Loss of income from cows shedding *Mycobacterium avium* subspecies *paratuberculosis* prior to calving compared with cows not shedding the organism on two Minnesota dairy farms

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ABSTRACT

Quantification of the financial effect of *Mycobacterium paratuberculosis* infection on lactation performance is essential to encourage participation of dairy cattle producers in Johne's disease (JD) control programs. The objective of this study was to evaluate the differences in net income per lactation of cows shedding *Mycobacterium paratuberculosis* before calving compared with test-negative cows. Two Minnesota dairies were enrolled in the study and fecal samples were collected from 1,048 cows during the close-up period. Milk production, clinical diseases (other than clinical JD), and reproductive performance data were recorded for each cow. Overall, fecal-culture-positive (FCP) cows produced 1,355 kg less than fecal-culture-negative (FCN) cows. Fecal-culture-positive cows that survived their current lactation produced \$276 less in milk income than cows that were FCN (\$1,956 vs. \$1,680; SD \$526, \$570). Fecal-culture-positive cows were 3.0 (95% confidence interval: 1.6–5.8) times more likely to be culled than FCN cows. The mean days open (number of days from calving to conception) was not statistically significant and the cost differences for clinical disease other than JD were small and neither statistically nor economically significant between FCP and FCN cows. Among all FCP cows, income over feed costs losses were \$366 per cow per lactation compared with FCN cows. Among FCP nonculled cows, income over feed costs losses were \$276 more compared with FCN cows and this difference was statistically significant. There was a total loss of \$155 per lactation for nonculled FCP cows retained in the herd compared with FCN cows retained in the herd. Among culled cows, FCP cow losses were \$50 less because of age at culling and \$120 for reduced beef value. This totaled a loss of \$441 for culled FCP cows compared with culled FCN cows. The losses as

a result of lower lactation performance and early culling from the herd should alarm dairy producers and motivate them to implement the appropriate control measures for the disease.

Key words: *Mycobacterium paratuberculosis* shedding, milk production, income over feed cost, dairy cow

INTRODUCTION

Johne's disease (JD), a chronic and progressive intestinal disease in ruminants caused by *Mycobacterium avium* ssp. *paratuberculosis* (MAP), imposes large direct and indirect productivity losses on affected farms (Bennett et al., 1999; Chi et al., 2002). Production losses include reduced milk production, increased mortality, weight loss, premature culling, and reduced slaughter value (Chiodini et al., 1984; Raizman et al., 2007).

Infection with MAP in cattle can be categorized into 4 stages (Whitlock and Buerge, 1996). In stage 1, cattle are infected although no clinical signs are observed and MAP cannot be detected in feces. In cattle in stage 2, MAP can be detected in feces, although clinical signs of disease are not evident. Cattle may remain in these stages without developing clinical disease or may progress to clinical stages, typically after at least 2 yr of infection. Fecal shedding of MAP can be intermittent and its detection in culture is imperfect, especially when few organisms are shed in the feces (Merkal et al., 1968). Stage 3 cattle have observable clinical signs with weight loss and diarrhea, sometimes advancing to stage 4 with advanced clinical disease signs including lethargy, emaciation, and profuse diarrhea. Development of clinical signs is generally gradual and varies among individuals.

Although increasing information is becoming available on lactation performance of fecal-culture-positive (FCP) cows (Lombard et al., 2005; Beaudeau et al., 2007; Gonda et al., 2007; Raizman et al., 2007), limited studies have addressed the financial effect of the disease on a dairy farm. Since the first economic evaluation on the herd level was published in the United States by

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Ott et al. (1999), only a few studies have addressed the cost of maintaining or culling JD serologic- or fecal-positive cows in the herd. The literature provides different estimations about production losses per individual ELISA-positive cow within the herd or for a serologic- or fecal-positive herd. More accurate estimates of the financial effect would be useful because this information coupled with within-herd prevalence will help producers, veterinarians, and animal health authorities make cost-effective decisions about how to control the disease. The objective of this study, therefore, was to evaluate the financial effect of cows shedding MAP in 2 large Minnesota dairy herds.

