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Effects of quarter individual and conventional milking systems on teat condition

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Abstract

An on-farm experiment was performed to investigate the effects of two milking systems on bovine teat condition over a period of seven months. An auto-tandem milking parlor made by GEA® with a conventional milking cluster (CON) and a single tube milking system called MultiLactor® (MULTI) from Siliconform GmbH were tested. For both milking systems, from a total of about 600 milking Holstein cows on farm 73 cows that were around the 100th day-in-milk and had healthy udders were selected and divided into two groups randomly. To assess the effect of milking on teat condition, each teat was scored according to teat-condition evaluation systems. To evaluate teat condition, the teat color, ring formation at the teat base and formation of teat hyperkeratosis were assessed. The evaluation was conducted once a month after milking. The collected data were then statistically analyzed with generalized mixed models. The only differences found between the two milking systems occurred with respect to their effect on teat color. MULTI showed significantly better scores compared to CON. There were no significant differences between the milking systems with regard to teat-end hyperkeratosis and ring formation at the teat base.

Keywords: Hyperkeratosis, quarter individual milking, teat condition, milking system

1. Introduction

Teat condition refers to the observable and palpable state of the teat. After removal of the milking cluster, the teats should retain a similar appearance as before milking: pink, smooth and dry (Hubal, 2010). To evaluate teat condition, Mein et al. (2001) distinguished between short-term changes (e.g. teat color, ring formation at the teat base or swelling at the teat end), medium-term changes (e.g. teat skin condition or vascular damage) and long-term changes (e.g. teat-end hyperkeratosis). Teat condition is affected by physiological conditions and especially by the milking equipment used. Milking machine factors like high vacuum level (Gleeson et al., 2004), over milking (McDonald, 1975, Rasmussen, 2004), heavy cluster weight (Hillerton et al., 2000) and high liner compression (Zucali et al., 2008) influenced the teat condition negative. The Siliconform GmbH & Co. KG developed the MultiLactor®, a milking system with quarter individual-tube guidance that considers the requirements of cows and the ergonomic requirements of dairy workers. Therefore, the aim of the present study was to determine whether teat condition improved after the installation of a new quarter individual milking system in a dairy herd that was previously milked with a state-of-the-art conventional milking system.

2. Materials and methods

2.1 Animals and study design

From a total of approximately 600 milking Holstein cows, 106 cows that were at approximately the 100th day-in-milk were selected and examined regarding udder health. The 73 cows with healthy udders then were randomly divided into two groups and stratified by three parity sub-groups: parities 1, 2, 3 or higher. Both test groups were housed in the same freestall barn opposite each other across a common feeding conveyor belt from which they received the same feed ration. The cows were milked twice a day in one of two auto-tandem parlors. Only the milking equipment differed between the groups. Thirty-seven cows were milked with a conventional cluster (CON), and 36 cows were milked with a quarter individual milking system (MULTI). All milking procedures in both systems were performed by both dairy workers (Müller et al., 2011).

2.2 Milking equipment

Group I (CON) was milked by a Westfalia® 2x6 auto-tandem milking parlor equipped with a Classic Westfalia 300 milking cluster (GEA, Bönen, Germany). The machine vacuum was adjusted to 40 kPa, and the cluster weight was 2,400 g with a claw volume of 300 ml. Alternate pulsation was used with a pulsation rate of 60 min-1 and a pulsation ratio of 60:40. CON used a pulsation rate of 300 cycles min-1 at a vacuum level of 19 kPa for a pre-stimulation duration of 60 s (Müller et al., 2013a, b). Group II (MULTI) was milked by a 2x4 auto-tandem milking parlor equipped with a clawless MultiLactor® milking system (Siliconform GmbH, Türkheim, Germany). The machine vacuum was adjusted to 37 kPa, the single teat cup weight was 300 g and a sequential pulsation at a rate of 60 min^{-1} and a pulsation ratio of 65:35 was used. Additionally, periodic air inlet from the BioMilker® system was used. The equipment of the MultiLactor® included an Aktuator®, a mechanical actuator that stimulates each teat and the whole udder with oscillating movements of the long milk tubes during the milking period. Teat cups were detached when the milk flow at udder level was below 300 g min^{-1} (CON) and 200 g min^{-1} (MULTI) (Müller et al., 2013a).

