Characteristics of dairy calf ranches: Morbidity, mortality, antibiotic use practices, and biosecurity and biocontainment practices

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ABSTRACT

The utilization of farming operations specializing in rearing dairy heifer calves has increased since the early 1990s. However, these operations have not been as well characterized as US dairy operations with respect to demographic and health-related measures, particularly during the preweaning period. The objective of this study was to characterize morbidity, mortality, antibiotic use, and biosecurity and biocontainment practices on operations rearing preweaned heifers only or preweaned heifer and bull calves (mixed) in the United States. A cross-sectional survey was performed using a standardized method that included a preletter, initial survey, postcard follow-up, and second survey delivered by mail. Additional follow-up contacts were attempted by telephone. Descriptive statistics for morbidity, mortality, antibiotic use, and biosecurity and biocontainment practices were computed at both the operation and calf levels. The overall response rate was 50%. Crude yearly mortality averaged 6.9% at the calf level, with the median operation reporting 3.6% mortality. Diarrhea was experienced by 18% of calves, with 73% receiving an antibiotic. The median operation reported 20% diarrhea morbidity with 83% receiving an antibiotic. Respiratory disease was experienced by 9.0% of calves, with 82% receiving an antibiotic. The median operation reported 5.3% respiratory morbidity, with 100% receiving an antibiotic. Heifer-only and mixed operations did not differ in operation median morbidity, mortality, or antibiotic treatment rates. Written antibiotic protocols were available on 65% of operations. Medicated milk replacer was used by 56% of operations. Passive immunity was routinely measured by 46% of operations. Direct contact between calves in housing units was not allowed by 45% of operations. Of all farms informed of disease concerns at the source farm, 76% changed their

daily routine as a result. Almost all operations uniquely identified calves and recorded mortality. The heifer-only and mixed operations in this study were similar to US dairy operations for key health, antibiotic use, and biosecurity and biocontainment metrics. This research provides initial estimates of key demographics usable by calf ranches, veterinarians, and other professionals serving this segment of the US dairy industry.

Key words: dairy, calf ranch, morbidity, mortality

INTRODUCTION

Financial concerns, consolidation, increasing herd size, and greater emphasis on the production of saleable milk have fueled the growth of farming operations specializing in rearing dairy replacement heifers (Wolf, 2003). Since the early 1990s, the percentage of US dairy operations utilizing specialized contract heifer rearing facilities to develop replacement heifers has increased almost 3-fold from 1.6 to 4.6%, currently representing 11.5% of the US dairy heifer population (USDA, 1993, 2007). These specialized operations are commonly referred to as “calf ranches,” “heifer ranches,” or “custom heifer growers,” and are generally located apart from the source dairy.

When choosing whether to utilize a calf ranch or when selecting a specific calf ranch, several factors may be considered, such as economics, morbidity, mortality, antibiotic use practices, and biosecurity practices. To date, few studies of calf ranches have reported this type of information for the entire calf ranch industry. One report describes basic operation characteristics, contract terms, and management practices, but morbidity, mortality, antibiotic use, and an in-depth examination of preweaning calf biosecurity practices were not within the scope of the study (Wolf, 2003). However, this study found that 83% of custom heifer growers raised heifers for multiple clients (Wolf, 2003), a finding that underscores the importance of knowing biosecurity and other management practices relevant to preventing transmission of disease. Other studies have investigated mortality on heifer and dairy-beef calf ranches rearing

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preweaned calves but each was limited to a single calf ranch (Tyler et al., 1998; Moore et al., 2002).

Clearly, the need exists for a broad-based demographic survey of calf health metrics, antibiotic use, and biosecurity and biocontainment on calf ranches in the United States. Industry-wide data will provide initial benchmark estimates for use by calf ranches, dairy farms, and their advisors. Accordingly, the overall objectives of this study were to describe herd demographics, health metrics, antibiotic use practices, and biosecurity and biocontainment practices on calf ranches rearing preweaned calves in 2006 and to evaluate the relationships among morbidity, mortality, antibiotic use practices, and biosecurity and biocontainment practices on these calf ranches. The specific objective of this report was to characterize morbidity, mortality, antibiotic use practices, and biosecurity and biocontainment practices. Future reports will examine the relationship of morbidity and mortality to both antibiotic use practices and biosecurity and biocontainment practices.

MATERIALS AND METHODS

Study Population

The study population consisted of a convenience sample of operations believed to be engaged in rearing of preweaned dairy heifer or heifer and bull calves within the United States. Sources of contact information included the membership roster of the Dairy Calf and Heifer Association (DCHA, Chesterfield, MO), personal contacts of the authors, and freely accessible websites. A calf ranch was considered as an operation raising someone else's preweaned heifer or bull calves alone or in addition to raising his or her own calves.