MATERIALS AND METHODS

Herds

Two Minnesota dairy herds (approximately 650 and 750 cows, respectively) with a total of approximately 1,400 milk cows were selected for this study based on 4 criteria: 1) at least 400 milking cows, 2) at least 10% of culled cows with clinical signs consistent with JD in the previous year, 3) routine use of computerized dairy herd management software program (Dairy Comp305, Valley Agricultural Software, Tulare, CA), and 4) participation in DHIA.

General Herd Management

In each herd, cows were housed in a freestall barn and grouped into pens based on parity (primiparous and multiparous) and stage of lactation. Cows were milked twice per day and milk yields were recorded monthly for individual cows through official DHIA testing. Lactating cows were fed a TMR formulated by the herd nutritionist. In herd A, lactating cows were fed 3 different TMR: fresh, milking, and late lactation/pregnant cow rations. In herd B, all lactating cow groups were fed a single TMR. Both herds fed cows a transition ration in the last 3 wk of gestation. In herd A, recombinant bST (Posilac, Monsanto Corp., St. Louis, MO) was used from 63 d postcalving (DIM) to 200 d postconception (days carried calf; **DCC**), whereas in herd B recombinant bST was started on d 90 and 120 postcalving for cows and heifers, respectively, and was stopped for heifers and cows at 220 DCC.

Fresh Cow Management

In each herd, rectal temperatures and clinical ketosis (defined as a cow with decreased appetite and evidence of elevated ketones in milk, urine, or breath in the absence of other concurrent disease) were monitored daily

in fresh cows for the first 10 d postcalving. Temperature above 39°C was considered abnormal. In herd B, the uterus of each postpartum cow was examined by the herd veterinarian once a week to detect metritis.

Reproductive Management

The voluntary waiting period for the first postpartum AI in herd A was 50 d postcalving and in herd B was 70 and 90 d for cows and heifers, respectively. Pregnancy diagnosis was performed in herd A by transrectal ultrasonography beginning 30 d postbreeding and repeated at 60 d postbreeding to identify abortions or twins. In herd B, pregnancy diagnosis was performed by weekly rectal palpation of all cows that were not already confirmed pregnant and were more than 36 d postbreeding. In both herds pregnancy confirmation was performed between 180 and 170 DCC for herds A and B, respectively. Cessation of lactation (dryoff) occurred at approximately 200 and 220 DCC for cows in herds A and B, respectively.

Cow Sampling

In both herds, all cows and heifers calving between January 2002 and March 2003 were enrolled in the study. A fecal sample was collected from enrolled animals during the close-up period preceding calving (average 262 DCC). Each sample was collected with a single-use disposable obstetric glove lubricated with sterile water. Cow and heifer sampling was performed during visits to the farm by the first author, approximately every 14 d from January 2002 through March 2003.

Milk production, clinical diseases (other than clinical JD), and reproductive performance data were recorded for each cow as described below.

Fecal Testing

Fecal samples were processed at the Minnesota Veterinary Diagnostic Laboratory (University of Minnesota, St. Paul) using the bacterial culture method described previously (Wells et al., 2002). Briefly, a sedimentation culture procedure was used with 72 h of sedimentation before inoculation of 4 tubes containing Herrold's egg yolk medium. Colony counts were recorded weekly for 16 wk and final results were reported as negative, light (mean of 0.25 to 9 colonies/tube), moderate (mean of 10 to 49 colonies/tube), and heavy (mean of >50 colonies/tube) fecal shedding. For the purposes of this study, we assumed 99% specificity for the fecal culture method. It is important to mention, however, that this specificity refers to the method itself and not to the individual cow infection status because in a heavily infected herd

it is reasonable to expect that some cows are passively shedding the bacteria in their feces without actually being infected.

