Prev Vet Med. 2013 Nov 1;112(3-4):330-7. doi: 10.1016/j.prevetmed.2013.08.009. Epub 2013 Aug 27.

Perceptions of veterinarians in bovine practice and producers with beef cow-calf operations enrolled in the US Voluntary Bovine Johne's Disease Control Program concerning economic losses associated with Johne's disease.

Bhattarai B, Fosgate GT, Osterstock JB, Fossler CP, Park SC, Roussel AJ.

Departments of Veterinary Integrative Biosciences, College of Veterinary Medicine and Biomedical Sciences, Texas A&M University, College Station, TX 77843 (Bhattarai); Department of Production Animals Studies, Faculty of Veterinary Science, University of Pretoria, Onderstepoort 0110, South Africa (Fosgate); Zoetis, 333 Portage St, MS KZO-300-210SE, Kalamazoo, MI 49007 (Osterstock); National Animal Health Monitoring System, USDA APHIS Veterinary Services Centers for Epidemiology and Animal Health, 2150 Centre Ave, Bldg B, Mail Stop 2E7, Fort Collins, CO 80526 (Fossler); Texas A&M AgriLife Research and Extension Center, PO Box 1658, Vernon, TX 76384 (Park); Veterinary Large Animal Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Texas A&M University, College Station, TX 77843 (Roussel)

Perceptions of veterinarians in bovine practice and producers with beef cow-calf operations enrolled in the US Voluntary Bovine Johne's Disease Control Program concerning economic losses associated with Johne's disease

Bikash Bhattarai*[a], Geoffrey T. Fosgate[b], Jason B. Osterstock[c], Charles P. Fossler[d], Seong C. Park[e] and Allen J. Roussel[f]

a Department of Veterinary Integrative Biosciences, Texas A&M University, College Station, TX 77843

b Department of Production Animals Studies, University of Pretoria, Onderstepoort, South Africa

c Zoetis, Kalamazoo, MI 49007

d USDA:APHIS:VS:CEAH, National Animal Health Monitoring System, Ft. Collins, CO 80526

e Texas A&M AgriLife Research, Vernon, TX 76385

f Department of Large Animal Clinical Sciences, Texas A&M University, College Station, TX 77843

*Corresponding author Tel.: (+1) 979-862-1177, Fax: (+1) 979 847 8981

Email: bbhattarai@cvm.tamu.edu

Abstract

This study compares the perceptions of producers and veterinarians on the economic impacts of *Mycobacterium avium* subspecies *paratuberculosis* (MAP) infection in cow-calf herds. Questionnaires were mailed to beef producers through the Designated Johne's Coordinators and to veterinarians belonging to a nationwide professional organization. Important components of losses associated with MAP infected cows were used to estimate total loss per infected cow-year using an iterative approach based on collected survey data. Veterinarians were more likely to perceive a lower calving percentage in MAP infected cows compared to producers (P=0.02). Income lost due to the presence of Johne's disease (JD) in an infected cattle herd was perceived to be higher by veterinarians (P<0.01). Compared to veterinarians without JD certification, seedstock producers were more likely to perceive genetic losses due to culling cows positive for MAP (P<0.01). There were mixed opinions regarding the magnitude of lowered weaning weight in calves from infected cows and perceived differences in risk of other diseases or conditions in infected cows. An annual loss of $235 (95% CR: $89 to $457) for each infected animal was estimated based on information from the producer survey. The analogous estimate using information inputs from veterinarians was $250 ($82 to $486). Mean annual loss due to JD in a 100 cow herd with a 7% true prevalence was $1,644 ($625 to $3,250) based on information provided by producers. Similarly, mean annual loss based on information collected from veterinarians was $1,747 ($575 to $3,375).

Keywords: Johne's disease, beef cattle, *Mycobacterium avium* subspecies *paratuberculosis,* economics

1. Introduction

Johne’s disease (JD), or paratuberculosis, caused by infection with *Mycobacterium avium* subsp. *paratuberculosis* (MAP) is a disease of worldwide economic importance (Johnson-Ifearulundu et al., 1999; Harris and Barletta, 2001). Infection with MAP causes reduced production in dairy herds (Ott et al., 1999; Harris and Barletta, 2001; Tiwari et al., 2008; Raizman et al., 2009). Mortalities and sale of underweight infected cows represent a loss of revenue for beef producers and may have negative impacts on the reputation of seedstock producers (Roussel, 2011). There are negative impacts related to regulatory and ethical issues (Rossiter and Burhans, 1996) as well as legal liabilities for the sale of an infected cow, contamination of land, and breeding animals from infected herds (Kennedy and Allworth, 2000).

The National Animal Health Monitoring System (NAHMS) periodically evaluates producer attitudes and knowledge of JD as well as use of management practices related to herd biosecurity (NAHMS, 1994, 1999, 2010). A NAHMS study on beef in 1997 estimated that 92 percent of beef producers were either unaware of JD or only recognized the name (NAHMS, 1999) and a more recent study in 2007-08 found that 69% of beef producers were either unaware of JD or only recognized the name (NAHMS, 2010). The United States Voluntary Bovine JD Control Program (VBJDCP) was created in 2002 to provide minimum national standards for the control of JD and to educate veterinarians and producers regarding management, prevention and control of JD (VBJDCP, 2002). Beef producers with herds having low risk of JD (level 4) in the US Voluntary Bovine Johne's Disease Control Program (VBJDCP) believe that a control program becomes economically beneficial as it progresses (Benjamin et al., 2009). A total of 59% of producers and 50% of veterinarians in Texas believed that losses in beef production due to JD are substantial

(Benjamin et al., 2010). However, only 25% of producers with JD low-risk herds perceived a significant benefit of participation in control programs (Benjamin et al., 2009).

