Changes in teat end condition following installation of an individual quarter pulsation system

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Abstract

The objective of this study, conducted at the University of Kentucky Coldstream Dairy, was to examine changes in teat end hyperkeratosis in a herd transitioning from a standard pulsation system to an individual quarter pulsation milking system. Teat end hyperkeratosis (HK) was evaluated immediately after cluster removal using the scoring system outlined by Mein et al. (2001) where N signifies no ring; S signifies a smooth, raised ring; R signifies a rough ring; and VR signifies a very rough ring. Scorings were classified for 69 cows (48 Holstein, 12 crossbred, and 9 Jersey) relative to installation (April 28, 2011) of the Milpro P4C^{TM} (Milkline, Gariga di Podenzano, Italy) system as follows: PRE1-April 7; PRE2-April 21; POST1-May 12; POST2-May 26; POST3-June 9. The Milpro P4C^{TM} system stops milking individual quarters using a unique individual quarter pulsation system with four pulsation channels instead of two. Hyperkeratosis classifications were converted to numerical scores as follows: N = 1; S = 2; R = 3; VR = 4. The MIXED Procedure of SAS® (Cary, NC) was used to evaluate fixed effects of age, breed, parity, teat position and all interactions on teat end HK score with variables repeated by scoring with cow within breed as subject. The effects of teat position and scoring × breed on teat end HK score were significant ($P < 0.01$). Holstein HK scores improved from PRE1 to PRE2 (1.75 ± 0.10 and 1.63 ± 0.10, respectively, $P = 0.04$), PRE1 to POST1 (1.75 ± 0.10 and 1.59 ± 0.10, respectively, $P = 0.02$), PRE1 to POST2 (1.75 ± 0.10 and 1.53 ± 0.10, respectively, $P < 0.01$), PRE1 to POST3 (1.75 ± 0.10 and 1.42 ± 0.10, respectively, $P < 0.01$), PRE2 to POST3 (1.64 ± 0.09 and 1.42 ± 0.10, respectively, $P < 0.01$), POST1 to POST3 (1.59 ± 0.10 and 1.41 ± 0.10, respectively, $P < 0.01$), and POST2 to POST3 (1.53 ± 0.10 and 1.42 ± 0.10, respectively, $P < 0.05$). Crossbred HK did not differ among scorings ($P > 0.05$). Jersey HK scores increased from POST1 to POST3 (1.32 ± 0.21 and 1.63 ± 0.22, respectively, $P = 0.04$). Right front HK scores were higher than right rear or left rear HK scores (1.58 ± 0.09, 1.37 ± 0.09, and 1.36 ± 0.09, respectively, $P < 0.01$). Left front HK scores were higher than right rear and left rear HK scores (1.62 ± 0.09, 1.37 ± 0.09, and 1.36 ± 0.09, respectively, $P < 0.01$). Individual quarter pulsation systems may prevent overmilking and reduce HK.

Keywords: hyperkeratosis, teat end, individual quarter pulsation

Introduction

The teat end or orifice is an important first line of defense in protecting the udder from mastitis pathogen invasion (Gleeson et al., 2004). The maintenance of healthy teat skin and teat ends is a key component of an effective mastitis prevention program (Mein et al., 2001). After repeated

milkings, changes appear in teat end tissue, resulting in the development of a callous ring around the teat orifice, termed hyperkeratosis (**HK**; Neijenhuis et al., 2001a).

Overmilking can exacerbate teat end HK. Mechanical forces exerted by vacuum and the moving liner during machine milking are associated with teat end HK changes (Neijenhuis et al., 2000; 2001a). Other factors that affect the degree of teat end HK include teat end shape and genetic predisposition (Gleeson et al., 2004), seasonal weather conditions (Mein et al., 2001), and milking duration (Zucali et al., 2008). Zucali et al. (2008) explained that long milking durations increased HK scores more than liner type and liner compression. However, liner compression may contribute to the development of teat end HK (Zucali et al., 2008). Teats with milking duration < 4.3 min were much less likely to develop HK than teats with a milking duration > 5.3 minutes, reflecting fewer liner collapses (Zucali et al., 2008).

Dairy advisors often associate HK with increased clinical mastitis incidence (Neijenhuis et al., 2001b). O'Shea (1987) proposed that changes to teat end condition resulting from milking might increase the likelihood of bacteria penetration into the udder. Neave et al. (1969) explained that changes to the teat end and teat canal alter the risk of new mastitis infections. Lewis et al. (2000) concluded that changes in teat end condition increased subclinical mastitis prevalence. Although rough teat ends are more difficult to clean during pre-milking preparation and provide a site for bacteria colonization (Zucali et al., 2008), Shearn and Hillerton (1996) failed to identify a significant relationship between mean SCC and degree of HK at the herd level. Other studies have also failed to demonstrate that poor teat end condition is a direct cause of intramammary infection (Natzke et al., 1978; Gleeson et al., 2004). Hyperkeratosis may be an indicator of the level of attention toward animal welfare (Shearn and Hillerton, 1996) as teat end HK may contribute to cow discomfort.

