

# Effect of vacuum and ratio on the performance of a monoblock silicone milking liner

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## Abstract

The vacuum and teat-cup chamber ratio are important operating parameters that affect milking performance by milking machines. In addition, the design and composition of materials are major elements affecting the performance characteristics of (teat-cup) milking machine liners. The objective of this experiment was to determine the effects of vacuum and teat-cup chamber ratio on the performance of a unique monoblock silicone milking machine liner that is round in the open position and triangular in the collapsed position. System vacuum settings (set at receiver) were 40.6, 43.9, and 47.3 kPa, whereas teat-cup chamber ratios were 60:40, 65:35, and 70:30. Milk yield was greatest at a vacuum of 43.9 kPa. Manual adjustments and kickoffs were very low (<2%) at all vacuum levels and for all ratios. The interaction of vacuum level and ratio was significant for milking duration, peak flow rate, and average flow rate, but not for milk yield. Average and peak milk flow rates increased at each increasing vacuum level and each wider ratio, whereas milking duration decreased.

## Introduction

Characteristics of (teat-cup) milking machine liners (also referred to as inflations) are variable, and this variability affects milking performance. Milking system vacuum and ratio are major operating parameters that affect milking performance (Smith and Peterson, 1946). In addition, the interaction of liner characteristics with milking machine settings may be important. O’Shea et al. (1980) reported differences in milking characteristics from variations in the pulsation rate, phase, and ratio. Wide ratios, expressed as the ratio of liner open time to liner collapse time, resulted in shorter milking times, and high pulsation rates (65 cycles/min) resulted in greater strip milk yields. Hacker et al. (1967) observed reduced labor when cows were milked with a 70:30 ratio compared with a 50:50 ratio. Milking rates progressively increase with an increase in vacuum over the range of 34 to 84 kPa (Cowie et al., 1959). Thomas et al. (1991) reported lower machine-on times and greater yields for a 70:30 ratio than for 60:40 and 50:50 ratios. Pulsation rates of 50 or 60 cycles/min did not affect the milking rate or milk yield. Peak milk flow rate probably reaches a maximum level at a pulsator ratio

within the range of 60 to 70%, depending on the characteristics of the liners used for particular studies (Mein et al., 2004). Spencer and Rogers (1991) reported that milking machine liner type interacted with vacuum level and that manual adjustment of milking units increased at lower vacuum levels. Mein et al. (2003) described a hypothetical relationship of the liner “touchpoint,” the residual vacuum for massage, and the overpressure (or compressive load) applied to the teat. Hillerton (2005) recognized the variation in liners with regard to milking performance, cow behavior, udder health, and teat responses. Spencer and Rogers (2004) found an interaction of vacuum and ratio with 2 conventional liner types. The optimal settings for milking system vacuum and ratio are likely dependent on liner characteristics.

## Objective

The objective of this experiment was to determine the effects of vacuum and chamber ratio on the performance of a unique silicone milking machine liner (Lauren AgriSystems, New Philadelphia, OH). This silicone liner is round in the open position and triangular shaped when collapsed.



## Material and Methods

The silicone liner was tested in a herd of 174 milking cows, milked twice daily. Only 160 cows had usable records after removal of cows having missing observations for one or more milkings. Milking observations were made during 18 d, with 36 milkings per cow. The milking system was a DeLaval system (DeLaval, Tumba, Sweden) having a typical low-line, double-8 herringbone parlor configuration. Pulsator rate was 60 cycles/min and the A-, B-, C-, and D-Phases of the pulse chamber vacuum at a 70:30 ratio were as follows: a = 111 to 115 ms, b = 580 to 585ms, c = 90 to 94 ms, and d = 209 to 214 ms. Pulsator characteristics were within American Society of Mechanical Engineers and International Organization for Standardization standards and the limitations of some commercial companies. The system was checked before the trial and met or exceeded American Society of Mechanical Engineers standards and National Mastitis Council guidelines. A mercury column was used to accurately set vacuum near the receiver. Claw vacuum ranged from 1.8 to 5.5 kPa less than receiver vacuum at peak flow. Nine combinations of vacuum and ratio were used. Each combination of vacuum and ratio was used twice, in reverse order, as shown in Figures 1 and 2; hence, the second 9-d period was essentially a replicate of the first 9 d. Vacuum settings were 40.6, 43.9, and 47.3 kPa, and chamber ratios were 60:40, 65:35, and 70:30.

