Management practices associated with high mortality among preweaned dairy heifers

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Summary. In a national survey of US dairy operations, 1685 dairy operations reported 47057 new dairy heifers (either births or acquisitions) and 4427 deaths (9·4%) of preweaned dairy heifer calves over a 3 month period. Stepwise logistic regression was used to identify management practices associated with high mortality among preweaned heifers in dairy operations where at least three dairy heifer calves were born alive or moved on to the operation. Analysis was done twice: once by separating all operations by size into high or low mortality; again using only operations with < 2 and > 10% mortality to eliminate dairy operations with intermediate levels of mortality from the comparisons. Results were similar. Dairy operations in the West were more likely to fall in the high mortality category than dairy operations in the rest of the country. In addition, the following dairy operation characteristics were associated with high death levels in both models: rolling herd average milk production < 7710 kg, preweaned heifers placed in groups of seven or more, a male having primary responsibility for the care and feeding of preweaned heifers, calves not receiving hay or other roughages until > 20 d old, calves fed on mastitic or antibiotic milk after colostrum and calves not given whole milk after colostrum.

Calf mortality represents an economic loss to the dairy industry (Martin & Wiggins, 1973; Oxender *et al*. 1973). Dairy operations sampled nationally in the US National Animal Health Monitoring System 1991–1992 National Dairy Heifer Evaluation Project (NDHEP) reported a mean death loss of 8·4 ± 0·4% of preweaned heifers (US Department of Agriculture (USDA), 1993). The most common causes of death were scours followed by respiratory problems (USDA, 1993).

A number of researchers have examined management, feeding and environmental factors associated with calf mortality (Hartman *et al*. 1974; Jenny *et al*. 1981; Collier *et al*. 1982; Curtis *et al*. 1988). However, no previous study was based upon a national survey of dairy operations. Dairy producers and those serving their needs require a better understanding of the impact that management practices can have on mortality of preweaned calves.

The objective of this study was to examine relationships between dairy operation management practices and deaths among preweaned dairy heifer calves.

MATERIALS AND METHODS

The NDHEP was a year-long study conducted by the Animal and Plant Health Inspection Service, Veterinary Services of the USDA (USDA, 1993). The NDHEP was designed to provide statistically valid national estimates of parameters related to the management and health of dairy cattle (principally dairy heifers) on operations in the US, and to examine relationships between management practices and various indicators of health and productivity of US dairy operations (Garber *et al*. 1994; Heinrichs *et al*. 1994; Losinger *et al*. 1995; Losinger & Heinrichs, 1996).

Enumerators from the USDA National Agricultural Statistics Service (NASS) visited the dairy operations selected for the NDHEP to administer a questionnaire. In response to the questionnaire, the producers reported the number of dairy heifer calves that were born alive or moved on to the operation during the 3 months prior to the interview, and the number of preweaned dairy heifer calves that died on the operation during the 3 months prior to the interview. In addition, the producers provided herd level information on management practices.

The examination of associations between management practices and high mortality among preweaned dairy heifer calves was performed for dairy operations where the producer reported that three or more dairy heifer calves were born alive or moved on to the operation during the 3 months prior to interview. To compare solutions and evaluate validity of this information, stepwise logistic regression was used to build two models: once using all dairy operations with three or more new dairy heifer calves, and again using only operations with three or more new dairy heifer calves and < 2 or $> 10\%$ mortality.

For the first model, dairy operations were assigned to either a low mortality or a high mortality category based on the number of dairy heifer calves that were born alive or moved on to the operation in the 3 months prior to the interview, and on the number of preweaned dairy heifer calves that died during the same 3 month period. Table 1 summarizes the categorization scheme.

