BIOSECURITY ON DAIRY FARMS: THE ECONOMIC BENEFITS

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SUMMARY

A more closed farming system can be a good starting point for eradication of infectious diseases. However, the economic implications of biosecurity measures are not always obvious to farmers. The management decisions regarding biosecurity may be related to different parts of the farm and are farm specific. A model to support such management decisions was developed as a first attempt to model the economic consequences of certain biosecurity measures. A simple model, which is static and deterministic in design, was chosen. The risk factors in the model were solely based on bovine herpesvirus 1, but losses due to introduction of other infectious diseases (bovine viral diarrhoea virus, *Leptospira hardjo* and *Salmonella dublin*) were also added into the model. The economic consequences of these biosecurity measures for various risk factors are shown.

INTRODUCTION

Infectious diseases cause economic losses, one of which is the potential future loss of market access caused by the risks to animal or public health (Wells et al., 1998). One way of achieving a higher animal health status is through disease eradication. The responsibility for eradication is often at the farm level which implies that individual farmers are responsible for the health level of their own animals. In the Netherlands, a considerable number of farmers participate in eradication programmes for bovine herpesvirus type 1 (BHV1), bovine viral diarrhoea virus (BVDV), *Leptospira interrogans* serovar *hardjo* (*L. hardjo*) and *Salmonella enterica* subsp. *enterica* serotype *Dublin* (*S. dublin*). For a successful eradication programme, farms should remain disease-free and should take adequate biosecurity measures to prevent reinfection of the herd.

In practical terms, a dairy farm cannot become completely closed as there are always necessary contacts with the outside world, such as with veterinarians, AI-technicians or cattle grazing outside. In this paper, professional visitors are visitors that enter the animal area of the barn and come into contact with cattle. Protective farm clothing is defined as overalls/overcoats and boots that are provided by the farmer for use by visitors before their come into contact with the cattle. A sanitary barrier is a covered area outside the barn in which visitors can change into protective farm clothing. A sanitary barrier has a 'dirty' side,

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where visitors change clothing and a 'clean' side, where visitors wear the dedicated protective clothing and can then enter the barn.

The economic implications of biosecurity measures are not always obvious to farmers. Management adaptations need to be made for different parts of the farm and tend to be farm specific. The management measures required to become a more closed system will differ in effectiveness in terms of risk reduction and costs. Furthermore, the possible benefits of biosecurity measures, as expressed by the losses avoided from the decreased risk of disease introduction, will also differ depending on the characteristics of the farm. An economic model can provide better insight into this complex management problem. For effective on-farm decision support, the inputs for such an economic model have to be farm specific. It should represent the situation on the farm, and it should be able to evaluate a wide range of strategies. Furthermore, the output of the model needs to be recognisable and applicable to the farmer (Jalvingh, 1992).

Management strategies can be evaluated using simulation or optimisation. Optimisation models are generally developed for a specific situation and are less suited to study the consequences of a wide range of management strategies (Jalvingh, 1992). Furthermore, the goal of the current economic model was to give farmers an insight into the possibilities of a more closed farming system. The final solution of the model does not necessarily have to be the optimal solution from a financial or risk perspective. Therefore, a simulation model was preferred to model the economic consequences of biosecurity measures.

A deterministic design is the most straightforward and simplest modelling approach. Other, more elaborate approaches are probabilistic or stochastic modelling. In probabilistic modelling, probability distributions are included to model uncertainty. Random number generators are added when a stochastic modelling approach is used. In the deterministic approach, the resulting average performance of the farm is always equal for the same input (Jalvingh, 1992). Chance and uncertainty are important features of disease introduction. However, the present model was developed as a first attempt at modelling the economic consequences of biosecurity measures and therefore a simple, static, deterministic design was chosen.

The objective of the present study was to describe and discuss the results of an economic model for on-farm decision support. The economic consequences of several biosecurity measures aimed at preventing the introduction of certain diseases will be shown.

