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# Increased take-off level in automatic milking systems – effects on milk flow, milk yield and milking efficiency at the quarter level

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## Abstract

This research communication describes how different detachment levels (0.48, 0.3 and 0.06 kg milk/min) at the quarter-level affect milk flow profiles and overall milking efficiency in automatic milking systems. We hypothesized a higher detachment level would result in greater mean flow rates without affecting the volume of harvested milk per cow during 24 h compared to lower detachment levels. The data suggest milk flow decreased to a rate below the overmilking limit within the 6-s delay time required for termination in all treatments, but the duration of overmilking was shorter for the greatest detachment level compared to the other treatments. We conclude that setting a detachment level at a greater milk flow rate reduces the duration of overmilking without affecting the amount of milk harvested when applied to cows in mid-lactation during quarter-level milking. We also suggest that the steepness of the decline phase of the milk flow curve might have a larger effect than the actual detachment level on the duration of overmilking.

Successful management of an automatic milking system (AMS) requires high efficiency and appropriate function of the milking unit (MU). It is well established that an increased detachment level, i.e. earlier removal of the teat cups at the end of milking, can decrease milking time substantially with minimal to no milk yield loss (Rasmussen, 1993; Magliaro & Kensinger, 2005; Jago et al. 2010; Edwards et al. 2013*a*, *b*; Besier & Bruckmaier, 2016; Ferneborg et al. 2016). However, these studies were all conducted on cluster level, and some studies suggest an increase in residual milk or strip yield at increased cluster detachment levels, which indicates decreased udder emptying (Edwards et al. 2013*a*, *b*; Ferneborg et al. 2016). The well-described effects of milk flow for cluster detachment at the udder level are not necessarily translatable into quarter-level milking, which is standard in AMS. The effect of an elevated detachment level on udder emptying was not replicated in our recent publication performed on quarter-level detachment, where neither residual milk yield nor proportion of residual milk were affected by increasing the detachment level (Krawczel et al. 2017).

The use of milk flow for cluster detachment is an almost 50 year old and well-studied concept (Armstrong et al. 1970; de la M Nichols, 1972). However, the effects of quarter-level detachment levels on milking efficiency and milk flow profiles in AMS have yet to be established. Weiss & Worstorff (2001) reported quarter-level detachment of teat cups compared to cluster detachment decreased average cup-on time by approximately 20%, reducing or completely eliminating the occurrence of overmilking. Work published by our group suggested a reduction in milking time from increased detachment level at both udder and quarter levels (Ferneborg et al. 2016; Krawczel et al. 2017). The aim of this study was, therefore, to investigate how different detachment levels at the quarter level would affect milk flow profiles and milking efficiency in AMS in an on-farm setting. We hypothesized that an increased detachment level would result in greater mean flow rates compared to lower detachment levels without altering milk yield.

## Materials and methods

Performance data presented in this paper were collected for the study by Krawczel et al. (2017). Thirty dairy cows were allocated into six groups balanced by lactation number, lactation stage, breed, and milk yield, and subjected to a 3 × 2 factorial arrangement of treatments in a Latin

**Table 1.** Milking times, milk flow and duration of milk flow phases for take-off levels 0.06, 0.3 and 0.48 kg/min on quarter level

| | Treatments | | | | Effects | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.06 | 0.3 | 0.48 | SEM | TO | Quarter | Yield | Yield × TO |
| Total milking time on udder level (s) | 316[a] | 281[b] | 273[b] | 17 | <0.001 | – | <0.001 | <0.05 |
| Total milking time on quarter level (s) | 256[a] | 231[b] | 224[b] | 12 | <0.01 | <0.001 | <0.001 | = 0.42 |
| Time from set TO level to actual cup removal (s) (back-transformed in brackets) | 0.48[a] (3) | 1.06[b] (11) | 0.99[c] (10) | 0.01 | <0.001 | = 0.34 | <0.001 | = 0.12 |
| Peak flow (kg/min) | 1.09 | 1.12 | 1.11 | 0.06 | = 0.34 | <0.001 | <0.001 | = 0.25 |
| Actual flow at TO (kg/min) (back transformed in brackets) | 0.90[a] (0.00) | 2.24[b] (0.025) | 3.06[c] (0.09) | 0.09 | <0.001 | <0.001 | <0.001 | <0.001 |
| Increase phase (s) | 27[a] | 26[ab] | 26[b] | 1 | <0.01 | <0.001 | <0.001 | – |
| Plateau phase (s) | 57 | 55 | 57 | 6 | = 0.87 | <0.001 | <0.001 | – |
| Decline phase (s) | 42[a] | 32[b] | 28[c] | 1 | <0.001 | <0.001 | = 0.16 | <0.01 |
| Overmilking phase (s) (back-transformed in brackets) | 1.75[a] (9) | 1.05[b] (1) | 0.56[c] (0) | 0.05 | <0.001 | <0.001 | <0.001 | <0.01 |

TO, Take-off level and SEM, Standard Error of Means.
Superscript letters show significant differences between treatments ($P \le 0.05$).
Time from set take-off level to actual cup removal was log10 transformed.
Actual flow at TO and duration of the overmilking phase was fourth root transformed.

square design. The treatments were take-off level (TO) at milk flow rates of 0.48 kg milk/min, 0.3 kg milk/min, or 0.06 kg milk/min on individual quarters with a milking interval of 7.5 ± 0.38 h. Each TO level was tested in the presence or absence of a concentrate teaser feed administered upon cow entry into the MU. This was included as feeding during milking was suggested to enhance milk ejection (Svennersten et al. 1995). However, as shown in our previous study (Krawczel et al. 2017), provision of teaser feed during milking treatment did not affect milk flow and results on this effect are, therefore, not presented. Each treatment period lasted 7 d and data from the last 10 ± 2 milkings per cow and treatment period were used to evaluate treatment effects on milk flow.

