Association of serologic status for *Neospora caninum* with postweaning weight gain and carcass measurements in beef calves

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RUMINANTS

Objective—To determine the seroprevalence for *Neospora caninum* in a population of beef calves in a feedlot and the association of serologic status with postweaning weight gain and carcass measurements.

Design—Longitudinal observational study.

Animals—1,009 weaned beef steers from 92 herds.

Procedure—Samples were obtained from all steers at time of arrival at a feedlot. Serologic status for *Neospora* spp was determined, using an agglutination test. Results of serologic testing were compared with calf growth and carcass data, using multivariate regression with generalized estimating equations.

Results—Of 1,009 calves, 131 (12.98%) were seropositive, and 54 of 92 (58.7%) consignments had ≥ 1 seropositive calf. Median within-consignment prevalence for consignments in which there was ≥ 1 seropositive calf was 20%. Seropositive status was associated with significant reductions in average daily gain, live body weight at slaughter, and hot carcass weight and an increase in ribeye area-to-hot carcass weight ratio. Seropositive status also was associated with significant increases in cost of treatment and significant reductions in income. Sick seropositive calves had the highest cost of treatment. An economic loss of $15.62/calf was projected for seropositive calves.

Conclusions and Clinical Relevance—Significant reductions in postweaning weight gain, carcass weight, and economic return were associated with detection of antibodies to *N caninum* in beef calves in a feedlot. (*J Am Vet Med Assoc* 2000;217: 1356–1360)

Neospora caninum causes abortion in cattle, and congenital infection with *N caninum* is associated with calves that have CNS disorders and encephalomyelitis or calves that do not have apparent signs of infection.[1-8] This disease reportedly causes considerable economic loss to livestock producers.[9,10] Estimates of economic loss are based on the potential of neosporosis to affect herd fertility and associated culling rates, diminish milk production, and increase neonatal mortality.[8,11,12] Even though dairy cattle that are seropositive for *N caninum* reportedly have reduced production performance,[13] we are not aware of any studies in which the investigators evaluated the effects of neosporosis on weight gain, carcass measurements, and economic return of feedlot calves.

Dynamics of *Neospora* infections and immune system interactions in cattle currently are being studied. Many questions persist concerning the immune response of cattle after challenge-exposure to *Neospora* sp; however, cell- and humoral-mediated immune responses are stimulated by *N caninum*.[14-18] It is not known whether these immune responses are capable of eliminating infections in cattle. It has been inferred that *Neospora* tissue cysts may persist in CNS tissues despite stimulation of the immune system, and these tissue cysts are capable of activation and reproduction (recrudescence).[2,5,8,19-23] Recrudescence is believed to be responsible for disseminating *Neospora* tachyzoites in cattle tissues. *Neospora caninum* tachyzoites and associated inflammation have been identified in the brain and spinal cord, heart, lungs, kidneys, liver, and muscles of aborted bovine fetuses.[4] A hypothesis regarding incomplete immune system protection and recrudescence suggests that *Neospora* sp may persist for prolonged periods in specific cattle, similar to the situation for a chronic infection.

In multiple studies,[24-26] investigators have reported that other infectious agents cause chronic subclinical disease in feedlot cattle, impairing growth performance and causing economic loss. The potential for subclinical disease is of great concern to producers who retain ownership of their calves through the feedlot stage of production. The objectives of the study reported here were to determine the seroprevalence for *N caninum* in beef calves in Texas enrolled in a retained-ownership feedlot program (ie, the Texas A&M University Ranch-to-Rail Program) and the effect of serologic status for *N caninum* on weight gain after weaning, carcass measurements, and economic gain.[a]

Materials and Methods

Animals—During a 4-day period in October 1998, 1,009 beef steers that were > 6 months old and from ranches in Texas were transported to either of 2 feedlots in Texas. Calves were part of the 1998 to 1999 Texas A&M University Ranch-to-Rail Program, a feedlot performance and carcass merit program sponsored by components of Texas A&M University. Participation in the program was voluntary and available to all producers in Texas. The calves represented consignments from 92 geographically diverse ranches throughout Texas. The consignors did not have prior knowledge of the study; thus, they were not biased in the calves they selected for transport to the feedlots.

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The feedlot to which cattle were transported was determined on the basis of the consignor's preference. One feedlot was located near Corpus Christi (ie, near the Gulf of Mexico), and the other feedlot was located near Amarillo (ie, the panhandle region of Texas). Cattle included in the study were of *Bos taurus*, *B indicus*, and mixed-breed origin. Calves ranged from 6 to 12 months old. Calves consigned from a particular ranch were of similar age and breed. All calves in the study were castrated males.