2.3 Data Collection

Teat condition was classified during the morning milking period according to criteria established by Mein et al. (2001). The scoring was conducted once a month for seven months from June to December 2009. All observations were done on the same day in the month and by the same person. Classification was carried out immediately after cluster removal because hyperkeratosis is more obvious in the relaxed teat. Additionally, the color and teat-end condition of the teats were scored after cluster removal. The level of hyperkeratosis was classified with scores ranging from one to four as follows: a rating of one indicates a healthy teat end or a slightly white ring at the teat end; a rating of two indicates a white ring at the teat end; a rating of three indicates a raised and roughened keratin ring extending up to 2 mm; and a rating of four implies a severely roughened keratin ring extending more than 2 mm. To evaluate the color change of the teat, a classification system with scores ranging from one to three was used. The color changes were recorded as a share rate of discolored teats to all pale teats. Black pigmented teats could not be scored for color change. The color scores were classified as follows: a score of one indicated a normal pink-colored teat; a score of two indicated that part of or the whole teat was red; and a score of three indicated that part of or the whole teat was blue or violet. Scores ranging from one to three were also used to classify the formation of rings at the teat base as follows: a score of one indicated normal teats without swelling; a score of two indicated teats with a visible ring-shaped impression at the head opening; and a score of three indicated teats with noticeable swelling and a tangibly thickened ring formation.

2.4 Statistical analysis

Influencing factors on the scores for hyperkeratosis, teat color and ring formation were all tested with a generalized linear mixed model approach that assumed a binomial distribution with a logit link function. A multinomial distribution model with a cumulative logit link function (McCullagh and Nelder, 1989) could not be used because the assumption of proportional odds between scores was violated: therefore, a sequential logit model was used. Given the observed score yijkms for the ijkm-th teat with scores ranging from 1 to s, with s=4 for hyperkeratosis and s=3 for teat color and ring formation, binary responses were created as follows: (a) score = 1 versus score ≥ 2; (b) score ≤ 2 versus score ≥ 3; (c) score ≤ 3 versus score = 4 (in case of hyperkeratosis). Models (a) through (c) examined the ratio between the probability of observing score r or lower and the probability of observing scores higher than r with logit Lr for a maximum r of s-1:

$$L_r = \ln\left(\frac{P(Y \leq r)}{P(Y > r)}\right) = \ln\left(\frac{P(Y \leq r)}{1 - P(Y \leq r)}\right) = \theta_r + \eta_r$$

where θr is the threshold value for score r and ηr is a linear predictor. The linear predictor ηr is calculated as follows:

ηijklm = αi + βj + γk + λx + dlm + εijklm

where αi is the fixed effect of milking system i; βj is the fixed effect of parity j; γk is the fixed effect of teat k; λ is the regression coefficient for the day in milking system x; dlm is the random effect of cow l in month m; and eijklm is the independent logistically distributed residual. To account for repeated measurements within cows during the seven months (m), a first-order autoregressive correlation structure was chosen. The individual models were also checked for interactions between parity and milking system as well as teat and milking system. Therefore model (a) for ring formation required an additional interaction term (αγ)ik for the fixed effect of interaction between milking system and teat position.

The models were fitted using the SAS 9.3 software package (SAS Institute Inc., Cary, NC, USA) GLIMMIX procedure and set up to model the probability of observing lower scores. Null hypotheses included a lack of influence of the milking system, parity, teat and days in milking system on the scores of hyperkeratosis, teat color and ring formation. The ODDSRATIO option in the MODEL statement requested estimates for odds ratios (OR) for all fixed factors. Tests were performed at a significance level of 0.05. Tests of pairwise differences between parities and teats were performed using the ESTIMATE statement. The SIMULATE option was used to keep the global significance level by adjusting p-values for multiple testing. Confidence limits of 95 % for the estimated odds ratios were obtained using the CL and EXP options in the ESTIMATE statement.

Initial and final distributions of scores within and between groups were compared with chi-square tests. Because this required all four tests, a Bonferroni correction was applied to account for multiple testing. To keep the global significance level of 0.05, the significance level was set to 0.0125 for the individual comparisons.

3. Results

3.1 Hyperkeratosis

Of the theoretical maximum of 2,044 teat scores for 73 cows with four teats scored seven times each, a total of 1,796 teat scores (916 and 880 in CON and MULTI, respectively) were recorded during the examinations.