Sampling Frame

The overarching goal of the sampling frame was to be maximally inclusive because no single list of calf ranches in the United States was available. The sampling frame was initially constructed from the DCHA membership roster by extracting all known calf ranches and including all other members of unknown status. The sampling frame was augmented with contact information from calf ranches identified by personal contacts of the authors and contact information obtained from freely accessible websites using the search terms "heifer" and "calf." Entries were excluded immediately if it was known from personal or contact information that they were not calf ranches. After removing duplicate entries, the total sampling frame included 416 potential calf ranches representing 37 states and 1 US territory.

Study Design

A cross-sectional study was performed with a mail survey data collection scheme. The mail survey was conducted according to a standardized survey methodology (Dillman, 2007). In June 2007, potential respondents received a preemptive letter explaining the purpose of the survey with notification to expect a survey packet. One week later, the survey packet containing the questionnaire and a cover letter was mailed. Two weeks after the initiation of the survey, a postcard reminder was sent thanking respondents and encouraging those not yet responding to do so. Four weeks after study initiation, a second survey packet with a different cover letter was mailed to nonrespondents. Attempts to contact nonrespondents via telephone were made 7, 9, and 13 wk after initiation of the survey. Additional potential respondents identified during the course of the study underwent similar survey procedures beginning as soon as possible after those growers were identified. Attempts were made to contact respondents with ambiguous or uninterpretable responses and to determine eligibility status when unknown.

Respondents and nonrespondents were categorized into regions analogous to a previous survey with arbitrary modifications to accommodate additional states (USDA, 2002). Regions and their associated states were as follows: West: Arizona, California, Idaho, Kansas, North Dakota, New Mexico, Oklahoma, Oregon, South Dakota, Texas, Washington, and Wyoming; Midwest: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin; Northeast: Massachusetts, New York, Pennsylvania, and Vermont; and Southeast: Florida, Georgia, Kentucky, Maryland, North Carolina, Tennessee, and Virginia.

Mail Questionnaire

Calf growers were asked 54 questions regarding operation-level demographics, morbidity, mortality, herd-level policies and estimates for antibiotic usage, and herd-level policies for biosecurity and biocontainment during 2006. To facilitate comparability with US dairy operations, some questions were adapted from previous surveys conducted by the USDA's National Animal Health Monitoring System (USDA, 1993, 1994, 1996, 2002, 2007). Questions on herd demographics included the number of preweaned calves reared in 2006, average age at weaning, and liquid feeding policies. Questions regarding disease demographics included estimates of number of calves experiencing crude and disease-specific (diarrhea or respiratory disease) morbidity or mortality, antibiotic-use policy, and availability of

written records and treatment protocols. All morbidity and mortality data were self-reported estimates. Nutritional demographic questions included primary source of milk, feeding methods, and whether nutrient content was increased during certain seasons of the year. An increase in one or more of the following was considered increased nutrient content: volume, amount of powder for milk replacers, or percentage of CP or crude fat. Seasons were defined as follows: spring = March, April, and May; summer = June, July, and August; fall = September, October, and November; and winter = December, January, and February. Respondents were asked to report individual calf-level management and health data, including the use of unique identification, mortality, morbidity, disease treatments, and passive immunity status.

Respondents were asked questions regarding the use of various biosecurity and biocontainment practices during 2006, with answers typically dichotomized as yes or no. Biosecurity was defined as “any measures taken to help prevent disease from being introduced to your farm” and biocontainment was defined as “any measures taken to help prevent the spread of disease within your farm.” Questions focused on the use of generally accepted biosecurity or biocontainment practices, including sanitation, transportation policies, use of personal protective equipment, assessment of direct contacts, and communication with the source dairy. Each respondent was asked to rate his or her perception of current biosecurity and biocontainment policies on a 4-level ordinal scale from “poor” to “excellent.” Each respondent was asked to enumerate his or her perception of the risk engendered by various personnel potentially encountered by a calf ranch on a 5-level ordinal scale from “low” to “high” with an additional category of “not applicable” (NA) for personnel not encountered on a given operation.

Two veterinarians familiar with the calf rearing industry, a university dairy scientist, and 2 calf ranchers reviewed potential questions before the final questionnaire was constructed. All survey results were entered into an Access 2007 database (Microsoft Corp., Redmond, WA) upon receipt. The survey was granted exempt status after review by The Ohio State University Institutional Review Board.

