

Comparison of calf weaning weight and associated economic variables between beef cows with and without serum antibodies against or isolation from feces of *Mycobacterium avium* subsp *paratuberculosis*

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Objective—To compare calf weaning weight and associated economic variables for beef cows with serum antibodies against *Mycobacterium avium* subsp *paratuberculosis* (MAP) or from which MAP was isolated from feces with those for cows that were seronegative for antibodies against or culture negative for MAP.

Design—Retrospective study.

Animals—4,842 beef cows from 3 herds enrolled in the USDA National Johne's Disease Demonstration Herd Project.

Procedures—Individual cow ELISA and culture results were obtained from the project database. During each parity evaluated for each cow, the 205-day adjusted weaning weight (AWW) of its calf was calculated. The AWW was compared between test-positive and test-negative cows by use of multilevel mixed-effect models. The median value for feeder calves from 2007 to 2011 was used to estimate the economic losses associated with MAP test-positive cows.

Results—The AWW of calves from cows with strongly positive ELISA results was 21.48 kg (47.26 lb) less than that of calves from cows with negative ELISA results. The AWW of calves from cows classified as heavy or moderate MAP shedders was 58.51 kg (128.72 lb) and 40.81 kg (89.78 lb) less, respectively, than that of calves from MAP culture-negative cows. Associated economic losses were estimated as \$57.49/calf for cows with strongly positive ELISA results and \$156.60/calf and \$109.23/calf for cows classified as heavy and moderate MAP shedders, respectively.

Conclusions and Clinical Relevance—Calves from cows with MAP-positive test results had significantly lower AWWs than did calves from cows with MAP-negative test results, which translated into economic losses for MAP-infected beef herds. (*J Am Vet Med Assoc* 2013;243:1609–1615)

Johne's disease in cattle is caused by infection with MAP, and the disease has a long subclinical phase that eventually progresses to diarrhea, debilitation, cachexia, and death.^{1–3} Results of a study⁴ conducted on a Florida beef herd indicated that cows that tested positive for serum antibodies against MAP as determined by an ELISA took longer to conceive, had calves with lower birth and weaning weights, and had a reduced ability to maintain weight than did cows that tested negative

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ABBREVIATIONS

AWW	205-day adjusted weaning weight
BCF	Bacterial culture of feces
CFU	Colony-forming unit
CI	Confidence interval
dtp	Days to positive
JD	Johne's disease
MAP	<i>Mycobacterium avium</i> subsp <i>paratuberculosis</i>
NJDDHP	National Johne's Disease Demonstration Herd Project
S/P	Sample-to-positive control

for antibodies against MAP. Additionally, the death or sale of underweight cows infected with MAP represents lost capital for beef producers and may have a negative impact on an individual producer's reputation and ability to market breeding stock.⁵ Consequently, JD causes substantial direct and indirect economic losses for beef producers.

Multiple studies^{6–10} have been conducted to estimate the prevalence of JD on US beef herds; however, the JD prevalence varies considerably depending on the method used to identify MAP-infected cattle. A survey⁶ of cow-calf herds in 23 states indicated that 8% of herds

contained cattle infected with MAP and the within-herd JD prevalence was 0.4% as determined by means of a serum ELISA. However, investigators of other studies⁷⁻¹⁰ have reported within-herd JD prevalences of up to 9% for individual beef herds. Recommendations for the control and prevention of JD are available; however, the efficacy of those recommendations is largely unknown. In 2003, the USDA initiated the NJDDHP to evaluate the feasibility and efficacy of the implementation of JD control measures over time in beef and dairy herds with MAP-infected cattle. The NJDDHP ended in 2010. In some instances, individual states had instituted JD control demonstration projects prior to 2003, and relevant data from those states were incorporated into the NJDDHP database, with the earliest data obtained during 1999. Progress toward control of JD for herds enrolled in the NJDDHP was monitored by annual assessment of herd management practices and testing individual cattle for MAP.¹¹

Because the success of any coordinated disease control or eradication program is dependent on producers conceding that such a program is necessary, information regarding the economic consequences of JD is important. Results of a survey¹² of beef cow-calf producers in 24 states during 2007 and 2008 indicated that only 37% of producers believed that JD was an important problem for the US beef industry. In a 2009 survey¹³ of beef producers that had herds classified at level 4 (ie, 99% probability of not containing MAP-infected cattle) in the US Voluntary Bovine Johne's Disease Control Program, only 25% (9/36) of producers perceived a substantial benefit from participation in the program, despite ongoing educational and scientific efforts to aid in their understanding of the impact of JD on the US beef industry.

