Food Animal Economics

Farm-level economic analysis of the US National Johne’s Disease Demonstration Herd Project

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Objective—To evaluate farm-level economic costs and benefits related to control of paratuberculosis (Johne’s disease) in dairy herds in the National Johne’s Disease Demonstration Herd Project (NJDDHP).

Design—Economic analysis.

Sample Population—40 dairy herds enrolled in the NJDDHP.

Procedures—A farm-level economic analysis of the US NJDDHP was performed. Costs and benefits of management-related practices to control Johne’s disease were estimated on the basis of results for 40 dairy operations enrolled in the project. From these costs and benefits, the net present value (NPV) for control of Johne’s disease was estimated.

Results—Analysis revealed a mean NPV of $34/animal (equivalent to approx $3/animal/y) when there were no testing costs for producers and a mean NPV of ~$14/animal when testing costs were borne by the producers.

Conclusions and Clinical Relevance—Management-related practices to control Johne’s disease were typically found to be of marginal economic benefit when the costs of testing were not borne by producers. The continuation of the NJDDHP for another 2 to 4 years would allow more precise estimation of the economic benefits of a control program for Johne’s disease. (J Am Vet Med Assoc 2008;233:1852–1858)

Paratuberculosis (Johne’s disease) is a contagious and chronic infection caused by Mycobacterium avium subsp paratuberculosis that affects the small intestine of ruminants and other animals. In dairy cattle, Johne’s disease can cause economic losses to dairy operations as a result of a reduction in milk production, lower slaughter value, and suboptimal culling.

Investigators have used various approaches and techniques in an attempt to quantify the economic losses of Johne’s disease in dairy cattle. Estimates of losses vary widely as a result of differences in prevalence, herd and production performance, and study design, among other factors. Nonetheless, from the perspective of a producer deciding how to proceed with management and control of Johne’s disease, knowing the losses caused by Johne’s disease is insufficient information for making decisions. Producers also need an estimate of future losses that can be prevented by various control measures and how much those control measures will cost. Analysis based on these 3 components (estimated losses with and without control of the disease and costs of control programs) can be used to estimate return on investment, and an appropriate economic decision can be made.

Investigators have used various computer simulations in an attempt to estimate the costs and benefits of a range of control efforts for Johne’s disease. Although simulation studies are widely used and provide a range of advantages (such as decreased cost and less time [ie, duration of the study]), compared with field studies, they can be difficult to validate. In addition, simulations require field data as an input (often complemented with expert opinion).

Investigators have examined losses attributable to Johne’s disease and the costs and benefits for use of a vaccine. To our knowledge, no large-scale field trial has been conducted to evaluate the costs and benefits.
of management-related practices to control Johne's disease. A likely reason that so few studies have attempted to quantify both the costs and benefits is that to estimate reductions in losses, a study would need to be of sufficient duration to account for changes in herd performance related to control of Johne's disease. For example, in the case of management-related practices used to control Johne's disease, a minimum of 3 years is required because the intent of such practices is to limit infection of young calves, and clinical signs of Johne's disease do not often manifest before the cattle reach 3 years of age. In addition, field trials typically have considerably higher costs than do simulation studies or case-control studies.

The NJDDHP, which is a field trial, was started in 2003 and has been described elsewhere. The main goal of the project is to evaluate the long-term feasibility and effectiveness of management-related practices designed to control Johne's disease on dairy cattle operations. The study reported here was performed to determine the farm-level economic costs and benefits for herds involved in the NJDDHP.

**Materials and Methods**

**Sample population**—Sixty-five dairy producers were enrolled in the NJDDHP. Two main data sources were obtained for use in the economic analysis.

**Data collection**—Data on herd production and management from the beginning of the NJDDHP in 2003 until the end of January 2007 were obtained. These data were used to estimate economic losses attributable to Johne's disease and costs associated with diagnostic testing and disease prevention and control.

