EFFECTS OF CALFHOOD RESPIRATORY AND DIGESTIVE DISEASE ON CALFHOOD MORBIDITY AND FIRST LACTATION PRODUCTION AND SURVIVAL RATES

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Key words: calfhood disease, morbidity, age at first calving, mortality.

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ABSTRACT

Calf health data and first lactation records for 2556 cows born in a commercial dairy herd between June 1998 and June 2001 were studied to determine the effects of calfhood disease on survival and performance. Operator-treated respiratory disease occurrences within the first year of life and digestive disease occurrences within the first 45 d of life were analyzed to determine their effects on calfhood morbidity, age at first calving, 305-d first lactation production, and mortality in first lactation. Of the 2556 records used, 2083 calves contracted respiratory or digestive disease at least once, 1254 calves had digestive disease only, 771 had respiratory disease only, and 191 calves had both diseases. Occurrence of calfhood digestive disease increased the chance of calfhood respiratory disease 2-fold. Age at first calving increased 0.53 mo with multiple occurrences of respiratory disease versus none. Calves born in the winter calved at 25.4 mo, whereas calves born in spring calved at 24.5 mo. Respiratory disease had the largest effect on calves born in the spring, resulting in 23.9 mo age at first calving for no occurrence and 25.4 mo for multiple occurrences. No significant effect of disease was detected for 305-d milk yield, fat yield, or SCC, but protein yield decreased by 0.05 kg/d with increased calf respiratory disease. Although calfhood disease had no influence on illness as a cow, disease-free calves had a 5% advantage in probability of remaining in the herd through 305-d, and an 8% advantage at 730-d compared with calves with 2 or more disease occurrences. In conclusion, calfhood occurrences of respiratory and digestive disease had a slight impact on age at first calving, depending on season of birth, and minimal impact on production performance through 305-d of first lactation. The occurrence of respiratory or digestive disease caused a decrease in survival rate from calving through 305-d in first lactation and 730 d after calving.

Key words: calfhood disease, morbidity, age at first calving, mortality.

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Review of Literature

Results of Calfhood Diseases on Growth and Lactation Performance

Rearing of dairy heifers affects age at first breeding and subsequently the age of first calving as well as body weight at first calving. Therefore, weight gain needs are important to understand and control to achieve the most advantageous pre- and post-pubertal weight gains and an optimal age at first calving (Hendricks et al., 1991).

This section discusses previous research that has dealt with common practices of heifer rearing and subsequent effects on milk production performance of the cow. Topics include: the effect of calfhood disease on average daily gain and milk production, how average daily gain affects age at first calving and milk production, and how age at first calving influences milk production and culling rate, along with the effect of body weight at first calving on milk production.

Disease has an important effect on average daily gain. Virtala et al. (1996) concluded that the occurrence of pneumonia in calves during the first 3 mo of life reduced average daily gain. The study involved 410 dairy calves from 18 commercial herds in NY over a 1-year period. Through the use of multiple linear regression with seasonal effects in the model, it was concluded that each week of diagnosed pneumonia reduced body weight by 0.8 kg and height by 0.2 cm for the first 3 mo of life.

Whereas calfhood disease impacts average daily gain of calves, studies found no significant difference in milk production between cows that contracted diseases as calves and cows without calfhood disease. Britney et al. (1984) conducted a study on 460 calves from two institutional herds over a 7-year time frame. Cumulative disease incidences of calves having respiratory, gastro-intestinal, navel-joint, and other diseases prior to 4 mo of age were 5.8, 3.3, 2.9, and 16.7%, respectively. The study found no significant difference in milk production per completed first lactation between a disease-free group and disease groups for respiratory, gastro-intestinal, navel-joint, and other diseases.

In earlier results, Hatch et al. (1974) stated that calfhood pneumonia had no effect on first lactation production among 18 heifers that recovered promptly, compared with production of herdmates from the same sire. Likewise in a study of 728 heifers from 25 NY Holstein herds, researchers found that there was no significant detrimental effect of owner-diagnosed calfhood disease on first lactation milk production (Warnick et al. 1995).