The lack of estimates of direct economic impacts of JD on beef operations may be 1 reason why many beef producers fail to perceive benefits from participation in a JD control program. The objective of the study reported here was to compare calf weaning weight for cows that had antibodies against MAP or from which MAP was cultured from feces with that for cows that were seronegative for antibodies against MAP or from which MAP was not cultured from feces. Our hypothesis was that cows that had antibodies against MAP or from which MAP was cultured from feces would have calves with lower weaning weights than cows that were seronegative for antibodies against MAP or for which MAP was not cultured from feces. Provided that hypothesis was not rejected, an additional objective was to estimate the economic losses associated with decreased calf weaning weights for cows that tested positive for MAP infection (antibodies against MAP or MAP cultured from feces).

Materials and Methods

Animals—Data for the 22 beef herds enrolled in the NJDDHP between 1999 and 2009 were reviewed. To be included in the NJDDHP, herds had to annually test at least 80% or an acceptable statistical subset (for extremely large herds as defined in the *Uniform Program Standards for the Voluntary Bovine Johne's Disease Control Program*¹⁴⁻¹⁶) of eligible cattle (cows \geq 36 months old and

bulls \geq 24 months old) for MAP infection by means of serum ELISA or BCF, and the tests had to be performed by accredited laboratories that had achieved satisfactory scores on the National Veterinary Services Laboratories Johne's Disease Proficiency Test for the given test method performed. To be included in the study reported here, individual animal test results and data on calf age and weight at weaning had to be available for cows that raised a calf to weaning during each respective year. On the basis of these criteria, only 3 herds (2 located in Florida and 1 located in North Dakota) were eligible for inclusion in the study.

Data collection—Data extracted from the NJDDHP database for analyses included the following: herd identification, herd size, calendar year, year since inception of JD control program, cow identification, breed, age of cow, parity, source of cow (purchased or home raised), ELISA used (ELISA1^a for Florida herds or ELISA2^b for the North Dakota herd), diagnostic laboratory that performed the ELISA, ELISA results (S/P ratio), BCF method used (BCF1^c for the Florida herds or BCF2^d for the North Dakota herd), diagnostic laboratory that performed the BCF, BCF results (estimated CFUs/tube or dtp), and calf age and weight at weaning. The ELISA results were classified dichotomously (positive [ELISA1, S/P ratio $>$ 0.24; ELISA2, S/P ratio, $>$ 0.99] or negative) and categorically (negative [ELISA1, S/P ratio $<$ 0.10; ELISA2, S/P ratio $<$ 0.50], suspect [ELISA1, S/P ratio \geq 0.10 to 0.24; ELISA2, S/P ratio \geq 0.50 to 0.99], positive [ELISA1, S/P ratio $>$ 0.24 to 0.99; ELISA2, S/P ratio $>$ 0.99 to 3.49], or strongly positive [ELISA1, S/P ratio $>$ 0.99; ELISA2, S/P ratio $>$ 3.49]). Similarly, the BCF results were classified dichotomously and categorically (negative, very low shedder [BCF1, not defined; BCF2, $>$ 35 dtp], low shedder [BCF1, 1 to 5 CFUs/tube; BCF2, 29 to 35 dtp], moderate shedder [BCF1, 6 to 50 CFUs/tube; BCF2, 22 to 28 dtp], or heavy shedder [BCF1, $>$ 50 CFUs/tube; BCF2, $<$ 22 dtp]). The AWW was calculated by use of the following equation: (observed calf weaning weight/calf age at weaning) \times 205.

