

Milk Loss and Treatment Costs Associated with Two Treatment Protocols for Clinical Mastitis in Dairy Cows^{*,†}

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ABSTRACT

The objective of this study was to compare milk loss and treatment costs for cows with clinical mastitis that were given antibiotics in addition to supportive treatment or supportive treatment alone. Between January 1994 and January 1996, 116,876 daily milk records on 676 lactations were taken at the University of Illinois Dairy Research Farm. Clinical mastitis was diagnosed during 124 lactations with 25,047 daily milk records, and 1417 of the daily milk records were on days when clinical mastitis was present. Cows with clinical mastitis were randomly assigned to one of 2 treatment groups: N (supportive treatment only) or A (antibiotics in addition to supportive treatment). Extent of antibiotic and supportive treatment varied according to twice daily severity scores. Projected and actual daily milk yields were estimated utilizing a random regression test-day model, and the differences were summed over 305 d of lactation to estimate lactational milk yield loss. The actual amount of discarded milk was added to milk yield loss to determine total milk loss per lactation. A cost analysis that included milk loss and treatment costs was then performed. Cows with clinical mastitis that were given only supportive treatment lost 230 ± 172 kg (mean $\pm$ standard error of mean [SEM]) more milk and incurred $\$94 \pm 51$ (SEM) more cost per lactation than cows given antibiotics and supportive treatment. Cows given only supportive treatment showed a response pattern of 305-d milk yield loss and economic loss per lactation that varied 2 to 3 times as much as cows treated with antibiotics. Based on reduced milk loss, better reliability (less variable response), and

lower economic loss, the addition of antibiotics to supportive treatment was more efficacious and cost effective than supportive treatment alone.

(**Key words:** clinical mastitis, antibiotics, economics, milk yield)

Abbreviation key: A = antibiotics plus supportive treatment, ALC = actual lactation curve, CM = clinical mastitis, DMR = daily milk records, N = nonantibiotic treatment (supportive treatment only), PLC = projected lactation curve, rBST = recombinant bovine somatotropin, RRM = random regression test-day model.

INTRODUCTION

Mastitis is one of the most costly problems in the dairy industry. Nationally, mastitis is estimated to cost dairy producers 1.2 to \$1.7 billion per year or approximately 6% of the value of production (Wells and Ott, 1998). Reduced milk production is the major cost associated with subclinical mastitis and a substantial cost associated with clinical mastitis (CM) (Eberhart et al., 1987). A review by Schepers and Dijkhuizen (1991) indicated that mastitis caused a 40 to 50% decrease in the economic net margin per cow, with the largest part of this loss due to a 5 to 7% decrease in milk yield per lactation. Estimates of milk yield loss range from 100 to 500 kg/cow per lactation (Erb et al., 1985; Firat, 1993; Hortet and Seegers, 1998). When CM occurs, additional costs result from discard of abnormal milk, drugs, and veterinary services. Each case of CM has been estimated to cost between \$100 to \$200 per cow within the lactation (Jasper et al., 1982; Hoblet et al., 1991; Wilson et al., 1997).

Antibiotics are commonly used to treat CM episodes (Ziv, 1992). A variety of supportive treatments, such as oxytocin, frequent milk removal, intraruminal or intravenous fluids, and steroidal or nonsteroidal anti-inflammatory drugs, sometimes in conjunction with antibiotics, have also been used (Erskine et al., 1993), but few studies have compared the efficacy and cost effectiveness of different treatment protocols. Administration of antibiotics usually requires a withdrawal time,

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during which milk is unmarketable and must be discarded or fed to calves (Plummer et al., 1984). This cost can be substantial and is used as justification for avoiding antibiotic use. For example, Morse et al. (1987) calculated that the cost associated with discarded milk ranged from \$29.72 to \$166.18 per treated lactation at a milk price of \$11.50/cwt.

