Farm economic impacts of bovine Johne's disease in endemically infected Australian dairy herds

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Objective To determine the farm economic impact of bovine Johne's disease (BJD) infection and controls in commercial Victorian dairy herds.

Design Benefit-cost analysis of BJD and various control methods in a Victorian dairy herd.

Results Farm losses from BJD occurred from clinical disease. Clinical cases occur on average in 5-year-old cows, resulting in losses of A$1895 in the year of culling and A$221 in the year preceding culling, giving a total loss of A$2116. Early removal also resulted in loss of future profit equating to A$375 per year. This is the annualised value of foregone future income and costs expressed as a net present value (NPV). The total loss from removal of a clinical case was estimated as A$2491. The average clinical incidence in infected dairy herds prior to entry into the Victorian Bovine Johne's Test-and-Control Program (TCP) was 1.8% and the average Victorian dairy herd size was 262 cows in 2013–14, resulting in annual losses of 4.7 clinical cases if infected and implementing no BJD control. Farm annual loss of profit was estimated as A$11,748 ($44.84 per cow/year). Control of BJD using vaccination, test-and-cull or combined approaches was economical but the cost of implementation in initial years would exceed disease costs. Vaccination-based control provided minimal long-term losses and was the most cost-effective control over a 10-year planning horizon.

Conclusion Endemic BJD resulted in modest but persistent losses in typical infected dairy herds. Control of disease using test-and-cull, vaccination or combined test-and-cull with vaccination was cost-effective.

Keywords bovine Johne's disease; dairy cattle; economics; modelling

Abbreviations AHA, Animal Health Australia; BJD, bovine Johne's disease; DFMP, Dairy Farm Monitor Project; FCP, faecal culture-positive; MAP, *Mycobacterium paratuberculosis* subsp. *avium*; NPV, net present value; TCP, test-and-control program

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The management of Johne's disease (JD) in Australia is under review and national deregulation may be an outcome – now or in the future. Deregulation of JD control would place the onus for disease control with producers and their supply chain and this would effectively reclassify JD as a production disease. Farmers would be free to choose to decide if and how to control JD, manage the risk of JD introduction, and/or adapt their enterprise and marketing to meet supply chain JD requirements. It is important to inform decision making by providing information on the effect of uncontrolled JD in herds, as well as the expected effectiveness, timeliness and cost and benefits of voluntary control program options. This can then be compared with the expected costs, benefits and outcomes from other potential uses of the same farm resources (finance, time, labour etc.) if directed towards other farm problems or even off farm. The expected cost of uncontrolled JD in an infected herd provides part of the required information; that is, the maximum benefit returned should an infected herd spontaneously eradicate disease. However, not all of the maximum benefit is recoverable in herds that undertake active controls, because control measures cost and some disease would most likely persist despite control.

Information on the cost of disease in Australian cattle herds infected with bovine JD (BJD) is incomplete. Although the economic impact of BJD in beef cattle herds in Australia was reported in 2012,[1] there has been no economic assessment of BJD in commercial dairy herds for the past 20 years. This report presents an estimate of the farm cost of BJD in endemically infected dairy herds and the costs and benefits of various BJD controls using vaccination, test-and-cull or combined test-and-cull and vaccination as alternatives to managing BJD in dairy herds under expected levels of effectiveness.

BJD in Australia

The majority of BJD in Australia is caused by infection of cattle with the cattle-adapted strain of *Mycobacterium paratuberculosis* subsp. *avium* (MAP).[2] Approximately 1150 Australian cattle herds are classified as infected with BJD.[3] There are also a large number of dairy herds of suspect or unknown disease status (the true prevalence of infected dairy herds most likely exceeds 50% in the intensive southern dairying regions), suggesting that more herds are infected than are known to be classified. Infection occurs rarely in beef herds, with disease mostly identified in beef herds having close contact with infected dairy cattle.[1] The highest herd prevalence occurs in the major dairying states of Victoria and Tasmania, but disease is also common in the (smaller) dairy sectors of New South Wales and South Australia. Elsewhere infection is absent or occurs rarely.[3] A recent trace forward of purchases from a bison strain-infected Queensland beef stud identified a number of trace-forward contact beef herds spread throughout the northern Australian beef industry where disease eradication plans in these herds are underway.