## Analysis

Statistical analyses for the dependent variables of milk yield, duration, peak milk flow, and average milk flow were done using the Mixed procedure of SAS (SAS Institute, 1999). Independent variables of the mixed model included the random effect of cow and the fixed effects of period, vacuum, ratio, a.m. or p.m. milking, and the vacuum × ratio interaction. Period was included in the model to account for the replication of each vacuum × ratio combination: period 1 = d 1 through 9, and period 2 = d 10 through 18 (Figures 1 and 2). Average milk flow rate, peak flow rate, and duration were recovered from the DeLaval Alpro data acquisition system. Peak flow rate was determined by the metering system during the 15-s time period when milking rate was greatest. Milking duration was machine-on time and Journal of Dairy Science Vol. 90 No. 4, 2007 Figure 2. Sequence for 9 combinations of chamber ratio and vacuum during period 2 (d 10 to 18) was determined by milk flow rate, beginning and ending when milk flow rate reached 0.45 kg/min. Machine removal occurred when flow rate dropped to 0.45 kg/min after a 5-s delay.

Milking operators enumerated manual adjustments when a return trip to a cow was required to adjust the unit for a liner squawk, kickoff, or falloff. Because occurrence of an adjustment or a

kickoff during the milking of a cow is a binomial variable, the Logistic procedure of SAS (SAS Institute, 1999) was used to analyze the effect of vacuum, ratio, a.m. or p.m. milking, and the vacuum × ratio interaction on these 2 variables. Multiple kickoffs or adjustments during a single cow milking were coded as 1, and no kickoffs or adjustments were recorded as 0. Independent variables included the fixed effects of vacuum, ratio, a.m. or p.m. milking, and the vacuum × ratio interaction.

## Results

Least squares means for the effect of chamber ratio setting on milk yield, milking duration, peak flow rate, and average flow rate are shown in Table 1. Milking duration, peak flow rate, and average flow rate differed ( $P \leq 0.05$ ) for all ratios. Peak flow rate and average flow rate increased ( $P \leq 0.05$ ) with increasing chamber ratio. Milking duration was 0.44 min/cow less at a 70:30 ratio compared with a 60:40 ratio. Milk yield at the 60:40 ratio was greater ( $P \leq 0.05$ ) than at the 65:35 ratio.

Least squares means (Table 2) for milking duration, peak flow rate, average flow rate, and milk yield indicated that vacuum level was important for these milking parameters. Milking duration decreased ( $P \leq 0.05$ ) by 0.74 min/cow as vacuum increased from 40.6 to 47.3 kPa. Peak flow rate and average flow rate increased ( $P \leq 0.05$ ) as vacuum level increased. Milk yield was greatest at the intermediate vacuum of 43.9 kPa. Perhaps a short-term study such as the present one may not be a valid indicator of yield vs. vacuum and longerterm trial periods are justified.

The interaction of vacuum × ratio was significant ( $P < 0.05$ ) for milking duration, peak flow rate, and average flow rate (Figure 3). Milking duration decreased ( $P < 0.05$ ) as vacuum level increased and ratio increased. Peak flow rate and average flow rate increased ( $P < 0.05$ ) as vacuum level and ratio increased. A significant vacuum × ratio interaction occurred as a result of the performance of the liner at a vacuum of 43.9 kPa and a ratio of 65:35. At these settings, peak flow and average flow were less than what would have been expected based on the flow rates at greater and lesser vacuum levels and ratios. The vacuum × ratio interaction for milk yield was nonsignificant. Manual adjustments were greater ( $P < 0.05$ ) at the smallest of the 3 vacuums (40.6 kPa) than for the higher vacuums of 43.9 and 47.3 kPa. The odds ratio (calculated from the Logistic procedure) for the vacuum of 40.6 kPa was 1.88, which indicates that the odds of having an adjustment at the vacuum level of 40.6 kPa is 88% more than for a vacuum of 47.3 kPa. Kickoffs did not differ among vacuum levels. Kickoffs and manual adjustments were not different for the various ratios tested. Frequency of adjustments and kickoffs for the 5,760 milkings in this study was very small, 1.1 and 1.3%, respectively.