In a previous report based on the same data set used here, Morin et al. (1998) concluded that an antibiotic treatment protocol consisting of intramammary cephalosporin and intravenous oxytetracycline, combined with supportive treatment, resulted in less severe disease, higher clinical and bacteriological cure rates, and a lower CM recurrence rate, compared with supportive treatment alone. Those results suggested that antibiotic therapy was beneficial in terms of cow health and welfare, but economic factors were not reported. The recovery of milk yield, the amount of unmarketable milk, and drug costs all may have been affected by treatment protocols. The objective of this study, therefore, was to compare milk loss and treatment costs for cows with CM that were given antibiotics in addition to supportive treatment or supportive treatment alone.

MATERIALS AND METHODS

Mastitis Diagnosis and Treatment

Between January 1994 and January 1996, 116,876 daily milk records (DMR) on 676 lactations were taken at the University of Illinois Dairy Research Farm. Clinical mastitis was diagnosed during 124 lactations with 25,047 DMR, and 1417 of the records were on days when CM was present. Clinical mastitis was diagnosed if milk from one or more glands was abnormal in color, viscosity, or consistency, with or without accompanying heat, pain, redness, or swelling of the gland, or generalized illness (fever $>103^{\circ}\text{F}$, heart rate >90 beats per minute, rumen contractions <2 per 2 min, or dehydration $>6\%$). Based on initial physical examination, each cow was assigned a severity score of 0 (least severe) to 3 (most severe) and randomly assigned to 1 of 2 treatment groups (**A** or **N**). Affected cows were examined twice daily, within 30 min after machine milking, and severity scores, and treatments were adjusted accordingly (Morin et al., 1998). Examinations and treatments were discontinued when a cow received 3 consecutive severity scores of zero (no evidence of CM). If CM developed again within 60 d after previous diagnosis, the cow was returned to its previous treatment group. If CM developed more than 60 d after the last diagnosis, the episode was considered new, and the cow was randomly assigned to a treatment group.

Supportive treatment. Supportive treatment of cows with severity score 1 consisted of administration

of 20 units of oxytocin intravenously or i.m. within 30 min after machine milking, followed by hand milking of the affected gland(s) until milk removal was complete. A third oxytocin injection and milk removal was performed midway between a.m. and p.m. milkings for cows with a severity score of 2. Cows with a severity score of 3 received oxytocin and were hand milked every 3 h and were also given flunixin meglumine (Banamine; Schering-Plough Animal Health, Kenilworth, NJ; 1.1 mg/kg of BW) i.m. every 8 h. A chlorhexidine teat germicide (Fight Bac; SmithKline Beecham Animal Health, Exton, PA) was sprayed onto teats after milk was removed.

Antibiotic treatment. Cows in the antibiotic group received the same supportive treatment as cows (with comparable severity score) in the supportive treatment group, with the addition of antibiotics. Antibiotic treatment depended on the severity of the mastitis. For cows with a severity score of one, 200 mg of cephalosporin sodium (Cefa-Lak; Fort Dodge Laboratories, Fort Dodge, IA) was infused into the affected gland(s) twice daily. Cows with a severity score of 2 received intravenous oxytetracycline (16.5 mg/kg of BW) every 24 h, in addition to cephalosporin twice daily. Cows with a severity score of 3 received only intravenous oxytetracycline along with supportive treatment. Justification for the selection of these antibiotics is provided in Morin et al. (1998).

Structure of Data

Breed identification, parity, freshening dates, and recombinant BST (**rBST**) records were obtained from the University of Illinois Dairybase database (Spahr et al., 1993). Dry matter weights were converted to kilogram equivalent by a conversion factor (1 kg = 2.20463 lb). Season-year of freshening was coded as a continuous period from September to February or March to August for all cows with DMR in the 2-yr period and contained 6 levels. Each DMR was coded with a "status" variable. If the DMR was in a lactation that was free of CM, the status variable was coded with a zero. If CM was diagnosed within a lactation, the lactation was considered mastitic, and each DMR within the lactation was coded with a status of 1 to 6: 1—within 15 d before initial CM diagnosis; 2—CM present; 3—intermastitis interval (days in between 2 CM episodes); 4—within 30 d after end of CM (no subsequent episodes); 5—days before status 1; 6—days after status 4.