The relationship of average daily gain on age at first calving and later milk production is unclear. Although many studies have been conducted, the results differ. Onset of puberty is determined primarily by body weight of the heifer as described by Bortone et al. (1994). They studied 89 Holstein heifers fed 100% and 115% of 1989 NRC nutrient requirements for heifers gaining 0.7 kg/d from 3 mo until 12 mo of age. It was deduced that the onset of puberty was determined by body weight of the dairy heifer since both groups had similar body weights at puberty of 278 kg and 281 kg. Holstein heifers begin puberty at 275 kg, which is approximately 43% of their mature body weight. Little et al. (1981) also stated that puberty is primarily associated with body weight, which averaged 242 kg for British Friesian heifers born in all seasons. Furthermore, because the length of gestation is fixed, age at first calving is a function of age of puberty and, specifically, age at conception.

Abeni et al. (2000) analyzed 42 Italian Holstein-Friesian heifers fed a diet to gain at a moderate (0.7 kg/d) and accelerated (0.9 kg/d) average daily gain to determine differences in first lactation milk performance, body condition, and metabolic profile. A four-period feeding regimen consisted of the same moderate daily gain diet until a body weight of 150 kg was reached. For the next 7 mo, the two groups were either fed a moderate or accelerated daily gain diet, and for the next 7 mo after that period the groups were both fed a moderate daily gain diet. The study showed that post-weaned calves fed to gain an average daily gain of 0.7 kg verses an average daily gain of 0.9 kg for 7 mo displayed no difference in age at first calving. Other studies by Little et al. (1979) showed that when prepubertal growth rates of heifers were increased, production in the first lactation decreased. Of 110 British Friesian and British Friesian-Ayrshire crosses studied, two groups were rapidly reared at a rate greater than 1 kg/d and one group was normally reared at a rate of 0.74 kg/d from 13 to 39 weeks of age. Results showed a significant difference between the groups, with the rapidly-reared group producing 1507 kg/305-d less milk than the normally-reared group.

Mouritis et al. (1999) proved that although it would be best economically if the prepubertal period could be reduced to 7 mo by increasing average daily gain, there are expected disadvantages, such as reproductive problems and low milk yield in first lactation, that that more than offset the saving in feed costs. This results in an optimal average prepubertal period of 12 mo, and prepubertal growth rate of 0.7 kg/d. These recommendations are similar to those of Sejrsen et al. (1997), who stated that a prepubertal average daily gain of between 0.7 and 0.8 kg/d is required to enable the heifer to calve at around 24 mo of age. The interrelationship between rearing strategies and the productivity and profitability of the dairy replacement are not well understood (Mouritis et al., 1997).

While an optimum age at first calving maximizes?? prepubertal feed cost, effects of average daily gain on subsequent milk production are meaningful as well. Abeni et al. (2000) reported that a moderate (0.7 kg/d) or accelerated (0.9 kg/d) average daily gain before puberty in 42 Italian Holstein-Friesian heifers did not significantly influence milk production or fat and protein concentration for first lactation. Moderate versus accelerated average daily gain after puberty also had no effect on milk production or fat and protein concentrations in first lactation. In addition, Pirlo et al. (1997) and Waldo et al. (1998) found that a prepubertal average daily gain of greater than 0.8 kg/d had no effect on first lactation milk production.

Similarly, Van Amburgh et al. (1998) analyzed 273 heifers during their prepubertal period and concluded that body weight gains, when evaluated on a continuum from 0.5 to 1.1 kg/d, explained little of the variation in milk yield and did not significantly affect milk yield during first lactation.

