Control Programs for Johne's Disease

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■ Take Home Message

General

‣ Because of concern about an apparent increasing in prevalence and economic losses of Johne's disease and a possible role of *Mycobacterium avium* subsp. *paratuberculosis* (*Map*) in some cases of Crohn's disease in humans, there is an increased demand for effective and economically attractive control programs against Johne's disease;

‣ Field studies on Johne's disease control programs are necessary, but are often very expensive and time consuming. Risk analysis and simulation studies provide useful tools to support decision-making in the development and improvement Johne's disease control programs.

Johne's Disease Infected Farms

‣ The majority of the losses by Johne's Disease are caused by premature (not optimal) culling of infected animals;

‣ Test-and-cull programs alone do not reduce the Johne's disease prevalence and are on average economically unattractive;

‣ Improved calf hygiene, focused on separation of calves and adult animals, can effectively reduce the prevalence and for an average infected dairy farm provides economic benefits;

‣ Vaccination reduces the losses of Johne's disease and, for an infected US dairy farm is on average economically attractive. It however does not greatly decrease the prevalence.

Low-risk Johne's Disease Farms

‣ The designation 'Johne's disease free' should be changed to, for example, 'low-risk Johne's disease' because many unsuspected herds are in reality still infected;

‣ Pooled fecal testing can provide a good alternative to individual fecal testing in certification-and-monitoring programs for Johne's disease;

‣ In monitoring programs, bi-annual testing instead of annual testing can decrease costs while resulting in comparable epidemiological efficacy.

◼ Introduction - Why the Interest in Johne's Disease Control Programs?

There are two main reasons that during the last decade there has been an increased interest in Johne's disease control and certification-and-monitoring programs.

First, in recent decades, concerns have been raised about the apparent increase in the global prevalence of Johne's disease, the increasing economic costs and potential trade implications (Rideout et al., 2003). Worldwide, Johne's disease causes great losses for milk producers (Benedictus et al., 1987; Jones, 1990; Ott et al., 1999). The on-farm losses due to Johne's disease include (1) reduced milk production, (2) lower slaughter value of infected cows, (3) sub-optimal culling and (4) diagnosis and treatment costs. Dairy producers have very little or no control over the milk-price and therefore an important way to improve profit margins is to reduce the production costs. Improving animal health through disease control or eradication programs can play a major role in achieving this (Dijkhuizen and Morris, 1997).

Secondly, consumers desire healthy products from healthy animals. Johne's disease has received increasing attention because of concern (not confirmed nor disproved) over the potential role of *Map* in some cases of Crohn's disease in humans (Collins, 1997; European Commission, 2000). If *MAP*, as some fear, becomes widespread in the environment and the food chain, Johne's disease could become a serious public health problem (Rideout et al., 2003).

Both the apparent increase of losses caused by Johne's disease and the rising public health concern have resulted in an increasing *need* and *demand* for effective and economically attractive control strategies against Johne's disease.

■ Difficulties of Johne's Disease Control

There are several important reasons why it is hard to develop effective control program for Johne's disease.

‣ First, the long subclinical phase of infected animals often allows the infection to spread without occurrence of any clinical signs of illness.

‣ Second, although a range of diagnostic tests is available, all have their difficulties (Rideout et al., 2003). Their main difficulty is that they are often not sensitive enough to detect animals in the subclinical phase of the disease (Whitlock et al., 2000; Wells, 2003).

‣ Third, once an infected animal develops clinical signs, it is often hard to distinguish them from clinical signs of other common ruminant diseases.

‣ Finally, the current vaccines have not yet shown to be effective enough to eradicate Johne's disease (Kormendy, 1992; Wentink et al., 1994) and are therefore not considered a viable option for eradication (Rideout et al., 2003).

The above difficulties all relate to how effective Johne's disease programs are in reducing the prevalence on infected herds and accurately proving disease freedom on free herds. However, for any Johne's disease program, it is also very important that the program will be economically affordable. Most of the organized Johne's disease control (for infected herds) and certification-and-monitoring (for unsuspected herds) programs are currently voluntary. To warrant participation of dairy producers, it is therefore critically important that programs for Johne's provide real economic benefits to the producer.

