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Estimating probability of insemination success using milk progesterone measurements

P. Blavy,*[1] N. C. Friggens,* K. R. Nielsen,† J. M. Christensen,† and M. Derks‡§#
*UMR Modélisation Systémique Appliquée aux Ruminants, INRA, AgroParisTech, Université Paris-Saclay, 75005 Paris, France
†Lattec I/S, Slangerupgade 6, DK-3400 Hillerød, Denmark
‡Institut National de la Recherche Agronomique, Unité Mixte de Recherche 1213 Herbivores, F-63122 Saint-Genès Champanelle, France
§VetAgro Sup, BP 10448, Clermont Université, F-63000 Clermont-Ferrand, France
#VetAgro Sup, Unité Mixte de Recherche 1213 Herbivores, Université de Lyon, F-69280 Marcy l'Etoile, France

ABSTRACT

The aim of this study was to quantify the effects of progesterone profile features and other cow-level factors on insemination success to provide a real-time predictor equation of probability of insemination success. Progesterone profiles from 26 dairy herds were analyzed and the effects of profile features (progesterone slope, cycle length, and cycle height) and cow traits (milk yield, parity, insemination during the previous estrus) on likelihood of artificial insemination success were estimated. The equation was fitted on a training data set containing data from 16 herds (6,246 estrous cycles from 3,404 lactations). The equation was tested on a testing data set containing data from 10 herds (8,105 estrous cycles from 3,038 lactations). Predictors were selected to be implemented in the final equation if adding them to a base model correcting for timing of insemination and parity decreased the overall likelihood distance of the model. Selected variables (cycle length, milk yield, cycle height, and insemination during the previous estrus) were used to build the final model using a stepwise approach. Predictors were added 1 by 1 in different order, and the model that had the smallest likelihood distance was selected. The final equation included the variables timing of insemination, parity, milk yield, cycle length, cycle height, and insemination during the previous estrus, respectively. The final model was applied to the testing data set and area under the curve (AUC) was calculated. On the testing data set, the final model had an AUC of 58%. When the farm effect was taken into account, the AUC increased to 63%. This equation can be implemented on farms that monitor progesterone and can support the farmer in deciding when to inseminate a cow. This can be the first step in moving the focus away from the current paradigm associated with poorer estrus detection, where each detected estrus is automatically inseminated, to near perfect estrus detection, where the question is which estrous cycle is worth inseminating?

Key words: progesterone, probability of insemination success, dairy cow, fertility

INTRODUCTION

For almost 40 yr, progesterone measurements have been used to assess the reproductive status of the cow (Bulman and Lamming, 1978). Interpretation of these progesterone profiles is not always straightforward. Features and shapes may differ according to environmental and cow specific traits, such as feed regimen (Rabiee et al., 2001; Vasconcelos et al., 2003) and milk yield (Wiltbank et al., 2006; Endo et al., 2013). Changes in progesterone concentrations in turn affect the quality of the oocyte and early embryo survival (Carter et al., 2010; Fair and Lonergan, 2012), and thus the overall pregnancy rate.

As the shape and features of progesterone profiles are linked with fertility characteristics that affect pregnancy rate, in theory they could be used to calculate a chance of insemination success for a given estrus in a given cow. To our knowledge, only one published model used progesterone profile features for this purpose (Friggens and Chagunda, 2005; Friggens and Løvendahl, 2008). That model aimed to provide information in real-time to aid decision making about whether or not to inseminate a cow detected in heat. It predicted the chance of future insemination success by looking at the declining slope of progesterone pre-estrus and cycle length of the previous estrous cycle, with chances declining when slope or cycle length move further away from optimal. However, this decrease in chance of insemination success was based on expert opinion and literature, not on actual studies of progesterone profiles. Also, their model did not take into account other factors that have

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[1]Corresponding author: pierre.blavy@agroparistech.fr

been found to be influential in literature, such as milk yield. Studying actual progesterone profiles should improve our knowledge of the effects of profile features and shapes on chance of insemination success. Also, if cow-specific data (e.g., milk yield) can be linked to the profiles, the effects of cow and environmental traits on progesterone profile features can be made visible. Accordingly, the aim of our study was to quantify the effects of progesterone profile features and cow-related factors on insemination success and to provide a real-time predictor equation of probability of insemination success.

