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A SIMULATION MODEL FOR ASSESSMENT OF ECONOMIC CONSEQUENCES OF MASTITIS IN DAIRY HERDS

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Les mammites sont les maladies de la vache laitière les plus fréquentes malgré la mise en place de plans de maîtrise. L'objet du simulateur est d'estimer l'impact économique des mammites. L'évolution du troupeau de vaches laitières est simulée en fonction des mesures de prévention en place et des traitements, du niveau de prévalence des mammites et de leurs effets (sévérité, durée). La production de lait est simulée au niveau de chaque vache en fonction de la parité et du stade de lactation en particulier. Il s'agit d'un modèle dynamique avec un pas de temps de un jour, et stochastique, où les événements sont simulés selon des lois de probabilités. Ainsi, la répétition des simulations permet de reproduire une certaine variabilité dans les résultats. Le simulateur utilise en entrée une description du troupeau dans son état 'initial' vache par vache, des variables de conduite du troupeau, des règles de décisions et des paramètres économiques. Les principaux modules concernent la reproduction, la production laitière, la réforme et le renouvellement, les mammites et la gestion de l'objectif de production sur la campagne. La survenue des mammites et leurs effets sur la production laitière sont simulés. Des mammites subcliniques et différents types de mammites cliniques définis par leurs effets sont proposés. La gestion du quota permet de prendre en compte différentes attitudes de conduite du troupeau et d'adapter les règles de conduite à la situation. Ce programme, conçu autour d'un gestionnaire de base de données, permet de produire les informations nécessaires à la vérification de chacun des modules et de créer, en résultats de simulation, des jeux de données détaillés sur lesquels peuvent être réalisées des analyses approfondies.

INTRODUCTION

Mastitis are still the most frequent health disorders in dairy herds despite major effort in developing control programs. Because risk factors and consequences of mastitis exist mainly at the herd level, decisions to implement control methods are made at the herd level. Decision makers need information on economic impact of mastitis in the herd and expected economic efficiency of the available control methods. Costs of control methods can be measured or estimated from empirical data, whereas economic losses and economic effect of control measures cannot.

The purpose of this paper is to give a general description of a simulation model developed for the assessment of economic consequences of mastitis in a dairy herd.

IDENTIFICATION OF THE SYSTEM OF CONCERN

The system of concern, the dairy herd, is defined by the production process and the management (figure 1).

Prevalence of mastitis in the herd depends on exposure to risk factors and implementation of control measures. Some risk factors can be controlled by prevention whereas others are uncontrollable. Treatments are also available control measures. The herd status regarding prevalence of mastitis is defined, on the one hand, by frequency, duration and severity of clinical cases and subclinical udder infections, and on the other hand, by the characteristics of the mastitic cows (lactation number, stage of lactation...). At the cow level, mastitis effects on production are lower milk yield, poorer milk quality and higher risk of being culled and in some cases death. Production consequences at the herd level result from lower outputs and higher inputs.

The decision maker needs information about production consequences to assess control costs and economic losses in the current herd status. Decisions to adjust control methods are based on comparison of current costs and losses with expected ones if a change in prevention or treatment is implemented. Control costs include costs of preventive actions, of surveillance and of treatments.

DESCRIPTION OF THE SIMULATION MODEL

Classification of the model

The model is a dynamic time stepping model with time steps of one day. It is a mechanistic model where each cow within the herd is simulated. The herd is represented as a group of cows and heifers. Events are simulated at the cow level. Management decisions are defined at the herd level. It is a stochastic model: occurrence of discrete events is triggered stochastically and based on probabilities. Consequently, different runs of the model will result in variable outcomes. Replications of simulation will provide distribution describing variability of expected results.

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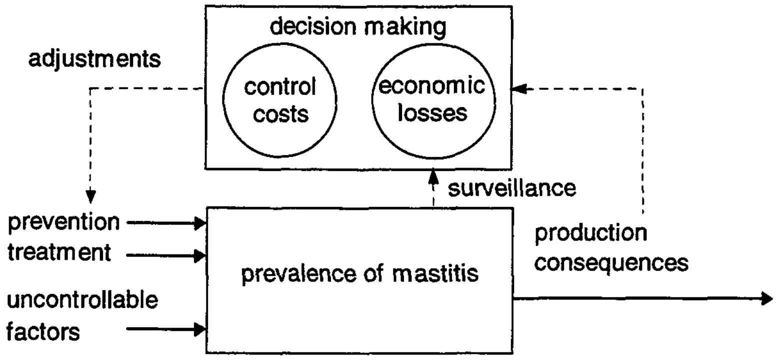
Figure 1
A model for mastitis in the dairy herd as system of concern



Variables in the model
state variables
Each cow is described by a set of state variables which values change throughout the simulation. These variables refer to age, reproduction (oestrus, insemination, gestation), milk production (lactation stage, yield, fat, protein), mastitis status of the cow (somatic cell count, clinical mastitis). At the start of the simulation, state variables are set to values describing the herd of concern. Changes in state variables are triggered by the simulation processes.

driving variables
Driving variables are available to the user to manipulate the simulation model. Values of the driving variables must be defined before starting a simulation.
The first group of driving variables is used to define herd and farm parameters (e.g. milk quota, herd size).
The second group includes variables used to define decision rules for management of the herd:
- reproductive strategy variables: e.g. minimum age to look at heat in heifers, minimum calving to first AI interval, calving season,
- replacement-culling strategy variables: e.g. selection of heifers, selection of cows to be culled,
- milk production strategy variables: e.g. shape of the lactation curve, drying off,
- quota management variables: e.g. prefered actions in case of predicted over-production or under-production, thresholds to do these actions,
- mastitis control strategy variables: e.g. treatment at drying off, treatment of clinical cases, culling of mastitic cows, efficiency of preventive actions on occurrence at the herd level.

