Direct production losses from subclinical *Mycobacterium avium* subspecies *paratuberculosis* infection in Canadian dairy herds

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ABSTRACT

The objective of this study was to determine the estimate and range of annual direct production losses from *Mycobacterium avium* subspecies *paratuberculosis* (MAP) for an average, MAP-seropositive, Canadian dairy herd. A stochastic, partial budget, simulation model with four components of direct production losses (decreased milk production, premature voluntary culling, mortality and reproductive losses) was developed using @RISK software with Latin hypercube sampling. Input values were obtained primarily from a national study of 373 Canadian dairy farms in 8 of 10 provinces, with a few values coming from peer-reviewed literature. The model took into account the variability and uncertainty of the required input values and consequently produced probability distributions of the estimated losses. For an average Canadian dairy herd with 12% of 61 cows seropositive for MAP, the mean loss was CD $2,992 ($143 – $9741., 95% C.I.) annually, or CD $49 per cow per year. Additional culling losses were responsible for 46% (CD $1374) of the total losses from MAP. Decreased milk production, mortality and reproductive losses accounted for 9% (CD $254), 16% (CD $488) and 29% (CD $875) of the losses, respectively. MAP-seropositive dairy farms sustain substantial, although somewhat variable, economic costs associated with these production losses, and dairy producers should use best management practices to reduce these annual losses.

INTRODUCTION

Mycobacterium avium subspecies *paratuberculosis* (**MAP**) is a slow-growing, acid-fast bacterium causing chronic, progressive, granulomatous enteritis in domestic and exotic ruminants called Johne's disease (**JD**). Also known as paratuberculosis, JD has no known cure (Chiodini et al., 1984) and is distributed worldwide (Boelaert et al., 2000; Gasteiner et al., 1999; Muskens et al., 2000; Tiwari et al., 2005a). Dairy cattle infected with MAP have been associated with premature culling (Benedictus et al., 1987; Tiwari et al., 2005b), decreased milk production (Benedictus et al., 1987; Tiwari et al., 2005c), increased mortality (Kreeger, 1991), and decreased reproductive efficiency (Johnson-Ifearulundu et al., 2000).

Costs due to reduced productivity have been estimated to be as high as US$200 per cow per year in herds where the prevalence of clinical cases among culled cows was $\geq$10% (Ott et al., 1999). In a Canadian study, the annual costs for MAP were estimated at CD$2472 per infected herd (having at least two seropositive cows) using an average herd size of 50 cows (Chi et al., 2002). However, for the following reasons, additional research on the economic costs of MAP infection is still needed, particularly in a large number of representative farms, using analyses that adjust for variations in productivity estimates. First, the study population has frequently been based on a small number of herds that may not have been representative of the wide diversity of herds in the dairy industry and their differences in management or seroprevalence (Benedictus et al., 1987; Chi et al., 2002). Also, estimation methods have utilized either regression or direct multiplication of the estimated prevalence with costs of effects, rather than stochastic methods, so that the interpretation of these estimates is limited to individual herds (Benedictus et al., 1987; Ott et al., 1999).

The objective of this study was to determine the estimate and range of annual direct production losses for an average Canadian dairy herd infected with MAP, utilizing Canadian estimates of MAP seroprevalence and distributions of impacts of subclinical MAP infection. Results will greatly benefit a newly launched national Johne's disease control program in Canada.

METHODS AND RESULTS

A stochastic, partial budget, simulation model, adapted from Bennett et al. (1999) and Chi et al. (2002), was used in this study and included the impacts of MAP infection on milk yield, additional mortality, additional culling and reproductive losses. Input values were obtained primarily from a national study of 373 Canadian dairy farms in 8 of 10 provinces, with a few values coming from peer-reviewed literature. The model took into account the variability and uncertainty of the required input values and consequently produced probability distributions of the estimated losses.

Data for the seroprevalence of MAP were obtained from a stratified two-stage random sample of 373 herds in 8 Canadian Provinces (Tiwari et al., 2005a). Overall, 3.1% (2.3-3.8, 95% C.I.) of dairy cattle had positive tests for antibodies against MAP. The mode of the within-herd seroprevalence in herds having at least two MAP-seropositive cows was set at 6%, with 95% of the values being less than 33.3%. Consequently, a beta distribution (• =1.5488, • =9.5973) was utilized for estimating the range of infected herd losses.

