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Effects of pre-haul management and transport duration on beef calf performance and welfare

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Abstract

Behavioural and physiological indicators of stress as well as growth performance, and morbidity rates were assessed in 174 steer calves (220 ± 37 kg) for 30 days after transport from ranch-to-feedlot. The calves were conditioned (C) or not (NC), and subjected to short- (2.7 h, S) or long-hauling duration (15 h, L), yielding treatments CS, CL, NCS and NCL. Upon arrival at the feedlot, calves were randomly assigned to 16 pens (four pens per treatment, one of which was equipped with a radio frequency identification system for continual monitoring of individual bunk attendance (15 calves)). As part of the NC treatment calves were also exposed to a short (2 h) transport 24 h after their initial arrival to the feedlot. All calves were fed a barley silage/barley grain-based starter ration and weighed every 7 days. Cortisol concentrations were higher in NC compared to C calves regardless of transport distance ($P < 0.05$). NC calves also had higher pre- and off-loading cortisol concentrations than C calves. In transit, CS steers had the lowest heart rate (HR, 67.8 bpm ±0.61; $P < 0.0001$). HR was highest ($P < 0.05$) during the first 15 min of the journey for all calves and gradually declined until 121–161 min into the trip. NC calves spent more time at the feed bunk (222.9 min day^{-1} versus 128.6 min day^{-1}) in the first 2 days in the feedlot. CL calves were observed more frequently at the water than NCL calves ($P < 0.05$). An interaction was observed for shrinkage ($P < 0.001$) and ADG ($P < 0.01$). Shrinkage was greater in CL than in NCL steers (23.6 kg versus 14.6 kg), and in NCL than in either CS (7.8 kg) or NCS

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(9.2 kg) steers. The lowest ($P < 0.005$) ADG was recorded for CL and NCS calves (0.8 and 0.9 kg, respectively), although their DM intake (6.0 and 6.8 kg day^{-1}) was similar ($P > 0.05$) to calves in the other treatment groups. Morbidity rate was 5.17% with no treatment effect. Conditioning calves prior to transport allowed calves to better tolerate the stressors of transport and handling.

Keywords: Cattle; Conditioning; Transport distance; Health

1. Introduction

Stress associated with the management of light weight calves into feedlots has been attributed to a combination of factors including transport, weaning, and mixing, as well as exposure to novel feed and environment. The link between these management factors and reduced animal health and performance has been reported by many researchers (Launchbaugh, 1995; Ribble et al., 1995b; Price et al., 2003; Chirase et al., 2004; Mackenzie et al., 1997; Stanger et al., 2005).

Preconditioning is a management technique developed to reduce large economic losses associated with high morbidity and mortality due to acute respiratory disease in highly stressed weaned and transported beef calves (Radostits, 2000). Calves are typically vaccinated at least 3 weeks prior to sale or shipment and are at least 4 months of age prior to being vaccinated. They are also castrated, treated for warbles and dehorned at least 3 weeks prior to sale (Radostits, 2000). A preconditioning program also requires that calves be weaned for a minimum of 45 days and have some experience eating from a feed bunk prior to leaving their place of origin. Many studies have indicated the positive effect of preconditioning including improved rate of gain, increased sale weights (Karren et al., 1987; Shipper et al., 1989) and health status which included reduced treatments for bovine respiratory disease (BRD) in the first 28 days in the feedlot (Macartney et al., 2003). Occasionally not all the requirements of a preconditioning program can be met; however, benefits of partial preconditioning or ‘‘conditioning’’ program may still be warranted. Several studies looking at the effect of transport length on cattle and other species have reported pronounced physiological and behavioural changes indicative of a stress response (Broom, 1993; Tarrant and Grandin, 1993; Broom et al., 1996; Kannan et al., 2000). The objective of this experiment was to determine if conditioning reduces stress responses associated with transport and improves calf health and performance.

2. Materials and methods

All calves involved in this trial were cared for according to the standards set by the Canadian Council on Animal Care (1993).

2.1. Experimental design

The effect of conditioning and hauling were tested in a 2 × 2 arrangement of treatments. Eighty Angus and 94 Charolais steer calves (220 ± 37 kg) were equally assigned to conditioned (C) or non-conditioned (NC) groups and were transported for either 15 h (long-haul, L) or 2.7 h (short-haul, S), yielding CL ($n = 44$), CS ($n = 44$), NCL ($n = 43$), and NCS ($n = 43$) treatments. A chronological list of treatments including timelines, sampling points and provision of feed and bedding are outlined in Table 1.

Prior to the initial journey from ranch-to-feedlot (RF) all calves were weighed, blocked by breed and birth date and assigned to treatments. The average age of the calves was 149.9, 156.2, 149.4 and 155.5 days

Table 1
Chronology of behavioural and physiological sampling points for light weight steer calves exposed to long- (15 h) and short-haul (2.7 h) distances and conditioning and non-conditioning treatments

Timeline/samples	Long-haul (15 h)		Short-haul (2.7 h)	
	Conditioned	Non-conditioned	Conditioned	Non-conditioned
Pre-loading ranch-to-feedlot (RF) journey/cortisol sample 1	1905–2058	1647–1857	0857–1042	0702–0837
Truck departure RF journey (day 1 for long-haul; day 0 for short-haul)	2200	2200	1129	1129
Truck arrival at feedlot RF journey (day 0)	1300	1300	1410	1410
In transit/heart rate sample 1 (days 1 and 0)	2100 (day 1)–1300 (day 0)	2100 (day 1)-1300 (day 0)	1050–1410 (day 0)	1050–1410 (day 0)
Immediately off-loading post RF journey/cortisol sample 2 (day 0)	1453–1620	1331–1445	1459–1610	1629–1750
Availability of feed, water and bedding	Feed, water, no bedding	No feed, water, no bedding	Feed, water, bedding	No feed, water, bedding
2 h Post RF journey/behaviour observation 1 (day 0)	1623–1823	1623–1823	1755–1955	1755–1955
2 h post off-loading after RF journey/cortisol sample 3 (day 0)	1835–1911	1917–1956	2013–2052	2054–2129
Immediately pre-loading for auction simulation (AS) journey/cortisol sample 4 (day 1)	N/A	0941–1059	N/A	0909–1022
Truck departure for AS journey	N/A	1109	N/A	1030
Truck arrival to the feedlot after AS journey	N/A	1309	N/A	1230
Immediately off-loading at feedlot post AS journey/cortisol sample 5 (day 1)	N/A	1321–1431	N/A	1251–1403
Availability of feed, water and bedding (day 1)	Feed, water, no bedding	Feed, water, no bedding	Feed, water, bedding	Feed, water, bedding
2 h post AS journey/behaviour observation 2 (day 1)	1446–1646	1446–1646	1432–1633	1432–1633
2 h post off-loading AS journey/cortisol sample 6 (day 1)	N/A	1709–1742	N/A	1646–1726
14 d post RF journey/behaviour observation 3 (day 14)	1402–1602	1402–1602	1406–1606	1402–1602
14 d post RF journey/heart rate 2 (day 14)	1402–1602	1402–1602	1406–1606	1402–1602