Statistical Analysis

Estimates of the number of calves experiencing morbidity, mortality, and antibiotic treatment were used as the numerator for computing operation-level proportions as needed for descriptive statistics and modeling purposes. Additionally, and for descriptive comparison, morbidity, mortality, and antibiotic-use estimates were

weighted by ranch size to yield calf-level estimates of all operations. Responses to operation-level policy questions and numerical estimates were categorized as needed to facilitate description and analysis. Descriptive statistics and computations for continuous variables were reported at the operation-level as a median and inter-quartile range, and categorical variables were reported as proportions in tabular format. Calf-level estimates were computed as a weighted mean. Formal statistical analyses were conducted for operations rearing only preweaned heifer calves (HC) and those rearing both preweaned heifer and preweaned bull calves (MC). Operations rearing only preweaned bull calves ($n = 18$, BC) were excluded from descriptive statistics and statistical analyses because the sample consisted of too few observations to be considered representative. For descriptive statistics, antibiotic treatment rates were expressed as a proportion of cases of a given disease. Continuous operation-level demographic variables were compared using the median test and binary demographic variables compared with a 2-sample proportion test. Univariable associations between categorical variables and HC or MC operations were assessed with Chi-square tests or Fisher's exact test. The overall type I error rate was protected across multiple comparisons using a Bonferroni-corrected P -value. All descriptive statistics and analyses were generated in Stata/IC 10.1 (2009; StataCorp LP, College Station, TX).

RESULTS AND DISCUSSION

In total, 416 initial surveys were distributed to potential respondents. Of the 416 potential respondents, 204 reported not raising preweaned calves for sale or return to the source dairy and were ineligible for the study. Of the 212 eligible potential HC, BC, and MC respondents, 105 usable responses were received, yielding a 50% response rate. The distribution of responses for HC and MC operations was Midwest 49%, Northeast 24%, West 18%, and Southeast 9.0%. The response rate for HC and MC operations ranged from 84% in the Northeast to 28% in the West. We were unable to ascertain what influence the distribution of responses or the distribution of nonrespondents in each region had on our estimates because no other estimates were available for this population, the population distribution of calf ranches has not been enumerated, and little information was available on nonresponders to facilitate comparison with responders.

Demographic and Nutritional Characteristics

The median number of preweaned calves reared in 2006 was 450, with a range of 14 to 100,000 (Table 1).

Table 1. Operation-type-specific demographics of preweaned calf rearing operations in 2006

Operation type ¹	n ²	Percentile				
		Median	Minimum	25th	75th	Maximum
HC						
Total number of calves	48	301 ^b	14	93	1,241	32,190
Arrival age (d)	48	3 ^a	1	2	5	10
Weaning age (d)	48	49 ^a	35	41	53	90
MC						
Total number of calves	38	750 ^a	20	300	8,897	100,000
Arrival age (d)	38	2 ^b	1	1	5	25
Weaning age (d)	39	45 ^a	27	42	60	90
Overall						
Total number of calves	86	450	14	120	2,200	100,000
Arrival age (d)	86	3	1	2	5	25
Weaning age (d)	87	48	27	42	56	90

^{a,b}Medians within column for a similar metric with different superscripts differ for HC and MC ($P < 0.05$).

¹Operation type: HC = preweaned heifer calves only; MC = preweaned heifer and bull calves.

²n = number of respondents for a given question.

The HC operations reared fewer calves ($n = 301$) than MC operations ($n = 750$, $P = 0.018$). Of all preweaned calves reared on MC operations, a median of 73% were heifers and 27% bulls. The median MC operation reported receiving calves at 2 d of age, whereas HC operations received calves at 3 d of age ($P = 0.030$). The median age at weaning was 48 d with a range of 27 to 90 d. The HC operations ($n = 48$) represented 74,274 calves, and MC operations ($n = 38$) represented 397,501 calves.

The primary source of liquid nutrition during the preweaning period on 45 of 48 (94%) HC and 27 of 39 (69%) MC operations was milk replacer ($P = 0.003$). In comparison, 68.6% of US dairy operations report using at least some milk replacer (USDA, 2008b). Most HC and MC operations (56 of 86, 65%) had a policy of feeding calves according to more “traditional” methods of 20% CP, 20% crude fat milk replacer, or whole milk fed at a rate of 1 gallon per day. The majority of operations (70 of 86, 81%) had a policy of purposefully increasing the nutrient content of liquid feeds at some point during the year, with this increase occurring more often during winter than in other seasons ($P < 0.005$).

General Morbidity and Mortality

Overall operation-level median preweaning mortality was 3.6% (Table 2). The HC operations had a median 3.0% mortality, somewhat lower than the 4.3% herd-specific median crude mortality reported in a study of New York State dairy operations (Virtala et al., 1996c). On a calf-level basis, mortality on HC operations averaged 5.4%, slightly lower than the 7.8% estimated for heifer calves on US dairy operations in 2006 (USDA, 2007), lower than the 7.9% reported on a single heifer-

rearing facility over 10 yr (Tyler et al., 1998), and less than the 4-wk mortality of 13% on a Holstein bull-calf beef operation (Moore et al., 2002). Our results suggest that the overall calf mortality experience on surveyed calf ranches was not different from common conventional metrics.