Thirty herd level management practices (listed in the appendix) hypothesized to be associated with mortality among preweaned dairy heifer calves were examined for differences in mortality category. A herd level management practice was defined to be a management practice that the producer reported (on the administered questionnaire) that he/she routinely applied as a matter of general herd policy on his/her operation. A χ^2 test (Hogg & Craig, 1978), using the FREQ procedure of SAS (SAS, 1990), was performed on each of these herd level management practices to test the null hypothesis of no relationship between the herd level management practice and the death level category. This test served as an initial screening to determine whether individual herd level management practices should be considered for inclusion in a multivariate logistic model. Herd level management practices with $P < 0{\cdot}10$ were considered to have passed this initial screening. Sample weights were not used in the analyses. To obtain awareness of potential collinearity among the model's explanatory variables, Spearman rank correlation coefficients (Hogg & Craig, 1978) were examined using the CORR procedure of SAS (SAS, 1990) among the screened herd level management practices.

The logistic regression available in the PROBIT procedure of SAS (SAS, 1989) was used to build a multivariate logistic regression model (Hosmer & Lemeshow, 1989). The process included only those dairy operations that had provided information for all of the screened variables. The logarithm of the odds of a dairy operation being classified in the high mortality category served as the dependent

Table 1. *Definition of high* v. *low mortality among preweaned dairy heifer deaths*

No. of dairy heifer calves born alive or moved on to operation†	Low mortality	High mortality
3–18	No deaths	⩾ 1 deaths
19–30	0–1 death	⩾ 2 deaths
31–74	0–2 deaths	⩾ 3 deaths
⩾ 75	< 6% died	⩾ 6% died

† Reference period is 3 months prior to interview.

variable. As in previous NDHEP analyses (Garber *et al.* 1994; Losinger *et al.* 1995; Losinger & Heinrichs, 1996), region and herd size (determined by the number of dairy heifer calves born alive or moved on to the operation in the 3 months prior to the interview) were forced into the model to prevent variables from entering the model merely because of regional or herd size differences in management. Both region and herd size reflected the study design (Heinrichs *et al.* 1994). Stepwise variable selection was employed to develop the final logistic regression model (Hosmer & Lemeshow, 1989). A significance level of $P < 0{\cdot}05$ was required for variables to enter and remain in the model.

The above procedures were repeated, using only dairy operations with three or more new dairy heifer calves and either < 2 or > 10% mortality among preweaned dairy heifers.

RESULTS

A total of 1685 producers reported that at least one dairy heifer calf was born alive or moved on to his or her dairy operation in the 3 months prior to the interview. The number of new dairy heifer calves ranged from 1 to 1370, and totalled 47057 calves. During the 3 months prior to the interview, these producers reported that 4427 preweaned heifers (9·4%) died.

Table 1 summarizes the scheme for assigning dairy operations to mortality categories for the first model. Sixty-one operations where the producer indicated that only one or two dairy heifer calves were born alive or moved on to the operation in the 3 months prior to the interview were not assigned to a mortality category and were not included in the analyses. No deaths of preweaned heifers were reported among these 61 operations.

Table 2 reveals the number of dairy operations assigned to each death level category. Table 3 shows that the West had the greatest concentration of larger dairy operations, while the Midwest and Northeast tended to be characterized by smaller operations.

The construction of the final model was based on 1539 dairy operations that provided responses to each of the variables that passed the initial screening. The odds ratios for the multivariate regression model that resulted from the stepwise selection process on the screened variables occupy Table 4. The overall test for herd size suggested no statistically significant herd size differences although, individually, operations with 19–30 new calves were found to be significantly more likely to be in the high mortality category than operations with 75 or more new calves. Dairy operations in the West were more likely to occur in the high mortality category than dairy operations in the rest of the country, even when the effect of herd size was controlled in the model. Operations with rolling herd average milk production

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Table 2. *Distribution of mortality categories by operation size*

No. of dairy heifer calves born alive or moved on to operation	Low mortality	High mortality	Total
3–18	552 (58·7%)	389 (41·3%)	941
19–30	166 (47·7%)	182 (52·3%)	348
31–74	117 (52·0%)	108 (48·0%)	225
⩾ 75	55 (50·0%)	55 (50·0%)	110
⩾ 3	890 (54·8%)	734 (45·2%)	1624