■ This Study - The JohneSSim Model

The goal of the study presented in this paper is to provide better insight into the epidemiologic and economic consequences of Johne's disease control and certification-and-monitoring programs. This can help policy-makers, veterinarians and producers design and develop optimal Johne's disease programs.

To meet this goal, a computer simulation model (called 'The JohneSSim model') was developed. This model simulates and calculates the economic and epidemiological effects of different strategies for control and certification-and-monitoring of paratuberculosis (i.e. Johne's disease) in dairy herds. Field studies to study Johne's disease control programs are useful and necessary, but are unfortunately very time-consuming and expensive. Alternative research approaches such as computer simulation models can therefore supplement

existing field data and have a range of advantages, including being much more affordable and faster than field studies (Dijkhuizen and Morris, 1997).

Simulation of Johne's Disease Programs

The JohneSSim model simulates a dairy herd and the spread of Johne's disease within this herd over a 20 year period. In addition, it calculates the economic consequences of Johne's disease programs. Losses due to Johne's disease in the model included:

‣ milk production losses,

‣ reduced slaughter values and

‣ premature culling.

The benefits of control were calculated as the <u>reduction</u> in the losses caused by Johne's disease. The costs of each strategy were calculated on basis of <u>actual costs</u> of each item within the program (e.g. costs of testing). Finally, the benefits of the control program (reduction of the losses = losses without control minus losses with control) were compared to its costs (see Figure 1).
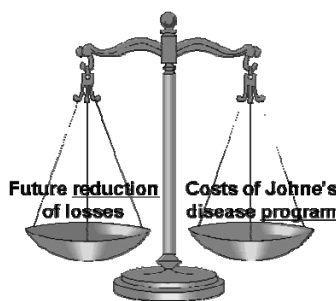

Figure 1. Graphical representation of the evaluation of the economic consequences of Johne's disease control by a comparison of the benefits (= future reduction of the losses) and the costs of control

For <u>Johne's disease infected herds</u>, the goal is to reduce the prevalence (and losses) and possibly eradicate Johne's disease. Many different control strategies were simulated, including (1) test and cull, (2) calf-hygiene management and (3) vaccination strategies.

For <u>Johne's disease non-suspected herds</u>, the goal is to obtain a high likelihood of being truly free of Johne's disease. A range of alternative certification-and-monitoring programs were simulated, varying in tests used, test frequency, age

of tested animals and the number of animals tested. A distinction was made between the testing scheme to reach a 'Johne's disease free status' ("*certification scheme*"), and the testing scheme to monitor the 'Johne's disease free status' ("*monitoring scheme*").

Results Shown in This Paper

The JohneSSim model was used to support decisions regarding Johne's disease programs in The Netherlands, the U.S. and New Zealand. Unfortunately, there is a limit to the length of this paper, and we therefore only show a few result for **control programs** and for **certification-and-monitoring programs** in The Netherlands and the USA. For more information about the Dutch study, please read Groenendaal et al. (2003) and Weber et al. (2004). The US study is described in more detail in Groenendaal and Galligan (2004).

■ Main Results

Johne's Disease Control Programs For Positive (Infected) Herds

No Control: The results of simulations with JohneSSim for the US (similar results where found for The Netherlands) indicated an increase in the average animal prevalence of the disease if no changes to the current calf-hygiene management or other control efforts are made (Figure 2). This is in agreement with field data (Jackobson et al., 2000) and another model study (Collins and Morgan, 1992).
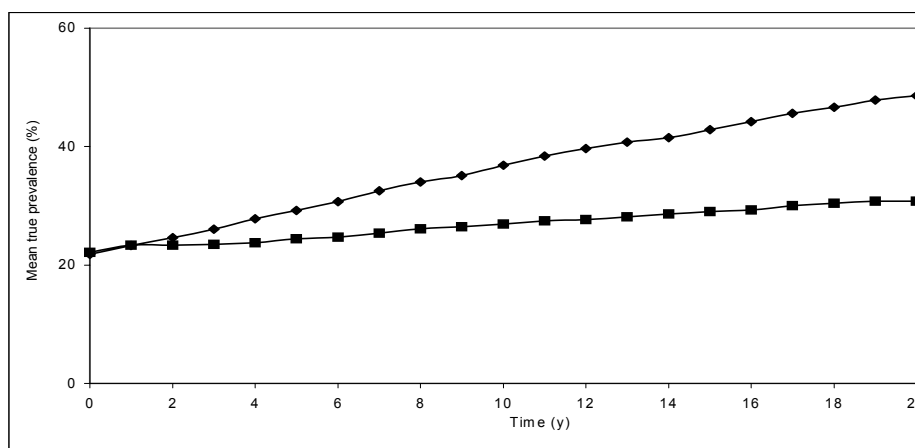