Overall operation-level median diarrhea morbidity was 20% with 1.2% mortality because of diarrhea (Table 2). The median HC operation reported 22% diarrhea morbidity, the same as was found in another study of dairy operations (Virtala et al., 1996c). At the calf level, HC diarrhea morbidity averaged 43% and diarrhea mortality averaged 4.1%. Comparable cross-sectional studies of preweaned heifer calves on US dairy operations reported diarrhea morbidity of 23.9% (USDA, 2008a) and mortality of 4.4% (computed from available USDA statistics) in 2006 (USDA, 2007). Prospective estimates for the US dairy industry indicated that 27.2% of heifer calves experienced diarrhea in the first 8 wk of life (USDA, 1994). Others have reported diarrhea morbidity of 15.2% in heifer calves up to 16 wk of age (Sivula et al., 1996) and 35% up to 6 mo of age (Donovan et al., 1998). The operation median morbidity in this survey approximated the US national average, indicating that surveyed ranches had a similar experience to the national average. The calf-level morbidity observed here was influenced by higher morbidity in one larger ranch. However, no overall trend associating morbidity or mortality with ranch size was apparent. Overall, diarrhea morbidity and mortality experience across responding HC and MC operations corresponded to that of US dairy operations.

The HC and MC operations reported median respiratory morbidity of 5.3% and mortality of 0.47% (Table 2), similar to another study reporting median herd-spe-

Table 2. Operation-type-specific yearly and disease-specific demographics of preweaned calf rearing operations in 2006

Operation type ¹	n ²	Percentile		
		Median	25th	75th
HC				
Yearly mortality (%)	47	3.0	1.2	5.3
Diarrhea morbidity (%)	47	22	10	36
Diarrhea mortality (%)	48	1.0	0.22	2.5
Respiratory morbidity (%)	46	5.7	1.8	10
Respiratory mortality (%)	46	0.35	0.0	1.0
MC				
Yearly mortality (%)	35	4.5	2.5	6.7
Diarrhea morbidity (%)	31	19	6.7	40
Diarrhea mortality (%)	33	1.4	0.33	4.0
Respiratory morbidity (%)	31	5.0	2.0	12
Respiratory mortality (%)	34	0.84	0.14	1.7
Overall				
Yearly mortality (%)	82	3.6	1.9	5.7
Diarrhea morbidity (%)	78	20	9.1	36
Diarrhea mortality (%)	81	1.2	0.32	3.2
Respiratory morbidity (%)	77	5.3	2.0	11
Respiratory mortality (%)	80	0.47	0.0	1.3

¹Operation type: HC = preweaned heifer calves only; MC = preweaned heifer and bull calves. For a given disease, morbidity = proportion of all calves experiencing a case of a given disease, and mortality = proportion of all calves dying from a given disease.

²n = number of respondents for a given question.

cific respiratory morbidity of 4.0 to 20% (Virtala et al., 1996b). At the calf level, HC operations in our study averaged 17% respiratory morbidity and 1.0% respiratory mortality. In 2006, preweaned heifer calves on US dairy operations had an estimated 12.4% respiratory morbidity (USDA, 2008a) and 1.8% mortality (computed from available USDA statistics; USDA, 2007). Prospective estimates for US dairy heifer calves found that 8.9% experienced respiratory disease in the first 8 wk of life (USDA, 1994), whereas other studies suggest that between 7.6% (Sivula et al., 1996) and 21% of heifer calves experience respiratory disease (Donovan et al., 1998). Although the median level of respiratory disease and death was less than the overall US average, the calf-level descriptors again indicated a greater disease burden in larger operations in this survey.

Case fatality rate, a measure of diagnostic and treatment intervention effectiveness, was a median 7.7% for diarrhea at the operation level and 6.7% for HC operations, which is comparable to 7.6% median herd-specific case fatality for diarrhea in dairy operations (Virtala et al., 1996c). At the calf level, the case fatality rate for diarrhea was 11% for HC operations. Our estimate for calves on HC operations was in accord with prospective case fatality estimates for diarrhea in heifer calves that ranged from 7.7% (Donovan et al., 1998) to 17.9% (Sivula et al., 1996). Median case fatality rate for respiratory disease was 9.0% at the operation level. At the calf level, respiratory disease case fatality rate was 7.5% for calves on HC operations. Our estimates

are in line with prospective estimates of respiratory disease case fatality of 9.4% (Sivula et al., 1996) and 13.8% (Donovan et al., 1998). Overall, our case fatality results suggest interventional success comparable to that of dairy operations.