MATERIAL AND METHODS

An economic model was developed to calculate the costs and benefits of a more closed system on dairy farms. The economic model is a static model, which means that time was not included as a variable. Furthermore, the model is deterministic and contains no probability distributions to model uncertainty in the behaviour of the system. The inputs for the model were obtained from previous studies that focused on introduction of BHV1 (Van Schaik et al., 1998, 1999a, 1999b, 2000a, 2000b). The odds ratios (ORs) of the risk factors in the model were therefore solely based on BHV1, but were assumed to be the same for introduction of the other infectious diseases, BVDV, *L. hardjo* and *S. dublin*. The model contained the potential losses as a result of introduction of BHV1, BVDV, *L. hardjo* and *S. dublin*, as calculated by Van Schaik et al. (1999b), Groenendaal (1998), Bennett (1993) and Visser et al. (1997), respectively. The potential losses were used to calculate the benefits (or avoided losses) of certain biosecurity measures. The costs of the biosecurity measures were calculated by partial budgeting (Dijkhuizen and Morris, 1997). The net revenue of every management measure was calculated per year for the Dutch situation. Changes over time and uncertainty of the costs were not included in the calculations. Each biosecurity measure was assumed to reduce the risk of a risk factor by a certain percentage set between 0% and 100%. The risk reduction of each biosecurity measure was not based on scientific results, but was estimated based on common sense and discussions with farmers and experts.

The model was divided in four modules. A module for general farm characteristics ('farm-input module') contained information on BHV1 status, farm size, farm intensity, number of cattle sold and the distance to neighbouring cattle farms. A module for the management measures ('management module') consisted of numerous biosecurity measures, which may eliminate or reduce the risk of the risk factors. In the 'losses module', the losses as a result of introduction of infectious diseases were calculated. In the 'results module', the chance of introduction, costs of the management measures and losses of introduction of BHV1, BVDV, *L. hardjo* and *S. dublin* were combined to calculate the possible benefits of the biosecurity measures. A more thorough description of the model is available (Van Schaik, 2000c).

Several biosecurity measures incorporated into the model to counteract the various risk factors are presented in this paper. The results show which measures are profitable and under what conditions. The benefits of the biosecurity measures were calculated as follows:

Benefit = total disease introduction losses*(1–remaining risk) – costs of biosecurity measures

where remaining risk = OR_{farm} after biosecurity measures / OR_{farm} with initial management

with $OR_{farm} = e^{(\beta 1+\beta 2+\beta 3+\beta 4+\ldots+\beta n)}$ and

β_n = regression coefficient of the n^{th} risk factor

The total losses from the introduction of an infectious disease were calculated for a fictitious farm as described previously (Van Schaik et al., 2000c). These losses were kept constant at 9531 Dutch guilders (Dfl.). This hypothetical farm was used in all the analyses presented in this paper. The costs and benefits were calculated over a 5 year period.

RESULTS

Input of economic model

The ORs of all risk factors in the farm-input module are shown in Table 1. The fictitious farm used for the calculations was a 55 cow dairy farm, at 350m distance from another cattle farm with an average of two professional visitors per week to the cattle barn. The herd is free of BHV1, BVDV, *S. dublin* and *L. hardjo*. The farm only sells young bull calves for fattening and does not sell breeding bulls or heifers. The losses due to the introduction of the infectious diseases are shown in Table 2.

Table 1. Risk factors for a fictitious 55 cow dairy herd in the farm-input module

Risk Factor	OR
Distance to other cattle farms (in 100 metres)	0.70 [a]
The number of purchased BHV1-free heifers (per year)	1.32 [a]
Participation in cattle shows (yes/no)	3.54 [a]
Cattle returned to the farm e.g. rejected for export (yes/no)	4.59 [b]
Cattle are grazed at other farms or other cattle at the home farm (yes/no)	1.28 [c]
Hectares of land where cattle were grazed adjacent to neighbouring cattle (ha.)	1.22 [c]
Young stock are served by a purchased bull (yes/no)	1.28 [c]
The number of professional visitors in the barn (per year)	1.004 [a]
Has a temporary employee that also works at other farms (yes/no)	3.27 [a]

[a] Van Schaik et al. (1998)
[b] Van Schaik et al. (1999a)
[c] estimated based on the univariable results of Van Schaik et al. (1998, 1999a, 2000a)

Table 2. Potential losses from the introduction of infectious disease onto the fictitious dairy farm (Dfl.)

