

Effect of transport on feeder calves

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SUMMARY

One hundred fifty feeder steers (mean body weight, 195 kg) were assigned to 1 of 3 transport groups and were deprived of feed and water (fasted) for 24 hours. Additionally, calves were transported on a commercial livestock trailer for 0 (control—fasted only), 12 (short haul), or 24 (long haul) hours. Blood samples were obtained from the jugular vein before calves were loaded on the transport vehicle and immediately after calves of the long-haul group returned to the research feedlot. Complete blood counts were performed and 32 mineral, enzyme, and biochemical constituents were measured. Calf morbidity, mortality, and average daily weight gain were evaluated during the next 56 days. Duration of transport did not affect average daily gain; however, calves of the short-haul group had significantly ($P < 0.05$) higher morbidity and mortality than did those of the control and long-haul groups. In all groups, results of differential leukocyte counts were indicative of stress response. Significant ($P < 0.05$) linear contrasts were observed between duration of transport and erythrocyte, leukocyte, segmented neutrophil, lymphocyte, and eosinophil counts and results of serum enzyme (alanine transaminase, hydroxybutyrate dehydrogenase, total lactate dehydrogenase [LD], and LD-1, LD-3, and LD-4 isoenzymes), iron, urea nitrogen, β -globulin, glucose, and urea nitrogen-to-creatinine ratio determinations. Significant ($P < 0.05$) quadratic contrasts were observed between duration of transport and serum unsaturated iron binding capacity, total iron binding capacity, and LD-5 percentage. Calf source had a significant ($P < 0.05$) effect on almost all variables tested. Results indicated that transport is a stressful event to feeder calves; however, other factors, possibly related to the timing of stress events or adaptation to several different stressors during a short period, may have a greater effect on feeder calves' subsequent health.

In the southwestern United States, large numbers of feeder calves are transported long distances from cow-calf producing areas to feedyards. Generally, these calves are purchased, within several days of weaning, by an order buyer at small local auctions, are transported to the order

buyer's facility (where they are kept until a sufficient number are obtained to fill the purchase order), and then are transported to the feedyard. This combination of numerous stressors and exposure to viral and bacterial pathogens can lead to high frequency of bovine respiratory tract disease.

Transportation stress alters rumen function,^{1,2} serum biochemical constituents,¹⁻³ and serum cortisol concentration³ more than does fasting alone. These changes, however, may be dependent on the duration of the transport period. In addition, compared with fasting alone, transportation increases weight loss⁴ and nitrogen excretion.² Using records from commercial feedyards, Schake et al⁵ reported that the distance calves were hauled from the sale barn to the feedyard was related significantly to the number of days calves were affected adversely. Their analysis, however, only included calves transported for < 5 hours. The study reported here was designed to determine the effects of duration of transportation on weight loss (shrinkage), health, performance (daily weight gain and gain-to-feed ratio), and hematologic and serum biochemical constituents of feeder calves.

Materials and Methods

Calves and experimental design—One hundred fifty feeder calves (mean body weight, 195 kg) were purchased at a cattle auction in Amarillo, Tex. All calves originated from 6 ranches in the local area and had been at the auction facility for 3 days. After purchase, calves were transported 32 km to the USDA Texas Agricultural Experiment Station research feedlot at Bushland, Tex. After a 6- to 8-hour rest period, calves were individually weighed and ear tagged, rectal temperature was recorded, and blood samples were obtained. Calves were identified by ranch of origin, assigned to 3 groups of 50 calves each, and placed in separate pens. Calves from each ranch were represented equally in each transport group. Calves were provided alfalfa hay and water ad libitum for 18 hours. At 8 AM the next day, calves from 2 groups (long and short haul) were loaded onto a double-decked livestock trailer and transported for 12 hours (800 km). After returning to Bushland, calves of the short-haul group were unloaded and placed in their assigned pens without feed and water (fasted). The long-haul group was transported for an additional 12 hours (total, 1,600 km) before being unloaded and fasted. Control calves (fasted only) were kept in a pen without feed and water during the 24-hour transport period. When the long-haul group of transported calves arrived at Bushland, calves within each treatment group were assigned to 12 pens with fence-line feed bunks (4 pens/treatment group). Each calf was weighed, a blood sample (from the jugular vein) was obtained, and rectal temperature was recorded. Transport groups were rotated, so that the average time from unloading to weighing and blood sample collection was equal for all treatment groups.

