Effect of Foot Lesions on Milk Production by Dairy Cows[1]

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ABSTRACT

Individual curves for milk production of 428 cows affected by foot lesions were compared with control curves drawn from data of healthy lactating cows. First, differences were classified into patterns of milk loss, and their distribution was analyzed among the patterns with regard to breed, season, parity, stage of lactation, and milk production. Then, individual milk losses were estimated and analyzed according to the same factors. During early lactation, as during mid to late lactation, no marked modifications of the lactation curves occurred for about one-half of the cases. In 25% of the cases, milk production was affected for an expanded period (medians were 17 wk for early lactation and 12 wk for mid to late lactation). Corresponding median milk losses were 440 and 270 kg, respectively. Summer foot lesions were more severe than winter lesions, regardless of stage of lactation. Milk production at foot lesion onset was a determining factor of the amount and pattern of milk loss only for cases occurring during mid to late lactation.
(**Key words**: dairy cows, foot lesion, milk production loss)

INTRODUCTION

Foot lesions are one of the major health problems of dairy cows (7). Associated risk factors have been extensively studied, especially environmental factors such as season (5, 6) and feeding practices (9, 12, 14), and a few studies have considered the influence of cow characteristics such as parity, milk production (4, 5, 6), or genetic aspects (15). Few studies (3, 13) have assessed the effects of foot lesions on milk production, and, to our knowledge, none has taken into account the individual variability of responses. Nevertheless, a previous study (10) on the impact of mastitis on milk production by dairy cows showed such variability. Using the same process, this present study was developed to describe and analyze the pattern of alteration of the lactation curve caused by foot lesions, according to cow characteristics (breed, lactation number, stage of lactation, and milk production) and season. Milk losses associated with each pattern were estimated and analyzed.

MATERIALS AND METHODS

Available Data

The data used in this study were recorded and arranged in a relational database for 3851 lactations in 1179 cows managed at three experimental farms (Institut National de la Recherche Agronomique; Theix, Orcival, and Marcenat, France) over the last 10 to 20 yr (11). The cows were in tie-stall barns in winter and grazed between May and October.

Foot lesions were clinical cases detected through observation of cow behavior and specified by foot examination. Classifications included lameness (6% of all the health disorders recorded in the database) and interdigital inflammation (phlegmona interdigitalis; 15% of all health disorders recorded in the database), which together represented the most frequently observed health disorders after mastitis in our database. Foot lesions were systematically treated with antibiotics and sometimes by hoof trimming. For each foot lesion, the characteristics of affected cows (breed, lactation number, production potential, and production at foot lesion onset), the period of occurrence (time of year and stage of lactation), and weekly milk production throughout the lactation were known. The production potential was estimated from the initial production (d 4, 5, and 6 of lactation) (2). Cases occurring near the time that cows were turned out to pasture (±3 wk) were excluded from the original sample because of the difficulty of observing any effect of foot lesion that was independent of turning out to pasture. During this period, milk production is affected by sudden, great changes (1).

Data Processing

Data processing was conducted as described by Lescourret and Coulon (10). The general principle

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was to examine the differences between individual production curves affected by foot lesion and control curves, according to variation factors, and separately for cases occurring in early lactation (first 5 wk of lactation) or in mid to late lactation (beyond the 5th wk). To avoid confusion between the effect of foot lesion and effects of other health disorders (such as mastitis, milk fever, or placental retention) on milk production, only cases not closely preceded or followed by one of these disorders were studied. Therefore, during early lactation, the only cases considered were unique cases not preceded and not followed within 5 wk by any of those other disorders. In mid to late lactation, the only cows considered were those that had been free of all previously mentioned diseases in early lactation and did not experience any of those diseases within 5 wk. Using data only from cows with no other complications in the lactation would have been best, but many cows in the data file would have been excluded. Our exclusion criteria were verified to be relevant by exhaustive graphical examination of the selected curves, which showed no abnormal alteration apart from the effect of foot lesions. Four control curves, defined by parity and initial production, were constructed by plotting mean milk production for each week of lactation drawn from the database for cows that had been free of any health disorder for the first 35 wk. Variation factors included season (winter housing period or pasture period, hereafter termed winter and summer, respectively), breed (Montbéliarde, Holstein, or Holstein × French Friesian, French Friesian, or Holstein × Montbéliarde), parity (1 or >1), week of lactation when the foot lesion occurred, and reference milk production. For cases occurring in early lactation, reference milk production was estimated from the initial production as in Lescourret and Coulon (10) and, for cases occurring in mid to late lactation, by the mean production of wk 4 and 3 preceding the onset of the foot lesion.