Key aspects of BJD epidemiology

JD is a complex disease that is difficult to manage because spread can occur by faecal–oral, milk and in utero routes.[2,4,5] Disease

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generally follows a long incubation period and the organism can survive for extended periods in the environment.[6] Diagnostic tests have low sensitivity, especially in the early stages of the disease. The within-herd prevalence is typically low in cattle.[7] Practically, this means that the majority of farmers do not know precisely how or when infection first entered their herd and this obscures the full economic impact of the disease.

Control programs in Australia have to date focused on removing infection from the herd using individual animal testing and culling (test-and-cull) combined with systems to reduce exposure of high-risk animals to infection (typically by removing calves and isolating them from their mothers and other adults). Some countries combine these controls with vaccination to increase the resistance of exposed animals to infection. Although individual animal testing can identify some infected animals, it is essentially ineffective at identifying all latent and subclinical animals. Undetected animals allow herds to remain infected by contaminating the environment (infectious faeces), maintaining indirect transmission pathways to other animals and the direct transmission to calves in utero or through the milk. It is increasingly difficult to effectively isolate young stock from all sources of bacteria and routes of infection, especially as herd sizes increase. A recent development in Australian BJD control is the availability of a vaccine. Vaccination provides incomplete immunity and cannot be administered to newborn calves, making it unable to directly prevent in utero or milk-borne transmission. Vaccination, like other control methods, may not eliminate disease but may help reduce disease in infected herds.

Farm economic impacts of BJD

BJD has a direct economic effect in infected herds. This can be separated from and estimated in isolation from the effects of regulatory programs such as livestock sale restriction, thereby providing a more realistic estimate of the economic effect of the disease in a deregulated environment. Although infection can remain subclinical for the productive life of many infected animals, a proportion will go on to develop clinical disease, resulting in loss of production and profit and premature removal from the herd. Progression of clinical disease is associated with declining production and weight loss, poor reproductive performance and increased clinical symptoms and high mortality rates.[8,9]

Analysis of the Victorian BJD Test-and-Control Program (TCP) data identified the average annual incidence of clinical cases on infected farms in the year immediately preceding entry into the TCP as 1.8% of milking cows and the average age of a clinical case at removal was 5.9 years. The clinical disease incidence in TCP herds was increasing in the years immediately preceding enrolment, implying that if disease had remained unmanaged in these herds the incidence of clinical disease would most likely have exceeded 2.0% of milking cows per annum. Using a BJD computer simulation model of disease in a seasonally-calving Victorian dairy herd, the long-term average steady-state annual clinical incidence was predicted to be 2.6% of milking cows per year. This model was validated using recent industry reproductive performance data[10] and the BJD sub-model was in turn validated by comparing predicted ELISA test reactor and clinical case rates and average ages against observed rates and ages from the Victorian TCP database.[11] Both the TCP data and BJD simulation model identified the typical clinical case to be a 5-year-old cow during its third lactation. The removal of a clinical cow during its 5th year of life (i.e. during its third lactation) results in losses from early termination of the current lactation, lost cull value and also lost future profit from missed future lactations as well as decreased production and profit in the year preceding clinical disease (subclinical losses). An annual premature loss rate of 2–3% of the lactating herd as 5-year-old animals potentially may represent a significant loss of profit.

Losses from BJD occur only in the clinical and (late) subclinical stages of the disease.[8,9] Latently-infected animals are assumed to represent neither physical nor financial loss. Early removal of an animal is in economic terms the premature loss of an item of capital[12] and this results in both reduced return on capital (less income and an altered expenditure stream) and of capital (reinvestment to replace the animal capital required earlier than if the animal did not have the disease). The total reduction in return on capital and return of capital across the reduced lifespan of the capital must therefore be estimated to quantify total economic losses arising from premature removal.

