J. Dairy Sci. 101:1–12
https://doi.org/10.3168/jds.2017-14153

Association of quarter milking measurements and cow-level factors in an automatic milking system

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ABSTRACT

The primary aim of this observational study, in a single herd milked using multiple automatic milking system units, was to describe associations of quarter milk yield variability and quarter peak milk flow rate with cow-level factors. Information from the current lactation of 1,549 primiparous and multiparous cows was collected from January to December 2015. Data from each individual milking used in the analysis included quarter milk yield (QMY), udder milk yield, quarter peak milk flow rate (QPMF), quarter average milk flow rate (QAMF), quarter milking time, and milking interval. Milking interval and milk yield were used to calculate milk production rate (kg/h) at the quarter and udder levels. We investigated associations between QPMF and milking interval, QPMF and days in milk, and QMY and QAMF. A strong association between QPMF and both QAMF and milking interval was observed. A moderate association was found between QPMF and stage of lactation. However, QMY was not a useful indicator of QPMF because of the weak association observed between these variables. In this study, rear quarter QPMF was significantly increased by 3% compared with front quarter QPMF (1.45 vs 1.41 kg/min). Quarter milk yield was calculated as a percentage contribution of total udder milk yield per 10-d in milk window and ranked from lowest to highest contribution. Quarter contribution to udder milk yield showed a high level of variability, with 39% of animals having all 4 quarters change contribution rank at least once during part of or the whole lactation. Only 14% of cows were observed to have no change in quarter rank. When quarter contribution was assessed, irrespective of physical position of quarter within the udder, the percent of highest to lowest contribution across the lactation was relatively stable. The standard deviation of quarter milk production rate for each cow was regressed against the same cow's peak udder milk production rate, within a lactation, to ascertain whether quarter milk production rate variance could be used to predict peak udder milk production rate. Knowledge of the intra-udder quarter milk production rate standard deviation for an individual cow is not useful in predicting peak udder milk production rate. Quarter milking time appears to be a useful indicator to predict the optimal order of teatcup attachment. Analysis from this large, single-herd population indicates that QPMF is associated with the cow-level factors milking interval and days in milk, and that intra-udder QMY is highly variable.
Key words: automatic milking system, milking interval, milk production rate

INTRODUCTION

The introduction of automatic milking systems (**AMS**) in the early 1990s has facilitated a focus toward milking performance of individual quarters compared with performance solely at the cow level. Milking parameters that are routinely measured at the quarter level in each milking in AMS include milk yield (**QMY**), average milk flow rate (**QAMF**), and peak milk flow rate (**QPMF**). Milk synthesis is largely regulated at the local level of the quarter (Wall and McFadden, 2012; Weaver and Hernandez, 2016); hence, differences between QMY are of potential interest. Despite the ability to explore milk yield at the quarter level, much of the research into optimization of AMS has used udder milk yield as the production variable (de Koning and Ouweltjes, 2000; Hogeveen et al., 2001; André et al., 2010).

Very few researchers have explored variation in QMY in either commercial AMS installations or research herds with quarter milking capability. The repeatability of QMY has been reported to be high (Rothenanger et al., 1995). To quantify variation in QMY between quarters, intra-udder, only the coefficient of variation (**CV**) has been reported in the literature. Forsbäck et al. (2010) reported within-cow, quarter-level CV of 7%

Received November 18, 2017.
Accepted March 21, 2018.
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in a small Swedish research herd, whereas Fogsgaard et al. (2015) used CV to quantify the degree of variability in QMY following clinical mastitis cases in 2 commercial herds. In that observational study, they observed a within-cow, quarter-level CV of approximately 19 to 23% in the control group.

