The effect of various automatic cluster removal switch-point settings on milking and overmilking duration and total, peak and overmilking claw vacuum in dairy cows

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Abstract

This research communication describes the effect of three automatic cluster removal (ACR) switch-point settings on machine-on time, overmilking duration, and the mean, peak-flow and overmilking vacuums. The objective was to reduce the overmilking and milking time, attaining a lower mean claw vacuum during overmilking. In a randomised experiment, 25 cows were subjected to three ACR switch-point settings at flow rates of 0.840 kg/min, 0.630 kg/min and 0.504 kg/min each for 15 morning-milkings. Pre-milking preparations and cow comfort were observed and evaluated, showing evidence that the switch-point setting of 0.840 kg/ml denoted the least proportion of behavioural problems (1.1% ± 0.6) compared to the settings at 0.640 kg/ml (16.0% ± 2.2) and 0.504 kg/ml (9.4% ± 1.7). A VaDia device (Biocontrol) determined the machine-on time and vacuum levels at the claw, mouthpiece and pulsator chamber. The machine-on time varied from 290 ± 72.8 (mean ± sd) to 289 ± 64.4 and 303 ± 66.3 for the 0.840, 0.630 and 0.504 kg/min settings, respectively. Overmilking was shortened by 29.3% and 26.4% and the claw vacuum during overmilking was reduced by 3.7 kPa and 4.3 kPa when using the 0.840 kg/min switch-point setting, compared to the others. An increased cluster-removal milk flow threshold reduced both overmilking and vacuum level during overmilking, lowering the risk of teat damage. Adapting ACR switch-point settings offers a valuable opportunity to increase parlour efficiency and cow comfort in dairy herds.

Keywords: ACR setting; cluster take-off time; cow comfort; Milking machine; overmilking

Milking machine development has advanced over the years, often with a focus on rapid milk harvesting and preservation of the teat canal preservation and, hence, cow longevity. High milking vacuum and overmilking increase the risk of inadequate teat conditions and intra-mammary infections (IMI) (Hillerton *et al.*, 2002). Likewise, various claw vacuum levels influence the milking performance and teat condition (Besier and Bruckmaier, 2016), with short-term damage in the teat being a consequence of circulation impairment and the teat canal openness. Milk from the teat and udder cisterns starts the milk flow. The ACR should detach the cluster once milk flow has decreased below a pre-set level or switch-point (kg/min), affecting the cluster's time on the teats (Jago *et al.*, 2010). The same authors reported that the ACR setting influences milking duration without reducing milk yield. When set optimally, an ACR should maximise milking efficiency (cows milked per operator), preserve teat canal integrity and minimise overmilking (Ginsberg *et al.*, 2018). Extending milking time is the primary cause of overmilking (Rasmussen and Madsen, 2000). These aspects are discussed in more detail in the online Supplementary File Supporting Literature.

There are no ISO standards for ACR settings with guidelines to apply for setups (Ginsberg *et al.*, 2018). The authors concluded that combining a switch-point setting with a maximum cluster attachment time during early or peak lactation reduced milking duration with no negative effects. An optimal termination point can be determined in the milk-flow curve decline phase before the overmilking phase (Tančin *et al.*, 2006).

The study objective was to assess the effects of three ACR switch-point settings on milking and overmilking durations and on vacuum levels during overmilking and peak milk flow, including cow comfort during milking.

Materials and methods

Experimental design

This study was conducted at the Experimental Farm of the University of Pretoria, South Africa (Hillcrest Campus) with a Waikato milking machine (New Zealand, LP) and Afimilk (Afikim, Israel) advanced management system with a low milk line. The mean daily milk yield was 36 kg. All milking machine settings, except the switch-point volumes, were consistent throughout the study. A VaDia device (Biocontrol AS, Rakkestad, Viken, Norway) determined the machine-on time and vacuum levels at the claw, mouthpiece and pulsator chamber, as described in detail in the Online Supplementary materials and methods.

Milking events

The observed milking events included pre-milking preparations and cow discomfort. Weight shifting or stepping, kicking, teat base swelling and ring swelling were recorded during milking. Clinical mastitis, liner slip and cluster fall-off was defined as incomplete information and this s well as inconclusive VaDia graph data (12.1%) were excluded from the final calculations.

Milking machine settings

The pulsation ratio was 65:35 with 60 cycles/min and the milking (system) vacuum was 43.5 kPa with the second-minute teat end vacuum of 37.6 kPa for the average producers with an average fluctuation of 2.1 kPa and a 5 s delay time. For each switch-point setting, measurements occurred during the morning milking of 25 cows for 15 consecutive days. Cow selection was based on teat size and udder conformation, excluding those with teats shorter than 3 cm and asymmetric udders. The three switch-point settings were evaluated in series with a three-day adaption period among test groups. Flow rates where the milking ends at 0.840 kg/min, 0.630 kg/min and 0.504 kg/min were selected. The switch-point setting of 0.504 kg/ml was used for the machine; increasing volumes were chosen based on previous research (Jago *et al.*, 2010; Ginsberg *et al.*, 2018). Guidelines from Tančin *et al.* (2006) determined the start of milking, defined as when vacuum first increased in the mouthpiece chamber (MPC) or short milk tube (SMT) as well as the start of the incline phase (peak flow), start of overmilking (decline phase) and the end of milking (the point where all MPC and SMT traces returned to the non-milking vacuum level or 0 kPa) (online Supplementary materials and methods and Figure S1).