JD Control

Neither herd participated in the Minnesota state JD control program during the course of the study. In addition to the fecal samples collected during the close-up period, serum was collected from herd B for the detection of MAP antibodies from cows before the dryoff period. The primary JD control measure adopted in both herds during the study period was the feeding of colostrum from individual cows to heifer calves. Fecal culture results were reported only to the owner of herd A during the course of the study (with owner consent, approximately 6 mo after sampling).

Milk Production, Milk SCC, and Reproduction Data

Milk production data were obtained from DHIA records using the computerized record system when cows completed a 305-d lactation (milk production) or when cows left the study or completed the lactation before 305 DIM (total milk). The mean and maximum linear score SCC from the first 10 DHIA test days were obtained from DHIA records for all cows with milk production records. Reproductive parameters evaluated included number of AI services, days from calving to conception (days open), and number of times bred. In addition, previous lactation dry period length (in days) was also recorded for each cow.

Culling Data

Culling information was recorded for all cows that were culled (died or sold) before the end of their lactation. Information collected included reason for culling, date of culling, DIM at culling, and signs of clinical JD, if present. A cow was considered to complete the study if she was pregnant, ended the current lactation, and entered the dry period in preparation for a subsequent lactation. For each cow that completed the study, DIM in the study was recorded.

Net-Income Analysis

The economic evaluation model was built in an Excel spreadsheet (2003; Microsoft Corp., Redmond, WA). Cows were defined as MAP-positive if they had positive fecal culture for MAP during the close-up period preceding the observed lactation. For the current analysis, consensus of estimates by investigators was based on prevailing economic conditions in the industry.

Milk Produced and Milk Income

Actual milk produced during the study lactation was measured based on DHIA test reports. Milk price was set at \$14.00 per hundred pounds of milk (cwt) or \$0.31/kg. Milk production for each individual cow's lactation in the herd was estimated by setting the herd's average 305 DIM mature-equivalent (**305 ME**) milk production (12,300 kg/cow) in a way that the predicted herd-average milk production (10,989 kg/cow; calculated based on the distribution of cows by lactation) closely matched the actual herd-average milk production (10,941 kg/cow).

Feed Costs

Overall feed costs were calculated using both maintenance costs and milk production costs. Feed costs per cow per day were assumed to be \$1.76, based on 10 kg of DMI for maintenance multiplied by \$0.176 (cost of the ration) per kg of DMI. Feed intake to support milk production over maintenance was estimated as \$0.07 per kg of milk produced, based on 0.4 kg of DMI per kg of milk produced multiplied by \$0.176 (cost of the ration) per kg of DMI. Using this approach, the cost of producing any level of milk could be calculated.

Income Over Feed Costs

Income over feed costs (**IOFC**) was calculated as the difference between the total milk income and the total feed costs. This approach for calculating IOFC may tend to diminish the apparent effect of fecal-positive cows because it assumes that positive cows that produce less milk also eat less feed, which is not necessarily always the case.

Reproduction Management and Disease Cost

The cost of an additional day open above a baseline of 85 d was defined as \$2.50, and the cost of each AI service was defined as \$12. The costs of clinical diseases were estimated based on reasonable values for the costs of therapy and the acute milk lost during the clinical event (Table 1). Long-term costs of reductions in milk production, reproductive performance, and culling were not included in the disease costs because these 3 areas were accounted for directly in the study.

Culling Cost

The value of an average cow at the beginning of each lactation was calculated based on the proportion of lifetime production that would remain for a cow that

Table 1. Cost of disease differences in *Mycobacterium paratuberculosis* fecal-culture-positive (FCP, n = 21) and fecal-culture-negative (FCN, n = 636) cows that were not culled during the lactation in 2 dairy herds in Minnesota (2002–2003)

