Herd Management Practices and Their Association with Bulk Tank Somatic Cell Count on United States Dairy Operations

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ABSTRACT

The objective of this study was to evaluate associations between bulk tank somatic cell count (BTSCC) and herd management practices using data collected in the National Animal Health Monitoring System Dairy 2002 study. Twenty-six percent and 17.8% of 1,013 operations reported a BTSCC <200,000 cells/mL and >400,000 cells/mL, respectively. Univariate analysis identified associations between management variables and BTSCC. The use of mattresses, sand, and newspaper as bedding were all associated with a lower BTSCC. Primary lactating cow housing facility, outside maternity housing area, flooring type cows walk or stand on, and use of automatic take-offs were also associated with BTSCC. Multivariate associations between management variables and BTSCC were determined by backward elimination ordinal logistic regression. The odds of an operation from the West, Midwest, and Northeast having a high BTSCC were lower than those from the Southeast. The odds of a higher BTSCC were 2 times greater for operations with a rolling herd average milk production <9,090 kg/cow per year compared with those with ≥9,090 kg/cow per year. Operations using composted manure were 2.9 times more likely to have a higher BTSCC than those not using composted manure. Finally, operations that reported not using a coliform mastitis vaccine were 1.7 times more likely to have a higher BTSCC than those using one. Future studies of the association between management practices and BTSCC should include an evaluation of the quality of management practice application and herd prevalence of contagious mastitis pathogens. Significant variables identified in this study dealt with housing, use of composted manure for bedding, and coliform mastitis vaccine use, suggesting the effect of environmental masti-

tis pathogens may be more influential on BTSCC than previously thought.

Key words: bulk tank somatic cell count, mastitis, management

INTRODUCTION

Bulk tank SCC (**BTSCC**) is a function of the prevalence of IMI within a dairy herd and is a key indicator of milk quality. The legal maximum BTSCC (750,000 cells/mL) in the United States is higher than in other developed, dairy-exporting countries, and an evaluation of DHIA SCC data indicated 29% of herd test days had an SCC that exceeded 400,000 cells/mL, with the highest percentage of those test days (40%) coming from the Southeast region of the country (Norman et al., 2000). If the US dairy industry is to remain competitive in the global market and maintain a positive image, further work is needed to lower BTSCC. Furthermore, many processors pay quality premiums for low-BTSCC milk, because there is a negative relationship between SCC and casein composition and shelf life of processed fluid milk (Ali et al., 1980; Ma et al., 1999). Ott and Novak (2001) demonstrated that herds with a BTSCC <200,000 cells/mL attained significantly more profit per cow than herds with a BTSCC ≥400,000 cells/mL. These data indicate that it is worthwhile to implement cost-effective management practices that reduce BTSCC.

Numerous studies have attempted to determine associations between management practices and BTSCC level or herd mean SCC. These studies were from Europe (Faye et al., 1997; Barkema et al., 1998) and different states and regions within the United States (Erskine et al., 1987; Hutton et al., 1990; Bartlett et al., 1992; Goodger et al., 1993; Norman et al., 2000; Rodrigues and Ruegg, 2005). However, there have been no recent reports of the association between producer-reported management practices and BTSCC on a national level in the United States.

The objective of this study was to evaluate associations between BTSCC and herd management practices using data collected in the National Animal Health

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Monitoring System Dairy 2002 study representing the US dairy industry.

MATERIALS AND METHODS

States and operations selected to participate in the National Animal Health Monitoring System Dairy 2002 study were chosen to represent more than 80% of dairy cows and operations. Final selection included 21 states from 4 regions (West: California, Colorado, Idaho, New Mexico, Texas, and Washington; Midwest: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin; Northeast: New York, Pennsylvania, and Vermont; Southeast: Florida, Kentucky, Tennessee, and Virginia).

