Association of Cow and Quarter Level Factors at Dry Off and New Intramammary Infections in the Dry Period

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Summary

Data from 300 cows and 1,178 quarters were analyzed to determine factors associated with new dry period intramammary infections (IMI). Teat-ends that were cracked and teats that did not close during the dry period were 1.7 and 1.8 times more likely to develop new IMI, respectively. The level of milk production on the last day of lactation significantly influenced new IMI and teat canal closure. More ($P<0.05$) cows (36%) producing 21 kg of milk developed new IMI than cows (18%) producing less. When milk production was 21 kg or higher, teat canals were 1.8 times more likely to remain open. These data provide new insight into mastitis risk factors and new management areas for cows prior to dry off.

Introduction

The importance of the dry period with respect to udder health management and the increased rate of new intramammary infections (IMI) that occur during this time, have been recognized for quite some time. For the first few weeks after the beginning of the dry period, and then again immediately before calving, cows are at an increased risk of developing IMI. Research supports that this susceptibility is related to variations in the teat streak canal and inherent biochemical and cellular changes occurring in the udder during this period. The time in which the udder is most resistant to new infections in the dry period is when the udder has become fully involuted, and a natural teat canal keratin plug has formed, which acts as a physical barrier in each teat.

Risk factors affecting susceptibility to new IMI can be categorized as occurring at the quarter, the cow, and at the herd level. At the level of the individual quarter, bacterial populations present at the teat end, the integrity of the teat end, and timely formation of the teat canal keratin plug are very important. Due to this recognized importance, a standardized classification system for teat-end integrity was proposed. A method to assess closure of the teat streak canal during the dry period has been documented.

Cow level risk factors have been studied previously as well. The influence of age and the level of milk production of a cow at the time of dry off have been investigated, in addition to various approaches to enhance the process of involution. Debate over the relative importance of milk production at dry off continues to evolve, especially as the genetic potential for milk production of cows continues to increase. A need exists to determine the importance of milk production at drying. In addition, the most effective strategies currently being employed by dairy producers to dry off cows need to be identified. No specific recommendations are given to producers on how to manage a cow from the 2 weeks before the dry period until early in that period.

In the current study, cows were evaluated from 2 weeks before dry off through to the next lactation, to describe the influence of specific cow and quarter factors on the rate of new dry period IMI. The variables of interest were daily milk production, teat-end integrity, and closure of the teat streak canal during the dry period. Information on breed, parity, days in milk and the season of dry off were also recorded. The underlying hypothesis was that with an enhanced understanding of drying-off management, and the influence of various factors on the development of new IMI, future recommendations on the process of dry off could be made.

Procedures

Research herds associated with Kansas State University, Iowa State University, the State University of New York in Cobleskill, and the University of Guelph in Ontario Canada, participated in this study for a period of just over one year. Dairy cows ending their first or subsequent lactation were enrolled in this study at 2 weeks before the scheduled dry period. The majority of cows were ending their first or second lactations at enrollment, and were Holsteins. Other breeds in this study included Ayrshires, Jerseys, Guernseys, Milking Shorthorns and Brown Swiss. The routine dry cow management program, including the administration of dry cow antibiotic therapy at the end of lactation, was not altered in any herd. At the time of enrollment prior to dry off (day -14), aseptic quarter milk samples were collected from all cows for bacteriological culture, days in milk of each cow was recorded, and each of the four quarters were scored for teat-end lesions. Daily milk weights were recorded from this time up until dry off (day 0). All cows were milked just once on the day of dry off, and following that milking, quarter milk samples were obtained prior to administration of a dry cow antibiotic, and teat-ends were scored again. Once a week for the first 6 weeks of the dry period, research technicians evaluated each cow for teat-end scores and formation of the teat canal keratin plug. Weekly dry period examinations ended when all four quarters of a cow were determined to be closed, or at 6 weeks after dry off, whichever came first. Within the first week after calving (day 1), a final quarter milk sample was obtained for culture, and teat ends were scored one final time. Teat ends were aseptically prepared prior to milk

sample collection and samples were sent to a laboratory at each participating site. Each laboratory had Standard Operating Procedures in place for handling samples, culture techniques, and interpretation of results consistent with recommended procedures of the National Mastitis Council. Quarters were defined to harbor a new infection when a mastitis-causing pathogen was isolated on the sample post-calving, and that pathogen was not present in the same quarter prior to dry off.