Current management	IBR	BVD	*L. hardjo*	*S. dublin*	Total
Total loss over 5 years	8882	28215	18975	24585	
Probability of introduction[a]	11%	10%	3%	21%	
Risk before measures	100%	100%	100%	100%	
Average loss over 5 years[b]	977	2822	569	5163	9531

[a] Van Schaik et al. (2000b)
[b] average loss = total loss * probability of introduction * risk before measures

The benefits of biosecurity measures

The economic benefits of biosecurity measures to eliminate or reduce the risk of the risk factors in the model on the fictitious dairy farm are shown in Tables 3 – 8. The tables contain various current management options as well as the potential biosecurity measures that can be taken. The economic comparison (costs of measure and benefits of the additional biosecurity measure) is given in the body of the tables in Dutch guilders[1] over a 5-year period. Positive benefits mean that the measure is profitable compared with current management practices. When the benefits are negative, biosecurity measures are not profitable compared with current management practices. The remaining risk was stated as a percentage and is the remaining farm risk after the implementation of the biosecurity measures divided by the initial risk before biosecurity measures. The initial risk was based on the risk factors of the current farm situation.

In Table 3, the farmer purchases two cows per year and to eliminate or reduce the risk of purchasing cows, the farmer may take certain biosecurity measures. The economic benefits of several potential measures are shown.

[1] Dfl. 1 = 0.45 EURO = US$ 0.41 = GB£0.28 (Dec. 2000)

Table 3: Benefits of certain biosecurity measures taken to reduce the risk from purchasing two cows per year (Dfl.)

	Current management					
	Purchase of any two cows			Purchase of two BHV1-free cows		
Biosecurity measures	Costs	Risk	Benefit	Costs	Risk	Benefit
Purchased cows tested for BHV1 and quarantined till result.	3000	59%	932	1000	97%	-732
Stop purchasing cows by:						
Rear 2 extra heifers for which forage has to be purchased and housing and labour costs are incurred.	13300	57%	-9214	11300	95%	-10781
Suboptimal replacement of dairy cows.	3100	57%	986	1100	95%	-581
Not filling the milk quota at end of year.	1500	57%	2586	500	95%	19
Leasing part of quota to other farm.	-16050	57%	20136	-14050	95%	14569

In the situation where the farmer purchases two cows without knowing their disease status, most biosecurity measures are profitable because the overall farm risk is reduced greatly by such measures. In other words, the purchase of 2 cows contributes a lot to the overall farm risk and the benefit of reduced risk of introduction of infectious diseases outweighs the costs of the measures. The only exception to this was when the farmer stops purchasing and has to incur extra costs from purchasing forage, housing and labour to rear two more heifers. In the second option in Table 3, the farmer already purchases BHV1-free cows. In this situation, the overall risk of introduction of BHV1 was much smaller and therefore most biosecurity measures were not profitable. The only economically attractive options in this situation were, not filling the milk quota (Dfl. 19) at the end of the year or leasing the surplus milk to other farmers (Dfl. 14569).

Table 4 illustrates the situation where a farmer enters cows into cattle shows and compares no biosecurity measures with a scenario in which the farmer tests and quarantines the cows after the show. Both biosecurity measures that the farmer could take were profitable. However, not participating in shows might cause a reduction in the potential value of the price received for any pedigree heifers that are sold. However, if the value of the heifers that are sold on a yearly basis exceeds Dfl. 1128, then the benefits of participation in cattle shows with testing and quarantine afterwards would be greater than the benefits of not participating (=Dfl. 1128).

Table 5 depicts a farm that grazes ten heifers at other farms with cattle from those farms or grazes the heifers separate from other cattle. In both situations, it was not profitable to purchase extra land so that cattle can be grazed at the home farm, or when additional costs were incurred for forage, housing and labour. However, it was profitable for the farmer to graze the heifers with other BHV1-free cattle or for the heifers to be quarantined and tested before returning them to the herd.

Table 4. Benefits of biosecurity measures to reduce the risk from participation in cattle shows by a pedigree farm selling heifers (Dfl.)

	Current management					
	No measures			Test and quarantine after show		
Biosecurity measures	Costs	Risk	Benefit	Costs	Risk	Benefit
Cows are BHV1 tested after show and quarantined	500	32%	5964	N/A.	N/A.	N/A.
Farm stops participating in cattle shows	0	28%	6827	0	88%	1128

Table 5. Benefits of biosecurity measures to reduce the risk from ten heifers that are grazed at other farms (Dfl.)