Statistical analysis—The association of calf AWW with the dam's MAP test status for the corresponding parity was assessed with multilevel linear mixed-effects models. Four models were created, including 1 for each permutation of dam's MAP test status as the primary fixed effect of interest (ie, 1 for ELISA test results classified dichotomously, 1 for ELISA test results classified categorically, 1 for BCF results classified dichotomously, and 1 for BCF results classified categorically). For all models, random effects were included to account for cows with repeated measures (ie, cows for which multiple parities were evaluated) and cows nested within herds. For each permutation of dam's MAP test status, multivariable models were created to identify potential confounding variables and other independent variables. Variables assessed as potential confounders included age of cow, parity, source of cow, years since the inception of a JD control program, herd size, breed, and laboratory that performed the test. Confounders were defined as variables that, when evaluated in conjunction with dam's MAP test status, resulted in at least a 20% change in the regression coefficient for MAP test

status. Confounders were not identified and independent variables were retained in the final multivariable models on the basis of the highest reduction in the Bayesian information criterion, compared with that for the univariable model.¹⁷ Age of cow and parity were correlated, but retention of both variables in the model improved (ie, decreased the Bayesian information criterion) the model fit. All regression analyses were performed with statistical software,^c and values of $P < 0.05$ were considered significant.

The cost of the difference in calf AWW between test-positive (positive results for ELISA or BCF) and test-negative (negative results for ELISA or BCF) cows was estimated by multiplying the weight difference by the mean value (\$2.68/kg [\$1.22/lb]) for US feeder calves for the 5-year period of 2007 to 2011 that was obtained from the National Agricultural Statistics Service.¹⁸ These data were used for the calculation of a simple benefit-cost ratio to evaluate the effect of within-herd JD prevalence on the economic benefit of screening cows within a herd for MAP by ELISA or BCF. The benefit-cost ratio was defined as the total benefits divided by the total costs and was calculated for all possible values of within-herd true prevalence (ie, 0% to 100%). Benefits were estimated as the summation of the amount lost per test-positive cow because of decreased calf AWW, and the amounts used to calculate the benefits for ELISA (\$14.81/test-positive cow) and BCF (\$89.01/test-positive cow) testing were those determined when the results were dichotomously classified. The estimated costs were those for testing all cows in the herd and were \$9.60/cow and \$18.00/cow for ELISA and BCF, respectively.¹⁹ A cost for labor was not included in the analysis because it was assumed that sample collection could be performed during annual examination of cows for pregnancy. Estimates for the sensitivity and specificity of the ELISA and BCF were

obtained from consensus guidelines²⁰ and were 0.30 and 0.99, respectively, for ELISA and 0.60 and 1.00, respectively, for BCF. Apparent prevalence was calculated from true prevalence as follows: (true prevalence \times [test sensitivity + test specificity - 1.00]) \div test specificity + 1.00.¹⁷ For example, a 100-cow herd that has 20 cows infected with MAP (true prevalence, 20%) would have an apparent prevalence as determined by ELISA of approximately 7%. Thus, there would be 7 ELISA test-positive cows in the herd. The benefits for this herd would be \$103.67 (ie, $7 \times \$14.81$), the cost for testing would be \$960 (ie, $100 \times \$9.60$), and the benefit-cost ratio for screening the herd by ELISA would be 0.11 (ie, $\$103.67/\960). A benefit-cost ratio equal to 1 is considered the breakeven point (estimated benefits equal the estimated costs). An investment with a benefit-cost ratio > 1 is considered economically beneficial, whereas an investment with a benefit-cost ratio < 1 is considered economically unbeneficial.

Additionally, the percentage of US beef herds by the within-herd true prevalence of cows infected with MAP was plotted. It was assumed that 20% of US beef herds contain at least 1 cow infected with MAP, and the distribution of those herds by true prevalence was estimated from the distribution of within-herd apparent prevalences reported in other studies.^{7,9}

Results

Herds—Data for the Florida herds were obtained during 2002 through 2009, and data for the North Dakota herd were obtained during 2005 through 2009. Data were available for 4,842 cows. One thousand three hundred thirty-seven cows with 1,620 test results were evaluated from 1 Florida herd, and of the 1,404 test results for which breed information was available, 1,000 (71%) were Angus, 13 (1%) were Angus crossbred, 389

