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A note on the effects of teat-end vacuum on milking characteristics

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The magnitude of vacuum applied to the teat end can have a major effect on milking characteristics. While milking vacuum is usually measured in the milk pipeline, the teat-end vacuum during milk flow depends on the configuration of the milking unit. The objective was to establish the effect of teat-end vacuum, recorded during flow simulation, on actual milking time, milk yield, and both mean and peak milk-flow rates. Four configurations of milking units were set up to give vacuum levels of 35, 38, 40 and 42 kPa at the apex of an artificial teat during simulated milking. The experiment involved a latin square design with four groups of Friesian cows (14/group), four 2-day periods and four treatments (vacuum level). Altering the vacuum level had no significant effect on milk yield. There were no differences in milking characteristics between vacuum levels of 38 and 40 kPa. A vacuum level of 42 kPa gave a shorter milking time ($P < 0.001$), higher average milk-flow rate ($P < 0.01$) and higher peak milk-flow rate ($P < 0.001$) than the three lower vacuum levels. Milking time was significantly longer ($P < 0.001$) and peak milk-flow rate lower ($P < 0.001$) with a vacuum of 35 kPa compared to other vacuum levels.

Keywords: Milking machines; milking time; vacuum

Introduction

The influence of vacuum on milking characteristics is often contradictory. While the milking vacuum for milking systems is generally defined as the vacuum in the milk pipeline or at the regulator, the level of vacuum loss between the teat end and milk pipeline or milk receiver during milking can influence the rate of milk extraction from the teat. Measurements of vacuum in the claw or the short milk tube during cow milking are not reliable, as the flow through individual quarters is not known. The exact levels of vacuum loss are generally measured with flow simulators under controlled flow conditions. There is a paucity of data on the effect of incremental levels of vacuum loss that occur in milking units on milking

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characteristics. Most of the vacuum losses in milking systems occur between the teat end and the milk pipeline. In most commercial milking parlors vacuum losses in milk pipelines are minimal. Rasmussen and Madsen (2000) recorded vacuum conditions in the short milk tube and gave average values per cow over complete milking to represent the teat-end vacuum. O'Callaghan (2002) recorded vacuum at the apex of an artificial teat during both liner open and closed phases of pulsation with a new design of milk flow simulator. This showed that with specific milking units the teat-end vacuum level during the 'b-phase' of pulsation differed significantly from the average teat-end vacuum measured over complete pulsation cycles. Since the teat-end vacuum level during the 'b-phase' of pulsation is the milk extraction vacuum it is a more appropriate measurement than average teat-end vacuum measured over complete pulsation cycles. Worstorff and Hollweck (1995) suggested that by installing long milk tubes with 16-mm internal diameter the loss in vacuum between the teat end and the system vacuum could be reduced. Schmidt and Van Vleck (1969) showed an inverse relationship between the level of vacuum at the teat end and milking time. Spencer and Rogers (1989) showed that when system vacuum was reduced from 50 kPa to 40 kPa milking time per cow was 1.11 min longer. Gleeson, O'Callaghan and Rath (1999) found a similar increase in milking time when the system vacuum was reduced from 50 kPa to 44 kPa. Hamann, Mein and Wetzel (1993) found that by reducing vacuum from 40 to 30 kPa machine-on time was increased by 37% for high-level milking systems and 38% for low-level systems. Rasmussen and Madsen (2000) showed that milking at a milkline vacuum of 38 kPa compared with 48 kPa for a high-level milking system decreased milk yield and milk flow rate and increased milking or machine-on time. The main difficulty with most publications on the effect of milking vacuum on milking characteristics is that there is no measurement or correlation between the system vacuum and the teat-end vacuum during milk flow. The main objective of the present experiment was to establish the effect of teat-end vacuum during the 'b-phase' of pulsation, as defined during flow simulation, on milking characteristics.