A uniform teat-end score classification guide was created by the authors. The specific classification used was adapted from a similar teat-end callosity classification recently published. Scores from one to five with 0.5 increments were used that incorporated both smooth and rough callosity as well as the degree of callosity. A score of 1 described a teat with no ring (callosity) or roughness (cracking). Scores of 1.5 to 3 represented teats with a smooth callosity ring (no roughness/cracking). By comparison, scores from 3.5 to 5 represented teats with a rough callosity ring and cracking.

Descriptive statistics were generated using the univariate and frequency procedures. Estimates of mean values, and differences among means across various strata (herd, milk production, season) were calculated with a least squares mean procedures. A Chi-square test was used to test the significance of a single factor on the proportion of new IMI. Generalized estimation equations were used to model the probability of both an individual cow and quarter to develop a new IMI.

Results and Discussion

Complete data from 300 cows and 1,178 quarters were available for analyses. Descriptive statistics of the cows used in this trial are presented in Table 1. The average duration of the dry period was 65 days, and varied significantly in duration among the five herds. Although this trial was conducted for a period of just over one full year, over 60% of the cows were dried off in the summer and fall months. One herd had a seasonal calving pattern.

Bacteriological results from the quarter milk samples revealed that 11.1% of quarters developed a new IMI during the dry period. An individual cow was considered newly infected if she had at least one quarter develop a new IMI. Using that definition, 20.7% of cows developed new infections. Significant differences were detected in both the quarter and cow rate of new IMI among herds (Table 2). The majority of these new infections were caused by environmental organisms. The proportion of new IMI caused by environmental streptococci sp, *E. coli*, and *Staphylococcus aureus* were 22.9%, 14.5% and 10.7%, respectively. A total of 66% and 2.7% of the 1,178 quarter samples yielded no growth and nonsignificant bacterial growth, respectively. The predominance of environmental organisms causing new dry period IMI was not surprising. However, the finding of 10% new *S. aureus* IMI may be a result of the sampling schedule used. It is plausible that these infections were not detected before the dry period, and indeed were not initiated during the dry period.

A total of 24.5% of teats scored were classified to be cracked teat ends at some time during the study. The specific time at which most teats were observed to be cracked was on the actual day of dry off. The individual teat-end scores were pooled to quantify the occurrence of cracked teats in cows. In total, 24.7% of cows had at least one cracked teat during the study. This finding, relative to the overall number of individual cracked teats, indicated that cows tended to have multiple cracked teat ends. As the dry period progressed, there was a general improvement in teat end scores, which is consistent with other studies that have shown improvements in teat end callosity when the mechanical forces of machine milking are reduced or absent (dry period).

A marked decline occurred in the percentage of open teats early in the dry period, with over 50% of teats closing in the first week. However, after 6 weeks of observation, 23.4% of teats remained open. Significant differences in the closure of teats were detected among herds as well. After all four teats were closed per cow, 63.3% of cows met that criteria within 6 weeks of the dry period. Teat closure at the cow level varied among herds from 18.5% to 89.8% (Table 3).

The relative importance of teat-end integrity and teat canal closure on new IMI was evident from the the univariate association of these factors on that outcome (Table 2). This importance was evident at both the level of the individual quarter and the cow. Overall, 14% of teats that took longer ($P<0.05$) than 3 weeks to close developed new IMI, compared to only 9.7% of teats that closed in the first 3 weeks. Teats that were cracked developed more ($P<0.05$) new IMI than teats that were not cracked (14.8% and 9.8%, respectively). Similarly, cows that had at least one teat cracked developed more ($P<0.05$) new IMI than cows that did not have any teats cracked (31.1% and 17.3%, respectively). Also, only 12.8% of cows that had all four teats close in the first 3 weeks of the dry period developed a new IMI, compared to 28.5% of cows that took longer ($P<0.01$) than three weeks for all teats to close.

A general but variable decline in the level of milk production occurred among herds from the time of enrollment until the day of dry off. On the day prior to dry off, which was the last time when two milkings occurred, the average milk production was 12.9 ± 0.4 kg. Level of milk production among herds at this time varied between 8.3 and 18.8 kg (Table 3). In total, more ($P<0.05$) cows (35.6%) that were producing greater than 21 kg on the day prior to dry off developed new IMI during the dry period, than cows (18%) producing less than that amount of milk developed a new IMI. An interesting finding from this study was the association between the level of milk production prior to dry off and the rate of teat canal closure. Using the same cutpoint of 21 kg of milk yield on the day prior to dry off when cows were producing above that level, teat canal closure took longer ($P<0.05$) time to occur than when milk production was less than 21 kg (Figure 1). The final proportional hazards model revealed that when milk production was greater than 21 kg, the hazard ratio (HR) for

a teat to close was reduced (HR=0.56), which implies that a teat remained open longer ($P<0.01$).

