Mortality and health treatment rates of dairy calves in automated milk feeding systems in the Upper Midwest of the United States

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ABSTRACT

Automated calf feeding systems are increasing in use across the United States, yet information regarding health and mortality outcomes of animals in these systems is limited. The objective of this study was to investigate the relationship between farm management practices, housing, and environmental factors with mortality and health treatment rates of preweaned dairy calves housed in groups with automated feeding systems. Farm records were collected for health treatments and mortality on 26 farms in the Upper Midwest of the United States. Relationships between factors of interest and mortality or treatment rate were calculated using a correlation analysis. Overall median annual mortality rate was 2.6 (interquartile range = 3.6; range = 0.24–13.4%), and 57% of farms reported mortality rates below 3%/yr. Farms that disinfected the navels of newborn calves had lower mortality rate (mean = 3.0%; standard error = 0.8; 78% of farms) than farms that did not disinfect (mean = 7.3%; standard error = 1.6; 22% of farms). Farm size (number of cows on site) was negatively associated [correlation coefficient (r) = -0.53], whereas the age range in calf groups was positively associated (r = 0.58) with mortality rate. Average serum total protein concentration tended to be negatively associated with annual mortality rate (r = -0.39 ; median = 5.4; range = 5.0–6.4 g/dL). Health treatment rate was positively associated with coliform bacterial count in feeder tube milk samples [r = 0.45; mean $\pm$ standard deviation (SD) = $6.45 \pm 4.50 \ln(\text{cfu/mL})$] and the age of calves at grouping (r = 0.50; mean $\pm$ SD = 5.1 ± 3.6 d). A positive trend was detected for coliform bacterial count of feeder mixing tank milk samples [r = 0.37; mean $\pm$ SD = $3.2 \pm 6.4 \ln(\text{cfu/mL})$] and calf age at weaning (r = 0.37, mean $\pm$ SD = 57.4 ± 9.6 d). Seasonal patterns indicated that winter was the season of highest treatment rate. Taken together, these results indicate that, although automated feeding

systems can achieve mortality rates below the US average, improvements are needed in fundamental calf care practices, such as colostrum management and preventing bacterial contamination of the liquid diet and the calf environment.

Key words: calf mortality rate, calf health treatment rate, automated feeder

INTRODUCTION

Most farms in the United States house calves individually (69.7% of the farms; USDA, 2016). Recent public pressure and legislation are discouraging the use of isolation-based housing systems, such as individually housed calves (Rushen et al., 2008). A combination of animal, societal, and economic factors have most likely contributed to a recent increase in the number of farms considering group housing as an option for preweaned calves.

Although early work indicated a significant health benefit to housing preweaned calves individually (Waltner-Toews et al., 1986a), more recent studies have found contradictory outcomes. Group housing systems have been shown to have no difference in morbidity and mortality (Losinger and Heinrichs, 1997; Svensson et al., 2003; Svensson and Liberg, 2006) as long as the groups are small (less than 6–8 calves). Multiple studies have found no association between housing type and the chance of infection by pathogens such as *Cryptosporidium parvum* (Mohammed et al., 1999), *Salmonella* spp. (Losinger et al., 1995), or *Escherichia coli* (Rugbjerg et al., 2003). Ultimately the differences in health outcomes may be more related to management practices other than group size by itself (Rushen et al., 2008).

Computer-controlled automated calf feeding systems are one option available to farm operators managing calves in group housing. These systems are designed to mix, heat, and deliver a liquid diet to calves in the preweaning period and to record calf feeding behaviors, which can be used to alert producers to potential changes in animal health status. The use of automated feeders is increasing in popularity in the United States;

Received May 19, 2017.

Accepted August 8, 2017.

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however, information regarding feeder management in a North American context is relatively limited. The objective of our study was to describe the patterns of calf mortality and health treatment rates on farms using automated calf feeding systems and to relate these to management and housing factors.