The third group of driving variables are parameters used for economic analysis: e.g. milk pricing system, meat price, cost of each available control action.
The fourth group of driving variables are parameters defined by the user which are used in the stochastic simulation processes: e.g. probability of oestrus detection, conception rate, probabilities of occurrence of mastitis, probability of evolution of somatic cell count, probability of success of treatments.

Simulation processes
reproduction
Cycling ovarian activity of heifers starts at a user-defined age. Cycling ovarian activity of cows starts after a minimum interval after calving. Heat occurs according to the distribution of interval between calving and first heat or interval between heats of each animal. Heat is detected according to detection rate. Decision to inseminate is based on reproductive strategy variables. Result of insemination depends on conception rate. Abortion may occur according to abortion rate. At calving survival and sex of the calf depend on mortality rate at birth and sex ratio respectively. Heat, heat detection, conception, abortion, day of calving, calf survival and sex of calf are triggered stochastically.
milk production
Daily milk, protein and fat yield are modelled by 'Wood' equation (Wood, 1967). Feed consumption is deduced from milk yield. The result of 'Wood' equation is expected yield. Effect of mastitis is then substracted to calculate actual yield. Production level and persistency of each cow are corrected by lactation number effect to define 'Wood' equation parameters. Production level and persistency of heifers entering the herd are defined stochastically. Production level of a heifer depends on the production level of her mother and the progress in production between generations.
replacement and culling
Death and involuntary culling that cannot be delayed occur stochastically. Heifers kept in the herd depend on a strategy (to keep all heifers or to keep a number of heifers sufficient to reach replacement rate). Pregnant cows are ranked according to their production level. Heifers born from the 10% cows with the highest or lowest production level are kept or sold respectively. Among the other ones, decision to keep depends on month of birth. Ranking of cows candidate to culling is based on different criteria: reproductive status, milk yield, mastitis status. Culling of candidate cows depends on both herd size limits and milk shipping compared to the quota.

mastitis
Subclinical udder infection is simulated by somatic cell count levels. Change in SCC level occur stochastically and is based on probabilities defined by current herd infection rate, lactation stage and lactation number. Effect of SCC on milk yield is modelled according to relationships described by Hortet et al. (1997). Several types of clinical mastitis are defined by their effects on yield, cells, culling or death. Occurrence of clinical mastitis is triggered stochastically and depends on lactation incidence rates defined at the herd level, and on lactation (or dry period) stage, lactation number, and milk yield. For each type of mastitis, duration and range of milk yield decrease are modelled to fit patterns described from empirical data (Lescourret and Coulon, 1994).
quota
Each month total expected campaign production is calculated from current status of the herd: milk yield from the beginning of the campaign, milk yield to the end of the campaign expected from lactating cows, pregnant cows and heifers. The difference between expected production and quota is calculated. If the difference is within thresholds defined by the user, no specific decision regarding quota management is made. If the difference shows an over-production, decisions are made on drying off, culling, sales of cows or heifers. If the difference shows an under-production, decisions are made on purchase of cows or pregnant heifers.

Software program
The software program was written in the Microsoft Access™ Basic language 2.0. Data describing state variables and results of simulation are organised in databases and can be edited easily in different Microsoft Windows softwares or exported as ASCII format files.

DISCUSSION
The simulation model was built in order to assess the economic consequences of mastitis in a dairy herd. It is assumed that in some cases, the estimate of these economic consequences can be low. Therefore, the simulation model must account for all the other factors influencing the economic results in a higher or comparable range than expected effect of mastitis. Therefore, all the main production processes in the herd (e.g. reproduction, replacement, milk production) were simulated contrary to simulation models described in the literature, which are focused on specific strategies, e.g. relative to reproduction (Oltenacu et al., 1980) and/or replacement (Dijkhuizen et al., 1986, Marsh et al., 1987). To provide a good precision of the estimate of the economic results, these processes were simulated in more details than in the models built by Congleton (1984) and Sorensen et al. (1992). The resulting 'simulation error' must be lower than the economic effect of mastitis.
Moreover, this model takes into account quota management (control of annual milk shipping) and farmer's strategies regarding bulk milk somatic cell count. These criteria influence the evolution of the herd along the simulation period and consecutively the economic results but were not included in the existing models.
Few dairy herd models included mastitis occurrence and effect (Congleton, 1984, Sorensen et al., 1992). They simulated occurrence of clinical mastitis, effect on milk yield and treatment costs. In the present model, different types of mastitis were defined including subclinical mastitis and different degrees of severity of clinical cases. In addition to milk yield and treatment costs, effects on somatic cell counts was simulated.
This model was built with the purpose of user-friendliness all along the simulation process. The outputs of the simulations are included in tables and can be easily manipulated. In addition, intermediate tables, which allow to check the course of each simulation process, are continuously built on user's request. Special attention was paid to the ability of the evolution of the program.

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