While these studies found that body weight gain during the prepubertal period did not significantly affect milk yield during first lactation, Gardner et al. (1997) found dissimilar results. They concluded that first lactation yield was 10 to 25% less when prepubertal growth rates exceeded 0.8 kg/d. Hoffman et al. (1996) also demonstrated a negative relationship between accelerated growth and first lactation milk yield. Although the difference between an accelerated and control feeding regimen favored the control feeding by 486 kg/305 d for milk yield, the difference was not significant. The control feeding regimen was favored by 16.9 kg/305 d for milk fat yield and 16.2 kg/305 d for milk protein yield.

Whereas most results showed no effects or negative effects on milk yield, studies such as Little et al. (1979) showed a positive effect on milk yield in the first lactation due to an accelerated growth rate of the heifers. A study where 110 dairy heifers were split into two groups; one fed to gain at a normal rate of 0.74 kg/d and the other fed for an accelerated rate of 1 kg/d. The group that was reared normally had a 1507 kg/305 d advantage in milk yield over the accelerated group.

Lowering the age at first calving will decrease rearing expenses of the heifer, but it is important to understand the relationship that an earlier age at first calving will have on future production performance. Lin et al. (1985) concluded that an earlier first breeding age of 11.7 mo and a resulting age of 23.3 mo at first calving were preferred to a breeding age of 15.4 mo and a resulting calving age of 26.5 mo. Although earlier breeding resulted in lower conception at first service than later breeding, 38% and 47% respectively, and produced smaller yields in first lactation, 174 kg less milk in 168 d of production, there was an economic advantage from a quicker return of income and a savings of rearing costs. Therefore breeding heifers at a younger age along with maintaining a proper rearing program offers a promising approach to increased profit in the dairy industry.

Abeni et al. (2000) concluded that early calving, based on insemination at a body weight of 370 kg, negatively influenced milk production by 3.26 kg/d. Little et al. (1979) also demonstrated that breeding at 10 mo led to a 1198 kg/305 d decrease in first lactation milk yield compared with heifers bred at 18 mo. Ducrocq (1994) showed that age at first calving did not increase the probability of being culled. Rather, the probability of being culled increased with advancing days in milk and also increased for low producing cows. Any numbers here? Later compare with your survival results.

Along with the age at first calving, body weight at first calving also affects milk production. Keown et al. (1986) studied 305,000 Holstein records from DHI and found that heifers with a postcalving body weight of 544 to 567 kg had optimal milk production for first lactation. A first lactation cow having a postcalving weight of 567 kg produced, on average, 806 kg more milk than did a first lactation cow calving at less than 408 kg. Van Amburgh et al. (1994) agreed with these findings and specified an optimal postcalving body weight of 545 to 565 kg.

Morbidity and Mortality

Morbidity is the condition of being diseased, whereas mortality is defined as death. This section provides information regarding the effects of occurrence of disease on morbidity and mortality of dairy cattle from calfhood into lactation.

Waltner-Toews et al. (1986) conducted a study on 104 randomly selected Holstein dairy herds in southwestern Ontario and uncovered an association between heifer calf management and morbidity for scours and pneumonia. Statistical analysis was by two-way tables, stratified by year, with differences tested by chi-square or Fisher's Exact test. Scours and pneumonia were significantly associated with each other at both the herd and calf level. Risk of pneumonia in individual calves increased by a factor of three while they had scours. There was no association between individual calf management practices and the likelihood of being treated for scours.

Curtis et al. (1988) found results corresponding with those of Walter-Toews (1986). A total of 1171 calves in NY born over a two-year period were analyzed using logistic regression to compute a relative risk of disease. The study concluded that calves with scours within 14 d of birth, dullness, which was owner diagnosed decrease in physical appearance, from 15 to 90 d of age, and scours from 15 to 90 d of age were at increased risk of respiratory illness, with relative risks of 2.5, 7.7. and 3.1 respectively.

Warnick et al. (1996) conducted a study looking at the association of owner-diagnosed calfhood diseases with the length of herd life after calving in 25 NY Holstein herds over a 10-year period. Owners recorded occurrences of dullness, respiratory disease, and scours. Statistical analysis was done through Cox's proportional hazards model. Although no disease categories were found to be significantly associated with herd life, the hazard function for dullness was 1.3. Warnich et al. concluded that this finding indicates that further evaluation of the long-term effects of calfhood morbidity is necessary.

