Responses of milk removal characteristics of single quarters on different vacuum levels

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Summary

The capacity of a milking system is determined by a number of different aspects. This experiment focussed on the possibilities to increase the milk flow rate by increased vacuum levels. However, higher vacuum levels might result in more udder health problems and increased amounts of residual milk. To restrict these negative effects, the suction phase of the milking machine was lowered from 65 to 10% in the low milk flow phases, that occur at the beginning and the end of the milking process. The main objective of this research was to study the effects of milking vacuum level on the milk removal characteristics of single quarters.

During a trial of 18 days with 16 FH/HF dairy cows the effect of vacuum levels 42, 45 and 48 kPa on the milk removal parameters were examined. It was shown that the average milk yield (32-33 kg per day) was not affected through the vacuum level. The mean effective milk flow rate on a quarter base (duration of overmilking was excluded) at 42, 45 and 48 kPa was respectively 696, 741 and 753 grams per minute ($p<0.05$). The peak quarter milk flow rate was respectively 1027, 1110 and 1141 grams per minute ($p<0.05$). It was concluded that an increase of the vacuum level from 42 to 45 kPa decreased machine on time with about 6%; a further increase to 48 kPa reduced machine on time with another 2%. However, the responses of several milk removal parameters differed sometimes largely between cows and quarters. It is concluded that a milking machine system should be developed consisting of hardware and software that in a dynamic way takes care of optimal settings per quarter for a fast and sound milk removal.

Key words: *Vacuum, milk removal, quarter, milk flow rate*

Introduction

Many factors are affecting the capacity of a machine milking system. This research is focussing on possibilities to increase the milk flow rate. It is known that milkability properties of cows are for a large part heritable.

Further it is known that higher milking vacuum levels can increase the peak milk flow rates considerably. Because of negative effects on the teat condition and on the completeness of milk removal these higher levels are often not applied. For milking installations with low milk transport lines vacuum levels between 40-44 kPa (van der Haven et al., 1996) are generally advised.

Negative effects of higher vacuum levels are especially expected in that phases of the milk removal process in which milk flow rates are low such as the first phase and the last or fourth phase (figure 1). Therefore in this research increased vacuum levels will as good as possible only be applied in the phase in which the milk flow rate is on the steady state level. In order to reduce negative effects of high vacuum on the teats the length of suction phase in a pulsation cycle will be strongly shortened in favour of the rest phase. In the first phase of the milking process often little milk is available (loose milk) and through a short suction period in this phase this milk will only partly be removed. So-called overmilking will be prevented, while the pulsating action of the liner will stimulate milk ejection. Also in the last or fourth phase there will be only little milk available in the udder. Because it is technically not possible to detach the liner from a quarter that was coming into this overmilking phase (imbalance of cluster), it was decided to switch then again to a short suction period and a long rest period of the pulsation cycle. In this way negative effects of overmilking should be restricted.

In the research the effects of different vacuum levels on the duration of the milking process will be tested. Because of the short duration of the research it will not be possible to conclude about any effects on teat and udder health.

Material and methods

The milk- and pulsation vacuum levels in this research were 42, 45 and 48 kPa. The settings for the other milking machine parameters applied during the experiment were 65:35 for the pulsation ratio and a pulsation rate of 58 cycles per minute.

In phase 1 of the milking process (figure 1) the pulsation ratio was adapted three times: during the first 15 s (~during attachment) the normal setting of 65:35 was applied, than during 30 s 10:90 (~no milk removal) and than form 45 s after the start of the attachment the setting was switched to 65:35 again.

During phase 4 (overmilking), that starts when the quarter milk flow rate was fallen below 100 g per min the pulsation ratio was set back to 10:90. This prevented the liner from falling from the teat because the liner was mainly closed the impact of the vacuum on the teat was restricted.

In the experiment 16 dairy cows were used, 4 were in their first, 6 in their second and 6 in their third or higher parity. Thirteen cows had less than 100 lactation days. The daily milk yields varied between 19 and 42 kg. Each vacuum treatment was applied during 2 consecutive days. All treatments were repeated three times. The order of the treatments within a repetition was obtained by lot. The experimental period lasted 18 days (3 treatments x 2 days x 3 repetitions).

The cows were milked twice daily in a 2x3 open tandem-milking parlour of the former IMAG experimental farm "De Vijf Roeden". This parlour was equipped with devices for recording the milk removal process per quarter including the final milk yield. The cows entered the parlour one by one. The udder was cleaned and massaged during 5-10s with a dry clean towel. After this udder preparation the teat cups were immediately attached. The teat cups were detached when during a period of 12s the total milk flow of all four quarters together dropped below 300 g/min. The liners in the experiment had a small air inlet in the mouthpiece.

In the statistical analyses the effect of the vacuum treatments on several parameters were tested. Because of the chosen block structure it was possible to take into account the variance caused by individual cows or quarters and repetitions.