In this study we estimated the average annual costs of BJD in an infected commercial dairy herd operating in a non-regulated environment. The costs and benefits of vaccination, test-and-cull and combined vaccination and test-and-cull management controls for BJD were also examined to determine if control is an economically viable option in a deregulated, user-pays environment and to identify the most effective control option.

Materials and methods

Economic framework

The annual physical and economic performance of a herd in a steady state and free of BJD was estimated and compared with the performance of a herd with endemic BJD and undertaking no control measures. The difference in performance between the herd without disease and the herd with disease represents the total loss of profit that can be assigned to the (uncontrolled) disease. Current losses of profit arise from lost milk income in late subclinical cows and lost sale value of culled clinical cows. Breakdown into clinical disease is typically precipitated by stress such that most clinical cases are identified in the period shortly after calving; therefore, we have assumed that all the lactation income is lost in the year of clinical disease as well as the loss of cull cow income. These losses are partly offset by (total) reductions in feed and herd costs of the removed cows. We have also assumed that any replacement of prematurely lost cows only occurs for the following calving season (via purchase of a pregnant cow). Lost future profits arising from early removal of clinical cases also arise from lost future net milk income because of premature culling. These accrue across a number of years following removal of a clinical case.

The total future loss arising from premature removal of a clinical case depends in part on the expected lifespan of the cow if not diseased. A cow (a capital item) that lasts a number of years will return more lifetime profit than a cow that lasts for a shorter time. This results from a combination of a lower rate of annual depreciation of longer-lived cows and, as is often the case with livestock, improved profitability of the cow in middle age where production peaks and survival rates are high. The net income foregone in the future from a lost BJD-infected cow, and additional and early capital expenditure on the replacement, must be estimated. These two alternatives (without disease and with disease) provide different streams of costs and benefits into the future. These costs and benefits are converted into net present values (NPV), using a discount factor of 10% that represents the alternative earning capacity of the capital involved. The NPV is the discounted sum of future income and expenditure from the capital item across it working life.[12]

The NPV represents the total future profit in today's dollars that is foregone, expressed in equivalent current dollar values. This estimate of lost profits is converted into an annuity that is a constant amount that if received each year for the time over which the NPV was calculated totals to the NPV. Annuity values represent the annual return on capital and return of capital. This annuity approach allows assets with different lifespans and different income and expenditure patterns and horizons to be compared on the basis of annual performance.[12] Differences in the annuity values that are equivalent to the streams of cash flow over the life of two capital items (e.g. a cow lost prematurely as a result of clinical BJD and a non-diseased herd mate) reflect the annual loss that can be attributed to the defective capital item.

Economic estimates

A clinical case of BJD resulting in premature loss of the milking cow requires estimation of the reduction in profit in the current year (clinical disease), and the reduction in profit for the preceding lactation (late subclinical disease), as well as lost cull cow income (clinical cases cannot be sold for human consumption and are destroyed) and lost future profit arising from premature removal and replacement. Every milking cow that is lost from the herd, whether prematurely from disease or naturally after a long productive life, must be replaced on removal for the herd to remain at a constant size and production level. Replacement of a culled cow is by the introduction of a heifer (home-grown or purchased) and this capital replacement cost is the final cost in the stream of income and expenditure over the lifetime of a cow.

The expected actual lifetime profit of a cow was estimated by combining age-specific factors such as annual survival rates, predicted milk production and income, cull values and rearing, health and feed costs, as well as the replacement costs at disposal. The lifetime annual income and cost streams were calculated for a typical cow free of BJD and also for a typical cow with BJD that subsequently develops clinical disease. The estimates of the stream of annual income and costs for the lifetime of both cows were converted to their NPVs. These NPVs were then converted to their equivalent streams of annuities. The difference between the annuities of a without-disease cow and a with-disease cow represents the annual loss from clinical disease in an animal that has or will break down with clinical JD. This difference in annuity values can be multiplied by the expected number of animals in the herd at steady state that are predicted to break down with clinical disease per year to estimate total herd annual losses from uncontrolled BJD.