Curtis et al. (1989) analyzed records of 1069 heifer calves in 24 herds in NY born in a 2-yr period. Cox's proportional hazards model was used to compute the effects of morbidity variables on survival. The only illness related to survival was dullness within 90 d of birth, which increased the hazard rate for death after 90 d of age 4.3-fold above that for heifers without dullness within 90 d of birth, after adjusting for herd, season, and year of birth. There were no significant effects of season and associated year of birth on survival distributions after 90 d of age.

Britney et al. (1984) utilized records from 460 calves born into two institutional dairy herds over a 7-year period to determine the relationship between calfhood health status and subsequent dairy herd survivorship and productivity. The results showed no significant difference between healthy cohorts of calves for respiratory, gastrointestinal, septicemia, and ‘other’ groups for survival function, milk production, or reproductive performance.

Perez et al. (1990) analyzed 3061 calves from 63 commercial Dutch dairy farms with between 40 and 70 milking cows each. Incidence rate for respiratory disease was 5.8% for female calves, which is lower than results from U.S.A. studies of 7.4% and Canadian studies of 15%. Increased risk factors for diarrhea were the outdoor season from the end of April until the middle of October, first parity of the dam, colostrum fed within the first day, poor climate conditions, group housing and poor bedding material. The risk factors for respiratory disease included no navel treatment, with a relative risk of 2.45, denoting that calves were 2.45 times more likely to suffer from respiratory disease. Daily milk replacer fed within 5 d of birth had a relative risk factor of 1 (neutral) whereas waiting more than 5 d had a relative risk of 1.91 for respiratory disease. Previous cases of diarrhea lead to a relative risk factor of 3.79 for respiratory disease, and a relative risk factor of 3.31 for diarrhea. Although a previous case of diarrhea increased the relative risk factor for diarrhea and respiratory disease, a previous case of respiratory disease did not affect respiratory disease or diarrhea occurrence.

Economics

Many of the previous studies discussed the effects of calfhood disease and average daily gain during both pre- and post-pubertal periods on subsequent milk production, as well as mortality and morbidity. While these studies looked at occurrences and lasting effects, they did not go as far as to equate these finding with an economic value. Warnick et al. (1995) concluded that further economic analysis needed to be conducted to show if significant financial differences existed, even though there were no significant statistical differences in production performance between diseased groups and non-diseased groups. He proposed that differences would be due to increased costs of veterinary and medical care, increased disease susceptibility of the diseased groups, and decreased efficiency of productivity such as feed conversion; therefore, diseased groups would have a lower net return than healthy groups.

This section presents studies that established an associated cost for the occurrence of calfhood diseases. These studies vary from different regions of the world and times within the past few decades, with prices relevant to time and place where the study occurred.

Andrews (2000) conducted a study in 12 commercial herds in Britain where pneumonia outbreaks were monitored on a weekly basis during the winters of 1997 to 1998 and 1998 to 1999. Eight of the twelve herds, were dairy herds, and of those herds 186 out of 272 (68.4%) calves contracted pneumonia. Most of the pneumonia outbreaks occurred during moist weather with high humidity. Costs were calculated by herd, and the average for all herds per ill calf was £43.50 ($65.25), and £29.58 per calf in a group, which was $44.37 (1 Great Britain Pound = 1.50 U.S. Dollar). The cost percentages for weight loss, medicines, veterinary, labor, mortality, materials and other were 26.4, 22.4, 18.9, 11.3, 7.1, 7.0 and 6.8% respectively. It is important to note that one study analyzed vaccinated calves for Respiratory Syncytial Virus, Parainfluenza-3, and Infectious Bovine Rhinotracheitis, and the costs per calf were by far the lowest at £3.85, approximately $5.78 per calf in a group. Andrews (2000) concluded that costs associated with pneumonia outbreaks were important to farm economics. While outbreaks were associated with weather changes, management factors such as inadequate feedings also played a role, and various organisms were present at the time of the outbreaks. Viruses were the most common. Vaccinations against common viruses were the most effective management practice, decreasing the cost by nearly £16.00/calf, approximately $24/calf in a group.