MATERIALS AND METHODS

Data Collection

A total of 64 dairy farms using automated feeding systems were identified by extension faculty, farm equipment dealers, and other dairy producers in Minnesota, Wisconsin, and northwest Iowa. From this list, 38 farms were randomly selected to be visited, and 26 farms with accurate on-farm calf health records (farms which fully recorded treatment reason, date, therapy used, and calf identification for each treatment administered) were selected for analysis of mortality and health treatment rate in the current study. These farms used Förster-Technik (Engen, Germany) automated feeders, with the exception of 1 farm with an Urban (Wüsting, Germany) feeder. Farms reported an average of 68.3 ± 47.2 (mean $\pm$ SD; range = 20 to 180) calves (50% of farms raised exclusively heifers, 50% a mixture of bull and heifer calves) on site at a given time. The study was carried out in accordance with the recommendations of the Institutional Animal Care and Use Committee of the University of Minnesota and the protocol was approved by the committee. Consent was granted by the farm operators.

Factors of interest were measured at the time of visit to each facility (84.6% of farms were visited 8 times, with 92.3% visited 6 or more times). These included building design (e.g., barn construction type, ventilation system, pen size) and environmental factors (e.g., temperature, humidity, aerial ammonia concentration, light intensity, bedding type, bedding depth, bedding wetness). Practices covering the calf experience from calving to weaning (e.g., maternity pen factors, grouping protocol, feeding plans, barn cleaning and maintenance, automated feeder management, painful procedures) were gathered via a questionnaire, as described by Jorgensen et al. (2017). In addition, blood samples were collected at each visit from the jugular vein into vacutainer tubes from all available healthy calves 24 h to 7 d of age. Samples were centrifuged at $1,800 \times g$ for 10 min at room temperature and tested for serum total protein (STP) using a hand-held light refractometer (model HR-200 ATC, AFAB Enterprises, Eustis, FL). The refractometer was calibrated using distilled water before testing the samples collected that day.

Milk samples were collected quarterly at each farm (at 5 visits) from the mixing tank (mixer) and from the tubing immediately anterior to the nipple from which the calves nurse (tube-end), immediately stored on ice, and fully frozen within 6 h of collection. Because a calf had to be present to activate the feeder, this site of collection was selected to most closely represent the milk being ingested while avoiding interference or contamination of samples from the animal itself. Samples were analyzed for standard plate count and coliform bacteria count at the University of Minnesota Veterinary Diagnostic Laboratory (Saint Paul, MN). Milk samples were also collected twice (in summer and winter) from the mixer and analyzed for milk components (fat, protein, solids) at AgSource Laboratories (Marshfield, WI) using wet chemistry methods [method 985.09; method 930.29 (AOAC International, 2012); SMEDP 15.114 (SMEDP, 2004), respectively].

Producer records for calf health treatments for all (or a portion) of the study period between November 2012 and May 2014 were collected by research personnel. These records were used to estimate the incidence of health treatments on these farms. Calf treatment data included the farm identification, calf identification, calf birthdate, date of treatment, producer-reported reason for treatment, treatment type, and outcome of the illness (recovery/death), although not all of these categories were recorded by each producer for every treatment. Treatments for calves within 14 d of the previous treatment were counted as 1 treatment. Mortality events (not including stillbirth events) were collected from 23 farms because 3 farms in the subset did not record calf deaths. The beginning (November 2012) and final periods of farm visits (March to May 2014) did not cover an entire calendar season and were excluded from the analysis of seasonal effects. Seven farms were identified with the most comprehensive treatment records for the full seasons recorded, encompassing a total of 1,949 individual calf treatments and 126 deaths recorded during winter 2013 (December 21, 2012, to March 20, 2013), spring 2013 (March 21 to June 20, 2013), summer 2013 (June 21 to September 20, 2013), and fall 2013 (September 21 to December 20, 2013), and were used to compare seasonal patterns of health treatment and mortality rates.