Operations were randomly selected from a list sampling developed by the National Agricultural Statistics Service. Within each state, a stratified random sample was selected based on herd size. Operations with 1 or more milking cows were eligible for data collection via a questionnaire conducted by the National Agricultural Statistics Service enumerators from December 31, 2001, until February 12, 2002. Of the 3,876 eligible operations, 3,466 operations completed the initial questionnaire. Operations completing the initial questionnaire and milking 30 or more cows were invited to participate in an additional management questionnaire. A total of 1,013 operations completed the management questionnaire administered on-farm by a veterinary medical officer or animal health technician from February 25 to April 30, 2002. Additionally, producer-reported BTSCC was compared with a single milk sample collected at the time of the management questionnaire administration on a subset of 741 operations.

Producer-reported BTSCC was categorized as follows: <200,000 cells/mL, from 200,000 to 400,000 cells/mL, and >400,000 cells/mL. Management variables plausibly associated with BTSCC were selected for univariate analysis. Univariate associations between a priori-selected management variables and BTSCC category were evaluated using the PROC CROSSTAB procedure in SUDAAN software (SUDAAN Release 9.0, Research Triangle Institute, Research Triangle Park, NC), which accounts for the sampling design weights. Ordinal variables present after univariate screening ($P < 0.25$) were subjected to oblique principal components cluster analysis using a maxeigen value = 1.0. Adult herd size and rolling herd average (RHA) milk production variables were ordinal variables not included in the cluster analysis, because we wanted to examine their role as confounders and effect modifiers in the final model construction. Indicator variables chosen from each cluster for inclusion in the ordinal logistic regression model were those with the lowest $1-R^2$ within

each cluster, indicating they were most representative of the cluster. Backward elimination ordinal logistic regression using the PROC MULTLOG procedure in SUDAAN was used to create a final model, which included variables with a Wald- $F P \leq 0.05$. Ordinal logistic regression analysis assumes the effect of a variable is the same when comparing the lowest BTSCC group with the middle as comparing the middle with the highest group. This assumption may not be true, and the use of SUDAAN, which allowed analysis of weighted data, does not provide a proportional odds test to evaluate this assumption. Therefore, the final model obtained from SUDAAN was run without weighting in SAS, and the score test for the proportional odds assumption was evaluated.

RESULTS

Observations from 1,013 operations were included in the analysis. Twenty-six percent and 17.8% of operations reported a BTSCC <200,000 cells/mL and >400,000 cells/mL, respectively. Of the 741 operations in which BTSCC was measured from collected milk samples, only 17.3% of operations reported a BTSCC lower than the measured BTSCC. Thirty-eight of 88 selected management-related variables were significant via weighted univariate screening and were eligible for inclusion in the final model (Table 1). Region of the country and adult herd size were associated with BTSCC ($P < 0.001$; Table 1). Operations reporting ≥ 500 adult cows were associated with a lower BTSCC and those in the Southeast with a higher BTSCC. A higher RHA milk production ($\geq 9,090$ kg/cow per year) was associated with a lower BTSCC ($P < 0.001$). Cattle importation practice variables indicated 55.9% of operations imported new cattle during 2001, and there was no association with BTSCC. Weaned heifers were imported onto 9.6% and lactating cows onto 19.9% of operations. There was a tendency for an association between bringing weaned heifers onto the operation and a higher BTSCC ($P = 0.059$). Concrete flooring for cows to walk and stand on was reported by 69.3% of operations, and there was an association between flooring type and BTSCC ($P = 0.045$; Table 1).

Associations were also identified between bedding types used for lactating cows and BTSCC. Mattress use was reported by 22.7% of operations and was associated with a lower BTSCC ($P < 0.001$). Sand bedding use was reported by 21.5% of operations and was associated with a lower BTSCC ($P = 0.022$). Newspaper bedding use was reported by 7.2% of operations and was associated with a lower BTSCC ($P = 0.006$). Composted manure use was reported by only 6.1% of operations, and there was a tendency for an association with a higher

Table 1. Herd management variables associated ($P < 0.25$) with bulk tank SCC (BTSCC) by univariate analysis of data from 1,013 dairies in 21 states