At the beginning of this study, 49 of 144 (34 %) of the scored teats milked in the MULTI system were normal or showed only a slight ring formation (score 1), 84 of 144 (58.3 %) had a white ring at the teat end (score 2) and 11 of 144 (7.6 %) showed a raised and roughened keratin ring (score 3) extending up to 2 mm. Teats with a score of 4 were not found. For the cows that were milked in the CON system, 17 of 148 (11.5 %) of the teats were normal or showed only a slight ring formation (score 1);107 of 148 (72.3 %) had a white ring at the teat

end (score 2); 20 of 148 (13.5 %) had a raised and roughened keratin ring at the teat end (score 3); and 4 of 148 (2.7 %) had a severely roughened keratin ring extending more than 2 mm (score 4). Figure 1 showed the probability of occurrence of one of the four hyperkeratosis-scores for both milking systems depending on the parity for the left rear (LR) and the right front (RF) teat.

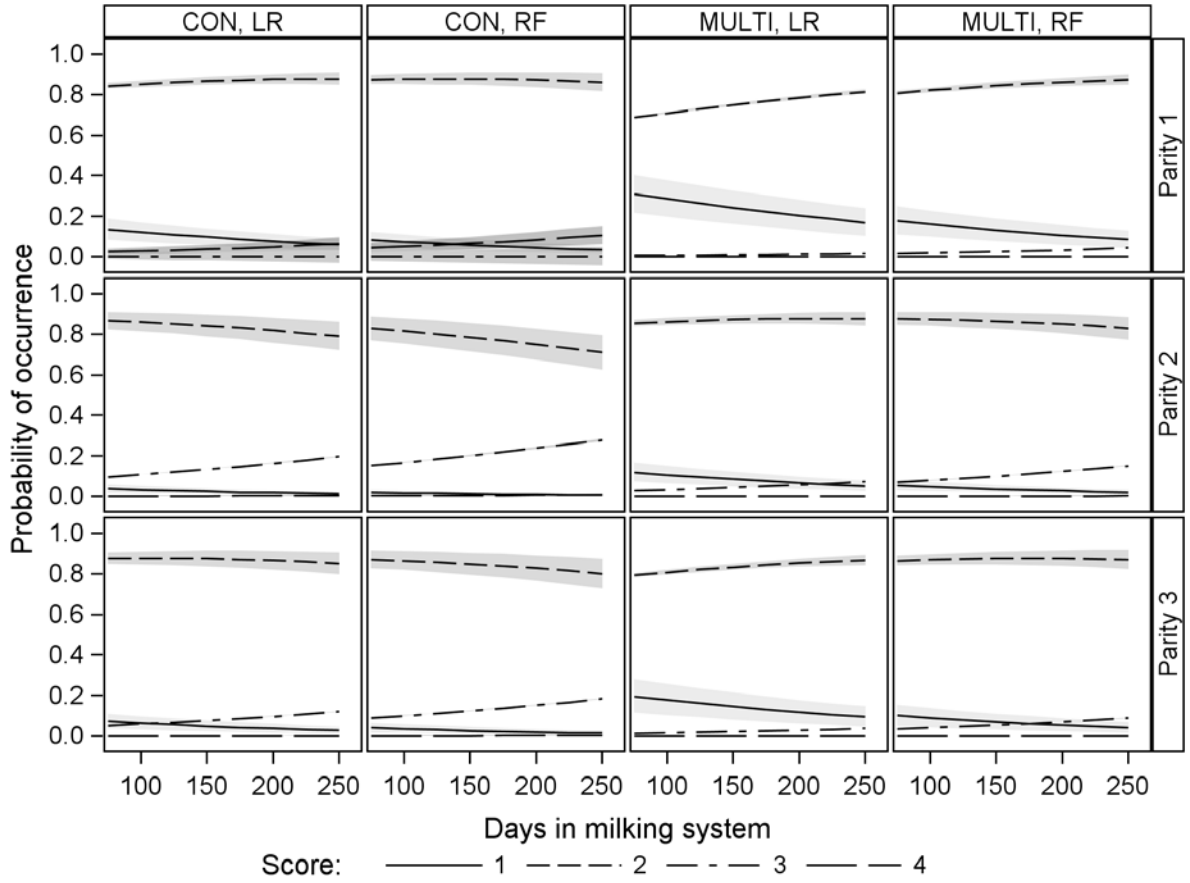

Figure 1: The probability of occurrence of one of the four scores for both milking systems depending on the parity for the left rear (LR) and the right front (RF) teat.