Data to estimate losses from JD in the US beef herds are limited. Bovine JD can cause herd-level losses even in the absence of clinical disease (Benedictus et al., 1987; Johnson-Ifearulundu et al., 1999; Johnson-Ifearulundu et al., 2000; Gonda et al., 2007). Veterinarians presumably influence opinions of producers regarding the estimation of JD associated costs, testing and other control measures (Benjamin et al., 2010). The purpose of this study was to describe and compare the perceptions of producers and veterinarians related to economic impacts of MAP infection in beef cow-calf herds using responses from mailed questionnaire surveys.

2. Materials and Methods

The study protocol was approved by the Institutional Review Board at Texas A&M University (protocol number 2010-06666).

2.1. Questionnaire development

The beef producer questionnaire contained 31 questions with applicable sub-questions in three major sections. The first section considered general herd information. The second section included questions about disease burden, perceived losses and differences between the productivity of MAP infected and non-infected cattle, possible costs associated with implementing control programs, facility upgrades deemed necessary for testing, and herd health management. The final section included questions related to activities for the control of MAP transmission.

The majority of questions for the veterinarian questionnaire were designed to be comparable to those in the producer questionnaire. There were three major sections with 35 main questions with some sub-questions, and two open ended questions for explanations related to preceding questions. The first section considered general demographic information including type and size of the veterinary practice. The second part was related to estimating disease burden in practice clientele herds, perceived losses, and differences between the productivity of MAP infected and non-infected cattle. The final section included questions related to control of MAP transmission in client herds. The veterinarian questionnaire was pre-tested by administration to bovine practitioners in the listserv of a professional veterinary organization via the internet and revised based on the responses and comments.

Both questionnaires utilized a combination of free numerical or text responses, 5-category Likert scales, dichotomies (yes/no), and multiple choice questions. Both questionnaires were designed to be completed within 30 minutes. All questionnaires were printed in booklet form with a page containing survey information, rights of the respondents, and ethical approval. The questionnaire packet also included a cover letter that described the purpose of the questionnaire and was signed by two of the investigators (BB and AR). Guidelines for completing the questionnaire were explained in the cover letter and information sheet.

2.2. Questionnaire administration

Questionnaires were mailed during November and December, 2010 to all beef producers that had risk assessments performed and herd management plans developed for JD. Participants were contacted by the Designated Johne's Coordinators (DJC) of the 9 states in the USA (FL, GA, IA, MO, ND, SC, SD, WI, WV), who were willing to send the study questionnaires to the producers in their respective states. All eligible participants were selected to receive the questionnaire. A personal cover letter from the State DJCs was included with the questionnaire booklet. Introductory letters prior to the questionnaire, incentives and reminders were not sent to producers because information concerning questionnaire recipients was not disclosed to investigators.

Veterinarians with active membership in a US professional veterinary organization who listed “bovine” as one of their practice types as of July 2011 served as the sampling frame. All listed veterinarians satisfying the inclusion criteria from the same 9 states used for the producer survey were contacted. Questionnaires were uniquely coded to protect confidentiality. Veterinarians were contacted with an introductory letter 12 days prior to the mailing of questionnaires. Reminder post-cards were mailed 8 days after the questionnaire. A business reply envelope and a $2 bill were included in each questionnaire packet as an incentive to improve response proportions (Bhattarai and Fosgate, 2010).

2.3 Analysis

Responses from the completed questionnaires were recorded using SelectSurvey (ClassApps.com, 2006, SelectSurvey.NET 1.5.1) on a secure server located at the College of Veterinary Medicine and Biomedical Sciences, Texas A&M University. Unsolicited personal information revealed by some producers in free text comments were not recorded in the database. Data were downloaded and analyzed using Stata® version 11.2 (StataCorp., College Station, TX) and OpenEpi (Dean et al., 2011). Descriptive statistics were stratified by veterinarians and producers. Statistical analysis was performed with categories of respondents: veterinarians with and without JD certification, seedstock producers, commercial cow-calf producers, and producers with both seedstock and commercial cow-calf operations. Continuous outcomes were reported with the mean, minimum, median, and maximum. Wilcoxon rank-sum tests were used to compare continuous variables that were not normally distributed based on the

Shapiro–Wilk test. Associations between categorical exposures and outcomes were evaluated using chi-square tests. Beliefs concerning risks of disease and categorical responses related to economic metrics were evaluated among producers and veterinarians using odds ratios. Crude and adjusted odds ratios were calculated for different groups within cow-calf producers and veterinarians. Potential confounding variables were evaluated by manually entering different covariate combinations and evaluating a change of 20% or more in the odds ratio being evaluated. Potential confounding was controlled by including herd-size, herd infection status (infected or uninfected), and the perception of the respondent whether veterinary expense is higher for infected cows in the final models. Covariates retained in the final models were selected on the basis of improvement in the Bayesian information criterion (Dohoo et al., 2003). Herd size was categorized as small (<50 head), medium (50-149) or large (150 or more). Two-sided statistical tests were performed and results were interpreted at the 5% significance level.

