Modelling the economic impacts of bovine viral diarrhoea virus at dairy herd level; the case of Slovenia

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Poster paper prepared for presentation at the EAAE 2014 Congress
'Agri-Food and Rural Innovations for Healthier Societies'

August 26 to 29, 2014
Ljubljana, Slovenia

Abstract

In the last decade Bovine viral diarrhoea (BVD) was listed by the World Organisation for Animal Health (OIE) as a notifiable disease, due to the fact that it causes significant production losses in cattle industry worldwide. The production losses include reduced milk production, reduced conception rate, abortions, growth retardation, early culling, increased mortality and an increased occurrence of other diseases. This paper presents a possible approach to how an economic analysis of BVD virus, could be conducted at the herd level. For this purpose a spreadsheet model in MS Excel has been developed utilizing Monte Carlo Simulations (MCS). Simulation results show that economic losses at the heard level could exceed 18,000 €. Obtained results suggest that this could be promising approach for analysis BVD effect at herd or animal level.

Keywords: Modelling, Spreadsheet model, Bovine viral diarrhoea, Disease cost

Introduction

The objective of animal health economics is to facilitate decisions in animal health management (Dijkhuizen and Morris, 1997). Optimization of disease control is a complex task due to the diversity of diseases. It is necessary to take into account the differences in epidemiology, course and clinical signs of disease, as well as significant differences in treatment, prognosis and preventive measures (Tisdell, 2011). Animal health economics is an interdisciplinary field of research which tries to provide a framework of concepts, procedures and data that help to quantify economic impact of animal disease and to develop methods for economic analysis.

In the literature one can find different methods for the analysis of measurable effects of disease on livestock productivity and the comparison of alternative control programs. Most often applied basic methods are partial budgeting, cost-benefit analysis and decision analysis. Whereas for more realistic and complex situations, advanced methods should be applied i.e. linear programming, dynamic programming, Markov chain simulation and Monte Carlo simulation (MCS) (Dijkhuizen and Morris, 1997).

The calculation of the economic impact offers a concrete criterion for consideration of the significance of animal disease (Dijkhuizen and Morris, 1997). Detailed analysis of economic impacts of infection with Bovine viral diarrhoea (BVD) virus at the herd level contributes to farmers as a decision support tool to initiate the control of the disease.

BVD virus is classified in the genus Pestivirus in the family Flaviviridae. It is distributed worldwide. Although the prevalence of BVD virus infection varies among regions, it tends to be endemic in many populations. The disease is most common in cattle herds between six months and two years of age, although cattle of all ages are susceptible (Kahn, 2011). The virus usually causes a transient infection (TI), but when the fetus is infected in the first four months of gestation, the born calf may be persistently infected (PI) (Houe, 1995). Infected animals suffer a number of negative effects. The key effects are in particular production losses that significantly influence economic efficiency of breeding. These relate to reduced milk production, reduced conception rate, abortions, growth retardation, early culling, increased mortality and as well as an increased occurrence of other diseases (Houe, 2003).

The researchers' approaches of evaluating the cost of BVD are very diverse. Gunn et al. (2004) simulated an outbreak of BVD in a typical Scottish beef suckler herd. Financial losses were estimated based on the outcomes of an epidemiological model. The main advantages of this approach is definitely possibility to apply published data, rerunning the model if any changes occur and that parameter values can be linked with uncertainty and variation respectively. Results suggest that an outbreak can be costly even if several immune animals are in the herd. Chi et al. (2002) determined direct production losses and treatment costs due to BVD in an infected average herd of 50 cows in the Maritime province in Canada. A sensitivity analysis revealed that changes in milk yield had major influence on losses. Fourichon et al. (2005) also used partial budgeting to calculate losses in 100 cow dairy herd with on-going infection. Sorensen et al. (1995) developed a dynamic, stochastic model for a dairy cattle herd affected by BVD virus. Technical and economic consequences were simulated by state changes of the individual cows and heifers.

Review of previous studies reveals that the costs of BVD at the herd level vary significantly (Chi et al., 2002; Houe, 2003; Fourichon et al., 2005). This is partly explained by use of different methodology, but more importantly by the amount of various negative effects of BVD on an individual herd level. Therefore it is reasonable to financially evaluate BVD effects and prevention measures on herd specific data (Houe, 2003). Moreover, it is not appropriate to generalize and transfer estimates of the disease costs to another region or time period. Deviation from realistic assessments may appear due to differences in jurisdictions (e.g. mandatory disease control), input and output prices, monetary values and production systems (Chi et al., 2002). Since to date a comprehensive analysis of the economic impact of BVD has not been conducted in Slovenia, this is also the main purpose of this study.