Item	LDA ¹	Ketosis	Lameness	Clinical mastitis	Metritis	Milk fever	Pneumonia	Retained placenta	Total
Assumed cost/case, \$	150	30	50	90	50	20	50	50	
FCN cows									
Cases, n	40	15	175	179	42	8	48	60	
Incidence rate, %	6	2	28	28	7	1	8	9	
Loss/cow, \$	9.43	0.71	13.76	25.33	3.30	0.25	3.77	4.72	61.27
FCP cows									
Cases, n	1	0	9	8	1	0	3	2	
Incidence rate, %	5	0	43	38	5	0	14	10	
Loss/cow, \$	7.14	0	21.43	34.29	2.38	0	7.14	4.76	77.14
Difference loss (FCP – FCN), \$ ²	2.29	0.71	(7.67)	(8.96)	0.92	0.25	(3.37)	(0.04)	(15.87)

¹LDA = left displaced abomasum.²Parentheses indicate positive surplus.

successfully calved into that lactation. This value depended on the lactation-specific culling rates for the study herds and for projected milk production in each lactation derived from herd-average 305ME milk production in the study herds (12,300 kg; Table 2). Using these data, the remaining proportion of projected lifetime milk production for a cow at the start of any lactation was calculated. This number was applied to the total projected lifetime depreciation of value of an average cow (value at the first calving minus cull beef value) to derive the remaining value of an average cow at the start of each lactation. The calculated loss if the cow was culled in that lactation was the calculated cow value at the start of the study lactation minus salvage beef value.

Cost of Rearing Heifers

Because wide ranges of rearing costs across the United States exist in the literature (Wolf and Harsh, 2001; Benson, 2002; Tozer et al., 2009) and specific data were not available from the study herds, it was difficult to stipulate a specific value of a calving heifer that would

hold in all conditions. For the purposes of this model, as an estimate of the value of a calving heifer, we chose \$1,800 to reflect conditions that have prevailed for several years in the market. The estimates of a cow's value at the start of each lactation are presented in Table 2. Thus, for example, a cow that started her third lactation was assumed to have a value of \$1,282. If this cow was culled, the loss to the dairy was that value minus the \$600 salvage value of the cow for beef, or \$1,282 minus \$600 (\$682). Nevertheless, it is important to note that, in the past several years, the demand for springing heifers has been such that market values have been at historic highs, ranging between \$1,800 and \$2,000 or more.

Statistical Analysis

Statistical analysis was conducted using the SAS statistical package (2004 version, SAS Institute Inc., Cary, NC). Descriptive statistics were used for production and reproductive parameters such as DIM, AI service, and so on. Linear regression was used to assess the effect of fecal shedding status on milk production. Lactation

Table 2. Milk production (kg) adjusted depreciation by lactation and calculated value at the beginning of each lactation in 2 Minnesota dairy herds (2002–2003)

Lactation	Average cow's estimated value at start of lactation, ¹ \$	305 ME ² factor for estimating actual milk production expected, %	Expected milk production in lactation based on average ME milk production, ³ kg	Lifetime lactations expected at start of given lactation in remaining population, n	Herd culling rate by lactation, %	Lifetime milk production still to come, %
1	1,800	75	9,200	2.74	26	100
2	1,499	91	11,700	3.36	39	75
3	1,282	97	12,000	4.22	44	57
4	1,142	100	12,300	5.16	39	45
5	1,014	100	12,300	5.91	53	34

¹\$1,800 = cost of introduction of a new heifer; \$600 = salvage value of a cow culled for beef.²ME = mature equivalent.³Average ME milk production for both herds was set at 12,300 kg.

Table 3. Summary of production parameters for *Mycobacterium paratuberculosis* fecal-culture-positive (FCP, n = 21) and fecal-culture-negative (FCN, n = 634) cows that were not culled during the lactation in 2 Minnesota dairy herds (2002–2003)