Values indicate the time of day sampling and or transport took place.

for the CL, CS, NCL and NCS treatment groups, respectively. On arrival at the Lethbridge Research Centre (LRC) feedlot calves were randomly allocated (within a treatment) to 1 of 4 pens. As part of the NC treatment calves were unloaded into receiving pens at the feedlot and held for a 24 h period before being loaded onto a truck again and transported a total of 2 h (round trip) back to the feedlot. During the 24 period after unloading NC calves had access to water but not feed while C calves did have access to water and feed. This additional transport was to simulate the typical conditions NC calves are exposed to with the exception of lack of contact with calves outside their herd of origin. Body weight was not recorded after the auction simulation (AS) trip. It should be noted that conditioning is not generally defined as non-auction. However, in attempts to emulate current management practice in Western Canada the auction simulation was added because the majority of NC calves are managed this way.

2.2. *Pre-loading management and transport*

A typical preconditioning program requires producers castrate and dehorn calves at an early age, vaccinate them against a number of respiratory tract pathogens and wean them onto a diet of roughage and concentrate at least 30 days before shipment (Macartney et al., 2003; Radostits, 2000). Calves in the current study were weaned and vaccinated 13 and 29 days, respectively, prior to transport and therefore were defined as conditioned (personal communication, Dr. Eugene Janzen) as opposed to preconditioned since an integral part of preconditioning is having been weaned for between 30 and 45 days prior to shipping. All calves in this study were dehorned and castrated 10–14 days after birth. All animals were given 25 cm^3 of Dectomax® pour-on (Pfizer, London, Ontario) for internal parasites, 2 cm^3 of Somnustar Ph™ s.c. (Novartis, Missauga, Ontario) for hemophalus, 2 cm^3 BarVac™ 3 i.m. (Boringer-Engelheim, Burlington, Ontario) for bovine viral diarrhea, and 5 cm^3 Fortress-7 s.c. (Bayer, Toronto, Ontario) for clostridial related diseases. Vitamins A, D, and E were given by intramuscular injection (Vital E®(A + D, 5 mL, Schering-Plough, Kenilworth, New Jersey). Non-conditioned calves were weaned on the day of transport and were vaccinated (as per the conditioned group) 1 day after their arrival at the feedlot.

Conditioned and non-conditioned calves were loaded onto one of two commercial tandem transport trailers and C and NC calves were held in separate compartments within the truck to avoid co-mingling (nose-to-nose contact). All cattle were weighed at the ranch and again upon arrival to document any weight loss (shrink) associated with transport.

2.3. *Post-transport management*

All calves were weighed, tagged and placed into 1 of 16 pens (10–15 calves per pen; 4 pens per treatment group) 1 day following arrival at the feedlot. Pens measured 21 m × 27 m with 15 m of concrete bunk. Linear bunk space and pen space available for each steer were 25.4 cm and 12.6 m^2, respectively. Calves were fed a backgrounding diet consisting of 17% rolled barley, 80% barley silage and 3% supplement (as fed) delivered as a total mixed ration at 09:00 and 13:00 h daily over a 30-day feeding period. Diets were balanced in accordance with NRC (1996) to meet nutritional requirements and fresh water was available at all times. Short-haul calves received straw bedding in their pens on days 0, 1 and 14 of the study while long-haul calves were not provided with bedding until day 14. The addition of straw to the short-haul pens was an error made by the feedlot staff and not meant to be part of the experimental design. As unequal access to straw could affect treatment comparisons between the behaviours accessed it is important to acknowledge for statistical comparisons.

2.4. *Behaviour*

2.4.1. *Feeding behaviour*

Four of the 16 feedlot pens used in the study were equipped with an electronic feed bunk monitoring system (GrowSafe™ Systems Ltd., Airdrie, Alta.) as previously described by Gibb et al. (1998) and Schwartzkopf-Genswein et al. (1999). A subset of 60 calves (15 from each treatment group) were fitted with an ear tag transponder and each treatment was randomly assigned to 1 of the 4 feed bunk monitoring pens (1 pen per treatment group). Frequency and duration of bunk attendance were obtained using the feed bunk monitoring system and data were collected on all 60 steers for 24 h day^{-1} throughout the 30-day feeding period. The system was checked every 2 days throughout the trial to ensure that it was operational (Schwartzkopf-Genswein et al., 2002). Frequent system monitoring indicated that there were no inoperable cells from days 1 to 30 of the study in all pens. All occasions when animals were removed from their pens were recorded and data for that day and animal were discarded from the behavioural data set. Unfortunately data acquisition was lost in 1 of the 4 monitoring pens due to a malfunction in the electrical system within the first day (day 0) of calves arriving at the feedlot. For this reason, only the main effects of haul and condition could be assessed.

Table 2
Description of beef calf behaviours recorded post-transport in a feedlot pen

Behaviour	Description
Eating	Head down in the feed bunk or straw bedding, observed consuming and masticating feed
Ruminating	Visible rhythmic cud chewing and eructation, not associated with feed consumption
Lying	Lateral or sternal recumbency
Standing	Up right position on all limbs, not walking or running; includes normal head and body movement
Moving	Any locomotion including walking, running, pacing, etc.

For the purpose of summarizing bunk attendance data, a meal criterion of 300 s was selected based on survival analysis theory (de Haer and Merks, 1992) and validation work carried out by Gibb and McAllister (1999). Intervals between visits shorter than 300 s were regarded as within a meal.

2.4.2. Post-transport behavioural activity patterns

Behavioural observations were made simultaneously on all 60 calves (15 per treatment group) that were housed within the feed bunk monitoring pens. Direct observations were made for 2 h; after arrival and processing at the feedlot; after the AS trip (both NC and C calves were observed at this time); and 2 weeks after arrival to the feedlot. During these observations, instantaneous scan samples of selected behavioural states were recorded every 5 min on a per pen basis. Scan samples were made by 2 people (2 pens per individual) previously trained and with experience during 2 similar preceding behavioural studies. Training consisted of watching cattle with an experienced observer who coached the individual in the correct method for taking instantaneous scan samples and in correctly identifying the behaviour categories used in this study. Behaviours observed and recorded included; eating, ruminating, moving, standing, and lying (Table 2). Continuous observations were made of the water trough for the first 24 h that the calves were in the feedlot and included quantifying the number of calves drinking within each hour of the 24 h period. A single individual viewed and recorded drinking events from the video recordings. Calves were considered to have had a drink when seen lowering their heads into the trough.