Table 3. *Distribution of operation size by region*

	No. of dairy heifer calves born alive or moved on to operation				
Region	3–18	19–30	31–74	⩾ 75	⩾ 3
West	88 (27·2%)	77 (23·1%)	90 (27·9%)	68 (21·1%)	323 (100%)
Midwest	466 (74·1%)	106 (16·9%)	49 (7·8%)	8 (1·3%)	629 (100%)
Northeast	254 (68·5%)	79 (21·3%)	29 (7·8%)	9 (2·4%)	371 (100%)
Southeast	133 (44·2%)	86 (28·6%)	57 (18·9%)	25 (8·3%)	301 (100%)
Total	941 (57·9%)	348 (21·4%)	225 (13·9%)	110 (6·8%)	1624 (100%)

The participating states included in each region were as follows
West California, Colorado, Idaho, Oregon and Washington
Midwest Illinois, Indiana, Iowa, Michigan, Minnesota, Nebraska, Ohio and Wisconsin
Northeast Connecticut, Maine, Massachusetts, New Hampshire, New York, Pennsylvania, Rhode Island and Vermont
Southeast Alabama, Florida, Georgia, Maryland, North Carolina, Tennessee and Virginia

⩾ 7710 kg were less likely to be in the high death category than lower producing herds ($P < 0{\cdot}001$). Operations that placed preweaned dairy heifers in groups of seven or more were more likely to fall in the high mortality category than operations that either did not group preweaned heifers or that placed preweaned heifers in groups of two to six. Housing preweaned heifers in a barn with cows was associated with reduced death among preweaned heifers. Operations where a male had primary responsibility for care and feeding of preweaned heifers were more likely to be in the high death category than operations where a female had primary responsibility. Operations that delayed offering hay or other roughages to calves until 20 d of age were more likely to fall in the high death category than operations that offered hay or other roughages sooner. Feeding with mastitic or antibiotic milk after colostrum was associated with high mortality among preweaned heifers. The feeding of whole milk (from a bulk tank) after colostrum was associated with low deaths among preweaned heifers. Correlations between model variables were not strong enough to warrant concern about the effects of multicollinearity ($P < 0{\cdot}25$ in all cases).

Excluding dairy operations that had between 2 and 10% mortality left 1201 dairy operations. Table 5 shows how the remaining operations varied by high and low death according to operation size.

The logistic regression model that resulted from the stepwise selection process is in Table 6. The construction of this model was based on 1138 dairy operations that provided responses to all of the screened variables in this phase of the analysis. The results were similar to the analysis using the larger data set, except that housing preweaned heifers in barns with cows did not enter the model. Instead, operations where the owner or spouse had primary responsibility for the care and feeding of preweaned heifers had significantly lower mortality than operations where someone

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Table 4. *Results of stepwise logistic regression for risk factors of an operation being in the high mortality category for preweaned dairy heifer calves*

Variable/response	Odds ratio	95% Confidence interval	*P*
No. of dairy heifer calves born alive or moved on to operation			0·206
3–18	1·336	0·842–2·119	0·219
19–30	1·611	1·002–2·591	0·049
31–74	1·267	0·777–2·065	0·342
⩾ 75	1		
Region			0·002
Midwest	0·569	0·414–0·781	0·001
Northeast	0·576	0·407–0·814	0·002
Southeast	0·577	0·405–0·823	0·002
West	1		
Rolling herd average milk production			
< 7710 kg	1·453	1·167–1·810	0·001
⩾ 7710 kg	1		
Grouping of preweaned dairy heifers			0·001
Not grouped	0·601	0·442–0·819	0·001
2–6 in group	0·483	0·328–0·710	< 0·001
⩾ 7 in group	1		
Preweaned heifers are housed in cowbarns			
Yes	0·748	0·585–0·958	0·021
No	1		
Sex of person primarily responsible for care of preweaned dairy heifers			
Male	1·529	1·214–1·926	< 0·001
Female	1		
Mean age of calves when first offered hay or other roughages			
> 20 d	1·433	1·149–1·786	0·001
< 20 d	1		
Calves are fed on mastitic or antibiotic milk after colostrum			
Yes	1·338	1·079–1·659	0·008
No	1		
Calves are fed on whole milk from a bulk tank after colostrum			
Yes	0·778	0·618–0·980	0·033
No	1		

Table 5. *Operations with < 2% mortality and > 10% mortality among preweaned dairy heifers classified according to operation*

No. of dairy heifer calves born alive or moved on to operation†	< 2% Mortality	> 10% Mortality	Total
3–18	552 (66·4%)	279 (33·6%)	831
19–30	112 (53·1%)	99 (46·9%)	211
31–74	46 (43·4%)	60 (56·6%)	106
⩾ 75	21 (39·6%)	32 (60·4%)	53
⩾ 3	731 (60·9%)	470 (45·2%)	1201

† Reference period is 3 months prior to interview.