For 56 days, all calves were fed a 40% roughage⁶ diet ad libitum. Calves were weighed on days 7, 14, 28, 55, and 56. The final weight was determined from the mean of the weights on

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days 55 and 56. Calves were observed daily for signs of bovine respiratory tract disease (anorexia, nasal discharge, ocular discharge, depression, diarrhea), and those subjectively determined to be affected were moved to hospital pens and treated with antibiotics^a for at least 3 days or until they were considered healthy enough to return to their assigned pen. Calves that died were transported to the Texas A&M Veterinary Diagnostic Laboratory at Amarillo, Tex, for necropsy and histologic and microbiologic examinations to determine the cause of death.

Blood analysis—A blood sample obtained from the jugular vein of each calf was divided into 3 portions and placed in 3 separate tubes: 1 containing 15 mg of dry sodium edetate/10 ml of blood, a 2nd containing 3.8% sodium citrate solution (1 part citrate solution/9 parts of blood for fibrinogen determination), and a 3rd containing no additive. The 3rd portion was allowed to clot at 20 C for 30 minutes, and serum was obtained after centrifugation at 2,000 × g for 25 minutes. All hematologic procedures, except reading of blood smears, were performed immediately after sample collection in the tubes containing sodium edetate as anticoagulant. Total RBC and WBC counts were determined by use of an electronic particle counter.^b Hemoglobin concentration was measured by use of a hemoglobinometer,^c and PCV was determined directly by centrifugation.^d Serum specimens for determination of lactic dehydrogenase (LD) and α-hydroxybutyric dehydrogenase (HBD) activities, iron concentration, and total and unsaturated iron binding capacities (TIBC and UIBC, respectively) were stored at approximately 20 C and were analyzed within 72 hours after collection. Serum for other biochemical determinations was kept frozen until analyzed. Serum concentrations of Ca, Mg, Na, and K were determined, using an atomic absorption spectrophotometer.^e Serum LD isoenzyme and protein fractions were separated according to their electrophoretic mobility on cellulose acetate plates and were quantitated densitometrically after appropriate preparation.^{f-h} Serum TIBC and UIBC,ⁱ HBD^j and total LD^k activities, and iron concentration were determined, using commercially available reagents and semiautomated equipment.^l Methods used for fibrinogen (analyzed in citrated plasma specimens),⁷ serum cortisol,⁸ and remaining biochemical determinations⁹ were performed as previously described.

Statistical analysis—Absolute blood constituent concentrations were analyzed statistically by analysis of variance as a split plot in time, with the subplot being time of blood sample collection. The main plot was analyzed as a 6 × 3 factorial arrangement of treatments. Sources of variation included in the model were ranch of origin, duration of transport, ranch × transport duration, sample collection time, and all possible sample collection time × main plot interactions. Calf (source × duration of transport) was used as the error term for the main plot. Performance data and changes in blood, plasma, and serum constituents during transport and/or fasting were analyzed statistically by analysis of variance as a 6 × 3 factorial arrange-

TABLE 1—Shrinkage, health status, and performance of calves transported for 0, 12, or 24 hours

Variable (units)	Duration of transport (h)			SEM	OC
	0	12	24		
Weight before transport (kg)	193	194	197	3.5	NS
Shrinkage (kg)	9.8	13.6	14.9	0.44	L
Shrinkage (%)	5.1	7.0	7.6	0.21	L
Average daily gain from weight before transport (kg)					
Week 2	0.31	0.04	0.60	0.47	Q
Week 4	0.99	0.84	1.20	0.16	Q
Week 8	0.96	0.94	1.06	0.19	NS
Dry matter intake (kg/head/day)					
Week 4	4.1	3.7	4.6	0.62	NS
Week 8	5.3	5.2	6.0	0.42	NS
Gain-to-feed ratio*					
Week 4	241	225	258	26	Q
Week 8	182	182	176	12	NS
Morbidity (%)	22	54	26	...	Q
Days ill	1.48	3.34	1.62	0.29	Q
Rectal temperature					
before transport (C)	39.1	39.0	39.0	0.07	NS
Rectal temperature (C)†	0.55	0.50	0.34	0.06	NS
Mortality (%)	4	24	8	...	Q

* Grams of weight gain per kilogram of feed dry matter consumed. † Increase in rectal temperature during transport and/or fasting.

OC = orthogonal contrasts, NS = not significant, L = linear, Q = quadratic ($P < 0.05$).

ment of treatments. Transport effects were compared by linear and quadratic orthogonal contrasts. All analyses were conducted, using the general linear models procedure of a computerized statistical analysis system.¹⁰ Differences were considered statistically significant at $P < 0.05$.