Statistical analyses

Generalised linear models (GLMs) were applied to the cows with behavioural events to indicate cow discomfort from the total milked per day. The binomial distribution and the logit link function defined the required transformation, enabling a linear model (online Supplementary File). The predicted means were compared using Tukey's test at the 5% significance level. The statistical software GenStat® (VSN International, Hemel Hempstead, UK) was used for the data analysis. The three ACR switch-point settings were compared for machine-on time, overmilking duration, total vacuum, vacuum at peak flow, and vacuum during overmilking. The Shapiro–Wilk test evaluated the normality distribution for each factor, which was not normally distributed for any of these the variables. Therefore, the non-parametric Kruskal–Wallis rank-sum test was used to compare the three ACR switch-point settings. The Kruskal–Wallis test indicated significant differences, therefore, this test was followed by the Wilcoxon Rank-sum test to compare the differences among the separate groups (details in online Supplementary File) for machine-on time, overmilking duration, mean total claw vacuum, claw peak flow vacuum, and claw overmilking vacuum.

Results and discussion

Cow comfort during milking

The cows that kicked or shifted their weight (stepping) towards the end of milking were 2.2%, 5.7% and 0%. Ring formation or slight teat base swelling was evident at 0.3%, 2.2% and 1.9% of all cows at switch-point settings of 0.840 kg/min, 0.630 kg/min and 0.504 kg/min, respectively. Back-transformed means of the proportion of cows with behavioural events indicated cow discomfort per setting (Table 1).

Compelling evidence ($P < 0.001$) indicates that the switch-point setting of 0.840 kg/ml specified the least proportion of kicking and stepping, teat base swelling, and rings post milking (Table 1). This agreed with Cerqueira *et al.* (2017), establishing that overmilking led to significantly more stepping and kicking behaviour during milking. More cows had somatic cell counts exceeding 200 000 cells/ml of milk at this setting.

Table 1. Back-transformed means of the proportion of cows with behavioural events per set

Setting	Mean	Standard error	Sample size	Back-transformed, 95% Confidence interval
0.504 kg/min	0.094^{b}	0.017	9	(0.063–0.137)
0.630 kg/min	0.160^{c}	0.022	8	(0.199–0.213)
0.840 kg/min	0.011^{a}	0.006	8	(0.003–0.036)

Different superscript lower case letters indicated values differed significantly at the 5% level.

Machine-on time

Reduced machine-on time may lower the risk of teat canal damage and reduce overmilking without harming milk production, milk components, or yields. These aspects are discussed in more detail in the online Supplementary File Supporting Literature. Various studies, including the current study, agree that when the switch-point settings increased, machine-on time decreased (Jago *et al.*, 2010; Besier and Bruckmaier, 2016; Ginsberg *et al.*, 2018; Boloña *et al.*, 2020). In the current study, machine-on time decreased significantly (P < 0.05) by 4.65% when the switch-point setting was increased from 0.504 kg/min to 0.630 kg/min. However, when each of the switch-point setting were compared separately, the machine-on time indicated no significant differences for 0.840 kg/min vs. 0.630 kg/min and 0.840 kg/min vs. 0.504 kg/min (Table 2). As the ACR switch-point settings approached their optimal setting for the parlour, the improvement in machine-on time was reduced.

Table 2. Comparison of the variables measured by the VaDia for the three switch-point settings of a dairy cow milking machine.

Variable	ACR switch-point (kg/min)	Mean	Minimum	Maximum	Kruskal–Wallis rank test *P* value	Wilcoxon test *P* value (mean differences)
Machine-on time (s)	0.840	290.0[a]	175.0	670.0	0.035	0.010
	0.630	289.2[a]	184.0	858.0		
	0.504	303.3[b]	195.0	936.0		
Overmilking (s)	0.840	76.5[a]	1.0	389.0	<0.0001	<0.0001
	0.630	103.9[b]	0	323.0		
	0.504	108.2[b]	1.0	367.0		
Mean total vacuum (kPa)	0.840	28.2[a]	12.7	35.0	<0.0001	<0.0001
	0.630	31.2[b]	17.7	43.0		
	0.504	31.0[b]	18.6	36.4		
Mean vacuum during peak flow (kPa)	0.840	28.1[a]	12.2	35.6	<0.0001	<0.0001
	0.630	31.6[b]	16.5	42.8		
	0.504	31.0[b]	16.5	36.2		
Mean vacuum during overmilking (kPa)	0.840	28.6[a]	10.7	36.4	<0.0001	<0.0001
	0.630	32.9[b]	13.6	43.9		
	0.504	32.3[b]	13.2	37.5		
Comparison of mean vacuums	0.840	n/a	n/a	n/a	n/a	<0.0001
	0.630	n/a	n/a	n/a		
	0.504	n/a	n/a	n/a		

Superscript letters [a] and [b] next to the mean values indicate the significant differences between the Wilcoxon and Kruskal–Wallis tests. *P*-values for the machine-on time were significant at $P \leq 0.05$ level of significance; all other variables were significant at the $P \leq 0.0001$ level of significance.