The 15-d period before and 30-d period after were chosen based on a preliminary analysis of the data using all combinations of 15, 30, and 45 d before and after clinical mastitis episodes. The analysis showed that the period of 15 d before and 30 d after clinical mastitis

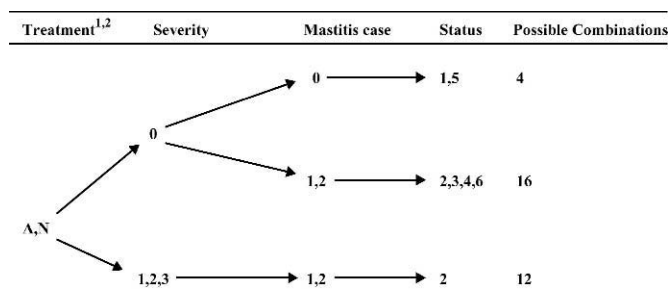


Figure 1. Construction of “mastitis treatment” variable. ¹Period of >150 d and ≤ 150 d coded for all levels. ²Treatment of no mastitis (NM) was ‘0’ for all levels.

was the period that showed the most significance when compared with all other days before or after clinical mastitis diagnosis.

A “mastitis treatment” variable was assigned to each DMR. The variable was constructed with treatment group (no treatment, supportive treatment only, or supportive treatment plus antibiotic treatment), severity score (0 to 3), mastitis episode (first, second, or greater), status code (0 to 6), and period of mastitis occurrence (≤150 DIM, >150 DIM). Of the 65 possible combinations (Figure 1) of variables for construction of “mastitis treatment,” 6 were never observed. If cows were treated with rBST, a variable “day” was coded with the deviation of the test-day from last administration of rBST up to d 14, otherwise “day” was coded with a zero. A breakdown of breed, lactation number, period of mastitis occurrence, and treatment group assignments can be found in Morin et al. (1998).

Statistical Analysis

Data were analyzed using a random regression test-day model (RRM) to estimate the effect of treatment protocol on daily milk yield. Estimates were obtained from the Proc Mixed procedure of SAS (Littell et al., 1996).

The model equation was:

$$Y_{ijklmnop} = \mu + TD_i + B_j + P_k + D_l + M_m + S_n + \sum_{q=0}^4 \beta_q z_{opq} + \sum_{q=0}^4 \alpha_{oq} z_{opq} + PD_{kl} + BPS_{jkn} + e_{ijklmnop} \quad [1]$$

where

$Y_{ijklmnop}$ = daily milk yield on test day i , on DIM p , for cow o of breed j , in parity k , freshening in season-year n , in rBST day l , with mastitis treatment m ,

μ = overall mean,

TD_i = fixed effect of test-day, $i = 1$ to 730,

B_j = fixed effect of breed, j = Holstein or non-Holstein,

P_k = fixed effect of parity, $k = 1$ or 2 and greater,

D_l = fixed effect of days after rBST, $l = 0$ to 14,

M_m = fixed effect of mastitis treatment, $m = 1$ to 59,

S_n = fixed effect of season-year of freshening, $n = 1$ to 6, and

β_q and α_{oq} = fixed and random regression coefficients, respectively, $q = 0$ to 4.

Let

$$z_{opq}^1 = (z_{p0} \ z_{p1} \ z_{p2} \ z_{p3} \ z_{p4}) = (1 \ c \ c^2 \ d \ d^2)$$

where

$c = t_p/305$ and $d = \ln(305/t_p)$ and

t_p = random effect of DIM $\sim \text{iidN}(0, \sigma_t^2)$,

PD_{kl} = fixed effect of the 2-way interaction among parity and days after rBST,

BPS_{jkn} = fixed effect of the 3-way interaction among breed, parity, and season,

$e_{ijklmnop}$ = random residual term $\sim \text{iidN}(0, \sigma_e^2)$.

Additional interactions were included in preliminary analyses but were found not to be significant.