Results

Mean initial weights were similar for all transport groups (Table 1). Transportation caused a significant ($P < 0.05$) increase in shrinkage, compared with fasting alone; most of the shrinkage took place during the first 12 hours of transport. Transportation stress quadratically ($P < 0.05$) affected average daily gain and gain-to-feed ratio during the first 28 days in the feedlot, but did not affect these variables at 56 days. Of 51 calves treated for respiratory tract disease, 18 died. In the 18 calves that died, microbial agents isolated from the lungs included *Pasteurella haemolytica* ($n = 12$ calves), *P. multocida* ($n = 4$ calves), *Haemophilus somnus* ($n = 2$ calves), *Corynebacterium pyogenes* ($n = 4$ calves), and bovine viral diarrhea virus ($n = 8$ calves). Calves of the short-haul group had higher morbidity and mortality than did calves of the control and long-haul groups. Calves of the short-haul group also tended to become affected and to die sooner than did calves of the other groups (Fig 1 and 2); however, the principal differences in morbidity and mortality took place after day 5. Few calves of the control and long-haul groups became affected after day 5; however, > 50% of the morbidity in the short-haul group took place after day 5. A similar trend was observed for mortality.

Complete blood count results are given in Table 2. Transport duration did not affect PCV, hemoglobin concentration, RBC indices, or the absolute numbers of band cells, monocytes, or basophils. Numbers of RBC, WBC, segmented neutrophils, lymphocytes, and eosinophils were linearly ($P < 0.05$) affected by duration of transport.

Serum iron concentration was linearly ($P < 0.05$) affected and UIBC and TIBC were quadratically ($P < 0.05$) affected by duration of transport (Table 3). Serum Ca, Mg,

^a Erythromycin, Ceva Laboratories, Inc, Overland Park, Kan.

^b Model ZBI, Coulter Electronics Inc, Hialeah, Fla.

^c Hemoglobinometer, Coulter Electronics Inc, Hialeah, Fla.

^d International IEC microcapillary centrifuge, model MB, International Equipment Co, Needham Heights, Mass.

^e Model 403, atomic absorption spectrophotometer, Perkin-Elmer Corp, Norwalk, Conn.

^f LD Isoenzyme electrophoresis procedure No. 6, revised 6/82(5), Helena Laboratories, Beaumont, Tex.

^g Serum protein electrophoresis procedure No. 1, 12/77, Helena Laboratories, Beaumont, Tex.

^h Quick Scan electrophoresis densitometer No. 1020, Helena Laboratories, Beaumont, Tex.

ⁱ Bulletin No. 565, revised June 1980, Sigma Chemical Co, St Louis, Mo.

^j HBD Reagent Set, Gilford Diagnostics, Cleveland, Ohio.

^k Statzyme LDH (L-P) reagent, Worthington Diagnostics, Division of Millipore Corp, Freehold, NJ.

^l Model 3500, computer directed analyzer, Gilford Instrument Laboratories Inc, Oberlin, Ohio.

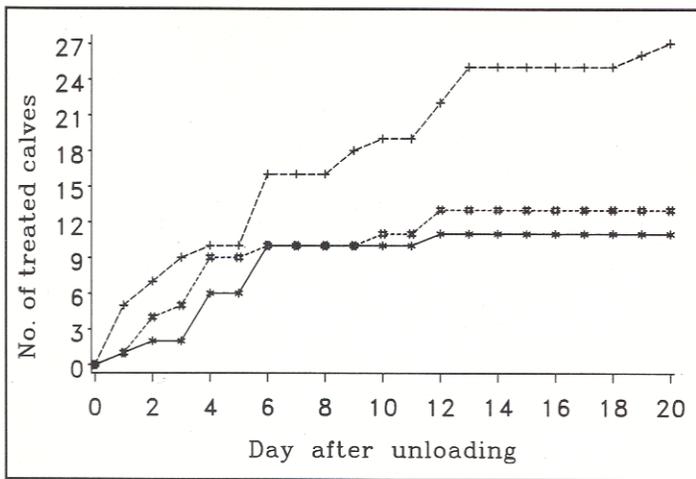


Fig 1—Cumulative number of calves in each transport group treated for respiratory tract disease during the first 20 days in the feedlot. Each group contained 50 calves. * = nontransported calves (controls); + = calves transported for 12 hours (short haul); # = calves transported for 24 hours (long haul).