Cost data were obtained from a voluntary questionnaire that was provided to all NJDDHP investigators to be administered to participating dairy farmers. Of the 65 dairy producers enrolled in the NJDDHP, the survey was completed by 39 producers (60% response rate) representing 40 operations in 10 states (Colorado, Florida, Indiana, Kentucky, Michigan, Mississippi, New York, Oregon, Vermont, and Wisconsin). Herd size of the typical respondent was 466 lactating cows (range, 41 to 1,517 cows). The questionnaire focused on obtaining data that could be used to estimate the costs of management-related practices to control Johne's disease. In addition, it contained questions related to each producer's perception of Johne's disease control in general and the associated economic costs and benefits.

**Costs of disease control**—The 2 main cost categories of the control efforts were for diagnostic testing and for management-related practices to control Johne's disease. Diagnostic tests performed during the duration of the study were paid for by cooperative agreements with the USDA, APHIS, Veterinary Services. Test results were used to estimate the prevalence of Johne's disease in the study herds. Diagnostic test results were reported to each dairy producer, who was then able to use them to support decisions regarding animal replacement. Therefore, in the farm economic analysis, 2 cost scenarios were calculated. In the first scenario, only the costs of improvements in management (eg, calf management) were included because producers would not likely perform the same amount of diagnostic testing if they were not enrolled in the NJDDHP field study. In the second scenario, costs of improvements in management and costs of diagnostic tests performed during the field study were included. Test costs were assumed to be $5/ELISA and $17/bacterial culture of a fecal sample.

To estimate the costs of improved management, producers were asked to report costs that they incurred as part of the Johne's disease control program that they otherwise would not have sustained. Costs were organized into 4 categories (ie, supplies, labor, management, and capital investments).

**Losses attributable to Johne's disease**—Three economic losses for infected cattle were included in the analysis (reduction in milk production, lower slaughter value, and loss of future income attributable to suboptimal culling).

Production records from the Dairy Herd Improvement Association and test results from the diagnostic laboratory were used to estimate 305-day milk production for each of 8 groups of cattle: positive results for both an ELISA and culture of fecal samples, positive results for an ELISA and negative results for culture of fecal samples, negative results for an ELISA and positive results for culture of fecal samples, negative results for both an ELISA and culture of fecal samples, no results for an ELISA and positive results for culture of fecal samples, no results for an ELISA and negative results for culture of fecal samples, positive results for an ELISA and no culture of fecal samples, and negative results for an ELISA and no culture of fecal samples). The reduction in 305-day milk production of all 5 categories of cattle with positive test results was determined by comparing it with the mean for cattle with negative test results while simultaneously controlling for lactation, year, and breed. A milk price of $0.327/kg ($14.88/100 lb) was assumed, consistent with the mean milk price paid to the producers included in the study.

Mean loss attributable to a lower slaughter value for cattle clinically affected by Johne's disease was estimated by calculating the mean of the values provided by producers in the survey.

The third category of loss attributable to Johne's disease is caused by suboptimal (premature) culling of clinically infected cattle. Loss attributable to suboptimal culling (premature culling of an animal clinically affected with Johne's disease) is equal to the RPO. The RPO of an animal is defined as the total extra profit to be expected from trying to keep a cow in the herd for its optimal life span, compared with immediate replacement, while accounting for the risk of premature removal of retained animals. Therefore, the RPO was calculated for every clinically affected animal culled during the study period. An economic spreadsheet model was used to calculate the RPOs of all clinically affected cattle culled. Inputs to calculate the RPO values were data for each farm, including milk price, costs of replacement heifers, and mean milk production; in addition, 305-day milk production, lactation number, and number of days in the current lactation for the clinically affected cows were also used as inputs. In situations in which data for a clinically affected animal were not available, a mean value for RPO was used.