	Current management					
	Grazing with cattle of another farm			Grazing separate from other cattle		
Biosecurity measures	Costs	Risk	Benefit	Costs	Risk	Benefit
Heifers are grazed with BHV1-free cattle	2500	11%	6026	N/A.	N/A.	N/A.
Heifers are BHV1 tested and quarantined	5000	11%	3526	5000	37%	1024
Stop grazing on other farms:						
Purchase of extra land	12000	8%	-3252	12000	29%	-5200
Rearing on own farm for which costs for forage, housing and labour are incurred	10650	8%	-1902	10650	29%	-3850

Table 6. Benefits of biosecurity measures to reduce the risk of grazing close to cattle of other farms (Dfl.).

	Current management					
	Grazing cattle within 3m distance of cattle from another farm			Grazing cattle at least 3m apart of cattle from another farm		
Biosecurity measures	Costs	Risk	Benefit	Costs	Risk	Benefit
Field that borders neighbours is converted to grow cereals	16200	55%	-11900	15300	86%	-13973
Cattle graze least 25 m apart from other cattle	900	55%	3400	0	86%	1327
A permanent double fence is built that keeps cattle at least 3 m separate	2010	62%	1623	1110	97%	-882
Field is not used when other cattle graze at 3 m distance of the field	900	64%	2553	N/A.	N/A.	N/A.

In Table 6, cattle were grazed close to cattle from other farms. In the first scenario, this was within a 3m distance and all biosecurity measures are profitable except converting a field to grow cereals. In the second scenario, cattle grazed at least 3m apart from other cattle and, in this case, the only profitable measure a farmer can take to further reduce the risk is to keep cattle at a distance of at least 25m.

Van Schaik et al. (2000a) found that cattle escaping from their fields and mingling with other cattle was an important risk factor for introduction of BHV1 to certified BHV1-free farms. Therefore, biosecurity measures to reduce the risk of this factor were all highly profitable (Table 7).

Table 7. Benefits of biosecurity measures aimed at reducing the risk of one cow per year escaping and mingling with cattle from other farms (Dfl.)

	Current management		
	No measures; one animal escapes per year		
Biosecurity measures	Costs	Risk	Benefit
Field that borders neighbours is converted to grow cereals.	2700	15%	5433
Field is not used when other cattle graze at a 3 m distance of the field.	150	24%	7122
Construction of a permanent double fence that keeps cattle at least 3 m separate.	335	22%	7144
Cattle are grazing at least 25 m apart from other cattle.	150	15%	7983

Table 8 shows that when more professional visitors enter the farm on a weekly basis then it was more profitable to employ measures to reduce the risk from those visitors. The use of protective farm clothing will be profitable when more than one professional visitor enters the cattle barn per week. The construction of a sanitary barrier will be profitable when more than two professional visitors enter the cattle barn per week. When more than four professional visitors enter the barn per week, it is more profitable to have a sanitary barrier than only providing protective farm clothing (Dfl. 175, data not shown in Table 8).

Table 8: Benefits of biosecurity measures to reduce the risk of professional visitors at the farm (Dfl.).

	Current management								
	One professional visitors per week			Two professional visitors per week			Three professional visitors per week		
Biosecurity measures	Costs	Risk	Benefit	Costs	Risk	Benefit	Costs	Risk	Benefit
Sanitary barrier is constructed.	3415	84%	-1788	3415	69%	-439	3415	57%	680
Professional visitors use protective over-coats and boots before entering the barn.	1485	88%	-367	1485	78%	620	1485	69%	1491

DISCUSSION

The economic model of biosecurity measures illustrated within this paper was based on the Dutch situation. Other countries may have other diseases with different probabilities of introduction and other economic factors that required consideration. Therefore, the exact benefits calculated by the model may not be valid for dairy farms in other countries. However, the model is a good tool for providing a more educated view on the relative benefits of biosecurity measures.

In many cases, the calculations illustrated that there were profitable biosecurity measures that could be taken to reduce the risk of introduction of infectious diseases. However, for intensive farms which can only rear a limited number of replacement heifers, not purchasing replacement cattle or not grazing at other farms can be very expensive options. Nevertheless, these farms can implement other profitable biosecurity measures, such as vaccination, testing and quarantine to considerably reduce the risk of disease introduction. Reducing the risk from professional visitors or a temporary employee through the provision of protective farm clothing will almost always be a profitable option that can be easily implemented. Additionally, most farms will have more than one professional visitor per week entering their cattle barn.