Procedures at the feedlots—At the time of arrival at the feedlots, calves were administered vaccines against viral (infectious bovine rhinotracheitis virus, parainfluenza virus, bovine respiratory syncytial virus, and bovine viral diarrhea virus) and clostridial (*Clostridium chauvoei, C novyi, C septicum, C sordelli, C perfringens* types C and D, and *C hemolyticum)* pathogens, ivermectin with clorsulon for control of internal and external parasites, and a growth promotant implant. Blood samples were collected and serum harvested for use in detection of antibodies to *N caninum*. Each calf was identified by use of a double ear tag system, and body weight was determined. Calves were assigned to 1 of 11 home pens. Calves were assigned to a home pen on the basis of body weight; 4 weight ranges were used as a criterion for pen assignment. Calves were allowed ad libitum access to rations containing an ionophore. Calves were given a second growth promotant implant in accordance with a schedule determined on the basis of body weight at time of arrival.

Calf health was monitored daily by feedlot personnel. Health records were maintained for each calf. A calf was considered to need treatment when it was lethargic, inappetent, diarrheic, lame, or ataxic, or it had copious nasal discharge, excessive coughing, or ruminal tympany. In the study, all calves treated by feedlot personnel were considered sick. Sick calves were placed in a hospital pen and treated. After each sick calf was considered to have recovered, it was returned to its respective home pen.

All calves were weighed prior to slaughter. Calves were slaughtered in groups, which were determined on the basis of visual appraisal and estimation of a back-fat thickness of 1 cm.

Data collection—Data collected for analysis included body weight at time of arrival, number of days at the feedlot, average daily gain, live body weight at slaughter, hot carcass weight, ribeye area, ratio of ribeye area-to-hot carcass weight, cost of medical treatment (ie, treatment costs), USDA quality grade, USDA yield grade, fat thickness at the 12th to 13th ribs, and percentage of kidney, pelvic, and heart fat. Income per calf was determined on the basis of a grid calculation of carcass value.[b]

Serologic analysis—A blood sample was collected from each calf during processing (eg, vaccination, deworming, and other procedures) performed on the day of arrival at the feedlots. Blood was allowed to clot at room temperature (21 C [70 F]) and then was centrifuged, and aliquots of serum were decanted and stored at –70 C until analyzed.

Sera were tested for antibodies against *N caninum* by use of a direct agglutination test for detection of *Neospora* sp.[27,c] The agglutination test has a sensitivity of 95% and specificity of 95%.[c] Each sample was analyzed at increasing dilutions up to a maximum of 1:320. The minimum cutoff value for a positive result was a dilution of ≥ 1:80.

Statistical analysis—Statistical analyses were performed, using a commercially available statistical software program.[d] Overall prevalence was determined by using the number of seropositive calves as the numerator and the number of all calves tested as the denominator. Consignment prevalence was computed similarly for each consignment. Two-by-two tables and the Fisher exact test were used to determine associations between serologic status of each calf and morbidity, mortality, and the likelihood of that calf being slaughtered early because of substandard production performance.

Multivariate regression analysis, using generalized estimating equations[28] with an unstructured correlation matrix, was used to determine effects of serologic status of a calf on performance and economic variables independent of the effects of morbidity and pen. Generalized estimating equations were used to account for intraconsignment correlation, with model-specific standard errors used to compute **95% confidence intervals (95% CI)**. All possible bivariate interactions among main effects were examined. All dependent variables were continuous, except for carcass quality grade and yield grade, which were ranked prior to regression analysis. The Wilcoxon rank sum test also was performed on data for carcass quality grade and yield grade; however, that analysis did not consider intraconsignment correlation.

Results

Overall seroprevalence for *N caninum* antibodies was 12.98% (131/1,009), with a 95% CI of 10.9 to 15.1%. Median within-consignment prevalence for consignments with ≥ 1 seropositive calf was 20% (intraquartile range, 10 to 28.8%). The proportion of consignments with ≥ 1 seropositive calf was 54/92 (58.7%). The 92 consignments consisted of 1 to 116 calves (mean, 11 calves).

Antibodies against *N caninum* were not associated with morbidity, mortality, or a calf being slaughtered early because of substandard performance. Thirteen of 131 (9.9%) *N caninum*-positive calves required treatment because of sickness, whereas 129 of 878 (14.7%) seronegative calves were treated because of sickness. Mortality rate for the *N caninum*-positive calves was 3.1% (4/131), and it was 2.4% (21/878) for the seronegative calves. Two of 131 (1.5%) *N caninum*-positive calves and 9 of 878 (1.0%) seronegative calves were slaughtered early because of substandard performance.