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Benefits—To estimate benefits (ie, reduction of losses attributable to Johne’s disease), it was assumed that the losses attributable to Johne’s disease would remain the same throughout the study (ie, same as for the first year of the study) if no additional control measures were implemented (Figure 1). Therefore, annual benefits of the Johne’s disease control measures were calculated as the losses attributable to Johne’s disease for the first year of the study minus the losses attributable to Johne’s disease in the subsequent years of the study. In addition, the economic analysis accounted for future economic benefits (ie, benefits after the duration of the study) by projecting that the economic losses would follow a linear decrease until eradication, which was assumed to occur 20 years after start of the control efforts,11 or they would remain constant in future years and Johne’s disease would not be eradicated after 20 years.

The costs and benefits were both accounted for when calculating the NPV of each farm’s investments in Johne’s disease control measures. Net present value is a standard method for the financial appraisal of long-term projects and is used widely in economics. Within an NPV, all cash flows in time (ie, both costs and benefits) are discounted back to the first year of the investment (in this situation, the first year of the field study) to account for the time-value of money and the riskiness of the investment decision. All capital investments were converted to annuities. The NPV is a standard economic measure used to value investments that have an extended time component12 and is calculated by use of the following equation:

\[
\text{NPV} = \sum_{t=1}^{n} \frac{C_t}{(1 + r)^t} + \frac{C_n}{r(1 + r)^{n+1}}
\]

where n is the total number of years during which annual cash flows are estimated, t is the index of period (year), C_t is the net cash flow for period t, r is the discount rate, and C_n is the constant net cash flow expected for years after year n.

The discount rate reflects the opportunity cost of capital, which for agriculture is generally low, compared with the discount rate for other sectors of the economy. Therefore, the discount rate was initially assumed to be 8% (it was varied later in a sensitivity analysis), which is higher than the risk-free rate and lower than discount rates generally used in other economic sectors. The NPV analysis included a terminal value calculation to reflect the future benefits resulting from the investment in management improvements. The terminal value was reflected in the NPV equation as C_n divided by the discount rate.

Results

Costs of disease control—Annual costs of diagnostic testing per animal were determined (Table 1). The NPV analysis in the study reported here was performed with and without these costs. During the duration of the study period, the number of tests performed decreased, which was evident as the decrease in mean cost per animal from the first to fourth year of the study.

Annual costs for control of Johne’s disease by category were calculated (Table 2). The survey revealed that management changes were primarily made to correct issues with hygiene and management of calves. Common supplies purchased by producers as part of the control program included milk replacer, ear tags, leg bands, and, in some cases, propane for a pasteurizer. The most frequent increase in supplies was for purchase of milk replacer instead of feeding waste milk. Supply costs increased a mean of $6.41/cow/y, with a maximum increase of $39.05/cow/y. Eleven farms indicated no increase in supply expense.
Labor costs increased on farms as a result of increased testing and hygiene efforts. Labor costs increased a mean of $5.25/cow/yr, with a maximum increase of $61.46/cow/yr. Sixteen farms had no increase in labor expenses as a result of the project.

Managerial expenses reflected increased time required for that dairy’s manager or managers to provide guidance, perform tasks, maintain records, and assess performance of the project. Typically, producers spent an additional $3.37/cow/yr on management for control of Johne’s disease. Six farms had no increase in managerial expense.

Capital investments were the final category of expense. Capital investments included skid loaders and buckets used to keep feed and manure separate, on-farm pasteurizers, and cattle facilities (e.g., maternity pens). Capital investments were annualized on the basis of the number of years the investment was expected to last (e.g., 7 years for machinery). Capital investments for control of Johne’s disease were estimated at a mean of $4.83/cow/yr. Seven farms had no increase in capital expenses, and several farms with an increase in supplies, labor, and managerial expenses had small annual investments. Large capital investments could be a liquidity impediment for participating in control programs for Johne’s disease. However, most of the participants spent < $5/cow/yr on investments related to control of Johne’s disease (Table 2). Higher expenditures were related to facilities that may have yielded returns beyond those measured with respect to Johne’s disease but were not considered in this study (e.g., a new freestall barn).