Estimate of 305-d Milk Yield Loss

Two RRM were evaluated to derive 305-d milk yields. Due to missing milk-yield records, 305-d lactation curves could not be simply assembled by taking cumulative daily yields over the lactation. Four lactations used both treatment protocols and were eliminated from analysis. The first RRM used the full available data set to develop “actual lactation curves” (ALC). A second edited data set was created by removing DMR on days affected by CM (status 2), days in-between 2 episodes of CM (status 3), and the 30-d period after CM (status 4). The remaining DMR, which made up the edited data set, were assumed to be unaffected by CM. The edited data set was used in the second RRM to develop “projected lactation curves” (PLC). The 2 RRM were parameterized with the respective set of estimates to predict daily milk yields for the 124 mastitic lactations. Each DMR was coded with the cow, lactation, and treatment variable. The daily milk yields were summed for each lactation to get 305-d milk yield estimates for both the ALC (mastitic) and the PLC (mastitis-free). The difference in yields between the ALC and PLC was considered the 305-d milk yield loss due to CM.

Table 1. Predicted lactational (305-d) milk yield.

Random regression model	Treatment group	Number of observations	Mean	SD	Min	Max
					(kg)	
PLC ¹	All	120	8265	1733	4383	13,495
	A ²	61	8205	1538	4975	11,123
	N ³	55	8359	1991	4383	13,495
ALC ⁴	All	124	7849	1662	3064	11,163
	A	63	7975	1517	5002	11,163
	N	57	7838	1870	3064	11,111

¹Projected lactation curves: predicted yields for mastitic lactations assuming no clinical mastitis.

²Antibiotics plus supportive treatment.

³Supportive treatment only.

⁴Actual lactation curves: actual yields for mastitic lactations.

Cost Analysis

A cost analysis was performed for lactations with at least one episode of CM. The data set contained 63 lactations in which antibiotics were used in addition to supportive treatment, 57 lactations in which supportive treatment alone was used, and 4 lactations in which both treatment protocols were used. Costs of medications and supplies were taken from the catalogs of Valley Veterinary Supply (summer 2000), KV Vet Supply (2000), Omaha Vaccine Company (2000 spring/summer catalog), Lambriar Animal Health (November 1999), and Jeffers (spring 2000).

The frequency of each mastitis severity score >0 in the lactation was multiplied by the associated cost of treating that score (drugs and supplies) to arrive at the total cost of treatment per lactation. For cows in the antibiotic group, milk produced during episodes of CM plus milk produced for 4 d after the end of antibiotic treatment were considered unmarketable due to antibiotic residues and subtracted from the cow’s marketable milk yield total. Milk produced during CM episodes was considered unmarketable for cows in the supportive treatment group. Milk produced for 3 d after treatment with flunixin meglumine was considered unmarketable for both groups of cows. After deletion of daily milk yields for unmarketable milk days, new adjusted 305-d “marketable” milk yields were tabulated. The difference was taken between the adjusted and projected 305-d milk yield to calculate the total milk loss due to unmarketable or unproduced milk. A milk price of \$0.2632/kg of milk, as calculated from the February 2001 class 1 mover price of \$11.94/cwt, was used to determine the cost of milk loss per lactation.

RESULTS AND DISCUSSION

A full complement of statistical tests of hypotheses along with parameter estimates can be found in the thesis of Shim et al. (2001).

Milk Losses Due to Clinical Mastitis Under the 2 Treatment Protocols

Predicted 305-d milk yields for the actual and projected data sets for mastitic lactations are shown in Table 1. Four mastitic lactations had DMR only during the period of CM and the 30-d period after CM. Predicted lactation curves could not, therefore, be formulated for these 4 lactations due to a lack of remaining DMR after data edit. The distribution of 305-d milk yields for both PLC and ALC was approximately normal.

The most appropriate way to estimate 305-d milk yield loss was to calculate the loss for each individual mastitic lactation. This method accounted for individual variability in milk response by calculating milk loss from projected and actual 305-d yields for each mastitic lactation. The results are presented in Table 2.

On average, the addition of antibiotics to supportive treatment “recovered” 346 ± 172 kg (difference in unproduced milk between 2 treatment groups) of milk yield, although not all of the “recovered” milk was marketable (Table 2). When adjusted for discarded milk, the increase in recovered milk associated with antibiotic treatment decreased to 230 ± 181 kg (difference in unmarketable milk between 2 treatment groups). Hortet and Seegers (1998) estimated the average milk yield loss associated with CM to be 300 to 400 kg per lactation (4 to 6%). Their estimate was based on single cases of CM in Holstein cows. The average milk yield loss due to CM in our study was 327 ± 172 kg and within the range estimated by Hortet and Seegers (1998). Although our data set contained breeds other than Holsteins and lactations with more than one CM episode, 63% of the data was from Holsteins with single episodes of CM.

