# Milking-time tests in conventional and quarter-individual milking systems

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## Abstract

The effect of machine milking on udder health has been recognized for the past 100 years and many studies have been conducted in order to show the detrimental effects of conventional clusters since these systems result in permanent deformation of udders and scarred teat canals. Due to these unwanted effects of conventional systems (CON), a new quarter-individual milking system called the Multilactor® (MULTI) (Siliconform GmbH, Türkheim, Germany) has been developed in the last five years. The objective of this study was to determine the effects of milk flow on average liner vacuum during the b- and d-phase of pulsation in both systems by using the milking-time test defined by International Dairy Federation (IDF, 1999). Measurements were conducted in two different milking parlours where a conventional milking system (CON) and MULTI were installed separately. The vacuum data during milking were examined and the milk flow curve was recorded using a LactoCorder® (WMB, Balgach, Switzerland). It was found out that, at an average flow rate of approximately 5.0 l/udder/min, the average vacuum in the liner during the b-phase was 30.2 kPa in CON and 27.7 kPa in MULTI system which was not significantly different. In contrast the average liner vacuum during the d-phase was significantly different between the systems. It was 28.5 kPa for CON and 16.3 kPa for MULTI. This big difference is caused by the Multilactor® using the BioMilker® system (Siliconform GmbH, Türkheim, Germany) that allows periodic air ingress to the pulsation chamber.

It is shown that introduction of periodic air inlet to the teat cups in quarter individual systems can be useful. The Multilactor® system offers this combination.

*Keywords: Vacuum, quarter-individual milking, milking-time test, b- and d-phase*

## Zusammenfassung

### Vakuummessungen unter Melkbedingungen in konventionellen und viertelindividuellen Melksystemen

Ein Einfluss der Melkmaschine auf die Eutergesundheit ist schon seit über 100 Jahren bekannt. Ein neues viertelindividuelles Melksystem (Multilactor®, Siliconform GmbH, Türkheim, Germany) wurde in den letzten fünf Jahren entwickelt, um die nachteiligen Einflüsse und Belastungen auf das Eutergewebe und das Zitzengewebe zu reduzieren.

Das Ziel der vorliegenden Studie war es, den Effekt des Milchflusses auf den mittleren Vakuumabfall während der b- und d-Phase bei konventionellen und Einzelschlauchmelksystemen mit Hilfe von Messungen unter Melkbedingungen (International Dairy Federation IDF, 1999) zu charakterisieren. Die Untersuchungen wurden in zwei Tandem-Melkständen durchgeführt, in denen ein konventionelles System (CON) und ein viertelindividuelles Melksystem, der Multilactor® (MULTI) (mit periodischem Lufteinlass) eingebaut waren. Das Vakuumverhalten wurde an verschiedenen Punkten im Melkzeug erfasst und die Milchflusskurven mit Hilfe des LactoCorders® (WMB, Balgach, Switzerland) aufgezeichnet. Es konnte festgestellt werden, dass bei einem mittleren Milchfluss von ungefähr 5,0 l/min/Euter das mittlere Vakuum an der Zitze während der b-Phase 30,2 kPa im CON und 27,7 kPa im MULTI betrug (n.s.). Das mittlere zitzenendige Vakuum in der d-Phase hingegen unterschied sich signifikant voneinander. Es betrug 28,5 kPa für CON und 16,3 kPa für MULTI. Der Grund für die hohe Vakuumdifferenz zwischen den beiden Systemen liegt vermutlich darin begründet, dass der Multilactor® Melkbecher mit periodischem Lufteinlass verwendet.

Die Ergebnisse haben gezeigt, dass der periodische Lufteinlass auch bei viertelindividuellen Systemen eingesetzt werden kann.

*Schlüsselwörter: Vakuum, b- und d-Phase, viertelindividuelles Melken, Messen unter Melkbedingungen*

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## Introduction

Since 1851 first tries to understand the mechanical suckling of calves are documented (Herrmann, 1996). Alexander Gillies developed in 1903 the two-chambered teat cup, and in 1927 the first well working milking machine was presented.

