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Factors associated with increased milk production for automatic milking systems

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ABSTRACT

Automatic milking systems (AMS) are increasingly popular throughout the world. Our objective was to analyze 635 North American dairy farms with AMS for (risk) factors associated with increased milk production per cow per day and milk production per robot per day. We used multivariable generalized mixed linear regressions, which identified several significant risk factors and interactions of risk factors associated with milk production. Free traffic was associated with increased production per cow and per robot per day compared with forced systems, and the presence of a single robot per pen was associated with decreased production per robot per day compared with pens using 2 robots. Retrofitted farms had significantly less production in the first 4 yr since installation compared with production after 4 yr of installation. In contrast, newly built farms did not see a significant change in production over time since installation. Overall, retrofitted farms did not produce significantly more or less milk than newly constructed farms. Detailed knowledge of factors associated with increased production of AMS will help guide future recommendations to producers looking to transition to an AMS and maximize their production.
Key words: automatic milking system, traffic type, number of robots per pen, milk production, benchmark

INTRODUCTION

Automatic milking systems (**AMS**) are becoming increasingly popular throughout the world, especially in North America. A variety of recommendations have been made for AMS facility structure and management to maximize production, but few of these recommendations have been explored scientifically (as reviewed by Jacobs and Siegford, 2012). As AMS are integrated into farms with larger herds, facility details such as the number of robots per pen and traffic type (i.e., how cows move among the AMS, lying stalls, and feeding area) become increasingly important as minor effects on milk production in the short term can have major economic implications in the long term.

In free traffic barns, each cow decides when to enter the AMS and can move freely among the AMS, lying stalls, and feeding area. Non-free traffic (i.e., forced) may vary in the level of guidance that is applied during movement, but always directs movement from the lying stalls to the AMS before allowing access to the feeding alley. In strictly forced traffic situations, a cow is always milked before entering the feeding area, whereas alternative arrangements use selection gates (i.e., guided, semi-forced, or select) to select only those cows that have exceeded their milking interval (Melin et al., 2006).

Current literature does not give a clear consensus as to the ideal traffic type for maximizing production. The few studies published examining the relationship between traffic type and milk yield were limited by sample size. Hermans et al. (2003) and Bach et al. (2009) did not find a significant difference in milk yield between different traffic types but were limited to 85 cows and 130 cows, respectively. Similarly, Munksgaard et al. (2011) demonstrated slightly greater production with free traffic barns, but this was not a significant finding potentially due to their limited sample size (70 cows). Gygax et al. (2007) collected data from 20 cows per farm on 4 free traffic type farms and 4 forced traffic type farms each with either Brown Swiss or Holstein cows, but found no significant difference between traffic types.

The effect of the number of robots per pen of cows has also never been investigated in AMS herds. It has been suggested that producers keep group sizes under 100 cows to ensure that all cows recognize each other (Grant and Albright, 2001); however, this value has not

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been formally evaluated in an AMS (Rodenburg, 2002). Although, no significant difference in milk production or behavior was found between group sizes of 6 or 12 cows (Telezhenko et al., 2012), no similar studies have examined larger groups.

To date, no large-scale data analyses are available comparing AMS facility structures that account for differences in management and specific environments (as reviewed by Jacobs and Siegford, 2012). The general aim of this study was to apply multivariable generalized mixed linear regression models to a data set from 635 North American dairy farms to identify risk factors and interaction terms significantly associated with milk production per cow per day and milk production per robot per day. Our hypothesis is that traffic type and the number of robots per pen are risk factors significantly associated with milk production per robot per day and per cow per day. Factors that significantly affect a herd's maximum production limit could be used to create benchmark comparison groups for producers in the future. Detailed knowledge about factors associated with increased production of AMS will help guide future recommendations to producers looking to transition to an AMS and maximize their production.

MATERIALS AND METHODS

We analyzed a data set collected from weekly observations collected over 4 yr (2011–2014) at 635 North American dairy farms with Lely Astronaut AMS (Lely Industries N.V., Maassluis, the Netherlands). These data included 71,213 weekly observations containing 21 AMS variables.

Of the 21 available variables, frequencies per category were computed for 9 categorical variables (Table 1). Traffic_Type was coded as "Free" or "Forced." "Forced" Traffic_Type included both strictly forced and guided traffic (i.e., semi-forced, select) as both use one-way traffic to guide the cows and they have the same effect on low-ranking cows (Thune et al., 2002; Melin et al., 2006). The Robots_per_Pen variable represented the number of robots per pen of cows. By default, this variable also represents the number of cows in a pen and the pen's physical dimensions. By design, each pen will have about 60 cows per robot. For example, Robots_per_Pen of "1" is designed with one robot in a pen of about 60 cows and Robots_per_Pen of "2" is designed with 2 robots in a pen of about 120 cows. Because the number of robots per pen was of more interest, the number of cows per pen was not included in the regression to avoid multicollinearity. The physical sizes of the farms' pens were not available for our analysis; however, the number of cows per robot was included to account for different ratios of cows to robots (Table 2). Observations that were labeled as having a Robots_per_Pen of "Unknown" or "0" were coded as missing values. Breed was categorized into 3 levels: "Holstein," "Jersey," and "Other." Breed "Other" represents all other breeds including Ayrshire, Brown Swiss, Guernsey, Red and White, Crosses, Mixed, and Unknown. Farm_Goal was either characterized by the "Quota" system for farms in Canada or "Max_Production" for farms in the United States that produce with the goal of maximum milk production. Grazing and organic farms (n = 3,768 observations) were not included in the analysis because they had relatively few observations. Year_Since_Install represented the time from the installation of the robots to the time of each observation. Observations from farms utilizing robots for more than 4 yr were grouped together as "> 4 yr." Robot_Free_Time is the average percentage of time per day the robot is unoccupied by a cow (this does not include the time per day the system is automatically cleaning the robot and the milk lines to the tank). Robot_Free_Time was broken down into 5 levels (Table 1). Record_Year was limited to 2011 to 2014. "Winter" was classified as December through February, "Spring" as March through May, "Summer" as June through August, and "Fall" as September through November.

The 12 numeric variables were summarized using descriptive statistics. The names of the numeric variables and their explanation are listed in Table 2. Observations with missing values were omitted. Observations that had fewer than 10 Cows_per_Robot or greater than 90 Cows_per_Robot were removed as outliers. The histogram of Average_DIM showed outliers beginning at 365 d. After observations with an Average_DIM greater than 365 d were omitted, 54,065 observations remained representing 529 farms. The number of observations per categorical variable and their reference level are detailed in Table 1. Categorical levels were chosen as the level we were least interested in estimating an effect while still having a balanced amount of observations. The summary statistics of the numeric variables are shown in Table 2. All statistical analyses were performed in R version 3.0.1 (R Development Core Team, 2013).

All numeric variables were inspected for normality by creating histograms. Numeric variables were log-transformed when normality was not present upon visual inspection of the histogram or when the order of magnitude of the values was more than 3 logs higher than the other variables. All numeric variables were scaled and centered using the scale function in R (i.e., the mean of each variable was subtracted from all values per variable in the data set and then divided by the variable's standard deviation). The correlations between each pair of numeric variables were examined.

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