Nine hundred seventy-three calves completed the study. Data for 36 calves were eliminated from the performance and economic analyses because of incomplete records as a result of the calves dying during the feeding period or being slaughtered early because of substandard performance. Descriptive statistics of performance variables and economic variables were determined (**Table 1** and **2**). Significant differences in performance and economic variables were found for serologic status, using multivariate regression analysis. Seropositive status had a significant adverse impact on average daily gain, live body weight at slaughter, hot carcass weight, and ribeye area-to-hot carcass weight ratio (**Table 3**).

Seropositive status had a significant adverse impact on treatment cost and income. Seropositive status was associated with a significant ($P < 0.001$) increase in treatment cost (1.38; 95% CI, 0.65 to 2.11) and a significant ($P = 0.015$) decrease in income (–14.24; 95% CI, –25.70 to –2.76).

A significant ($P < 0.001$) effect was found for main effects and a bivariate interaction (serologic status X effect of morbidity) for the cost-of-treatment model.

RUMINANTS

Table 1—Descriptive statistics of performance variables in beef calves seropositive or seronegative for *Neospora caninum* in 2 feedlots in Texas

	Seropositive calves (n = 126)			Seronegative calves (847)		
Variable	Mean	SD	Range	Mean	SD	Range
ADG (kg)	1.38	0.25	0.59–2.03	1.42	0.23	0.46–2.12
Starting weight (kg)	275	39.45	184–372	276	40.90	165–426
No. of days at feedlot	176.0	25.8	121–225	173.4	27.5	121–225
Slaughter weight (kg)	538	57.22	436–695	542	52.13	384–714
HCW (kg)	327	36.10	253–442	331	33.83	218–439
REA (cm^2)	88.29	12.43	58–132.26	87.61	10.83	58–120.64
REA:HCW	27.23	4.45	16.38–40.42	26.70	4.09	17.08–41.99

ADG = Average daily gain. HCW = Hot carcass weight. REA = Ribeye area. REA:HCW = Ribeye area-to-hot carcass weight ratio.
To convert kg to lb, multiply value by 2.2.

Table 2—Descriptive statistics of economic variables for beef calves that were seropositive or seronegative for *Neospora caninum* in 2 feedlots in Texas

	Seropositive calves (n = 126)			Seronegative calves (847)		
Variable	Mean	SD	Range	Mean	SD	Range
Treatment cost ($/calf)	2.30	8.17	0.00–48.32	2.64	7.70	0.00–80.04
Income ($/calf)	737.13	74.14	566–966.21	744.19	75.28	456–980.87

Treatment cost = Cost of treatment if a calf became sick; there were 11 seropositive and 115 seronegative calves that required treatment. Income = Revenue from sale of calf.

RUMINANTS

Table 3—Effects* of seropositive status for *N caninum* on performance variables after weaning in beef calves in 2 feedlots in Texas

Variable	Variable estimate	95% CI	*P* value
ADG (kg)	–0.05	–0.10, –0.01	0.015
Slaughter weight (kg)	–7.5	–15.05, –0.01	0.053
HCW (kg)	–6.23	–11.18, –1.28	0.021
REA:HCW	0.77	0.27, 1.34	0.012

*Determined on the basis of multivariate regression analysis that used generalized estimating equations, which controlled for intraconsignment correlation effects.
Model covariates were serologic status for *N caninum*, pen, and morbidity. 95% CI = 95% Confidence interval.
See Table 1 for remainder of key.

The economic effect for cost of treatment was $0.00 for seropositive and seronegative calves that were not sick. The economic effect for cost of treatment for seronegative calves that were sick was $16.14/calf (115 calves), and the cost for seropositive calves that were sick was $26.78/calf (11 calves). Serologic status did not significantly affect ribeye area, fat thickness at the 12th to 13th rib, percentage of kidney, pelvic, or heart fat, USDA carcass quality grade, or USDA carcass yield grade.

Multivariate regression analysis revealed that a *N caninum*-positive calf had a reduction in average daily gain of 0.05 kg/d (0.11 lb/d), compared with that for a seronegative calf, and a sick calf had a reduction in average daily gain of 0.04 kg/d (0.09 lb/d), compared with that for a calf that was not sick.

Discussion

Multivariate regression with generalized estimating equations was used to account for intraconsignment correlation. Intraconsignment correlation was evident for several reasons. The first reason was that each consignment was composed of calves of similar age and breed. The second reason was clustering at the consignment level (an overall prevalence of 12.98% and a median within-consignment prevalence of 20% for consignments that had ≥ 1 seropositive calf, with 58.7% of consignments having ≥ 1 seropositive calf). Pen was treated as a fixed effect, because assignment of a calf to a feedlot pen was based on a preselected criterion (ie, body weight), and calf placement was relegated only to pens designated as those included in the Ranch-to-Rail Program. Controlling for fixed effects of morbidity and pen and accounting for intraconsignment correlation attributable to breed and age provided conservative estimates of the effects of serologic status on dependent variables while controlling for confounding at the pen level and provided a population average effect for *N caninum* serologic status.