Item	All cows			Lactation 1			Lactation 2			Lactation ≥ 3		
	FCN	FCP	Diff ¹	FCN	FCP	Diff	FCN	FCP	Diff	FCN	FCP	Diff
Cows, n	634	21		216	7		165	6		253	8	
Average milk, kg	10,985	9,630*	1,355	9,786	7,973*	1,803	11,543	10,350	1,193	11,644	10,539	1,105
SD milk	2,209	2,461		1,658	2,706		2,056	2,550		2,300	1,501	
Average DIM	373	348	24	387	369	18	367	321	46	364	351	13
SD DIM	94	74		99	88		99	29		86	87	
Average milk/d	31	29	2	26	22	4	33	32	1	33	31	
SD milk/d	8.0	8.0		7.0	9.0		7.7	6.0		8.2	6.4	

¹Diff = difference between FCP and FCN.*Difference is statistically significant ($P < 0.05$).

number and presence and absence of diseases were used to adjust for possible confounding. For other continuous variables, linear regression was used to compare fecal-negative and fecal-positive cows in which $P \leq 0.05$ was considered as the cutoff for significance. Logistic regression analysis was used to assess the association between culling and fecal shedding status (positive and negative) in which lactation, lactation milk production, and diseases were used to adjust for confounding. Odds ratio was reported as the measure of association of this analysis.

RESULTS

Fecal Culture Results

Fecal samples were collected from a total of 1,048 cows during the close-up period between January 2002 and March 2003. Of these, 84 cows (8%) had positive fecal cultures; 46% were light shedders, 26% were moderate shedders, and 28% were heavy shedders.

Performance of Cows Shedding and Not Shedding MAP

Milk Production and IOFC. For this analysis, milk production information was available from 655 cows that ended the lactation without being culled (Table 3). Twenty-one cows entered the lactation as FCP and completed the lactation; 76, 14, and 10% were light, moderate, and heavy shedders, respectively. These cows produced less milk than FCN cows (n = 634). After adjusting for lactation number, overall FCP cows produced 1,355 kg less than FCN cows ($P < 0.001$). This effect was more pronounced in first-lactation cows in which FCP cows produced 1,803 kg less than FCN cows (Table 3). Overall, given the assumptions about prices described above, FCP cows that survived their current lactation produced \$276 less in milk income than FCN cows (\$1,956 vs. \$1,680; SD \$526, \$570). This difference

was statistically significant and was consistent with the finding that FCP cows gave less milk in the current lactation.

Reproduction Management and Disease Costs. Mean days open were 151.6 and 118.9 and mean AI services were 3.1 and 2.5 for FCN and FCP cows, respectively. These differences were not statistically significant. The cost differences for any clinical disease were small and neither statistically nor economically significant. For cows not culled, FCP cows tended to have fewer clinical diseases than FCN cows ($P > 0.05$).

Cows Culled During the Lactation. Of the 84 FCP cows, 63 cows (75%) were culled during the current lactation. Of these 63 cows, 33 cows (52%) were culled because clinical signs of JD were present and the other 30 cows (48%) were culled because of other reasons. Overall 9% of all culled cows during the study period were culled because JD clinical signs were present (15 and 12% for herds A and B, respectively). Of the 964 FCN cows, 328 (34%) were culled during the current lactation (58 and 42% were from herds A and B, respectively). Thus, the culling risk difference between FCN (34%) versus FCP (75%) was 41% (95% confidence interval: 31–51%). Logistic regression results indicate that FCP cows were 3.0 times (95% confidence interval: 1.6–5.8) more likely to be culled than FCN cows after adjusting for lactation number and lactation milk production. The culling results in the study cows by lactation are presented in Table 4. Average lactation number at culling was 2.94 and 2.77 for FCP and FCN cows, respectively; the difference, however, was not statistically significant. Based on our model results, the average cost of culling for the FCP and the FCN cohorts was \$746 and \$796 per culled cow, respectively. The \$50 difference was not statistically significant. The economic effect of whatever production income or feed and disease costs that may have been incurred during the cow's final lactation are assumed to be accounted for in the other aspects of this financial evaluation.

