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# Influence of quarter-individual milking in a conventional milking parlor on milk constituents of dairy cows

*Einfluss des viertelindividuellen Melkens im konventionellen Melkstand auf die Milchinhaltsstoffe bei Milchkühen*

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**Summary**

To evaluate the effect of milking with single tube guidance (MULTI) in comparison with conventional milking clusters (CON), various milk parameters were analyzed in foremilk samples. The two milking systems had the following technical configurations: milking vacuum was set to 37 kPa (MULTI) and 41 kPa (CON), respectively. Pulsation ratios were 65:35 (MULTI) and 60:40 (CON); both milking systems worked with a pulsation rate of 60 cycles/min. Furthermore, MULTI allowed periodic air inlet into the pulsation chamber of the teat cups (BioMilker®) and used sequential pulsation. For the experiment, 57 German Holstein cows were randomly allocated to two groups (group 1: exclusively milked with MULTI, 28 cows; group 2: exclusively milked with CON, 29 cows). Foremilk samples were analyzed for fat, lactose, electrical conductivity (EC) and somatic cell count (SCC). Milking system could not be found to have a significant effect on the analyzed parameters. The fixed effect trial week had a significant effect on all examined traits. Furthermore, parity showed a sigificant impact on most investigated traits with exception of EC, and the covariable day in milk (DIM) showed a significant impact on fat, lactose and EC. In summary, milking with single guided milk tubes did not change the percentage of milk components (fat, lactose) and the level of milk characteristics (EC, SCC), compared with conventional milking.

**Keywords:** Single tube guiding, lactose, somatic cell count, electrical conductivity

**Zusammenfassung**

Zur Untersuchung des Effekts eines Melksystems mit Einzelschlauchführung im Vergleich zu einem konventionellen Melksystem wurden verschiedene Milchinhaltsstoffe aus Vorgemelksproben untersucht. Die zwei Melksysteme wurden mit folgenden technischen Einstellungen betrieben: Melkvakuum von 37 kPa (MULTI) bzw. 41 kPa (CON); Pulsationsverhältnis von 65:35 (MULTI) und 60:40 (CON); beide Melksysteme hatten eine Pulsationsrate von 60 Zyklen/min. MULTI war gekennzeichnet durch den periodischen Lufteinlass in die Pulsationskammer des Zitzenbechers (BioMilker®) sowie einer sequenziellen Pulsation. Für das Experiment wurden 57 Deutsch Holstein Kühe randomisiert in zwei Gruppen eingeteilt (Gruppe 1: ausschließlich mit MULTI gemolken, 28 Tiere; Gruppe 2: ausschließlich mit CON gemolken, 29 Tiere). Die Vorgemelksproben wurden auf Fett, Laktose, elektrische Leitfähigkeit (EC) und Zellzahl (SCC) untersucht. Das Melksystem hatte keinen signifikanten Einfluss auf die analysierten Parameter. Der fixe Effekt der Versuchswoche beeinflusste alle untersuchten Parameter signifikant. Zudem hatte die Laktationsnummer einen signifikanten Effekt auf die meisten Parameter, ausgenommen der EC. Die Variable Laktationstag (DIM) zeigte einen signifikanten Einfluss auf Fett, Laktose und EC. Zusammenfassend lässt sich festhalten, dass das Melken mit Einzelschlauchführung im Vergleich zum Melken mit dem konventionellen Melksystem weder die Anteile der Milchinhaltsstoffe (Fett, Laktose) noch die Werte für Milchparameter (EC, SCC) verändert.