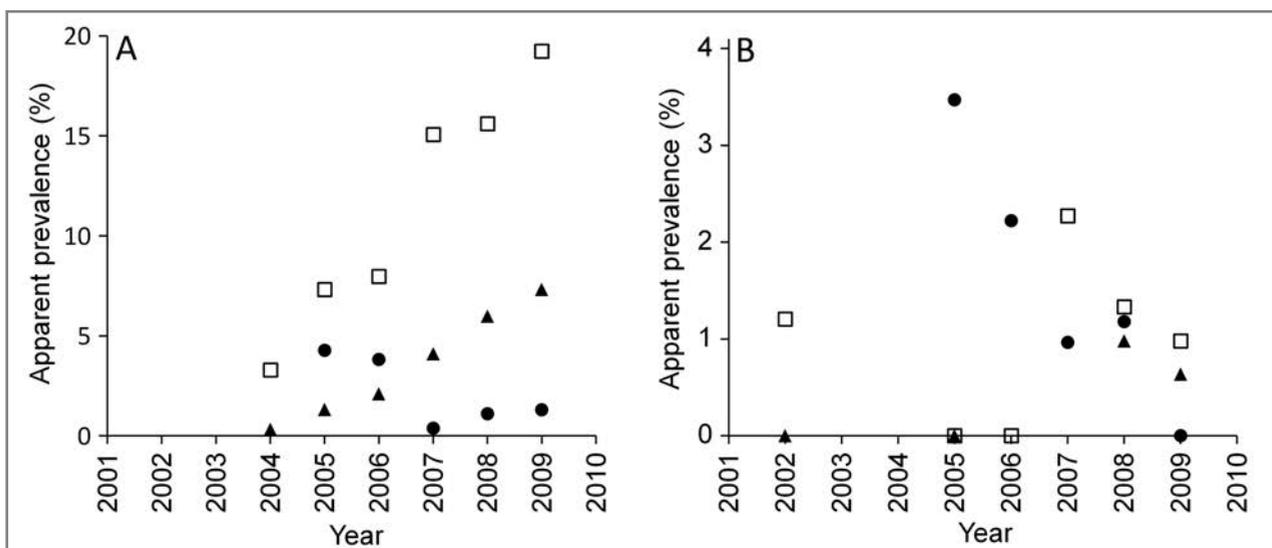


Figure 1—Annual apparent prevalence of MAP test-positive cattle as determined by serum ELISA (A) or BCF (B) for 3 beef cow-calf operations located in Florida (herd 1, black triangles; herd 2, white squares) and North Dakota (herd 3, black circles) that were enrolled in the USDA NJDDHP. Cattle in the Florida herds were tested for MAP by use of a different serum ELISA (ELISA1^a) and BCF method (BCF1^b) than were cattle in the North Dakota herd (ELISA2^a and BCF2^b). For ELISA1, a positive test was defined as an S/P ratio > 0.24 , and for ELISA2, a positive test was defined as an S/P ratio > 0.99 .

(28%) were Brahman, and 2 (0.1%) were Limousine. One thousand three hundred eighty-two cows with 1,722 test results were evaluated from the other Florida herd, and of the 1,066 test results for which breed information was available, 585 (55%) were Angus crossbred, 229 (21%) were Angus, and 252 (24%) were Brahman or Brahman crossbred. Two thousand one hundred twenty-three cows with 2,243 test results were evaluated from the North Dakota herd; breed information was available for all test results and included 1,377 (61%) Angus, 711 (32%) Angus crossbred, and 155 (7%) crossbred.

Results of serum ELISA and BCF—Results from 3,482 ELISA tests and 2,103 BCF were evaluated.

When ELISA results were classified dichotomously, 3,290 (94.5%) were negative and 192 (5.5%) were positive. When ELISA results were classified categorically, 2,969 (85.3%) were negative, 321 (9.2%) were suspect, 153 (4.4%) were positive, and 39 (1.1%) were strongly positive. When BCF results were classified dichotomously, 2,086 (99.2%) were negative and 17 (0.8%) were positive, of which 5 were categorized as heavy shedders, 3 were categorized as moderate shedders, 4 were categorized as low shedders, 4 were categorized as very low shedders, and the extent of shedding was not defined for 1. During the observation period, the apparent prevalence of MAP-infected cows within each herd as determined by serum ELISA ranged from 0% to

Table 1—Mean (95% CI) decrease in AWW and associated estimated economic loss for calves born to beef cows that were seropositive for antibodies against MAP when serum ELISA results were dichotomized and categorized, compared with those for calves born to cows that were seronegative for antibodies against MAP.