Optimization of any AMS installation is primarily concerned with the maximum milk yield per AMS in a defined period (Sonck and Donkers, 1995). Findings from an observational study of 635 North American herds using AMS indicated that an increase in cow milk yield was associated with increased milkings and total box time/day, in addition to increased milk flow rate (Tremblay et al., 2016). No difference was observed between front and rear QPMF in one Dutch study (Tancin et al., 2003), which differed from increased QPMF observed in rear quarters in 2 other studies (Rothschild et al., 1980; Wellnitz et al., 1999). Quarter milk yield was not found to be associated with QPMF when QPMF was categorized into low, medium, and high milkability (Tancin et al., 2006).

A better understanding of cow-level factors influencing QPMF under constant milking machine settings, in addition to a clearer description of intra-udder QMY variability, could assist in executing more optimal milking management strategies where milk is harvested at the quarter level, such as with AMS. The primary aim of this observational study was to describe QMY variability and QPMF associations with cow-level factors in a large commercial herd using multiple AMS. The secondary aim was to describe relationships between other milk harvesting indicators to support the primary aim.

MATERIALS AND METHODS

This observational study was conducted on a 1,549-cow (Holstein Friesians) commercial dairy farm located in the northeastern United States using 20 AMS units (De Laval VMS, DeLaval, Tumba, Sweden). Cows in the study herd had an average daily milk yield of 34.6 kg and 2.3 average lactations, and were housed in freestalls on sand bedding. The feed base was a partial mixed ration supplemented with approximately 3 kg of concentrate feed/cow per day. Concentrate feeding was not adjusted according to individual cow production levels. Each AMS serviced a pen of 55 cows, with 6 pens of primiparous cows (**L1**) and 14 pens of multiparous cows (**L2+**). The number of animals per AMS was within the stocking rate range of 50 to 70 cows/AMS reported by Hallen Sandgren and Emanuelson (2017) but lower than the average because of management decisions emphasizing cow comfort and access to feeding areas to improve daily milk yield. As animals freshened, they were allocated to evenly distribute cow DIM between pens. Fewer than 10% of the animals were moved to different pens in a 12-mo period. Milking permission was granted to L1 cows if they had not been successfully milked in the previous 5 h, whereas milking permission was granted to L2+ cows if they had not been successfully milked in the previous 6 h. No milk production parameters were used to determine milking permission. Milking configuration of the AMS (system vacuum and pulsation settings) was not altered during the study period. Teatcup removal was based on a threshold of 0.2 kg/min applied at the quarter level. Under normal farm protocol, cows were only fetched if they had not recorded a successful milking within 24 h of the previous milking. Within an individual pen, cow flow between the freestall area, AMS, and feedbunk was via a guided or semi-guided traffic system. All 20 pens were of consistent design and size, with the exception of gate location for the guided or semi-guided traffic system.

Observational Data Study Base

Cow identification, milking start time (date, hour, minute, second), time in the AMS (minute, second), and QMY (kg), QAMF (kg/min), QPMF (kg/min) and incomplete milkings were recorded for each cow milking (Delpro, DeLaval). Quarter average milk flow rate was calculated as QMY/total quarter teatcup attachment time, and QPMF was defined as the maximum milk flow rate during any individual quarter milking. An incomplete milking was defined as a quarter milking where the teat was not located by the AMS, or the recorded QMY was less than 50% of expected QMY. An incomplete milking was not identified by the AMS when QMY was >3 kg or when expected QMY was <1 kg. Data were grouped by lactation number (1–6) or by 10-d DIM window. All milking records from January through December 2015 were collected. Data were only eligible for analysis if the following criteria were met: (1) data were from an individual cow's most recent lactation in 2015 if she recorded parts of 2 lactations in that calendar year; (2) an individual milking had no record of any quarter having an incomplete milking, typically resulting in little or no milk yield and milk flow; (3) udder milk yield was within the range from 1 to 70 kg, QMY was within the range from 0.1 to 15 kg, and QAMF or QPMF was greater than 0.1 kg/min; (4) the milking interval (**MI**), based on elapsed time between 2 milking events, was not greater than 48 h. Eligibility criterion (3) was to remove milk yield and milk flow rate values from analysis that were deemed biologically implausible based on herd milk recording history and typical MI. Eligibility criterion (4) was set