**Schlüsselwörter:** Einzelschlauchführung, Laktose, Zellzahl, elektrische Leitfähigkeit

Journal of Food Safety and Food Quality 64, Heft 4 (2013), Seiten 93–124

## Introduction

Milk producers have a major interest to keep the bovine udder healthy because only healthy cows can be used to produce a wide range of milk products and to satisfy consumer demands for milk quality (Hamann, 2002). Factors which influence the content of milk components are breed, diet, age and stage of lactation (Le Maréchal et al., 2011) as well as ration composition, milking frequency, milking interval and milk fraction (Haug and Grimm, 2004; Beerda et al., 2007; Ouweltjes et al., 2007; Forsbäck et al., 2009). Lactation stage significantly affected fat content, milk yield and somatic cells (Forsbäck et al., 2009). For example, the fat contents decreased (P<0.001) during the first 14 weeks of lactation (Beerda et al., 2007). With regard to the milk fraction, the fat content increases in the course of the milk release and reaches its highest concentration in the stripping and residual milk (Nielsen et al., 2005). In general terms, it can be noted that electrical conductivity (EC) and lactose content in stripping decreased while somatic cells (SCC) and fat content increased compared with foremilk (Bansal et al., 2005). Moreover, it should be mentioned that the concentrations of various milk parameters differ significantly from the physiological norms when SCC exceeds a threshold of 100,000 cells/ml (Hamann, 2002). It was shown that milk from diseased udders had significantly higher EC and SCC, but lower lactose content (Bansal et al., 2005; Forsbäck et al., 2009). While Forsbäck et al. (2009) found that fat yield was lower in affected quarters, Bansal et al., 2005 could not show significant differences between milk from healthy and diseased udders.

Machine milking can also influence udder health and milk quality. However, only limited information is available concerning milking techniques and their effects on various milk parameters. Spolders et al. (2004) found that milk fat content was significantly lower for cows milked in automatic milking systems (AMS) (4.03 % in the AMS versus 4.36 % in the milking parlour). The MultiLactor® (MULTI), a new quarter-individual milking system with four single tubes, has been developed to eliminate negative forces on the udder tissue which are often a problem in conventional milking systems (CON). Furthermore, quarter-individual milking systems can eliminate the transfer of bacteria among teats during milking (crossinfections) and they are mostly installed in AMS (Spencer, 1989; Öz et al., 2010).

The objective of this study was to compare a quarter-individual (MULTI) and a conventional (CON) milking system based on their effects on udder health on quarter level basis considering various milk components, SCC and EC.

## Material and methods

### Animals and milking routine

The experiment was carried out at a dairy farm located in Thuringia (Germany) between June and December 2009. Cows between 37th and 156th day-in-milk at the beginning of the trial period and without clinical symptoms (SCC ≤ 100,000 cells/ml and without bacteriological findings) were investigated. A total of 57 primiparous and multiparous German Holstein cows were randomly divided into two groups stratified by parities (29 in CON, 28 in MULTI). Distribution of cows between milking systems, stages of lactation and parities throughout the experiment is shown in Figure 1. Both groups were housed in the same cubicle barn and were fed with the same feedstuff ration. Additionally, each cow got concentrates corresponding to its milk production level. All cows were milked twice daily at 06·00 p.m. and 06·00 a.m. in auto-tandem milking parlors: one group with a conventional (CON) and the other with a quarter-individual (MULTI) milking system. Milking operations were performed by two milkers in each group. In both groups premilking procedures included forestripping and cleaning of the teats with disinfection tissues as well as teat dipping at the end of milking.

### Milking systems

During the experiment, a conventional milking system (CON) (Westfalia® manufactured by GEA Farm Technologies, Bönen, Germany) and a quarter-individual milking system (MULTI) (MultiLactor® manufactured by Siliconform GmbH, Türkheim, Germany) were examined in regard to milk quality. Both auto-tandem milking parlors had a low level milk line and were equipped with milk meters. Milking vacuum was set to 37 kPa (MULTI) and 41 kPa (CON), respectively. Pulsation ratios were 65:35 (MULTI) and 60:40 (CON) with a pulsation rate of 60 cycles/min for both milking systems. CON was equipped with a conventional milking cluster with a claw volume of 300 ml (Classic Westfalia 300® manufactured by GEA Farm Technologies, Bönen, Germany). MULTI had a single tube guiding system with silicon liners. Removal of single tubes depending on quarter-individual milk flow was not implemented, since this would require quarter-individual recording of milk yield. MULTI allowed periodic air inlet into the pulsation chamber of the teat cups (BioMilker®) and used sequential pulsation, dividing the pulse phase into four even parts and starting successively in each liner. Additionally, MULTI applied a special prestimulation with a mechanical actuator stimulating each teat and the whole udder with vibrating movements of the four single milk tubes.