Statistical Analysis

Limited data are available regarding the management and housing of automated feeding systems in the United States, making power calculations difficult. The sample of farms represented was the maximum subset available (all operations that kept accurate calf health

and mortality records) taken from a larger study that investigated health outcomes on approximately 60% of farms using automated feeding in 3 states (Minnesota, Wisconsin, Iowa) in the Upper Midwest of the United States at the time of study initiation (Jorgensen et al., 2017). The sample size used in the current study was not large enough to perform multivariable risk factor analysis for mortality and treatment rate; therefore, the relationship between these outcomes and the management, housing, and environmental factors mentioned were investigated by univariable analysis. Those factors are described in more detail in a previous publication (Jorgensen et al., 2017).

Annual treatment and mortality rates were calculated for each farm by dividing total observed treatments or death loss, respectively, by the estimated annual calf population on that farm (farm average stocking rate $\times$ 365 d/time calves spent on the feeder). Distributions of the response variables were analyzed using the Shapiro-Wilk test for normality, which found that treatment rate of calves was normally distributed ($P = 0.28$) and mortality rate was positively skewed ($P < 0.05$). Relationships between annual mortality rates (Spearman's rank-order correlation) or annual treatment rates (Pearson correlation) and farm-level factors of environment and management were calculated using the correlation procedure of SAS (PROC CORR; SAS 9.3, SAS Institute Inc., Cary, NC) for continuous variables (e.g., farm-average STP, group size, calf age at grouping, age range in calf group, weaning age, log of bacterial count) and ANOVA (PROC ANOVA; SAS Institute Inc.) for categorical variables [e.g., season (winter, spring, summer, fall), disinfection of the navel at birth (yes/no), disinfection of the calf pen between calf groups (yes/no), use of drinking speed as health alert (yes/no)].

On the 7 farms with the most complete seasonal records, the relationship between season and mortality or treatment rate was analyzed using a univariable model (PROC GLIMMIX; SAS Institute Inc.). The model used a Gaussian error distribution with an identity link function. Farm was fitted as a random effect. Least squares means were determined for mortality or treatment rate by season and were compared using Bonferroni contrast *t*-test. Significance for all procedures was set at a *P*-value < 0.05 and tendencies for relationships at a *P*-value < 0.10 .

RESULTS AND DISCUSSION

Mortality

The period of consistent record-keeping averaged 353 ± 137 d (mean $\pm$ SD; range = 66–515 d), and a

total of 231 mortality events were reported across the 23 farms included in the mortality subset. Estimated median annual population (extrapolated to 365 d) was 250 calves/farm [interquartile range (IQR) = 148–364; range = 148–1,179]. Farm annual mortality rate (Figure 1) was 2.6% (IQR = 3.6; range = 0.24–13.4%). Only 13% of the farms reported mortality rates above 7%, and 57% of the farms reported mortality rates below 3%. In 61.5% of the mortality events, the animal received at least 1 treatment before death. Administration of antibiotics (104 treatments; 73.2%) was the primary treatment type provided to calves that did not survive, followed by administration of a vitamin B supplement (23 treatments; 16.2%), electrolytes (10 treatments; 7.0%), probiotics (4 treatments; 2.8%), and anti-inflammatory medication (1 treatment; 0.7%). It is known that producer records can be problematic in terms of reliability and accuracy (Vasseur et al., 2010) and might not be a particularly sensitive diagnostic tool. Treatment, especially, is not necessarily reflective of morbidity. Efforts were made in the current study to focus data collection and analysis on only those records that were taken reliably and thoroughly on each farm, which was verified with the dairy producers at each visit.

The US calf mortality rate is 6 to 8% (7.8%, USDA, 2007; 8.1%, USDA, 2010; 6%, USDA, 2017), inclusive of all housing types. The overall median mortality rate observed in the current study indicates that automated feeding systems can achieve lower calf death loss than the US average. However, it is important to acknowledge that this was not the case on every farm.