Results

In table 1 the effects of the vacuum levels on milk yield and milk removal on udder basis are given.

Table 1 shows that the vacuum level did not affect the milk yield. The peak milk flow rate increased with 8.3% (3992 vs. 4324 g per min; $p<0.05$) when the vacuum level was raised from 42 to 45 kPa. A further increase from 45 to 48 kPa showed an increase of the peak flow rate with 2.8% (4324 vs. 4445 g per min; $p<0.05$). The mean milk flow rate increased with 5.6% (2411 vs. 2547 g per min; $p<0.05$) when the vacuum level was raised from 42 to 45 kPa. When the vacuum level was raised from 45 to 48 kPa there was a smaller not significant increase. The machine-on duration decreased significantly (421 vs. 397s; $p<0.05$) when the vacuum was raised from 42 to 45 kPa. A further vacuum increase to 48 kPa gave no significant decrease in the machine-on duration. The mean and peak milk flow rate and the milk yield in the 2nd min showed significant increases from 42 to 45 kPa as well as from 45 to 48 kPa.

In table 2 the effects of the vacuum levels on milk yield and milk removal on quarter basis are given.

The size of the effects on quarter basis (table 2) corresponds roughly with that on udder basis (table 1). The mean effective milk flow rate per quarter, at which the overmilking duration was excluded, increased with 42 to 45 kPa; a further increase from 45 to 48 kPa resulted in an increase of 1.6% (741 vs. 753 g per min; $p<0.05$);

The duration of phase 1 as well as phase 2 significantly ($p<0.05$) decreased when the vacuum level was increased from 42 to 45 kPa, while the duration of phase 3 significantly ($p<0.05$) increased. The effective milking duration, defined as the sum of the duration of the phases 1, 2 and 3, however, showed a significant decrease ($p<0.05$) when the vacuum was increased from 42 to 45 kPa.

A further increase of the vacuum level from 45 to 48 kPa gave significant ($p<0.05$) effects for the parameters mean effective milk flow rate, peak milk flow rate and milk yield in the 2nd min.

Discussion and conclusions

Increasing the vacuum level from 42 to 45 kPa gave an increase in the peak milk flow of about 8%. From 42 to 48 kPa the increase in the peak milk flow was about 11%. The increase of the mean milk flow was with respectively 6 and 8%, clearly smaller. This was mainly caused because the gain obtained in the 1st (increasing flow phase) and the 2nd phase (steady state phase) was partly lost again in the 3rd phase (descending flow phase). The gain of time in the 1st phase was reached because the steady state phase started 3 to 4s earlier. The steady state phase was shorter because of the higher milk flow rate in this phase. The descending phase, in which the milk flow rate falls from the steady state level to 100 g/min, lasted in the higher vacuum levels 5s longer, while the amount of milk that was removed in this phase was larger.

At the end resulted an increase of the vacuum level from 42 to 45 kPa in a decrease of the machine-on duration of about 6%. A further increase of the vacuum level to 48 kPa shortened the machine-on duration with another 1.5% (not significant). The relative small effect of the increase from 45 to 48 kPa was striking. Only the milk yield in the 2nd min was significantly larger at 48 kPa than at 45 kPa. In the 3rd min this difference was already of no importance.

We noticed that there are large differences in the responses of different cows to the tested vacuum levels. These differences were even larger on quarter basis. An increase of the vacuum level from 42 to 45 kPa resulted in an average increase of the peak flow rate on udder basis of 8.3%, ranging between 2.1 and 14.5% for the individual cows. On quarter basis the average peak flow rate increased also with 8.3%; the range was then between –1.1 and +23.6% for individual quarters. The increase of the vacuum level from 45 to 48 kPa gave on quarter basis an average peak flow rate increase of 2.8% with a range between –8.0 and +11.8%.

There are different phenomena that play a role in the differences in the responses. In principle a higher vacuum level will result in a larger pressure difference between the inner wall of the udder and the liner leading to a larger milk flow rate. However when there is not enough milk available in the teat cistern this larger milk flow rate will not be maintained during the full suction phase. Further it is known that higher vacuum levels can lead to teat congestion (Gleeson & O'Callaghan, 1998, Neijenhuis et al., 2001). This can result in a higher flow resistance trough the teat canal, which has a negative effect on the milk flow rate. Finally with higher vacuum levels climbing of the liners upon the teats will occur more easily. This might negatively effect the opening between teat and udder cistern so that the milk flow from the udder is somewhat diminished.

There is a large variation in the external and internal properties (dimensions, tissue types, structure) of individual teats and quarters. These properties together with the milk let down reflex determine the possibilities for milk removal. The milking machine will affect at least some of these properties and by that affect milk removal.