2.3.1 Economic losses

Data obtained from completed questionnaires were used to estimate losses associated with MAP infected animals and predict overall herd-level monetary losses in typical cow-calf production scenarios. Pre-weaning losses were estimated using reduction in percent calving in infected cows and pre-weaning mortality of their calves. The loss in monetary terms was estimated based on the calf-crop at weaning and the prevailing price from the National Agricultural Statistics Service (USDA, 2012). Additional veterinary expenses for MAP infected cows reported by respondents were used as the loss due to additional cost of treating MAP infected cows. Total loss was the sum of component losses and reported in US$ (Table 1).

2.3.2 Parameter estimates

Triangular and beta distributions were used to model parameter inputs within the economic model using available software (@Risk, version 5.7, Palisade Corp, Ithaca, NY). Monte Carlo sampling was used for 50,000 iterations. Beta distribution parameters were estimated from questionnaire data using available freeware BetaBuster (Su, 2006). Means and 95% credible regions (95% CR) were estimated for losses. Herd-level losses were projected to a cow-calf herd of 100 cows with a mean seroprevalence of 3% (Roussel et al., 2005), which corresponds to a 7% true prevalence after adjustment for the sensitivity and specificity of available serum ELISAs (Collins et al., 2006). Regression sensitivity analysis was conducted within @Risk to estimate the influence of each model input to estimate its impact on the total loss estimate. The @Risk software calculates the regression coefficients by a process called stepwise multiple regression. Input with the highest correlation is entered first into the regression. Partial correlation coefficients of other inputs not in the current regression with the output are then calculated, and the variable with largest correlation value is entered into the regression next. The process is continued for every input, and each input is tested for significance and removed if not significant in F-test. The process of selecting the variable with highest correlation and testing for significance is continued until the only remaining variables have been rejected. The final regression equation contains inputs not rejected from the regression. The coefficients reported by @RISK are thus the regression coefficients for each input. A larger coefficient indicates a greater impact and the positive and negative sign indicates the positive or negative direction of the impact on the outcome.

3. Results

3.1 Description of respondents

Altogether, 160 of 989 (16%) producers contacted provided responses. The average (minimum, median, maximum) herd size was 155 head (1, 70, 2500). A total of 41% (66/160) of producers had only commercial cow-calf herds, 40% (60/160) had only seedstock and 19% (30/160) had both cattle types. All participating producers were considered to have participated in a control program at one point since they had completed a JD risk assessment or management plan in the past. A total of 95% (149/157) of producers had tested their herds at least once and 74% (117/158) were enrolled in a control program at the time of survey.

Of 1,080 questionnaires sent to veterinarians, 325 (30%) were completed and returned. A total of 41% (132/325) of veterinarians reported that they had been JD certified. Unregistered cow-calf operations (not registered in breed registry) were the most frequent type of clients (85%, 275/325) followed by registered commercial cow-calf (69%, 224/325), registered seedstock (58%, 189/325), and unregistered seedstock operations (32%, 107/325). There were veterinarians with other client types including feedlot (57%, 184/325) as well as clients with dairy, stockers, backgrounders, club-calf (i.e., producers focused on breeding and sale of cattle specifically for exhibition) and non-bovine species (20%, 64/325).

3.2 Economic metrics

Baseline calving percentage and weaning weight of calves were reported to be higher ($P<0.001$) by producers compared to veterinarians (Table 2). However, producers reported a lower pre-weaning calf mortality percentage ($P<0.001$). Income lost due to the presence of JD in an infected herd was perceived to be higher by veterinarians ($P<0.001$). Compared to veterinarians without JD certification, seedstock producers were 5 times more likely to agree (P=0.001) that there is genetic loss due to culling cows positive for MAP (Table 3). Models adjusted for herd-size, infection status, and the perception of the respondent whether veterinary expense is higher for infected cows revealed that seedstock producers were 6 times more likely (P=0.002) to agree that there is genetic loss compared to veterinarians without JD certification. Seedstock producers were less likely to believe that MAP infected dams have calves with lower weaning weights (P<0.002), and excess pre-weaning mortality (P=0.023). Adjusted models also estimated that seedstock producers were less likely to believe MAP infected dams wean lighter calves (P=0.006) or have higher pre-weaning mortality (P=0.020) compared to veterinarians without JD certification.

3.3 Risk of diseases / conditions

Compared to the reference category of veterinarians without JD certification, the perceived odds of lameness in MAP infected cattle were higher for producers with both seedstock and commercial cow-calf operations based on crude (P=0.019) and adjusted (P=0.021) models (Table 4). Odds of neurologic diseases in MAP infected cattle were perceived to be lower by veterinarians with JD certification compared to those without based on both crude (P=0.020) and adjusted (P=0.017) models. Producers with commercial cow-calf perceived 4 times higher odds (P=0.008) of neurologic diseases based on crude model, but odds were non-significant in adjusted model. In general, perceptions of JD certified veterinarians and other producer categories generally did not differ regarding an increased risk of diseases and conditions in MAP infected cows.