Figure 2—Average prevalence on a typical mid-size US dairy farm infected with paratuberculosis (Johne's disease) estimated by use of a simulation model. Estimations were obtained for a herd that did not have a paratuberculosis control program (diamond) and herds that implemented a test-and-cull strategy (square).

In addition, the model indicated that the losses due to Johne's disease are also rising (Table 1) and are current, on average, US$34 per cow per year on infected dairy herds in the U.S., which is consistent with past findings in the field. However, there is a great variation between farms, ranging from less than US$1 to more than US$83 per cow per year (Table 1). In addition, the results indicated that about 75% of the losses due to Johne's disease are caused by suboptimal culling of infected animals.

Table 1—Total and categorized losses due to Johne's disease on a typical infected 100-cow U.S. dairy farm without any control program (in US$).

Total loss				Categorized loss		
Year	Mean	10% *	90% **	Milk production	Suboptimal culling	Reduced slaughter value and treatment costs
1	3,450	50	8,350	300	2,750	350
10	5,250	150	13,050	550	4,100	600
20	7,200	400	14,950	750	5,600	850
Discounted total loss***	61,300	10,300	127,850	NA	NA (~78%)	NA

* this is the 10% percentile, which means that 10% of infected dairy farms have losses of this and lower
** this is the 90% percentile, which means that 10% of infected dairy farms have losses of this and higher
*** The discounted total loss stands for the total loss in today's dollars

Test-and-Cull: Simulation of 'test-and-cull' strategies with the JohneSSim model then showed that eradication of Johne's disease based on 'test-and-cull' strategies alone would not be possible within 20 years (see also Figure 2). In addition, the average costs of the different test-and-cull strategies were higher than the benefits of the programs. Table 2 shows an example economic analysis of the average costs and benefits. The 10th and 90th percentiles show that there is a large variation between herds in the economic consequences of test-and-cull strategies.

Table 2 - Comparison of the reduction of the economic loss attributable to Johne's disease (benefits), and costs of the test-and-cull program on a typical infected 100-cow U.S. dairy farm (in US$).

Year	Reduction in losses	Costs of test-and-cull
1	427	916
10	2,820	3,410
20	4,371	3,659
Discounted total	**31,298**	**37,418**
Average benefits minus costs:		**-6,121**
10th percentile		-19,374
90th percentile		7,911

Improved Calf Management Strategies: Strategies that focus on improved calf management were much more effective in reducing the prevalence of Johne's disease (see Figure 3) and were economically more attractive, both in The Netherlands and in the U.S. Figure 3 shows how different calf-hygiene management strategies affect the average prevalence on farms in The Netherlands according to the JohneSSim model.
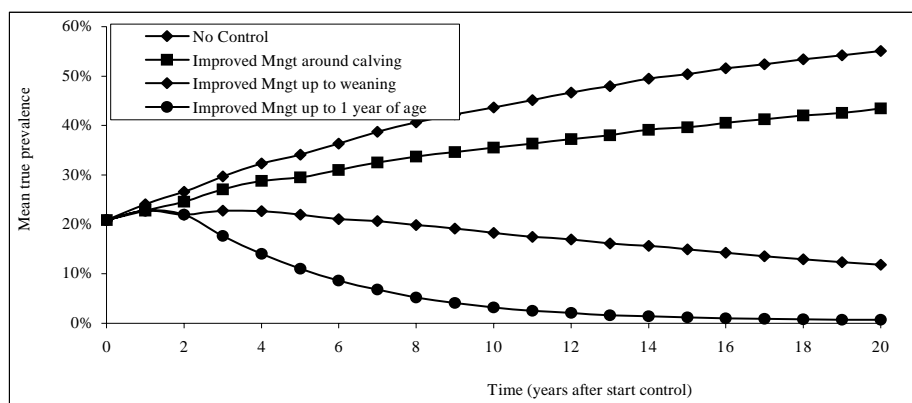