Individual quarter pulsation systems may prevent overmilking and improve teat end condition (Neijenhuis et al., 2000). The objective of this research was to examine changes in teat end condition in a herd transitioning from a standard single quarter pulsation system to an individual quarter pulsation milking system.

Materials and methods

This study was conducted at the University of Kentucky Coldstream Dairy from April to June 2011. Teat end HK was evaluated immediately after cluster removal using the scoring system outlined by Mein et al. (2001) where N signifies no ring; S signifies a smooth, raised ring; R signifies a rough ring; and VR signifies a very rough ring. Scoring periods were classified relative to installation (April 28, 2011) of the Milpro P4C™ (Milkline, Gariga di Podenzano, Italy) system as follows: PRE1-April 7; PRE2-April 21; POST1-May 12; POST2-May 26; POST3-June 9.

Before installation of the new system, cows were milked using Surge™ Eclipse™ claws with 06 shells, 1st Choice™ triangular inflations, and Surge™ Omni™ cylinder detachers with optical sensors (GEA Farm Technologies, Inc., Naperville, IL). The Milpro P4C™ (Milkline, Gariga di Podenzano, Italy) system stops milking individual quarters based on flow rates using a unique individual quarter pulsation system with four pulsation channels instead of one and silicon liners. Pulsation ratio and frequency are variable and driven by the milk flow in the Milpro P4C™ system. As the flow increases the length of the milking phase (A+B) increases, while the rest phase (C+D) remains constant and the pulsation rate slows down. When milk flow is below 1.2 kg/min, the pulsation ratio is 60:40 and the pulsation rate is 60 pulses/min. The

milking phase (A+B) increases dynamically when milk flow is between 1.2 and 7.5 kg/min, while the rest phase remains at 400 ms. Although the milking system used in this study detects individual quarter milk flow and stops milking individual quarters, pulsation still occurs every 20 s and the liner remains in a massage phase between pulses. This process would reduce overmilking, acting on each quarter individually.

Teat end HK was evaluated for 109 cows during the study. Only cows with scores available for the entire study period were included in the final analysis (n = 69, 48 Holstein, 12 crossbred, and 9 Jersey). Teat end HK scores were converted to numerical values progressing from most desirable to least desirable as follows: N = 1; S = 2; R = 3; VR = 4 (Table 1). When a given HK score differed from preceding and subsequent scores by more than ± 1, that score was removed from the data set.

Score frequencies were calculated by scoring period using the FREQ Procedure of SAS® (SAS version 9.3, SAS Institute, Inc., Cary, NC). The MIXED Procedure of SAS® (Cary, NC) was used to evaluate fixed effects of breed, parity, teat position, and all interactions on teat end HK score. Variables repeated by scoring with cow within breed as subject. All main effects were kept in each model regardless of significance level. Stepwise backward elimination was used to remove non-significant interactions ($p \leq 0.05$).

Results and Discussion

Mean milk production, parity, days in milk, and SCS for the herd were 34.31 ± 9.92 kg, 2.30 ± 1.24 lactations, 153.38 ± 90.10 days, and 1.66 ± 1.24, respectively. The frequency of more desirable teat end condition classifications (N and S) increased after the installation of the individual quarter pulsation system (Table 1). The frequency of less desirable teat end HK classifications decreased from 8 and 15 (R and VR, respectively) at PRE1 to 3 and 7 (R and VR, respectively) at POST3. Ambient weather conditions did not vary much during this study reducing the likelihood of weather influences on results observed. Changes in teat end HK are not immediate and should be monitored over months. The timing of changes in teat end HK observed in this study is consistent with the 2 to 8 weeks necessary for a change in teat HK described by Mein et al. (2001) and Gleeson et al. (2004). Zucali et al. (2008) explained that teats that started with a HK classification of N were less likely to become R and VR than teats starting with a HK classification of S. In the same study, teats that started with a HK classification of R or VR were much more likely to end with a classification of R or VR than teats starting the experiment with a classification of S. These results demonstrate the difficulty recovery process from severe HK.