The farms in the survey typically incurred approximately $21.86/cow/yr in additional expenses (total of all expense categories) for control of Johne’s disease. The largest total expense for a farm was $108.87/cow/yr. Two farms indicated no increase in expenses because both of those farms were already enrolled in a Johne’s disease control program.

Because the distribution of expenses per herd was skewed to the right, the median expenditures were extremely different than the aforementioned mean values. At the 50th percentile, the expenditure for supplies was $2.03/cow/yr, labor expense increased $1.10/cow/yr, managerial expenses increased $1.92/cow/yr, and capital investment increased $0.80/cow/yr.

For the lower percentiles, farms had to make few changes to implement a control program. At the other extreme were farms that made large investments and increased labor costs to control the disease. It is important to remember that the farms participating in this study were voluntary participants and not a random sample of US dairy operations and therefore were not necessarily representative of the US dairy industry as a whole. We might expect herds that have large disease problems to participate and take advantage of the financial incentives (i.e., free testing) and expertise that could accompany the program. These farms would likely have high control

<table>
<thead>
<tr>
<th>Test result</th>
<th>No. of cows</th>
<th>305-day milk production (kg [lb])</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELISA+/C+</td>
<td>763</td>
<td>8,809 (19,380)</td>
<td>990 (2,179) 10.1 324</td>
</tr>
<tr>
<td>ELISA+/C–</td>
<td>643</td>
<td>8,873 (19,521)</td>
<td>526 (2,030) 9.5 303</td>
</tr>
<tr>
<td>ELISA+ nt/C–</td>
<td>1,011</td>
<td>9,277 (20,410)</td>
<td>522 (1,149) 5.3 171</td>
</tr>
<tr>
<td>ELISA nt/C+</td>
<td>593</td>
<td>9,348 (20,565)</td>
<td>452 (994) 4.6 148</td>
</tr>
<tr>
<td>ELISA–/C+</td>
<td>1,262</td>
<td>9,652 (21,081)</td>
<td>217 (478) 2.2 71</td>
</tr>
<tr>
<td>ELISA–/C–</td>
<td>24,292</td>
<td>9,774 (21,503)†</td>
<td>0 (0) 0 —</td>
</tr>
<tr>
<td>ELISA–/C nt</td>
<td>15,509</td>
<td>9,746 (21,441)†</td>
<td>0 (0) 0 —</td>
</tr>
<tr>
<td>ELISA– nt/C–</td>
<td>7,504</td>
<td>9,952 (21,983)†</td>
<td>0 (0) 0 —</td>
</tr>
</tbody>
</table>

*Percentage loss, compared with mean production for cows without a positive test result. †Mean production of cows without a positive result for an ELISA or culture of fecal samples was 9,709 kg (21,599 lb).

ELISA+ = Positive results for an ELISA. C+ = Positive results for culture of fecal samples. C– = Negative results for culture of fecal samples. C nt = No results for culture of fecal samples. ELISA– = Negative results for an ELISA. — = Not applicable.

Figure 2—Mean (squares), 10th percentile (diamonds), 50th percentile (circles), and 90th percentile (triangles) annual losses attributable to Johne’s disease in 40 dairy herds involved in the NJDDHP.
costs. On the other hand, herds that have been diligent about control of Johne’s disease may also have been willing participants and would likely have low control costs. Thus, although the costs did not represent results from a statistically valid sample of farms, the ranges were valuable for use in assessing potential scenarios for costs of disease control.

Benefits of disease control—Production records from the Dairy Herd Improvement Association and test data from the diagnostic laboratory were used to estimate effects on milk production for cattle with different diagnostic test results (Table 3). In addition, results from the producer questionnaire revealed that the mean reduction in slaughter value for cattle clinically affected with Johne’s disease was $296/animal. The RPOs of clinically affected animals were calculated to be a mean of $1,351/animal (range, $0/animal to $4,099/animal).

For all clinically affected cattle for which production or mate effects on milk production for cattle with different diagnostic test results were valuable for use in assessing potential scenarios for costs of disease control.

