Effects of low vacuum levels on vacuum dynamics during milking

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ABSTRACT: One of critical points of the milking unit is the short milk tube. Here milk plugs can cause abrupt variations in vacuum which are stressful for the animals. Our trials allowed us to define the effects of the operational vacuum and pulsation on vacuum stability in the short milk tube. Reducing the vacuum from 42 to 28 kPa did not produce appreciable variations in vacuum fluctuation. It was 9.2 kPa for the low vacuum and 9.8 kPa for the standard vacuum. Changing the pulsation rate from 150 to 120 cycles/min did not modify the vacuum stability in the short milk tube. By contrast, raising the pulsation ratio from 50% to 60% significantly increased the amplitude of vacuum fluctuation in the short milk tube.

Key words: Operative parameters, Vacuum fluctuation, Sheep, Milking.

INTRODUCTION – The driving force necessary to move milk throughout the milking unit is supplied by the vacuum. Normally during milking milk flows from the teat to the long milk tube, where the vacuum is higher. In efficient milking systems the teat-end vacuum should be at a level and degree of stability compatible with rapid, complete milk extraction and minimal tissue trauma. An excessively high vacuum level and acute vacuum fluctuations may have a harmful effect on the teat end.

The milking machine can, indeed, be a vector for transferring pathogens to the teat, either passively, by teat contact with the contaminated liner (Woolford *et al*., 1980), or actively, if important fluctuations are generated in the teat end vacuum. Two types of vacuum fluctuation have been described within an individual cluster. Irregular vacuum fluctuations are caused by sudden air leakage between liner and teat during normal use of the milking machines as milking units fall-off and liner slips, vigorous machine stripping, abrupt cluster attachment or removal. Cyclic vacuum fluctuations occur by the combination of pulsation cycle and the presence of milk in the short milk tubes and liners.

Some relations have been shown between the above-mentioned fluctuation typologies and the penetration of the teat-canal by micro-organisms causing mastitis. The first one is the reverse flow that occurs when the milk does not flow rapidly through the short milk tube. In this case, during the massage phase, the milk trapped in the dead space between the teat and the closed liner can be sucked in by the sphincter as the liner opens and the vacuum increases rapidly (Such and Caja, 1992; Billon *et al*., 1998). The other is known as the impact mechanism. This is caused by sudden inlets of air from the liner mouthpiece, as a result of liner slips, incorrect cluster detachment, or vigorous machine stripping with associated liner slip. These effects generate such a great vacuum differential within the liner and the short milk tube, that milk droplets impact the other teat with sufficient force and speed to enter the teat canal (O'Shea *et al*., 1984). This mechanism is most dangerous at the milking end, when the milk flow is lower and the sphincter is open so that the micro-organisms can easily enter the teat-canal (Blowey and Edmonson, 1995).

Some elements which cause higher fluctuations within the cluster are: inadequate claw and absence of air inlet (Pazzona A.,1999), insufficient diameter of the short and long milk, and higher milk flow and higher pulsation rate (Billon *et al*.,1998; Gonzalo and Marco, 1999).

The relationship between an increase of new mastitis infection rate and vacuum fluctuations has been demonstrated in cows, when cyclic and irregular fluctuations increase, in particular at the milking-end (Billon, 1998), and the number of "impacts" of bacteria-contaminated milk droplets against the teat (O'Shea, 1987) increase. The knowledge of vacuum dynamics in the short milk tube is one possible way of obtaining information on mechanical milking effect at the closest point to the teat apex.

The objective of this study was to investigate the vacuum variations at the teat end during milking at standard (42 kPa) and low (28 kPa) vacuum level and different pulsator settings (150 and 120 cycles/min; 50 and 60%).