A median of 50% of all deaths was attributed to diarrhea on HC and MC operations. At the calf level, HC operations in the present study had 63% of all mortality attributable to diarrhea, whereas on US dairy operations, 56.5% of all heifer calf mortality was attributed to scours, diarrhea, or other digestive problems in 2006 (USDA, 2007). Still lower, another study estimated that only 43.8% of heifer deaths were due to diarrhea (Sivula et al., 1996). The HC and MC operations reported a median 19% of all mortality attributed to respiratory disease. At the calf level, HC operations averaged 20% of all mortality attributed to respiratory disease, whereas in 2006, heifer calves on US dairy operations had an estimated 22.5% of all mortality attributed to respiratory disease (USDA, 2007); another study found that 29.7% of deaths were due to respiratory disease (Sivula et al., 1996).

Our results suggest that calves reared on HC and MC calf ranches have values for common health metrics at least equivalent to those of calves reared on an “average” US dairy operation. However, the median calf-level estimates suggest improved calf health compared with national metrics. The population of calf ranches in this survey was very diverse with respect to the number of calves reared. Some differences that exist between

Table 3. Operation-type-specific diarrhea and respiratory disease antibiotic treatment demographics of preweaned calf rearing operations in 2006

Operation type ¹	n ²	Percentile		
		Median	25th	75th
HC				
Diarrhea antibiotic treatment rate ³ (%)	45	83	35	100
Diarrhea multiple antibiotic treatment rate ⁴ (%)	42	35	2.2	86
Respiratory antibiotic treatment rate ⁵ (%)	40	100	100	100
Respiratory multiple antibiotic treatment rate ⁶ (%)	41	33	0.0	60
MC				
Diarrhea antibiotic treatment rate (%)	28	85	10	100
Diarrhea multiple antibiotic treatment rate (%)	23	67	14	100
Respiratory antibiotic treatment rate (%)	24	100	100	100
Respiratory multiple antibiotic treatment rate (%)	26	50	19	100
Overall				
Diarrhea antibiotic treatment rate (%)	73	83	30	100
Diarrhea multiple antibiotic treatment rate (%)	65	50	8.0	100
Respiratory antibiotic treatment rate (%)	64	100	100	100
Respiratory multiple antibiotic treatment rate (%)	67	47	7.1	100

¹Operation type: HC = preweaned heifer calves only; MC = preweaned heifer and bull calves.

²n = number of respondents for a given question.

³Proportion of calves with diarrhea that were treated with an antibiotic.

⁴Proportion of calves with diarrhea treated with an antibiotic that received more than one type of antibiotic.

⁵Proportion of calves with respiratory disease that were treated with an antibiotic.

⁶Proportion of calves with respiratory disease treated with an antibiotic that received more than one type of antibiotic.

our calf-level estimates and estimates from other studies may be due to the influence of some larger operations in our sample. For example, the HC operation contributing the most to the weighted average diarrhea morbidity reported 60% diarrhea morbidity at the operation level; when this operation was omitted from the weighted calf level estimates, diarrhea morbidity declined to 30%. Therefore, when comparing metrics among calf ranches or comparing calf ranches to the industry, the median demographic estimates at the operation level may be the most appropriate option.

Antimicrobial Use

The operation median percentage of preweaned calves on HC and MC operations with diarrhea that were treated with an antibiotic was 83% (Table 3). At the calf level, 62% of calves on HC operations with diarrhea received an antibiotic compared with 74.5% of diarrheic heifer calves on US dairy operations in 2006 (USDA, 2008a). The median operation surveyed reported that 50% of calves treated with an antibiotic for diarrhea received more than one type of antibiotic. At the calf level, 36% of calves receiving an antibiotic for diarrhea received more than one type of antibiotic. Our results suggest that characteristics of antibiotic use on HC and MC operations mirror that of US dairy operations.

The operation median treatment rate with an antibiotic for respiratory disease was 100% (Table 3),

whereas at the calf level, 96% of calves with respiratory disease received an antibiotic on HC operations. On US dairy operations, an estimated 93.4% of heifer calves with respiratory disease received an antibiotic (USDA, 2008a). The median operation reported that 47% of calves treated with an antibiotic for respiratory disease received more than one type of antibiotic. Although our finding suggests that polymicrobial therapy may not be uncommon in individual calves, some caution in this interpretation is advised. The term “antibiotic” was not defined and a list of antibiotics from which to choose was not given to respondents. As a result, respondents may have unintentionally misclassified therapies such as nonsteroidal antiinflammatory drugs as antibiotics, thereby overestimating the true level of antibiotic use. In addition, no attempt was made to delineate use of multiple antibiotics for a single condition (e.g., diarrhea) versus multiple conditions (e.g., diarrhea and respiratory disease) so multiple antibiotic use may indicate treatment of multiple concurrent diseases.