Method

To assess economic effects of BVD on a hypothetical dairy herd in Slovenia, a complex simulation model has been developed. The spreadsheet model utilizes Monte Carlo Simulations (MCS). To run simulations, an additional professional simulation software package, Risk Solver Platform V 10.5.0.0 (RSP) from Frontline Systems has been used. Beside advanced methods to perform simulations, it enables sensitivity analysis and parameterized simulations, creating a wide range of statistics and risk measures.

Simulations require probability distributions for their uncertain inputs, from where the simulation model randomly selects sample values. In one simulation RSP performed 5,000 replicates of random sampling.

The simulation model is set for a hypothetical herd of a hundred dairy cows. The basic assumptions of the model are that the disease is present in the herd and that animals are not vaccinated against BVD virus. On Figure 1 scheme of modular tool is presented.

The effects of BVD are estimated on average annual bases, expressed as gross margin (GM). Total revenues include revenues from the sale of milk, calves and culled cows, including also proportional part of direct payments. As baseline average quantity of milk per cow per year is considered. Variable costs include the cost of renewal of the herd, milk for the calves, fodder costs, other material costs and the costs of insemination, veterinary services, medicines, insurance and financing costs.

Simulation model consists of three sub-models, depending on infection with BVD virus. First sub-model is presumed for non-infected cows (N cow), second sub-model is in place for transiently infected cow (TI cow) and the third sub-model simulates effects of BVD for persistently infected cow (PI cow). All sub-models consider the same annual assumption. Uncertainty in the model is mainly associated with the BVD impact on production parameters and enters the model through random variables, which are supported by various random distributions. Most of the data were obtained from available literature.

As it is apparent from Figure 1, in the case of a non-infected cow, effects of BVD are expressed only through the potential effects on the susceptible calves. Due to simplification it is assumed that the non-infected cows are free of all other diseases. The effects of BVD are in main cases different for TI and PI cows. In such examples they are based on different frequency distributions of random variables. Main random variables integrated in the model for infected cows are: loss of milk yield, culling rate, reduced slaughter value, mortality risk, reduced conception rate, abortion risk, incidence of clinical mastitis and incidence of retained placenta. It is presumed that PI cow always gives birth to a PI calf, while a TI cow may have a sensitive, an immune or a PI calf. Further logic is that a PI calf may die, be diseased or subclinical. A susceptible calf may die, be diseased or non-infected. A diseased calf has reduced weight gain and there is a certain probability of needed additional treatment.