MATERIAL AND METHODS – Both vacuum levels and vacuum dynamics were recorded during milking. Tests were carried out in a low line milking machine designed for working at low vacuum level. Recordings were performed using a computer–based data acquisition system (DAS-M, Star Ecotronics – Milano), equipped with three pressure transducers (Trafag, Mod. 8891.23.3317) and a maximum sampling rate of 100 kHz. The pressure transducers have a range which varies from -100 kPa to +150 kPa, a exit tension of from 0 to 10 V, and a vacuum accuracy of ± 0.25 kPa to 50 kPa, which is superior to the 0.6 kPa required by the ISO 6690/96 regulations. Vacuum was measured in the short milk tube (8 mm internal diameter), which gives a good indication of the vacuum beneath the teat end.
Three 21 day tests were carried out on two experimental groups of 24 sheep, milked at 28 and 42 kPa and changing rate and ratio of pulsation as in the following scheme:

28 kPa ; 150 cycles/min ; 50% - 42 kPa ; 150 cycles/min ; 50%
28 kPa ; 150 cycles/min ; 60% - 42 kPa ; 150 cycles/min ; 60%
28 kPa ; 120 cycles/min ; 60% - 42 kPa ; 120 cycles/min ; 60%

The statistical analysis was carried-out by comparing the vacuum fluctuations among the three tests, using a Mann-Whitney and Wilcoxon test (Whitley and Ball, 2002) from the SPSS program (v. 15.0, SPSS, Inc., Chicago, III)

RESULTS AND CONCLUSIONS – The trials allowed us to define the effects of both the operating vacuum and pulsations on vacuum stability at the teat-end. No significant differences were found in short milk tube vacuum variations for milking at 28 kPa and at 42 kPa (tab.1). This agrees with the results of Murgia and Pazzona (1999) obtained in simulated milking. For both vacuum levels, a significant increase in fluctuations (32-64%) was found when the pulsation ratio was changed from 50% (test I) to 60% (tests II and III). The difference between the II and the III tests was not appreciable, as only the pulsation rate changed. The fluctuations of 6.7-11.8 kPa recorded in a short milk tube were overall lower than the values (12.9 - 16.6 kPa) found in the laboratory, with a short milk tube of the same diameter and a constant flow of 1.5 l/min (Murgia and Pazzona, 2001). This can be explained by the lower average milk flow rate measured during milking conditions at both vacuum levels (0.55 and 0.64 l/min).
Table 1 shows that the 50% pulsation ratio tends to lower the average vacuum in the short milk tube. Indeed, the 26.8 and 40.1 kPa average vacuum was lower than the value set at the regulator and read near the receiver (28 and 42 kPa). By contrast the 60% pulsation ratio increased the vacuum, raising it above the level indicated by the regulator. This can be explained by the fact that the vacuum in the short milk tube increases in correspondence of the liner opening, i.e. during phase "b" of the pulsation cycle, and thus as the pulsation ratio rises, the duration of this phase increases.

Table 1. Average vacuum level and fluctuations in short milk tube during milking.

Thesis	Vacuum (kPa)		Vacuum Fluctuations (kPa)	
	28 kPa	42 kPa	28 kPa	42 kPa
I (150 cycles/min; 50%)	26.8	40.1	6.7 ± 2.04^{A}	7.6 ± 2.16^{A}
II (150 cycles/min; 60%)	29.8	42.4	9.9 ± 2.24^{B}	10.0 ± 2.61^{B,C}
III (120 cycles/min; 60%)	30.7	42.9	11.0 ± 1.82^{B}	11.8 ± 2.27^{B,D}

^{A,B} = *P<0.01*; ^{C,D} = *P<0.05.*

The values of the average vacuum, obtained from the change of the pulsation rate in the second and third tests, are not significant because of the greater influence of the pulsation ratio on vacuum dynamics. The vacuum variations registered during all tests were limited.

This made it possible to milk regularly at low vacuum levels, i.e. without interruptions caused by liner slips or milking unit fall-off. These results suggest that, in order to permit more comfortable milking for the animal when a low or standard vacuum is used, it is advisable to adopt a pulsation rate of 150 cycles/min and a pulsation ratio of 50%. This combination allows a faster milk extraction, avoiding the negative effects on vacuum level and stability caused by the 60% pulsation ratio.

The authors contributed equally.

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