

Simulating Control Strategies For *Neospora caninum* Infection In Dutch Dairy Herds

Bartels, C.J.M., Santman-Berends, I.M.G.A., Dijkstra, Th., Wouda, W.

Animal Health Service, PO Box 9, 7400AA Deventer, the Netherlands

ABSTRACT

Middle-long term (2009-2020) herd prevalence and economic losses of *Neospora caninum* in Dutch dairy herds were simulated. Current conditions were compared with simulated effects of possible control strategies. A dynamic stochastic model with three herd-infection states (susceptible (S; < 3% within-herd prevalence), low infection (I_{low} ; <15% within-herd prevalence) and high infection (I_{high} ; \geq 15% within-herd prevalence) was build. This distinction was used as abortion problems were related with high within-herd prevalence. The costs consisted of direct losses due to infection and costs for control strategies. Simulated control strategies focused on reducing the risk of farm dogs, testing of animals that were newly introduced into the herd and annual bulk-milk testing (indicating I_{high} state) to raise awareness of herd owners. Various levels (25%, 50% or 75%) of risk reduction with measures for dogs were assumed. In the current situation, 21% of herds were susceptible, 63% had status I_{low} and 16% status I_{high} . The average annual economic losses were €7.2 million of which 72% was attributed to I_{high} herds. Measures to separate dogs from cattle were most effective. When assuming measures for dogs to be 75% effective, I_{high} prevalence reduced to 4% in 2020 and annual economic losses reduced by 33%.

Keywords: *Neospora caninum*, stochastic, simulation modeling, disease control, dairy cattle

INTRODUCTION

One of the leading causes of bovine abortion is the protozoan parasite *Neospora caninum* (*N. caninum*). *N. caninum* has a heteroxenous life cycle in which cattle are intermediate hosts and dogs and coyotes are the only recognized definitive hosts. The major route of transmission is by recrudescence of a persistent infection and subsequent infection of the fetus (vertical transmission). Postnatal infection (horizontal transmission) is important to sustain infection level in cattle and occurs when naïve cattle ingest sporulated *N. caninum* oocysts shed by dog feces. Control of neosporosis focuses on separation of dogs and dog feces from cattle, culling of seropositive cattle or selective breeding. Currently, vaccines are able to reduce abortion problems by *N. caninum* but so far no vaccines are available that prevent vertical transmission of infection. Chemotherapeutic treatment of infected animals is not yet possible but may offer a possibility in the future.

In the Netherlands, 76% of the dairy herds are infected. Within these herds, 13% of the cattle test positive for *N. caninum*. Average economic losses were estimated to be € 100 per infected farm per year. However, in herds with abortion problems due to *N. caninum*, these losses amount to € 125 per cow over a two-year period (Bartels, 2007). Given this situation, Dutch policymakers wanted to learn what control measures could be applied best to reduce the impact and economic losses due to neosporosis in the Dutch dairy sector. In this study, the middle-long prevalence of *N. caninum* in dairy herds was simulated under current conditions and compared with simulated effects of possible control strategies. Additionally, for each control strategy, the economic consequences were estimated to support decision makers on deciding about future control strategies.

MATERIAL AND METHODS

A dynamic stochastic simulation model was build using two modules (epidemiological and economical) with 'average Dutch dairy herd' as the unit of interest. The output of the epidemiological module was used as input for the economic module. Input data were obtained from previous Dutch studies and/or literature. When no information was available, we made use of expert opinion. The model was build in @Risk (Palisade, USA). Because of variation and/or uncertainty about input parameters, probability distributions were used. Thousand simulations were performed to have sufficient indication of the variation in the results.

In the state-transition model, herds could change each month between three herd infection states: susceptible (S, <3% seroprevalence in adult cows, correcting for non-optimal test specificity), low infected (I_{low} , between 3 and 15% seroprevalence in adult cows) and high infected (I_{high} , \geq 15% seroprevalence in

adult cows) herds (Table 1). The distinction between I_{low} and I_{high} was based on previous studies, in which increased risk for abortion problems occurred in herds with $\geq 15\%$ within-herd prevalence. These two herds states can be distinguished with bulk milk testing.