We found a trend for a negative relationship between mortality rates and farm averages for STP ($r = -0.39$, $P = 0.08$). The recommended targets for successful passive transfer are a minimum of 5.0 to 5.2 g/dL (Weaver et al., 2000; Calloway et al., 2002) and, although the median STP of 5.4 mg/dL (IQR = 1.0; range = 3.2–8.3) on all calves measured in this study was above this recommendation, it is worth noting that 36.0% of all samples were below 5.2 g/dL and 23.3% below 5.0 g/dL. Additionally, 38.1% of farms had STP averages below 5.2 g/dL and 9.5% below 5.0 g/dL. The link between passive immunity and mortality is especially relevant for calves in group housing, where calves may face increased risk of infection from pen mates. Although the importance of passive immune transfer to calf health and survival is well accepted, colostrum management continues to be an issue nationwide, with 19.2% failure of passive transfer being reported on dairy farms in the United States (USDA, 2010).

In the current study, farms that reported disinfecting the calf navel had a lower ($P = 0.03$) mortality rate (mean = 3.0%, SE = 0.8; 78% of farms) than farms

Figure 1. Estimated annual mortality rate [(recorded calf death/estimated yearly calf population) $\times$ 100] for 23 farms in the Upper Midwest of the United States using automated milk feeders for preweaned dairy calves.

that did not disinfect (mean = 7.3%, SE = 1.6; 22% of farms). Farms in the current study that reported disinfecting the pen between calf groups had a lower ($P = 0.04$) annual mortality rate (mean = 2.6, SE = 0.9; 59% of farms) than those that did not disinfect (mean = 5.8, SE = 2.6%; 41% of farms). The pen environment represents a reservoir of potential infectious pathogens (Maunsell and Donovan, 2008), and it has been demonstrated that disinfecting the floor of calf pens between animals has a significant effect reducing levels of infection and the risk of shedding (Castro-Hermida et al., 2006; Hammes et al., 2006). Specific factors related to farm size may play a role in the ability of farms to sanitize calf areas regularly; housing calves in an all-in, all-out system provides managers with a period of time in which these areas can be cleaned, a management strategy that may not be accessible to producers with more dynamic (i.e., calves added and removed from the automated feeder individually or in small groups, rather than all at once) grouping strategies. Barn design may also play a role in the decision to apply disinfectant to the calf pens; possibly those with dirt floors or floors with poor drainage were less likely to use chemicals. Nineteen percent of the farms in the current study housed calves in pens with dirt floors, whereas 81% had concrete floors (62% of them with drainage systems in place).

We found that farm size (number of cows in the lactating herd) was negatively associated with annual mortality rate ($r = -0.53$, $P = 0.01$). For large farms (median = 750 cows; IQR = 412) median mortality rate was 1.5 (IQR = 2.6), and for medium farms (median = 259 cows; IQR = 218) median mortality rate was 2.7 (IQR = 3.9). In a US survey (USDA, 2010), it was found that large farms (>500 cows) had lower pre-

weaned calf mortality (6.5%, SE = 0.4) than medium (100–499 animals; 9.1%, SE = 0.4) and small farms (<100 animals; 8.3%, SE = 0.4). This trend appears to be consistent in the current study. Only 2 of the farms reporting mortality were custom calf raisers, with 1 reporting markedly low mortality (0.5%) compared with the other (4.5%). We also found a negative correlation ($P = 0.008$) between the number of calves on site at a time and annual mortality rate ($r = -0.57$; median = 45; IQR = 55.8; range = 20–180 calves). Taken together, these results might indicate available benefits for calves on large farms that are not available on medium or small farms, such as a trained labor force, better transition cow and calf care protocols, disinfection of pens between calf groups, more calvings per day resulting in narrow age range in calf groups, and so on.