Materials and Methods

Four configurations of milking units were set up in a commercial (mid-level) side-by-side milking parlor and performance characteristics were assessed using a portable flow simulator (O'Callaghan, 2004). The flow simulator was placed on the cow standing and artificial teats placed in the teatcups. The system vacuum level for the milking plant was set at 49 kPa. A pulsation rate of 60 Hz was used and the 'a', 'b', 'c' and 'd' values of the pulsation chamber waveform were 12.0%, 56.2%, 11.3% and 20.5%, respectively. Each cluster type was fitted with wide-bore tapered liners, a 150-ml claw and had a cluster weight of 3.16 kg. The milk pipeline was sloped towards the cow exit and each milking unit consisted of a cluster, a swing arm, a milk diversion valve and an electronic milk meter (Dairymaster Weighall, Dairymaster Ltd, Causeway, Co. Kerry). Simultaneous (4 × 0) and alternate (2 × 2) pulsation patterns and two bores of long milk tubes (LMT) were used to establish vacuum levels, during the 'b-phase' of pulsation, of 35, 38, 40 and 42 kPa at the apex of one artificial teat at a water flow rate of 4 l/min (Table 1). The vacuum traces recorded with the flow simulator for the four treatments are shown in Figure 1.

A 4 × 4 latin square design was used with the four vacuum levels obtained from the flow simulator as treatments for a milking trial. Friesian cows (n=56) were assigned to four groups based on daily milk yield and

Table 1. Details of milking treatments

Treatment	Pulsation pattern	Bore of long milk tube (mm)	Vacuum at a flow rate of 4 l/min (kPa)
T1	4 × 0	16.0	42
T2	4 × 0	13.5	40
T3	2 × 2	16.0	38
T4	2 × 2	13.5	35

were milked for eight days with two days per treatment. The treatments were applied at AM milkings, at PM milking all cows were milked with the unit used for Treatment 1 (Table 1). Milk yield and milk flow profile were recorded automatically with Dairymaster Weighall electronic milk meters. Clusters were removed automatically at a milk-flow rate of 0.2 kg/min. Milking time was computed as the time interval from cluster application to when the milk flow reached 0.2 kg/min. Pre-milking preparation consisted of washing teats with warm running water and drying with individual paper towels.

Statistical analysis

The data on milking characteristics were analyzed by analysis of variance using Genstat (Genstat 5 Release 3.2, 1993). The analysis for milk yield, milking time and both average and peak milk-flow rate was performed on the mean of two AM recordings.

Results and Discussion

Vacuum variations in the claw and at the apex of the artificial teat during flow simulation tests were identical during the 'b-phase' of pulsation. The vacuum traces recorded at a flow rate of 4 l/min with the flow simulator for the four treatments are shown in Figure 1. The high level of milking vacuum during the 'b-phase' of pulsation followed by a large drop in vacuum during the 'c-phase' shown in Figure 1(A) and Figure 1(B) is a characteristic of wide-bore tapered liners when used with simultaneous pulsation (O'Callaghan and Gleeson, 1997). The effect of increasing the bore of the LMT from 13.5 mm to 16 mm improved the teat-end vacuum by 2 kPa with 4 × 0 pulsation and by 3 kPa with 2 × 2 pulsation. In the milking trial (Table 2) increase in milking vacuum from 40 kPa to 42 kPa reduced ($P < 0.001$) the milking time by 40 s per cow and increased both the average and the peak milk flow. There was no effect on milk yield. Rasmussen and Madsen (2000) reported a milk yield reduction of 5% when milkline vacuum was reduced from 48 kPa to 38 kPa. With 2 × 2 pulsation the teat-end vacuum increased from 35 kPa to 38 kPa when the LMT was increased from 13.5 mm to 16 mm, this reduced ($P < 0.001$) the mean milking time by 36 s per cow and also significantly increased peak milk-flow rate.