Differences among cows were classified according to type of milk response pattern to the foot lesion (intensity and duration). The pattern was analyzed according to variables (season, breed, parity, and reference production) through clustering of combinations of variables with respect to the distribution of response patterns. Each defined response profile corresponded to a specific probability distribution of response pattern (e.g., with three possible patterns,

TABLE 1. Characteristics of the three patterns of milk loss production response to foot lesion occurring in early lactation.

	Response pattern[1]			
	A	B	C	P
Cases				
no.	66	23	32	
%	55	19	26	
Reference production,[2] kg/d	18.6	21.5	19.2	NS[3]
Parity, no.				NS
1	25	4	11	
>1	41	19	21	
Breed, no.				**
Montbéliarde	17	4	13	
Holstein or Holstein × French Friesian	12	12	6	
French Friesian or Holstein × Montbéliarde	37	7	13	
Season, no.				*
Summer	5	0	7	
Winter	61	23	25	
Milk loss, kg				
First quartile	0	41	220	
Median	10	54	440	
Third quartile	18	99	722	

[1]Pattern A, no response; pattern B, decreased production with return to control values ≤5 wk following foot lesion; and pattern C, decreased production for >5 wk.

[2]Mean production of d 4, 5, and 6 of lactation.

[3]$P > 0.05$.

*$P < 0.05$.

**$P < 0.01$.

X, Y, and Z, 60% of pattern X, 10% of pattern Y, and 30% of pattern Z). Each profile concerned cows corresponding to one or more combinations of factors (e.g., Montbéliarde primiparous cows with low production, having experienced foot lesion in winter. Possible confounding effects between factors were taken into account, such as that between breed and milk production. Reference production levels were ≤17 kg/d, between 17 and 22 kg/d, or >22 kg/d. For each foot lesion case, milk loss was estimated as the cumulative difference between the control curve and the curve of the affected cow from the onset of the foot lesion until the end of the effect. The intraresponse pattern variation of production loss was analyzed according to the variables by means of a linear model when loss could be considered large enough.

RESULTS

Because of the exclusion criteria previously mentioned, only 438 of the 1284 observed cases were studied. Four response patterns were identified: no response (decrease in production relative to control <1 kg/d; pattern A), decreased production with return to control values within 5 wk following the foot lesion (pattern B), decreased production for >5 wk (pattern C), and early drying off (pattern D). Pattern D was the most severe; the median computed milk losses were 2132 kg. However, pattern D included only 10 cases (4 in early lactation and 6 in mid to late lactation) and was not considered thereafter. To define response profiles through combinations of factors with respect to the distribution of response patterns, we used combinations representing at least three cases of foot lesion, which amounted to 13 of the 36 theoretically possible and to 19 of the 24 during early lactation and during mid to late lactation, respectively. For pattern C, the duration of the effect was graphically assessed for each case, and loss was computed over this duration; to restrict bias, only cases not followed after 5 wk by severe disease were considered here (81 and 88% of cases in early lactation and in mid to late lactation, respectively).

The type of foot lesion (lameness or interdigital inflammation) was never significant for explaining response patterns or milk losses, except for pattern B losses in mid to late lactation.

Foot Lesions in Early Lactation

Description of response patterns. One hundred twenty-one foot lesions were studied. Only 12 cases occurred in summer. Fifty-five percent of the cases were not followed by marked modification of the milk production curve (pattern A). In contrast, 26% were followed by long-term modifications (pattern C, Table 1), which expanded over a period ranging mostly from 11 to 27 wk (first and third quartiles) with a

TABLE 2. Description and characteristics of the four response profiles for foot lesions in early lactation.

	Response profile			
	1	2	3	4
Cases	18	54	19	20
Combinations[1]	4	6	2	1
Response patterns, no.				
A	6	33	15	7
B	1	5	4	9
C	11	16	0	4
Parity, no.				
1	9	20	8	0
>1	9	34	11	20
Breed,[2] no.				
MO	14	16	0	0
HF	0	5	0	20
OB	4	33	19	0
Season, no.				
Summer	9	3	0	0
Winter	9	51	19	20
Reference production, kg/d	17.8[ac]	16.7[a]	21.9[bc]	25.6[b]

[a,b,c]Means in rows with different superscripts differ ($P < 0.05$).