### Milk sampling and laboratory analysis

Milk samples were taken from each cow once a week during the morning milking over a period of 27 consecutive trial weeks. The teats were cleaned with disinfectant tissues and the first three milk jets were discarded. Thereafter, foremilk samples of 50 ml were taken before attaching the teat cups of the milking machine in the following order: quarter 1=left front, quarter 2=left rear, quarter 3=right rear and quarter 4=right front. Manual collecting of foremilk samples was done as quickly as possible to avoid a large share of ejected milk in the last sampled quarter. Immediately after sampling, the unpreserved foremilk samples were stored for at most 24 hours in a cold box at 4–6 °C until analysis in laboratory.

The measurement procedure was made in the following order: preheating of the foremilk samples at a temperature of 40 °C and subsequent measurement of somatic cells. SCC was counted by Fossomatic 5000 (FOSS, Hillerød, Denmark). In the next step, the foremilk samples were cooled down in a water bath to a temperature of nearly 20 °C and afterwards electrical conductivity was determined. In the final step, the foremilk samples were swirled slowly to homogenize the emulsion-like solution followed by the measurement of the milk components (fat, lactose). Analysis of fat and lactose matter were performed on a Milkoscan S50 (FOSS, Hillerød, Denmark).

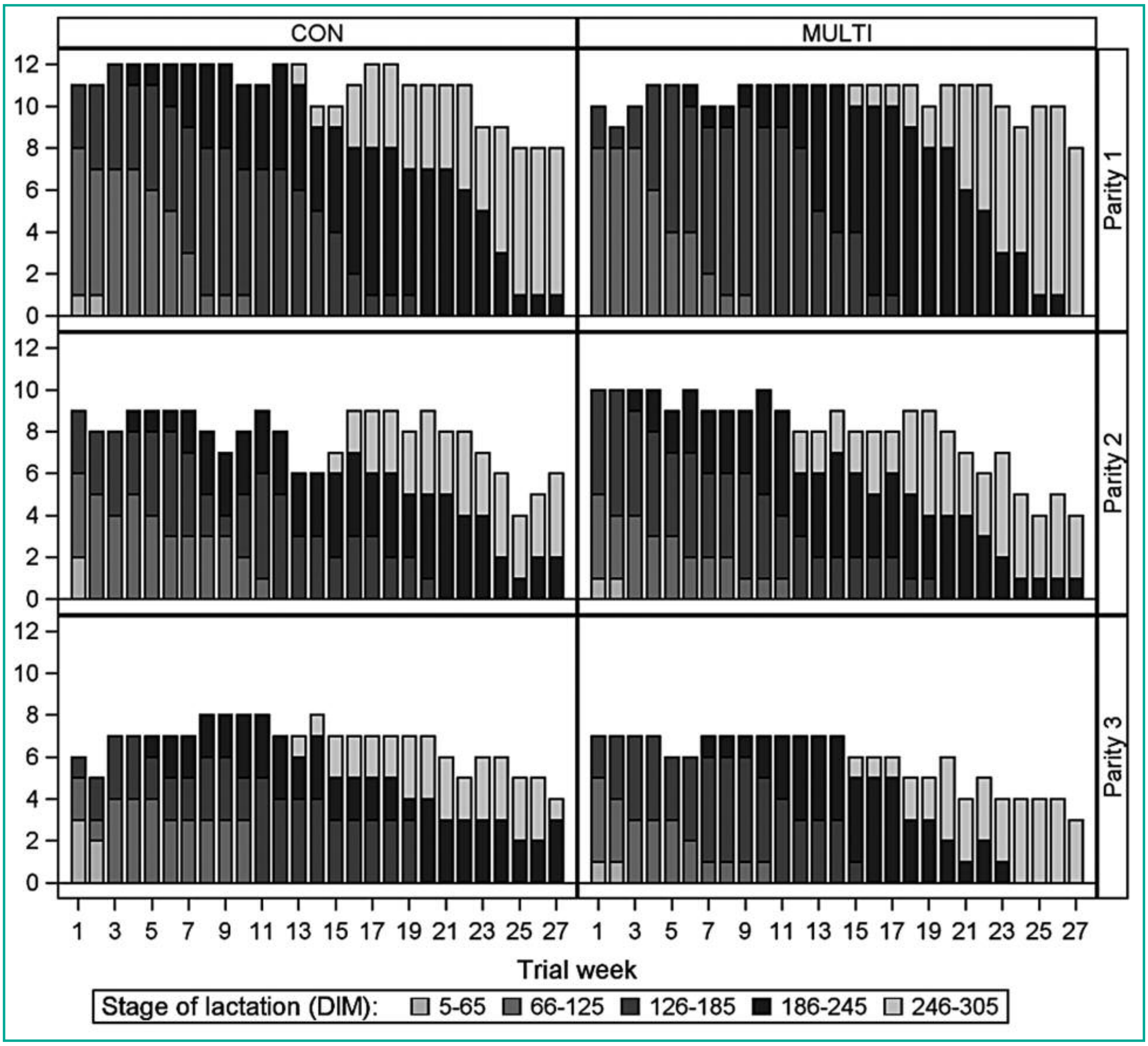


**FIGURE 1:** *Distribution of cows between milking systems, stages of lactation and parities.*

### Study design and statistical evaluations

Measurements recorded during the four weeks adaptation period were excluded from further calculations. Evaluation period consisted of 27 trial weeks until a cow reached the 305th day in milk. Some cows were dried off before the 305th day in milk because of too low milk yield. Additionally, measurements of cows entering the trial groups subsequently were not included in the statistical analysis. SCC values were subjected to a transformation as suggested by Ali and Shook (1980) for the statistical analysis (SCC-AS = ln(SCC/1000 + 10)).

Factor effects on the four traits were tested with a mixed linear model as follows:

$$y_{ijklm} = \mu + MS_i + TW_j + (MS \times TW)_{ij} + PAR_k + DIM \cdot x + (PAR \times DIM)_k \cdot x + Q_l + (COW \times Q)_{lm} + (COW \times Q \times DIM)_{lm} \cdot x + (COW \times Q \times PAR \times DIM)_{klm} \cdot x + \varepsilon_{ijklm} \quad (1)$$

where $y_{ijklm}$ is the observed value of the trait in milking system $i$ (MS; $i$=1, 2) in test week $j$ (TW; $j$=1, …, 27) in parity $k$ (PAR; $k$=1, 2, 3) on the $l$th quarter (Q; $l$=1, …, 4) of the $m$th cow (COW; $m$=1, …, 57). Fixed effects are the general mean $\mu$, MS, TW, interaction between MS and TW, PAR, and Q, while the covariables day-in-milk (DIM) and the interaction between PAR and DIM are included as a fixed linear regression on $x$, where $x$ is (DIM/305). Random effects include the quarter-specific effect as well as a random linear regression on $x$ in the same way as the fixed regression effects, given for every single quarter which can be addressed as *(COWxQ),* and the independent normally distributed residual $\epsilon$. Repeated measurements in TW for each Q within COW were accounted for with a first-order autoregressive variance-covariance matrix.

All tests were carried out using the MIXED procedure in the SAS 9.3 software package (SAS Institute Inc., Cary, NC, USA). Null hypotheses were that the effects of the factor levels were equal to 0, and they were tested at a significance level of $\alpha$=0.05. Degrees of freedom were calculated according to the method by Kenward and Roger (1997). Custom contrasts were used to test differences between MS within each TW, using the LSMESTIMATE option. For the other fixed effects the LSMEANS option was used to test pair-wise differences between factor levels. The SIMULATE option was used to adjust p-values for multiple testing to keep the global significance level.

Journal of Food Safety and Food Quality 64, Heft 4 (2013), Seiten 93–124

**TABLE 1:** *Statistical values of milk constituents for both experimental herds.*

| Trait | MS | MEAN | SD |
|---|---|---|---|
| FAT (%) | CON<br>MULTI | 1.97305<br>2.04089 | 0.87732<br>0.82357 |
| LACTOSE (%) | CON<br>MULTI | 4.68919<br>4.70817 | 0.51902<br>0.35478 |
| SCC-AS | CON<br>MULTI | 3.99605<br>4.22764 | 1.09477<br>1.19462 |
| EC (mS/cm) | CON<br>MULTI | 5.16207<br>5.10215 | 0.73733<br>0.49957 |