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Table 6. *Results of stepwise logistic regression comparing operations with < 2% mortality and operations with > 10% mortality over the 3 month period prior to interview*

Variable/response	Odds ratio	95% Confidence interval	P
No. of dairy heifer calves born alive or moved on to operation			0·014
3–18	0·680	0·354–1·305	0·246
19–30	1·003	0·510–1·972	0·992
31–74	1·295	0·632–2·652	0·480
⩾ 75	1		
Region			0·003
Midwest	0·504	0·342–0·743	0·001
Northeast	0·489	0·321–0·744	0·001
Southeast	0·534	0·343–0·830	0·005
West	1		
Rolling herd average milk production			
< 7710 kg	1·592	1·230–2·061	< 0·001
⩾ 7710 kg	1		
Grouping of preweaned dairy heifers			0·010
Not grouped	0·613	0·428–0·879	0·008
2–6 in group	0·529	0·340–0·822	0·005
⩾ 7 in group	1		
Sex of person primarily responsible for care of preweaned dairy heifers			
Male	1·423	1·077–1·881	0·013
Female	1		
Person with major responsibility for care and feeding of preweaned heifers			
Operator or spouse	0·757	0·578–0·992	0·044
Someone else	1		
Mean age of calves when first offered hay or other roughages			
> 20 d	1·354	1·038–1·765	0·025
⩽ 20 d	1		
Calves are fed on mastitic or antibiotic milk after colostrum			
Yes	1·324	1·023–1·713	0·033
No	1		
Calves are fed on whole milk from a bulk tank after colostrum			
Yes	0·678	0·513–0·897	0·007
No	1		

else (such as a son or daughter, someone hired especially for the job, or a general farm worker with multiple tasks) had this responsibility. In addition, the number of dairy heifer calves born alive or moved on to the operation had statistical significance overall in the model with the smaller data set (Table 6).

DISCUSSION

The NDHEP was the second National Animal Health Monitoring System national study (Heinrichs *et al*. 1994). A limitation of many previous livestock studies was that operations were not selected to permit inferences relating to larger populations to be drawn (King, 1990; Bush & Gardner, 1995). The NASS list frame, from which a probability sample design was used to select participants for the

NDHEP, listed nearly all agricultural producers in the USA (Heinrichs *et al.* 1994). An area frame, or census of all producers from randomly selected local land areas in the USA was used to adjust for incompleteness of the NASS list frame (Heinrichs *et al.* 1994). The sample selection method used in the NDHEP created the highest likelihood that the majority of dairy operations in the USA had a known probability of being selected (Heinrichs *et al.* 1994). The NDHEP was designed to represent 78% of the USA dairy cow population (Heinrichs *et al.* 1994).

Because dairy operations with < 30 dairy cows were not included in the NDHEP (Heinrichs *et al.* 1994), the results do not necessarily apply to dairy operations with < 30 dairy cows. Similarly, the results do not necessarily apply to states not included in the NDHEP. Moreover, as this analysis was restricted to operations that had three or more new dairy heifer calves over a 3 month period, the results cannot necessarily be extended to operations that had fewer than three new dairy heifer calves during this period. In addition, the percentages of preweaned heifers that died as reported here were calculated from unweighted totals only, and therefore differ from previously reported weighted national estimates (USDA, 1993; Heinrichs *et al.* 1994).

To afford more precise national estimates for USA dairy cattle, the NDHEP sampling scheme called for larger dairy operations to be sampled at a higher rate than smaller dairy operations (Heinrichs *et al.* 1994). As a result, more large dairy operations were included in the NDHEP than if operation size had not been considered in the selection process (Losinger *et al.* 1995).