Economics

The economic model is a static model, which means that time was not included as a variable. Furthermore, the model is deterministic and contains no probability distribution to model uncertainty in the behaviour of the system. This simple modelling approach has its advantages and disadvantages. The advantage is that the model was relatively simple to build and adaptations to the model are straightforward. However, the model would become more realistic if a probability distribution of the risk estimates and the probability distribution of disease introduction were included. The probability distributions could be based on the confidence intervals obtained from studies or based on other estimates. In the deterministic model, the costs of disease introduction were spread over a five-year period and assumed that disease introduction occurred in the first year. In reality, introduction of diseases will be a stochastic process and the year of outbreak will be a random event. Therefore, the model overestimates the losses from the introduction of infectious diseases. A probabilistic or stochastic model would be more appropriate to generically determine the costs and benefits of biosecurity measures for an average Dutch dairy farm. However, the goal of the current model was to provide a simple tool to support farmers in their farm specific decisions on biosecurity measures and not to build a generic model.

Biosecurity measures usually do not significantly influence the farming system as a whole. This assumption is a precondition for the use of partial budgeting. A disadvantage of partial budgeting is that neither a specific time pattern nor a high degree of uncertainty are included in the method.

Model input

The magnitude of the risk factors for BHV1 in the model was such that direct animal contacts were more important than other sources such as visitors. This will be true for most infectious diseases of dairy cattle. The biosecurity measures in the model were also assumed to prevent the introduction of BVDV, *L. hardjo* and *S. dublin*. Many studies show that these infectious diseases share the same risk factors as BHV1.

The reduction of risk due to the specified biosecurity measures was arbitrarily chosen. It is clear that 'no purchase' will reduce the risk of introduction by purchased animals to 0%. However, it is less clear how much the risk posed by professional visitors is reduced when the visitors use protective clothing. Previous studies of Van Schaik et al. (1998; 1999a; 2000a) gave an indication of the reduction in risk when professional visitors use protective clothing, but the exact amount is hard to quantify and, in the model, the risk reduction was set at 60%. Information on the reduction of risk is difficult to obtain. The 'success' of a biosecurity measure in reducing the risk will also depend on the quality of management of the farmer. For example, the risk reduction of protective clothing will be smaller when protective farm clothing is not consistently used. It is worthy of note that the figures used in the model can be easily modified to suit an individual farmer.

The probability of introduction of infectious diseases used in the economic model was assumed to be equal to the average probability of infectious disease introduction of a cohort of BHV1-free Dutch dairy farms (Van Schaik et al., 2000b). The remaining risk was relative to the initial risk, which was based on the initial biosecurity status of the farm. Therefore, the avoided losses of infectious disease introduction were dependent on the initial risk and the final risk of a particular farm situation. However, the relative probability of introduction of the four infectious diseases was kept constant (11%, 10%, 3%, and 21% for BHV1, BVDV, *L. hardjo*, and *S. dublin*, respectively). The benefits of biosecurity measures will vary depending on the probability of introduction of the specific diseases. The results of the economic model are most valid for a situation in which the relative probability of introduction of the infectious diseases is similar.

When a farm is at risk from more diseases, biosecurity measures will become more beneficial. Furthermore, an eradication programme for an infectious disease may also enhance the benefits of biosecurity measures. It is costly to eradicate a disease once it has been introduced. On the other hand, an eradication programme will decrease the probability of introduction of the disease since the national prevalence will decrease as a result of the programme. The economic model will allow for replacement of the probability of introduction, losses from the introduction of BHV1, BVDV, *S. dublin* and *L. hardjo*, and inclusion of other diseases. The four diseases that were included in the model should be seen as an indication of the costs of introduction of infectious diseases. The model indicated that the benefits were maximal for farms that are already relatively closed and that are at risk from BHV1, BVDV, *L. hardjo* and *S. dublin*. Conversely, the economic benefits of implementing the biosecurity measures will be lower for farms that are less closed or for farms that are not at risk from the introduction of diseases (i.e. diseases are exotic to area or are already present at the farm).

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