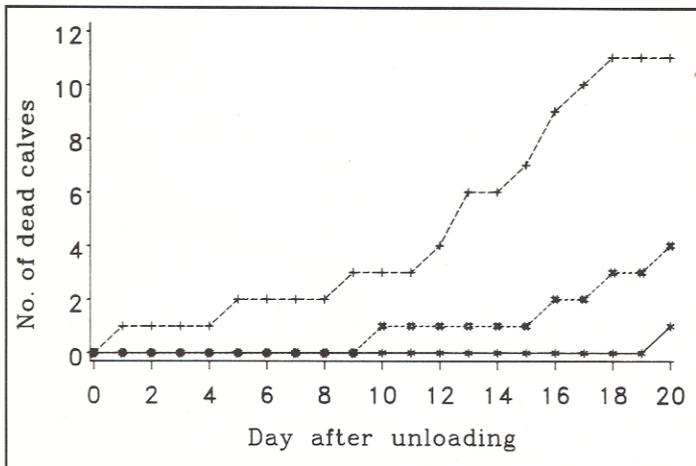


Fig 2—Cumulative number of calves in each transport group that died of respiratory tract disease during the first 20 days in the feedlot. Each treatment group contained 50 calves. * = nontransported calves (controls); + = calves transported for 12 hours (short haul); # = calves transported for 24 hours (long haul).

K, Na, and P concentrations were not significantly affected by duration of transport.

Transport did not affect serum alkaline phosphatase, aspartate transaminase (AST), creatinine kinase (CK), or LD-2 activities (Table 4). However, duration of transport had a significant ($P < 0.05$) linear effect on alanine transaminase (ALT), HBD, and total LD activities and on LD-1, LD-3, and LD-4 percentages of total LD activity; it had a quadratic effect on the LD-5 percentage of total LD activity. The LD-1 percentage increased in calves of the control and short-haul groups, but decreased in calves of the long-haul group. The LD-3 percentage decreased in calves of all groups, with the decrease being less in calves transported for 24 hours (long haul). The LD-4 percentage decreased in calves of the control and short-haul groups, but increased slightly in calves of the long-haul group. The LD-5 percentage decreased in calves of the short-haul group and increased in calves of the control and long-haul groups.

Serum protein, albumin, uric acid, creatinine, triglyceride, cholesterol, cortisol, and α - and γ -globulin concentrations and plasma fibrinogen concentration were not affected by duration of transport (Table 5). Serum glucose concentration increased linearly as duration of transport increased, but serum urea nitrogen concentration and the urea nitrogen-to-creatinine ratio decreased.

Nontreated calves—To exclude changes that may have been attributable to infection, data from all calves that subsequently became ill were deleted, and means and orthogonal contrasts were determined. Values that were significantly ($P < 0.05$) affected by duration of transport are given in Table 6. In general, hematologic and serum biochemical value changes were similar in direction and magnitude to changes observed when data from ill calves were included. Serum cholesterol concentration and CK and AST activities were not significantly affected by duration of transport when data from ill calves were included, but were affected when data from ill calves were omitted. In contrast, TIBC and RBC count were significantly ($P < 0.05$) affected by duration of transport when data from ill calves were included, but were not affected when data from ill calves were omitted. Lymphocyte and WBC counts and serum LD-3 and LD-4 percentages along with β -globulin concentration were significantly ($P < 0.05$) affected by duration of transport when data from ill calves were included. When data from ill calves were omitted, the effects were not statistically significant; however, a strong trend ($P < 0.10$) was evident.

Ranch of origin—The ranch of origin had a significant ($P < 0.05$) effect on all variables tested except LD-2 and LD-5 percentages and band cell count; however, ranch \times treatment interactions were not obtained. Morbidity of calves from each ranch ranged from 15 to 63%, and mortality ranged from 0 to 30%. Although the origin of each calf was known, data were not obtained from each ranch; therefore, the possible reasons for the ranch differences could not be determined.

Discussion

Feed and water deprivation accounted for 66% of transport shrinkage. This was similar to the value reported by Phillips and Leining^m; feed and water deprivation accounted for 63% of shrinkage in calves transported for 5 hours. These results agreed with reports indicating that transport stress increases fecal, urine, and tissue losses, with most of the increased loss taking place during the first 5 to 11 hours of transport.⁴ In agreement with previous reports,^{3,m} transported calves compensated sufficiently for the greater weight loss; by day 56, a difference in calf weight or average daily gain was not detected.

Calves transported for 12 hours had higher morbidity and mortality, became ill earlier, and became ill or died during a longer period than did calves of the control and long-haul groups. The reason for this effect was not apparent. Indicators of health status before transport were similar in calves of the short-haul and long-haul groups. Before transport, mean rectal temperature and serum urea

^m Phillips WA, Leining KB. Weight changes during transportation of stocker calves. Oklahoma Agricultural Experiment Station, Animal Science Research Report, MP-108, April 1981; 110-112.