Initial model variable	Variable level	Herds (%)	Herds by BTSCC (%)			P-value ²
			<200 ¹	200 to 400 ¹	>400 ¹	
All operations (weighted)		100	26.0	56.2	17.8	
Region	West	20.5	23.6	61.4	15.0	<0.001
	Midwest	44.2	25.5	57.0	17.5	
	Northeast	27.5	32.9	54.4	12.7	
	Southeast	7.8	4.4	49.7	45.9	
Rolling herd average (kg/cow per yr)	<9,090	46.8	20.2	56.3	23.5	<0.001
	≥9,090	53.2	34.3	56.2	9.5	
Herd size (adult cows)	<100	39.4	23.6	61.4	15.0	<0.001
	100 to 499	38.7	25.5	57.0	17.5	
	≥500	21.9	32.9	54.4	12.7	
Cattle importation practices						
Any cattle brought onto operation	Yes	55.9	26.2	52.3	21.5	0.097
	No	44.1	25.7	59.7	14.6	
Weaned heifers brought onto operation	Yes	9.6	40.7	48.7	10.6	0.059
	No	90.4	24.7	56.9	18.4	
Lactating cows brought onto operation	Yes	19.9	21.4	53.2	25.4	0.122
	No	80.1	26.9	56.9	16.2	
Housing						
Flooring cows walk and stand on	Concrete	69.3	27.6	55.6	16.8	0.045
	Dirt	10.6	18.5	58.0	23.5	
	Pasture	9.4	11.8	58.4	29.8	
	Other	3.5	38.4	52.1	9.5	
	Rubber over concrete	7.2	30.9	58.8	10.3	
Surface moisture during winter	Usually dry	51.0	26.3	53.0	20.7	0.009
	Wet 50% of the time	23.6	19.8	60.6	19.6	
	Almost always wet	25.4	32.4	57.1	10.5	
Surface moisture during summer	Usually dry	33.5	24.5	54.9	20.6	0.020
	Wet 50% of the time	28.0	23.5	60.8	15.7	
	Almost always wet	38.5	36.0	55.2	8.8	
Mattress bedding for lactating cows	Yes	22.7	35.2	57.8	7.0	<0.001
	No	77.3	24.0	55.9	20.1	
Composted manure bedding for lactating cows	Yes	6.1	12.0	60.4	27.6	0.082
	No	93.9	26.3	56.1	17.6	
Straw bedding for lactating cows	Yes	40.8	26.3	53.5	20.2	0.224
	No	59.2	25.5	59.5	15.0	
Sand bedding for lactating cows	Yes	21.5	35.5	53.3	11.2	0.022
	No	78.5	23.8	56.9	19.3	
Newspaper bedding for lactating cows	Yes	7.2	48.1	43.4	8.5	0.006
	No	92.8	24.0	57.4	18.6	
Manure pack used	Yes	44.5	26.6	59.9	13.5	0.075
	No	55.5	25.5	53.3	21.2	
Primary outside area lactating cows	Drylot	36.7	31.7	49.6	18.7	0.151
	Pasture	32.6	21.6	59.7	18.7	
	None	30.7	27.2	58.1	14.7	
Primary outside maternity area	Drylot	35.1	24.5	58.0	17.5	0.012
	Pasture	32.4	18.8	61.0	20.2	
	None	32.5	35.7	49.1	15.2	
Primary lactating cow housing facility	Free stall	52.9	30.0	57.7	12.3	0.014
	Multiple-animal area	13.9	21.3	54.1	24.6	
	Tie stall, stanchion	26.9	25.3	55.4	19.3	
	Pasture, drylot	6.3	10.5	57.2	32.3	
Milking and cow management						
Use of automatic takeoffs	Yes	59.3	22.8	65.8	11.4	<0.001
	No	40.7	27.7	50.9	21.4	
Times per day cows are milked	1 to 2	18.7	26.0	55.7	18.3	0.233
	3+	81.3	24.8	64.7	10.5	

Continued

Table 1 (Continued). Herd management variables associated ($P < 0.25$) with bulk tank SCC (BTSCC) by univariate analysis of data from 1,013 dairies in 21 states

