmol·l^{-1}	0.12 ± 0.05	0.11 ± 0.05
TP, g·dL^{-1}	0.71 ± 0.15	0.69 ± 0.20
Cortisol, pg·dl^{-1}	0.28 ± 0.22 [a]	0.81 ± 0.31 [b]
Na, mg·dl^{-1}	586 ± 441	97 ± 333
K, mg.dl-^{1}	-11.9 ± 6.8	-8.1 ± 6.1

βHB= β-hydroxybutyrate; FFA= free fatty acids; TP= total proteins; Na= sodium; K= potassium.
[ab] Different letter superscripts in the same row indicate significant difference (P<0.05).

Glucose levels (GLU) differed between treatments (P<0.05). However, the treatment interaction by transport distance for GLU and FFA was also significant (P<0.05). Animals in the PRE and PREβ treatments originating in Veracruz (500 km) exhibited a greater increase in GLU than those in the POST and POSTβ treatments. In contrast, GLU decreased in animals in the PREβ, POST and POSTβ treatments originating in Chiapas (851 km) and remained essentially unchanged in PRE. Concentrations of FFA behaved inversely, with higher increases in all treatments for animals from Chiapas (851 km). In the animals from Veracruz (500 km) the increases in FFA for PREβ, POST and POSTβ were lower and below that of PRE (P<0.05).

Cortisol (COR) increased in all treatments, but none of the differences were significant (P>0.05). Neither were differences present due to treatment or transport distance for βHB, TP, Na and K (P>0.05; Tables 2 and 3). However, K concentration was affected by the interaction between the treatment and transport distance (P<0.05). Animals in the PREβ treatment from Veracruz (500 km) had higher K levels than the other treatments (PRE = 5.3, PREβ = 21.6, POST = 5.3, POSTβ = 12.6 mg·dl^{-1}). Those from Chiapas (851 km) had overall lower K levels, but particularly so in the POSTβ and PREβ treatments (PRE = -14.5, PREβ = -38.2, POST = -17.5 and POSTβ = -38.6 mg·dl^{-1}).

Stress indicators post-transport (P2*)*

During P2 (unloading to 10 d post-unloading) no differences were present between treatments (*P*>0.05) (Table 4). In all the treatments the animals recovered almost 85 % of the weight lost during transport, representing an average daily weight gain of 3.5 kg per animal. The other physiological indicators (COR, GLU, βHB, FFA and TP) decreased.

Table 4: Least squared means ± standard errors for changes in stress indicators due to the treatments in P2 (unloading to 10 days post-unloading)

	Treatment			
Indicators	**PRE**	**PREβ**	**POST**	**POSTβ**
Live weight, kg	33.8 ± 15.6	33.1 ± 19.6	35.5 ± 6.4	39.4 ± 25.9
Glucose, $mg \cdot dl^{-1}$	-20.9 ± 4.7	-21.9 ± 3.0	-15.8 ± 4.5	-26.4 ± 3.8
βHB, $mmol \cdot l^{-1}$	-0.12 ± 0.05	-0.13 ± 0.07	-0.11 ± 0.05	-0.01 ± 0.07
FFA, $mmol \cdot l^{-1}$	-0.47 ± 0.04	-0.50 ± 0.05	-0.54 ± 0.04	-0.45 ± 0.06
TP, $g \cdot dl^{-1}$	-0.61 ± 0.25	-1.18 ± 0.24	-0.71 ± 0.23	-1.13 ± 0.23
Cortisol, $pg \cdot dl^{-1}$	-1.78 ± 0.43	-1.71 ± 0.54	-1.55 ± 0.44	-1.73 ± 0.59
Na, $mg \cdot dl^{-1}$	-4 ± 515	651 ± 836	-106 ± 410	-1093 ± 619
K, $mg \cdot dl^{-1}$	18.1 ± 7.0	14.5 ± 9.5	17.2 ± 7.8	21.3 ± 11.9

βHB= β-hydroxybutyrate; FFA= free fatty acids; TP= total proteins; Na= sodium; K= potassium.
PRE= preloading reception management at point of origin; PREβ= PRE + β-blocker at loading; POST= reception management after unloading at feedlot; POSTβ= POST + β-blocker at loading;

During P2 transport distance only affected (*P*<0.05) COR and TP concentrations (Table 5). Animals from Chiapas (851 km) had lower COR levels than those from Veracruz (500 km), while TP decreased more in animals from Veracruz than those from Chiapas. No differences were observed in the other stress indicators after transport due to transport distance (*P*>0.05).

Table 5: Least squared means ± standard errors for changes in stress indicators due to place of origin in P2 (unloading to 10 days post-unloading).

Indicators	Transport distance (km)	
	500	851
Live weight, kg	36.6 ± 2.8	34.2 ± 4.0
Glucose, mg·dl^{-1}	-24.8 ± 3.0	-18.8 ± 3.0
βHB, mmol·l^{-1}	-0.11 ± 0.05	-0.09 ± 0.04
FFA, mmol·l^{-1}	-0.50 ± 0.04	-0.48 ± 0.03
TP, g·dl^{-1}	-1.21 ± 0.17 [a]	-0.53 ± 0.17 [b]
Cortisol, pg·dl^{-1}	-1.29 ± 0.23 [a]	-2.17 ± 0.44 [b]
Na, mg·dl^{-1}	601.2 ± 467.2	54.4 ± 314.4
K, mg·dl^{-1}	16.6 ± 6.8	16.2 ± 5.5

βHB= β-hydroxybutyrate; FFA= free fatty acids; TP= total proteins; Na= sodium; K= potassium.
[ab] Different letter superscripts in the same row indicate significant difference (P<0.05).

