A note on the design and testing of single teatcups for automatic milking systems

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In automatic milking units single independent teatcups or shell/liner combinations are required. The milking characteristics of three designs of single-teatcup milking units were compared with a conventional milking unit in a pipeline milking system. The combined weight of each single-teatcup shell and liner used in the single-teatcup units was 0.18 kg, 0.38 kg or 0.56 kg. The conventional milking cluster had a claw volume of 150 mL and a weight of 3.16 kg. The single sets of teatcups were applied manually and removed automatically when milk flow from the four teatcups reached 0.2 kg/min. The experiment involved a latin square design with four groups of Friesian cows (10 cows/group), four 2-day periods and four treatments. At a flow rate of 4 L/min during simulated milking the mean vacuum level at the teat-end (artificial teat) during the “b-phase” of pulsation was 43.8 kPa with the conventional milking unit and 33 kPa for the three single-teatcup units. The corresponding mean and minimum teat-end vacuum in the “d-phase” were 38.46 kPa and 29.54 kPa, respectively, for the conventional system and 24.95 kPa and 17.59 kPa, respectively, for the single-teatcup configuration. The light teatcup (weight 0.18 kg) gave longer time to milk letdown, longer milking time and both lower peak and average milk flow than the conventional cluster.

Keywords: automatic milking; milking machine; teat cup

Introduction
Most automatic milking systems use single independent teat cups usually linked to a milk meter or recording jar via single long milk tubes. Svennersten-Sjaunja (2000) compared an automatic milking system (AMS) with a conventional system, where the four teatcup liners are attached to a common claw, for milking characteristics and udder health. In a conventional
milking system the four teatcup liners are attached to a common claw whereas in an AMS system each teatcup is independent and has a separate long milk tube. The results indicated that milking in AMS increased production, lowered somatic cell count in quarter milk samples and improved teat condition. While vacuum levels at the milk receiver, and pulsator settings in automatic milking systems are similar to conventional milking systems (Hillerton, 1997) the teat-end vacuum levels or levels of vacuum loss during milk flow may differ.

A recently designed portable milk-flow simulator (O’Callaghan, 2004) allows the configuration of automatic and conventional milking units for specific vacuum conditions at the teat-end at selected water flow rates. The objective of the present test was to compare the milking characteristics of single teatcups, configured in a conventional parlor in a mode similar to that used in an automatic milking system, with a conventional milking unit. The vacuum profiles at the teat-end from simulated milking were similar for both the single-teatcup configurations and the conventional unit, which was used as the control or reference system.

Materials and Methods
The experiment had a $4 \times 4$ latin square design with four groups of Friesian cows (10 cows/group), four 2-day periods and four treatments. The treatments consisted of one conventional cluster and three sets of single-teatcup designs as treatments. The combined weights of each single teatcup shell plus liner were 0.18 kg, 0.38 kg and 0.56 kg, respectively. Cows were randomized across the four treatment groups based on the average of three previous AM milk yields. The conventional milking cluster had a claw volume of 150 mL, a weight of 3.16 kg and Dairymaster type 916S liners (Dairymaster, Causeway, Co. Kerry). This liner is classified as a wide-bore tapered type with an upper barrel bore of 31.5 mm and a taper of 10 mm. Dairymaster type 916SL liners (Dairymaster, Causeway, Co. Kerry) were fitted in the single teatcup shells. The internal dimensions of both liner types used were identical; the mouthpiece of the Dairymaster 916SL is modified for use with a lightweight cluster. Simultaneous pulsation was used, pulsation rate was 60 cycles/min and the pulsator ratio was 68%.

The system vacuum level for the mid-level milking plant was set at 50 kPa and vacuum reserve was 1500 L/min. Milk lift with the conventional milking system from the cow standing level to a vacuum shut-off valve was 1.8 m; the top of the milk meter (Dairymaster Weighall, Dairymaster, Causeway, Co. Kerry) was located 12 cm below the shut-off valve. A 16 mm bore long milk tube was used and the air admission in the claw was 10 L/min. The single teatcups were connected to 9 mm bore long tubes with a stainless steel bend. The stainless steel bend had a 0.75 mm hole that admitted air at 8 L/min. The long milk tubes were routed to a claw 1.5 m above cow standing level; the lift from the claw outlet to the vacuum shut-off valve was 44 cm. The claw had an air admission of 8 L/min and the top of the milk meter (Dairymaster Weighall, Dairymaster, Causeway, Co. Kerry) was located 12 cm below the shut-off valve.

A flow simulator (O’Callaghan, 2004) was used to establish the teat-end vacuum levels during the “b-phase” and the “d-phase” of pulsation chamber vacuum in the conventional milking chamber and for the milking units with four single teatcups linked to the high level milk meter at two water flow rates (4.0 and 6.2 L/min).
For the conventional cluster and for each group of four teatcups, measurements of milk yield, milking time, average milk flow rate, peak milk flow rate and time from teatcup or cluster application to a milk yield of 1 kg were made at morning milkings. Clusters were removed automatically at a milk flow-rate of 0.2 kg/min for both conventional system and for the combined flow of the four teatcups. Milking time was computed as the time interval from cluster/teatcup application to when the milk flow reached 0.2 kg/min. The milk let-down time was defined as the interval from cluster/teatcup application to when a milk yield of 1.0 kg was recorded. The data on each element of the milking characteristics was the mean for two successive morning recordings. The data were analyzed by analysis of variance using Genstat (1993). Cows on all four treatments were milked with the conventional high-level machine at the evening milkings.