Initial model variable	Variable level	Herds (%)	Herds by BTSCC (%)			P-value ²
			<200 ¹	200 to 400 ¹	>400 ¹	
Forestripping performed	All	48.8	26.2	56.6	17.2	0.060
	Some	38.5	22.6	61.0	16.4	
	None	12.7	36.0	39.3	24.7	
Postdip used in winter	Yes	95.1	24.8	57.5	17.7	0.123
	No	4.9	41.0	40.1	18.9	
Use of coliform mastitis vaccine	Yes	49.5	32.1	54.9	13.0	0.017
	No	50.5	22.5	57.0	20.5	
Use of <i>Salmonella</i> vaccine	Yes	17.1	35.0	53.6	11.4	0.225
	No	82.9	25.0	56.5	18.5	
Vitamin A-D-E injection given	Yes	21.8	18.6	63.6	17.8	0.143
	No	78.2	27.4	54.8	17.8	
Se injections given	Yes	25.5	28.1	59.8	12.1	0.228
	No	74.5	25.4	55.4	19.2	
Antibiotic treatment at end of lactation	None	4.4	14.8	64.4	20.8	0.062
	Some	14.4	19.3	54.6	26.1	
	All	81.2	28.5	56.1	15.4	
Cows with docked tails in herd	Yes	55.9	26.3	59.4	14.3	0.088
	No	44.1	25.6	52.9	21.5	
Time calves separated from dam	Immediate	56.8	28.8	56.1	15.1	0.003
	<12 h	22.5	23.2	62.4	14.4	
	12 to 24 h	13.7	24.4	53.4	22.2	
	>24 h	7.0	14.9	45.6	39.5	
Percentage of cows culled	<20%	33.4	22.8	56.3	20.9	0.192
	≥20% and <30%	38.8	31.2	52.8	16.0	
	≥30% and ≤40%	22.8	20.9	63.3	15.8	
	>40%	5.0	35.9	49.8	14.3	
Culled for reproductive problems	0%	13.6	24.5	49.8	25.7	0.067
	>0% and <30%	41.9	28.5	56.5	15.0	
	≥30% and <60%	35.9	21.7	62.6	15.7	
	≥60% and ≤100%	8.5	36.5	43.3	20.2	
Wash pen used in summer	Yes	9.5	13.7	71.5	14.8	0.040
	No	90.5	26.4	55.7	17.9	
Waste management						
Manure composted	Yes	7.8	35.7	58.1	6.2	0.062
	No	92.2	25.6	56.5	17.9	
Earth basin waste storage	Yes	37.5	27.5	60.0	12.5	0.170
	No	62.5	25.5	55.3	19.2	
Treatment lagoon waste storage	Yes	15.0	13.1	63.0	23.9	0.022
	No	85.0	27.1	56.0	16.9	
Below floor, deep pit waste storage	Yes	14.9	26.9	65.3	7.8	0.232
	No	85.1	26.0	55.3	18.7	
Alley flushed with fresh water	Yes	4.9	10.4	75.1	14.5	0.232
	No	95.1	26.4	55.8	17.8	
Alley flushed with recycled water	Yes	11.3	14.6	63.1	22.3	0.232
	No	88.7	26.5	55.9	17.6	

¹Bulk tank SCC ($\times 1,000$ cells/mL) category.²Weighted univariate log-likelihood χ^2 .

BTSCC ($P = 0.082$). The reported primary outside maternity area was evenly distributed among drylot, pasture, or no primary outside maternity area and was associated with BTSCC ($P = 0.012$; Table 1). The primary lactating cow housing facility reported by operations was associated with BTSCC ($P = 0.014$; Table 1).

Free stall and tie stall or stanchion housing was reported by 52.9 and 26.9% of operations, respectively.

