**Economic Analysis of Johne's Disease Control Strategies in Dairy Herds**

**Poster, 10581, has been scheduled on Monday, July 26, 2010 in Plaza Ballroom DE**

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# Economic Analysis of Johne's Disease Control Strategies in Dairy Herds

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## ABSTRACT

Infectious diseases play a critical role in determining the profitability of individual farms and maintaining the viability of livestock industries, international trade, and trade policies. Thus, it is critical to analyze the economic consequences of infectious diseases, and the effects of producer strategies to control or eliminate diseases in a cost efficient approach. Also, important is the goal to rally support for the development of public disease control programs.

This study examined the long-term feasibility and effectiveness of various producer strategies to prevent and control Johne's disease in dairy herds, an infectious and incurable disease which has significant economic repercussions for the dairy industry. There are few previous studies available on the economic aspects of Johne's disease and there remains a knowledge gap with regard to the economics of the disease and the economic justification of the disease controls associated with the biological characteristics of the disease. This study contributes to this body of knowledge. We constructed an optimal control model integrating the biology of animals and disease into an economic framework to estimate the best control method in terms of maximizing an individual farm's profit and minimizing disease elimination periods.

Our results show that any Johne's disease control method yields a higher net present value compared to no control. Implementing a single control strategy can control the disease, but a combination of control strategies in different categories is the most profitable and effective way to reduce the infection rate in a disease-infected herd. The results of the study are directly applicable to managing this disease on US dairy farms and contribute to controlling a high-priority pathogen in an important industry.

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## INTRODUCTION

Johne's disease (JD) is a chronic, infectious, incurable intestinal disease of ruminants, caused by the pathogen *Mycobacterium avium* subsp. *paratuberculosis* (MAP). The disease inflicts significant economic loss, $200 to $250 million annually, on the dairy industry due to a reduction in milk production, lower slaughter value, and suboptimal culling. Although definitive proof has not been established, MAP has been postulated to be a cause of Crohn's disease (CD) in humans. This potential link between JD and CD, coupled with the high cost of JD, increases the need for evaluating the cost-effectiveness of JD control methods.

Johne's disease control is difficult because of the absence of either an effective treatment or vaccination for the disease, the long incubation period of the disease, and the low sensitivity of currently available MAP tests. Given these limitations, the control and possible elimination of the disease can best be done by decreasing or eliminating infection transmission between infected and susceptible animals. Control strategies that were modeled to accomplish this include test-and-cull with annual and biannual MAP testing, improved calf-hygiene management, contract calf-rearing, and herd replacement practices. Given incomplete effectiveness of vaccination and limited data on its impact on reducing or delaying pathogen shedding it was not included as a control.

The objective of this research was to evaluate the long-term economic feasibility and effectiveness of various JD control methods on the individual farm. An optimal control model for profit-maximizing producers was constructed and solved to derive optimal behavioral responses of producers making economic decisions on controlling the disease. Results for combinations of control strategies are compared to determine the most profitable, least time-consuming, and recommended methods for controlling the disease over a 50 year planning duration of a dairy farm.

## METHODS

Optimal control model was constructed integrating biology of animals and disease into an economic framework. Since the effects of JD control are often slow to become distinguishable, as infections take several years to reach clinical status, evaluating the benefits of control programs can best be done by constructing a model that employs NPV with the dynamics of MAP transmission within a herd (Figure 1).

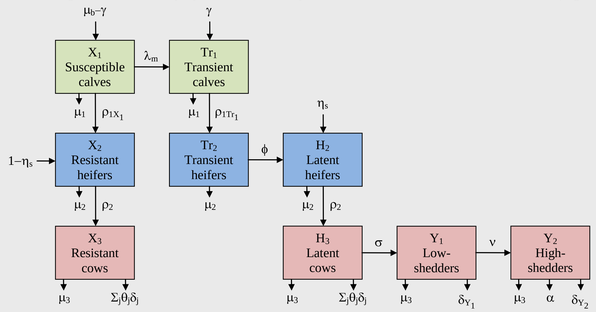


**Figure 1.** Flow diagram of age-and-state dependent animal movement model
**Note:** Figure 1 was modified from Mitchell et al. (2008) and compartment names and transition rates are provided on the supplementary pages

## OBJUCTIVE FUNCTION AND CONSTRAINTS

**Expected NPV of a Farm's Net Cash Flow:**

$$NPV = \sum_{t=1}^{T}(1+r)^{-t}[NR_{Z}S_{Zk}(t) + NR_{Y_1}S_{Y_1k}(t) + NR_{Y_2}S_{Y_2k}(t) + \mu_3(t)SR_{Z}S_{Zk}(t) + \delta_{Y_1k}(t)SR_{Y_1}S_{Y_1k}(t) + \delta_{Y_2k}(t)SR_{Y_2}S_{Y_2k}(t) - C_{N_1}N_1(t) - C_{N_2}N_2(t) - C_mN_3(t) - C_kN_3(t)\tau - C_sW(t)]$$

**Equations of Motion for MAP Transmission and Animal Movement between Age Cohorts:**

(1) $X_1(t+1) = (\mu_b - \gamma(t))N_3(t) + [1-(\lambda_m(t) + \mu_1 + \rho_{1X_1}(t))]X_1(t)$

(2) $X_2(t+1) = \rho_{1X_1}(t)X_1(t) + [1-(\mu_2+\rho_2)]X_2(t) + (1-\eta_s)W(t)$