Classification of ELISA results	No.*	Category	Decreased AWW (kg)	P value†	Estimated economic loss (\$)‡
Dichotomous	192	Positive	5.53 (1.05 to 10.02)	0.016	14.81
Categorical	321	Suspect	2.78 (−0.90 to 7.84)	0.139	7.43
	153	Positive	2.85 (−2.13 to 7.99)	0.261	7.64
	39	Strongly positive	21.48 (11.66 to 31.30)	< 0.001	57.49

Data were obtained from the NJDDHP database for 3 beef herds (2 located in Florida and 1 located in North Dakota). Serum samples from cows (n = 3,482) were tested for serum antibodies against MAP annually between 2002 and 2009 (Florida herds) by use of a commercially available ELISA^a (ELISA1) or between 2005 and 2009 (North Dakota herd) by use of another commercially available ELISA^b (ELISA2). Results for each ELISA test were paired with the AWW for the calf that cow raised the year that the test was performed. The outcome of interest was AWW. Multilevel linear mixed-effects models were used to assess the effect of dam's test status on AWW. Results of ELISA tests were modeled in 2 ways, dichotomously (positive [ELISA1, S/P ratio > 0.24; ELISA2, S/P ratio, > 0.99] or negative) and categorically (negative [ELISA1, S/P ratio < 0.10; ELISA2, S/P ratio < 0.50], suspect [ELISA1, S/P ratio ≥ 0.10 to 0.24; ELISA2, S/P ratio ≥ 0.50 to 0.99], positive [ELISA1, S/P ratio > 0.24 to 0.99; ELISA2, S/P ratio > 0.99 to 3.49], or strongly positive [ELISA1, S/P ratio > 0.99; ELISA2, S/P ratio > 3.49]). Both models included random effects to account for cows clustered within herds and repeated measures within cows (ie, cows that were evaluated for > 1 parity) and were adjusted for age of cow, parity, and number of years since the inception of the JD control program.

*When results were classified dichotomously, the number of negative results was 3,290. When results were classified categorically, the number of negative results was 2,969. †P value for the comparison between cows with the given ELISA test result and cows with a negative ELISA test result. ‡Calculated as the mean decrease in AWW × the mean value for US feeder calves between 2007 and 2011 (\$2.68/kg) as determined by the National Agricultural Statistics Service.

Table 2—Mean (95% CI) decrease in AWW and associated estimated economic loss for calves born to beef cows from which MAP was isolated by means of BCF when BCF results were dichotomized and categorized, compared with those for calves born to cows from which MAP was not isolated by means of BCF (n = 2,086).

Classification of BCF results	No.*	Category	Decreased AWW (kg)	P value†	Estimated economic loss (\$)‡
Dichotomous	17	Positive	33.26 (18.79 to 47.73)	< 0.001	89.01
Categorical	4	Very low	12.75 (−16.63 to 42.13)	0.395	34.12
	4	Low	17.81 (−14.76 to 50.37)	0.284	47.66
	3	Moderate	40.81 (7.64 to 73.99)	0.016	109.23
	5	Heavy	58.51 (32.50 to 84.53)	< 0.001	156.60

Fecal samples from cows (n = 2,103) were cultured for MAP annually between 2002 and 2009 (Florida herds) by use of a solid culture system^c (BCF1) or between 2005 and 2009 (North Dakota herd) by use of a liquid culture system^d (BCF2). The result for each BCF was paired with the AWW for the calf that cow raised the year that the test was performed. Results of BCF were modeled in 2 ways, dichotomously (positive or negative) and categorically (negative, very low shedder [BCF1, not defined; BCF2, > 35 dtp], low shedder [BCF1, 1 to 5 CFUs/tube; BCF2, 29 to 35 dtp], moderate shedder [BCF1, 6 to 50 CFUs/tube; BCF2, 22 to 28 dtp], or heavy shedder [BCF1, > 50 CFUs/tube; BCF2, < 22 dtp]).

*For categorical classification of BCF results, the shedding level was not defined for 1 cow from which MAP was isolated by means of BCF. †P value for the comparison between cows with the given BCF result and cows with a negative BCF result.

‡See Table 1 for remainder of key.