Numerous cow management variables were associated with BTSCC. The use of automatic takeoffs was reported by 59.3% of operations and was associated with a lower BTSCC ($P < 0.001$). Forestripping of all,

Table 2. Results of principal components cluster analysis of herd management variables significant via weighted univariate screening

Cluster	Proportion of variation explained ¹	Variable ²	1-R ² ratio ³
1	0.5446	Surface moisture during winter	0.294
		Surface moisture during summer	0.349
		Use of automatic takeoffs	0.639
		Earth basin waste storage	0.743
2	0.4063	Composted manure used for bedding	0.460
		Recycled water used to flush alley	0.465
		Wash pen used during summer	0.569
		Treatment lagoon waste storage	0.605
		Manure is composted	0.784
		Fresh water used to flush alley	0.806
3	0.5241	Any cattle brought onto operation	0.288
		Lactating cows brought onto operation	0.456
		Weaned heifers brought onto operation	0.703
4	0.7391	Vitamin A, D, and E injections given	0.273
		Se injections given	0.281
5	0.2899	Straw used for bedding	0.539
		Newspaper used for bedding	0.657
		Sand used for bedding	0.795
		Culled for reproductive problems	0.909
6	0.4040	Use of coliform mastitis vaccine	0.485
		Times per day cows are milked	0.616
		Use of <i>Salmonella</i> vaccine	0.681
		Time calves separated from dam	0.774
7	0.3776	Mattresses used for bedding	0.517
		Cows with docked tails in herd	0.656
		Manure pack used	0.719
		Below floor and deep pit waste storage	0.760
8	0.4144	Forestripping performed	0.507
		Percentage of cows culled	0.649
		Antibiotic treatment at end of lactation	0.663
9	1.0000	Postdipping performed during winter	0.000

¹Proportion of variation explained by a cluster indicates how well the cluster represents its constituent variables.

²The first variable listed in a cluster had the lowest 1-R² ratio, indicating it was most typical of the cluster and was submitted for ordinal logistic regression modeling.

³The 1-R² ratio gives the ratio of 1-R² of a variable's own cluster to 1-R² of the variable's next closest cluster. A variable closely correlated with more than 1 cluster has a ratio close to 1, but a variable typical of its cluster has a ratio close to 0.

some (i.e., mastitic and fresh cows), or none of the cows was reported by 48.8, 38.5, and 12.7% of operations, respectively, and tended toward an association with BTSCC ($P = 0.06$; Table 1). Use of a coliform mastitis vaccine was reported by 49.5% of operations and was associated with a lower BTSCC ($P = 0.017$). All, some, and none of the cows received prophylactic antibiotic treatment at the end of lactation [dry cow therapy (DCT)] on 81.2, 14.4, and 4.4% of operations, respectively. There tended to be an association between DCT and BTSCC ($P = 0.062$; Table 1). Fifty-six percent of operations reported having some cows with docked tails, and there tended to be an association with a lower BTSCC ($P = 0.087$).

Principal components cluster analysis of 31 ordinal variables resulted in 9 clusters that explained 46% of

the variation of those variables (Table 2). The low proportion of variation explained by many clusters indicated that there was heterogeneity among variables within those clusters. Cluster 2 mostly represented waste management variables; cluster 3 represented cattle importation practices; cluster 4 described supplement administration; and all but 1 variable in cluster 5 dealt with lactating cow bedding type. Cluster 9 contained only 1 variable: postmilking teat dipping (PMTD) practices in winter. The remaining clusters were not easily categorized based on their constituent variables.

Backward elimination ordinal logistic regression modeling resulted in a final model containing 5 variables (Table 3). To test the assumption of the final model that the effect of a variable was the same comparing

Table 3. Final logistic regression model describing the association between management variables and producer-reported bulk tank SCC level

Variable	Level	Odds ratio ¹	95% odds ratio confidence interval	Final model <i>P</i> -value
Region	Intercept 1	0.65	0.32 to 1.35	<0.001
	Intercept 2	11.08	5.33 to 23.04	<0.001
	West	0.19	0.09 to 0.38	<0.001
	Midwest	0.20	0.11 to 0.38	
	Northeast	0.13	0.06 to 0.26	
Rolling herd average (kg/cow per yr)	Southeast		Referent	
	<9,090	2.15	1.50 to 3.08	<0.001
Vitamin A, D, and E injection	≥9,090		Referent	
	Used	1.58	1.05 to 2.35	0.027
Composted manure bedding	Not used		Referent	
	Used	2.88	1.27 to 6.55	0.012
Coliform mastitis vaccine	Not used		Referent	
	Used	1.65	1.14 to 2.40	0.008

¹Odds of having a higher bulk tank SCC level.

the lowest BTSCC group with the middle group as comparing the middle with the highest was valid; the final model was run without weighting in SAS. The score test for the proportional odds assumption was not significant ($P = 0.08$), suggesting that the slope coefficients were equal across the cumulative logits for each predictor variable. This supported the proportional odds assumption in our final model.