3.4 Predicted losses

Losses were predicted based on the survey responses. An annual average loss of $276 (95% CR: $149 to $478) for each infected animal was estimated based on information from the producer survey. The analogous estimate using information collected from veterinarians was $273 ($115 to $483). Lowered weaning weight of calves from infected cows alone contributed an average of $123 ($82 to $170) or 48% (24 to 79%) of total loss per infected cow based on the data from producers, and $76 (26 to 150) or 31% (9 to 66%) based on the data from veterinarians. Annual average loss in a 100 cow herd at 7% true prevalence for MAP was $1,935 (95% CR: $1,041 to $3,344) based on the information collected from the producers. Estimated mean annual loss was $1,908 ($806 to $3,382) based on data from veterinarians. Regression sensitivity analysis suggested that the percent decrease in calving from an infected cow (regression coefficient, b = 0.92), increased veterinary cost for infected cattle (b = 0.25), and lowered weaning weight in calves from infected cows (b=0.18) were the most influential inputs for herd level losses based on the producer survey. Similarly, percent decrease in calving from an infected cow (b = 0.76), increased veterinary costs for infected cows (b = 0.59), and lowered weaning weight in calves from infected cows (b = 0.22) were the most influential factors based on veterinarian survey data.

4. Discussion

Producers and veterinarians both perceived losses associated with JD in beef cow-calf operations due to lowered production and additional expenses. There were some differences in perceptions between producers and veterinarians regarding losses due to reduced calving proportions, higher calf mortality, lower weaning weight and higher veterinary expenses. These differences may reflect either inconsistency in effectiveness of veterinary education efforts or systematic differences in opinions between perceptions of veterinarians surveyed in this study and the specific veterinarians that consult with the producers surveyed here.

The effects of JD within beef cattle may cause premature culling of affected animals, decreased milk production reducing the weaning weights of calves, reduced body weight of culled animals and loss of potential markets (Roussel, 2011). Some of these losses are analogous to MAP infected dairy herds having higher replacement costs (Johnson-Ifearulundu et al., 1999), lower milk production and additional feed costs (Ott et al., 1999; Raizman et al., 2009). Affected cows have higher mortality and there is a decrease in the weight of cows that are culled (Johnson-Ifearulundu et al., 1999). Subclinical MAP infection contributes to a decrease in total milk, fat, and protein over the lactation and a shorter productive lifespan (Gonda et al., 2007). Subclinical cows also have reduced fertility (Johnson-Ifearulundu et al., 2000) and receive lower slaughter prices (Benedictus et al., 1987) usually due to a decrease in the weight of cull cows (Johnson-Ifearulundu et al., 1999).

Compared to veterinarians without JD certification, certified veterinarians and all classes of producers were generally less likely to perceive losses associated with calving and weaning performance. In spite of the differences in estimated medians, significant differences were not observed in some of the comparisons mainly due to low precision of estimates due to a lower number of responses. Nevertheless, producers perceived significantly lower percentage of income lost due to MAP presence within the herd.

Lameness, pneumonia and mastitis have been reported the most common clinical diseases among fecal culture positive dairy cows in specific herds (Raizman et al., 2007). This contributes to the perception that there is additional veterinary expense per infected cow. Significant differences were observed as JD certified veterinarians perceived higher risk of lameness but lower risk of neurological diseases compared to non-certified veterinarians. Increased incidence of diseases and conditions in MAP infected cattle is a possible reason for the additional cost of treatment reported by 68% of producers and 64% of veterinarians. However, the perceived magnitude of losses varied among respondent classes. One of the reasons for mixed opinions is due to different burden of MAP infection in the respondent producer herds leading to a different degree of experience related to diseases and conditions. Another reason could be the higher premium of cows owned by seedstock producers, which is much different from commercial cow-calf producers.

Compared to the reference category of veterinarians without JD certification, seedstock producers were more likely to perceive a genetic loss when MAP infected cows are culled. This is consistent with the typical objective of seedstock operations to breed and market cattle of superior genetic merit. While seedstock producers are more concerned about genetics, commercial cow-calf producers are more concerned about the weaning-weight loss, presumably because total weight of weaned calves is typically the primary source of income for commercial cow-calf operations. The perceived average loss in weaning weight of 31 kg and 27 kg by producers and veterinarians, respectively, was consistent with prior estimates (Bhattarai et al., 2013).

Of beef producers with level 4 herds in the VBJDCP, 75% did not recognize a significant benefit or perceived only a marginal benefit from participation in the VBJDCP (Benjamin et al., 2009). However, dairy producers appear somewhat more concerned about the impact of JD. Level 3 and 4 (low risk) dairy producers in the VBJDCP believed it was an economically beneficial strategy (Kovich et al., 2006). However, in a study of 40 dairies actively working to control JD on their operations, 15 (38%) producers perceived financial benefit while only 5 (13%) producers perceived an actual increase in revenue (Groenendaal and Wolf, 2008). In a previous study, 64% of veterinarians had educated beef producers on management strategies for the control or elimination of

JD, but only 36% of veterinarians had received specific training regarding JD and 29% were JD-certified (Benjamin et al., 2010). In Canada, veterinarians had positive attitudes towards training for the prevention and control of JD and the majority also thought that training should be completed every few years (Sorge et al., 2010).

A limitation of this study is the exclusive enrollment of producers who had on-farm risk assessments performed and herd management plans developed. Only 16% of the producers and 31% of veterinarians responded to the surveys and this indicates a possibility of non-response bias. Information regarding non-responders was not available and the impact of this potential bias could not be assessed. Comparability was attempted by recruiting producers and veterinarians from the same nine states, but the study design did not support determination of whether veterinary respondents were in fact associated with producer respondents. Another limitation of this study was only selecting producers who had risk assessment and herd management plans from a subset of US states. These producers are therefore more likely than a typical producer to perceive benefits or losses because they had voluntarily enrolled to control JD. Estimates of the effects of Johne’s disease would have likely been different from a randomly selected population that had not been involved in a JD control program. Producers with infected cows might be less likely to respond or report about losses despite the assurance that researchers would not collect any identifying information. A further limitation was the inability to evaluate whether responses varied by the geographic location of respondents.