We found a positive relationship ($P = 0.005$) between the reported age range between the youngest and oldest calves in the group and farm mortality rate, indicating that wider age ranges may be problematic for calf mortality ($r = 0.58$; median = 3 wk; IQR = 2; range = 1–10 wk). Older calves are a known source of infection for younger calves (Radostitis et al., 1994); therefore, maintaining calf age difference small as possible may be a factor that affects farms' ability to successfully house calves in slightly larger groups.

Among the difficulties of housing calves in groups is monitoring individual animals for adverse health status. Automated feeders provide youngstock managers with data for each individual calf in the group including milk intake (per meal, daily), number of visits to the machine (rewarded, unrewarded), interruptions of a feeding bout, and drinking speed. Farms that reported using drinking speed as an alarm for identification of sick calves had a lower ($P < 0.001$) annual mortality

rate (mean = 2.4, SE = 0.8%; 74% of farms) than those that did not (mean = 6.6, SE = 1.1%; 36% of farms). Calf drinking speed has been previously investigated in relation to digestion and physical growth (McInnes et al., 2015). The use of drinking speed as an alarm has been described previously (Cramer et al., 2016). Although feeding behavior appears to be a useful tool for identifying potentially sick animals, it must be noted that the behavioral data recorded by automated feeding systems is variable in detection sensitivity and specificity depending on the disease present (Knauer et al., 2017); therefore, it is not recommended that these metrics completely replace live observation of animals. It is possible that the use of additional metrics to monitor health may reflect the overall diligence of calf care staff, or comfort in using the technology, rather than the ability of the measurement to detect disease.

Group size and space per calf were found to have an association with health outcomes when investigating calf health scores (Jorgensen et al., 2017), but we did not find a correlation between calf mortality rate and group size (per pen) in the current study. The median group size for farms in the current study was 18.3 (IQR = 4.1; range = 10.4–60.6) animals, with only 1 farm averaging a stocking rate lower (9.2 animals) than 10 calves/group. The average group size in the current study may have reduced our ability to detect a relationship between group size and mortality. However, the number of farms with low mortality rates might be an indication that it is possible to have low calf mortality in group-housing systems with automated feeders. It has been previously reported that large group size can increase risk for calf mortality, with large groups typically categorized as having several animals in, or above, the high single digits showing higher mortality (large >6 to 8 animals, Losinger and Heinrichs, 1997) and disease incidence (large = 6–30 animals, Svensson et al., 2003; 12–18 animals, Svensson and Liberg, 2006) than those housed in smaller groups. Ultimately, the effect of group size is not clearly defined in the literature, and it is likely that the success or failure of a system may depend more on other management factors, including, but not limited to, cleaning procedures, number of nipples per feeder, type of feeder, as well as barn design and ventilation (Rushen et al., 2008).

No relationship ($P > 0.10$) was detected between mortality rate and season in the current study, although previous work has shown that patterns of calf mortality followed a seasonal pattern. Mortality in preweaned calves has been shown to be higher in winter than in summer (Waltner-Toews et al., 1986b; Svensson et al., 2006). Seasonal changes in precipitation and temperature are likely to affect seasonal changes in mortality (Martin et al., 1975), so it may be that housing calves

inside barns, as most farms with automated feeders do, has a mitigating effect on these changes. Because the group of farms that could be compared directly across 4 consecutive seasons was small, there also may have been insufficient power to detect a seasonal difference in mortality rate.

As has been demonstrated, the relationships detected between annual mortality rate and environmental and management factors in our study were generally consistent with previous work measuring calf health in other husbandry systems. Indeed, many focus on fundamental calf care issues, such as colostrum management and navel disinfection, that are commonly problematic for farms regardless of housing type. The sample size for this analysis was somewhat limited, with 23 farms reporting mortality, which certainly affected the ability of the analysis to detect significant relationships. In addition to controlling for possible confounding variables, a larger study could result in those trends described above becoming significant, along with certain other relationships that were not detected. Despite the limitations of this data set, it appears that the improvement of some basic calf care procedures, particularly with respect to colostrum management, group dynamics, and limiting pathogen loads in both the environment and diet, can help reduce calf mortality rate on farms using automated feeders.