Medicated milk replacer use on HC and MC operations (56%, Table 4) was similar to that on US dairy operations (57.5%; USDA, 2007) and higher than estimates obtained from Washington State (22.2 to 27.5%; Raymond et al., 2006) and dairy herds across Michigan, Minnesota, New York, and Wisconsin (49.5%; Zwald et al., 2004). Fifty-four percent of operations reported using antibiotics for preventing diarrhea or respiratory disease. Among operations with a policy of preventive

Table 4. Operation-type-specific antibiotic use demographics of preweaned calf rearing operations in 2006

Respondent characteristic	Operation type ¹						Responses ² (n)	P-value ³
	HC		MC		Overall			
	n	%	n	%	n	%		
Used medicated milk replacer	26	54	23	59	49	56	87	0.653
Antibiotics were given for preventing diarrhea or respiratory disease ⁴	23	48	24	62	47	54	87	0.205
Written antibiotic protocols or usage guidelines were available	29	60	27	71	56	65	86	0.304
Collected antibiotic treatment information for individual calves	34	71	35	90	69	79	79	0.036 ⁵
Identified and ceased antibiotic treatment of chronic animals	25	52	24	62	49	56	87	0.377

¹Operation type: HC = preweaned heifer calves only; MC = preweaned heifer and bull calves; Overall includes HC and MC.

²Total number of HC and MC operations responding to a given question.

³All *P*-values are for the comparison of HC and MC operations.

⁴Preventive antibiotic use included use of medicated milk replacer if it was specifically given for preventive purposes.

⁵*P*-values are derived from Fisher's exact test.

antibiotic use, antibiotics were administered for a median of 7 d, representing 17% of the preweaning period. These findings suggest that when antibiotics are used for preventing diarrhea and respiratory disease in preweaned calves, calf ranches tend to target use within a specific period of increased risk of disease. Metaphylactic use of antibiotics has been shown to decrease morbidity in dairy-beef calves on a calf ranch (Berge et al., 2005).

Written antibiotic use protocols can help promote consistency in health care delivery, thereby reducing errors (Raymond et al., 2006). Approximately two-thirds of HC and MC operations (65%) had written antibiotic treatment guidelines available. In contrast, written protocols for treating common medical conditions were present on only 27% of Washington State dairy operations surveyed (Raymond et al., 2006), 21% of Pennsylvania dairy operations surveyed (Sawant et al., 2005), and 32% of South Carolina dairy operations (Friedman et al., 2007). Our finding suggests that calf ranches may utilize written antibiotic use guidelines more frequently than dairy farms. Antibiotic treatment information was collected for individual calves on 90% of MC operations versus 71% of HC operations (*P* = 0.036).

Fifty-six percent of HC and MC operations identified chronically ill calves and ceased antibiotic treatment, although the proportion of calves considered chronic (1%) was minimal (Table 4). Identification of chronically ill animals is a first step in their removal, which may improve overall herd health by removing a source of pathogens for healthy animals (McGuirk, 2004), thereby positively affecting animal well-being and welfare. Results of a study of heifer calves in New York State herds suggest that improvements in average daily gain might be made by reducing the occurrence of chronic pneumonia (Virtala et al., 1996a). Measuring

biological risk and optimizing the decision-making process regarding chronic individual cases deserves further study.

Herd-Level Biosecurity and Biocontainment Practices

Calf. Assuring adequate colostral IgG intake is generally regarded as the single most important management activity to minimize disease in early calf life. Representing 78% of all calves in the study, almost one-half of calf ranches (46%, Table 5) routinely measured passive immunity. The number of operations using this procedure is considerable given that only 2.1% of all US dairy operations (14.5% when restricted to large US herds) reported routine measurement of this important health risk factor (USDA, 2007). Given that calf ranches typically receive calves at or after 1 d of age, little opportunity exists to influence colostral transfer of IgG. Reasons why calf ranches favor measuring passive immunity might include assessing risk of illness and death for individual calves, monitoring colostrum management on client dairies, providing evidence during disease outbreak investigations, or determining rearing costs for a given client. Our finding suggests that calf ranches perceive utility in measuring passive immunity and appear to use this practice more frequently than dairy farms. With this information, they are positioned to anticipate disease problems and to favor dairy clients with excellent colostrum management and fewer ensuing losses.

Housing. Housing plays an important role in biosecurity and biocontainment (Anderson, 1998), with the central principle being to break transmission by preventing contact among individual calves (Reynolds, 2009). Individual pens or hutches are primarily used to house preweaned calves on 67.9% of US dairy opera-

Table 5. Operation-type-specific biosecurity and biocontainment practices on preweaned calf rearing operations in 2006