MS = milking system, SD = standard deviation, CON = conventional milking system, MULTI = MultiLactor®, SCC-AS = ln(SCC/1000 + 10

## Results

### Description of milk parameters

Table 1 presents statistical values for all analyzed milk parameters in the different milking systems. Milk yield amounted on average 14.18 kg (MULTI) and 13.98 kg (CON). SCC-AS values of cows milked conventionally were on average at 3.99 and for MULTI at 4.22. The trend of SCC-AS along the trial is shown in Figure 2. The values are given for MS and parity. The investigated foremilk samples showed a relative low fat content with regard to all analyzed foremilk samples; MULTI had 2.04 % and CON had 1.97 % of fat content. The values for lactose and electrical conductivity were 4.71 % and 5.10 mS for MULTI respectively 4.69 % and 5.16 mS for CON.

### Influencing factors on milk parameters

Significance of fixed effects and covariables concerning milk parameters was tested and the results were presented in Table 2. The results of the F-tests showed that the milking system had no significant influence on EC and the SCC-AS, which are often used as indicators to determine the udder quarter health status. Additionally, it could be noticed that the parameters fat and lactose were also not affected by the milking system. Other fixed effects like trial week and the interaction MSxTW had a significant influence on all examined traits. Furthermore, DIM and PAR showed a significant impact on the fat content. For the other parameters an interaction between DIM and PAR was found. The udder quarter only was found to be an influencing factor for lactose content.

The emphasis in the analysis lay on possible significant differences between the two examined MS. Therefore, the differences of least square means (Tab. 2) were analysed for the levels of the fixed effects MS, PAR and Q. It could