There is a practical benefit in increasing the bore of the LMT with either simultaneous or alternate pulsation and a wide-bore tapered liner. Most milking plants in Ireland have LMT in the range 13.5 to 14 mm. The results indicate that new milking plants and conversions would benefit, in terms of higher milking vacuum, in having 16-mm bore LMT and 16-mm bore entries in the milk pipeline. This is in agreement with the work of Worfstorff and Hollweck (1995). An alternative approach to using large milk tubes and simultaneous pulsation is to increase the system vacuum level to compensate for the loss in vacuum during milk flow. Worstorff and Hollweck (1995) showed that by compensating for vacuum loss, milk yield was reduced with the higher vacuum. The higher vacuum probably increased teat penetration and gave

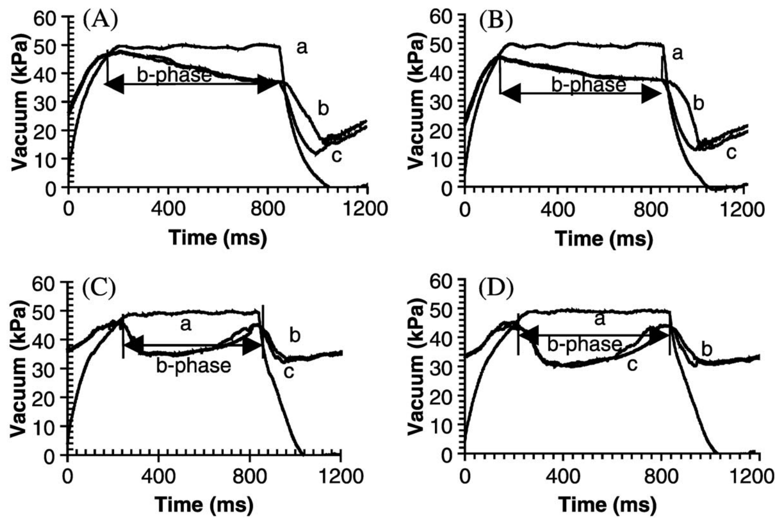

Figure 1: Vacuum traces for pulsation chamber vacuum (a), claw vacuum (b) and teat-end vacuum (c) at a water flow rate of 4 l/min with 16-mm bore long milk tube and simultaneous pulsation with a mean teat-end vacuum in 'b-phase' of pulsation of 42 kPa (A), with 13.5-mm bore long milk tube and simultaneous pulsation with a mean teat-end vacuum in 'b-phase' of pulsation of 40 kPa (B), with 16.0-mm bore long milk tube and alternate pulsation with a mean teat-end vacuum in 'b-phase' of pulsation of 38 kPa (C), with 13.5-mm bore long milk tube and alternate pulsation with a mean teat-end vacuum in 'b-phase' of pulsation of 35 kPa

Table 2. Effect of milking vacuum level on milk yield and milking time and on average and peak milk-flow rates

	Treatment[1]				s.e.d.	F-test
	T1	T2	T3	T4		
Milk yield AM (kg)	20.1	20.2	19.9	19.7	0.4	
Milking time AM (s)	427	467	463	499	8.6	***
Average flow rate AM (kg/min)	2.9	2.6	2.6	2.5	0.05	**
Peak flow rate AM (kg/min)	4.9	4.6	4.5	4.2	0.08	***

[1]See Table 1.

excessive restriction between the gland and teat sinus during the low flow period of milking. The ratio of the peak-flow rate to the average-flow rate was higher than reported by Rasmussen and Madsen (2000). When milkline vacuum was 38 kPa instead of 48 kPa in a high-level milking plant they recorded a drop in peak flow from 2.8 kg/min to 1.9 kg/min and average flow drop from 2.0 kg/min to 1.4 kg/min These differences may be caused by the method used for recording peak and average flow rates.

It is concluded that vacuum level at the teat end during the 'b-phase' of pulsation, recorded during milk-flow simulation, is correlated with milking time and with both peak and average milk-flow rate during actual milking.

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