2.5. Blood sampling

Blood samples were obtained from a subset of 72 calves (18 from each treatment group) via jugular venipuncture and collected into 10 mL heparinized Vacutainer® tubes while the animals were restrained in a squeeze chute prior to being weighed and loaded onto the truck. Samples were stored on ice for 20 min before being centrifuged at 1100 × *g* for 17 min to allow removal of the plasma portion. Plasma was stored at −40 °C until assayed for cortisol.

Each animal was sampled according to the following schedule: one sample per animal was taken prior to transport so that individual basal concentrations of plasma cortisol could be obtained. Two additional samples were obtained from all animals, the first immediately upon unloading at the feedlot and the second 2 h after the unloading sample was taken. The same schedule (relative to when the transport commenced) was used for both the original (RF) transport and AS groups.

2.6. Cortisol assay

Plasma samples were assayed in triplicate using a Clinical Assays™ GammaCoat™ Cortisol RIA kit (CA-1549) from DiaSorin Inc. (Stillwater, Minnesota) as outlined in Mears et al. (2001). The assay kit was validated for bovine use by establishing that dilutions of bovine plasma resulted in a curve identical to that obtained with human standards supplied with the kit. Intra-assay CV ranged from 0.16 to 8.05% for a bovine plasma pool and inter-assay CV was 3.30–6.90%.

2.7. Heart rate

Prior to transport a subset of the blood sampled calves (32 steer calves, 8 from each treatment group) were fitted with heart rate monitors (Polar® Accurex Plus, Polar Electro Oy, Finland) which consisted of two electrodes and a transmitter attached to an elastic girth belt. To ensure good contact of the electrodes, the cattle were shaved at the contact points (Hopster and Blockhuis, 1994) and electrocardiogram (ECG) gel was applied over the area. Heart rate data were stored on the monitor and downloaded using an interface and program designed by the manufacturer. Heart rate was recorded at 60 s intervals as beats per minute (bpm) beginning 1 h prior to transport and ending 2 h (data collection occurred between 14:00 and 16:00 h) following transport after all calves had been placed in their feedlot pens. Heart rates recorded on the first day in the feedlot while calves were in their pens were meant to serve as a post-transport measurement for comparison with loading, off-loading and during transit values.

2.8. Shrink, intake, performance and morbidity

Shrink (kg) was calculated as the difference between weight immediately before transportation from the ranch and weight on arrival at the feedlot and did not include the AS journey. Dry matter intake (DMI; kg day^{-1}) was determined by recording feed offered daily (to the pen) and subtracting weekly feed refusals (orts) and dividing by the number of animals in the pen. Individual animal intake was approximated by dividing the total kg of feed consumed per pen by the number of calves within each pen. Dry matter intake was calculated using the DM content of the feed and orts which were determined by drying samples (0.5 kg) at 55 °C. Average daily gain (ADG; kg) was measured over 30 days as 30 day weight minus arrival weight. Medical treatment records were documented for all calves over the entire 30-day period following transport. The percentage of animals needing medical intervention (treatment with antibiotics) within each treatment group was compared.

2.9. Statistical analyses

The main effects of conditioning, haul distance and their interactions were tested using the mixed model procedure in SAS (SAS Institute Inc., 2001). When interactions were significant all 4 treatments are discussed however, when no interaction effects were observed only main effects were discussed. Only the non-conditioned calves were subjected to the AS journey; therefore, only the haul distance effect was included in the model for any separate analysis of that data. For overall (combined data) analysis, measures taken at different time points on the same animal were treated as repeated measures in the model. However, count data for behaviour was log-transformed and analyzed with the GENMOD procedure using a Poisson distribution (SAS Institute Inc., 2001). The OFFSET option was included in the model to adjust for the unequal number of total counts among the different treatments and times.

For discussion clarity the behaviour data is presented as the percent of observations (per pen basis) calves spent performing different maintenance activities within a 2 h observation period after unloading on the day of transport (day 0), 24 h after (day 1) and 14 days after calves were placed in their feedlot pens. Percentages were calculated as the observed counts (i.e. eating, etc.) divided by all possible observations (number of animals multiplied by the number of scan samples) $\times$ 100. Due to inconsistencies in the provision of bedding across treatments and days, treatment comparisons for behavioural activity patterns were limited to comparing NCL to CL and NCS to CS. Day comparisons within a treatment were limited to only days 0 and 1 for the NCL and CL groups while day comparisons for the NCS and CS groups were made for days 0, 1 and 14 as these groups had bedding on all days. On day 14 the interaction between haul and condition was significant and all groups could be compared as they all had bedding.

Morbidity rates were very low and therefore could not be compared statistically. Pen was considered the unit of analysis for DMI, and ADG, while individual animals were the unit of analysis for cortisol, heart rate, and shrink, as well as bunk attendance duration and frequency. Treatment effects were declared significant at $P < 0.05$ and trends were reported at $P \geq 0.05$ and $P \leq 0.10$.

Table 3
Effect of hauling (H) duration (long; L (15 h), short; S (2.7 h)) and conditioning (C) (non-conditioned; NC, conditioned; C) on the feeding behaviour of beef calves ($n = 45$; 15 calves/treatment) over a 30-day period after transport

	Condition		S.E.M.	Haul		S.E.M.	*P*-values	
	NC	C		L	S		C	H
Overall (1–30 days post-transport)								
Total daily bunk attendance (min day^{-1})	259.9	240.4	4.05	261.8	238.5	4.34	<0.001	<0.0001
Daily bunk visits	11.6	10.5	0.19	10.6	11.5	0.19	<0.0001	<0.0001
Day 1 post-transport								
Total daily bunk attendance (min day^{-1})	222.9	128.6	11.60	216.6	141.2	11.60	<0.0001	<0.0001
Daily bunk visits	13.7	9.3	0.74	12.0	12.6	0.74	<0.001	0.16
Day 14 post-transport								
Total daily bunk attendance (min day^{-1})	278.9	223.0	10.80	262.0	256.7	10.80	<0.001	0.05
Daily bunk visits	12.8	11.2	0.48	11.9	13.0	0.48	0.16	0.66

No data was collected for conditioned short-haul calves due to a malfunction of the feed bunk monitoring system; therefore, haul × condition interactions could not be tested.

