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An ex ante analysis of the economic profitability of automatic oestrus detection devices in different dairy farming systems in France

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Abstract

The reproductive performance of dairy herds is mainly influenced by the physiological reproductive status of the cows and by herd management. The objective of this work was to evaluate the economic benefits of investment in a sensor system for oestrus detection (pedometer or activity meter) in different dairy farming systems in France.

A stochastic dynamic model was used to simulate all the physiological and management processes occurring in a dairy operation. Seven French dairy farms with different breeds (Holstein, Montbéliarde and Normande), size (30 to 119 cows), milk price (conventional or protected designation of origin) and calving strategies (grouped or continuous calving) were simulated. Six scenarios with different oestrus detection rates (50% before and 90% after use of the equipment) and percentage of cows equipped (40%-80%-100%) were applied to each farm. The internal rate of return was used to evaluate the economic benefits of the investment. It was estimated that the system for transmitting and analysing data from pedometer and activity meter systems would cost €6,498 and €4,430 respectively.

The use of an automatic oestrus detection device reduced the calving interval by between 7d (herds with Normande cows) and 23d (herds with Holstein cows) and increased the annual gross margin per cow by between €8 (small herd with Normande cows) and €92 (herd with Montbéliarde cows). The investment appeared profitable in two-thirds of the situations, characterised by high milk prices, large herd size or low percentage of cows equipped.

These results suggest that the return on investment should be estimated at each farm level.

Keywords: dairy farming systems, reproductive performance, economic profitability, automated oestrus detection, model.

Introduction

The negative impact of poor reproductive performance on the economic profitability of dairy farms has been demonstrated in several studies carried out on simulated data using mathematical models (Cabrera, 2014; Inchaisri et al, 2010). Factors influencing the reproductive performance of dairy herds are related, on the one hand, to the intrinsic characteristics of cows (genetic value, age, reproductive function, disorders and health problems) and, on the other hand, to herd management practices (production and feeding strategy, heat detection and culling strategy) (Hudson et al, 2012; Lucy, 2001). Better heat detection by the farmer has a significant impact on reproductive performance; it has been proven in many studies that increasing the sensitivity (Se) of heat detection improves the techno-economic performance of dairy cattle farms (Inchaisri et al, 2010). However, improving the Se of heat detection by the farmer without increasing the labour time requires an investment in equipment such as an automatic oestrus detection device.

Rutten et al, 2014 showed that investment in activity meters is economically profitable, depending on the culling rate and the initial Se of visual heat detection by the farmer. However, in their study, the impact of dairy farming systems was not taken into account. In France, there is great heterogeneity between the different dairy farming systems in terms of reproduction management (grouped or continuous calving), culling strategy, cattle breeds and milk yield. To take all these elements into account, the objective of this work was to evaluate the economic benefits of investment in a sensor system for oestrus detection (pedometer or activity meter) in different dairy farming systems in France.

Materials and methods

Model simulation

A dynamic individual-based stochastic model, operating in discrete time, was developed to simulate the life of a cow, from its entry into the herd (birth or purchase) until its exit (culling or death). The time step used is the day. The model was created using Access software (Microsoft Corporation, Redmond, WA, USA). All discrete events at the animal level (such as ovulation, heat detection, conception, foetal sex, health and reproductive disorders) are generated stochastically by random draw from the appropriate probability distribution.

The model simulates the biological processes (genetic value, reproductive cycle, lactation function and health problems), the herd management practices (feeding,

renewal, sale, culling, purchase and reproduction management) and the interaction between the biological processes and the herd management practices.

Simulated herds

Seven dairy herds corresponding to 7 different dairy farming systems in France were simulated with the model (Table 1). These herds differ in terms of dairy breed (Holstein, Normande and Montbéliarde), herd size (from 30 to 119 cows), average milk yield per cow per year (from 5200 l to 8450 l), location (plains vs. mountains), and type of milk produced (conventional vs. PDO). Thus, these herds have different breeding practices (compact: grouped calving over 5 months vs. continuous: calving over the whole year). The data for these 7 herds were obtained from the INOSYS breeding networks of the Institut de l'Élevage France.