We conclude that:

- there are large differences in the responses between cows; these differences are even larger between teats/quarters. This often also counts for quarters within the udder of a cow.
- it might be worthwhile to look for possibilities to optimize the milking machine settings per quarter by analyzing the responses of certain milk removal parameters.
- a system for optimizing the milking machine settings per quarter should consist of hardware for measuring milk flow and vacuum levels, for adjusting vacuum levels, pulsation rates and ratios, for detaching teat cups and software for analyzing the measurements (milk flow rates, vacuum levels) and based on these analyses together with information about expected milk yields predict switch points for the milking machine settings.

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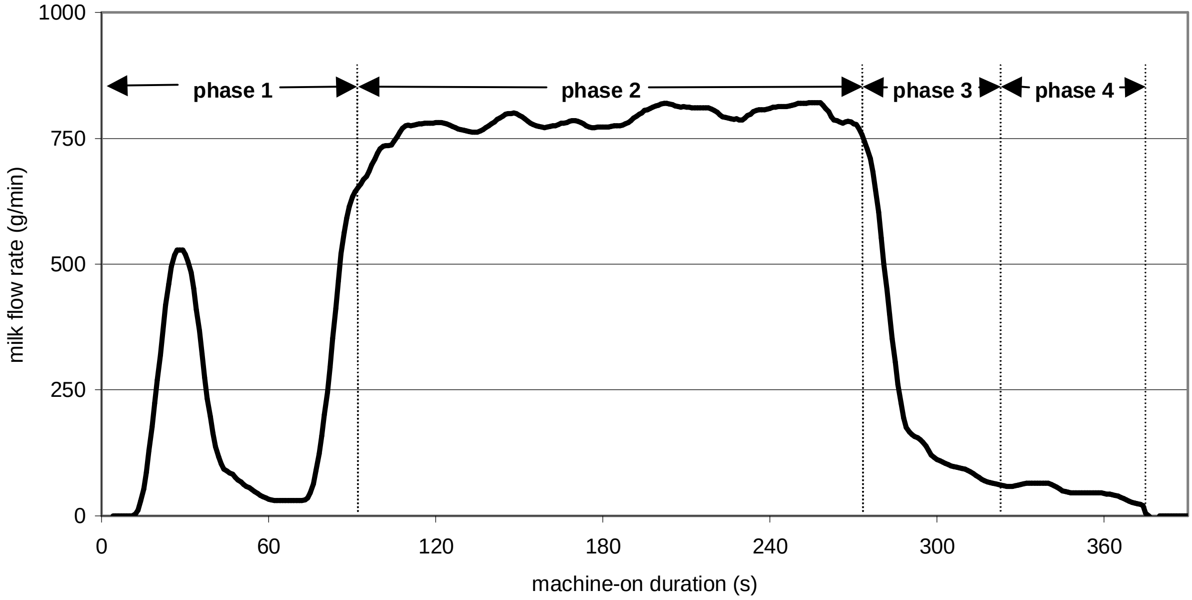

Figure 1. Phases of quarter milk removal curve.

Table 1. Results of three vacuum levels on milk yield and milk removal parameters on udder basis.

Parameter	Vacuum level (kPa)		
	42	45	48
Milk yield (g)	16491	16469	16616
Machine-on duration (s)	421[a]	397[b]	390[b]
Mean milk flow rate (g/min)	2411[a]	2547[b]	2605[c]
Peak milk flow rate (g/min)	3992[a]	4324[b]	4445[c]
Milk yield in 1st min (g)	739[a]	866[b]	881[b]
Milk yield in 2nd min (g)	3543[a]	4012[b]	4139[c]
Milk yield in 3rd min (g)	3684[a]	3951[b]	3988[b]

[abc] Different letters in the same row mean a significant difference (p<0,05).

Table 2. Results of three vacuum levels on milk yield and milk removal parameters on quarter basis.

Parameter	Vacuum level (kPa)		
	42	45	48
Milk yield (g)	4123	4117	4154
Effective machine-on duration (s)	360[a]	338[b]	333[b]
Mean effective milk flow rate (g/min)	696[a]	741[b]	753[c]
Peak milk flow rate (g/min)	1027[a]	1110[b]	1141[c]
Milk yield in 1st min (g)	185[a]	217[b]	220[b]
Milk yield in 2nd min (g)	886[a]	1003[b]	1035[c]
Milk yield in 3rd min (g)	921[a]	988[b]	997[b]
Duration phase 1 (s)	70[a]	67[b]	66[b]
Duration phase 2 (s)	233[a]	209[b]	206[b]
Duration phase 3 (s)	57[a]	62[b]	62[b]
Duration phase 4 (s)	61	59	56
Milk yield phase 1 (g)	298	301	296
Milk yield phase 2 (g)	3380	3320	3349
Milk yield phase 3 (g)	408[a]	456[b]	468[b]
Milk yield phase 4 (g)	36	40	40

[abc] Different letters in the same row mean a significant difference ($p<0,05$)