3. Results

3.1. Behaviour

3.1.1. Feeding behaviour

No data was collected for CS calves due to a malfunction of the feed bunk monitoring system therefore, haul × condition interactions could not be tested. Comparisons for haul duration were restricted to the NC group while condition comparisons were restricted to the L calves. Both conditioning and haul duration had significant ($P < 0.001$) effects on feeding behaviour (daily bunk attendance duration and frequency) over the 30-day feeding period post-transport (Table 3). Long-haul calves attended the bunk longer compared to S calves over the 30-day period post-transport as well as on days 1 and 14 ($P < 0.05$, Table 3). Long-haul calves also made fewer visits overall than S calves while no differences were observed between the L and S groups on days 1 and 14. NC calves had higher bunk attendance durations on days 1, 14 and over the 30-day feeding period compared to C calves. On day 1 the NC group attended the bunk approximately 2 times longer than the C group. NC calves also made more visits than C calves on day 1 and overall (Table 3).

3.1.2. Activity patterns

3.1.2.1. Day comparisons within treatment of behavioural activities post-transport

3.1.2.1.1. Short-haul calves. As presented in Table 4, the C calves were observed eating 25 and 21% more frequently on day 0 than on days 14 and 1, respectively. However, NC calves had higher ($P < 0.05$) eating percentages on day 1 compared to days 0 and 14. Even though the NC calves did not have feed, they did have access to bedding and were observed to consume some straw. The largest differences in rumination were observed between day 0 and day 14 for both NC and C calves and day 1 was intermediate between day 0 and day 14. The highest percentages of

Table 4
Effect of hauling duration (long; L (15 h), short; S (2.7 h)) and conditioning (C) (non-conditioned; NC, conditioned; C) on behavioural activity patterns of beef calves ($n = 60$; 15 calves/treatment)

Day	Long haul[a]		Short haul[a]	
	NC	C	NC	C
Eating behaviour				
0	–	28.0(121)1	10.0943)y2	39.1(169)x1
1	43.5(188)x	0.5(2)y2	30.1(130)x1	18.5(80)y2
14	26.9(97)a	21.1(86)a	8.6(31)c2	14.2(58)b2
Ruminating behaviour				
0	3.7(16)y1	9.0(39)x2	0.0 y3	1.4(6)x3
1	0.0 y2	39.6(171)x1	10.9(47)y2	31.0(134)x2
14	30.8(111)c	31.6(129)b	30.6(110)c1	44.6(182)a1
Lying behaviour				
0	35.2(168)y	44.4(223)x2	22.5(97)2	24.5(112)2
1	44.2(191)y	52.8(378)x1	44.2(238)x1	35.4(285)y1
14	24.2(185)b	32.4(244)a	31.4(207)ab1	26.7(270)b2
Standing behaviour				
0	39.9(168)x1	15.1(65)y1	59.3(256)x1	22.9(99)y1
1	6.7(29)y2	5.8(25)y2	8.1(35)3	11.3(49)2
14	8.3(30)b	12.0(49)b	19.2(69)x2	9.3(38)y2
Moving behaviour				
0	21.8(94)x1	2.1(9)y	7.9(34)1	6.3(27)1
1	4.2(18)x2	0.5(2)y	3.5(15)2	2.6(11)2
14	2.8(10)a	1.2(5)ab	0.8(3)b3	0.7(3)b3
Drinking behaviour				
0	0.0	1.2(5)	0.5(2)	3.7(16)
1	0.9(4)	0.0	1.9(8)	0.2(1)
14	0.8(3)	1.0(4)	1.4(5)	0.5(3)

Statistical significance of the data was evaluated using PROC GENMOD in SAS with the options of Poisson distribution, log link and offset = log(total counts); while percent of total observed activities along with actual values in brackets are presented. Total number as a sum of days 0, 1 and 14 was 1224 and 1272 for non-conditioned and conditioned groups, respectively. Behaviour values within day 0 or 1 and hauling duration with different letters (x and y) differ ($P < 0.05$). Behaviour values within day 14 with different letters (a–c) differ ($P < 0.05$). Within a treatment and behaviour values with different numbers (1–3) differ ($P < 0.05$).

[a] Short-haul calves received straw bedding in their pens on days 0, 1 and 14 of the study while long-haul calves were not provided with bedding until day 14. Due to inconsistencies in the provision of bedding comparisons for behavioural activity patterns were limited to comparing NCL to CL and NCS to CS. Day comparisons within a treatment were limited to only days 0 and 1 for the NCL and CL groups while day comparisons for the NCS and CS groups were made for days 0, 1 and 14 as these groups had bedding on all days. Haul × conditioning interactions were significant on day 14 therefore least square means along with mean comparisons for interactions were reported.

standing and moving were observed on day 0 and were substantially higher ($P < 0.05$) than day 1 and day 14 for both NC and C calves. Lying activity was more frequent on day 1 and day 14 compared to day 0 for NC and C calves. There were no differences in lying activity between day 1 and 14 in either group of calves. No day effect was observed for drinking (Table 4).

3.1.2.1.2. Long-haul calves. Only day 0 and 1 could be compared for the long-haul calves as these were the days they did not have bedding. C calves were observed eating for more than 25% of their total activity on day 0 which is in great contrast to day 1 where they were virtually absent from the feed bunk (Table 4). Although rumination activity was low in NC calves it was higher

($P < 0.05$) on day 0 compared to day 1. C calves ruminated 30% more frequently on day 1 compared to day 0. Standing and moving activity was higher ($P < 0.05$) on day 0 compared to day 1 for both NC and C calves with the exception of moving for the C group in which there was no difference between the days. C calves were observed lying 8.5% more frequently on day 1 than day 0. Although numerically higher on day 1 than day 0, lying activity was not statistically different between the days for NC calves. No day effect was observed for drinking (Table 4).

3.1.2.2. Treatment comparisons within day 0: ranch-to-feedlot journey

3.1.2.2.1. Short-haul calves. Substantial differences in the behavioural patterns following the RF journey were observed between NC and C treatments for the first 2 h after off-loading (Table 4). C calves were observed eating 39% more frequently than NC calves. NC calves were not observed ruminating while and rumination activity was minimal in C calves but more frequent ($P < 0.05$) than for the NC group. No differences were observed in the percentages of time C and NC calves spent lying, moving or drinking. However, NC calves were observed standing almost three times more frequently ($P < 0.05$) than the C group.

3.1.2.2.2. Long-haul calves. C cattle spent 28% of their total activity at the feeding bunk. Feeding activity could not be compared between C and NC calves since NC calves were not provided with feed or bedding. C calves ruminated more frequently ($P < 0.05$) than NC calves. NC calves stood 24.8% more frequently, lie 9.2% less frequently and moved 19.7% more frequently than C calves ($P < 0.05$). No differences were observed in drinking (Table 4).