Important sources of losses are expected to vary by producer types and this was evidenced by the observation that only seedstock producers were concerned about the loss of valuable genetics. For the evaluation of perceived losses, most questions concerned directly measurable losses. Miscellaneous indirect costs could be substantial, but are difficult to perceive. More comprehensive methods such as standardized performance analysis are necessary to account for all losses. Such estimates can account for different herd sizes, feeding practices, real estate, machinery, breeding stock investments, calving percentage, death loss and breeding-season length. Management-related costs are important to estimate profit in cow-calf herds. The herd level losses might have been underestimated using the 7% true prevalence derived from 3% seroprevalence (Roussel et al., 2005) because there are also reports of 5% (Thorne and Hardin, 1997), and 9% seroprevalence (Hill et al., 2003) in beef herds in other US states.

5. Conclusions

There were mixed opinions and differences in the production metrics perceived by veterinarians and producers. One of the most significant economic concerns of commercial cow-calf producers was a lower weaning weight of calves from infected cows. The loss of valuable genetics when an MAP infected cow was culled was an important concern to seedstock producers. Similarly, compared to the veterinarians, producers reported a significantly higher percentage of herd income lost due to the presence of MAP infected cattle.

Conflict of interest statement

None. The funding agencies were not involved in the study design, in the collection, analysis and interpretation of data; in the writing of the manuscript; and in the decision to submit the manuscript for publication.

Acknowledgements

Funding for this study was provided by the Program for the Study of Johne's Disease in Texas and by a cooperative agreement with USDA-APHIS-VS. We would like to thank Dr. Lisa Benjamin for her valuable feedback on the questionnaires, and state DJCs of FL, GA, IA, MO, ND, SC, SD, WI, and WV for their help to administer producer questionnaires.

References:

Benedictus, G., Dijkhuizen, A.A., Stelwagen, J., 1987. Economic losses due to paratuberculosis in dairy cattle. Vet Rec. 121, 142-146.

Benjamin, L.A., Fosgate, G.T., Ward, M.P., Roussel, A.J., Feagin, R.A., Schwartz, A.L., 2009. Benefits of obtaining test-negative Level 4 classification for beef producers in the Voluntary Bovine Johne's Disease Control Program. Prev. Vet. Med. 91, 280-284.

Benjamin, L.A., Fosgate, G.T., Ward, M.P., Roussel, A.J., Feagin, R.A., Schwartz, A.L., 2010. Attitudes towards biosecurity practices relevant to Johne's disease control on beef cattle farms. Prev. Vet. Med. 94, 222-230.

Bhattarai, B., Fosgate, G., Osterstock, J., Fossler, C., Park, S., Roussel, A., 2013. Effect of positive test results for *Mycobacterium avium* subspecies *paratuberculosis* on weaning weights in beef cow-calf herds. J. Am. Vet. Med. Assoc. (in press).

Bhattarai, B., Fosgate, G.T., 2010. Increased response proportions for postal questionnaires in Texas veterinarians using incentives. Prev. Vet. Med. 93, 62-65.

Collins, M.T., Gardner, I.A., Garry, F.B., Roussel, A.J., Wells, S.J., 2006. Consensus recommendations on diagnostic testing for the detection of paratuberculosis in cattle in the United States. J. Am. Vet. Med. Assoc. 229, 1912-1919.

Dean, A.G., Sullivan, K.M., Soe, M.M., 2011. OpenEpi: Open Source Epidemiologic Statistics for Public Health, Version 2.3.1. Available at: www.OpenEpi.com.

Dohoo, I., Martin, W., Stryhn, H., 2003. Veterinary Epidemiologic Research. AVC Inc. Chalottetown, Canada.

Gonda, M.G., Chang, Y.M., Shook, G.E., Collins, M.T., Kirkpatrick, B.W., 2007. Effect of *Mycobacterium paratuberculosis* infection on production, reproduction, and health traits in US Holsteins. Prev. Vet. Med. 80, 103-119.

Groenendaal, H., Wolf, C.A., 2008. Farm-level economic analysis of the US National Johne's Disease Demonstration Herd Project. J. Am. Vet. Med. Assoc. 233, 1852-1858.

Harris, N.B., Barletta, R.G., 2001. *Mycobacterium avium* subsp. *paratuberculosis* in Veterinary Medicine. Clin. Microbiol. Rev. 14, 489-512.

Hill, B.B., West, M., Brock, K.V., 2003. An estimated prevalence of Johne's disease in a subpopulation of Alabama beef cattle. J. Vet. Diagn. Invest. 15, 21-25.

Johnson-Ifearulundu, Y., Kaneene, J.B., Lloyd, J.W., 1999. Herd-level economic analysis of the impact of paratuberculosis on dairy herds. J. Am. Vet. Med. Assoc. 214, 822-825.