Respondent characteristic	Operation type ¹						Responses ² (n)	P-value ³
	HC		MC		Overall			
	n	%	n	%	n	%		
Routinely measured passive immunity	22	46	18	46	40	46	87	0.976
Where typically housed, what is the number of potential physical contacts between calves?								
No contact	25	52	14	36	39	45	39	0.131
One or more contacts	23	48	25	64	48	55	48	
When sick calves were found, the calf was normally moved to a separate quarantine area	4	9.0	5	13	9	10	86	0.726 ⁴
When sick preweaned calves were treated or examined, the person treating or examining them usually entered their pen or individual housing area	43	90	29	74	72	83	87	0.062
Personnel were required to wear rubber or disposable boots while working with preweaned calves	19	40	18	46	37	43	87	0.538
Personnel were required to wear disposable gloves while working with preweaned calves	14	29	20	51	34	39	87	0.036
Written guidelines or protocols for biosecurity or biocontainment or both were available	17	35	15	38	32	37	87	0.770
Order of milk feeding								
Youngest to oldest	33	70	26	67	59	69	59	0.724
Other order	14	30	13	33	27	31	27	
Sick preweaned calves were normally treated								
During milk feeding	3	6.0	5	13	8	9.0	8	0.405 ⁴
Before milk feeding	3	6.0	4	10	7	8.0	7	
After milk feeding	42	88	30	77	72	83	72	
Separate feeding equipment was used for sick preweaned calves	35	73	32	82	67	77	87	0.314
Buckets, bottles, or nipples were used for more than one preweaned calf per feeding without washing at least the nipple of the bottle or washing the bucket between calves	2	4.0	4	10	6	7.0	87	0.401 ⁴
More than one customer's calves were on the truck or trailer at the same time	25	52	23	59	48	55	87	0.520
Each customer's calves were separated from other customer's calves so they could never touch each other ⁵	9	36	5	22	14	29	48	0.278
Your clients informed you or your employees of current or potential disease issues at the farm of origin that may affect the health of calves received from that farm	26	54	16	41	42	48	87	0.223
Your farm's daily routine was changed in any way as a result of this information ⁶	19	76	12	75	31	76	41	1.000 ⁴

¹Operation type: HC = preweaned heifer calves only; MC = preweaned heifer and bull calves; Overall includes HC and MC operation types.

²Total number of HC and MC operations responding to a given question.

³All P-values are for the comparison of HC and MC operations.

⁴P-value derived from Fisher's exact test.

⁵Of those operations transporting multiple clients' calves simultaneously.

⁶Of those operations with knowledge of disease issues at the farm of origin that may affect calf health.

tions (USDA, 2007). If individual pens are immediately adjacent or are constructed to allow direct contact, transmission of respiratory and gastrointestinal pathogens can occur (Barrington et al., 2002; Callan and Garry, 2002). Our work suggests that the majority (55%, Table 5) of calf ranches house calves in a manner allowing one or more direct contacts. Future studies of dairy calf housing, in addition to noting the type of housing (e.g., hutch, individual pen or group), should enumerate the number of contacts allowed among calves when assessing relevant health and welfare outcomes.

Isolation. A suggested principle of biosecurity and biocontainment is to isolate calves that are sick from healthy herdmates for 3 or more weeks to avoid buildup of pathogens shed in the environment (Barrington et al., 2002). However, 90% of calf ranches did not remove sick calves to an isolation area (Table 5), and most respondents that removed sick calves returned them to the original location after the calves appeared healthy (67%). In a French study, calves in herds with a policy of not isolating sick calves from healthy calves had twice the odds of morbidity between 1 and 15 d of age (Fourichon et al., 1997). Removal of calves from individual housing units may be impractical due to labor and facility constraints. Producers may feel that if sick calves are housed such that direct contact and the potential for fecal-oral transmission of pathogens are apparently minimized, then removal of sick calves is unnecessary. Housing features such as solid sidewalls or complete separation between housing units are important to help limit pathogen transmission (Barrington et al., 2002; Callan and Garry, 2002). Additionally, daily movement of personnel, including entering the animal pens to administer treatments, becomes more of a concern if ill animals are not isolated, because contact of personnel with adjacent healthy calves may facilitate pathogen transmission. This is important when considering that the housing unit was usually entered when examining or treating an individual calf on 83% of responding operations.

Personal Protective Equipment. The hygiene of hands and personal protective equipment such as coveralls and boots is an important tenet of biosecurity, particularly for gastrointestinal and respiratory disease (Barrington et al., 2002; Callan and Garry, 2002; Maunsell and Donovan, 2008). Fewer than half of HC and MC operations required boots (43%) or gloves (39%) when working with preweaned calves, suggesting that close scrutiny of these practices in future studies is warranted. It is known that feces, saliva, and nasal secretions pose a direct risk and can readily contain pathogens from the gastrointestinal and respiratory systems.

Biosecurity and Biocontainment Protocols.

Protocols are important tools to help manage biosecurity, biocontainment, disease treatment, feeding, hygiene, and expectations of employees (Heath, 1992; BAMN, 2001; Barrington et al., 2002; Maunsell and Donovan, 2008) and should be written and available for review by calf ranch personnel (Maunsell and Donovan, 2008). Our study indicated that 37% of calf ranches had written plans in 2006 with the caveat that our estimates may not include biosecurity and biocontainment guidelines conveyed orally (Table 5).