3.1.2.3. Treatment comparisons within day 1, 24 h after unloading at the feedlot: ranch-to-feedlot journey

3.1.2.3.1. Short-haul calves. NC cattle attended the bunk almost 1.6 times more often and ruminated 2.9 times less often than C calves ($P < 0.05$, Table 4). Lying was 8.8% more frequent in NC compared to C calves ($P < 0.05$). Standing, moving and drinking activity was not different between the two groups.

3.1.2.3.2. Long-haul calves. NC calves had more frequent eating activity and less frequent ruminating activity ($P < 0.05$, Table 4) than C calves. There were no differences between the groups for drinking and standing; however, NC calves moved more and lie down less than C calves ($P < 0.05$).

3.1.2.4. Treatment comparisons within day 14 after unloading at the feedlot: ranch-to-feedlot journey. Treatment differences were observed for all activities except for drinking on day 14 ($P < 0.05$, Table 4). Within a behaviour, the range between the highest and lowest percentage values on day 14 was were numerically smaller (18.3–0.6%) than those occurring within day 0 and 1 (44.2–1.9%). NCL and CL calves ate and moved more frequently than CS and NCS calves ($P < 0.05$). Conversely CS calves ruminated more frequently than the other groups. CL and NSC calves lie down and stood more frequently than the NCL and CS calves. No differences were observed in drinking behaviour.

3.2. Cortisol

No haul length × conditioning interactions were observed for cortisol during the RF journey except at off-loading where a trend ($P < 0.06$) toward significance was seen (Table 5).

Table 5
Effect of haul (H) duration (long, L (15 h); short, S (2.7 h)) and conditioning (C) (non-conditioned, NC, conditioned; C) on plasma cortisol concentration (ng mL^{-1}) of beef calves ($n = 72$; 18 calves per treatment)

	Condition		Haul		S.E.M.	*P*-value		
	NC	C	S	L		C	H	C × H
Ranch-to-feedlot haul								
Overall	32.7	23.2	28.9	27.1	1.08	<0.0001	0.25	0.38
Immediately pre-loading	28.6	20.9	25.8	23.7b	1.61	<0.01	0.35	0.44
Immediately off-loading	30.1	24.5	29.5	25.1b	2.00	0.05	0.12	0.06
2 h post off-loading	32.9	24.3	27.0	30.3a	2.13	<0.01	0.28	0.60
Auction simulation haul[a]								
Overall	–	–	37.3	32.6	2.13	–	0.13	–
Immediately pre-loading	–	–	38.5	33.5	2.61	–	0.19	–
Immediately off-loading	–	–	27.0	33.1	2.44	–	0.08	–
2 h post off-loading	–	–	37.2	31.2	2.95	–	0.15	–

Within a column values with different letters (a and b) differ ($P < 0.005$).
[a] Only non-conditioned calves were subjected to the auction simulation haul.

Consequently, effects of condition and haul were analyzed separately. Mean pre-loading cortisol values for NC calves were greater than C calves ($P < 0.01$; Table 5). NC calves also had higher ($P < 0.05$) cortisol concentrations than C calves at the time of off-loading and 2 h post off-loading and overall for the RF journey (Table 5). No differences in cortisol values were observed between L and S transport durations (Table 5). For the AS journey haul duration had no effect (Table 5).

There was a significant ($P < 0.005$) time × treatment effect on cortisol concentrations for the RF journey but not for the AS journey. L calves had higher ($P < 0.005$) cortisol concentrations 2 h after off-loading than at pre-loading or immediately after off-loading for the RF journey (Table 5).

3.3. Heart rate

Overall, there was a significant haul duration × conditioning effect ($P < 0.0001$) on heart rate values for the RF journey. When compared over the length of the short-haul transport (161 min) CS calves had consistently lower heart rates ($P < 0.01$) than CL, NCS, and NCL calves from 1 to 60 min into the journey. CL, NCS and NCL heart rates were not different from one another except between 31 and 60 min where NCS calves had lower heart rates than CL calves but higher than CS calves ($P < 0.01$; Table 6). No differences were observed between 161 and 900 min into the journey for CL and NCL calves.

Treatment × time interactions were significant ($P < 0.05$) when compared over the 900 min RF journey which was the length of the long-haul trip (Fig. 1). The overall average in-transit heart rate for the long-haul journey was 80.2 ± 3.12 bpm. NC calves had numerically higher heart rates than C calves at most time points over the 900 min trip; however, they were not statistically different. Heart rate was highest ($P < 0.05$) during the first 15 min of the journey and gradually decreased until 121–161 min where it remained significantly lower ($P < 0.05$) than the initial levels (1–15 min) until the end of the trip (Fig. 1). Heart rates during periods of time when the truck was stationary (217–420 and 712–750 min) were not different than values recorded when the truck was in-transit (Fig. 1).

Table 6
Effect of hauling (H) duration (long; L (15 h), short; S (2.7 h)) and conditioning (C) (non-conditioned; NC, conditioned; C) on heart rate (bpm) of beef calves ($n = 32$; 8 calves per treatment) during and after transportation

Time (min)	NC		C		S.E.M.	*P*-values		
	L	S	L	S		C	H	C × H
Ranch-to-feedlot								
Overall	76.5 b	79.6 a,1	79.1 a	67.8 c	0.61	<0.0001	<0.0001	0.05
1–15	91.2 a	97.4 a	107.5 a	74.0 b	7.03	0.60	0.05	0.05
16–30	87.4 a	91.6 a	99.9 a	67.9 b	6.78	0.39	0.04	0.05
31–60	89.3 ab	81.3 b	98.3 a	67.3 c	3.86	0.50	<0.0001	0.05
61–120	89.8	77.1	94.7	66.6	4.32	0.50	<0.0001	0.05
121–161	77.6	72.4	82.8	66.0	3.11	0.84	<0.001	0.05
161–270	76.0	–	82.2	–	3.18	0.18	–	–
271–420[a]	70.1	–	75.8	–	3.65	0.27	–	–
421–720	76.0	–	73.0	–	4.23	0.61	–	–
721–750[a]	73.2	–	71.5	–	5.03	0.80	–	–
751–900	76.2	–	73.2	–	5.79	0.70	–	–
Auction simulation								
Overall	77.2	65.5 2	–	–	0.63	–	<0.0001	–
1–15 min	86.0	71.7	–	–	7.71	–	0.18	–
16–30 min	81.8	69.2	–	–	6.71	–	0.17	–
31–60 min	79.3	67.0	–	–	4.68	–	0.06	–
61–116 min	73.1	62.0	–	–	3.58	–	0.03	–
Post-transport[b]								
Day 1	74.8 a	72.8 b,2	76.5 a,b	64.4 c	1.04	<0.0001	<0.0001	0.05

Within a row means followed by different letters (a–c) differ. Numbers 1,2 indicate significant difference ($P < 0.05$) between RF and AS journeys and post-transport for short-haul calves.