Table 1 State-transition matrix for *N.caninum* infections in dairy herds

From: To :	S	I_{low}	I_{high}
S	$1 - P_{SI_{low}}$	$P_{SI_{low}}$	0
I_{low}	$P_{I_{low}S}$	$1 - (P_{I_{low}S} + P_{I_{low}I_{high}})$	$P_{I_{low}I_{high}}$
I_{high}	0	$P_{I_{high}I_{low}}$	$1 - P_{I_{high}I_{low}}$

The probability of a herd to change from S to I_{low} was calculated as

$$P_{SI_{low}} = P_{basis} * (I_{low} + I_{high}) / N + P_e$$

where P_{basis} is the probability that a herd gets infected through a risk factor other than those explicitly included in the model. P_e is the probability that a herd gets infected by the risk factors included in the model.

$$P_e = (1 - e^{-\sum \beta_i * prev_i * (I_{low} + I_{high}) / N})$$

where β_i indicates the magnitude of risk factor 'i' (purchase of cattle, communal grazing, introduction of a new dog), 'prev' is the prevalence of risk factor 'i' and $(I_{low} + I_{high}) / N$ is the percentage of infected herds. The probability to change from I_{low} to I_{high} was calculated as

$$P_{I_{low}I_{high}} = P_{basis2} * (I_{low} + I_{high}) / N + P_b$$

where P_{basis2} is the probability that a low-infected herd becomes highly infected through a risk factor other than the presence of a new dog. P_b was the probability when at least one new dog is present and was calculated as

$$P_b = (1 - e^{-\sum \beta_{presence\ new\ dog} * prev_{presence\ new\ dog} * (I_{low} + I_{high}) / N})$$

The probability to change from I_{high} to I_{low} was calculated as

$$P_{I_{high}I_{low}} = 1 - e^{-1/\delta}$$

where ' δ ' is the average time for a herd to reside in state I_{high} . This period of time was based on the annual percentage of cows calving, the herd size, median lifetime on a dairy farm, the average annual abortion percentage, the relative risk for abortion in *N.caninum* seropositive cows, the increased culling rate for *N.caninum* seropositive cows and the average annual replacement rate. On average, dairy herds took 46 months (range 1 – 92) to change from I_{high} to I_{low} . The probability to change from I_{low} to S was calculated as:

$$P_{I_{low}S} = 1 - e^{-1/\gamma}$$

where ' γ ' is the average time for seropositive cows to leave a I_{low} herd and the same input information as given for ' δ ' was used. A I_{low} herd changed to state S in 76 months (range 1-127).

The economic module calculated costs for control strategies and losses due to *N. caninum* infection on a yearly basis. Costs included serological testing of purchased animals or whole-herd sampling and participation in the bulk-milk test program. The losses for I_{low} herds were €100/year (range €60-€200) and for I_{high} €1751 (range €200- €2932) including losses due to premature culling, extended calving interval, increased age at first calving, additional inseminations, treatment and diagnoses when cows aborted. To correct for inflation, a discount rate of 6% per year was applied.

Possible control strategies focused on reduction of contacts between dogs and cattle, testing of purchased cattle, annual bulk-milk testing or a combination of the above. In more detail, the following scenarios were simulated:

- Scenario 1-3; Reduction of contact between dogs and cattle. It was assumed that various combinations of measures (purchase of a young dog that can be trained not to roam around and defecate in designated places, no feeding of raw meat, castration or nurturing to prevent off-spring, tethering) could reduce transmission of infection by 25% (Scen 1), 50% (Scen 2) or 75% (Scen 3).
- Scenario 4; Testing of cattle before introduction into the herd. Test-positive cattle were not purchased.
- Scenario 5; Combination of scenario 3 and 4 (reduction of dog-cattle contacts by 75% and no purchase of test-positive cattle).
- Scenario 6; Annual bulk-milk testing in all dairy herds to raise awareness of herd owners. It was then assumed that no cattle were purchased from bulk-milk positive herds.