TABLE 2—Mean CBC results for calves before and during transport for 0, 12, or 24 hours

Variable (units)	Before transport				Change during transport				OC
	0	12	24	SEM	0	12	24	SEM	
PCV (%)*	39.5	39.7	38.3	0.40	1.33	1.62	0.47	0.25	NS
Hb (g/dl)*	14.4	14.4	13.9	0.14	0.44	0.54	0.22	0.06	NS
RBC (10 ⁹ /μl)*†	10.2	10.2	9.9	0.13	0.33	0.44	0.06	0.06	L
MCV (fl)	39.7	39.4	39.7	0.27	0.02	0.22	-0.02	0.08	NS
MCH (pg)	14.2	14.1	14.2	0.10	-0.03	-0.07	0.07	0.04	NS
MCHC (g/dl)	36.4	36.3	36.3	0.10	-0.09	-0.17	0.07	0.14	NS
WBC (× 10 ⁹ /μl)	9.88	10.60	10.90	0.25	-0.14	0.02	0.53	0.22	L
Bands (× 10 ⁹ /μl)*	0.13	0.14	0.12	0.01	-0.09	-0.07	-0.08	0.01	NS
Segs (× 10 ⁹ /μl)†‡	2.18 ^a	2.98 ^b	3.02 ^b	0.14	0.12	0.30	1.14	0.16	L
Lympho (× 10 ⁹ /μl)	6.85	6.88	6.92	0.18	0.11	0.00	-0.11	0.13	L
Eosin (× 10 ⁹ /μl)*†	0.26	0.21	0.35	0.02	-0.10	-0.09	-0.25	0.02	L
Mono (× 10 ⁹ /μl)*	0.44	0.41	0.48	0.02	-0.22	-0.13	-0.16	0.03	NS
Baso (× 10 ⁹ /μl)*	0.05	0.05	0.05	0.01	-0.01	-0.02	-0.02	0.01	NS

* Significant ($P < 0.01$) change during transport and/or fasting. † Significant ($P < 0.05$) treatment × sample time interaction. ‡ Significant ($P < 0.05$) change during transport and/or fasting.

^{a,b} Means in the same row without a common letter in their superscript differ significantly ($P < 0.05$).

Hb = hemoglobin concentration, MCV = mean corpuscular volume, MCH = mean corpuscular hemoglobin weight, MCHC = mean corpuscular hemoglobin concentration, Bands = band neutrophils, Segs = segmented neutrophils, Lympho = lymphocytes, Eosin = eosinophils, Mono = monocytes, Baso = basophils. See Table 1 for explanation of other abbreviations.

TABLE 3—Mean serum mineral concentrations in calves before and during transport for 0, 12, or 24 hours

Variable (units)	Before transport				Change during transport				OC
	0	12	24	SEM	0	12	24	SEM	
Ca (mg/dl)*	10.8	10.7	10.7	0.06	-0.12	-0.28	-0.09	0.08	NS
Mg (mg/dl)†	1.86	1.88	1.88	0.02	0.21	0.28	0.10	0.04	NS
K (mEq/L)†	4.94	4.86	4.84	0.03	-0.06	-0.21	-0.12	0.05	NS
Na (mEq/L)†	134	134	134	0.76	4.6	4.6	5.5	0.58	NS
P (mg/dl)†	7.86	8.02	7.41	0.14	1.00	0.39	0.59	0.16	NS
Fe (μg/dl)†‡	120	103	126	5.3	-30	-32	-59	4.9	L
UIBC (μg/dl)†‡	208	212	210	5.4	52	13	80	8.5	Q
TIBC (μg/dl)‡	328	315	336	5.1	23	-20	21	7.7	Q

* Significant ($P < 0.05$) change during transport and/or fasting. † Significant ($P < 0.01$) change during transport and/or fasting. ‡ Significant ($P < 0.05$) treatment × sample time interaction.

UIBC = unsaturated iron binding capacity, TIBC = total iron-binding capacity. See Table 1 for explanation of other abbreviations.

TABLE 4—Mean serum enzyme activities in calves before and during transport for 0, 12, or 24 hours

Variable (units)	Before transport				Changes during transport				OC
	0	12	24	SEM	0	12	24	SEM	
ALP (U/L)	87.2	82.4	79.7	2.6	-9.7	-6.7	-6.1	1.0	NS
AST (U/L)	49.1	51.5	51.6	1.3	3.0	0.8	6.1	1.5	NS
ALT (U/L)	22.5	23.2	22.1	0.6	3.1	3.6	6.2	0.6	L
HBD (U/L)*†	1,175	1,195	1,226	14.9	-46	-8	50	9.6	L
CK (U/L)	174	188	158	10.5	43	20	129	23.0	NS
LD (U/L)*†	598	617	624	8.0	-17.6	-6.9	32.4	5.8	L
LD-1 (%)†‡	41.9	42.1	42.1	2.7	2.23	2.02	-0.63	0.43	L
LD-2 (%)	32.4	32.2	32.0	1.4	-0.19	0.20	-0.24	0.25	NS
LD-3 (%)*†	18.4	18.6	18.8	1.5	-1.64	-1.58	-0.60	0.21	L
LD-4 (%)*	4.4	4.2	4.6	0.8	-0.60	-0.29	0.06	0.12	L
LD-5 (%)†	2.8	2.9	2.6	1.4	0.20	-0.54	1.43	0.29	Q