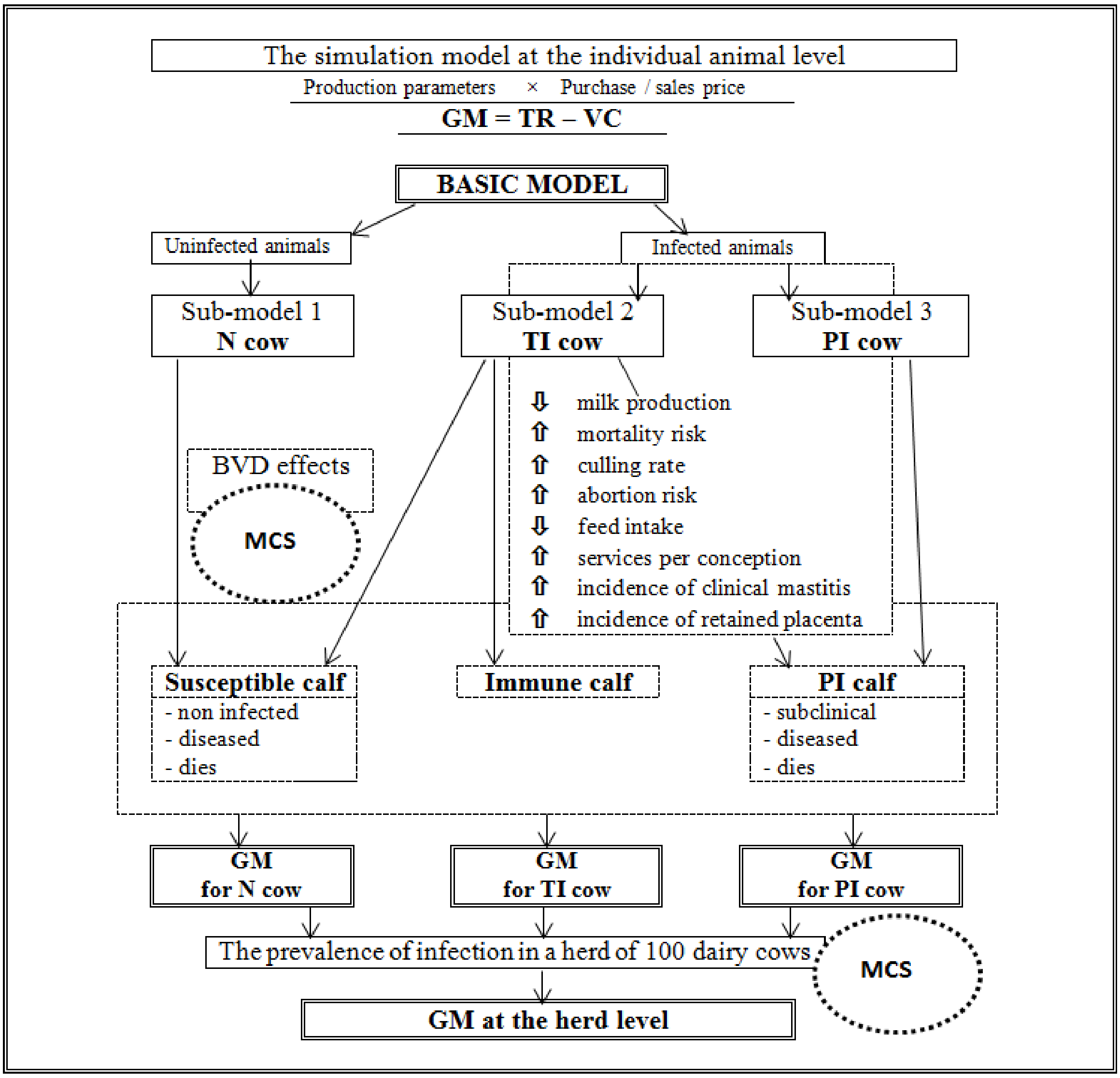

Figure 1. Scheme of the modular tool for analysis of BVD effects.

The technological parameters and monetary values were taken from Slovenian reports (Jerič et al., 2011). In the current version of the model all monetary values are assumed as deterministic, which is undoubtedly a weakness of the model. The model also does not consider lower quality of milk as a result of infection with BVD and consequently lower purchase prices. Nor does it capture market influences on the necessary inputs and outputs, which are reflected in price volatility.

An important assumption was that the immunity of the infected animals last at least one year. Also MCS based on pert distribution was applied to simulate share of each category of animals in the herd.

Results and discussion

Paper presents main results of simulating impact of BVD infection at the herd level. Due to the space limit only main economic indicators are presented and interpreted. Table 1 presents key items of revenues and variable costs that could be affected by BVD at the level of animal. Average values relate to 95 % confidence intervals. Furthermore for TI and PI cow the difference regarding the non-infected cow is also presented. In Table 2, the key statistical indicators of simulation at the level of individual animal are presented. Attention was paid to revenues, variable costs and gross margin at the 95 % confidence interval.

Table 1. Average revenues and variable costs per key items and gross margin for N, TI and PI cow.

	N cow	TI cow		PI cow	
	€	€	% of difference	€	% of difference
REVENUES					
Milk	2,131	1,885	-12	507	-76
Calf	241	230	-5	21	-91
Culled cow	115	113	-1	216	88
VARIABLE COSTS					
Renewal of the herds	331	346	5	1,298	292
Milk for calves	136	125	-8	19	-86
Feed	415	337	-19	118	-71
Costs of insemination	46	50	9	54	18
Costs of veterinary services and medicines	113	198	75	183	62
GROSS MARGIN					
	928	683	-26	-1.437	-255

Table 2. Key statistical indicators of simulation at the individual animal level.