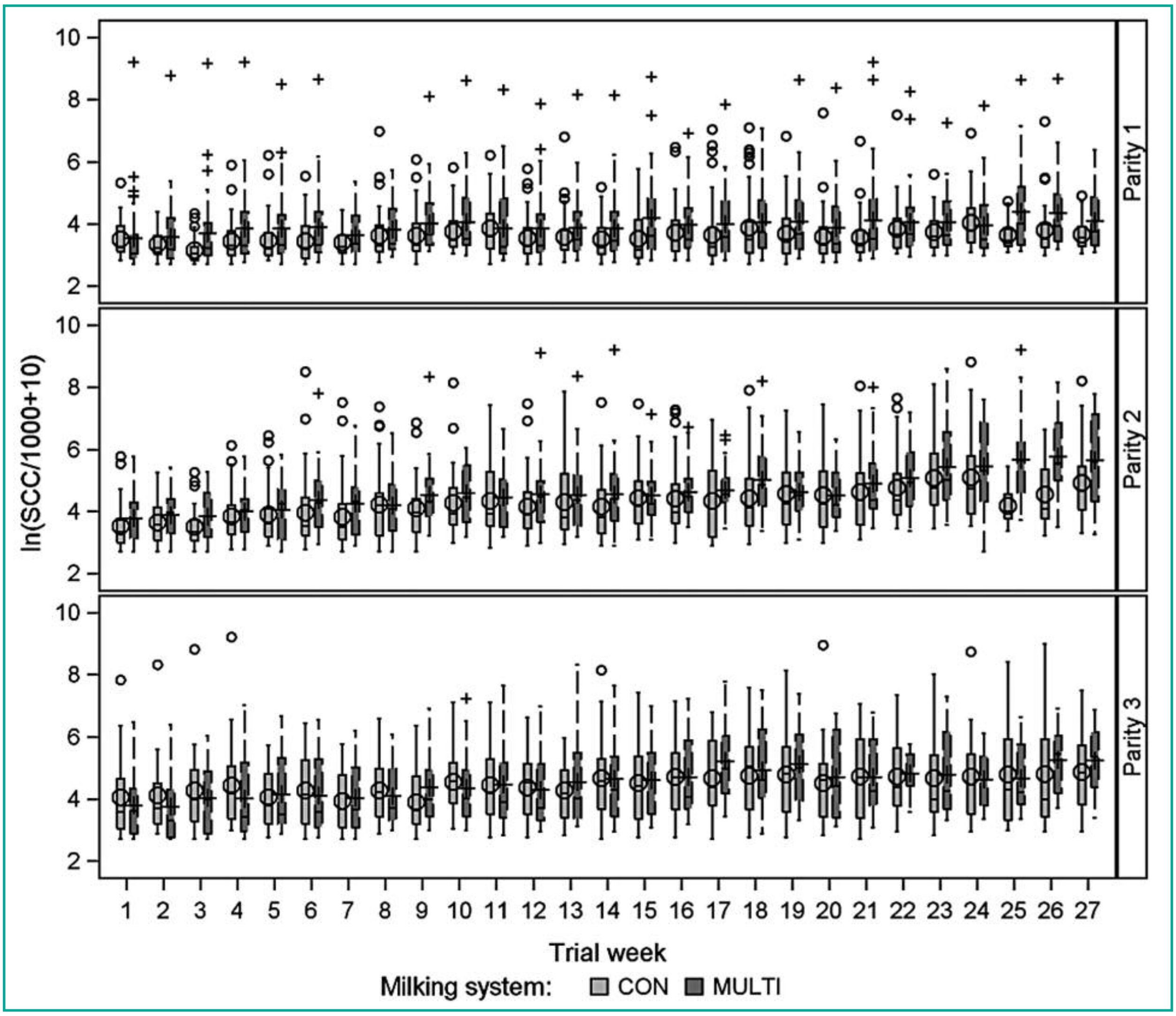


**FIGURE 2:** *Trends of SCC-AS over the trial period for milking systems and parities.*

**TABLE 2:** *Results of F-tests for fixed effects and covariables regarding milk parameters of udder quarter foremilk samples.*

| | Fat [%] | Lactose [%] | EC [mS/cm] | SCC-AS |
|---|---|---|---|---|
| Milking System | 0.2110 | 0.7150 | 0.2469 | 0.1276 |
| Trial Week | <.0001* | <.0001* | <.0001* | <.0001* |
| Milking System*Trial Week | <.0001* | <.0001* | <.0001* | <.0001* |
| Parity | 0.0210* | 0.0052* | 0.0607 | 0.0061* |
| DIM | 0.0121* | <.0001* | <.0001* | 0.6043 |
| DIM*Parity | 0.7141 | <.0001* | <.0001* | <.0001* |
| udder quarter | 0.2108 | 0.0269* | 0.0515 | 0.5204 |

* significant at a ≤ 0.05 (P > F); DIM = day in milk nested with lactation

be found interactions between all parameters and the trial week. For SCC-AS the interactions were found only for week 9. The differences of least squares means demonstrated that there were no significant differences between MULTI and CON with regard to fat content (Adj P = 0.2110) and lactose content (Adj P = 0.7150). Similar to the components, there were no significant differences between both MS relating to EC and SCC-AS as well.

## Discussion

### Description of milk parameters

In Germany, the content of fat as well as the number of somatic cells in milk plays an important role with the regard to the milk quality and the determination of the milk price. The aim of this study was to explore if milking with a quarter-individual milking system affects the concentrations of milk parameters compared to milking with a conventional milking system. The results showed that in both trial groups the average concentrations of milk parameters were on a similar level. Due to this fact, it can be assumed that all trial cows were on a similar performance level and were therefore comparable.