The income and expenditure streams of age cohorts within a typical Victorian dairy herd were estimated by expanding the physical and financial performance estimates for an average Victorian dairy farm in the 2013–14 financial year as reported in the Dairy Farm Monitor Project (DFMP).[13] This project collates standardised herd-level physical and financial data of 75 volunteer Victorian dairy farms each year to allow long-term farm performance benchmarking and monitoring. Expansion into age-cohort production and financial performance estimates was possible by combining industry cow age-cohort production and milk composition performances obtained from the Australian Dairy Herd Improvement Scheme,[14] with cow age-cohort lactation survival probabilities obtained by querying the extensive HiCo herd recording database (MISTRO™; www.mistro.ag). Cow age-cohort survival probabilities were calculated for farms using MISTRO™ for herd records and located in the Macalister Irrigation District of Gippsland, Victoria. The monetary values used in the analysis are 2103–14 Australian dollars and the opportunity cost discount rate used is a real 10% per annum. Annual rearing costs for replacement calves and yearlings of $400 and $500, respectively, were used. A bull calf was valued at $35 at 1 week of age, a heifer calf at $500, a replacement pregnant cow at $1500 and a cull cow at $550, with 75% of removed adult animals being sold for meat.

Annual prevalence and clinical disease rates were obtained from a detailed analysis of the Victorian BJD TCP.[7] This was a dataset of more than 680,000 animals from more than 550 herds participating in the then compulsory BJD management program in the years 1992–2002. Importantly, this included the clinical data from a significant proportion of herds in the years directly preceding their enrolment into the TCP, thereby allowing estimation of the clinical case rate and the average age of clinical breakdown in herds before the introduction of any BJD controls. These estimates of steady-state clinical disease incidence and age were supplemented with estimates obtained from a stochastic individual-cow computer simulation model of BJD within Victorian dairy herds that was in turn validated against the comprehensive TCP longitudinal data.[11]

Control scenarios

The effectiveness and costs and benefits of vaccination, test-and-cull and combined vaccination and test-and-cull controls for BJD were specifically evaluated under a user-pays system. The test-and-cull scenario mirrored the Victorian TCP1 program consisting of annual ELISA testing of all adults, with culling of reactors, immediate culling of clinical cases, preferential culling of high-risk contact animals, use of dedicated calf paddocks to ensure separation of calves from adults for a minimum of 12 months, and regular veterinary inspection and audits. The program was assumed to return 1.0% reactor rate each year but to reduce the incidence of clinical disease to 1 animal per year in a 262-cow herd (an annual incidence of 0.4%). Clinical disease rates reduced to this minimum after 3 years. Reactors were allowed to complete their lactation and to be sold for slaughter on termination. The cost of testing was assumed at $20.00 per ELISA test and including veterinary labour, laboratory and follow-up costs. The modelled performance mirrored actual performance of TCP1 over the period 1992–2002.[7]

The vaccination scenario entailed vaccination of all replacement calves during the first month of life and any purchased replacement with a single-shot vaccine. No ELISA testing or culling of reactors and no use of dedicated calf paddocks were assumed. Vaccination was also assumed to reduce clinical disease to 1 animal per year in a 262-cow herd (0.4% incidence). The rate of reduction in clinical cases was assumed to be slower than for ELISA testing with the minimum (baseline) rate of clinical cases attained after 7 years of vaccinating. Vaccine was costed at $35 per dose and including veterinary labour, administration and purchase costs. Vaccination efficacy was conservatively based around observations of clinical breakdown rates in monitored vaccinated animals in herds whose managers switched to vaccination instead of remaining in the Victorian TCP.

The combined test-and-cull and vaccination control program included 2 years of initial ELISA testing with concurrent and ongoing vaccination of calves. The test-and-cull component ceased when the first vaccinated animal attained 2 years of age (vaccination may result in false-positive ELISA test results). The combined scenario was also assumed to reduce clinical disease to 0.4% of cows at steady state.

