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Milking time and risk of over-milking can be decreased with early teat cup removal based on udder quarter milk flow without loss in milk yield

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ABSTRACT

Increasing the milk flow rate at which milking is terminated can shorten milking time and increase milking efficiency. The effects on milk yield and composition have not been fully investigated when the take-off is set at the udder quarter level and independent of feeding during milking. The objective of this study was to investigate the effect of 3 take-off levels at the udder quarter level (0.06, 0.3, and 0.48 kg/min) applied with or without feeding during milking on milking time, milk yield, the degree of udder emptying, milk composition, and free fatty acids. In this study, 30 cows were allocated into 6 groups, balanced by lactation number, lactation stage, and milk yield, and subjected to a 3 × 2 factorial arrangement of treatments using a Latin square design. Treatments were applied for 1 wk each. This study demonstrated milking time could be reduced by applying up to a take-off level of 0.48 kg/min on udder quarter level without losing milk yield or compromising milk composition or udder health.
Key words: lactation, milk synthesis

INTRODUCTION

Using the inherent nature of the milk flow curve provides an opportunity to set the optimal termination point of an individual milking, a concept first introduced by Armstrong et al. (1970). To maximize efficiency and minimize over-milking, the termination needs to occur within the decline phase of the milk flow curve, but before the over-milking phase has begun (Tančin et al., 2006). Several studies investigated the effect of setting cluster take-off levels above 0.3 kg/min on the whole udder level to maximize milking efficiency. Milking time decreased by approximately 0.5 min with higher milk flow take-off level in studies comparing 0.8 kg/min to 0.6 or 0.48 kg/min (Magliaro and Kensinger, 2005) or 0.4 to 0.2 kg/min (Rasmussen, 1993; Jago et al., 2010). A 2.5% reduction in milk yield was evident between 0.8 and 0.48 kg/min, but no effect on milk yield was observed in the other comparisons. Besier and Bruckmaier (2016) recently proposed that teat cup detachment levels of up to 1.0 kg of milk/min could be applied in cluster milking with minimal loss in milk yield and significantly lower milking times compared with 0.2 kg/min. This response was based on simulated take-off levels. The critical limitation across these studies was that the termination of milking was set at the udder level. This may still allow for some individual quarters to be over- or undermilked. Over-milking causes discomfort and damage to the tissue in the teat (Neijenhuis et al., 2001; Berglund et al., 2002), and thereby, increases the risk of mastitis (Natzke et al., 1982; Rasmussen, 2004).

Although optimizing the milking termination point affects efficiency of the milking unit (**MU**), cow- or management-based factors also have an effect (Deming et al., 2013). For example, the practice of providing a teaser feed ration of concentrate in the automatic milking station (**AMS**) was recommended to motivate cows to enter the milking station (Prescott et al., 1998) and reduce variation in milking intervals. However, few empirical data demonstrate the effect of this recommendation in AMS on the efficiency of the MU and voluntary visits to the MU (Halachmi et al., 2005). Moreover, the possibility of combining a higher take-off level at the udder quarter level with feeding during milking has not been tested.

Milk fat globule (**MFG**) size is affected by the duration of milk accumulation (Dutreuil et al., 2016) and also the completeness of milk removal, as the largest MFG are found in the residual milk (Kernohan and Lepherd, 1969). Larger MFG are more sensitive to breakage and lipolysis (Wiking et al., 2003), and a posi-

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tive relationship is present between increased milk fat production and MFG size (Wiking et al., 2004). However, no studies have been performed on the connection between milk removal and milk fat quality.