[1]Associations of the variation factors.

[2]MO = Montbéliarde, HF = Holstein or Holstein × French Friesian, and OB = other breeds (French Friesian or Holstein × Montbéliarde).

median of 17 wk. When considered independently of one another, cow characteristics did not appear to be very different among patterns (Table 1). However, when considered together through combinations of factors, four response profiles could be contrasted (Table 2). Profile 1 was characterized by a high incidence of pattern C responses (61% of cases). Profile 1 essentially involved Montbéliarde cows, and most of the summer cases of foot lesions belonged to this profile. Profile 2, the largest (54 cases among the 121), had a high incidence of pattern A (61%), and the incidence of pattern C response was also important (30%). For profile 3, pattern A predominated (79%), and no incidence of pattern C occurred. Profiles 2 and 3 involved mostly French Friesian or Holstein × Montbéliarde cows (the only breed for profile 3), and these cows differed in reference production, which was low for profile 2 and high for profile 3. Patterns were rather evenly distributed for profile 4, but pattern B slightly predominated. Profile 4 concerned only multiparous Holsteins or Holstein × French Friesian cows with high reference production (Table 2).

Milk loss analysis. For response pattern A, the median production loss was 10 kg. For pattern B, this median was 54 kg. Pattern B losses were higher for primiparous than for multiparous cows (median, 110 vs. 46 kg; $P < 0.05$). No other factor was significant. For pattern C, the median production loss was 440 kg. No factor explained the variability of pattern C losses.

Foot Lesions in Mid to Late Lactation

Description of response patterns. Three hundred seven cases were studied. Forty-five percent of cases were not accompanied by marked modifications of the milk production curve (pattern A). Twenty-five percent were followed by long-term modifications (pattern C, Table 3), which expanded over a period ranging mostly from 8 to 20 wk (first and third quartiles; median, 12 wk). Reference production increased from pattern A to pattern C. Pattern B and pattern C cases occurred more frequently in summer (67 vs. 47% of cases for pattern A). Montbéliarde cows differed from other breeds in that they experienced fewer pattern C responses. This result led to the grouping of other breeds for subsequent analyses.

Regardless of stage of lactation, four profiles were identified (Table 4). Profiles 1 and 3 were characterized by a high proportion of pattern A responses. The proportions of B and C patterns were reversed in both

TABLE 3. Characteristics of the three patterns of milk loss production response to foot lesion occurring in mid to late lactation.

	Response pattern[1]			
	A	B	C	P
Cases				
no.	139	91	77	
%	45	30	25	
Reference production,[2] kg/d	19.0	20.1	22.3	**
Foot lesion onset, wk	17.8	20.0	17.8	NS[3]
Parity, no.				NS
1	52	24	21	
>1	87	67	56	
Breed, no.				**
Montbéliarde	40	35	13	
Other breeds	99	56	64	
Season, no.				**
Summer	66	65	48	
Winter	73	26	29	
Milk loss, kg				
First quartile	1	32	176	
Median	6	53	270	
Third quartile	15	85	604	

[1]Pattern A, no response; pattern B, decreased production with return to control values ≤5 wk following foot lesion; and pattern C, decreased production for >5 wk.

[2]Mean production during wk 4 and 3 preceding foot lesion onset.

[3]$P > 0.05$.

**$P < 0.01$.

profiles (the relative proportion of pattern C was high in profile 1, and the proportion of pattern of B was high in profile 3). Profile 1 involved no Montbéliarde cows. This profile included highly productive cows that were mainly primiparous. Eighty-nine percent of profile 1 cases occurred in winter. Profile 3 involved mainly multiparous cows with low reference production. For profile 2, pattern B had a high incidence rate, and pattern C had a low incidence rate. Profile 2 involved only Montbéliarde cows for which a majority of foot lesions occurred in summer. Patterns B and C represented 78% of profile 4 cases. Profile 4 included only summer cases and multiparous cows with high reference production.

