Economic and epidemiological evaluation of possible Salmonella control strategies in dairy cattle.

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Abstract
Salmonella (Dublin and Typhimurium) infections in dairy herds are important because of their impact on farm economics and public health. Therefore, a control program is considered in the Netherlands. Salmonella control strategies were evaluated using a decision support model consisting of an epidemiological and an economical part. The epidemiological model is a state transition model. The unit of analysis was the individual farm and the infectivity of a herd for other herds was considered. Interventions were modeled as influencing the impact of risk factors on the transmission of Salmonella in the model. Different voluntary as well as obligatory strategies were defined. Amongst the interventions were prohibition of movement of potentially infectious animals and manure, culling of chronically infected animals and herd management measures such as separate housing of age-groups. Reduction of prevalence of infected herds, cost of the strategy for the dairy sector, and cost effectiveness were calculated for each strategy. Results of the model suggested that obligatory strategies, which included four-monthly bulk-milk sampling to determine and monitor the status of the herd, prevention of movement of potentially infected animals and the culling of chronically infected cattle from the herds were able to reduce the prevalence of test positive herds considerably and were most cost effective.

Introduction
Salmonella Dublin and *Salmonella Typhimurium* are the most prevalent *Salmonella* spp in Dutch dairy herds. Both Salmonella species are important because of their impact on farm economics and public health. Therefore, the control and possible eradication of *Salmonella* infections is of interest to both the dairy industry and society. The main routes for getting infected is introducing infected animals into the herd or introducing manure of infected animals. After an initial infection most of the herds get only temporally infected and infectious for other herds. However a number of herds become chronically infected and infectious for other herds. Recent research identified a number of important risk factors that influence the possibility of becoming a chronically infected herd. These are the presence of liver fluke infections, bad hygiene, colostrum management in which calves receive colostrum from other cows than their dam, and the change in housing of calves after 20 weeks of age (Veling, 2004) New insights into the factors related to the prevalence of *Salmonella* in dairy herds and the development of a ELISA technique with which the Salmonella status of dairy herds can be determined at relatively low costs (Veling, 2001) make it possible to define new control strategies for dairy herds.

Objective
The objective of the research was to explore the epidemiological and economic consequences of different control strategies to reduce the prevalence of Salmonella-infected dairy herds with a stochastic state transition model, which is designed to simulate the introduction and spread of *Salmonella* amongst Dutch dairy herds.

Methods
The epidemiological model is a state transition model (*Van der Gaag et al*., 2004). The unit of analysis was the individual farm and the infectivity of a herd for other herds was considered. Interventions were modeled as influencing the impact of risk factors on the transmission of Salmonella in the model. Different voluntary as well as obligatory strategies were defined. In table 1 the control strategies are briefly described. Amongst the interventions were prohibition of movement of potentially infectious animals and manure, culling of chronically infected animals and herd management measures such as separate housing of age-groups. Different strategies were evaluated on reduction of prevalence of infected herds, cost of the strategy for the dairy industry, and cost effectiveness. A cost effectiveness study was performed to get insight into differences between the control strategies. The results of an intervention strategy were compared with a hypothetical situation in which no losses and no costs were caused by Salmonella infections (also no costs for preventive measures). Control costs consisted of test and laboratory costs, cost to prevent introduction of Salmonella into the herd, and the culling costs. To value the projected cash flow for each alternative at one point in time the Net Present value was calculated (Berry, et al., 1995). Because it was expected that control strategies differ in costs and reduction of

Proceedings of the 11th International Symposium on Veterinary Epidemiology and Economics, 2006
Available at www.sciquest.org.nz

prevalence of sero-positive herds, a cost effectiveness study was performed, in which the amount invested was divided by the reduction in prevalence.

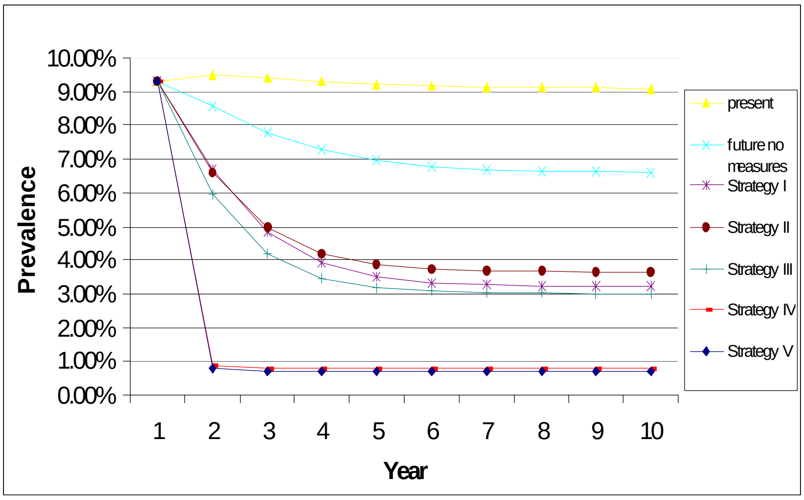

Figure 1 impact of different control strategies on the prevalence of Salmonella positive herds in the Netherlands

Results and conclusions

Table 1 End prevalence, costs and cost effectiveness of different control strategies

		End prevalence		Costs		Cost effectiveness	
		%	Rank	million €	Rank	Million€/ %/year	Rank
Autonomous development		6,60%	6	0,53	1	-	
Strategy I	no entry of infected animals	3,66%	5	2,22	3	0,57	2
Strategy II	Hygienic measures	3,21%	4	2,84	5	0,68	3
Strategy III	no entry of potentially infected animals or manure	3,02%	3	5,47	6	1,37	4
Strategy IV	no entry of potentially infected animals and culling of persistently infected animals	0,78%	2	3,79	4	0,56	1
Strategy V	All measures from the previous strategies	0,68%	1	9,50	7	1,51	5

The model was validated by comparing the results of a simulation the present situation in the Netherlands with the actual situation. The prevalence of Salmonella infections as estimated by the model was 9,1% (95% CI 2.9-11.6%) is within the estimate of the true prevalence in the Netherlands of 8,3% (95%CI0,7-15.8%0 .The results of the model after modeling the different control strategies are described in figure1 and table 1.

As a result of the autonomous developments due to environmental legislation and the anticipation of dairy farmers it is expected that farmers will purchase 20% less manure from other dairy herds. As a result of this the end prevalence of infected farms will drop from the present 10% to 6.6%.

It is possible to establish an additional reduction of the prevalence of Salmonella infected farms using the described strategies. %.

The different models are effective within a few years and the prevalence remains constant after four years (figure 1). The number of newly infected farms equals the numbers of farms recovered and becoming negative. When all the suggested measures to control Salmonella on dairy farms would be applied there would still be a limited risk of infection because of a possible source of infection from non-dairy farms. Thus, the end prevalence in our model never reached 0.

The evaluated strategies show considerable differences between the different programs in both effectiveness and costs.

Strategy IV, -no entry of infected animals and culling of persistently infected animals-, was based on cost effectiveness and reduction in prevalence the most preferred strategy. The prevention of potentially infected animals shows to be an important risk factors for farms to become infected. Persistently infected animals contribute in the model to a large to the infectivity of a farm for other farms.

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