In the final logistic models, which controlled for breed, parity, dry period duration and season, it was determined that teat-end integrity, teat canal closure and milk production all remained significantly associated with the development of new IMI. Quarters that remained open were 1.8 times more ($P<0.05$) likely to develop a new IMI than quarters that were closed via formation of a natural keratin plug. Quarters that were defined to have a cracked teat end were 1.7 times more ($P<0.05$) likely to develop infections, than quarters that were never defined to be cracked. The final logistic model for a cow to develop a new IMI found that cows that had all four teat ends close within the first 3 weeks of the dry period were 75% less ($P<0.01$) likely to develop new IMI than cows that had at least one teat remain open for longer than 3 weeks. Cows that had at least one teat with a cracked teat end were 2.5 times more ($P<0.05$) likely to develop new dry period infections than cows that had no cracked teats.

In summary, this observational study followed 300 cows from 2 weeks prior to scheduled dry off, until after the dry period. By classifying teat-end integrity, assessing teat canal closure and recording daily milk production, several new findings were reported, and the association of various factors were reemphasized. Although teat end integrity has often been implicated in clinical mastitis during lactation, little information exists about the integrity of teats during the dry period. This study has shown the strong influence of teat end integrity both at the quarter and at the cow level to be a risk factor for new dry period IMI.

Closure of the teat canal during the dry period, by means of a naturally occurring keratin plug, has been proven to be an important defense mechanism. This study has not only reemphasized how important timely closure is, but also that natural closure may not occur in a very high percentage of teats. Furthermore, the level of milk production prior to dry off may determine teat canal closure. This indirect effect of milk production and its impact of teat canal closure should be explored in much more detail.

It would appear that management strategies aimed at improving teat-end integrity as well as enhancing teat canal closure during the dry period would be of benefit to decreasing new dry period IMI. Further elucidation of the impact of milk production on teat canal closure, coupled with a recognition of important quarter-level factors may allow for future management recommendations to be forthcoming.

Table 1. Descriptive Statistics of 300 Cows and Herds Enrolled in Study From Five Participating Sites

Variable		No. (%)	Mean	S. D.	95% CI
Parity	1	131 (43.7)			
	2	88 (29.3)			
	3	39 (13.0)			
	4+	42 (14.0)			
Breed	Holstein	256 (85.3)			
	Other	44 (14.7)			
Dry period (days)	Overall		65.2	13.4	
	Herd 1		74.9[b]		71.9 - 77.9
	Herd 2		75.1[b]		71.4 - 78.7
	Herd 3		60.8[a]		57.9 - 63.6
	Herd 4		66.2[b]		62.7 - 69.6
	Herd 5		58.4[a]		56.2 - 60.8
Season of dry off	Spring		63 (21.0)		
	Summer		91 (30.3)		
	Fall		107 (35.7)		
	Winter		39 (13.0)		

[a,b]Means with dissimilar superscript letters differ ($P<0.05$).

Table 2. Proportion of New Intramammary Infections During the Dry Period Across Various Factors and Herd and Cow Specific Rates of Teat Canal Closure

Item	Factor	Level	No.	% new IMI
Quarter	Herd	1	211	12.3[a]
		2	151	11.9[a]
		3	256	10.6[a]
		4	176	17.6[b]
		5	384	7.6[a]
	Time until closed	< 3 weeks	803	9.7[a]
		≥ 3 weeks	375	14.0[b]
	Teat-end integrity	No crack	791	9.8[a]
		Cracked	275	14.8[b]
Cow	Herd	1	55	16.4[a]
		2	38	21.1[a]
		3	65	29.2[ab]
		4	44	36.4[bc]
		5	98	10.2[a]
	All teats closed	< 3 weeks		12.8[a]
		≥ 3 weeks		28.5[b]
	Teat end integrity	>one teat cracked		31.1[a]
		No teats cracked		17.3[b]
	Milk production	≥ 21 kg		35.6[a]
		< 21 kg		18.0[b]

[a,b,c]Percentages within column, and within the same level of a factor, not sharing a similar superscript are significantly different at $P<0.05$.