Our previous research observed that increasing cluster take-off level to 0.8 kg/min, decreased milking time, compared with a take-off level of 0.2 kg/min (Ferneborg et al., 2016). Our current understanding of the effect of take-off level on milk production, udder health, and its interaction with feeding during milking is based on the response at the udder level. This approach fails to capitalize on the ability to remove teat cups at quarter level in AMS. To evaluate the possible relationship between providing teaser feed and take-off level, our specific objective was to investigate the effect of 3 take-off levels at the udder quarter level applied in combination with or without teaser feed, on milking efficiency, milk composition, free fatty acids (**FFA**), and MFG. Our hypothesis was that a higher take-off level applied at the udder quarter level increases milking efficiency without affecting milk yield, if it is combined with a teaser feed.

MATERIALS AND METHODS

The study was conducted at the Swedish Livestock Research Centre, SLU, Uppsala, Sweden, and all animal handling was approved by the local Animal Ethics Committee.

Animals and Housing

The study included 30 dairy cows (Swedish Red, n = 21; Swedish Holstein n = 9) with average lactation number 2.9 ± 1.5, 142 ± 25 DIM, and 34.0 ± 11.7 kg of milk production per day (mean ± SD). All cows included had SCC <115,000 cells/mL at the udder level at the start of the study. They were housed in a loose housing system (DeLaval FeedFirst, DeLaval International AB, Tumba, Sweden) with concrete alleyways and rubber mats and chopped straw bedding in cubicles. Water and silage were provided ad libitum and concentrate was provided in separate feeding stations, in a ration based on milk yield according to the NorFor system (Volden, 2011).

Experimental Design

Cows were allocated into 6 groups balanced according to lactation number, DIM, and milk yield, then subjected to a 3 × 2 factorial arrangement of treatments in a Latin square design. The treatments were take-off level at flow: 0.48 kg of milk/min (0.48), 0.3 kg of milk/min (0.3), or 0.06 kg of milk/min (0.06) on individual quarters, combined with feeding during milking or no feeding during milking. The teaser feed ration was up to 2.6 kg of concentrate per cow at each milking and the amount fed was deducted from the daily allowance for each cow. There were in total 6 treatment periods. Each treatment period was 7 d long and measurements were made during the last 2 d of each period. Milk yield, peak and average flow, milking interval, and milking time were automatically recorded by the DelPro system (DeLaval International AB, Tumba, Sweden) for each cow during each milking throughout the whole experiment and data from the last 2 d of each treatment period were used for evaluation of treatment effects.

Milking was performed in an automatic milking system (DeLaval VMS Voluntary Milking System, DeLaval International AB) with system vacuum level set at 44 kPa, pulsation rate 60 cycles/min, and pulsation ratio 65:35. Flow rate was measured individually from each teat by the built-in flow meters using near-infrared light to estimate the milk flow; tube length from each teat cup to the flow meters was 3.8 m. Prestimulation consisted of cleaning of the teats with water for 8 s, forestripping for 1 s, and drying for 3 s, which is the standard setting for the AMS used. Attachment of teat cups was performed on quarter level with the attachment order of right rear, left rear, right front, and left front teat. Take-off occurred on the quarter level, when the flow was below the set level for 6 s, as programmed by the VMS. Milking permission was granted by the milking system after 6 h and cows were brought to the waiting area when the milking interval exceeded 8 h, hourly except during the night (2300–0600 h).

Milk Sampling and Storage

During the last 2 d (d 6 and 7) of each treatment period, milk samples were collected during each milking of all cows. Samples from both days were analyzed for fat, protein, and lactose content, and SCC. Additional samples were collected from 1 milking between 0600 and 0000 h on d 6 for analysis of MFG size distribution, milk fat globule membrane (**MFGM**) stability, and FFA content. In addition, residual milk removal was performed after the last milking in treatment periods 1, 3, and 5. Residual milk was harvested through intramuscular injection of 70 IU of oxytocin [Partoxin vet, Pharmaxim AB, Helsingborg, Sweden; 17 μg (10 IU)/mL] directly after milking. Milking was initiated again 3 min after the injection, using a bucket milking machine. Samples for milk composition and determination of SCC were preserved with bronopol (2-bromo-