## Discussion

Two measures of liner characteristics are the critical collapsing pressure difference and touchpoint pressure difference (TPPD). The critical collapsing pressure difference is the point at which the liner begins to buckle because of the pressure difference across the walls. It may not be an important criterion of the milking process. The TPPD is the pressure difference at the point at which the liner walls touch and is an important characteristic, especially as it relates to operating vacuum and endurance of the liner to maintain milking performance. Silicone liners with the same batch numbers as used in this study were measured when new and after 3,000 milkings in a 550-cow herd using a mercury column.

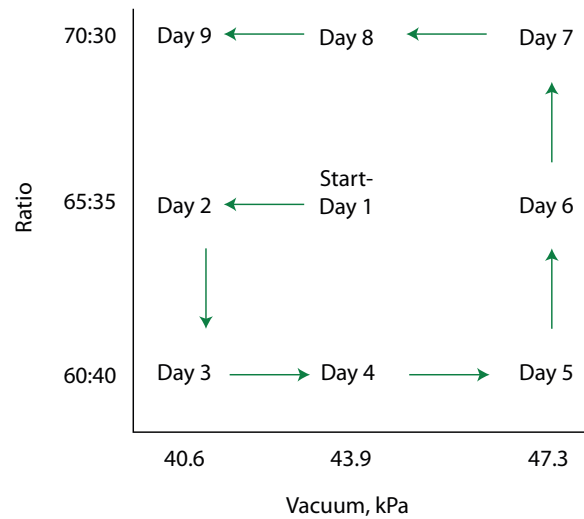
The TPPD of the liner was determined by putting the liner in a DeLaval 06 shell and placing it over a light source. Air pressure was applied to the liner or shell chamber and the pressure within the chamber was measured by a mercury column. The collapsing liner was viewed through the short milk tube of the liner. When 3 sides of the liner touched, the pressure was recorded. It should be noted that a round liner has 1 touchpoint to observe, whereas a triangular liner has 3 touchpoints. The critical collapsing pressure difference of 4 liners of the type used in this study averaged 6.77 kPa when new and 4.74 kPa after being used for 3,000 milkings.

The TPPD of these 4 liners averaged 33.52 kPa when new and 25.73 kPa after being used for 3,000 milkings. The largest number of manual adjustments occurred at the lowest vacuum in this study. A high TPPD suggests that the liner is best used at a relatively high vacuum. A high TPPD liner requires a higher vacuum to bring the liner closed to an optimal overpressure on the teat compared with a low TPPD liner.

The monoblock silicone milking machine liner in this study was responsive to differential vacuum levels and chamber ratios. At each increase in vacuum level and as the ratio got wider, average and peak milk flow rates increased and milking duration decreased. Milk yield was greatest at a vacuum of 43.9 kPa. The interaction of ratio × vacuum was important for milking duration, peak flow rate, and average flow rate.

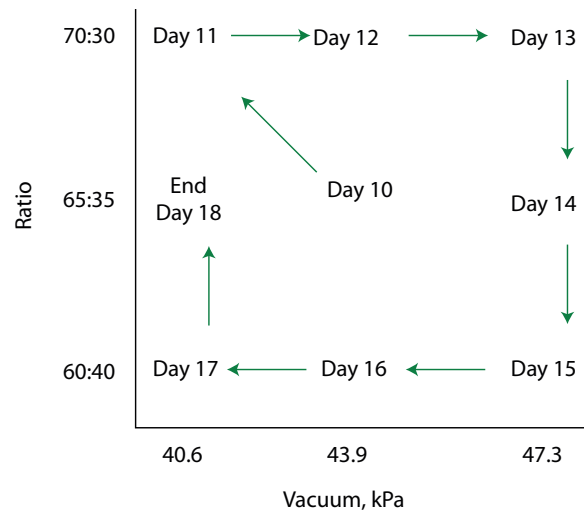
**Figure 1:**

Sequence for 9 combinations of chamber ratio and vacuum during period 1 (d 1 to 9).



**Figure 2:**

Sequence for 9 combinations of chamber ratio and vacuum during period 2 (d 10 to 18).



**Table 1:**

Least squares means for milk yield, milking duration, peak milk flow rate, and average milk flow rate for 3 chamber ratios during milking<sup>1</sup>.