* Significant ($P < 0.01$) change during transport and/or fasting. † Significant ($P < 0.05$) treatment × sample time interaction. ‡ Significant ($P < 0.05$) change during transport and/or fasting. ALP = alkaline phosphatase, ALT = alanine transaminase, AST = aspartate transaminase, HBD = hydroxybutyrate dehydrogenase, CK = creatinine kinase, LD = lactate dehydrogenase, LD-1 through -5 = LD isoenzymes expressed as a percentage of total LD activity. See Table 1 for explanation of other abbreviations.

nitrogen concentration were the same for both groups. Plasma fibrinogen concentration; total WBC, segmented neutrophil, band neutrophil, and lymphocyte counts; and serum total LD activity and cortisol concentration also were similar in calves of both groups. The number of calves with pretransport rectal temperature > 39.5 C also was similar across transport (9 vs 9 vs 10 for control, short-haul, and long-haul groups, respectively) groups. This suggested that calves of all transport groups had similar health status before being loaded on the transport vehicle and that transport effects on morbidity and mortality were not attributable to chance differences in initial health status of the calves of each group. Calves were loaded in compartments of the transport vehicle according to trans-

port times; therefore, calves transported for 12 hours may have been in compartments that produced more stress or increased exposure to pathogens. However, previous studies indicated that trailer compartments do not affect calf health or performance.¹¹

Calves transported for 12 hours arrived and were unloaded at the feedlot near sunset (8 PM). Subjective observations indicated that these calves were restless during the night. In contrast, calves of the long-haul group that were unloaded in the morning (8:30 AM) tended to rest during the day. Although calves of the control and long-haul groups had to adjust to only one stressor event (fasting or fasting plus transport), calves of the short-haul group had to adjust to 2 stressors (fasting plus transport

TABLE 5—Mean serum and plasma biochemical constituents in calves before and during transport for 0, 12, or 24 hours

Variable (units)	Before transport				Change during transport				OC
	0	12	24	SEM	0	12	24	SEM	
Protein (g/dl)*	7.4	7.4	7.5	0.07	-0.43	-0.30	-0.28	0.05	NS
Albumin (g/dl)*	3.7	3.7	3.6	0.03	-0.24	-0.20	-0.13	0.03	NS
Uric acid (mg/dl)*	1.04	1.02	0.97	0.02	0.06	0.02	0.12	0.02	NS
Urea nitrogen (mg/dl)*,†	14.2	13.8	13.8	0.29	2.2	1.1	0.6	0.29	L
Creatinine (mg/dl)*	1.55	1.45	1.44	0.02	0.10	0.09	0.12	0.01	NS
Urea nitrogen: creatinine†	9.4	9.8	9.7	0.24	0.60	0.04	-0.43	0.21	L
Fibrinogen (mg/dl)*	258	257	252	6.32	52	66	47	7.4	NS
Globulin (g/dl)									
α fraction‡	1.20	1.14	1.16	0.02	-0.05	-0.01	-0.01	0.14	NS
β fraction‡	0.89	0.91	0.89	0.02	-0.08	-0.02	0.00	0.21	L
γ fraction*	1.62	1.66	1.79	0.52	-0.06	-0.07	-0.14	0.26	NS
Glucose (mg/dl)†	88	79	81	1.8	-8.6	-1.9	9.7	1.8	L
Triglycerides* (mg/dl)	42.4	40.4	40.0	1.2	-10.8	-10.9	-8.6	1.1	NS
Cholesterol* (mg/dl)	122	119	119	3.2	-10.2	-9.4	-5.2	1.2	NS
Cortisol* (ng/ml)	38.6	38.9	35.4	1.4	-10.0	-11.7	-8.2	1.5	NS

* Significant ($P < 0.01$) change during transport and/or fasting. † Significant ($P < 0.05$) treatment \times sample time interaction. ‡ Significant ($P < 0.05$) change during transport and/or fasting. See Table 1 for explanation of other abbreviations.