An Excel™ (Microsoft Corp., Redmond, WA, USA) spreadsheet was constructed to calculate herd annual production, survival, income and costs for an average cow without BJD and for a cow with BJD that develops clinical disease resulting in premature culling. The total value of annual current losses in clinical cases was combined with the summed annuity difference between disease-free and clinically affected animals in cows destined to break down with clinical disease. This final total represents the total farm annual losses from BJD in an endemically infected average Victorian dairy herd that undertakes no BJD control. Costs and benefits estimates comparing BJD control options were evaluated across a 10-year horizon.

Results

Collated physical, financial and survival averages for the average dairy herd participant in the Victorian DFMP of 2013–14 are presented in Table 1. The age-cohort survival and production estimates for a typical Victorian dairy herd, produced by the model, are presented in Table 2. Age-specific survival, production, income and cost averages were expanded to estimate the performance for a 335-cow dairy herd in Victoria (this was the average herd size of the 75 Victorian dairy farms participating in the DFMP). The actual and age-cohort predicted herd production, income and costs and the level of agreement between actual and age-cohort predicted parameters for a 335-cow Victorian dairy herd are presented in Table 3. All individual predicted parameter estimates were within 2.0% of actual values and the overall gross margin estimation error was less than 0.5%.

Estimated age-specific incomes, costs, gross margins and cumulative gross margins are presented in Table 4. These data estimated the loss of profit in cows that develop clinical disease in the lactation immediately preceding breakdown (14% reduction in milk income and feed costs) as $221. Total current losses in the year of clinical disease and removal were estimated as $1895 per case and the total value of current losses in cows removed because of clinical disease was estimated as $2116 per case. The components of the estimated loss arising from the premature removal of a clinical case in a Victorian dairy herd are presented in Table 5.

The average newborn heifer calf at birth that experiences an average productive life and does not succumb to clinical BJD has a NPV of $4400 at birth, equating to an annuity value of $646 per annum across its productive lifespan. A newborn heifer calf that becomes infected with BJD and later develops clinical disease has a NPV for its shortened life of $1179 at birth and an annuity value of $271 for

Table 1. **Victorian Dairy Farm Monitor Project average herd physical and financial performance data from 75 participating Victorian dairy herds in 2013–14[13]**

Level	Parameter	Value
Farm	Cows (milking)	335
	Milk production (kg solids)	171,786
	Milk income ($)	1,186,861
	Livestock income ($)	75,797
	Other income ($)	41,690
	Feed costs ($)	519,369
	Herd & dairy costs ($)	86,197
Cow	Milk production (kg solids)	513
	Milk income ($)	3543
	Livestock income ($)	226
	Other income ($)	124
	Feed costs ($)	1550
	Herd & dairy costs ($)	257
Production	Milk price ($/kg milk solids)	6.91
	Feed costs ($/kg milk solids)	3.02

All monetary data in Australian dollars.

Table 2. **Modelled age-cohort survival and production for cows in an average Victorian dairy herd in 2013–14**

Age (years)	Cohort conditional survival	Cumulative survival	Annual litres	Annual milk solids (kg)
1	0.98	0.98	–	–
2	0.98	0.96	–	–
3	0.80	0.77	6044	443
4	0.85	0.65	6658	488
5	0.90	0.59	7258	532
6	0.90	0.53	7872	577
7	0.90	0.48	7872	577
8	0.80	0.38	7258	532
9	0.80	0.30	7258	532
10	0.70	0.21	6658	488
11	0.70	0.15	6658	488
12	0.00	0.00	6044	443
Total (lifetime)			58,145	4262
Av. (lactation)			6980	512

each year of (shortened) life. This is a NPV difference of $3221 and an annuity difference of $375 per annum between unaffected and clinically affected animals. The total loss of potential profit for a clinical cow lost at 5 years of age was estimated at $2491, comprising $2116 of current losses and $375 of (annualised) lost future profit.