[a] Indicates the block of time when the transport truck was stationary.

[b] Day 1 post-transport data were collected for a 2 h period between 1400 and 1600 h.

Comparisons between NCL, NCS, CL and CS treatments could only be made for 161 min as this was the length of the short-haul trip (Table 6). Heart rate was consistently lowest ($P < 0.01$) for CS calves for up to 60 min of the journey and tended to be higher from 61 to 161 min compared to all other treatments (Table 6). In contrast, CL calves had the highest heart rate for up to 161 min and heat rates of NCS calves were not different from CL calves for the first 30 min of the journey.

No differences were observed between time points within the AS journey. Overall, NCS calves had heart rates that were approximately 15 bpm lower ($P < 0.0001$) on the AS journey than on their first RF journey (Table 6). No treatment differences were observed between the overall heart rate measures for the RF and AS journeys and 1 day post-transport except for the NCS group. Heart rates recorded during the RF journey were higher than during the AS and 1 day post-transport for NCS calves ($P < 0.05$; Table 6).

3.4. Shrink, intake, performance and morbidity

A conditioning × hauling duration interaction was observed for shrink ($P < 0.0001$) and ADG ($P < 0.01$) but not DM intake (Table 7). Shrink was greater in CL than in NCL steers, and in NCL than in either CS or NCS steers (Table 7). The lowest ($P < 0.005$) ADG over the 30-day feeding period was recorded for CL and NCS calves (0.9 and 0.8 ± SE 0.18 kg, respectively). C

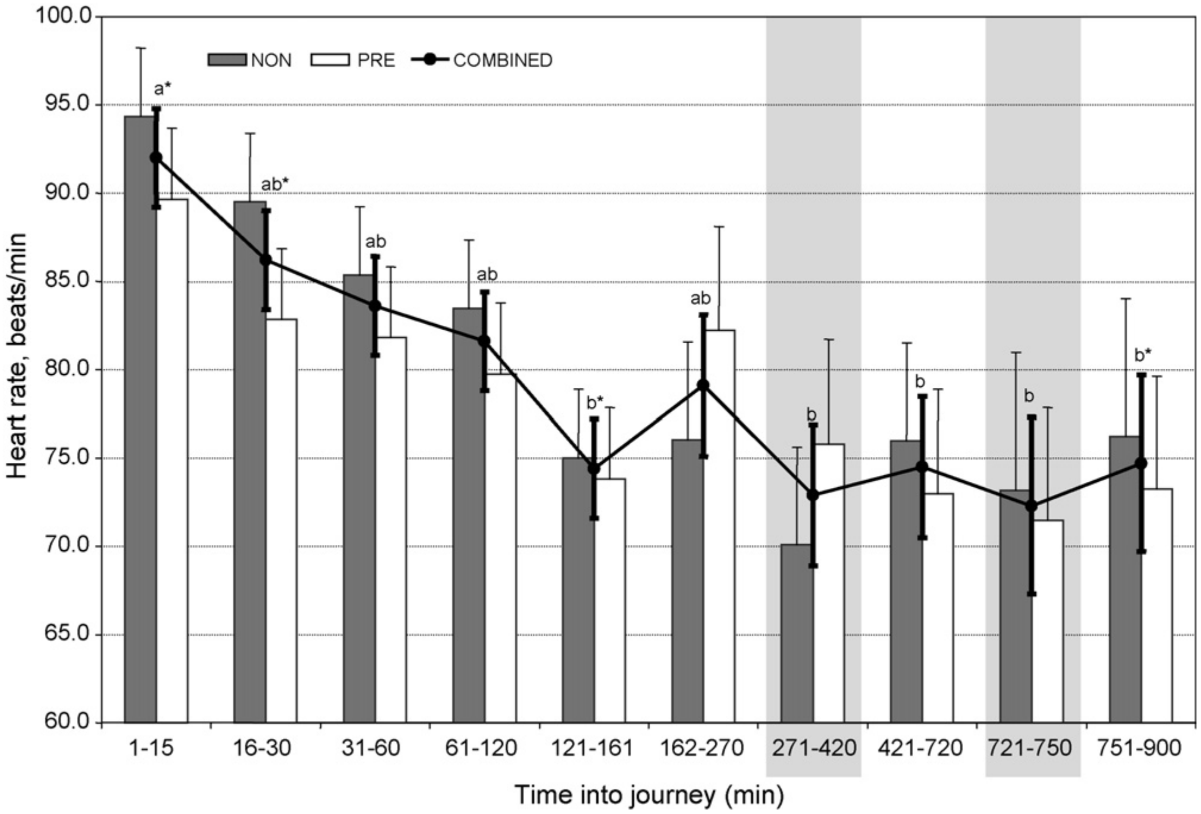

Fig. 1. Effect of hauling duration (up to 900 min) and conditioning treatment alone; non-conditioned (NC); and conditioned (C) and combined on heart rate (bpm) of calves ($n = 8$ calves/treatment) during transportation. Shaded areas indicate the block of time when the truck was stationary. Superscripts (a and b) indicate where the combined heart rate differed over time ($P < 0.05$).

calves had higher ($P < 0.01$) DM intakes than NC calves (Table 7). The overall morbidity rate was low at 5.17% with no treatment or interaction effects.

4. Discussion

4.1. Behaviour

4.1.1. Feeding behaviour

Calves spent an average of 250 min day^{-1} at the bunk over an average of 11 visits day^{-1} during the 30-day feeding period. These bunk attendance patterns are within the ranges reported

Table 7
Effect of haul (H) duration (long; L (15 h), short; S (2.7 h)) and conditioning (C) (non-conditioned; NC, conditioned; C) on shrink, intake and ADG of beef calves over a 30-day period after transport

	NC		C		S.E.M.	*P*-values		
	L	S	L	S		C	H	C × H
Dry matter intake (kg day^{-1})	6.1	6.0	6.8	7.3	0.35	<0.01	0.53	0.36
Shrinkage (kg)	14.6 b	9.2 c	23.6 a	7.8 c	0.76	<0.0001	<0.0001	<0.0001
Average daily gain (kg)	1.4 a	0.9 b	0.8 b	1.4 a	0.18	0.70	0.70	<0.01

Within a row different letters (a–c) indicate significant ($P < 0.05$) differences.