In any kind of milking installation, the main goal is to harvest the maximum milk from the animal in a short time without damaging the udder. In this respect, milk yield, raw milk quality and udder health are the key factors for all dairy farms. Many studies focused on how to improve these issues and also to reveal and expand the knowledge on machine milking and mastitis (Bockisch and Ordolff, 2006). The pulsation rate and ratio affect the impact of the milking cluster to teat. There are different estimations for the correct relation between them. Joe and McLean (1984) chose a ratio of 60 to 65 % and a pulsation rate of 55 to 60 for their investigations. They concluded that the proportion of clinical mastitis went down compared to a ratio of 70:30. Besides pulsation, vacuum also has an influence to udder health. DIN ISO 5707 (2007) suggests 32 to 42 kPa mean liner vacuum for gentle and efficient milking of cows. Optimizing these parameters in milking machines will help to reducing udder health problems.

Nevertheless, vacuum fluctuations especially in the claw during milking lead to milk moving between teat cups. Therefore, milking machine modifications, designed to prevent inter-quarter transfer, should usefully contribute to mastitis control (Mein et al., 1992).

Thus, quarter-individual milking is in the opinion of von Baer (1971) as well as Hamann and Tolle (1978) a condition precedent to stop respray and the spreading of bacteria among the teats. Additionally it is important to realize that the quarters of the udder are considered to be four separate compartments (Ipema and Hogewerf, 2008). When the quarters of the udders are four separate compartments, the milking with conventional milking clusters may cause spreading of the bacteria among the teats. For this reason quarter individual milking is a solution to prevent this unwanted effect.

Automatic milking system (AMS) approach includes quarter-individual milking. Many experiments on the effect on udder health were conducted by different scientists. Rasmussen et al. (2003), Wirtz et al. (2002) detected an increase in bulk-milk somatic cell count after introduction of AMS. This shows the necessity of having additional methods to detect clinically infected cows. Measuring somatic cell count (SCC) per udder quarter is useful to analyze the milk composition (Berglund et al., 2007). Hence, a special attention to use systems with quarter-individual milking in conventional milking parlours, where the milking person controls udder health status, should be given to reduce SCC and udder diseases (Rose et al., 2006). Investigations of Svennersten-Sjaunja et al. (2000) as well as Hamann and Reinecke (2002) showed a certain improvement in udder health once an automatic milking system was used.

It is necessary to measure the pressure characteristics in the milking system to understand the conditions at teat end. The use of electrical pressure transducers enables measuring not only the static pressure but also dynamic pressure with a high frequency.

New test methods were described (Rasmussen et al., 2003; Reinemann et al., 1996) to measure the vacuum changes during milking time to conduct test measurements closer to the cow. The International Dairy Federation (IDF, 1999) recommended different types of performance tests:

- *Dry test* - with machine running but without liquid in the machine
- *Wet tests* - with machine running and air and liquid flowing through the machine and an artificial udder
- *Milking-time tests* - measurements made while milking dairy cows.

For milking-time tests it is necessary to use a vacuum measuring system with an error of less than ± 0.6 kPa and repeatability within ± 0.2 kPa (DIN ISO 6690, 2007). For milking-time tests in the short milk tube the minimum sample rate should be 170 Hz and minimum response rate should be 2500 kPa/s.

In addition the National Mastitis Council (1996) specifies that the vacuum recording system must be capable of measuring at least 90 % of the true change in vacuum, without further description of the characteristics of such an instrument.

## Materials and method

Two different types of milking systems, a conventional and a quarter-individual milking system, were tested in two similar tandem milking parlours at a German dairy farm. Both milking parlours with a low level milk line were equipped with milk meters. The conventional milking cluster (Classic Westfalia 300) manufactured by GEA (Bönen, Germany) has a claw volume of 300 ml (CON) and was used as a reference cluster. Alternative pulsation at a rate of 60 cycles per minute and the ratio of 60:40 was applied. The system working vacuum level was set to 42 kPa.