Johnson-Ifearulundu, Y.J., Kaneene, J.B., Sprecher, D.J., Gardiner, J.C., Lloyd, J.W., 2000. The effect of subclinical *Mycobacterium paratuberculosis* infection on days open in Michigan, USA, dairy cows. Prev. Vet. Med. 46, 171-181.

Kennedy, D.J., Allworth, M.B., 2000. Progress in national control and assurance programs for bovine Johne's disease in Australia. Vet. Microbiol. 77, 443-451.

Kovich, D.A., Wells, S.J., Friendshuh, K., 2006. Evaluation of the Voluntary Johne's Disease Herd Status Program as a source of replacement cattle. J. Dairy Sci. 89, 3466-3470.

NAHMS, 1994. Chapa, Beef Cow/Calf Health And Productivity Audit, Part Iii: Beef Cow/Calf Health Management. National Animal Health Monitoring System, Animal and Plant Health Inspection Service, United States Department of Agriculture, 46.

NAHMS, 1999. Info Sheet: What do I need to know about Johne's Disease in Beef Cattle? National Animal Health Monitoring System, Animal and Plant Health Inspection Service, United States Department of Agriculture, 4.

NAHMS, 2010. NAHMS Beef Cow-Calf Studies, Part IV: Reference of Beef Cow-calf Management Practices in the United States, 2007–08. United States Department of Agriculture, National Animal Health Monitoring System, 122.

Ott, S.L., Wells, S.J., Wagner, B.A., 1999. Herd-level economic losses associated with Johne's disease on US dairy operations. Prev. Vet. Med. 40, 179-192.

Pope, K.F., Schroeder, T.C., Langemeier, M.R., Herbel, K.L., 2011. Cow-Calf Producer Risk Preference Impacts on Retained Ownership Strategies. J. Agr. Appl. Econ. 43, 497-513.

Raizman, E.A., Fetrow, J., Wells, S.J., Godden, S.M., Oakes, M.J., Vazquez, G., 2007. The association between Mycobacterium avium subsp. paratuberculosis fecal shedding or clinical Johne's disease and lactation performance on two Minnesota, USA dairy farms. Prev. Vet. Med. 78, 179-195.

Raizman, E.A., Fetrow, J.P., Wells, S.J., 2009. 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. J. Dairy. Sci. 92, 4929-4936.

Rossiter, C.A., Burhans, W.S., 1996. Farm-specific approach to paratuberculosis (Johne's disease) control. Vet. Clin. N. Am-Food A. 12, 383.

Roussel, A.J., 2011. Control of paratuberculosis in beef cattle. Vet. Clin. N. Am-Food A. 27, 593-598, vi.

Roussel, A.J., Libal, M.C., Whitlock, R.L., Hairgrove, T.B., Barling, K.S., Thompson, J.A., 2005. Prevalence of and risk factors for paratuberculosis in purebred beef cattle. J. Am. Vet. Med. Assoc. 226, 773-778.

Sorge, U.S., Mount, J., Kelton, D.F., Godkin, A., 2010. Veterinarians' perspective on a voluntary Johne's disease prevention program in Ontario and western Canada. Canadian Vet. J. 51, 403-405.

Su, C.-L., 2006. BETABUSTER 1.0. Bayesian Epidemiologic Screening Techniques. Available at: http://www.epi.ucdavis.edu/diagnostictests/betabuster.html

Thorne, J.G., Hardin, L.E., 1997. Estimated prevalence of paratuberculosis in Missouri, USA cattle. Prev. Vet. Med. 31, 51-57.

Tiwari, A., VanLeeuwen, J.A., Dohoo, I.R., Keefe, G.P., Weersink, A., 2008. Estimate of the direct production losses in Canadian dairy herds with subclinical *Mycobacterium avium* subspecies *paratuberculosis* infection. Canadian Vet. J. 49, 569-576.

USDA, 2012. National Statistics for Cattle, Cattle, Calves - Price Received, Measured in CWT $ / CWT. Available at: http://tx.ag/auveeb

VBJDCP, 2002. How to Do Risk Assessments and Management Plans for JD. United States Animal Health Association, Johne's Committee. Available at: http://www.tahc.state.tx.us/animal_health/johnes/RAs&MPs_Dairy&Beef_Herds.pdf

Table 1: Cow-calf producer and veterinarian parameter estimates used to estimate losses associated with *Mycobacterium avium* subspecies *paratuberculosis* infected beef cows

			Average (minimum, median, maximum)	
	P	Distribution	Producer[a]	Veterinarian[a]
A	Baseline calving percentage (all cows)	Beta P[b]:(36.7,2.9) V[b]:(28.8,3.3)	95(70,95,100)	90(10,90,100)
B	Percent decrease in calving from infected cows	Beta P[b]:(1.3,5.7) V[b]:(1.5, 6.4)	15.5(2.3,9.7, 54.3)	14.6(0.9,9.4, 85.5)
C	Baseline pre-weaning mortality percentage (all cows)	Beta P[b]:(1.4,70.9) V[b]:(6.2,99.7)	1.7(0, 1, 15)	5.4(0, 5, 95)
D	Percent increase in pre-weaning mortality in calves from infected cows	Beta P[b]:(1.0,33.1) V[b]:(1.3,55.0)	0.45(0.01,0.18,2.5)	0.9(0.1,0.5,9.5)
E	Baseline weaning weight (kg, all cows) [c]	Triangular	258.8(249.5, 263.1, 276.7)	238.1(226.8, 249.5, 260.8)
F	Percent decrease in weaning weight in calves from infected cows	Beta[b] P[b]:(27.0,131.2) V[b]:(5.0,39.2)	12.45 (3.2, 10.26, 30.4)	11.36(0.83, 10, 40)
G	Decrease in weaning weight in calves from infected cows	E*F		
N	Number of cows	Fixed	100	100
P	Prevalence	Fixed	7	7
H	Weaning weight per exposed female (uninfected)	A*(1-C)*E		
I	Weaning weight lost by average infected cow	(A-B)*(1-C-D)*(E-G)		
J	Weaning weight per cow adjusted for prevalence	[(1-P)*A*(1-C)*E]+[P*(A-B)*(1-C-D)*(E-G)]		
K	Decrease in total weaning weight per cow in herd	H-J		
L	US$ value of weaning weight (kg)[d]	Triangular	2.7(2.4, 2.7, 3.1)	2.7(2.4, 2.7, 3.1)
M	Value of decrease in WW in infected herds	K*L		