The experimental procedure required the sampling of quarter foremilk samples for two reasons. Firstly, in order to test the effect of the milking systems on milk parameters on quarter level. And secondly, each quarter to a large extent is an independent milk production unit by itself. We noticed that the percentages of lactose in foremilk samples were as similarly high as in composite samples when comparing our results with the results of Forsbäck et al. (2009) in healthy quarters. Bansal et al. (2005) came to different results, and they demonstrated higher concentrations for lactose (5.02±0.19 %) in foremilk samples of healthy quarters compared to the present study. Furthermore, Bansal et al. (2005) found that the fat content in foremilk samples of healthy quarters was 1.43±0.67 %. Compared with our own results (MULTI = 2.04 %, CON = 1.97 %), the differences could be attributed to the sampling mode. In particular, the differences could depend on whether the first milk streams were sampled or whether the time lag between the sampling of the first quarter and the last quarter was considered. That could result in a slightly increased fat content. The electrical conductivity of the milk in the healthy mammary gland shows significant variations due to physiological factors. In addition to the content of dissociated inorganic salts in the milk, the EC is also influenced by the fat content of the milk. With increasing content of the milk fat, the distance between conductive ions is increased, and the limited space, and thus conductive, the free flow of electrons (Krömker, 2007). A comparison of udder quarters between each other could be helpful to interpret the results. The mean EC in quarter foremilk samples with SCC ≤ 50,000 cells/ml was 5.45±0.48 mS (Hamann, 2002). Contrary to this result, the same author found that the mean EC in quarter foremilk samples with SCC > 400,000 cells/ml was 6.69±1.15 mS and thus clearly higher than in healthy quarters (Hamann, 2002). Also Bansal et al. (2005) have ascertained that EC in foremilk samples of quarters with specific mastitis was significantly higher than EC in healthy quarters. Against this background, it has to be mentioned that the results of the present study (EC ≤ 5.16±0.74 mS in CON and 5.10±0.50 mS in MULTI) were below the results of Bansal et al. (2005) which indicates generally a normal udder health status of the trial cows. SCC was on an upper level but did not exceed the threshold of 400,000 cells/ml.

### Influencing factors on milk parameters

In the current study, the milking system on its own could not be found as significantly influencing the milk parameters. Nielsen et al. (2005) found that all milk parameters were significantly influenced by quarter health and milking interval. They also described that SCC and fat increased during the milking process, whereas lactose decreased. Therefore, the authors concluded that foremilk was remarkably different for all milk parameters and should not be used as a representative milk sample to achieve the true level of a milk constituent (Nielsen et al., 2005). By this the interpretation of the effects on fat content should be made with reservation. The results of the current study found that the number of lactation had a significant influence on most investigated traits. Other studies have shown that the number of lactation and, therefore, the age of the animals had no significant influence on milk parameters. For example, Leitner et al. (2011) reported that lactation number had no significant effect on any of the parameters tested (SCC, fat and lactose). Abeni et al. (2008) compared automatic milking with conventional milking using six pairs of twins to evaluate the effects of variation of milking frequency. They found that fat content and SCC did not differ between the milking systems. In addition, mastitis is also known to have effects on the quantity, quality, and processing properties of the produced milk. For example, Nielsen et al. (2005) showed that milk from unhealthy quarters had a higher concentration of SCC during the entire milking. Two possible methodological approaches can be distinguished from each other when assessing a milking system and its influence on milk quality as well as on udder health. In the first approach, which is shown in numerous examples in the literature, the focus is on individual technical components or specific technical settings and their effect on certain milk parameters or health condition. As examples for such studies, trials that tested and evaluated the influence of vacuum level and air inlet as well as vacuum fluctuations can be mentioned. Moreover, some studies were carried out with regard to the mechanical stress on milk parameters and on teat tissue caused by the design of milking clawpieces as well as the layout of the milk tubes. Rasmussen et al. (2006) led to the observation that large vacuum fluctuations and unstable vacuum in conventional milking systems often occurs with long milk tubes. Hamann (1987) concluded that mastitis can be caused through sub-optimal adjustment of the milking technique such as failure in pulsation and through sub-optimal teat-end vacuum. Sub-optimal teat-end vacuum can lead to hyperkeratosis. Further showed Hamann et al. (2001) that in comparison to a conventional milking system, the milking with overpressure in the pressure phase (d-phase) results in significantly smaller teat duct diameters after milking. This is confirmed by other studies, which indicate that an average high milking vacuum while shortening the duration of milking, but provides much more open teat ends, causing a high load on the teat ends and the risk of entry of germs increases (Reinemann et al., 2001). In summary, it can be stated that there is no milking system available that can prevent mastitis promoting effects completely (Hamann, 2001).

## Conclusions

From these experiments it can be concluded that the installation of the MultiLactor® does not affect the milk quality. In summary, it can be said that milking with single guided milk tubes did not change the percentage of milk components (fat, lactose) and the level of milk characteristics (electrical conductivity, somatic cells), compared with conventional milking. However, it could be established that the trial week and the lactation number as well as the covariable milk yield had a significant effect on the examined traits. Especially the day in milk showed a significant influence on fat, lactose and the number of somatic cells.

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