The MultiLactor[1]® (Siliconform GmbH, Türkheim, Germany) (MULTI) is a quarter- individual milking system that can be used in a conventional milking parlour. The length of the long milk tubes and the inside diameter are 2100 and 10 mm, respectively. The pulsation rate and the ratios

[1] Mention of trademark or company name does not imply the endorsement of this product by the authors.

were adjusted to the same levels as in the conventional milking parlour. The system working vacuum level was set to 39.5 kPa. The system allows periodic air ingress to the pulsation chamber as in the Bio-Milker® system (Hoefelmayr et al., 1979) and uses silicon liners. This system has a different concept in terms of pulsation - sequential pulsation. Pulsation starts in each liner individually with successive teat cups being 25 % out of phase. This system provides a better distribution of the milk, when it arrives in the long milk tube. This unit is completely different from conventional units as four tubes join to one long milk tubes by a series of three Y-pieces.

Vacuum measurements were conducted using the milking-time test with two groups of Friesian Cows (six cows/group) in the afternoon milking time (IDF, 1999). Vacuum was measured using a Bovi Press measuring system (A & R Trading GmbH, Echem, Germany) with a sampling rate greater than 300 Hz and measuring accuracy of ± 0.1 kPa. The vacuum was recorded across the whole milking process at the teat end, in the pulsation chamber, in the claw and in the main vacuum line, simultaneously. The sensors were connected with T-pieces. From the data recorded, the average vacuum for the full pulse cycle, the average vacuum in the b-phase and the average vacuum in the d-phase were calculated according to the formulae presented in DIN ISO 6690 (2007).

The milk flow curve was recorded with LactoCorder® to determine the properties during milking and to calculate the vacuum at the teat end for specific milk flow.

*Statistical Analyses*

The determination of pulsation phases was made using a customised SAS macro based on the guidelines presented in ISO 5707 and 6690 (2007).

Evaluation of vacuum reduction was made by the use of parametric tests based on a linear model. The collected data of the MultiLactor® were compared with the vacuum data obtained in the conventional system. The data were analyzed with the statistic software SAS 9.2 TS Level 2M0. For the calculations of mean values the MEANS procedure was used, while the linear model was formulated with the MIXED procedure. Graphs were made with the GPLOT procedure.
The model equation was assumed as

$$\underline{y}_{ijk} = \mu + \alpha_{ijk} + \beta x_{jk} + \underline{e}_{ijk}$$

with

$\mu$ - general mean,
$\underline{y}_{ijk}$ - random variable vacuum reduction [N($\mu$; $\sigma^2_e$)],
$\alpha_{ijk}$ - (fixed) effect of i-th level of factor milking system,
$\beta$ - (fixed) effect of covariate x (flow rate),
$\underline{e}_{ijk}$ - independent residual [N(0; $\sigma^2_e$)],

each for front left and rear right quarter j=(1, 2) and repetition k=(1,2,3). The estimated effects were used to calculate the vacuum reduction for selected milk flows (2.0 and 5.0 l per min/udder).

**Results and discussion**

Figure 1 shows the results of the milking-time tests in the two different milking systems at flow rates ranging between 0 and 5 l/min. For both systems the teat end vacuum decreased with increasing flow, but the mean vacuum reductions for MULTI were greater than for CON (significance level $\alpha \leq 0.05$). Mean vacuum values indicate the averages of the b- and d-phase values. Thus, these systems have to be compared in terms of the differences in b- and d-phases.