Furthermore, the assignment of mortality categories was somewhat arbitrary and error was possible. In the first method, one death represented from 5·5 to 33·3% of calves in the lowest operation size category (Table 1). In the second method, which eliminated dairy operations with between 2 and 10% mortality, no operations with < 11 new dairy heifers could have been excluded from the analysis. An analysis using a continuous dependent variable (such as percent mortality) would have been invalid because the error variance was not constant across herd sizes (Maddala, 1988). Performing the analysis two different ways and arriving at similar conclusions served to validate the findings.

Although the present study found statistically significant associations between certain management practices and increased mortality, this result does not necessarily imply that these management practices were the cause of the increased mortality. The associations found here represent potential areas where further study by researchers and attention by dairy producers may be warranted.

Although the models showed some significant differences between herd sizes (as measured by the number of dairy heifer calves that had been born alive or had moved on to the operation in the 3 months prior to interview) in terms of the outcome variable, these results should not be construed as implying that herd size was either related or unrelated to death of preweaned heifers. In the first model, the assignment of operations to high and low death rate categories differed by herd size. The goal of the categorization scheme was to have similar proportions of operations in the high mortality category among herd size strata to facilitate the evaluation of other variables relating to farm management. In the second model, the proportion of operations eliminated from the analysis increased with herd size. In the context of this analysis, herd size represented an extraneous source of variation (Montgomery, 1976), and was forced into the model to account for its effect on other variables of interest. Hartman *et al.* (1974) and Oxender *et al.* (1973) found that calf mortality increased as herd size increased. Jenny *et al.* (1981), however, reported that calf mortality decreased with increasing herd size. Regionally, dairy operations in the

West had significantly higher odds of being in the high death level category than dairy operations in the rest of the country. In this study, the West also had a greater proportion of larger herds than other regions.

Management practices associated with increased milk production have been examined (Losinger & Heinrichs, 1996). Higher producing herds are more carefully managed than lower producing herds (Chase, 1993; Funk, 1993). Genetics also plays a role in milk production (Funk, 1993). The present study showed that herds with higher milk production also had decreased mortality among preweaned dairy heifers.

In the screening phase of this study, allowing calves to receive first colostrum by sucking the dam (as opposed to hand feeding) was found to be significantly associated with increased mortality. Nevertheless, this variable was very strongly correlated with rolling herd average milk production, and did not enter the model once milk production level was present in the model. The importance of colostrum feeding to the survival of newborn calves is undoubtedly higher than the level of milk production in the herd. However, in addition to feeding colostrum in the recommended way, higher producing dairy operations may be managing their preweaned dairy heifers in a number of other ways that enhance survival.

Waltner-Toews *et al.* (1986) and Peters (1986) reported increased calf mortality in operations that housed calves in group pens. Miller *et al.* (1980) reported that respiratory disease was clustered within calf crops, indicating that direct contact may have been important in the spread of disease. The results of the present study also indicate that dairy operations that place preweaned calves together in large groups may need to pay more attention to the health of their calves.

In the first model, operations that placed preweaned heifers in barns with cows were less likely to be in the high mortality category than operations that did not. No variables relating to calf housing entered the second model. Hartman *et al.* (1974) reported that housing calves separately from cows had no effect on calf mortality. Placing preweaned calves close to cows may have some benefit in very cold environments (Simensen, 1981). However, housing preweaned heifers in barns with cows is not generally recommended in most of the USA (Heinrichs, 1993). Stress factors often encountered in calf housing environments can have an impact on the incidence of disorders (Heinrichs, 1993), and cows can expose calves to many pathogens. Because this variable did not appear in both models, the validity of the association between reduced mortality and housing preweaned heifers in barns with cows in the USA may be questionable.

Hartman *et al.* (1974) reported reduced calf mortality in dairy operations where the wife of the dairyman had the principal responsibility for feeding the calves. Other studies have indicated associations between mortality and calf-rearing personnel (Martin *et al.* 1975; Jenny *et al.* 1981; Waltner-Toews *et al.* 1986). Why preweaned calf mortality should be lower when a female takes care of preweaned heifers is unclear, although statistically significant.