The odds of an operation from the West, Midwest, and Northeast having a high BTSCC were lower than those from the Southeast (Table 3). The odds of a higher BTSCC were 2.15 (1.50 to 3.08) times greater for operations with a RHA milk production <9,090 kg/cow per year compared with those with ≥9,090 kg/cow per year. The odds of a higher BTSCC were 1.58 (1.05 to 2.35) times greater for operations that reported using vitamin A, D, and E injection. The odds of having a higher BTSCC were 2.88 (1.27 to 6.55) times greater for operations using composted manure compared with those not using composted manure. Finally, operations not using a coliform mastitis vaccine were 1.65 (1.14 to 2.40) times more likely to have a higher BTSCC than those using one.

DISCUSSION

Cross-sectional studies based on questionnaires of management practices and measures of BTSCC are common (Hutton et al., 1990; Goodger et al., 1993; Faye et al., 1997; Barkema et al., 1998; Rodrigues and Ruegg, 2005). These studies shed light on associations between management practices and the level of SCC in the bulk tank, a proxy for udder health in the herd. They suffer, however, from several limitations including producer-

reporting bias, bias due to clustering of management practices, and the fact that differences in managerial skills are not represented in questions that merely ask if practices are used.

To decrease the potential for producer-reporting bias, the management questionnaire used in this study was standardized and pretested on multiple operations before being administered. Furthermore, the questionnaire was administered by trained personnel. Additionally, producer-reported BTSCC was compared with the BTSCC of a single bulk tank milk sample collected at the time of questionnaire administration on a subset of operations. Of the 741 operations in which BTSCC were measured, only 17.3% reported a category BTSCC lower than the measured BTSCC. These findings suggest that most producers did not underestimate their BTSCC, and the reported BTSCC is an accurate representation for these operations.

When there are many independent variables in a study, the objective of logistic model building should be to construct a parsimonious model that is numerically stable and can be readily generalized (Hosmer and Lemeshow, 2000). Too many variables in the model can result in overfitting and produce unstable estimates. We performed oblique principal components cluster analysis and selected the variable most representative (lowest $1-R^2$) of each of the 9 resulting clusters for model building (Nelson, 2001). This was done to achieve variable reduction and reduce the potential for bias associated with clustering of management practices within the final model. From a dairy management point of view, the variables within some clusters appeared to be grouped logically; however, it is important to realize this is not a necessary result of the cluster analysis.

A limitation of this study was the fact that potential differences in managerial skills were not identified by the questionnaire, which only asks if particular management practices were used. The quality and consistency of management practice application was not evaluated in this study and may confound associations between specific management practices and BTSCC. Technical skill, precision, and attention to detail in the implementation of a management practice likely have an important effect on associations with BTSCC. Barkema et al. (1999) specifically addressed this issue by grouping herds based on management style questions. In that study, herds with a "quick and dirty" management style had a higher BTSCC than herds with a "clean and accurate" style. This categorization related to a difference between groups such that the group that worked more precisely rather than quickly had better hygienic conditions and lower BTSCC. Hutton et al. (1990) found the majority of low-BTSCC ($\leq 283,000$ cells/mL) herds and high-BTSCC ($> 283,000$ cells/mL) herds implemented DCT; however, it was observed that significantly more low herds (96%) routinely disinfected teat ends before DCT than high herds (67%). Wilson et al. (1997) found no association between DCT or PMTD and BTSCC, and the authors suggested wide adoption of the practices ($> 80\%$) by herds in the study reduced the likelihood they would explain BTSCC differences among herds. In the current study, the postdipping performed during winter variable was in its own cluster, and DCT was in cluster 8 with the percentage of cows culled and forestripping variables. Neither the indicator variable from cluster 8 nor the PMTD variable was included in the final model. As with previous reports, a high proportion of operations in this study reported dry treating all cows (81%) and performing PMTD (75%). Furthermore, differences in quality of application of these practices were not assessed and may have confounded associations with BTSCC. Assessing managerial style or quality of management practice application in future studies may provide a better understanding of management factors influencing BTSCC.