The results of the sequential logit models show a significant influence for all fixed factors in the milking system (P<0.01 and P<0.001), teat (P<0.01 and P<0.0001) parity (P=0.04 and P<0.01) and covariable days in the milking system (P<0.01 and P=0.02) for models (a) and (b), whereas for model (c), there is not a significant influence of the milking system (P=0.96) and parity (P=0.48) but there are differences between teats (P<0.01) and the covariable days in the milking system (P<0.0001). Odds ratios of CON and MULTI are 0.13 in model (a) and 0.06 in model (b), resulting in overall lower scores for MULTI.

3.2 Color of teats

In both milking systems, all three scores were found at the beginning and at the end of the study. Black pigmented teats could not be used for scoring, leaving a total of 1,273 teats examined for color, of which 873 (68.6 %) were normal colored, 322 (25.3 %) were reddened and 78 (6.1 %) were partially or completely blue or violet after milking. The results of the sequential logit models show a significant influence of milking system (P<0.0001), teat (P<0.01) and parity (P=0.02) but not for the covariable days in the milking system (P=0.64) in model (a). Teat (P=0.05) parity (P=0.05) and covariable days in milking system (P<0.0001) have significant influence in model (b), but the milking system (P=0.65) did not have an effect. Figure 2 showed the probability of occurrence of one of the three scores regarding to teat color for both milking systems.