TABLE 6—Variables with significant ($P < 0.05$; $P < 0.01$) orthogonal contrasts attributable to duration of transport—data from affected calves deleted

Variable (units)	Duration of transport (h)			OC
	0 (n = 39)	12 (n = 23)	24 (n = 38)	
Initial weight (kg)	193	197	197	
Shrinkage (kg)	10.0	15.4	16.2	L*
Shrinkage (%)	5.16	7.85	8.22	L*
ADG (kg)	1.09	1.20	1.18	NS
--- Change during transport ---				
Urea nitrogen (mg/dl)	2.15	0.78	0.48	L†
Glucose (mg/dl)	-9.07	0.35	11.0	L*
Cholesterol (mg/dl)	-11.36	-3.39	-4.02	L†
Urea nitrogen:creatinine	0.47	-0.11	-0.50	L†
LD-1 (%)	2.66	2.14	0.40	L*
LD-5 (%)	-0.15	-0.57	0.67	Q†
Iron (μg/dl)	-27.6	-38.9	-66.2	L*
UIBC (μg/dl)	43.1	11.1	77.3	Q†
AST (U/L)	0.00	-0.30	3.63	L†
ALT (U/L)	2.89	3.61	5.28	L†
LD (U/L)	-22.9	2.7	20.3	L*
HBD (U/L)	-56.5	3.8	37.5	L*
CK (U/L)	31.1	0.04	74.1	Q†
Neutrophils ($\times 10^3/\mu\text{l}$)	-0.16	0.04	1.25	L†
Eosinophils ($\times 10^3/\mu\text{l}$)	-0.12	-0.08	-0.27	L*

* $P < 0.01$. † $P < 0.05$.

ADG = average daily gain. See Tables 1 and 4 for explanation of other abbreviations.

and then fasting in pen). Calves of the short-haul group, therefore, actually may have encountered greater cumulative stress during the 24-hour experimental period than did calves of the control or long-haul groups, thus resulting in higher morbidity and mortality. In addition, various degrees or rates of stress may have been encountered during the 24-hour fasting plus transport period. The cumulative amount of stress placed on the calf during a period may be a result of the duration as well as the severity of individual stressors encountered at various points during the experimental period. The time of day that each stressor event took place in relation to other stressors also may be important. Variation in the duration, severity, timing, or accumulated stress encountered by the calf could cause variability in the immunosuppression caused by the stress.

In general, changes in hematologic and serum biochemical values were similar to those changes observed in mature steers transported for 32 hours,¹ in freshly

weaned calves transported for 12 hours,³ and in yearling steers transported for 13 to 46 hours.² The linear increase in segmented neutrophil count and linear decreases in lymphocyte and eosinophil counts during transport were typical of stress response, although magnitudes of the changes were smaller than those reported.^{12,13}

In agreement with previous reports,^{1,3} serum Ca, K, and Na concentrations were not significantly affected by transport stress. Serum Ca, Mg, and K concentrations decrease and serum Na concentration increases after administration of adrenocorticotropin; however, this effect usually lasts for < 24 hours.¹² Because of the sample collection times used in this study, any transient changes in these serum mineral concentrations would not have been detected.

Crookshank et al³ reported that weaning but not transport (for 12 hours) resulted in increases in serum AST, ALT, CK, and LD activities. In contrast, Galyean et al,¹ using mature steers, reported that a 32-hour transport period resulted in increases in AST, ALT, and LD activities. Compared with results of fasting only, transport for 12 hours did not affect AST, ALT, CK, or total LD activities. However, transport for 24 hours resulted in increases in ALT, CK, and LD activities and tended ($P < 0.10$) to increase AST activity. These increases, as well as the increases in HBD and LD-5 activities during transport, suggested that calves of the long-haul group had more muscular trauma, were exercising more, or were catabolizing more body tissue than were nontransported calves.¹⁴

The decrease in serum cortisol concentration in calves during fasting and transport was interesting, because serum cortisol concentration usually increases during stress. Crookshank et al³ reported increases in serum cortisol concentration in calves transported for 12 hours; however, Galyean et al¹ did not observe a change in serum cortisol concentration during a 32-hour transport period. Administration of adrenocorticotropin usually increases serum corticoid concentrations for only 2 to 4 hours.¹² Crookshank et al³ reported that with repeated blood sample collections, calves adjusted to the collection procedure, and serum cortisol concentration decreased. A similar adjustment may have taken place in the calves of our study, or adrenal gland hormone production may have become depleted during the stress period.¹⁵