Milking was performed in an AMS (DeLaval VMS™ Voluntary Milking System, DeLaval International AB, Tumba, Sweden), with conditions consistent with commercial dairy production.

One out of 6 treatment periods, period 3, was removed from the data due to lack of flow log files from this period. Data from one cow during her exposure to TO 0.3 with teaser feed was excluded due to the onset of oestrus, and data from two cows were removed from the final data set due to high cell count throughout the study. Only data from successful milkings were included in the final dataset. Milkings were considered failed when labelled as incomplete by the DelPro software or when milk yield was <0.5 kg per quarter. Milk yield and milk flow per 2 s was retrieved from the AMS flow log files and these data were used to calculate yield per milk flow phase and mean flow in each phase. Milk flow curves required smoothing, as milk flow for each phase varied substantially during milking to allow automatic identification of the different phases. Using the smoothed curves (online Supplementary Fig. S1) the algorithm positively identified the increase phase, plateau phase (in darker colour; Supplementary Fig. S2), and the decline phase for each milking, cow, and quarter. The flow curves for each individual quarter varied substantially between and within udder.

The data on the different phases of the milk flow curves was analysed by ANOVA in a linear mixed-effects model using repeated measures in the statistical software SAS (SAS, v9.4, SAS Institute Inc., Cary, NC, USA). The model included the fixed effects of breed (Swedish Red or Holstein), parity (primi- or multiparous), teat cup (right rear, left rear, right front or left front), quarter milk yield (except when effect on yield was tested), TO (0.06, 0.3 or 0.48), feeding (feed or no feed), and interaction of TO and feed. The random effects included within the model were group, week, interaction of group, week, TO, and feeding, and the interaction of cow within group, week, TO, and feeding.

Values presented are least squares means (LSM) ± standard error of means (SEM) unless otherwise stated.

## Results and discussion

### *Treatment effects on milk flow, milk yield, and milking time*

Mean flow was increased with greater TO ($P < 0.001$; data not shown) without any effects on peak flow (Table 1) or the time to reach peak flow (data not shown), as predicted. Total milking time decreased at both udder and quarter level (Table 1) with greater TO level, with the longest milking times with TO 0.06. However, total milk yield at udder or quarter level, or in the different flow phases, did not differ between treatments (online Supplementary Table S1). The greatest detachment level in our study reduced the total milking time by 0.5 min per milking without decreasing the amount of harvested milk and, as previously described by Castro et al. (2012), reducing milking time by 0.5 min would significantly increase the efficiency of the AMS.

The actual flow at TO was for all treatments lower than the set TO level ($P < 0.001$), which together with the overmilking phase length shows a higher occurrence of overmilking in 0.06 compared to 0.3 and 0.48 (Table 1). This discrepancy between the set TO and actual TO levels is due to the delay time from the signal for TO and actual TO, in our case 6 s. Overmilking should, theoretically, be eliminated when milking at quarter level (Weiss & Worstorff, 2001), but in the current study, milk flow dropped below the overmilking limit and, sometimes, to 0 before take-off occurred. This was likely due to short, steep decline phases. This occurred on all treatments, but the time from set TO to actual TO was greatest at 0.3, while the length of the overmilking phase was longest on 0.06 (Table 1).

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The duration of the increase phase was approximately 0.5 min for all treatments, but was longer for 0.06 compared to 0.48 ($P < 0.01$; Table 1). The plateau phase was approximately 1 min long and the duration was not affected by treatment ($P = 0.87$; Table 1). The decline phase was longer with lower TO ($P < 0.001$; Table 1), but with no difference in milk yield harvested during this phase. This indicates sufficient emptying of the udder occurred when the greatest detachment level was applied. This is also supported by our previous publication from the same study, where residual milk yield was unaffected by treatment (Krawczel et al. 2017). In addition, Jago et al. (2010) observed no effect on strip yield in a long-term study on increased take-off levels at udder level.

### *Characteristics of the flow phases at quarter level*

Differences between front and rear quarters were evident for all flow phase lengths and for quarter level milking time ($P < 0.05$). These differences were all predicted and were most probably explained by the innate differences in milk yield and milk flow between the quarters (Tančin et al. 2006). We also observed a difference in actual flow at TO between front and rear quarters, with greater flow rates at TO in rear quarters than in front quarters (2.4 ± 0.1 and 2.3 ± 0.1 kg/min for the right and left rear quarters, respectively, and 1.9 ± 0.1 and 1.8 ± 0.1 kg/min for right and left front quarters, respectively; $P < 0.001$). The difference in decline phase length between front and rear quarters suggests that different delay times for different quarters or an adaptation of delay times to the milk flow pattern of each individual quarter could be beneficial.

## Conclusion

Our data suggest that the steepness of the decline phase has a major influence on the appropriate teat cup detachment level and delay times, which might vary between udder quarters. We also conclude that increasing the teat cup detachment level has no major influence on milk flow characteristics, but reduces over-milking and increases milking efficiency.

**Supplementary material.** The supplementary material for this article can be found at https://doi.org/10.1017/S002202991800078X.

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**Conflict of interest.** The study was conducted in collaboration with DeLaval International AB who kindly provided a software allowing us to set individual take-off levels per cow and provided us with access to flow data from the VMS. DeLaval International AB was allowed to read the final draft of the paper but had no impact on the nature of the results presented in the paper.

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