Ratio	Milk Yield, kg	Duration, min	Peak milk flow, kg/min	Average milk flow, kg/min
60:40	15.89 <sup>a</sup>	5.21 <sup>a</sup>	3.88 <sup>a</sup>	3.18 <sup>a</sup>
65:35	15.69 <sup>b</sup>	4.99 <sup>b</sup>	4.04 <sup>b</sup>	3.29 <sup>b</sup>
70:30	15.80 <sup>ab</sup>	4.76 <sup>c</sup>	4.28 <sup>c</sup>	3.46 <sup>c</sup>

<sup>a-c</sup>Means within a column having different superscript letters differ ( $P \leq 0.05$ ).

<sup>1</sup>Standard error for means by trait: 0.04 for milk yield, 0.02 for duration and 0.01 for peak and average flow.

**Table 2:**

Least squares means for milk yield, milking duration, peak milk flow rate, and average milk flow rate for 3 vacuum levels for one milking<sup>1</sup>.

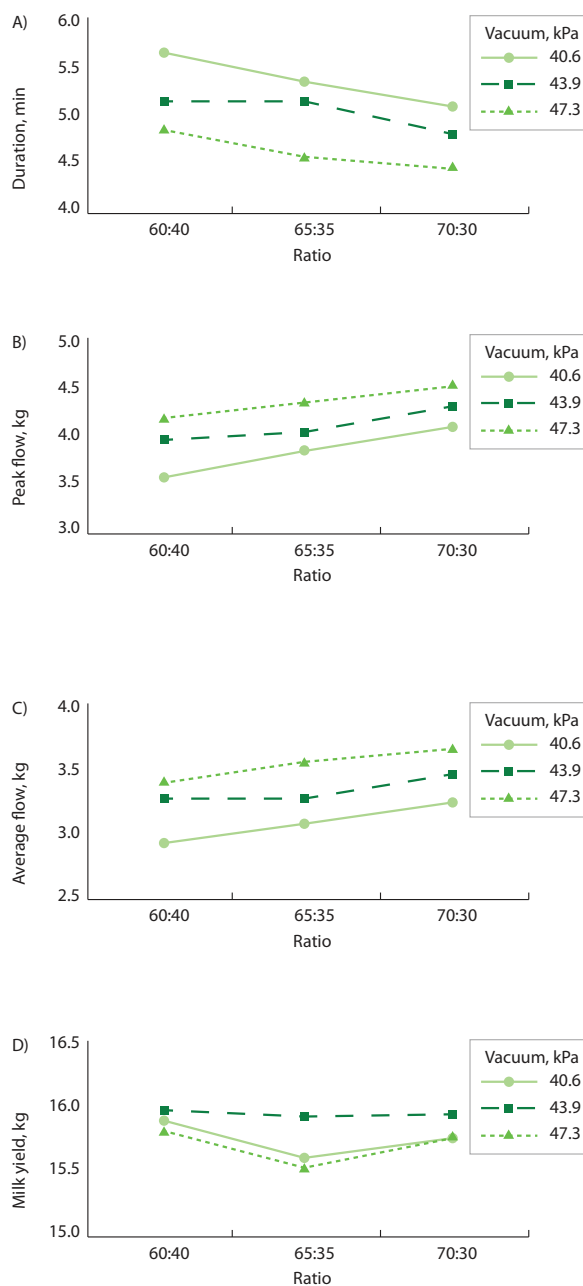
Vacuum, kPa	Milk yield, kg	Duration, min	Peak milk flow, kg/min	Average milk flow, kg/min
40.6	15.75 <sup>a</sup>	5.35 <sup>a</sup>	3.79 <sup>a</sup>	3.09 <sup>a</sup>
43.9	15.94 <sup>b</sup>	5.02 <sup>b</sup>	4.07 <sup>b</sup>	3.31 <sup>b</sup>
47.3	15.69 <sup>a</sup>	4.61 <sup>c</sup>	4.34 <sup>c</sup>	3.54 <sup>c</sup>

<sup>a-c</sup>Means within a column having different superscript letters differ ( $P \leq 0.05$ ).

<sup>1</sup>Standard error for means by trait: 0.04 for milk yield, 0.02 for duration, and 0.01 for peak and average flow.

**Figure 3:**

Interaction of chamber ratio × vacuum (kPa) for milking duration (A), peak milk flow rate (B), average milk flow rate (C), and milk yield (D). All interactions were significant ( $P < 0.05$ ) except for milk yield.



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