Overmilking duration

Significant differences (P < 0.05) were observed when comparing the mean vacuums at peak flow and overmilking for the three switch-point settings. The liner mouthpiece forms a seal at the teat base, constricting the annular ring. Milk flow between the gland and teat cistern is delayed when overmilking increases, leading to congestion and oedema of the teat (Tančin *et al.*, 2006; Ginsberg *et al.*, 2018). This study established a significant decrease of 31.7 s and 27.4 s in overmilking when increasing the switch-point setting from the 0.504 and 0.630 kg/min to the 0.840 kg/min, respectively (Table 2). Overmilking, as a percentage of the total machine-on time, increased as switch-point setting decreased. These findings confirm that overmilking correlates with increasing and decreasing milking and parlour efficiency. Ginsberg *et al.* (2018) established that rear teats were overmilked at a lower ACR switch point than front teats. Rear quarters not only produce more milk but have longer increases and plateau while decreasing milk flow phases (Tančin *et al.*, 2006).

Mean total milking vacuum

A milking vacuum that is too low may cause the claw vacuum to reverse during the a-phase of pulsation, risking milk reflux back from the claw to the teat tip or into the udder. This may lead to cross infections between quarters and teat canal damage (Ambord and Bruckmaier, 2010). The claw vacuum increased significantly from 28.2 kPa to 31.0 kPa when the switch point level was lowered from 0.840 kg/min to 0.504 kg/min, respectively. This finding agrees with those of Besier and Bruckmaier (2016), who concluded that a high milking vacuum compensates for a non-avoidable vacuum drop, allowing for good milking performance. The latter increases the risk of adverse effects on the teat end, which can be lessened by increasing the ACR switch point setting (Besier and Bruckmaier, 2016).

Peak flow claw vacuum

This study established a significantly lower vacuum during peak milk flow at the 0.840 kg/min switch point setting than the two lower settings. It differed little from the vacuum levels during mean and overmilking for similar settings. This might be caused by minor overmilking when starting the milking because of inadequate pre-milking preparations. On the other hand, bimodal milk flow was absent, while a low system vacuum in the low-line milking system was observed. Ambord and Bruckmaier (2010) identified a significant claw vacuum drop of 15 ± 0.7 kPa during peak milk flow. These authors recommend that for optimal milking performance and teat conditions, only a reasonable vacuum drop should occur during peak milk flow with a minimum claw vacuum above 30 kPa. The 28.1 kPa at a switch-point setting of 0.840 kg/min was closer to this value, whereas those of the lower switch point settings were higher.

Mean overmilking claw vacuum

The milk flow rate affects the claw vacuum, especially at high flow rates, as the vacuum in the claw approaches that of the system vacuum during overmilking (Rasmussen *et al.*, 2006). According to Besier and Bruckmaier (2016), the system vacuum did not affect teat health at the start of milking unless pre-stimulation was inadequate. The current study established a significant decrease in the mean overmilking claw vacuum of 4.3 kPa when lowering the switch-point setting of 0.840 kg/min to 0.630 kg/min (Table 2).

Comparing mean vacuums at peak milk flow and during overmilking

In this study, the mean claw vacuum at peak flow and overmilking differed significantly for the three switch-point settings (Table 2). No other published work could compare the mean vacuums at peak flow and overmilking. Tančin *et al.* (2006) indicated that a decline in the milking phase duration was more important at the quarter level when considering the physiological response of the cow to milking. Milk flow reduction, nearing the end of milking, lessened the chances of flushing out pathogens while increasing the risk of IMI. At the udder level, the fastest milking quarter determines the end of the plateau phase, whereas, at the quarter level, it is determined by the milk availability in that quarter. Boloña *et al.* (2020) established significant within-udder differences in overmilking between individual quarters varied from 1.28 min for the fastest to 0.47 min for the slowest milking quarter.

In conclusion, this study indicated that when machine-on time was decreased, overmilking was shorter. The vacuum during overmilking was lower when an ACR switch-point setting of 0.840 kg/min was used, compared to 0.504 kg/min. Similarly, overmilking and overmilking vacuum decreased when an ACR switch-point setting of 0.840 kg/min and 0.630 kg/min were compared. It was concluded that the best of the three ACR switch-point settings, which was 0.840 kg/min in this study, can lower the risk of teat-end damage because of shorter machine-on and overmilking times. Decreasing teat-end damage could assist with reducing new IMI and mastitis while improving parlour efficiency.

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