19% (mean, 4%; median, 0%) and that as determined by BCF ranged from 0% to 3.5% (mean, 0.6%; median, 0%; Figure 1).

Effect of dam's ELISA or BCF test result on calf AWW—The final multilevel linear mixed models for the association of calf AWW with each diagnostic modality for MAP (ELISA or BCF) and method for classifying results (dichotomous or categorical) included the same fixed effects, dam's test result, age, and parity and number of years since inception of the JD control program on the herd. The mean decrease in calf AWW and the associated economic loss for cows seropositive for antibodies against MAP (Table 1) or cows from which MAP was isolated from BCF (Table 2) were summarized.

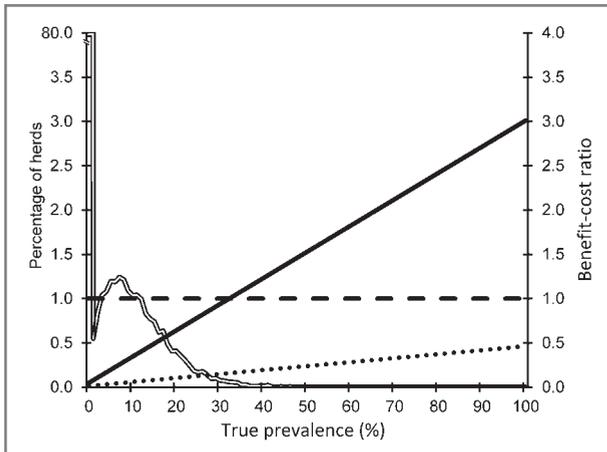


Figure 2—Plot of the estimated frequency distribution of US beef cow-calf herds by true prevalence of MAP-infected cattle within the herd (solid open line) with the results of the benefit-cost ratios for screening individual beef cows for MAP by serum ELISA (dotted line) or BCF (solid black line) calculated in the present study overlaid on that plot. It was assumed that 20% of US beef cow-calf herds contain at least 1 cow infected with MAP, and the distribution of those herds by true prevalence was estimated from the distribution of within-herd apparent prevalences reported in other studies.^{8,10} The mean decrease in calf AWW for cows that tested positive for MAP by means of serum ELISA or BCF, compared with the calf AWW for cows that tested negative for MAP by means of serum ELISA or BCF, was determined by multilevel linear mixed-effect models, which included random effects to account for cows clustered within herds and repeated measures within cows (ie, cows that were evaluated for > 1 parity) and fixed effects for cow MAP test status, age, and parity and number of years since inception of the JD control program in the herd. The benefit-cost ratio was defined as the total benefits divided by the total costs and was calculated for all possible values of true prevalence (ie, 0% to 100%). Benefits were estimated as the summation of the amount lost per test-positive cow because of decreased calf AWW, and the amounts used to calculate the benefits for ELISA (\$14.81/test-positive cow) and BCF (\$89.01/test-positive cow) testing were those determined when the results were dichotomously classified. The estimated costs were those for testing all cows in the herd and were \$9.60/cow and \$18.00/cow for ELISA and BCF, respectively. A cost for labor was not included in the analysis because it was assumed that sample collection could be performed during annual examination of cows for pregnancy. Estimates for sensitivity and specificity were 0.30 and 0.99, respectively, for ELISA and 0.60 and 1.00, respectively, for BCF. Apparent prevalence was calculated from true prevalence as follows: (true prevalence × [test sensitivity + test specificity – 1.00]) – test specificity + 1.00. A benefit-cost ratio equal to 1 is considered the breakeven point (estimated benefits = estimated costs; dashed line). An investment with a benefit-cost ratio > 1 is considered economically beneficial, whereas an investment with a benefit-cost ratio < 1 is considered economically unbeneficial. See Figure 1 for remainder of key.

Benefit-cost ratio for screening cows for MAP—The estimated frequency distribution of US beef herds by within-herd true prevalence of MAP-infected cattle was plotted with the results of the calculated benefit-cost ratio for screening cows for MAP by serum ELISA or BCF overlaid on that plot (Figure 2). Results of the benefit-cost ratio suggested that the breakeven point for screening cattle within a herd for MAP by use of BCF was a true prevalence of 31%, which would correspond to an apparent prevalence as determined by BCF of 19%. Thus, for herds with a true prevalence of MAP-infected cattle < 31%, there was no economic benefit of screening individual cattle for MAP by means of BCF. The breakeven point for screening cattle within a herd for MAP by use of a serum ELISA was not achieved at any true prevalence.