Table 4. Risk of culling for *Mycobacterium paratuberculosis* fecal-culture-negative (FCN) and fecal-culture-positive (FCP) cows compared with nonculled cows from 2 Minnesota dairy herds (n = 1,048; 2002–2003)

Total, %	Lactation	Culled		Nonculled		Total FCN	Risk of culling FCN, ¹ %	Total FCP	Risk of culling FCP, %	Relative risk	Lactational culling risk, ² %
		FCN	FCP	FCN	FCP						
29	1	73	7	217	7	290	25	14	50	1.99	26
27	2	87	21	165	6	252	35	27	78	2.25	39
21	3	80	16	119	4	199	40	20	80	1.99	44
13	4	46	8	81	3	127	36	11	73	2.01	39
6	5	26	10	32	0	58	45	10	100	2.23	53
2	6	8	1	8	1	16	50	2	50	1.00	50
1	7	7	0	7	0	14	50	0			50
1	8	0	0	6	0	6	0	0			0
0	9	1	0	0	0	1	100	0			
0	10	0	0	1	0	1	0	0			
100		328	63	636	21	964	34	84	75	2.2	

¹Risk of culling FCN = culled FCN/total FCN.²Lactational culling risk = total culled/total (FCN + FCP).

Summary

The summary of the various economic effects is provided in Table 5. Regardless of whether any of the observed differences were statistically significant, aggregating the financial effects for the 2 cohorts of cows (culled and not culled), the economic summation is as follows.

FCP Culled Cohort Cows Compared With the FCN Culled Cows. Among FCP cows, IOFC losses were \$366 more per cow compared with FCN cows, which was statistically significant. Semen costs were \$14 per cow less in FCP cows than in FCN cows and disease costs were \$19 more in FCP cows than in FCN; neither difference was statistically significant. Fecal-positive cow losses were \$50 less because of age at culling and \$120 for reduced beef value. This totaled a loss of \$441 for culled FCP cows compared with culled FCN cows.

Nonculled Cohort Per Cow Compared With Fecal-Negative Nonculled Cows. Among FCP nonculled cows, IOFC losses were \$276 more compared with fecal-negative cows and this difference was statistically significant. Fecal-positive cows, however, gained \$98 in fewer days open and had \$7 and \$16 lower inseminations and diseases costs, respectively. This resulted in a loss of \$155 for nonculled FCP cows compared with nonculled FCN cows. Assuming that these costs are applied to the herds studied and the relative prevalences of MAP FCP cows versus FCN cows, the loss per cow in the herd per each additional percent of prevalence was \$3.69. Thus, if a herd had a 10% prevalence of MAP FCP cows, then the herd would lose \$37 per cow because of the decreased performance of MAP-infected cows that were in stage 2 of disease. This assumes, however, that the loss is linear with a change in prevalence

and that all cows would suffer the same magnitudes of loss as the study herd.

DISCUSSION

The current study used 2 large Midwestern dairy farms. The management practices used in these 2 farms as described above are typical for mid- to large-sized dairy farms in the United States Midwest. Additionally, in both herds average lactation milk production was not statistically different from the 2004 average milk production of Minnesota DHIA herds for the herd-size category of 400 to 999 milking cows (10,400 kg; Raizman et al., 2007). Thus, both herds are representative for Minnesota and the Midwest of the same herd-size category in terms of milk production and management.

Table 5. Summary of economic effects on both *Mycobacterium paratuberculosis* fecal-culture-positive (FCP) culled and nonculled cohorts in 2 Minnesota dairy herds (2002–2003)

Item	FCP-cow losses, ¹ \$
Culled cohort	
Income over feed cost	366
Extra insemination	(14)
Disease	19
Culling	(50)
Loss of cull value due to Johne's disease	120
Total	441
Nonculled cohort	
Income over feed cost	276
Excess of days open	(98)
Extra insemination	(7)
Disease	(16)
Total	155

¹Fecal-culture-negative cows are the comparative baseline. Parentheses indicate positive surplus.