Giving hay or other roughages to heifers within the first 20 d of life was associated with decreased mortality among preweaned heifers. Heinrichs & Swartz (1990) recommend offering hay or other roughages to heifers as early as manageable. Although giving hay to preweaned heifers is generally discouraged for overall health and nutrition, Losinger *et al.* (1995) reported reduced *Salmonella* shedding among preweaned dairy heifers fed on hay.

The composition of the diet after the colostrum-feeding period can have a major impact on the incidence of disease and mortality of preweaned heifers (Roy, 1980). In this study, we found reduced mortality among preweaned heifers in operations that gave whole milk from a bulk tank to preweaned heifers, and increased mortality among preweaned heifers in operations that gave mastitic or antibiotic milk (discarded milk from sick cows) to preweaned heifers. Nationally, $32{\cdot}7 \pm 1{\cdot}7\%$ of operations gave whole milk (from a bulk tank) after colostrum, and $37{\cdot}7 \pm 1{\cdot}7\%$ of operations gave mastitic or antibiotic milk after colostrum (USDA, 1993).

Giving mastitic or antibiotic milk to calves is not generally recommended (Keys *et al*. 1979). However, Kesler (1981) reported that the incidence of health disorders in calves given mastitic milk was no greater than in calves given healthy milk. Fermentation of mastitic or antibiotic milk may make it possible to utilize this milk for calf feeding without causing health problems (Keys *et al*. 1979; Roy, 1980). No information in this study was collected on whether the mastitic or antibiotic milk given to preweaned heifers had undergone any fermentation. Wray *et al*. (1990) reported that colder climates might not encourage rapid natural fermentation of mastitic milk; they also reported that milk containing antibiotics was unpalatable and had high rejection rates for calves, and that calves fed on antibiotic milk had significantly reduced growth rates. The results of the present study indicated increased mortality among preweaned dairy heifers in operations that gave mastitic or antibiotic milk to preweaned calves.

APPENDIX

Herd level management practices examined

Rolling herd average milk production
- < 7710 kg
- > 7710 kg

Quarter of interview
- January–March
- April–June
- July–September
- October–December

How soon new born calves are separated from their mothers
- < 12 h
- $\geqslant 12$ h

Average age of calves when first offered grain or other concentrated feeds
- $\leqslant 6$ d
- > 6 d

Average age of calves when first offered hay or other roughages
- $\leqslant 20$ d
- > 20 d

Average age of calves when first offered free choice of water
- $\leqslant 20$ d
- > 20 d

Average age of calves at weaning
- < 8 weeks
- $\geqslant 8$ weeks

Grouping of preweaned heifers
- Not grouped
- 2–6 in group
- 7+ in group

Person with major responsibility for care and feeding of preweaned heifers
  Operator or spouse
  Someone else
Sex of person primarily responsible for care of preweaned heifers
  Female
  Male
The remaining variables had dichotomous (yes/no) responses:
  Operation is a Grade A dairy operation
  Main breed of the dairy herd is Holstein
  At least part of the dairy herd is registered
  Calves receive their first colostrum by sucking
  Calves are hand fed $< 3{\cdot}79$ l of colostrum
  Calves are fed on milk from cows that recently calved after colostrum
  Calves are fed on whole milk from a bulk tank after colostrum
  Calves are fed on mastitic or antibiotic milk after colostrum
  Calves are fed on milk replacer after colostrum
  Calves are fed on fermented milk after colostrum
  Preweaned heifers are tied in a barn
  Preweaned heifers are housed in an individual hutch
  Preweaned heifers are housed in a super hutch
  Preweaned heifers are housed in any hutch
  Preweaned heifers are housed in an individual pen
  Preweaned heifers are housed in a barn with cows
  Preweaned heifers are on wood flooring
  Preweaned heifers are on concrete flooring
  Preweaned heifers are on stone or gravel flooring
  Preweaned heifers are on dirt or sand flooring

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