R	Increased veterinary costs in infected herds cow	Triangular	33.4(0,22.5,100)	31.8(1,20,250)

[a]Producers estimated values in their own herds while veterinarians estimated values from client herds

[b] P denotes producers and V denotes veterinarians. Corresponding values in parenthesis were the parameters used in beta distribution. Proportions based on percentages reported in the table were used to estimate beta distribution parameters.

[c] 25th and 75th percentiles were used as lower and upper limits, respectively

[d] USDA, NASS, 5 year average feeder calf price

Table 2: Comparison of producer estimates for their own herds and veterinarian estimates for client cow-calf herds

Variables	Producers	Veterinarians	P[a]
Herd Productivity (all cows): Average (min, median, max)			
Calving percentage	95.3 (70, 95, 100)	89.96 (10, 90, 100)	<0.001
Pre-weaning calf mortality percentage	1.7 (0, 1, 15)	5.36 (1, 5, 95)	<0.001
Weaning weight of calves, kg	259 (35, 263, 352)	238 (32, 250, 363)	<0.001
Productivity lost due to MAP infection: Average (min, median, max)			
Percent decrease in calving	15 (2, 10, 54)	14.5 (1, 9, 86)	0.588
Percent increase in calf mortality	23.5 (1,20,50)	16.3 (0.5,10,75)	0.243
Lost weaning weight, kg	30.9 (9.1, 22.7, 79.4)	26.6 (2.3, 22.7, 90.7)	0.098
Expenses: average (min, median, max)			
US$ veterinary expense per cow	31.8 (0, 21, 150)	27.2 (2, 20, 200)	0.495
Additional veterinary expense per infected cow	33.4 (0, 22.5, 100)	31.8 (1, 20, 250)	0.465
Percent income lost due to presence of JD infected cattle in herd	3.24 (0, 0, 30)	7.19 (0, 5, 40)	<0.001

[a] P values based on Wilcoxon rank-sum

.

Table 3: Comparison of polar questions about economic metrics associated with *Mycobacterium avium* subsp. *paratuberculosis* infected herds reported by cow-calf producers and veterinarians

Respondent type	Odds Ratios (OR)			
	Crude		Adjusted[a]	
Calving percentage is lower	OR (95% CI)	P	OR (95% CI)	P
Veterinarians without JD certification (reference)				
Veterinarians with JD certification	0.97 (0.54,1.77)	0.931	1.17 (0.58, 2.37)	0.657
Producers with seedstock only	0.56 (0.23, 1.39)	0.210	0.43 (0.14, 1.28)	0.132
Producers with commercial cow-calf only	0.51 (0.21, 1.25)	0.142	0.56 (0.20, 1.64)	0.293
Producers with both seedstock and commercial cow-calf	0.43 (0.12, 1.49)	0.183	0.29 (0.06, 1.51)	0.142
Higher pre-weaning mortality				
Veterinarians without JD certification (reference)				
Veterinarians with JD certification	0.78 (0.43, 1.42)	0.422	0.79 (0.40, 1.58)	0.504
Producers with seedstock only	0.31 (0.11, 0.85)	0.023	0.22 (0.06, 0.79)	0.020
Producers with commercial cow-calf only	0.71 (0.30, 1.67)	0.434	0.67 (0.25, 1. 82)	0.436
Producers with both seedstock and commercial cow-calf	0.97 (0.31, 3.06)	0.957	0.37 (0.08, 1.81)	0.223
Lower average weaning weight				
Veterinarians without JD certification (reference)				
Veterinarians with JD certification	0.85 (0.35, 2.04)	0.709	1.08 (0.40, 2.94)	0.876
Producers with seedstock only	0.21 (0.77, 0.58)	0.002	0.19 (0.06, 0.62)	0.006
Producers with commercial cow-calf only	0.66 (0.21, 2.01)	0.460	0.58 (0.15, 2.24)	0.427
Producers with both seedstock and commercial cow-calf	-	-	-	-
There is a genetic loss when cows infected with MAP are culled				
Veterinarians without JD certification (reference)				
Veterinarians with JD certification	1.07 (0.62, 1.84)	0.811	1.07 (0.56, 2.04)	0.832
Producers with seedstock only	5.00 (1.97, 12.67)	0.001	6.15 (1.92, 19.65)	0.002
Producers with commercial cow-calf only	1.02 (0.50, 2.07)	0.960	1.66 (0.64, 4.23)	0.291
Producers with both seedstock and commercial cow-calf	0.98 (0.41, 2.36)	0.973	2.29 (0.58, 8.96)	0.235
Higher veterinary expenses [b]				
Veterinarians without JD certification (reference)				
Veterinarians with JD certification	0.75 (0.42, 1.33)	0.325	0.76 (0.43, 1.36)	0.358
Producers with seedstock only	0.90 (0.38, 2.12)	0.810	1.00 (0.41, 2.46)	0.996
Producers with commercial cow-calf only	0.81 (0.37, 1.77)	0.595	0.79 (0.34, 1.81)	0.582
Producers with both seedstock and commercial cow-calf	5.00 (0.62, 40.41)	0.131	5.45 (0.66, 45.05)	0.115