The average Victorian dairy herd in 2013–14 milked 262 cows.[15] Assuming a BJD clinical incidence of 1.8% (this was the pre-enrolment annual clinical incidence for Victorian TCP herds[16]) in infected herds that do not control BJD, we can expect an average of 4.7 clinical cases each year. This estimates the annual losses for the typical endemically infected 262-cow herd undertaking no control against BJD as $11,748 per annum ($44.84 per milking cow per year). If the clinical incidence rate was 2.6% (as predicted by simulation modelling) an average of 6.8 clinical cases per year would be expected. The estimated annual losses for this scenario were $16,970 ($64.77 per milking cow per year). Estimated annual farm losses for a range of herd sizes and clinical BJD incidence are presented in Table 6.

The estimated annual losses and the 10-year NPV of losses for uncontrolled BJD, vaccination, test-and-cull and combined vaccination and test-and-cull control scenarios were modelled and the results are presented in Table 7.

Table 3. **Actual and age-cohort modelled herd production, income, cost and profit estimates for an average Victorian dairy herd in 2013–14**

Parameter	Actual (DFMP)	Modelled	Error (%)
Milk production (kg milk solids)	171,207	171,786	0.34
Milk income ($)	1,183,041	1,186,861	0.32
Livestock income ($)	76,609	75,797	−1.06
Other income ($)	41,690	41,690	0.00
Total income ($)	1,301,339	1,304,348	0.23
Herd & shed costs ($)	87,100	86,197	−1.04
Feed costs ($)	513,621	519,369	1.12
Total costs ($)	600,721	605,566	0.81
Gross margin ($)	700,618	698,782	−0.26

All monetary data in Australian dollars.
DFMP, Dairy Farm Monitor Project.

Table 5. **Survival-adjusted age-cohort gross margin ($), lifetime net present value (NPV, $) and annuity ($) estimates for animals that develop clinical bovine Johne's disease (BJD) and animals that do not during their lifetime in a typical infected Victorian dairy herd taking no specific disease management action**

Lactation	Age (years)	BJD	No BJD	Difference
1	2	−400	−400	–
2	3	−445	−445	–
3	4	1698	1698	–
4	5	1249	1470	221
5	6	−352	1345	1697
6	7	–	1313	1313
7	8	–	1181	1181
8	9	–	1007	1007
9	10	–	805	805
10	11	–	608	608
11	12	–	−1074	−1074
	Term			
	NPV	1179	4400	3221
	Annuity	271	646	375

All monetary data in Australian dollars.

Table 4. **Modelled age-cohort cost, income and gross margin for a typical non-BJD-infected cow in an average Victorian dairy herd in 2013–14**

Age (years)	Milk income ($)	Livestock income ($)	Total income ($)	Feed costs ($)	Herd costs ($)	Total variable costs ($)	Gross margin ($)	Cumulative GM ($)
1	–	–	–	100	300	400	−400	−400
2	–	42	45	123	368	490	−445	−845
3	2943	198	3168	1278	192	1470	1698	853
4	2590	143	2749	1124	154	1278	1470	2324
5	2401	108	2518	1043	131	1173	1345	3669
6	2341	97	2447	1017	118	1134	1313	4981
7	2107	87	2202	915	106	121	1181	6163
8	1751	98	1862	760	95	855	1007	7169
9	1401	79	1490	608	76	684	805	7975
10	1027	75	1115	446	61	507	608	8583
11	719	53	781	312	43	355	426	9009
12	458	80	558	199	30	228	330	9339
Total	17,738	1062	18,934	7923	1672	9595	9339	–

All monetary data in Australian dollars.
BJD, bovine Johne's disease.

Table 6. Net present value (NPV, $) of estimated herd losses and average loss per milking cow from bovine Johne's disease (BJD) in Victorian dairy herds of varying size and clinical disease incidence

Herd size	BJD clinical prevalence					
	0.50%	1.00%	1.50%	2.00%	2.50%	3.00%
200	2382	4763	7145	9527	11,909	14,290
300	3573	7145	10,718	14,290	17,863	21,435
400	4763	9527	14,290	19,054	23,817	28,581
500	5954	11,909	17,863	23,817	29,771	35,726
600	7145	14,290	21,435	28,581	35,726	42,871
700	8336	16,672	25,008	33,344	41,680	50,016
800	9527	19,054	28,581	38,107	47,634	57,161
900	10,718	21,435	32,153	42,871	53,588	64,306
1000	11,909	23,817	35,726	47,634	59,543	71,451
Average annual cost ($/cow)	11.91	23.82	35.73	47.63	59.54	71.45

All monetary data in Australian dollars.