for steers during a feeding trial in which cattle were fed diets similar to those in this study (Schwartzkopf-Genswein et al., 1999, 2002, 2003). Based on the effects of transport distance and preconditioning reported in other studies NC and L calves were expected to make fewer visits of shorter duration to the feed bunk on day 1 post-transport as a result of stress associated with the effects of relocation, novel feed and water, feed bunks (Launchbaugh, 1995) and fatigue (Jarvis et al., 1996). In addition, several other studies (Cole et al., 1982; Zinn et al., 1988; Hicks et al., 1990) have reported decreased intake in receiving calves to be a common behavioural pattern observed in the first 2 weeks in the feedlot. However, the opposite effects were observed in our study with C and S calves having approximately half the number of bunk attendance min than NC and L calves 1 day post-transport. This same pattern was observed 14 days post-transport with C and S calves attending the bunk 55 and 6 fewer min day^{-1} than NC and L calves, respectively. This may be explained by the fact that L and NC calves were very hungry as a result of being without food for up to 24 h from the time of loading. However, it should be noted that attendance at the bunk does not imply intake indicating that NC and L calves came up to and stood at the bunk but may not have consumed feed. In addition, differences between L and S feeding durations should be viewed with caution as the S pens were provided with bedding and L pens were not. S calves may have attended the bunk less frequently because they were consuming some bedding. To date, no other studies have documented individual feeding duration and visits of calves following the transport of conditioned and non-conditioned calves.

4.1.2. Post-transport activity patterns

For the first 2 h off the truck C calves spent 39 and 28% (in the short and long- haul groups, respectively) of their time at the feed bunk while NC short-haul calves spent approximately 10% of their time consuming the straw bedding that was placed in their pen. No eating events were recorded for NC calves in the long-haul group because they were not provided with feed or straw bedding. C calves in the short-haul group spent 11% less time (numerically) at the feed bunk than C in the long-haul group which could be attributed to fatigue associated with the long-haul transport. Similar findings have been reported by Jarvis et al. (1996) who found that cattle transported for more than 128 km spent more time lying down in a 3 h period post-transport than cattle transported less than 128 km.

Day 1 observations were done after the NC group had completed their AS journey. This was also the first opportunity that NC calves were provided with feed within the feed bunks. The 20% increase in observed eating for NC calves in the short-haul group appears to be an obvious response following fasting for more than 24 h. These findings are consistent with Jarvis et al. (1996) who reported that cattle sold through markets were more hungry and thirsty on arrival at the lairage than cattle direct from farms. Hall et al. (1997) also observed increased eating in sheep following a 14 h deprivation of food and water as a result of transport. Although the NC calves had not been fed from a bunk or trough previously or fed a ration containing a silage based diet they appeared to be interested in the feed offered at the feedlot with little aversion to using the feed bunks. This is in contrast to the neophobia reported by Launchbaugh (1995) which is characterized by reduced intake of new feeds/novel feed bunks and is usually displayed when feedlot diets are first given to receiving calves even though the feeds are not toxic. However, the duration NC calves spent ruminating on day 1 was lower than C calves for both long and short-haul groups on the same day. Rumination time was also lower on day 1 compared to day 14 for the NC short-haul calves. This may also indicate that the calves exhibited behavioural responses consistent with neophobia and were not actually consuming feed, thus resulting in low rumination activity on day 1.

Based on the 24 h continuous observations of drinking frequency (after arrival to the feedlot; data not presented) C calves in the long-haul group were observed at the water trough 66% (11.43 visits/h) more frequently per hour than the NC (6.88 visits/h) calves and in the short-haul group C calves were observed at the water 47% (11.39 visits/h) more frequently per hour than the NC (7.77 visits/h) calves. The higher percentage of C versus NC calves drinking may be explained by access to feed on arrival as well as experience with drinking from a trough for the C calves. Previous work in cattle (Utley et al., 1970) and lambs (Cockram et al., 1999) has shown that water and feed intake are highly related and sufficient water will not be consumed if not provided in the presence of feed. NC calves were not provided with feed (only the NC calves in the short-haul group had access to straw bedding) which may have been related to their reduced water trough attendance. In addition, NC calves were only accustomed to drinking from a dugout prior to transport and therefore may have had some difficulty locating the water trough at the feedlot due to novelty and inexperience.

Beef cattle consuming high forage diets can spend as much as three quarters of their daily activity in the act of rumination (Fraser and Broom, 1990). In our study, rumination was severely disrupted (ranging between 0 and 9% of total activity) for all calves during the first 2 h after arrival to the feedlot from the ranch. The percentage of time that C calves were observed ruminating was 1.4 and 9.0%, for the short and the long-haul groups, respectively even though they spent 39 and 28% of the observation period at the feed bunk. This may indicate that although animals were at the bunk, actual feed consumption could have been low. A similar observation was made for NC calves on day 1 following auction simulation transport with rumination occurring between 0 and 10.9% of the observation period for the long and short-haul calves, respectively. Fraser and Broom (1990) indicate that the factors which may disturb or cause the cessation of rumination include any incident which gives rise to pain, hunger, anxiety or illness. By day 14, rumination accounted for between 30 and 45% of the 2 h observation period giving some indication that all calves were settled and resumed rumination.

Although statistical comparisons could not be made between the long and short-haul calves the percentage of time long-haul calves spent lying down on day 0 (44 and 35%) was numerically higher than for short-haul calves (22.5 and 24.5%) even though they were not provided with bedding. Studies have indicated cattle experience fatigue after extended periods in transit (Jarvis et al., 1996). Similarly, Grigor et al. (2001) indicated that during a mid-transport lairage period transported (12 h) calves spent significantly more time lying down than non-transported controls suggesting that the calves were fatigued by transport as they were observed to spend the majority of their in-transit time standing instead lying down inside the truck. No in-transit behavioural observations were made in our study. Overall, NC calves appeared more unsettled than C calves as indicated by the large portions of time spent moving and standing compared to C calves. This increased activity may be attributed to weaning stress and separation from their dams as NC calves demonstrated classic weaning stress behaviours such as bawling, pacing and standing as described by Stookey et al. (1997) and Price et al. (2003) on day 0. However, by day 1 and 14 for the short-haul calves, the percentage of time all calves spent moving, standing and vocalizing was drastically reduced. Stookey et al. (1997) also reported that calf milling and vocalizing had dropped by 50% 1 day following weaning as compared to the day of weaning.

4.2. Cortisol

The range of cortisol concentrations between NC and C calves was large and indicated that a stress response was elicited in some calves similar to restraint stress levels documented in other studies (Zavy et al., 1992; Grandin, 1997). NC calves had higher cortisol concentrations immediately off-loading than C calves which was expected because they were exposed to the combined stresses of handling, weaning, and transport on the day of transport whereas C calves were only exposed to the stresses of handling and transport. This is consistent with other studies indicating that transport and weaning appear to elicit similar responses (Zavy et al., 1992) and therefore the added stress of weaning in the NC group could raise cortisol levels above those measured in the C group.