Milk loss analysis. For response pattern A, the median production loss was 6 kg. For pattern B, this median was 53 kg. Pattern B losses were higher for cases of lameness than for cases of interdigital inflammation (median, 70 vs. 43 kg; $P < 0.05$). No other factor was significant. For pattern C, the median production loss was 270 kg. This loss (L) was linked to reference production (P), season (S; 0 = summer or 1 = winter), and week of foot lesion onset (W) according to the following model

$$L = 453 - 0.59P + 0.00021P^2 - 361S + 4226/W \pm 259; \; R^2 = 0.63.$$

The residuals were normally distributed.

DISCUSSION

This study has shown the very wide variability of milk production responses to foot lesions in both form and intensity as was observed previously for mastitis (10). The response pattern might have been a surrogate for lesion severity, the latter being unavailable in our data file, in that milk can provide indirect evidence of lesion severity. Throughout lactation, foot lesions had no effect on milk production in about one-half of the cases. These results might depend partly on peculiarities of therapies applied during the time our data were being assembled. Medicinal treatment was systematically applied at the time of detection. Detection was early, taking place >1 wk after the onset of production decrease in only 11% of the most obvious cases (patterns B or C). Moreover, most cows affected by foot lesions received special care during pasture and were grazed in paddocks close to the milking parlor in order to limit walking. As a consequence, mean losses did not appear to be drastic, a result that was in agreement with that of others (3, 13). Once adjusted for season, the distribution of patterns of loss was similar for early and mid to late lactation cases.

Season was a major factor affecting patterns and milk losses. The most severe effects occurred in summer, when the difficulty in grazing and pain experienced by affected cows explained the decreased

TABLE 4. Description and characteristics of the four response profiles for foot lesions in mid to late lactation.

	Response profile			
	1	2	3	4
Cases	83	31	106	82
Combinations[1]	5	3	8	3
Response pattern, no.				
A	44	11	62	18
B	13	18	29	31
C	26	2	15	33
Parity, no.				
1	44	11	39	0
>1	39	20	67	82
Breed,[2] no.				
MO	0	31	31	21
OB	83	0	75	61
Season, no.				
Summer	9	23	64	82
Winter	74	8	42	0
Reference production, kg/d	23.7[a]	19.2[b]	15.4[c]	23.0[ab]
Foot lesion onset, wk	12.2[a]	17.6[b]	22.0[b]	20.8[b]

[a,b,c]Means in rows with different superscripts differ ($P < 0.05$).

[1]Associations of the variation factors.

[2]MO = Montbéliarde; OB = other breeds.

production following onset of foot lesions. The higher the milk production was, the higher were the effects, because of greater nutritive requirements. This role of milk production was not observed during early lactation, either on patterns or on milk losses, probably because most cases occurred in winter when the cows did not walk (tie-stall housing). Milk production could not be considered to be a confounding effect, hiding the influence of live weight. Live weight has been proposed as an explanation for occurrence of foot lesions (8) and could also explain the severity of the effect on the lactation curve. However, there was no significant difference in live weight among patterns after adjustment for milk production and breed.

The effects of breed appeared to differ according to the stage of lactation during which foot lesions occurred. During early lactation, Montbéliarde cows were divided between patterns A and C, contrary to results for mid to late lactation. We could not interpret this difference. More generally, the associations of factors defining profiles for early lactation did not appear to be very consistent. In contrast, profiles for mid to late lactation were meaningful. The effect of season was different among breeds. Montbéliarde cows were affected mainly by pattern B cases in summer and by pattern A cases in winter. For other breeds, a cumulative effect of both season and milk production could be observed. Profile 4, which concerned cases occurring in summer for highly productive cows, had a minority of pattern A (22%), but profile 1, which concerned cases occurring in winter for highly productive cows, had a majority of this pattern (53%).

CONCLUSIONS

This study was limited by the difficulty of finding a consistent association of variables defining response profiles of milk production to foot lesions in early lactation. This difficulty may be solved partly by taking into account lesion severity. Moreover, knowledge is insufficient to allow interpretation of the interactions of variables during mid to late lactation. Cow response to medicinal treatment and other unknown characteristics, such as anatomy and grazing behavior, may be involved, but further research is needed to verify these points. As a consequence, these results should be used with caution in simulation models. In this study, the effects of foot lesions appeared to be less severe than those of mastitis, especially for milk loss (10), in agreement with results of Lucey et al. (13). Nevertheless, these results should not be neglected in simulation models of dairy cow performance.

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