Feeding Management. Whole or waste milk was used as the primary liquid feed source by 17% of calf ranches compared with 50.7% of US dairy operations (USDA, 2008b), with MC operations (12 of 39, 31%) utilizing whole or waste milk more often than HC operations (3 of 48, 6.0%; $P = 0.003$). Waste milk may pose a biological risk to calves (Selim and Cullor, 1997; Godden et al., 2005; Moore et al., 2009) that can be reduced by pasteurization (Elizondo-Salazar et al., 2010). Feeding pasteurized waste milk has been associated in the short term with lower diarrhea and respiratory disease morbidity and increased preweaning and postweaning weight gain (Jamaluddin et al., 1996a,b; Godden et al., 2005). Most (87%) HC and MC operations feeding primarily whole or waste milk used pasteurization compared with 5.9% of US dairy operations feeding some whole or waste milk to calves that used pasteurization (USDA, 2008b). Our data suggest most calf ranches feeding waste milk are cognizant of the inherent biological risk and take steps (i.e., pasteurization) to manage this risk.

Most operations (69%) fed milk to calves in order from youngest to oldest (Table 5). Sick preweaned calves were treated after milk feeding on 83% of calf ranches surveyed. In contrast, a pilot study of dairies in 2 California counties found that 57.9% and 85.1% of dairies surveyed treated calves with medication during feeding (Lopez-Nieto et al., 1972). Treatment during feeding would appear to increase the opportunity for contamination of feeding equipment and indirect pathogen transmission. Our study found that sick preweaned calves were fed with separate equipment on over three-fourths of calf ranches (77%). It has been suggested that salmonellosis may be spread readily through indirect mechanisms (Gardner et al., 2004), and one report suggested that 40% of secondary cases were due to routes other than spread via direct contact (Hardman et al., 1991).

Hygiene of shared equipment is an important element of biosecurity and biocontainment during the preweaning period (Barrington et al., 2002; Maunsell and Donovan, 2008). Current estimates of US dairy opera-

tions indicate that feeding equipment was cleaned and disinfected between calves on 24.4% of operations and daily on 58.5% of operations in 2006 (USDA, 2007). Although our survey did not ask about disinfection of feeding equipment per se, our findings suggest that feeding equipment hygiene on calf ranches should be at least similar and probably superior to efforts on US dairy operations in that during feeding, 93% of operations did not use buckets, bottles, or nipples without washing between calves.

Records. Almost all (99%) HC and MC operations surveyed uniquely identified calves and maintained records on individual calves. The most common information collected was mortality (92% of operations), individual antibiotic treatments (79% of operations), and morbidity (75% of operations). In contrast, one report indicated that of 63% of dairy operations keeping calf records, none kept sick calf treatment information (Goodger and Theodore, 1986). Another survey found that fewer than 12% of dairies kept calf health records with complete treatment information (Goodger et al., 1993). A third study reported that relatively few dairy herds (36.3%) and organic herds (34.4%) kept antibiotic treatment records for calves and heifers (Zwald et al., 2004). Failure to maintain diagnostic and treatment records greatly impedes herd disease problem solving and assessment of magnitude, duration, and cost of disease.

Study Limitations

The reader should bear in mind some limitations of this work. Our survey was cross-sectional, which precluded any temporal inferences. This survey was conducted at the herd-level so stated practices should be regarded as herd policies, rather than actual events experienced by individual calves, to avoid the “ecological fallacy” (Dohoo et al., 2009). Our goal was to be as inclusive as possible with our sampling frame; however, this frame may not be exhaustive and, to our knowledge, no all-inclusive list of calf rearing operations in the US exists. Although we cannot assess this bias with our data set, the reader should recognize the potential for bias insofar as the respondents may differ from the true population of calf ranches in the United States and that data from nonresponders may differ from that of responders. We asked respondents for estimates that were, by nature, retrospective and self-reported and as such, these estimates may be based either on recall or review of records, either of which might be subject to recall bias or information bias. Misclassification bias may have occurred in some responses because case definitions of common preweaning period diseases and terms such as “antibiotic” were not specifically defined.

In addition, the reader should bear in mind the potential limitations of comparing retrospective estimates to the available prospective estimates in the literature.

CONCLUSIONS

Calf ranches are generally similar and in some aspects superior to US dairy operations in morbidity, mortality, antibiotic use practices, and biosecurity and biocontainment practices. Calf ranches used more generally accepted biosecurity and biocontainment practices than typical commercial dairy operations and we surmise that operations rearing preweaned calves may benefit further from use of additional biosecurity practices. These data provide initial estimates of benchmark metrics at the operation level that should prove useful in the evaluation of calf ranches. Future work with calf ranches should focus on prospectively collecting data on morbidity, mortality, antibiotic use, biosecurity, biocontainment, and other management procedures experienced at the individual calf level.

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