Health Treatment Rate

From an estimated population of 8,679 calves on the 26 farms in the current study, a total of 5,926 treatments were administered to 4,706 individual calves during their time on the automated feeder. Of these calves, the great majority were treated only once (79.1% of animals), with smaller numbers receiving 2 treatments (16.8% of animals) or 3 or more treatments (4.1% of animals). The great majority of recorded treatments were antibiotics (5,177 treatments), followed by electrolytes (330 treatments), nutritional or vitamin supplements (218 treatments), probiotics (44 treatments), physical therapies (e.g., release of gas from bloat; 15 treatments), and Kaopectate (Chattem Inc., Chattanooga, TN; 11 treatments). Farms failed to record treatment type for 131 treatments. These records may be somewhat skewed by producer perceptions of what treatment types are worth recording; for instance, nonantibiotic treatments may not be recorded at the same rate as antibiotics. As previously discussed, 142 animals died despite receiving treatment. Calves on this set of farms were brought into group housing and enrolled on the automated feeder at an average age of 5.1 ± 3.7 d and were weaned and moved to heifer facilities at an age of 57.3 ± 10.1 d; therefore, the treatment rate observed

was not likely to be severely affected by calves staying in the system longer than hutch-housed calves. One potential benefit of feeding calves in automated systems is the reallocation of labor away from menial tasks, such as bottle washing, which may allow producers increased time for observation of calves themselves. However, to our knowledge, no studies have yet been conducted on whether this may lead to producers identifying and treating sick calves more frequently. Further investigation is suggested to learn whether producers tend to treat more calves than necessary (more than the calves that are obviously sick) in these group-housed systems as a preventative measure.

Sixty-five percent of the farms in the current study used milk replacer, 27% used supplemented whole milk and 8% used whole milk (referred to as milk throughout the manuscript). The log count of coliform bacteria [$\ln(\text{cfu/mL})$] in the automated feeder tube milk samples was positively associated ($P = 0.02$) with annual treatment rate [$r = 0.45$; mean = $6.45 \pm 4.50 \ln(\text{cfu/mL})$]. We also observed a positive trend ($P = 0.07$) between the count of coliform bacteria in the feeder mixing jar and the annual treatment rate [$r = 0.37$; mean = $3.2 \pm 6.4 \ln(\text{cfu/mL})$]. Coliform bacteria are one among several potential pathogens in calves, but are frequently cited as a possible cause of infection in milk fed to preweaned calves (Stewart et al., 2005). A high pathogen load in milk was shown to influence health scores of group-housed calves in automated feeding systems (Jorgensen et al., 2017).

The median raw count for coliform bacteria in milk samples was 10,430 cfu/mL (IQR = 233,111; range = 45–28,517,000) in the feeder tube end and 336 cfu/mL (IQR = 28,689; range = 0–25,621,330) in the mixing jar. It is recommended that bacterial contamination of milk fed to calves be limited to a maximum of 100,000 cfu/mL for standard plate count and 10,000 cfu/mL for coliform bacteria (McGuirk and Collins, 2004). Although appropriately stored milk and milk replacer products should face a low risk for contamination (McGuirk, 2008), this contamination is likely to be a major risk for calves in automated feeding systems. Exposure to pathogens is an inherent risk for negative health outcomes in dairy calves, and the ingestion of contaminated milk can be a major source of infection (Lorenz et al., 2011). It should be noted that bacterial contamination is not observed solely in automated feeding systems and that it can also be a problem in individual housing systems (Moore et al., 2009).