The variance of 305-d milk yield loss in the supportive treatment group (1129 kg)² was about 3 times greater than in the antibiotic treatment group (620 kg)². Simi-

Table 2. Predicted lactational (305-d) milk yield loss for cows with clinical mastitis.

Treatment group	Loss type	Number of observations	Mean loss	SD	Min	Max
			(kg)			
A ¹	Unproduced milk ²	61	182	620	−926	1883
A	Unmarketable milk ³	61	513	686	−471	2580
N ⁴	Unproduced milk	55	528	1129	−586	4049
N	Unmarketable milk	55	743	1181	−385	4248

¹Antibiotics plus supportive treatment.
²Milk loss due to unproduced milk.
³Milk loss due to unproduced milk plus discarded milk.
⁴Supportive treatment only.

larly, the variance in mastitis duration was a little less than twice as great in the supportive treatment group (10 d)² compared with the antibiotic treatment group (8 d)². Therefore, use of supportive treatment alone resulted in more variable rates of CM resolution and milk yield recovery than use of antibiotics plus supportive treatment.

Negative milk yield loss indicates that some cows had higher 305-d milk yield than projected without CM. This apparent milk gain associated with CM may be the result of inaccuracy in estimation of the 305-d milk yields due to underestimation of PLC, overestimation of ALC, or both. Dohoo and Martin (1984) discovered a small beneficial relationship between CM and milk production, and it is possible that a similar relationship occurred in this study (higher-producing cows had CM). The majority of lactations (20 of 24) with negative estimates of milk yield loss had less than 12 d of CM, and CM was diagnosed before 60 or after 250 d of lactation. In cases in which CM occurred before 60 d of lactation, most of the DMR used in the PLC estimate occurred after CM and may have been affected by the carryover effect of mastitis. Clinical mastitis that occurred before 60 d of lactation may also have affected peak milk yield. These 2 factors could have contributed to underestimation of projected 305-d milk yields. The low number of records at both extremes of lactation could have contributed to the underestimation of projected 305-d milk yield and led to a negative milk loss estimate.

Response of Milk Yield to Clinical Mastitis Treatment

Table 3 quantifies daily milk yield losses before, during, and after CM, as compared with projected milk yields using the differences between the ALC and PLC for each cow. For this analysis, days coded with a status of 5 (more than 15 d before first CM diagnosis) or 1 (within 15 d before CM diagnosis) were considered to be “before mastitis”; days coded with a status of 2 (CM

present) or 3 (days between 2 episodes of CM) were considered to be “during mastitis”; and days coded with a status of 4 (within 30 d of last CM diagnosis) or 5 (after 30 d of last CM diagnosis) were considered to be “after mastitis.” Average milk yield losses before and during CM were similar for cows in groups A and N, with a slightly greater loss during CM for cows given supportive treatment alone. However, after resolution of CM, cows given antibiotics along with supportive treatment returned to normal performance, whereas cows given supportive treatment alone incurred continued loss.

The continued milk yield loss in group N cows may have been the result of more persistent subclinical infections or more marked alteration of mammary gland function. Estimates of PLC were based on milk yields before CM onset and beyond 30 d after CM resolution. In calculating PLC, the assumption was made that milk yield before and after CM would be unaffected by CM. Based on continued loss, the use of yields after the CM may have led to low PLC estimates. In that case, actual milk yield losses for lactations of cows given supportive treatment alone may have been even greater than calculated.

Calculation of milk yield loss per lactation assumed that all cows with CM remained in the herd for the full lactation. In reality, not all cows stayed in the herd for

Table 3. Average daily milk yield loss in lactations with clinical mastitis.

	Treatment group			
	A ¹		N ²	
	Mean	SE	Mean	SE
(kg)				
Before clinical mastitis	0.36	0.06	0.18	0.11
During clinical mastitis	4.16	0.13	5.35	0.35
After clinical mastitis	−0.03	0.05	2.56	0.62

¹Antibiotics plus supportive treatment.
²Supportive treatment alone.