Although calves of the short-haul group had higher morbidity and mortality than did calves of the control and long-haul groups, the only blood or serum constituents with quadratic contrast were TIBC, UIBC, and LD-5 percentage. In calves of the control and long-haul groups, TIBC increased during fasting and fasting plus transport, but TIBC decreased in calves of the short-haul group. The increase in UIBC during transport was lower in calves of the short-haul group than in those of the control and long-haul groups. Serum LD-5 percentage increased in calves of the control and long-haul groups, but decreased in calves of the short-haul group. Serum glucose concentration decreased in fasted calves, increased in calves transported for 24 hours, and remained relatively constant in calves transported for 12 hours. Similarly, Galyean et al¹ reported a decrease in serum glucose concentration during a 32-hour fasting period, but an increase during a 32-hour fasting plus transport period. Crookshank et al³ reported that a 12-hour transport period did not affect serum glucose concentration. Cole et al² observed a decrease in serum glucose concentration during a 13-hour transport period, but an increase during a 46-hour transport period. These changes in serum glucose concentration probably are related to numerous factors including adrenal gland activity, quantity and source of nutrients being absorbed from the gastrointestinal tract, rate of lipolysis and/or glycogenolysis, and rate of tissue utilization of nutrients.

Results of our study indicated that transport caused additional stress on feeder calves beyond the stress of fasting alone. This agreed with findings of other studies.¹⁻⁴ The major amount of transport stress takes place during the early portions of transport, and longer periods may not add appreciably to the overall stress imposed on the calf.^{2,4,16,17} The major stress involved with transport may be related to the handling of cattle during loading and unloading.^{15,17} Transport stress alone probably was not the main cause of the high morbidity and mortality in calves transported for 12 hours. The timing of the major stressors and/or an accumulation of stress, caused by acclimation to various stressors of varying severity, may have been the cause. The large ranch-to-ranch variability in the health status, performance, and blood constituents of these calves handled similarly after arrival at the auction market indicated that management,

nutritional, and/or genetic factors that exist before movement to the auction market have a major role in determining the subsequent health and performance of calves in the feedlot.

References

1. Galyean ML, Lee RW, Hubert ME. Influence of fasting and transit on ruminal and blood metabolites in beef steers. *J Anim Sci* 1981;53:7-18.
2. Cole NA, Phillips WA, Hutcheson DP. The effect of prefast diet and transport on nitrogen metabolism of calves. *J Anim Sci* 1986;63:1719-1731.
3. Crookshank HR, Elissalde MH, White RG, et al. Effect of transportation and handling of calves upon blood serum composition. *J Anim Sci* 1979;48:430-435.
4. Phillips WA, Cole NA, Hutcheson DP. The effect of diet on the amount and source of weight lost during transit or fasting. *Nutr Rep Int* 1985;32:765-776.
5. Schake LM, Webster WW, Conway RC. Effect of origin and shipping distance on feedlot performance of cattle. *Beef Cattle Res Tex* 1979;90-93.
6. Hutcheson DP, Cole NA, McLaren JB. Effects of pretransit diets and post-transit potassium levels for feeder calves. *J Anim Sci* 1984;58:700-707.
7. Steel EG, Witzel DA. Acquired coagulation factor X activity deficiency connected with *Hymenoxys odorata* DC (Compositae), bitterweed poisoning in sheep. *Am J Vet Res* 1976;37:1383-1386.
8. Elissalde GS, Wagner GG, Craig TM, et al. Hypocholesterolemia and hypocortisolemia in acute and terminal *Babesia bovis* infections. *Vet Parasitol* 1983;12:1-11.
9. Harvey RB, Hambricht MB, Rowe LD. Clinical biochemical and hematologic values of the American Miniature Horse: reference values. *Am J Vet Res* 1984;45:987-990.
10. SAS User's Guide: *Statistics*. Cary, NC: SAS Institute Inc, 1982.
11. Camp TH, Stevens DG, Stermer RA, et al. Transit factors affecting shrink, shipping fever, and subsequent performance of feeder calves. *J Anim Sci* 1981;52:1219-1224.
12. Wegner TN, Stott GH. Serum minerals, leukocyte profiles, and plasma corticoids in dairy heifers after an injection of corticotropin. *J Dairy Sci* 1972;55:1464-1469.
13. Dorner JL. The leukon. In: Howard JL, ed. *Current veterinary therapy—food animal practice*. 2. Philadelphia: WB Saunders Co, 1986;703-706.
14. Faulkner WR, King JW, Damm HC. *CRC Handbook of clinical laboratory data*. 2nd ed. Cleveland: Chemical Rubber Co: 1968.
15. Phillips WA, Wetteman RP, Horn FP. Influence of preshipment management on the adrenal response of beef calves to ACTH before and after transit. *J Anim Sci* 1982;54:697-703.
16. Tennessen T, Price MA, Berg RT. Comparative responses of bulls and steers to transportation. *Can J Anim Sci* 1984;64:333-338.
17. Stermer RA, Camp TH, Stevens DG. Feeder cattle stress during handling and transportation. *Trans Am Soc Agr Eng* 1982;25:246-249.