The age at which critical management practices are implemented appears to be related to treatment rates on automated feeder farms. Many farms using automated feeding systems house calves individually for the first several days of life to allow neonates to develop

physically and immunologically before mixing with the other calves on the automated feeder. Whereas this practice is intuitively sensible, age of calves at grouping showed a positive association ($P = 0.01$) with treatment rate ($r = 0.50$; mean = 5.1 ± 3.6 d), a relationship that indicates an increased rate of treatment on farms grouping calves later. The underlying basis for this relationship is unclear, but several factors could have an influence. The individual housing area may not receive the attention that group pens do, leading to a build-up of pathogens in these areas over time; calves may contract infectious pathogens in individual housing, but only become infectious and spread them to other animals upon grouping. We suggest further investigation of the ideal age for introducing calves to group housing, in addition to evaluation of alternative management strategies for grouping very young calves separately from older animals.

We also detected a positive trend ($P = 0.07$) between the age at which farms wean calves and treatment rate ($r = 0.37$; mean = 57.4 ± 9.6 d). Weaning causes distress in calves (Weary et al., 2008); it has been shown previously that weaning calves at 7 wk, rather than 3 or 5 wk, resulted in a higher incidence of diarrhea in calves housed both indoors and outdoors (Jorgenson et al., 1970). In the current study, the effect of weaning later may be an artifact related to calves being in the system longer and therefore receiving more treatment. The effect of later weaning may also be affected by other factors that could not be accounted for in the current analysis, such as the age difference between the oldest and youngest calves in later-weaning systems or the retention of chronically ill calves, which may take longer to reach desired size and weight than healthy counterparts.

Treatment rates differed between seasons, with higher treatment rates occurring during the winter period (LSM = 103.9, SE = 10.1) compared with spring (LSM = 54.7, SE = 10.1; $P < 0.001$) and summer (LSM = 71.1, SE = 10.1; $P = 0.03$). The autumn season (LSM = 76.8, SE = 10.1) was not different from any other season, although a difference was detected between autumn and winter at the trend level ($P = 0.09$). We detected no relationship between mortality and season, but the seasonal patterns of treatment were consistent with the increase in adverse health outcomes and prescribed antibiotics observed during the winter period in previous work (Nonnecke et al., 2003). Adverse health outcomes and mortality have been observed in winter previously (Waltner-Toews et al., 1986b; Svensson et al., 2006), and winter was associated with worse health score outcomes (Jorgensen et al., 2017). The effects of winter are likely diverse, but include aspects of calf thermoregulation, barn ventilation, seasonal stocking

practices, and air quality at the calf level (Lago et al., 2006; Brscic et al., 2012).

CONCLUSIONS

Although concerns exist about the transmission of disease between calves housed in groups, the calf mortality rates shown in the current study appear to indicate that automated feeding systems can result in similar or lower calf mortality than the US average. Treatment rates appeared to be high, but there is limited information on treatment rates for individually housed systems for comparison. Despite good performance on mortality rates, it is clear that fundamental aspects of calf care remain crucial to raising calves successfully on automated feeders. Adequate care of the neonate, excellent colostrum management, and limited exposure to pathogens, particularly those in the liquid diet, are all practices that appear to be critical in automated feeding systems. It is important to note that the relationships between these factors and mortality and treatment rates are associative only and the sample size did not allow for analysis of potential confounding factors. Further research is necessary to determine causality of these variables on calf mortality and health outcomes.

ACKNOWLEDGMENTS

We thank all the dairy producers who participated in the study. In addition we thank Luis Espejo (St. Augustine, FL) for help with statistical analysis. Various students at the University of Minnesota helped with data entry and we thank them (Nathan Bos, Kelly Froehlich, Andrew Hetke, Andrew Plumski, Michael Schmitt). This project was supported by Agriculture and Food Research Initiative competitive grant no. 2012-67021-19280 from the USDA National Institute of Food and Agriculture (Washington, DC).

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