Table 1: The main characteristics of the seven simulated farms

| Farm identification | Breed type | Herd size | Milk yield (l)/cow/yea r | Calving management t | Milk price |
|---------------------|--------------|-----------|-----------------------------|-------------------------|------------------|
| 1 | Holstein | 50 | 5,755 | Grouped | Conventiona l |
| 2 | Normande | 56 | 6,350 | Grouped | PDO* |
| 3 | Normande | 68 | 6,322 | Grouped | PDO* |
| 4 | Holstein | 119 | 8,450 | Continuous | Conventiona l |
| 5 | Montbéliarde | 30 | 5,200 | Continuous | Conventiona l |
| 6 | Montbéliarde | 77 | 7,003 | Continuous | Conventiona l |
| 7 | Holstein | 38 | 7,021 | Continuous | Conventiona l |

* *PDO: Protected Designation of Origin*

Simulated scenarios

For each farm, six scenarios were simulated. These scenarios were obtained by combining:

- Two values of Se for heat detection: 50% (sensitivity of heat detection before use of automatic oestrus detection devices) and 90% (sensitivity of detection of heat with automatic oestrus detection devices). The specificity was kept at 95%.
- Three equipment rates (cows with collars): 40%, 80% and 100%. The 40% rate was not used in herds with grouped calving.

For each simulated scenario, 10 years were fitted, with 250 repetitions. Data from the first 5 years of simulation were not used in our study because they were used to calibrate the simulations. Consequently, the average of simulation results over the last 5 years was used to calculate the return on investment in a sensor system for oestrus detection.

The economic data (selling prices for milk and animals and purchase prices for concentrates) used to simulate each herd were obtained from the 2014 French economic context.

Estimation of economic profitability of a sensor system for oestrus detection

The difference in the annual gross margin (ΔAGM) before and after the use of a sensor system for oestrus detection was used to estimate the economic profitability of such an investment. Two types of automated heat detector were tested (activity meter and pedometer) with lifetime and investment costs specific to each type (Table 2). The annual maintenance and replacement costs for broken sensors were disregarded because of a guarantee. Two indicators of economic profitability were calculated: the net present value (NPV) and the internal rate of return (IRR).

The NPV is the difference between the sum of the ΔAGM updated during the detector lifetime and the initial investment cost (IIC):

$$NPV = \sum_{n=1}^{n=p} \frac{\Delta GM}{(1+DR)^n} - IIC \tag{1}$$

where n is the technical lifetime of automatic heat detectors, and DR is the discount rate. The value used in our study (2.1%) was set according to data from the Organization for Economic Co-operation and Development (OECD).

An investment is considered profitable if the NPV is greater than zero. The second indicator (IRR) corresponds to the discount rate value that nullifies the NPV. If the IRR is higher than the chosen DR (2.1%), this means that the investment is profitable.

Table 2: Economic input of two simulated sensor system for oestrus detection (activity meter and pedometer) obtained from technology providers in France

| | Pedometer | Activity meter |
|---------------------------------------|-----------|----------------|
| Technical lifetime (years) | 10 | 5 |
| Cost of sensor system | | |
| Data transmission system and software | 6,498 | 4,430 |
| Collar (€/cow) | 107 | 120 |

Results and discussion

Table 3 shows that the use of an automatic oestrus detection device decreases the calving interval by between 7d (herds with Normande cows) and 23d (herds with Holstein cows). These results are in agreement with the reproductive performances observed in the study by Delaby et al, 2013, which was carried out on an experimental farm in France: the success rates for first AI and cumulative AIs were higher in the Normande than in Holstein cows.