Table 4. Lactational (305-d) cost due to milk yield loss and treatment of cows with clinical mastitis.

Treatment group	Cost category	Mean loss	SD	Min	Max
A ²	Treatment cost	\$49	\$44	\$4	\$185
A	Unproduced milk ^{1,3}	\$48	\$163	-\$244 ⁴	\$496
A	Unmarketable milk ^{1,5}	\$135	\$181	-\$124	\$679
A	Total ⁶	\$201	\$199	-\$97	\$746
N ⁷	Treatment cost	\$28	\$22	\$3	\$109
N	Unproduced milk	\$139	\$297	-\$154	\$1066
N	Unmarketable milk	\$196	\$311	-\$101	\$1118
N	Total	\$295	\$329	-\$65	\$1757

¹Based on the February 2001 class 1 mover price of \$0.2632 per kg.
²Antibiotics plus supportive treatment.
³Milk loss due to unproduced milk.
⁴Milk was recovered rather than lost (economic gain due to clinical mastitis).
⁵The milk loss due to unproduced milk plus discarded milk.
⁶Cost of treatment plus unmarketable milk.
⁷Supportive treatment only.

the full 305-d period, but there was no significant ($P > 0.05$) difference in average lactation length between the 2 treatment groups. To make milk losses and economic cost more comparable, full 305-d lactations were assumed for both treatment groups.

Cost Analysis

Results of the cost analysis are shown in Table 4 and assume that none of the unmarketable milk was fed to calves. Use of antibiotics and supportive treatment, rather than use of supportive treatment alone, resulted in an increased treatment cost of $\$21 \pm 6$ (SEM) per lactation. However, the addition of antibiotics to supportive treatment reduced the total economic loss by $\$94 \pm 51$ (SEM) per lactation as a result of less milk yield loss. The variance of total cost in the supportive treatment group ($\$329$)² was about 3 times greater than in the antibiotic treatment group ($\$199$)².

In both treatment groups, treatment costs were significantly lower than the costs associated with milk loss without adjusting for milk fed to calves. In the antibiotic group, treatment costs were approximately one third of the costs of unmarketable milk, whereas in the supportive treatment group, treatment costs were less than one tenth of the unmarketable milk costs.

The total cost (cost of treatment plus unmarketable and unproduced milk) ranged from \$0 to \$399 for 78% of mastitic lactations treated with antibiotics along with supportive therapy. Total losses for lactations treated with supportive therapy alone were more varied, but 82% of the losses were between \$0 to \$399. Whereas treatment costs were higher and more varied when cows with CM were given antibiotics along with supportive treatment, the total 305-d milk loss and total economic loss were less varied. A producer might choose

to use antibiotics along with supportive treatment because the total economic loss is more predictable and manageable, whereas the effects of supportive treatment are more inconsistent and have a higher average cost. Higher milk prices would have made the addition of antibiotics to supportive therapy more economically beneficial.

The cost analysis was not all inclusive. Ideally, a cost analysis should include labor costs associated with treatment, losses associated with premature cullings and deaths, and a measure of feed intake, in addition to adjustment for discard milk fed to calves. In this study, labor was provided mainly by study personnel, and time spent examining each cow was longer than usual to collect research data. Therefore, labor costs were not quantified. Culling costs were also difficult to quantify because cows were typically culled for a combination of reasons, making it difficult to attribute culling specifically to CM. In this study, only 2 cows (both in the N group) died or were euthanized as a result of CM. These cows did not have enough DMR to be included in production and cost analysis.

CONCLUSIONS

Based on reduced 305-d milk loss, better predictability, quicker resolution of CM, and lower average economic loss, the addition of antibiotics to supportive treatment of CM was determined to be more cost effective than supportive treatment alone. When combined with previous data indicating improved efficacy and animal welfare associated with antibiotic treatment (Morin et al., 1998), the avoidance of antibiotics for CM seems imprudent and unethical. This study involved only one herd and one set of treatment protocols. Results cannot necessarily be generalized to other herds

using other treatments. Additional research involving alternate antibiotic and supportive treatment protocols in a variety of herds is warranted to determine the most efficacious and cost-effective methods of treating CM.

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