Table 7. Net present value (NPV, $) estimates from partial budgets assessing costs and benefits of various strategies for the management of bovine Johne's disease in a commercial dairy herd of 262 cows

Year	Uncontrolled		Vaccination only		Test-and-cull			Test-and-cull (2 years) + Vaccination		
	Clin. prev. (% pa)	Loss ($/pa)	Clin. prev. (% pa)	Loss ($ pa)	Clin. prev. (% pa)	React. prev. (% pa)	Loss ($/pa)	Clin. prev. (% pa)	React. prev. (% pa)	Loss ($/pa)
1	1.80	11,749	1.80	14,041	1.80	1.00	17,698	1.80	1.00	19,991
2	1.80	11,749	1.60	12,736	1.33	1.00	14,652	1.33	1.00	16,945
3	1.80	11,749	1.40	11,430	0.87	1.00	11,606	1.13	0.00	9690
4	1.80	11,749	1.20	10,125	0.40	1.00	8560	0.93	0.00	8384
5	1.80	11,749	1.00	8820	0.40	1.00	8560	0.73	0.00	7079
6	1.80	11,749	0.80	7514	0.40	1.00	8560	0.53	0.00	5774
7	1.80	11,749	0.60	6209	0.40	1.00	8560	0.40	0.00	4903
8	1.80	11,749	0.40	4903	0.40	1.00	8560	0.40	0.00	4903
9	1.80	11,749	0.40	4903	0.40	1.00	8560	0.40	0.00	4903
10	1.80	11,749	0.40	4903	0.40	1.00	8560	0.40	0.00	4903
NPV ($)		72,191		57,955			68,229			61,612

All monetary data in Australian dollars. Clin. prev., prevalence of clinical disease; pa, per annum; React. prev., prevalence of seroreactors.

Discussion

MAP is a well-adapted pathogen because infection does not result in a dramatic change to herd composition; that is, not all animals in a herd become infected and not all infected animals survive long enough within a commercial herd to develop clinical disease. Herd survival (and therefore pathogen survival) is not threatened. Infection of individuals within a herd occurs at an incidence sufficient to sustain the disease and bacterial production, and hence environmental contamination, by shedders is copious. This results in persistence of the organism within the environment and thus the herd. Eradication is very difficult and the physical and financial losses caused by BJD are moderate in most cattle herds. Disease-induced losses alone are unlikely to threaten to the financial viability of most commercial producers. A tangible loss of profit of the order of $12,00–17,000 per year arising from the premature removal of clinical cases can be expected for the average-sized and infected Victorian dairy herd undertaking no effective control of BJD.

A 2009 study in the USA found that faecal culture-positive (FCP) animals that completed their lactation provided 14% lower milk income and were 3-fold more likely to be culled than culture-negative herd mates on completion of the lactation. Culled FCP cows also returned US$441 less than non-FCP herd mates because of differences in carcase condemnation rates, bodyweights and age between the two groups.[8] Other studies have found an association between BJD and the average live weight of cull cows and also the cow mortality rate. A 10% increase in the proportion of cows testing positive to a BJD blood test was associated with a 33.4-kg reduction in the mean weight of cull animals. Herds with one or more positive BJD blood tests from a random sample of cows had 3.0% higher cow mortality than herds in which all tested cows from a random sample returned a negative test result.[9,17] These findings support the loss assumptions of the current work.

A 2012 economic analysis of the financial effects of BJD in beef cattle herds in Australia found that control of BJD was not cost-effective for most infected beef herds.[1] Annual mortality rates had to exceed 1.0% per annum with a 10% discount on price received for cattle sales required to justify destocking-based eradication program. The prevalence of infected herds and the within-herd prevalence of BJD in infected dairy herds is greater than occurs in the beef industry[1,7,16] and the production and profit of dairy cows is significantly different to beef herds, preventing valid extension of the conclusions of the 2012 beef study to Australian dairy herds.