(3) $X_3(t+1) = \rho_2X_2(t) + (1-\mu_3(t))(U_{X_3}(t) + Tn_{X_3k}(t)) + (1-\sum_j \theta_{jk}\delta_{jk}(t))Fp_{X_3k}(t)$

(4) $Tr_1(t+1) = \lambda_m(t)X_1(t) + \gamma(t)N_3(t) + [1-(\mu_1+\rho_{1Tr_1})]Tr_1(t)$

(5) $Tr_2(t+1) = \rho_{1Tr_1}Tr_1(t) + [1-(\mu_2+\phi)]Tr_2(t)$

(6) $H_2(t+1) = \phi Tr_2(t) + [1-(\mu_2+\rho_2)]H_2(t) + \eta_sW(t)$

(7) $H_3(t+1) = \rho_2H_2(t) + [1-(\mu_3(t)+\sigma)](U_{H_3}(t) + Tn_{H_3k}(t)) + (1-\sum_j \theta_{jk}\delta_{jk}(t))Fp_{H_3k}(t)$

(8) $Y_1(t+1) = \sigma(U_{H_3}(t) + Tn_{H_3k}(t)) + [1-(\mu_3(t)+\nu)](U_{Y_1}(t) + Fn_{Y_1k}(t)) + (1-\delta_{Y_1k}(t))Tp_{Y_1k}(t)$

(9) $Y_2(t+1) = \nu(U_{Y_1}(t) + Fn_{Y_1k}(t)) + [1-(\mu_3(t)+\alpha)](U_{Y_2}(t) + Fn_{Y_2k}(t)) + (1-\delta_{Y_2k}(t))Tp_{Y_2k}(t)$

**Capacity Constraint:**

(10) $N_{3\min} \le N_3(t) \le N_{3\max}$

**Note:** Definitions of variables and parameters are provided on the supplementary pages

## RESULTS

The constructed model for a farm with three possible MAP infection levels (0%, 10%, and 20%) was coded using the general algebraic modeling system (GAMS) software and empirically solved for optimal values of the control variables that maximize the NPV given the biological and economic constraints.

For a farm free of JD, the NPV was $346,510 with a steady-state herd size of the upper cow limit.

For a farm with JD present, the NPV was predicted to be much lower at $155,870 and $4,527 for a farm with moderate and high JD prevalence, respectively, in the absence of a control program. This illustrates the high cost of JD on dairy farms without control because the NPV of a JD-free farm was much higher at $346,510. The number of cows for a farm without JD control in place increased dramatically, reaching 26% of the herd with an initial infection rate of 10%, and 43% with an initial infection rate of 20% (Figure 2). Obviously, no farm would be able to survive the cost of these infection levels considering that fixed costs not included in the NPV computation would lead to negative income.

The recommended control method was predicted to be improved calf-hygiene management and test-and-cull using a biannual FC test, with a predicted NPV of $283,250 and elimination period of 7 years for a farm with moderate JD prevalence, and a predicted NPV of $268,279 and elimination period of 8.5 years for a farm with high JD prevalence, respectively (Figure 3). These NPVs are only $3,204 (moderate JD prevalence) and $1,971 (high JD prevalence) lower than the most profitable control method, improved calf-hygiene management and test-and-cull using an annual FC test. In fact, this control method generated the second highest expected NPV among all control methods available for a farm with JD present, but required only six more months to eliminate JD compared to the least time-consuming control method, contract calf-rearing and test-and-cull using a biannual FC test.

## DYNAMICS OF THE NUMBER OF ADULT ANIMALS

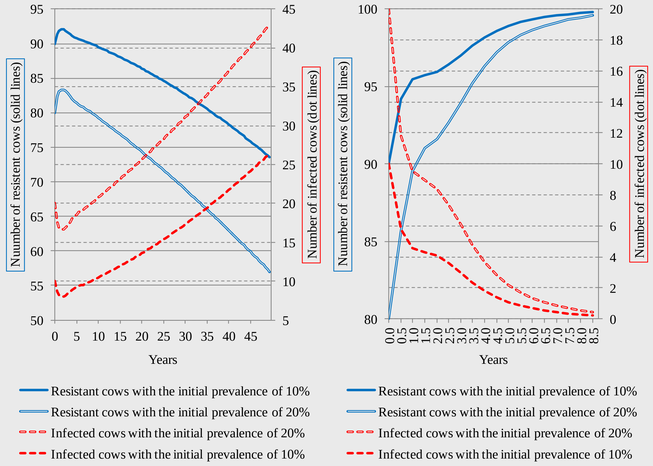


**Figure 2.** Number of cows without control




**Figure 3.** Number of cows with the recommended control method

## CONCLUSIONS

Results showed that any JD control method yields a higher NPV compared to no control. Elimination of JD required a long-term plan with implementation of either an additional calf-hygiene management or test-and-cull using a FC test, but these are most effective when combined with each other.

Given the lag between the period of JD elimination and the last period of detecting test-positive animals, it is important for producers to keep screening their herd using a FC test after eliminating the last test-positive animals in order to eliminate JD entirely. Even for monitoring purposes, the ELISA test is inefficient due to the low test specificity of the ELISA test, which generates false-positive test results in the herd free of JD. Moreover, with the low test sensitivity of the ELISA test infected animals may escape detection and infect many animals before they begin to be identified.

The results of the study are directly applicable for US dairy farms and would contribute to society if it becomes desirable to eliminate the disease from dairy herds as quickly as possible to either reduce the future economic externality cost to the dairy industry from the spread of JD across herds, or to prevent the public health risks associated with the potential link between JD and Crohn's disease in humans.

## ACKNOWLEDGEMENT

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