Figure 3. Average animal prevalence on Dutch dairy farms (infected or uninfected) as simulated by the JohneSSim model with 'no control' or three different calf management control scenarios

The economic consequences of the three different calf hygiene strategies shown above are summarized in Table 3. Based on the results of the JohneSSim model, on average improved calf management up to one year of age has higher benefits than costs and is thus economical attractive.

Table 3. Average annual and total reduction of losses compared with the costs three different Johne's disease control strategy (in €), as calculated by the JohneSSim model (in US$).

	Reduction of losses through control strategy		
Year	Around calving	Up to weaning	Up to one year
1	29	29	29
10	579	1,937	2,766
20	1,569	5,450	6,576
Total losses [a]	6,699	22,625	**29,196**
Total costs control [a]	8,846	18,276	**28,013**

[a] discounted total from year 1-20

Vaccination: Vaccination was also simulated as a possible Johne's disease control strategy for infected U.S. dairy herds. Although a reduction of the number of cattle with clinical evidence of paratuberculosis has been reported after vaccination (Kormendy, 1992; Wentink et al., 1994), the exact mechanism by which vaccination against paratuberculosis protects cattle is not well understood. Therefore, different assumptions were made within the JohneSSim model regarding this mechanism. None of the scenarios we assumed regarding the effects of vaccination, resulted in a decrease of the mean prevalence on infected farms (Figure 4).
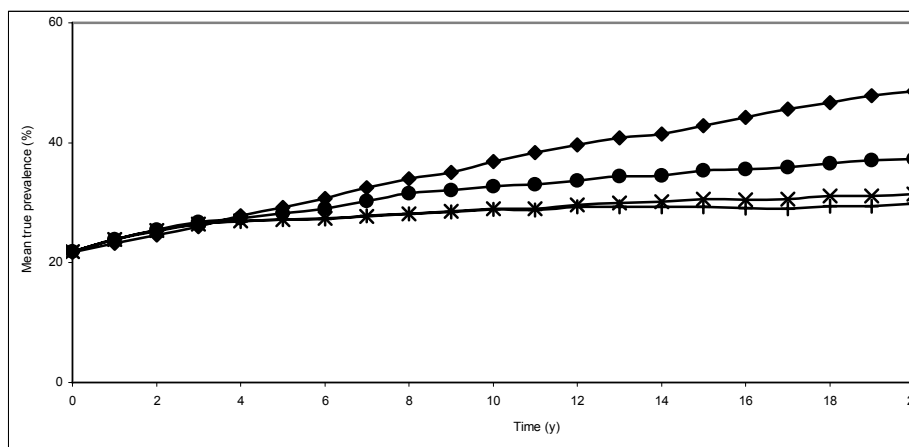
Figure 4. Average prevalence on a typical infected 100-cow U.S. dairy farm under 'do nothing' (diamond) or 'vaccination with the assumption that it would increase the age at which a cow became infectious for paratuberculosis by 1.5 years (cross), or reduce by 50% the probability that a cow would become infectious for paratuberculosis (circle); or a combination both (plus sign)

However, even though vaccination was not able to considerably reduce the average prevalence of Johne's disease, it was able to greatly reduce economic losses attributable to Johne's disease. The benefits of vaccination were on average higher than the cost, and vaccination was therefore on average, economically attractive for infected dairy herds (Table 4).

Table 4. Average annual and total reduction of losses compared with the costs three different Johne's disease control strategy (in US$), as calculated by the JohneSSim model for a typical infected 100-cow US dairy herds (see Figure 3 for epidemiologic consequences).