A direct association between the prevalence of *Streptococcus agalactiae* and *Staphylococcus aureus* and elevated BTSCC has been identified (Wilson et al., 1997). Hutton et al. (1990) found no difference between low ($\leq 283,000$ cells/mL) herds and high ($> 283,000$ cells/mL) herds in the prevalence of *Strep. agalactiae* (0.3 and 0.7% respectively) but identified a higher prevalence of *Staph. aureus* IMI in high herds (14.6%) compared with low herds (3.0%). Unfortunately, data on the prevalence of contagious mastitis pathogens was not available for inclusion in this study and may serve to confound associations between BTSCC and the management prac-

tices evaluated. Future studies evaluating the association between management practices and BTSCC should include some indication of the prevalence of contagious mastitis pathogens.

Previously, Hutton et al. (1990) identified an association between environmental factors and BTSCC. In that study, maternity cow area was significantly drier, and fewer herds had standing water in the pastures of low-BTSCC vs. high-BTSCC herds. Similarly, Barkema et al. (1998) showed that greater attention to dry cow hygiene and nutrition was associated with herds with lower BTSCC. Khaitsa et al. (2000) also found that dry cow management factors and housing of dry cows was associated with BTSCC. In the present study, the primary outside maternity area was univariately associated with BTSCC. Considering that 4 to 5 times more environmental IMI occur during the dry period than during lactation, taken together, these data suggest that environmental mastitis pathogens may be more influential on BTSCC than previously recognized. This may be especially true in herds that have successfully controlled contagious mastitis pathogens. This notion is further supported by the results of this study showing an association between a higher BTSCC and operations that did not use a coliform mastitis vaccine and the association between housing type and BTSCC. These associations were not very strong; however, they may have been confounded by contagious mastitis prevalence. Future studies focused on herds with a low prevalence of contagious mastitis pathogens may identify stronger associations between BTSCC and management factors that reduce exposure to environmental mastitis pathogens.

Further supporting the potentially important influence of environmental mastitis pathogens was the fact that reported use of specific bedding types was associated with BTSCC. In the univariate analysis mattress, sand and newspaper use was associated with a lower BTSCC. In the final multivariate model, the odds of a higher BTSCC were greater in operations using composted manure than those that did not. When interpreting these results, it is important to realize that the absence of a variable from the final model does not imply that there is not a significant association with the outcome, such as demonstrated by the univariate analysis. The multivariate model assesses the importance of variables given the presence of other variables in the model, and this may yield a different result than the univariate analysis.

The results of this and previous studies have identified associations between environmental mastitis pathogen risk factors (dry and lactating cow housing, bedding and coliform mastitis vaccine use) and BTSCC. This association is likely related to management style

on the operation as described above and maintenance of a clean, dry environment for both lactating and dry cows. None the less, failure of management to provide clean, dry housing conditions increases risk of environmental pathogen IMI, which may result in higher BTSCC. This is particularly true as more herds effectively control contagious mastitis pathogens and the prevalence of chronic *Escherichia coli* infections rises (Bradley and Green, 2001).

CONCLUSIONS

This study identified associations between management practices and BTSCC in US dairy herds. Variables such as RHA, region, and herd size were associated with BTSCC level and are likely catch-all variables that reflect general trends in management. The other significant variables dealt with housing, bedding used, and coliform mastitis vaccine use and suggest the effect of environmental mastitis pathogens may be more influential on BTSCC than previously thought. Future studies of the association between management factors and BTSCC should include evaluation of managerial style or quality of management practice application as well as herd prevalence of contagious mastitis pathogens.

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