Results and Discussion

Flow simulation measurements
For the conventional milking machine the teat-end vacuum, pulsation chamber vacuum and system or milkline vacuum are shown in Figure 1 at flow rates of 4 L/min and 6.2 L/min, respectively. With flexible wide-bore tapered liners and simultaneous pulsation the vacuum loss at the teat-end during the “b-phase” of pulsation was low and a drop in vacuum occurs during the “c-phase” (O’Callaghan, 2004). With the independent teatcup designs a claw with a volume of 150 mL and an air admission of 8 L/min had to be placed at 1.5 m above cow standing level in order to obtain the characteristic teat-end vacuum curve associated with a conventional cluster. The curves with the conventional machine and those from the single-teatcup configurations had similar profiles; the vacuum loss at the teat-end in the “b-phase” of pulsation was, however, higher with the single teatcups. At a flow of 4 L/min during simulated milking the mean vacuum level at the teat-end (artificial teat) during the “b-phase” of pulsation was 43.8 kPa for the conventional milking unit (Figure 1) and 33.0 kPa for the three single-teatcup configurations (Figure 2). The corresponding mean and minimum teat-end vacuum in the “d-phase” were 38.5 kPa and 29.5 kPa, respectively, for the conventional system and 25.0 kPa and 17.6 kPa, respectively, for the single-teatcup configurations.

At a flow rate of 6.2 L/min during simulated milking the mean vacuum level at the teat-end during the “b-phase” of pulsation was 35.0 kPa with the conventional milking unit (Figure 1) and 28.3 kPa for the three single-teatcup designs (Figure 2). The mean and minimum teat-end vacuum in the “d-phase” were 21.2 kPa and 15.7 kPa, respectively, for the conventional system and 15.7 kPa and 12.0 kPa, respectively, for the single-teatcup configurations.

Milking characteristics
The milking characteristics of the four treatments are presented in Table 1. The extended milk letdown time and milking time with the lightest teatcup compared to the conventional cluster were probably caused by excessive teat penetration and restriction between the gland and teat sinus. The low weight of single-teatcup units offers cost advantages particularly when an industrial robot arm is used for attaching the teatcups. The average and peak milk flow rates for the lightest single-teatcup design were significantly longer (P<0.001) than for the conventional cluster. O’Callaghan and Gleeson (2004) showed that the average and peak milk flow rates were reduced for milking
systems that had high teat-end vacuum losses during the “b-phase” of pulsation. In the present experiment the high level of air admission with the single-teatcup configuration may increase free fatty acid levels. Increases in free fatty acid levels with AMS have been reported by Jepsen and Rasmussen (2000) but this aspect was not measured in the present study. By using simulation measurements to reduce the vacuum losses and minimizing the air admission new improved versions of single-teatcup units that give good milking characteristics can be designed.

Figure 1. Vacuum traces for (a) system vacuum, (b) pulsation chamber vacuum and (c) teat-end vacuum at a water flow rates of (i) 4 L/min and (ii) 6.2 L/min with a conventional high-level milking machine.

Figure 2. Vacuum traces for (a) system vacuum, (b) pulsation chamber vacuum and (c) teat-end vacuum at water flow rates of (i) 4.0 L/min and (ii) 6.2 L/min for the single-teatcup units.
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Table 1. Effect of conventional and single-teatcup units on milk yield, time to milk letdown, milking time, and average and peak milk flow rates

<table>
<thead>
<tr>
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<th>Treatment¹</th>
<th>s.e.d.</th>
<th>F test</th>
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<tbody>
<tr>
<td></td>
<td>T1</td>
<td>T2</td>
<td>T3</td>
</tr>
<tr>
<td>Cluster/teatcup weight (kg)</td>
<td>3.16</td>
<td>0.18</td>
<td>0.38</td>
</tr>
<tr>
<td>Teat-end vacuum at 4 L/min (kPa)</td>
<td>43.8</td>
<td>33.0</td>
<td>33.0</td>
</tr>
<tr>
<td>Milk yield AM (kg)</td>
<td>17.2</td>
<td>16.6</td>
<td>17.0</td>
</tr>
<tr>
<td>Milk letdown² (s)</td>
<td>36.0</td>
<td>41.8</td>
<td>40.4</td>
</tr>
<tr>
<td>Milking time AM (s)</td>
<td>411</td>
<td>449</td>
<td>434</td>
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<tr>
<td>Average milk flow rate (kg/min)</td>
<td>2.6</td>
<td>2.3</td>
<td>2.5</td>
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<tr>
<td>Peak milk flow rate (kg/min)</td>
<td>4.5</td>
<td>3.9</td>
<td>4.1</td>
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¹ T1 = conventional cluster; T2, T3 and T4 = single-teatcup configurations.
² Time from start of milking to a milk yield of 1 kg.

References

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