Year	Assumption about the effect of vaccination		
	Increase age 1.5 yr	Reduce probability	Both
1	6	-3	17
10	616	1,546	2,162
20	1,836	3,419	4,266
Total reduction losses [a]	8,933	18,525	**24,073**
Total costs control [a]	5,977	5,977	**5,977**

[a] discounted total from year 1-20

The economic results of the vaccination scenarios in the JohneSSim model were consistent with a costs-benefit analysis of vaccination against Johne's disease in dairy cattle (Van Schaik et al., 1996) and with field observations that vaccination effectively reduces the incidence of the clinical disease (and hence reduced the losses due to suboptimal culling), but does not reduce the prevalence (Kormendy, 1992; Wentink et al., 1994; Kalis et al., 1999).

Certification-and-Monitoring Programs for Low-Risk (Negative) Johne's Disease Herds

Herds that are unsuspected to have Johne's disease (negative herds) can enter a certification-and-monitoring program with the goal of obtaining a high likelihood of disease freedom. This could increase the value of its livestock. It is also important that the certification-and-monitoring program is affordable.

Certification: The Dutch certification program in 2001 included one ELISA test and four annual pooled fecal cultures of all cattle ≥ 2 years of age. This program was simulated with the JohneSSim model, and results showed that 11% of the 'Johne's disease negative' herds (herds that are still negative after all five testing rounds) were not truly Johne's disease free - the infection was present but not yet detected (Fig. 4A, □). Furthermore, in the model the prevalence of Johne's disease was 22% at the beginning of the testing and 0.56% over all remaining test-negative herds (Fig. 4A, △). The distribution of the within-herd prevalence in herds that were positive in any herd examination and in remaining test-negative herds (i.e. certified 'Map-negative' herds) is shown in Fig. 4B.
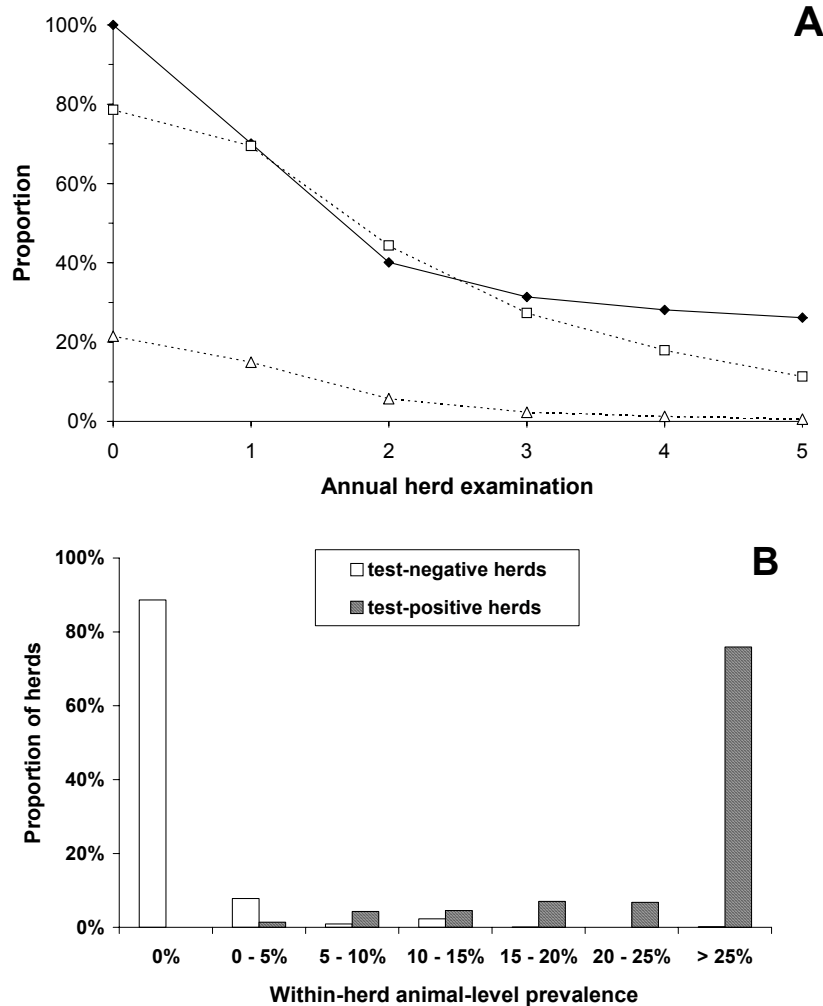
Figure. 4. Results of a simulation of four annual pooled fecal cultures of all cattle ≥ 2 years of age for Johne's disease in the Netherlands. (A) Proportion of remaining test-negative herds (◇), proportion of infected herds in the group of remaining test-negative herds (□), and proportion of infected animals in the group of remaining test-negative herds (△), at each herd examination. (B) Distribution of within-herd animal-level prevalence after five herd examinations for herds that were test-positive in any of the herd examinations, and in herds that were test-negative in all herd examinations, and therefore reached the status 'Map-free'.