Table 1. Teat end hyperkeratosis classification frequency by teat scoring period before and after the installation of an individual quarter pulsation milking system.[1,2]

	Scoring Period				
Score	PRE1	PRE2	POST1	POST2	POST3
N	60.9% (n = 134)	70.0% (n =134)	65.9% (n = 145)	67.3% (n = 148)	71.4% (n = 157)
S	28.6% (n = 63)	30.0% (n = 66)	27.7% (n = 61)	25.9% (n = 57)	24.1% (n = 53)
R	3.6% (n = 8)	5.9% (n = 13)	3.2% (n = 7)	4.5% (n = 10)	1.4% (n = 3)
VR	6.8% (n = 15)	3.2% (n = 7)	3.2% (n = 7)	2.3% (n = 5)	3.2% (n = 7)

[1]N signifies no ring; S signifies a smooth, raised ring; R signifies a rough ring; and VR signifies a very rough ring.
[2]PRE1 and PRE2 refer to teat end condition observations using a standard milking system while POST1, POST2, and POST3 refer to teat end condition observations using an individual quarter pulsation milking system.

Table 2. Type III tests of fixed effects for teat end hyperkeratosis score mixed model relative to the installation of an individual quarter pulsation milking system.[1, 2, 3, 4]

Source	Numerator DF	Denominator DF	F value	P-value
Teat position[1]	3	1097	11.14	< 0.01
Scoring period[2]	4	1097	0.31	0.87
Breed[3]	2	1097	0.60	0.55
Parity[4]	1	1097	0.01	0.93
Scoring period x breed	8	1097	3.13	< 0.01

[1]Teat position: left front, right front, left rear, right rear.
[2]Scoring period: PRE1 and PRE2 refer to teat end condition observations using a standard milking system while POST1, POST2, and POST3 refer to teat end condition observations using an individual quarter pulsation milking system.
[3]Breed: Holstein, Jersey, or crossbred.
[4]Parity: 1 or ≥ 2.

Teat position and scoring period × breed were significant predictors of teat end HK score (Table 2; $P < 0.01$). Scoring period, breed, and parity did not affect teat end HK score ($P > 0.05$). The parity effect observed in this study contrasts results from Mein et al. (2001) who concluded that HK scores increased with parity. Holstein HK scores improved from PRE1 to PRE2 (Table 3; 1.75 ± 0.10 and 1.63 ± 0.10, respectively, $P = 0.04$), PRE1 to POST1 (1.75 ± 0.10 and 1.59 ± 0.10, respectively, $P = 0.02$), PRE1 to POST2 (1.75 ± 0.10 and 1.53 ± 0.10, respectively, $P < 0.01$), PRE1 to POST3 (1.75 ± 0.10 and 1.42 ± 0.10, respectively, $P < 0.01$), PRE2 to POST3 (1.64 ± 0.09 and 1.42 ± 0.10, respectively, $P < 0.01$), POST1 to POST3 (1.59 ± 0.10 and 1.41 ± 0.10, respectively, $P < 0.01$), and POST2 to POST3 (1.53 ± 0.10 and 1.42 ± 0.10, respectively, $P < 0.05$). Crossbred teat end HK scores did not differ among scoring periods ($P > 0.05$). Jersey teat end HK scores increased from PRE2 to POST3 (1.34 ± 0.21 and 1.63 ±

0.22, respectively, P = 0.05). Jersey teat end HK scores increased from POST1 to POST3 (1.32 ± 0.21 and 1.63 ± 0.22, respectively, P = 0.04). Teat end condition did not improve for Jersey or crossbred cows, possibly reflecting differences in genetic predisposition or teat end shape. Neijenhuis et al. (2000) demonstrated that round teat ends showed more HK than inverted teat ends and front teats showed more HK than rear teats.

Right front HK scores were higher than right rear and left rear HK scores (Table 4; 1.58 ± 0.09, 1.37 ± 0.09, and 1.36 ± 0.09, respectively, P < 0.01) and left front HK scores were higher than for right rear and left HK scores (1.62 ± 0.09, 1.37 ± 0.09, and 1.36 ± 0.09, respectively, P < 0.01). Neijenhuis et al. (2000) reported similar results. Only 40% of milk resides in the front quarters, making them more prone to overmilking.