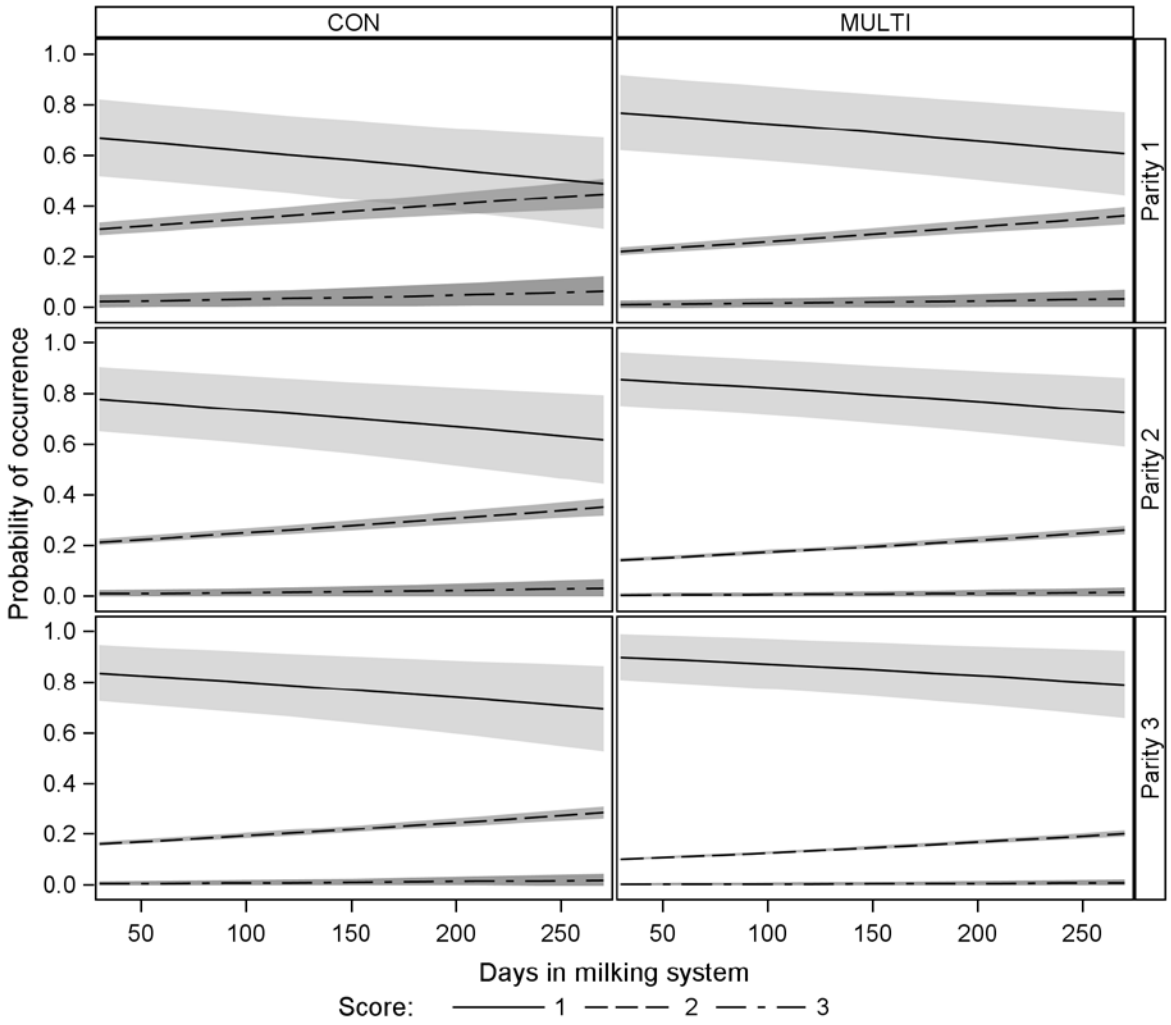

Figure 2: The probability of occurrence of one of the three scores regarding to teat color for both milking systems.

3.3 Ring formation

During the study, ring formation scores of one to three were found. For the sequential logit models, only the teats were found to have significant influence in model (b) ($P<0.01$), while in model (a) there was a significant interaction between teat and milking system ($P=0.0024$). In model (a) there were no differences between teats in the MULTI milking system and also no differences between the same teat positions between milking systems.

4. Discussions

Regarding the changes in hyperkeratosis scores for the MultiLactor®, it can be speculated that the threshold for teat cup removal was too low. High pressure load induces excessive production of keratin, suggesting that hyperkeratosis is caused by over-milking (Haeussermann et al., 2009). For both milking systems, physiological characteristics could be causal for hyperkeratosis. For example the formation of hyperkeratosis is significant for long teats compared to short teats (Graff, 2005), and these results have been confirmed by Wendt et al. (2007), who reported that teats that are too short or too long teats do not place properly within in the teat cup.

In the evaluation of the teat color, there were differences between the two groups at the beginning of the study. There were more normal-colored teats in the group milked by MultiLactor® than in the CON group. After the period of investigation, significant differences be-

tween both milking systems were found. While the CON group showed a significant deterioration of teat color, no changes in scores could be determined for the MULTI group. The MultiLactor® system milks with low vacuum pressure, and BioMilker® teat cups reduce the vacuum in d-Phase. Öz et al., (2010) and Rose-Meierhöfer et al. (2010) found that average liner vacuum values during d-phase differ between CON (34.2 kPa) and MULTI (12.3 kPa). Moreover, the weight of the milking cluster and the height of the vacuum have an influence on teat color. This finding confirms the results of Hillerton et al. (2000), who found that the use of a cluster with a greater weight results in a significantly higher amount of reddened and blue teats. Additionally, Ebendorff and Ziesack (1991) reported that milking with a lower vacuum pressure resulted in less color changes in the teats.
The results of this study show that there were no significant differences between MULTI and CON regarding ring formation at the teat base at the beginning of the investigation. At the end, significant differences between both milking systems were found, with MULTI showing increased ring formation. This result could be explained by increased on-machine time for MULTI. The threshold for teat cup removal has to be higher than what was achieved in this test. Rasmussen (2004) reported that the proportion of teats with ring formation increases with the length of over milking.
Currently, it is not possible to give detailed technical reasons for the differences between the systems. Technical parameters (vacuum, pulsation rate, cluster, etc.) of both systems were used according to the manufacturers' directions (Müller et al., 2013a, b). The subject of the experiment was the milking systems as a whole and their influence on teat condition.

5. Conclusions

Generally, it cannot be concluded that one system is superior to the other regarding hyperkeratosis. The new milking system MultiLactor® showed a significantly improved influence on teat color. Conversely, MULTI had a significantly worsened effect on the ring formation at the teat base. Clarification is required in further studies to show which technical features of the MultiLactor® have an influence on bovine teat condition (e.g., low machine vacuum, sequential pulsation, Aktuator® or periodic air inlet)

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