[a]Adjusted for herd-size, infection status, and the perception of the respondent whether veterinary expense is higher for infected cows
[b]Adjusted for herd-size and infection status

Table 4: Comparison of perceptions about higher risk of diseases and conditions in *Mycobacterium avium* subsp. *paratuberculosis* infected cows reported by cow-calf producers and veterinarians

Respondent type	Odds Ratios (OR)			
	Crude		Adjusted[a]	
Mastitis	OR (95% CI)	P	OR (95% CI)	P
Veterinarians without JD certification (reference)				
Veterinarians with JD certification	1.11 (0.63, 1.97)	0.711	0.99 (0.49, 2.00)	0.985
Producers with seedstock only	0.28 (0.07, 1.07)	0.063	0.31 (0.07, 1.34)	0.120
Producers with commercial cow-calf only	0.31 (0.11, 0.89)	0.029	0.29 (0.07, 1.25)	0.098
Producers with both seedstock and commercial cow-calf	0.26 (0.05, 1.28)	0.097	0.16 (0.02, 1.53)	0.112
Pneumonia				
Veterinarians without JD certification (reference)				
Veterinarians with JD certification	1.22 (0.67, 2.20)	0.520	1.18 (0.58, 2.44)	0.639
Producers with seedstock only	0.78 (0.30, 2.04)	0.618	0.69 (0.21, 2.24)	0.539
Producers with commercial cow-calf only	1.15 (0.46, 2.83)	0.769	1.68 (0.46, 6.13)	0.426
Producers with both seedstock and commercial cow-calf	1.21 (0.36, 4.08)	0.763	0.96 (0.15, 5.93)	0.962
Lameness				
Veterinarians without JD certification (reference)				
Veterinarians with JD certification	1.93 (1.05, 3.54)	0.033	2.07 (0.96, 4.43)	0.063
Producers with seedstock only	1.63 (0.50, 5.38)	0.420	2.68 (0.67, 10.73)	0.162
Producers with commercial cow-calf only	1.49 (0.57, 3.91)	0.414	1.12 (0.25, 5.01)	0.874
Producers with both seedstock and commercial cow-calf	4.18 (1.27, 13.76)	0.019	8.30 (1.37, 50.10)	0.021
Dystocia				
Veterinarians without JD certification (reference)				
Veterinarians with JD certification	1.00 (0.55, 1.82)	0.993	1.29 (0.64, 2.60)	0.469
Producers with seedstock only	1.47 (0.52, 4.17)	0.465	1.39 (0.43, 4.57)	0.580
Producers with commercial cow-calf only	1.90 (0.81, 4.66)	0.136	1.77 (0.56, 5.62)	0.333
Producers with both seedstock and commercial cow-calf	2.10 (0.64, 6.96)	0.222	1.94 (0.35, 10.84)	0.450
Grass tetany				
Veterinarians without JD certification (reference)				
Veterinarians with JD certification	0.61 (0.28, 1.32)	0.208	0.57 (0.22, 1.44)	0.230
Producers with seedstock only	1.77 (0.55, 5.76)	0.341	1.81 (0.43, 7.60)	0.415
Producers with commercial cow-calf only	2.05 (0.80, 5.29)	0.136	1.57 (0.43, 5.68)	0.494
Producers with both seedstock and commercial cow-calf	3.72 (1.15, 12.07)	0.028	1.98 (0.36, 10.76)	0.430
Neurologic diseases				

Veterinarians without JD certification (reference)				
Veterinarians with JD certification	0.39 (0.18, 0.86)	0.020	0.31 (0.11, 0.81)	0.017
Producers with seedstock only	2.02 (0.68, 6.05)	0.207	1.13 (0.27, 4.73)	0.870
Producers with commercial cow-calf only	3.76 (1.42, 9.94)	0.008	3.56 (0.85, 14.95)	0.083
Producers with both seedstock and commercial cow-calf	1.16 (0.32, 4.12)	0.823	0.49 (0.08, 2.93)	0.435
Non-diarrheal digestive diseases				
Veterinarians without JD certification (reference)				
Veterinarians with JD certification	0.64 (0.34, 1.21)	0.170	0.55 (0.26, 1.19)	0.133
Producers with seedstock only	0.57 (0.21, 1.54)	0.268	0.40 (0.12, 1.27)	0.120
Producers with commercial cow-calf only	1.45 (0.51, 4.12)	0.486	6.98 (0.83, 58.46)	0.073
Producers with both seedstock and commercial cow-calf	1.08 (0.29, 4.09)	0.906	0.30 (0.06, 1.46)	0.136

[a]Adjusted for herd-size, infection status, and the perception of the respondent whether veterinary expense is higher for infected cows