The lack of haul distance effects on cortisol concentrations suggest that increased transit duration did not result in increased cortisol secretion by calves in either the RF or AS journeys. Cole et al. (1988) reported similar findings with control (non-transported) calves having cortisol concentrations similar to calves transported 12 h. In addition, calves transported 24 h in Cole's study had lower cortisol concentrations than calves transported 12 h. Fazio et al. (2005) also found that both long- and short-haul transport resulted in similar increases in cortisol concentrations compared to basal levels. Possible explanations for lack of transport distance effect are habituation and or adrenal gland hormone production depletion (Phillips et al., 1985). No ACTH challenge test was conducted in our study and therefore the exhaustion of cortisol secretion could not be substantiated. The time × treatment effects observed for L calves may be explained by normal diurnal hormone fluctuations (Wagner and Oxenreider, 1972) that occur in cattle since the pre-loading sample was taken at approximately 2100 when cortisol levels are reported to 3–4 ng/ml lower (between 18:00 and 02:00 h) than any other time of the day. The off-loading and 2 h post off-loading were taken at 10:00 and 12:00 h, respectively.

4.3. Heart rate

Normal at-rest heart rates for calves range from 70 to 110 bpm (Rosenberger, 1979). Heart rates in our study ranged from 40 to 240 bpm. As haul duration could not be a factor for the treatment differences observed until after 161 min, the most likely explanation is a potential difference in transport conditions (i.e., on the truck, on the road, or in the driving quality between the S and L trucks). However, this cannot be substantiated as no measures of this kind were recorded in our study. No differences were observed between 161 and 900 min into the journey for CL and NCL calves indicating that conditioning did not play a role in reducing heart rate in long-haul calves. Higher initial heart rates may have been due to handling, animal movement and novelty of the truck and as calves became habituated on the truck, heart rates decreased. These data suggest that increased transport duration does not result in increased heart rate. Similar results have been reported by Grigor et al. (2001) who found no differences in the heart rates of transported (9 h) and control calves (82 and 86 bpm, respectively). The absence of a transport distance effect on the mean heart rate was also reported in several other studies (Stephens and Toner, 1975; Knowles et al., 1999). However, these results are in contrast to those reported by Van de Water et al. (2003) indicating that calf heart rates remained high during transport (38%) compared to pre-transport levels (100 bpm versus 135 bpm). Van de Water et al. (2003) also reported that calf heart rate increased 80 and 72% during loading and unloading, respectively, in relationship to the mean pre-transport values.

NCS calves had heart rates that were approximately 15 bpm lower on the AS journey than on their first RF journey suggesting that the RF journey caused a greater stress response in some calves than the AS journey. In addition, the data show that the calves did not have higher heart rates on the AS journey as would be expected if the calves were experiencing fatigue.

4.4. Shrink, intake, performance and morbidity

Shrink was greater in CL than in NCL steers, and in NCL than in either CS or NCS steers. This is not surprising given the 12 h difference in the duration of transit times between the L and S groups. Long-haul calves had more time in which to experience fecal, urine and tissue loss that has been reported to be greatest within the first 5–11 h in transport (Cole et al., 1988). Knowles et al. (1999) indicated that the pre-transport body weight was regained by calves within 8–16 h after transport but their mean weights remained below a control group for up to 72 h after transport. This did not include any associated effect of dehydration which has been observed to be as much as 8% of the calf's body weight (Zavy et al., 1992). No measures of dehydration were made in our study. Reasons for the marked difference in shrink between CL and NCL calves (23.6 and 14.6 kg, respectively) may be explained by the fact that CL calves had been weaned and introduced to long-hay and some grain 13 days prior to transport. In addition, CL and CS calves were accustomed to eating solid food and would have had substantial gut-fill associated with their forage (high fibre)/grain intake compared to NCL and NCS calves that were still suckling up until they were weaned on the day of transport. This difference in diet could have been the cause of the larger shrink observed in CL calves compared with the NCL group. In typical preconditioning programs calves are weaned at least 45 days (Radostits, 2000; Macartney et al., 2003) before transport which would give them a much longer period of time to adjust to a new diet and stress of weaning prior to shipping. The major difference between conditioning in our study and recommended preconditioning protocols was the time between weaning and transport; 13 days compared to 45 days, respectively. The findings of our study imply that the recommendation to ship cattle no less than 45 days after weaning may be important in keeping shrink to a minimum.

DM intake was on average 1 kg day^{-1} higher in C compared to NC calves over the 30-day feeding period post-transport showing a positive effect of conditioning. No other studies have reported the effects of preconditioning or conditioning on intake even though one of the reported benefits of preconditioning is to facilitate the consumption of novel feed (Radostits, 2000).

Low ADG for the CL calves in our study may be explained by that fact that just conditioning may not have the same beneficial effects on weight gain as preconditioning. Other studies (Karren et al., 1987; Shipper et al., 1989) have indicated preconditioned calves had ADG up to 2 times greater than those observed in non-preconditioned calves. However, CS calves in our study had significantly higher gains than NCS calves indicating that conditioning may have a positive effect on weight gain. In addition, our results for ADG are not consistent with what would be expected given that C calves had higher DM intakes. The effect of conditioning on ADG in our study is unclear and difficult to explain.

Low morbidity in our study was most likely the result of the entire group of calves being acquired from a single source (ranch) that were not co-mingled with calves from other ranches during either RF or AS transport, thereby reducing their exposure to infective pathogens. Our findings are supported by Ribble et al. (1995b) who reported a positive linear relationship between mixing of calves in truck loads from different sources and morbidity due to shipping fever. A similar study on transport distance found that short-haul calves had higher morbidity and mortality than either long-haul or non-transported calves (Cole et al., 1988). It was hypothesized that short-haul calves in that study may have encountered greater cumulative stress during a 24-h period than long-haul or control calves. In contrast, Ribble et al. (1995a) found that transport distance was not correlated with death loss from fatal shipping fever and he concluded that differences between short- and long-haul explained little if any of the variation in truck loads for risk of morbidity due to pneumonia.

5. Conclusions

Based on the results of this study, conditioning calves prior to transport allowed calves to better tolerate the stressors of transport and handling. This was observed in lower cortisol concentrations pre- and post-loading as well as higher percentages of time feeding and less time standing and milling in their pens immediately post-transport compared to non-conditioned calves. In addition, the combined effect of conditioning and short-haul transport was least stressful as witnessed by the low shrink, high DM intake and ADG in the first month after transport. Conditioning had some positive effects on the performance and well-being of transported calves and should be considered when preparing calves for sale and transport. Further studies comparing conditioning to preconditioning and their effects on cattle behaviour, performance and economic benefits are warranted.

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