Discussion

Descriptive statistics

The data in this section provide a useful initial record of the changes in physiological and LW indicators during cattle transport under specific conditions in Mexico.

The estimated LW losses observed in the present results are similar to previous reports[4,8,9]. These losses may be a consequence of the prolonged food and water deprivation involved in long distance transport. They have also been associated with dehydration, as well as stress-induced increases in urination and defecation[24]. One estimate is that more than 80% of weight loss in cattle during transport during a 24-h period is due to water and feed deprivation and the remaining 20 % is due to transport stress[28]. Physiologically this could be explained by lipolysis of fatty tissue, dehydration and muscle degradation to replace energy deficiencies[25]. The LW losses in the present results are higher than the 4-7 % reported in a study done in the United States[3]. In this study, the economic cost of transport from growing to finishing systems (USD 624 million) in the USA was mainly due to mortality during transport caused by long distances and respiratory diseases. No precise data is available in Mexico on the financial impact of respiratory diseases in cattle intended for finishing; however, respiratory problems were not observed during the present study, suggesting that any financial losses from transport would derive from LW loss.

The LW recovery observed in the present results 10 d after unloading is higher than the estimated 43 % reported for cattle under grazing conditions 14 d after transport[8].

The differences in LW loss between the animals that traveled 500 and 851 km (5.9 kg) from the place of origin to the finishing feedlots confirm that LW loss was higher the greater the transport distance and time. This is probably due to higher stress levels, greater physical exhaustion and feed and water deprivation[6]. Weight loss may have financial implications for livestock transporters when marketing animals.

The behavior of the LW, TP, Na, COR and FFA indicators in the present results at the different sampling times was similar to that described in another study[24]. The occurrence of normal COR and βHB values suggest that growth conditions were adequate prior to the transport and adaptation of the animals to stress stimuli such as dizziness, loading and unloading, and contact with people and other animals not from the herd of origin[29,30]. Small transport-induced increases in COR like those in the present results have been reported elsewhere[31,32]. The small decreases in βHB in the present study may be due to pretransport feeding and handling practices since βHB concentrations are not a good indicator of acute stress but are an accurate reflection of chronic stress[9].

The higher GLU levels recorded at unloading may have been due to the interaction of glycolysis and gluconeogenesis processes stimulated by transport-induced stress and long-term fasting[32]. This coincides with another study in which GLU levels increased in cattle after transport or after fasting for 3 and 16 h, which is attributed mainly to release of catecholamines in response to stress rather than to fasting period[9]. Free fatty acids (FFA) levels have been proposed as an indicator of fasting[24], which agrees with the present results in which FFA increased upon unloading and then subsequently decreased. Above normal Na values[27] at all sampling times may indicate dehydration or hemoconcentration caused by water deprivation; however, the highest value was recorded at unloading which coincides with levels reported for cattle after 36 h transport[8]. Prolonged water deprivation and consequent dehydration can favor increases in serum Na[33], which is consistent with the present results.

Stress indicators during transport (P1)

The lower LW losses in the PREβ treatment during P1 may be because the β-blocker used in the study (carazolol) acts on the β-adrenergic receptors. It reduces the sympathetic nervous system stimulation via epinephrine in the heart, blood vessels and smooth muscle, preventing the glycolytic effect of catecholamines and reducing the stress response[16,34]. These results suggest that the addition of the β-blocker to pre-loading management practices could provide financial benefits since the price per dose of carazolol was approximately half the price of one kg LW of the studied animals.

The greater LW losses with the 851 km transport distance were reflected in higher COR concentrations than with the 500 km transport distance. Regardless of the differences between treatments and transfer distances in the present results, GLU levels were generally higher than normal. Post-transport increases in GLU have been attributed to the action of catecholamines (adrenaline and norepinephrine) in the initial stress response[25]. These hormones stimulate hepatic gluconeogenesis which is further favored by increases in hormones such as COR since these have effects opposed to insulin (affecting GLU transporters), consequently reducing GLU efficiency and use in tissues and increasing its blood concentration[35].

Stress indicators post-transport (P2*)*

Post-unloading (i.e. P2) recovery of LW lost during P1 may be partially explained by a portion of the weight loss during transport being due to dehydration and gastrointestinal filling[36]; this can account for 12 to 25 % of animal weight[37]. Other factors may be the normal recovery process regulated by homeostasis mechanisms after stressful processes incurring body tissue loss, and possible compensatory growth[38]. An additional consideration is that the cattle studied here were grown in poor feeding systems (seasonal grazing), and therefore may have greatly improved their nutrient use efficiency after arriving at the finishing feedlots and feeding on balanced rations high in protein and energy[37,38,39].

Neither the treatments nor transport distances affected LW or other physiological indicators of transport stress during P2, suggesting that, under the study conditions, these effects had no financial consequences. Using a practical approach it is clear that further study is needed to understand the implications of handling practices during cattle loading and transport on animal health and financial parameters.

Conclusions and implications

Transport of calves to finishing feedlots produces important changes in the animals which can be quantified using physiological and productive indicators. Some of the main stress indicators in animals are changes in live weight and concentrations of cortisol, glucose and free fatty acids. Differences in these indicators were observed depending on transport distance and management practices (i.e. when reception management was done and use of a β-blocker), with negative effects being less pronounced at the shorter distance and with pre-loading management. In Mexico, cattle carriers routinely carry out reception management practices and administer a β-blocker prior to loading. This is financially more profitable because it reduces live weight loss during transport. Regardless of management practices, however, the studied animals had largely recovered any lost weight within ten days of arriving in the finishing feedlot; the period from loading to unloading therefore requires more attention to improve animal health and process profitability.

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