Table 4—The NPV (in dollars) per animal for control of Johne’s disease in herds involved in the NJDDHP, including and excluding the costs of diagnostic testing and assuming eradication is achieved after 20 years or is never achieved.

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Costs excluded and eradication achieved</th>
<th>Costs included and eradication achieved</th>
<th>Costs excluded and eradication never achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>34</td>
<td>–14</td>
<td>–107</td>
</tr>
<tr>
<td>10th</td>
<td>–452</td>
<td>–512</td>
<td>–820</td>
</tr>
<tr>
<td>50th</td>
<td>42</td>
<td>–34</td>
<td>–12</td>
</tr>
<tr>
<td>90th</td>
<td>556</td>
<td>519</td>
<td>355</td>
</tr>
</tbody>
</table>

Table 4—The NPVs (including and excluding costs of diagnostic testing) were calculated (Table 4). Assuming that eradication would have been possible after 20 years, the mean NPV per animal was $34 and –$14 when the costs of diagnostic testing were excluded or included, respectively. Analysis of the 10th and 90th percentiles revealed large variation of NPV per animal among participating dairy farms. The relationship between the number of years when eradication was assumed to be achieved and the mean NPV per animal (including and excluding costs of diagnostic tests) was estimated (Figure 4). Finally, the effects of alternative discount rates on economic calculations were determined (Table 5).

Producer perceptions—The survey was also intended to collect data on producer perceptions related to their experience with control of Johne’s disease. The 39 producers who responded were, in general, extremely positive about their experience and results. Fifteen (38%) indicated that the decision to participate had benefited them financially. Most of this increase in financial benefit was attributable to reduced losses because only 5 (13%) producers perceived an increase in revenues as a consequence of the program. Those producers who achieved an increase in revenues indicated an increase in animal value and new marketing opportunities. Twenty-nine (74%) producers indicated that they had achieved an increase in general herd health, which indicated that the management changes might spill over to other health issues to be considered when undertaking a Johne’s disease control program. Five producers indicated no change in general herd health, 2 indicated general herd health had decreased, and 1 could not indicate whether general herd health had increased or decreased. Thirty-seven (95%) respondents were glad that they were participating in the program and would continue with efforts to control Johne’s disease after the project is completed. These producers frequently mentioned the effort and investment in eradication to date and the need to continue these efforts to realize long-term benefits.
Table 5—The NPV (in dollars) per animal for control of Johne’s disease in herds involved in the NJDDHP excluding the costs of diagnostic testing and assuming eradication would be achieved after 20 years, as determined by the use of various discount rates.

<table>
<thead>
<tr>
<th>Value</th>
<th>6% discount rate</th>
<th>8% discount rate</th>
<th>10% discount rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>100</td>
<td>34</td>
<td>11</td>
</tr>
<tr>
<td>10th</td>
<td>-559</td>
<td>-452</td>
<td>-376</td>
</tr>
<tr>
<td>50th</td>
<td>84</td>
<td>42</td>
<td>32</td>
</tr>
<tr>
<td>90th</td>
<td>773</td>
<td>596</td>
<td>423</td>
</tr>
</tbody>
</table>

Discussion

Results of the economic analysis reported here suggest that the management-related practices for control of Johne's disease typically provided economic benefits of $34/animal (given a discount rate of 8%, which is comparable to $34/animal × 0.08/ yr = $3/animal/yr). However, the following limitations are important when considering and interpreting these results.

The 40 farms in this study were not necessarily representative of a typical US dairy herd. To participate, herds had to meet certain requirements and producers also had to volunteer to complete the economic questionnaire. Respondents to the questionnaire had a mean of 466 lactating cows, compared with 128 lactating cows for the typical US herd at the beginning of 2007. Therefore, our results cannot necessarily be extrapolated to the larger population of US dairy herds.

The results revealed that there is great variation among herds. All herd managers had proof that Mycobacterium avium subsp paratuberculosis was present in their herd at the start of the study, but herd size, management practices at the start of the study, costs of changes to management, and benefits of disease control varied widely.