MATERIALS AND METHODS

Data Description

In our study, progesterone profiles from 26 dairy herds were analyzed to determine actual effects of progesterone slope, cycle length, and cycle height on probability of insemination success. Other factors deemed to be important from literature (e.g., milk yield) were also included to see if they had any effect on probability of insemination success.

Two separate data sets were collected: one for training and one for testing the predictor equation. For the training data set, data were collected over the course of 1 yr (October 2013–November 2014) from 16 dairy herds. For the testing data set, data were collected from 10 other herds between January 2014 and January 2016. All farms were equipped with a Herd Navigator system (Lattec, Hillerød, Denmark). Herd Navigator takes regular milk samples in which, among other measurements, progesterone concentration is determined. Farms were selected based upon the farmers' willingness to provide their data, and were located in the Netherlands (n = 14), Denmark (n = 3), Sweden (n = 3), Canada (n = 2), France (n = 2), and Finland (n = 2). Average farm size was 202 cows (minimum = 81, maximum = 371).

Progesterone Sampling

Progesterone was sampled in milk using the Herd Navigator system. Whenever a cow was eligible for sampling, a milk sample was collected from that milking and sent to the sample intake unit. From there, it was directed to the in-line analyzer, where progesterone concentrations were determined using lateral flow analysis. After determination of progesterone concentration, the model provided feedback to the sampling system on when the next sample for this cow should be taken. To optimize estrus detection, the measurement method was calibrated to be more accurate for low values of progesterone; therefore, values higher than 30 ng/mL were replaced by 30 ng/mL.

The sampling window for progesterone in Herd Navigator is 20 to 240 DIM by default. Sampling frequency differs depending on the status of the cow (postpartum anestrus, cyclic, potentially pregnant) and the cycle itself (days from estrus, progesterone slope). The model parameters used to determine sampling frequency are discussed in detail in Friggens and Chagunda (2005). The progesterone profiles in the current study had an average of 1 sample every 2.3 d (SD = 0.7), and 95% of the cycles had at least 1 measurement every 7 d.

Estrous Cycle Detection

Raw progesterone data were used; that is, this study was not conditioned by the Herd Navigator software. For the purpose of characterizing estrous cycles, various points were identified in each progesterone profile (a profile refers to the progesterone trace within a given lactation of a given cow). Any increase in progesterone from <6 to >6 ng/mL (**X**) was marked, representing the start of a new luteal phase. The first point where progesterone was <6 ng/mL was marked as dropD; the first point where progesterone was <4 ng/mL (**OS**) was also marked (Figure 1). Moving through the lactation, cows were modeled to be in 1 of 3 different stages: unknown, luteal phase, or estrus. At the start of the sampling window or after a gap of >10 d, cows were in status unknown. When they moved through point X, they were assigned to status luteal phase. When they were in status luteal phase and moved through point OS, they were assigned to status estrus, where they remained until they move through X again (or if a gap >10 d was observed, in which case they were back in status unknown). The first X in a profile was assumed to indicate the end of the postpartum anestrus period.

These landmarks were used to determine cycle length (OS_n–OS_{n-1}), estrus to increase (X_n–OS_{n-1}), and estrus to dropD (OS_n–$dropD_n$). Cycles longer than 100 d were assumed to be the result of measurement error and were excluded, as were cycles where the interval estrus to increase exceeded 50 d, cycles where the interval estrus to dropD exceeded 70 d, and cycles where insemination happened >5 before or >10 d after ovulation.

Insemination and Insemination Success

Each insemination date was coupled to the closest estrus. As we did not have the timing of insemination available, inseminations were assumed to have occurred at 1200 h. This estimate was based on feedback from