The increase in the Se of heat detection due to the use of an automated heat detection system had a significant effect on calving interval in herds with continuous calving (reduction of between 10 and 23 days) compared to herds with grouped (reduction of between 6 and 11 days) (Table 3). This result is explained by the higher culling rate of cows with reproductive disorders or infertility in herds with grouped calving than in herds with continuous calving. Consequently, the improvement in the sensitivity of heat detection has a greater impact on herds with spread calving. This phenomenon is called selective survival bias.

Table 3: Variation in calving interval and in annual gross margin per cow between situation with (Se = 90%) and without (Se = 50%) use of an automatic oestrus detection device

| Farm identification | Variation in calving interval (days) | Variation in annual gross margin (€/cow) |
|---------------------|--------------------------------------|--|
| 1 | - 12 | + 49.5 |
| 2 | - 6 | + 8.5 |
| 3 | - 6 | + 38.4 |
| 4 | - 23 | + 24.6 |
| 5 | - 10 | + 92.5 |
| 6 | - 16 | + 36.6 |
| 7 | - 14 | + 31.7 |

In our study, the improvement in the sensitivity of heat detection achieved through use of an automated oestrus detection device had a great effect on the calving interval (reduction of between 14 and 23 days) for farms with high yields (> 7,000 l / cow / year) (Table 3, farms 4, 6&7). In fact, in several studies an increase in milk yield is associated with a decrease in the reproductive performance of dairy cows (Walsh et al, 2010). In addition, according to Plaizier et al, 1998, the impact of improved heat detection is greater when the initial herd reproductive performance is poor. Consequently, these two elements explain the important effect of an automated oestrus detection device on the calving interval in farms with high milk yields.

For the economic profitability of an investment in automatic oestrus detection device, Table 4 shows the value of IRR by type of equipment, equipment rates (cows with collars) and farms.

Table 4: Values of internal rate of return (IRR) according to type of automated oestrus detection device, equipment rate and dairy farming system

| Herd identification | Pedometer | | | Activity meter | | |
|---------------------|--------------------|-------|-------|--------------------|-------|--------|
| | Equipment rate (%) | | | Equipment rate (%) | | |
| | 40% | 80% | 100% | 40% | 80% | 100% |
| 1 | Not estimated | 16.9% | 14,3 | Not estimated | 3.9% | 1.4% |
| 15 | Not estimated | 0.2%* | 0.1%* | Not estimated | NF** | NF** |
| 27 | Not estimated | 16.6% | 13.6% | Not estimated | 6.1% | 1.1%* |
| 35 | 13.1% | 11.9% | 8.5% | 13.9% | 0.1%* | NF** |
| 41 | 26.8% | 25.6% | 23.4% | 33.8% | 22.7% | 18.4% |
| 42 | 18.4% | 16.7% | 13.5% | 21% | 5.6% | 0.05%* |
| 46 | 2.7% | 1.5%* | 0.8%* | 0.04%* | NF** | NF** |

* *Investment not profitable*

**NF: internal rate of return not found (*Investment not profitable*)

The investment appeared profitable in two-thirds of the situations, which were characterised by high milk prices, large herd size or low percentage of cows equipped. The effect of herd size corresponds to a reduction in the purchase price of a data transmission system and software, which is fixed whatever the size of herd. Similarly, the lower the equipment rate, the lower the investment cost. However, our study did not simulate the interaction between the equipment rate and the sensitivity of the automatic oestrus detection device. For the milk price effect, the main source of income for dairy farms is the sale of milk. The improvement in the sensitivity of heat detection increases the quantity of milk produced per cow (Rutten et al, 2014). Therefore, in farms where the price of milk is high (protected designation of origin), the benefits of improving the sensitivity of heat detection are more likely to cover the cost of investment. Additionally, greater benefits could be obtained if the farmer saves labour time while using the automatic oestrus detection device. Indeed, we chose not to include labour time in the estimation of the economic profitability because a previous study showed that only half of farmers considered that they saved on labour time (Allain et al, 2016).

Conclusions

The results of our study suggest that the return on investment should be estimated at each farm level, to take account of the variability in dairy farming systems.

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