Table 3. Summary Statistics of Teat Canal closure, Teat-end Integrity and Milk Production by Participating Herd

			Week						
Factor	Herd	Dry off	1	2	3	4	5	6	Total
% Open teats	Overall		46.8%	37.5%	31.8%	28.5%	24.8%	23.4%	23.4%
	1		42.2%	35.1%	27.9%	21.3%	16.1%	16.1%	
	2		51.7%	40.4%	35.8%	31.1%	26.5%	26.5%	
	3		83.2%	78.9%	75.0%	73.1%	69.5%	63.3%	
	4		23.9%	15.9%	11.9%	8.5%	7.4%	7.4%	
	5		33.6%	20.1%	12.8%	10.9%	7.0%	7.0%	
% Cracked teats	Overall	20.9%	6.0%	6.6%	9.4%	2.3%	2.1%	1.8%	
Milk production (kg)	Overall	12.9							
	1	12.7							
	2	12.1							
	3	18.8							
	4	15.9							
	5	8.3							

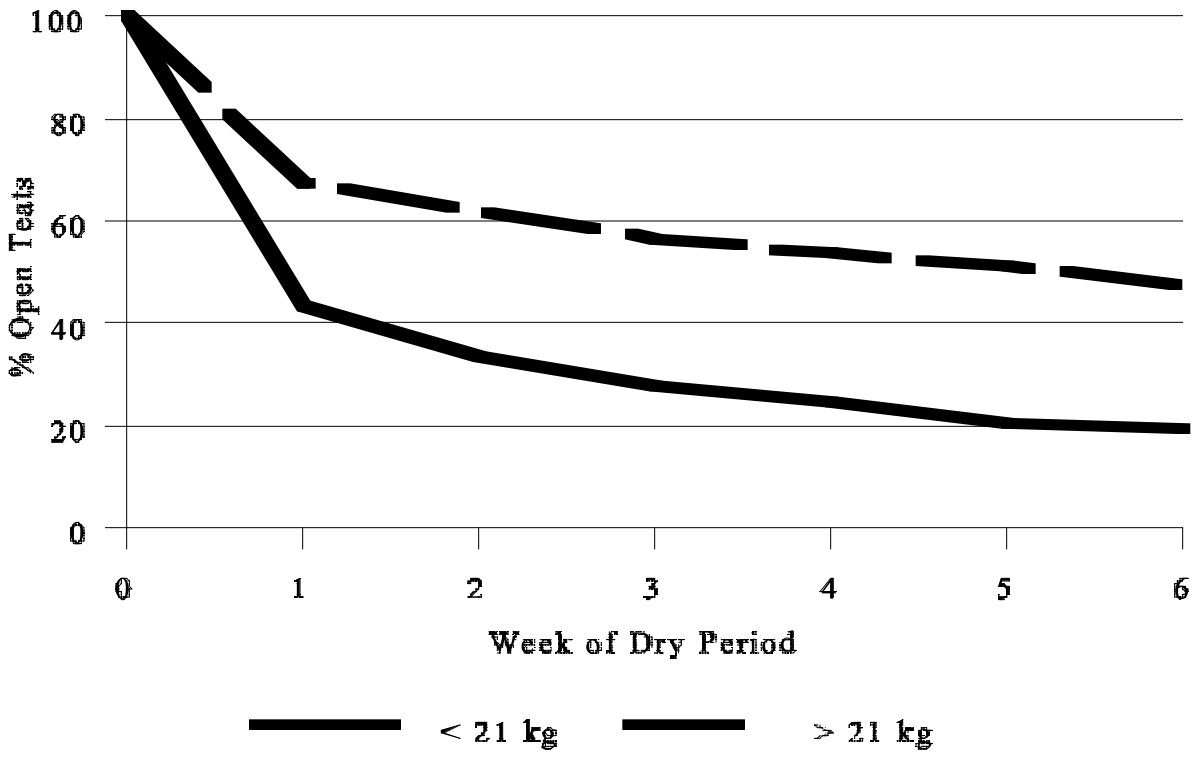

Figure 1. Proportion of Teats Classified as Open at Each of Six Weeks During the Dry Period, by the Level of Milk Production Prior to Dry Off.