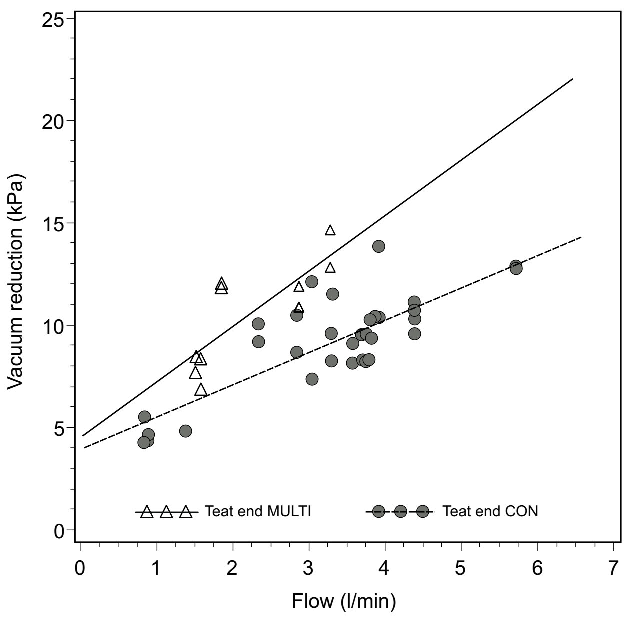


Figure 1:
Mean vacuum reduction at the teat end of CON and MULTI at different flow rates

Figure 2 shows the differences in mean vacuum at the teat end in b- and d-phases at different flow rates. The reductions in vacuum in the b- and d-phases have a similar slope for CON while the differences for the MULTI are considerably large. The mean vacuum in d-phase decreases dramatically in MULTI as the flow rate increases. This cannot be attributed to the differences in operating vacuum levels (42 kPa for CON and 39.5 kPa for MULTI). Table 1 and 2 show significant differences in average vacuum reduction and significant differences between MULTI and

CON for vacuum reduction in the d-phase (significance level $\alpha \leq 0.05$). The intercept μ was significantly different from zero. The estimate has a value of 3.63.

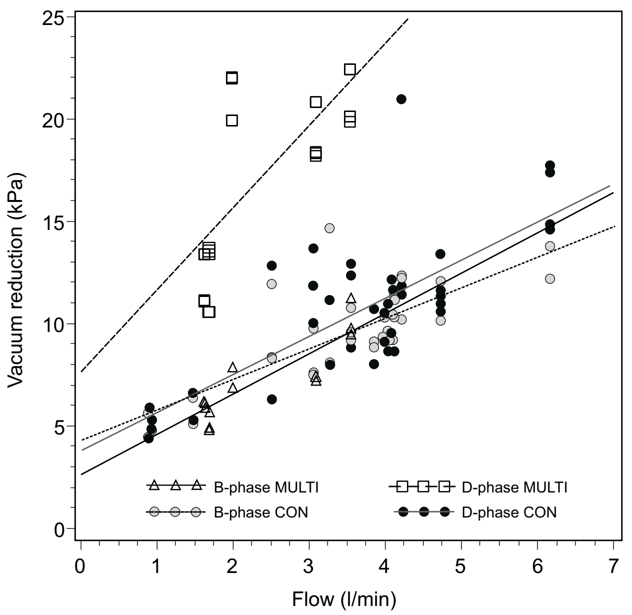


Figure 2:

Vacuum reduction at the teat end for b- and d-phase in CON and MULTI at different flow rates.

Mean vacuum values show the averages of the b- and d-phase values. In addition the wet-test measurements in the same parlour with simulated milking showed nearly the same mean vacuum level at teat end in artificial teats.