Secondly, the results showed that, compared to the current scheme (shown above), only one alternative scheme that was simulated (four pooled fecal cultures of all cattle ≥ 2 years of age at 2-year intervals) resulted in lower estimated costs and a lower Johne's disease prevalence when reaching the 'Johne's disease free' status.

Monitoring: After a farm reaches the 'low-risk Johne's disease' herd status, it enters a 'monitoring scheme'. The results of the JohneSSim model showed that a program with annual pooled fecal test of all animals ≥2 year was the best of all the simulated alternatives for the Dutch situation. The only suitable alternative was a monitoring scheme with fecal culture of all cattle ≥ 1 years of age at 2-year intervals because it resulted in lower annual costs and only a slightly higher prevalence of undetected Johne's disease compared to the best scheme.

■ Concluding Comments

The majority of the results of the JohneSSim model presented in this paper are peer reviewed and in general in agreement with past studies. However, they have to be interpreted carefully. Simulation studies are always a simplification of reality (as is any scientific study) and although the development of the JohneSSim model was based as much as possible on field and literature data, there is still great uncertainty about many aspects related to Johne's disease control.

First, it was concluded that the JohneSSim model, which was used in this study, proved to be a useful and flexible tool to gain better insight into the epidemiologic and economic effects of Johne's disease control and certification-and-monitoring programs. Certainly when Johne's disease programs are voluntarily, it is very important that program for Johne's disease not only effectively reduces the Johne's disease prevalence, but that is also provides real economic benefits to producers.

Second, from the results of the JohneSSim model, it was concluded that Johne's disease causes substantial losses on infected dairy farms (on average US $34 per dairy cow on infected herds) and that the average losses per herd gradually increase over time. Most losses by Johne's disease are caused by suboptimal culling of clinical and subclinical infected animals.

Thirdly, due to the low sensitivity of available tests for Johne's disease, test-and-cull strategies alone do not decrease the prevalence and are on average economically not attractive. An increasing number of studies agree that testing in the absence of calf hygiene management changes to control Johne's disease is futile and very costly (see for example also Kalis et al., 2004). On infected

farms, diagnostic tests should therefore only be used as a tool to stimulate producers to improve calf hygiene.

Fourth, control strategies based on separation of calves and adult animals are much more effective in reducing the prevalence of Johne's disease and are economically more attractive. Improved calf hygiene management strategies are considered critically important in any Johne's disease control program (McCaughan, 1990).

Fifth, a range of assumptions was made about the efficacy of vaccines against Johne's disease. Under all the assumed scenarios, vaccination was not able to greatly reduce the average prevalence but it was able to provide economic benefits to producers because it greatly reduced the losses due to premature (suboptimal) culling.

It was furthermore shown that within monitoring-and-certification schemes, it is better to speak about 'Low-risk Johne's disease' then it is to speak about 'Johne's-free'. In the Dutch example, 11% of the herds that were negative after four pooled fecal cultures testing-rounds were still infected (although all with a very low prevalence). The results also indicated that a certification scheme with bi-annual testing resulted in lower costs and a lower prevalence compared to the current scheme with annual testing.

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