An interaction was found between MAP-seropositivity and lactation number (Tiwari et al., 2005c), with a statistically significant reduction in milk yield being observed only in 4^{th} or higher lactation animals. This effect (loss of 212 kg (S.E. 106) in a 305 day lactation) would represent 2.34% (S.E. 1.18%) of the average yield used in this study. A triangular distribution (minimum=0.20, most likely=0.25 and maximum=0.30) was utilized for the proportion of 4 plus lactation animals in a herd (Tiwari et al., 2005a). Total herd milk losses were estimated by multiplying together the herd size, within herd seroprevalence of infection, losses associated with 4 plus lactation animals and the proportion of animals in this parity group.

The percentage of increased mortality risk in affected cattle was assumed to have normal distribution with • = 0.0315 and • = 0.015 (Johnson-Ifearulundu et al., 1999). The excess culling risk for infected cattle was assumed to have a normal distribution with • = 0.109 and • = 0.04 (Tiwari et al., 2005b). In the end, the increased calving interval (days) was assumed to have a normal distribution with • = 27.9 and • = 11.4 (Johnson-Ifearulundu et al., 2000). The other values assigned by authors included: 1) replacement cost of a cow (triangular distribution, min.= $1,500, max. = $2,500, most likely = $2,000 per head); 2) slaughter value of healthy cull cattle ($ per head) (triangular distribution, min=300, most likely=500, max=700); 3) percentage of affected cattle with reduced slaughter value (triangular distribution, min=0.2, most likely=0.25, max=0.3); and 4) increased calving interval cost ($/day) (Min=2.5, most likely=4.37, max=6.25).

To estimate the average losses for the Canadian dairy industry, a herd size of 100 cows was used and losses were expressed as being "per cow". For estimating the range of possible losses at the level of the individual infected herd, the average size of a Canadian dairy herd, as reported by Dairy Farmers of Canada in 2002 (n=61 cows), was used. The average milk production per cow per 305-day lactation (9,519 litres) and average milk price ($0.59/liter) were obtained from the Canadian Dairy Information Centre. Herd sizes, production level, and milk price were all treated as fixed values so that all estimates of MAP-associated losses were independent of differences in those parameters across herds.

The stochastic simulation model, which combined the above reported values into an overall estimate of the MAP-associated losses, was developed using @RISK (2002) (Version 4.5.2, Palisade Corporation) with Latin hypercube sampling and 10,000 iterations for each analysis. A sensitivity analysis was carried out on key parameters. The sensitivity analysis involved a re-analysis of the data, but utilizing expected values that were either 10% lower or 10% higher than estimated for each of the following parameters: seroprevalence, reduction in milk yield, risk difference for mortality, risk difference for culling, and difference in calving interval.

For an average, Canadian, MAP–seropositive, dairy herd, the mean loss per 61 cows was estimated to be $2992 (143-9741, 95%C.I.) annually ($49 per cow or $409 per seropositive cow per year), assuming an average within herd seroprevalence of 12%.. Additional culling losses were responsible for 46% (CD $1374, 46-4833; 95% C.I.) of the total herd losses from MAP. Decreased milk production, mortality and reproductive losses accounted for 9% (CD $254, 0.5-975; 95% C.I.), 16% (CD $488, 5-1828; 95% C.I.) and 29% (CD $875 23-3259; 95% C.I.) of the total herd losses, respectively. The results from the sensitivity analyses with the 10% changes in input estimates suggested that the changes in MAP-seroprevalence lead to the largest difference in the overall estimate of economic impact, from CD $2992 to CD $2691 and CD $3289, respectively, for a MAP-seropositive herd.

CONCLUSIONS

For an average Canadian dairy herd with 12% of 61 cows seropositive for MAP, the mean loss was nearly CD $3000 annually, or nearly CD $50 per cow per year. Additional culling losses were responsible for nearly half of the total losses from MAP. Decreased milk production, mortality and reproductive losses accounted for approximately 1/10, 1/6, and 1/3 of the losses, respectively, with MAP seroprevalence being the most influential parameter in the sensitivity analysis. MAP-seropositive dairy farms sustain substantial, although somewhat variable, economic costs associated with these production losses, and dairy producers should use best management practices to reduce these annual losses.

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ACKNOWLEDGEMENTS

Funding sources: Dairy Farmers of Canada, Quebec, Ontario, and PEI, provincial Depts. of Agriculture, Dairy Herd Improvement companies, Canadian Food Inspection Agency, Production Limiting Diseases Committee, PEI Agricultural Research Investment Fund, Western Economic Partnership Agreement