Although this field study is unique in its size and large amount of available data, there were some areas in which data were missing or incomplete (eg, the costs of management-related practices to control Johne’s disease were determined by use of a 1-time survey). In addition, only 2 to 4 years of data were available for most herds, and costs and benefits beyond this period had to be estimated. Given the epidemiologic aspects of Johne’s disease and the relatively prolonged time until benefits from a control program can be expected, it is therefore important that this study be continued for at least another 2 to 4 years.

It is important to consider (and account for in the economic evaluation) that the benefits of disease control extend beyond the study period. However, it is difficult to estimate these benefits, and the benefits varied greatly among herds. The default NPV calculations for the study reported here were based on the assumption that eradication would be achieved after a herd was enrolled in a control program for 20 years. However, if losses attributable to Johne’s disease do not eventually decrease to zero, the management-related changes would typically not be economically beneficial (Table 4). This again emphasizes the importance of extending this field study for several years and updating the economic evaluations with inclusion of data for the additional years. Furthermore, the number of years until losses attributable to Johne’s disease would be reduced to zero has a considerable influence on the magnitude of future benefits (Figure 4).

For this field trial, no control herds were available to evaluate the cost and benefits without the changes in management-related practices for control of Johne’s disease. Therefore, the situation at the start of the study (during the first year) was used as a proxy for the situation for herds in which there was no improvement. An important assumption of this study was that without implementation of the program to cause improvements, the losses attributable to Johne’s disease would have remained the same as those at the start of the study. If losses attributable to Johne’s disease had increased without the control measures taken in the study, as has been indicated in another study, the benefits for the study reported here would have been underestimated.

During the study, diagnostic tests were performed to estimate the prevalence of Johne’s disease. However, because dairy producers were informed about the outcomes of the tests, some may have used them to support their decisions regarding replacement animals; thus, some of the benefits of disease control may have been attributable to selective culling by producers of animals with positive test results. Therefore, the NPV calculations were performed both excluding and including the costs of these diagnostic tests.

In the study reported here, an NPV approach was used in which the costs and benefits (reduction in losses attributable to Johne’s disease) were estimated by measuring individual loss components for individual infected animals (ie, the focus was on infected cattle). A similar approach was used in another study in which investigators evaluated the economic effects of vaccination against Johne’s disease. This approach has the advantage that it measures each individual loss (eg, instead of evaluating the gross margins of herds), and therefore, one can better differentiate benefits of the program on the herds versus benefits of other changes (eg, higher milk yield as a result of better nutrition). However, this approach only measures the reduction in losses that are explicitly accounted for in the economic analysis, and it is more difficult to account for secondary benefits. If management-related practices to control Johne’s disease result in secondary benefits (eg, improved management of calves can reduce the prevalence of other diseases), then the cost-benefit analysis in this study would underestimate the benefits. The results of the questionnaire indicated that the participating dairy producers perceived a net gain in benefits, which may be one of the reasons that most participating producers had a positive impression of the program and planned to continue their control efforts after the conclusion of the study, whereas the NPV calculations revealed benefits for only approximately half of the herds on the basis of the results obtained from inception of the control program until the time of our economic analysis.

Nonetheless, we believe that ours is the first field study to estimate the economic costs and benefits of management-related practices for the control of Johne’s disease. Analysis of the results suggested that the practices typically yielded economic benefits when producers did not bear the costs of testing. The effect of the management-related practices on Johne’s disease could not be distinguished from the effects of the test-and-cull efforts. Modeling studies have revealed that the
effects of test-and-cull efforts on prevalence of Johne’s disease are relatively small. This suggests that test-and-cull efforts should be used to a limited extent or be subsidized for Johne’s disease control programs to be attractive to producers.

Results of the study reported here suggested that management-related practices for the control of Johne’s disease typically provide marginal economic benefits. The continuation of the NJDDHP for another 2 to 4 years would allow more precise estimation of the economic benefits of a Johne’s disease control program.


References