Discussion

Results of the present study indicated that calves born to cows that have serum antibodies against MAP or from which MAP was isolated from BCF have significantly lower AWW than do calves born to cows that are seronegative for antibodies against MAP or from which MAP was not isolated from BCF. For most commercial beef cow-calf operations, the primary source of income is from the sale of weaned calves, which are sold on the basis of weight; therefore, calves with decreased AWW can cause substantial economic losses for producers. Decreased AWW of calves can be caused by dam production inefficiencies such as poor milk production,^{3,21–25} which consequently results in a low nutritional plane for calves and poor weight gain.⁵ Young calves are at the greatest risk of becoming infected with MAP, especially beef calves of MAP-infected dams, because of the intimate contact between dam and calf prior to weaning. However, because of the prolonged incubation period for JD, it is unlikely that calves that become infected with MAP will have decreased AWWs resulting directly from the pathogenesis of MAP.^{1,2} Regardless of whether they are infected with MAP, the calves of MAP test-positive cows of this study would have to have substantial compensatory weight gain after weaning to achieve similar performance as that of calves of MAP test-negative cows. Moreover, severe or chronic retardation of growth in young calves is associated with decreased weight gain throughout the rest of the feeding period²⁶ such that the time and resources required for those calves to reach finished weight are extended.

In the present study, calf AWW decreased to a greater extent as its dam's antibody titer against MAP or amount of MAP isolated from BCF increased in a nonlinear manner. Results of another study⁴ indicate that the AWW of calves from cows classified as suspect, positive, or strongly positive by means of a serum ELISA decreased linearly by 2.3 kg (5.1 lb; 95% CI, 0.5 to 4.1 kg [1.1 to 9.0 lb]), 4.6 kg (10.1 lb; 95% CI, 2.8 to 6.4 kg [6.2 to 14.1 lb]), and 6.9 kg (15.2 lb; 95% CI, 1.6 to 12.2 kg [3.5 to 26.8 lb]), respectively, compared with that of calves from cows that were classified as negative. The linear nature of the association between calf AWW and ELISA score in that study⁴ was most likely the result of the ELISA score being modeled as a linear covariate,

whereas in the present study, ELISA scores were modeled as discrete categories and the association between calf AWW and ELISA score did not approximate a linear relationship.

Compared with calf AWW for MAP test-negative cows, the decrease in calf AWW was similar for cows that were categorized as strongly positive on the basis of results for serum ELISA and cows from which MAP was isolated from BCF and was most likely a reflection of the high probability that cows with those results were at advanced stages of JD (low probability that test results were incorrect [ie, false-positive]). Dichotomous classification of MAP test results, especially ELISA results, appeared to dilute the impact of test status on calf AWW, compared with when MAP test results were categorically classified, presumably because a substantial proportion of MAP-infected cows were in the subclinical stages of JD and had false-negative test results. Nonetheless, any cow with a positive result for MAP on BCF, irrespective of shedding level, is at risk of transmitting MAP to other cattle in the herd.

The benefit-cost ratio calculated for MAP ELISA screening of individual cattle failed to reach the break-even point in the present study, most likely because of the relatively small (5.53 kg [12.17 lb]) difference in AWW between calves from test-positive and test-negative dams. It is important to note that the benefits calculated in that ratio only accounted for recovering the decreased calf AWW by theoretically replacing test-positive cows with test-negative cows. Other benefits of screening cattle for MAP by means of ELISA were not assessed. Compared with cows not infected with MAP, MAP-infected cows have decreased reproductive efficiency and calves with lower birth weights, are at increased risk of morbidity and death, and are frequently culled prematurely and have a lower cull value because of weight loss.⁴ Additionally, the sale of MAP-infected cattle for production purposes can have a negative impact on the reputation of seedstock producers⁵ and lead to market discrimination and legal liabilities.²⁷ Therefore, the results of the benefit-cost ratios calculated in this study should be interpreted with caution until more comprehensive estimates are available.