In 1994, the (then) Victorian Department of Agriculture estimated the economic impact of BJD at farm level for both infected Victorian dairy and beef farms using a whole-farm computer model.[18] A partial-budget economic model across a 15-year horizon captured losses arising from premature removal of animals and reduced production. Importantly, regulatory-based losses such as those arising from livestock movement restrictions were included in the 1994 projection. The 1994 model estimated the enterprise losses arising from a single clinical case of BJD to be $1803 for an average Victorian dairy herd in 1994,[18] which equates to $3307 (exclusive of the goods and service tax) per clinical case in 2014 after adjusting for inflation since 1994.[19] The estimated NPV for a clinical case of BJD in an average 5-year-old cow in the current study of $2491 is less than the inflation-adjusted 1994 NPV estimate from the previous Victorian study. Differences arise because the 1994 study included regulatory effects whereas these were excluded in the current study and per cow production has also increased on Victorian dairy farm in the time between the two studies (ADHIS reports indicate that average lactation production has increased by more than 17% between 2002 and 2013[14,20]). The close fit between age-cohort based income and cost streams with herd-level and cow-level physical and financial data observed in the current study suggested that the current study was reflective of current physical and financial performance of Victorian dairy herds.

The BJD-status and within-herd prevalence of contributing farms in the DFMP is unknown and there is potential for bias in the cost estimates obtained from that work and used in the current study. The effect of existing BJD on the physical and financial performance estimates for cow age-cohorts is, however, likely to be small, suggesting minimal actual bias. It is unlikely that all monitor farms were infected and a proportion of infected farms will be or have been participants in the Victorian BJD TCP and therefore likely to have a very low clinical incidence. Any bias in age-cohort estimates is expected to be 1% or less as a result. This is not expected to invalidate the conclusions drawn from the current study.

The vaccination-alone program minimised losses under the performance assumptions, providing the smallest NPV for disease loss across the 10-year horizon. Vaccination, and the vaccination-only component of the combined control program, also resulted in the smallest annual steady-state loss from disease; annual losses stabilised at approximately $4900 per annum after 7 years with the combined control and after 8 years with the vaccination-only control. Test-and-cull resulted in the most rapid reduction in clinical disease and therefore the earliest minimisation of annual losses (≈$8500 per annum after 4 years); however, this steady-state loss was higher than the steady-state loss under vaccination-based controls because of ongoing premature loss of reactor cows from the herd. All three controls resulted in an increase in annual loss over uncontrolled BJD in the early years of the program, representing the combined effect of extra costs for the control and the minimal reduction in the clinical disease rate in the early years. Vaccination-based controls provided for the minimal annual losses in the long term. Test-and-cull control provided for ongoing removal of reactors and this premature loss of productive cows resulted in a higher average loss than with vaccination-based control. The vaccination-alone control was the most cost-effective strategy over a 10-year horizon from first implementation. Test-and-cull resulted in the fastest reduction in clinical cases and although the combined control reverts to solely vaccination-based protection after 2 years the cost of testing and accrued losses from premature removal of (productive) reactors from the herd made vaccination-alone the most cost-effective over the 10-year horizon under the performance assumptions. It should be noted that although all control methods were more cost-effective than no control, all resulted in increased losses in the early years of implementation. This transient increase in cost should be part of the consideration of farmers in their decision making to control the disease. Published estimates of BJD vaccine performance in commercial Australian dairy herds from controlled studies conducted across long time horizons (i.e. the expected maximum lifespan of a cow) are required and necessary to confirm or modify the vaccination scenario economic findings.

Endemic BJD resulted in modest but persistent losses in typical infected dairy herds. Control of disease using test-and-cull, vaccination or combined test-and-cull with vaccination were all profitable. Vaccination (alone) appeared to be the most profitable option over the longer term. If BJD control is deregulated, farmers can decide whether to control BJD in their herd and if they decide to control disease to choose a control strategy from an informed position.

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