	REVENUES			VARIABLE COSTS			GROSS MARGIN		
	N cow	TI cow	PI cow	N cow	TI cow	PI cow	N cow	TI cow	PI cow
Avg.	2,504	2,238	758	1,576	1,554	2,198	927	684	-1,440
SD	222	445	506	103	145	217	140	339	473
Min	1,359	17	17	1,154	1,150	1,170	140	-1,276	-2,289
Max	2,868	2,807	2,041	1,750	1,902	2,646	1,153	1,101	91
Skewness	-1.9108	-2.2496	0.4065	-2.1529	-0.5181	-1.8578	-1.4647	-3.0107	0.4135
Kurtosis	4.6517	6.6391	-0.6082	5.6439	-0.2396	4.8726	2.3192	11.7612	-0.4212
VaR 95 %	2,735	2,683	1,690	1,682	1,762	2,490	1,080	972	-638
CVaR 95 %	2,490	2,210	708	1,570	1,539	2,185	919	666	-1,491

According to main figures referring to uninfected cow with average lactation of 8,000 kg in average achieves 2,504 € of revenues which by average 1,576 € of variable costs results in annual 927 € gross margin (Table 2). Of course there are differences between animals in the herd. Most efficient animals could result in 1,153 € of gross margin, while BVD uninfected animals could result also with 140 € of annual gross margin. Later could happen due to other production and health risks not connected with BVD. As it is apparent from Table 1, model results show that by TI cow average GM is deteriorated for 26 %, which is mainly due to lower milk yield and also due to the additional costs for veterinary service caused by BVD. Similar pattern could be observed also for PI cow, where GM in average decreases even more significantly. Due to much shorter production period and consequential lower lactation production average gross margin is -1,440 € with standard deviation of 473 € (Table 2). Of course this influence is at the herd level not so significant, namely share of PI cows is in average relatively low (2 %). As it is apparent form Table 2 in 95 % GM would be -638 € or less.

Simulation results for prevalence of infection with BVD in herd revealed that on average our hypothetical herd consists of: 40 % non-infected cows, 58 % TI cows and 2 % PI cows. The average gross margin in infected dairy herd at the 95 % confidence interval is 74,354 €. The standard deviation is 25,443 € and mode 80,701 €.

Cows infected with BVD have reduced revenues from the sale of milk and calves, while revenue from a cull of the cows is reduced only in TI cows. The revenue from culled cows increased in PI cows as a result of much higher likelihood of culling and shorter longevity. Consequently the variable costs of renewal are much higher than for non-infected cows. Since the diseased animals have fewer calves, the costs of milk for calves are lower. The costs of feed are also reduced, as diseased animals have decreased feed consumption (Sorensen et al., 1992). Due to the high probability of death or culling of cows, feed costs for PI cows are considerably lower. The costs of insemination, veterinary services and medication in diseased animals are significantly increased.

As expected, the non-infected cows have the best results and show the least deviation from the average. Because of the negative effects of BVD, PI and TI cows have a lower gross margin. Interestingly, TI cows have slightly lower average variable costs compared to non-infected, but they show greater cost variability and higher maximum cost. The sensitivity analysis revealed that the gross margin of TI cows is most affected by the number of services per conception, the probability of culling, the likelihood of mastitis treatment and time of death or culling. The key influence on gross margin of PI cows, are the time of culling or death, the number of services per conception, the probability of culling and the number of years a cow is in production. The probability that a PI cow will reach gross margin of 0 € or more is only 0.1 %, while for the TI cows it is 95.7 %.

Conclusions

To assess the economic impact of BVD for a dairy herd in Slovenia, we have developed an economic model that is based on MCS approach of random sampling. Technological parameters and the monetary values describe the typical breeding of dairy cows in this region. The developed modular tool mimics the effects of BVD on reproduction, production and longevity of dairy cows. It also takes into account the increased incidence of clinical mastitis and a retained placenta.

The results indicate that additional costs and mainly lost revenues at a dairy herd due to BVD might have an important impact on economic efficiency of dairy production. A significant impact on gross margin is mainly due to lost revenues. According to our estimates, the loss in an infected one hundred cow dairy herd on an annual basis exceeds an average 18,000 €.

MCS has proven to be particularly useful in terms of understanding the problem and the possibility of using data from published literature. Obtained results show usefulness of the presented approach for financial analysis of BVD.

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