Antibodies to *N caninum* were associated with diminished weight gain after weaning and carcass measurements of beef calves in a modern feedlot system. Seropositive status was associated with reductions in average daily gain (0.05 kg/d) and live body weight at slaughter (7.5 kg [16.5 lb]). There was not an apparent association between serologic status and morbidity; however, seropositive calves that were sick had the highest treatment cost of any of the groups. The increased treatment cost for seropositive calves that were sick indicates the need for additional investigations, because this group consisted of only 11 calves. This information suggests that *N caninum*-seropositive calves in the study gained body weight at a slower rate and had a greater cost of treatment for sick calves.

Income generated by the calves reported here was determined by use of a grid calculation that placed weighted values on hot carcass weight, quality grade, and yield grade. Statistical analysis did not reveal significant differences in quality or yield grades for a calf on the basis of serologic status; however, the hot carcass weight of *N caninum*-seropositive calves was 6.23

kg (13.71 lb) lighter. Significant differences were not found between the ribeye area of seropositive and seronegative calves, but a significant difference was found in the ribeye area-to-hot carcass weight ratio, with the ratio of the seropositive calves being larger. With a lighter hot carcass weight but a similar ribeye area, the difference in ribeye area-to-hot carcass weight ratio suggests that seropositive calves had less muscle mass peripheral to the longissimus dorsi muscle. The importance of this finding requires investigation. The reduction in hot carcass weight resulted in a decrease in income of $14.24/carcass of seropositive calves. The loss in income and the increase in cost of treatment for seropositive calves produced a substantial economic loss of $15.62/calf for *N caninum*-seropositive calves.

The amount of research conducted concerning the association between serologic status for *N caninum* and calf performance is limited. In 1 study[21] of dairy calves that were seropositive prior to ingestion of colostrum, investigators did not find an association for increased risk of morbidity or mortality, compared with seronegative cohorts. The authors are not aware of any reports on investigations of the association of serologic status for *N caninum* and performance losses of beef calves after weaning in a cattle feedlot system. In the study reported here, an association was found between serologic status for *N caninum* and diminished weight gain, carcass weight, and economic returns to the consignors. The association between positive serologic status and growth performance after weaning further strengthens the hypothesis concerning recrudescence. It is possible that *N caninum* tachyzoites are intermittently released during stressful conditions (eg, weaning, transport to feedlot), with dissemination of tachyzoites to tissues of major body systems producing foci of inflammation[4] and causing subclinical impairment of body function. We believe that this is a possible mechanism for the reduction in weight gain after weaning and carcass weights.

Retained ownership of beef calves through the feedlot segment of the beef industry enables cow-calf producers to evaluate production and economic potential of ranch-based genetic and management resources. The Texas A&M University Ranch-to-Rail Program is an information feedback system that allows ranchers in Texas an opportunity to make these evaluations. The program has provided ranchers information concerning all phases of beef production, and important information regarding the impact of calf health on production and economic performance has been documented in previous populations included in the program.[25]

We do recognize the need for additional study into assessment of risk and determination of the impact of chronic disease and their mechanisms of action on health and performance of calves. We believe investigative efforts should be directed at explaining mechanisms of the host-parasite interaction that were responsible for the reported effects on performance of calves. Additional studies should investigate specific hypotheses to add to our ability to determine a causal inference between *Neospora* infection and the formation of muscle mass. Documenting the distribution of intramuscular tachyzoites and their effect on meat quality is 1 specific area that we recommend should be investigated. The association of increased cost of treatment for seropositive calves that are sick should be confirmed under similar conditions of stress (eg, weaning, transit, commingling)[29-32] and should include results for *N caninum*-infected calves when challenge-exposed to other pathogens of cattle.

[a]Barling KS. The study of *Neospora caninum* in a Texas beef cattle population. PhD dissertation, Department of Veterinary Pathobiology, College of Veterinary Medicine, Texas A&M University, College Station, Tex, 2000.

[b]Texas A&M University Ranch-to-Rail summary report, 1998–1999. College Station, Tex: Texas Agricultural Extension Service, Texas A&M University, 1999.

[c]Neospora agglutination test, Vétoquinol Canada Inc, Lavaltrie, QC, Canada.

[d]SAS, version 6.12, SAS Institute Inc, Cary, NC.

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