Table 1:

Tests of fixed effects of milking system ($\alpha_i$), milk flow (ß) for b-, d-phase and mean vacuum at teat end.

| Phase of pulse cycle | Effect | Num DF | Den DF | F-Value | Pr > \|t\| |
|---|---|---|---|---|---|
| b-phase | $\alpha_i$ | 1 | 123 | 2.32 | 0.1305 |
| | ß | 1 | 123 | 230.71 | <.0001 |
| d-phase | $\alpha_i$ | 1 | 123 | 212.46 | <.0001 |
| | ß | 1 | 123 | 109.15 | <.0001 |
| mean vacuum | $\alpha_i$ | 1 | 123 | 90.75 | <.0001 |
| | ß | 1 | 123 | 217.08 | <.0001 |

Table 2:

Differences of least square means of vacuum reduction at teat end for Multilactor (MULTI) and conventional milking system (CON)

| Phase of pulse cycle | Milking system | Esti-mate | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|---|
| b-phase | MULTI-CON | **0.48** | 0.31 | 1.52 | **0.1305** |
| d-phase | MULTI-CON | **-9.1939** | 0.63 | -14.58 | **<.0001** |
| mean vacuum | MULTI-CON | **-3.43** | 0.36 | -9.53 | **<.0001** |

At a flow rate of 2.0 l/min during milking the mean liner vacuum level at teat end during the b-phase of pulsation was estimated as 34.8 kPa for CON and as 32.3 kPa for MULTI. The mean liner vacuum during the d-phase at the same flow rate was 34.8 kPa for CON and 22.6 kPa for MULTI. On the other hand at a flow rate of 5.0 l/min during milking the mean liner vacuum level at teat end during the b-phase of pulsation was estimated as 30.2 kPa for conventional milking unit (CON) and as 27.7 kPa for single tube system (MULTI). The mean liner vacuum during the d-phase at the same flow rate was 28.5 kPa for CON and 16.3 kPa for MULTI. The much lower vacuum in the d-phase is as expected since the MULTI has periodic air ingress to the pulsation chamber. Worstorff et al. (1983) asserted that periodic air ingress led to better liner collapse during the d-phase with a substantial improvement (reduction) in teat hardness, teat end lesions and cell count. Hamann et al. (2001) showed that a positive pressure system resulted in smaller teat end diameters and less teat thickness compared to a conventional system. In contrast to other studies, the MultiLactor® with single teat cups has a low vacuum loss at the teat end. Preliminary studies showed that the MultiLactor® and the BioMilker® with long milk tubes have a significantly smaller vacuum decrease than the other investigated systems (Öz et al., 2010). Still, the presented results do not correspond well to other studies which showed higher vacuum loss at the teat end in the b-phase with the single teat cups in comparison to conventional system (O'Callaghan and Berry, 2008). But all other studies did not use clusters with periodic air inlet. Nevertheless, the presented results as compared to the preceding studies that used AMS and conventional milking systems (Rose et al., 2008) correspond well with other studies in which high fluctuations and stability problems with vacuum in the conventional system with long milk tubes were observed (Rasmussen et al., 2006). Additionally Hillerton (1997) found out that the teat-end vacuum levels or levels of vacuum loss during milk flow may differ, although vacuum levels at the milk receiver and pulsator settings in automatic milking systems are similar to conventional milking systems. Correspondingly, Rasmussen and Bjerring (2002) found out that vacuum fluctuations at the teat end are larger in AMS than in conventional milking systems. In conclusion of these aspects, MULTI can have advantages in comparison to AMS like periodical air inlet to pulsation chamber, lower vacuum loss at the teat end during b-phase and better massage effect during d-phase. However, future studies can show if it is useful to introduce periodical air inlet to the other quarter individual milking systems, especially automatic milking systems.

## Conclusions

For both conventional and quarter-individual systems the teat end vacuum decreased with increasing milk flow. The vacuum in the b-phase for both systems is probably normal since the system working pressures were similar. The reduction of the mean vacuum level in the d-phase as the flow rate increases must provide an effective massage on the teat. The effects of this combination, lower vacuum loss in b phase and better massage effect in d-phase, could be considered as an advantage of MULTI system and maybe for other systems with long "short milk tubes". Further research is needed to determine the effects of quarter individual milking system on the milking characteristics of the cows and their udder health in conventional parlour.

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