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Management practices associated with conception rate and service rate of lactating Holstein cows in large, commercial dairy herds

J. M. Schefers,*†[1] K. A. Weigel,* C. L. Rawson,† N. R. Zwald,† and N. B. Cook‡
*Department of Dairy Science, University of Wisconsin, Madison 53706
†Alta Genetics, Watertown, WI 53094
‡School of Veterinary Medicine, University of Wisconsin, Madison 53706

ABSTRACT

Data from lactating Holstein cows in herds that participate in a commercial progeny testing program were analyzed to explain management factors associated with herd-average conception and service rates on large commercial dairies. On-farm herd management software was used as the source of data related to production, reproduction, culling, and milk quality for 108 herds. Also, a survey regarding management, facilities, nutrition, and labor was completed on 86 farms. A total of 41 explanatory variables related to management factors and conditions that could affect conception and service rate were considered in this study. Models explaining conception and service rates were developed using a machine learning algorithm for constructing model trees. The most important explanatory variables associated with conception rate were the percentage of repeated inseminations between 4 and 17 d post-artificial insemination, stocking density in the breeding pen, length of the voluntary waiting period, days at pregnancy examination, and somatic cell score. The most important explanatory variables associated with service rate were the number of lactating cows per breeding technician, use of a resynchronization program, utilization of soakers in the holding area during the summer, and bunk space per cow in the breeding pen. The aforementioned models explained 35% and 40% of the observed variation in conception rate and service rate, respectively, and underline the association of herd-level management factors not strictly related to reproduction with herd reproductive performance.
Key words: reproductive performance, dairy cattle, management, machine learning

INTRODUCTION

Reproductive performance is influenced by many environmental and management factors, such as accuracy of estrus detection, semen handling techniques, use of synchronization or resynchronization programs, transition cow management, metabolic health, udder health, cow comfort, and lameness (Lucy, 2001; Caraviello et al., 2006).

Fertility of the service sire (Kuhn and Hutchison, 2008) and correct thawing and handling of semen affect cow fertility. Improper semen handling techniques can lead to damaged sperm membranes, reduced motility, and sperm death due to heat- and cold-shock (Foote and Parks, 1993). Caraviello et al. (2006) noted that the temperature at which semen is thawed was a significant factor affecting the proportion of cows pregnant by 150 d in milk.

Tenhagen et al. (2004) compared the economic considerations between timed AI after synchronized ovulation to AI at estrus and noted that evaluation of synchronization protocols should include reproductive performance along with the appropriate costs of treatment. When estrus detection rates are poor in herds, Ovsynch (Pursley et al., 1995) may help reproduction by increasing the service rate.

Calving-related disorders such as metritis, retained placenta, ketosis, and displaced abomasum predispose cows to reduced reproductive efficiency (Stevenson and Call, 1988; Walsh et al., 2007). Furthermore, cows consuming less dry matter during the periparturient period have delayed first ovulation and reduced fertility (Staples et al., 1990) and are predisposed to diseases that affect fertility such as metritis (Huzzey et al., 2007). Pen moves, grouping strategies, and bunk space are just a few of the factors that affect the subsequent health and performance of the transition cow (Cook and Nordlund, 2004).

Chebel et al. (2004) noted that cows with mastitis were 2.8 times more likely to experience embryonic loss than cows that did not have mastitis. Furthermore, cows with subclinical or clinical mastitis before the

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[1]Corresponding author: schefers@wisc.edu

first insemination tend to require a greater number of services per conception (Barker et al., 1998; Schrick et al., 2001; Santos et al., 2004).

Environmental conditions can have a major influence on a cow's ability or tendency to exhibit signs of estrus. Overcrowding and the presence of slippery floor surfaces can restrict mounting activity (Britt et al., 1986). Furthermore, mounting activity of cows with foot problems is reduced compared with cows with good foot health (Leonard et al., 1994). Garbarino et al. (2004) found that cows classified as lame had 3.5 times greater odds of delayed cyclicity compared with cows classified as nonlame.

Although many of the aforementioned studies have focused on a few related factors that may affect reproductive performance, they tend to be limited in scope. Recently, Caraviello et al. (2006) used a machine learning algorithm to construct alternating decision trees for prediction of first-service conception rate and pregnancy status at 150 d postpartum for individual animals. Such algorithms are powerful and flexible, because they can accommodate missing data, multicollinearity, and numerous explanatory variables. Caraviello et al. (2006) focused on classification of binary outcomes (i.e., pregnant or not pregnant) and the resulting decision trees were very complex. The objective of this study was to identify factors associated with conception rate and service rate from a large number of interrelated directly and indirectly associated variables using machine learning algorithms. The objective of the machine learning algorithms was to determine the predictability of such a method when a large number of variables associated with conception and service rate were missing. This was an important objective because the data set had many missing explanatory variables.

MATERIALS AND METHODS

Data regarding production, reproduction, culling, and milk quality of lactating Holstein cows in 108 dairy herds in the Alta Genetics (Watertown, WI) Advantage progeny testing program were extracted from Dairy Comp 305 herd management software (Valley Ag Software, Tulare, CA). The herds used in this study were located in Wisconsin (40), New York (20), Minnesota (12), California (11), Michigan (4), Pennsylvania (4), Iowa (3), Idaho (3), Indiana (2), Ohio (2), South Dakota (2), Illinois (1), Maryland (1), Oregon (1), Vermont (1), and Washington (1). Herd sized ranged from 163 to 3,394 milking cows, and mean herd size was 781 milking cows. Mean conception rates for individual herds ranged from 20 to 44%, with an overall mean of 32.2%. Mean service rates ranged from 39 to 76%, with an overall mean of 56.9%. Within each herd, annual conception rate and service rate were averaged across all successive 21-d time periods from September 1, 2006 to September 1, 2007. Conception rate was calculated as

$$\text{Conception rate} = 100 \times \frac{\left(\text{total no. of confirmed pregnancies}\right)}{\left(\text{total no. of breedings}\right)},$$

Furthermore, service rate was calculated as

$$\text{Service rate} = 100 \times \frac{\left(\text{total no. of breedings}\right)}{\left(\text{total no. of cows eligible for breeding}\right)}.$$

Cows that were eligible for breeding met the following criteria:

1. Past the voluntary waiting period (**VWP**) at the beginning of the period.
2. Nonpregnant at the beginning of the period.
3. Not marked as "do not breed" before or during the period.
4. Cow is present for >50% of the period.
5. Known outcome if inseminated before or during the period.

The VWP for a herd was defined as the number of days postpartum when 5% of cows had received their first AI. It was necessary to calculate a herd-specific VWP from the raw data, because the Dairy Comp 305 software assumes a 50-d VWP. Somatic cell score was calculated as the annual herd average from September 1, 2006 to September 1, 2007.

In addition, a survey regarding transition cow management, facilities, reproductive programs, and labor on a subset of 86 farms was completed by Alta Advantage consultants between February 1 and April 1, 2007. A total of 41 potential explanatory variables related to management factors and conditions that may affect conception rate or service rate were assessed in the survey. Preference was given to explanatory variables related to management, facilities, nutrition, and labor that could be easily and consistently measured by the Alta Advantage consultants in a 1-h walkthrough of the dairy. Furthermore, the survey used for this study was completed on only 86 of the 108 herds considered for this study because of time and labor constraints for data collection. Means, standard errors, and frequencies for explanatory variables considered in this study are provided in Table 1, and case definitions for selected explanatory variables are provided in Table 2. Because some of the continuous or categorical variables considered in this study did not apply to some herds, a