Table 3. Least squares means (± SE) within teat scoring period relative to the installation of an individual quarter pulsation milking system.[1,2,3]

		Scoring Period				
		PRE1	PRE2	POST1	POST2	POST3
Breed	Holstein	1.75 ± 0.10[a]	1.63 ± 0.10[b]	1.59 ± 0.10[b]	1.53 ± 0.10[b]	1.42 ± 0.10[c]
	Jersey	1.40 ± 0.21[ab]	1.34 ± 0.21[ab]	1.32 ± 0.21[b]	1.43 ± 0.21[ab]	1.63 ± 0.22[a]
	Crossbred	1.35 ± 0.17	1.47 ± 0.17	1.40 ± 0.17	1.49 ± 0.17	1.44 ± 0.17

[1]Least squares means within rows with different superscripts differ (P < 0.05).
[2]1 (N) signifies no ring; 2 (S) signifies a smooth, raised ring; 3 (R) signifies a rough ring; and 4 (VR) signifies a very rough ring.
[3]PRE1 and PRE2 refer to teat end condition observations using a standard milking system while POST1, POST2, and POST3 refer to teat end condition observations using an individual quarter pulsation milking system.

Table 4. Least squares means (± SE) of teat end HK score by teat position relative to the installation of an individual quarter pulsation milking system.[1,2]

	Teat Position			
	Left Front	Left Rear	Right Front	Right Rear
Teat end HK scores for all cows (± SE)	1.62 ± 0.09[a]	1.36 ± 0.09[b]	1.58 ± 0.09[a]	1.37 ± 0.09[b]

[1]Least squares means within rows with different superscripts differ (P < 0.05).
[2]1 (N) signifies no ring; 2 (S) signifies a smooth, raised ring; 3 (R) signifies a rough ring; and 4 (VR) signifies a very rough ring.

Conclusions

Holstein teat end hyperkeratosis decreased after installation of an individual quarter pulsation milking system, which may reflect decreased overmilking. Individual quarter pulsation systems may decrease overmilking and reduce teat end HK. Additional research is needed to determine if these results are applicable to varying herd conditions and to understand the breed differences noted in this study.

List of References

Gleeson, D.E., W.J. Meaney, E.J. O'Callaghan, and M.V. Rath. 2004. Effect of teat hyperkeratosis on somatic cell counts of dairy cows. Intern J Appl Res Vet Med. 2: 115-122.

Ipema, A.H., V. Tancin, and P. H. Hogewerf. 2005. Responses of milk removal characteristics of single quarters on different vacuum levels. Pages 55-60 in ICAR Technical Series 10 Proc. Nitra, Slovak Republic.

Lewis, S., P.D. Cockcroft, R.A. Bramley, and P.G.G. Jackson. 2000. The likelihood of subclinical mastitis in quarters with different types of teat lesions in the dairy cow. Cattle Practice 8: 293-299.

Mein, G.A., F. Neijenhuis, W.F. Morgan, D.J. Reinemann, J.E. Hillerton, J.R. Baines, L. Ohnstad, M.D. Rasmussen, L. Timms, J.S. Britt, R. Farnsworth, N. Cook, and R. Hemling. 2001. Evaluation of bovine teat condition in commercial dairy herds: 1. Non-infectious factors. Pages 347-351 of the 2nd International Symposium on Mastitis and Milk Quality Proc. Vancouver, B.C., Canada.

Natzke, R. P., P. A. Oltenacu, and G. H. Schmidt. 1978. Change in udder health with overmilking. J. Dairy Sci. 61:233–238.

Neijenhuis, F., H. W. Barkema, H. Hogeveen, and J. P. T. M. Noordhuizen. 2000. Classification and longitudinal examination of callused teat ends in dairy cows. J. Dairy Sci. 83:2795–2804.

Neijenhuis, F., G.A. Mein, J.S. Britt, D.J. Reinemann, J.E. Hillerton, R. Farnsworth, J.R. Baines, T. Hemling, I. Ohnstad, N. Cook, W.F. Morgan, and L.Timms. 2001a. Evaluation of bovine teat condition in commercial dairy herds: 4. Relationship between teat end callosity or hyperkeratosis and mastitis. Pages 362-366 in Proc. of the 2nd International Symposium on Mastitis and Milk Quality.

Neijenhuis, F., H. W. Barkema, H. Hogeveen, and J. P. T. M. Noordhuizen. 2001b. Relationship between teat-end callosity and occurrence of clinical mastitis. J. Dairy Sci. 84:2664–2672.

O'Shea, J. 1987. Machine milking and mastitis. Section 2: Machine milking factors affecting mastitis-A literature review. Bull. Int. Dairy Fed. 215: 5-32.

Shearn, M. F. H., and J. E. Hillerton. 1996. Hyperkeratosis of the teat duct orifice in the dairy cow. J. Dairy Res. 63:525–532.

Zucali, M., D.J. Reinemann, A. Tamburini, R.D. Bade. 2008. Effects of liner compression on teat end hyperkeratosis. Pages 1-5 in 2008 ASABE Annual International Meeting Proc., Providence, Rhode Island.