To the best of our knowledge, this is the first study to evaluate the cow-level economic effect of MAP shedding and JD culling using fecal culture results. Previous studies have used mainly serum ELISA results for comparison (Ott et al., 1999; Lombard et al., 2005; Tiwari et al., 2008). In the current study, we defined a positive cow as a cow with FCP during the close-up period before calving. Using this definition would tend to reduce the observed measure of the effect of JD on cows because not all infected cows were likely to have been detected as fecal shedders before the study lactation. This misdiagnosis bias would mean that the observed difference seen between the shedding and nonshedding cows would be less than the real effect of JD. On the other hand, in a highly infected herd in which the environment is ubiquitously contaminated with MAP (Raizman et al., 2004), it is reasonable to expect that some of the cows digest the bacteria from the environment and shed it in their feces without actually being infected (Whitlock et al., 2006). These “false positive” healthy cows might cause an underestimation of the net income because of MAP fecal shedding. In both cases we see no practical way to avoid these biases.

In this study, both herds could use MAP testing to assist with their daily management decisions. The fecal culture results for herd A, however, were not received until 5 to 6 mo after the beginning of the lactation of each tested cow, whereas herd B used ELISA on serum obtained during the dryoff period by the herd veterinarian as an additional source for decision making. It is likely, therefore, that our findings with regard to disease costs are an artifact of the tendency of producers to more readily cull FCP or ELISA-positive cows and clinical JD cows earlier in the lactation, compared with test-negative cows. As a result, the 21 FCP cows that completed the lactation had a better general health status and hence had fewer disease events and disease costs. Because 76% (16) of these 21 cows were low shedders, it is plausible that some of them were transiently FCP as a result of passive shedding; however, currently we have no practical way to confirm that.

Similarly, our findings regarding reproduction performance are also probably a result of earlier culling and breeding decisions, reflected in the statistical analysis results, as opposed to a benefit from the disease. Fecal-culture-positive cows that bred back promptly were retained in the herd whereas those that did not were probably more likely to be culled. Using serum ELISA results, Johnson-Ifearulundu et al. (2000), however, found that seropositive cows had a 28-d increase in days open when compared with ELISA-negative cows. The authors suggested that this was a result of low energy balance caused by nutrient malabsorption. Lombard et al. (2005) found a decrease in days open for cows with a

strong positive ELISA but no overall difference between positive and negative ELISA. These findings agree with our assumption that FCP cows that are close to showing clinical signs are culled earlier. Indeed, most (76%) of the 21 FCP cows that completed the lactation were light shedders.

Fecal culture results can serve, therefore, as a management tool if used in a timely manner; producers can consider the results for culling decision along with other important factors such as milk production, reproduction, chronic mastitis, and lameness. Additionally, should the producer decide to maintain the cow in the herd despite the culture results, he or she can design a separate calving barn for fecal-positive cows to avoid MAP spread to other calves; this is one of the most important measures in controlling within-herd MAP spread.

Our results are in accord with previous studies (Buergelt and Duncan, 1978; Hutchinson 1996), which showed that the average cow culled because of JD clinical signs was older than the average fecal-negative culled cow. The findings by Lombard et al. (2005), however, do not suggest that MAP-infected cattle are prematurely culled. In addition, fecal-positive culled cows were assumed to be in poorer body condition than fecal-negative culled cows. Benedictus et al. (1987) estimated the loss of the salvage value to be 20%; hence the revenue from FCP culled cows when sold for beef consumption was assumed to be reduced by \$120. Nevertheless, the value of animals culled from a dairy may vary widely. Typical income values for culled dairy cows may range from \$350 to \$800 depending on the market and the cow's condition. Assuming a market value of \$0.88 per kg and a 680-kg animal, the value of a culled cow would be \$600.

In conclusion, using for the first time fecal MAP shedding to evaluate net income, our study shows that monetary loss caused by MAP subclinical infection, especially as related to milk production and IOFC, justifies producers' proactive intervention. The adopted measures should aim to control and reduce the spread of the disease within the herd and hence to alleviate the economic burden of the disease on the producer.

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