- Scenario 7; Measures for dogs as in Scen 3 combined with active monitoring of herd- and animal status. This included annual bulk-milk testing of herds and for test-positive herds, additional individual testing. Test-positive cattle could only be moved for slaughter. This scenario was included to demonstrate farmers the effect on seroprevalence when measures for dogs were taken.

RESULTS

With no control strategy applied, the prevalence of I_{low} and I_{high} remained around 64% and 16%, respectively. Economic losses between 2009 and 2020 were estimated to be € 86.5 million (Table 2) and 72% of these losses were attributable to I_{high} herds. Measures for dogs reduced the percentage I_{high} to 8% (Scen 1) or 4% (Scen 3). This was more than testing purchased cattle (Scen 4) or testing herds (Scen 6). Extensive testing in combination with measures for dogs (Scen 7) reduced the percentage of I_{high} herds most (1.3%). None of the scenarios reduced the prevalence of I_{low} herds significantly. Measures for dogs were most cost effective as there were no costs involved. Applying Scen 3 reduced economic losses by 33% between 2009 and 2020. Even Scen 7 reduced economical losses by €7.7 million (9%) over the study period.

Table 2 Results of simulated I_{high} prevalence in 2020 and total economic losses (2009-2020)

Scenario	I_{high} in 2020 (%) [90%CI]	Ranking I_{high}	Total economic losses (2009-2020) (x million) [90%CI]	Ranking economic losses
Current situation	16,1 [8,0-23,7]	8	€ 86,5 [€ 44,4-142,2]	5
Scen 1: measures for dogs, 25% effective	12,1 [5,2-19,2]	5	€ 76,8 [€ 39,1-121,2]	3
Scen 2: measures for dogs, 50% effective	8,1 [3,1-14,9]	4	€ 67,4 [€ 36,1-106,1]	2
Scen 3: measures for dogs, 75% effective	4,0 [0,0-10,1]	3	€ 57,4 [€ 29,5-89,2]	1
Scen 4: testing animals before purchase (100% effective)	14,8 [7,0-22,2]	6	€ 112,3 [€ 71,9-163,6]	8
Scen 5: combination of scenario 3 and 4	3,9% [0,0-10,0]	2	€ 86,9 [€ 59,5-123,2]	6
Scen 6: annual bulk-milk testing	15,1 [6,9-22,9]	7	€ 100,4 [€ 58,4-153,6]	7
Scen 7: annual bulk-milk testing, whole-herd testing for bulk-milk positive herds and measures for dogs (75% effective)	1,3 [0,0-4,5]	1	€ 78,8 [€ 45,0-115,8]	4

DISCUSSION

In our study, we simulated possible control strategies to reduce the impact of *N. caninum* infection in Dutch dairy herds. As we used an average dairy herd to simulate herd-based interventions, we simplified the real-life situation. However, with our objective to support policy makers on control options for neosporosis, the emphasis was on comparison of control options rather than on absolute results. This was different in a Swiss study simulating control strategies with the objective to eradicate *N. caninum* infection (Hässler et al., 2006). Most economic losses occurred in I_{high} herds. This means, that owners of these herds may be motivated best to apply control strategies. Taking measures for dogs seemed to be most cost effective. However, it requires the farmer to remove the dog(s) or to train dogs extensively. Prior to this, there is a need to evaluate the effect of different specific measures for dogs on transmission of infection between dogs and cattle. With our scenarios, the percentage of I_{low} herds would not be reduced. Here, our results indicated that current knowledge about the dynamics of herd introductions was insufficient. There is a need for more studies about the importance of stray dogs and/or unknown sources of postnatal infections.

REFERENCES

- Bartels, C.J.M., 2007. Occurrence, impact and monitoring of *Neospora caninum* infection in Dutch dairy herds. PhD thesis, ISBN 978-90-9021826-7, GD Deventer, pp
- Hässler, B., Regula, G., Stärk, K.D.C., Sager, H., Gottstein, B., Reist, M., 2006. Financial analysis of various strategies for the control of *Neospora caninum* in dairy cattle in Switzerland. *Prev. Vet. Med.*, 77, 230-253.