One limitation of the present study was that calf AWW could not be adjusted for calf birth weight because birth weight data were unavailable. For beef calves, estimation of adjusted weaning weight generally accounts for birth weight. However, MAP-infected cows might have calves with lower birth weights than do cows that are not infected with MAP⁺; therefore, in this study, adjustment for calf birth weight (had the data been available) might have negated, at least partially, the association between calf AWW and dam's MAP test status. Thus, the results of this study represent the overall loss in calf AWW associated with the dam's MAP test status instead of the association between dam's MAP test status and calf average daily gain before weaning.

Another limitation of the present study was the potential for selection bias by the use of data from the NJDDHP because the 3 herds evaluated may not be representative of US beef cow-calf operations. Herds enrolled in the NJDDHP had to have a history of confir-

mation of MAP infection in at least 1 animal by means of MAP isolated from BCF. It is possible that producers who chose to provide weaning weights for individual calves to the NJDDHP database were more concerned about JD than were producers who chose not to provide that information. We believe the fact that calves from MAP test-positive cows had a decreased AWW, compared with that of calves from MAP test-negative cows in the present study, is externally valid for all beef cow-calf operations; however, the magnitude of that decreased AWW may vary among herds dependent on cow and herd factors that were not evaluated in this study. The within-herd apparent prevalence of MAP test-positive cattle for each of the 3 herds evaluated in this study was similar to that for US beef herds reported by investigators of other studies.^{7,9,10} Apparent prevalence is dependent on the accuracy of the results of the diagnostic tests performed, and although 2 different MAP ELISAs and BCF methods were used, all diagnostic tests were performed by laboratories accredited to meet predetermined standards to ensure reproducible results.¹⁶

For beef herds, hindrances to effective JD control programs are the potential for introducing new cattle into the herd that are subclinically infected with MAP and having the herd share an environment with a wildlife reservoir for MAP,^{3,28,29} which makes it virtually impossible to eradicate JD. Other hindrances to JD control at the herd level include the lack of proven MAP-preventive management practices and a gold-standard diagnostic test,³⁰ low sensitivity of currently available diagnostic tests for MAP,^{31,32} and the potential for impaired diagnostic test specificity owing to crossreactivity with other *Mycobacterium* spp that are ubiquitous in the environment.^{33,34} Moreover, as can be seen in the plot of the benefit-cost ratios calculated for this study, diminishing economic returns are realized as within-herd prevalence of MAP-infected cattle decreases. From a regional or national perspective, it is likely that this principle of diminishing economic returns would also apply as the number of MAP-infected herds decreases. Given that a national survey⁶ estimated that only 8% of US beef cow-calf herds contained MAP-infected cattle and the mean within-herd apparent prevalence as determined by serum ELISA for those herds was 0.4% (equivalent to a true prevalence of 2%), it is difficult to economically justify screening individual cattle for MAP and removing test-positive animals from production. However, JD control programs may be justified on the basis of impact of MAP infection on sympatric wildlife or public health should MAP be determined to be a zoonotic agent.

Results of the present study indicated that, compared with calf AWW for MAP test-negative cows, calf AWW decreased to a greater extent for MAP test-positive cows as serum antibody titer against MAP or amount of MAP shed in the feces as determined by BCF increased. Thus, the identification and removal of MAP-infected cows in the more advanced stages of JD will help minimize economic losses for beef cow-calf producers. In the absence of state or federally mandated regulations for JD control on cattle operations or market incentives for herds with a low risk or prevalence

of MAP-infected cattle, dissemination of information about potential economic losses caused by JD, including those reported here, is necessary for practitioners and producers to appreciate the impact of JD on the US cattle industry and may motivate interest in developing and sustaining MAP testing and control programs.

- a. HerdChek M pt Antibody Test Kit, IDEXX Laboratories Inc, Westbrook, Me.
- b. Paracheck CSL, Biocor Animal Health, Omaha, Neb.
- c. Herrold's Egg Yolk media, BD, Franklin Lakes, NJ.
- d. ESP Culture System II, Trek Diagnostic Systems, Cleveland, Ohio.
- e. lme4 package, R, version 2.11.1, R Foundation for Statistical Computing, Vienna, Austria. Available at: cran.r-project.org/web/packages/lme4/index.html. Accessed Jan 23, 2013.

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