Sischo et al. (1990) conducted a study on 43 dairy herds in California to find economic information regarding disease occurrence and prevention. Calf diseases accounted for 4% of the total costs that cows incurred during their lifetime, with diarrhea and pneumonia being responsible for 86% of calf disease costs from birth to weaning.

Diarrhea cost $1.11/mo per calf, and pneumonia cost $0.82/mo per calf. Of these two diseases, the major fraction of cost was associated with calf death. The rest of the costs were for drugs, labor, and other. From weaning to calving, pneumonia cost was $2.05/yr per calf, while undiagnosed conditions caused $1.61/yr per calf in losses, all due to death. Prevention accounted for about 10% of the total cost of disease occurrence in all ages. Disease prevention in young-stock cost $1.59/yr and $0.36/mo per calf. These numbers are presented in Table 1.

Table 1. Disease costs for diarrhea, pneumonia and prevention in calves and young stock. [a]

Category	Calves to weaning Costs ($/yr)	Weaning to breeding Costs ($/yr)	Total cost per animal
Diarrhea	$13.32	$2.05	$15.37
Pneumonia	$9.84	$1.61	$11.45
Prevention	$4.32	$1.59	$5.91

[a]Values from Sischo et al. (1990)

Hurd et al. (1995) used a stochastic distributed delay simulation model to analyze the economics of respiratory disease in Michigan dairy cattle. The estimated cost of respiratory disease was $3116 which was more annually than initially thought on an average size MI dairy with 11 calves, 41 young stock and 81 cows. The mean cost of respiratory disease was $4604 annually, or $88.58/yr per heifer on the farm. The model considered effects of disease on growth, milk production, lost genetic potential, and replacement costs. The problem with the stochastic distributed-delay simulation model is that it cannot be easily applied and accepted in the dairy industry because it is difficult to explain and has limited flexibility according to Van der Fels-Klerx et al. (2001). It was suggested that a more user-friendly and flexible model is needed for use in dairy practices as well as for investigation of the uncertain information on the relationship of productivity and bovine respiratory disease.

Van der Fels-Klerx et al. (2001) calculated total annual losses associated with bovine respiratory disease outbreaks to be much lower than Hurd et al. (1995) proposed from their economic model. This study used a personal computer model to estimate economic losses associated with clinical bovine respiratory disease in replacement heifers raised on individual dairy farms. Besides price differences, the other variation between the models was that Hurd et al. (1995) included a reoccurrence of disease in the lactating cow which Van der Fels-Klerx et al. (2001) did not. Van der Fels-Klerx et al. (2001) detailed the evaluation of economic consequences of bovine respiratory disease through the use of specific farm figures directly reported by the producer, whereas Hurd et al. (1995) modeled the spread of disease to estimate number of animals in any given disease state, and made many more assumptions of the effect of disease on future performance. Van der Fels-Klerx et al. (2001) calculated a €27.0, or $33.21 (1 Euro = 1.23 U.S. dollars) cost associated with a seasonal bovine respiratory disease outbreak per heifer up to 15 mo of age on the typical Dutch farm. This equaled 2.3% of the farm net return to labor and management.

Disease costs include components for prevention and treatment of the occurrence when an outbreak arises. There are also lasting effects that were discussed previously such as decreased average daily gain and therefore increased age at first calving. Mourtis et al. (1997) addressed the issue of a later age at first calving. Since costs are generated from feed, veterinary treatment, housing and labor during rearing, and no income has been produced from these animals, rearing time should be minimized. The idea is to shorten the non-productive rearing period such that maximum profit can be reached with minimum negative side effects during the first lactation. Least-cost rations indicated that the savings from feed costs, when the age at calving was reduced from 26 to 22 mo, could vary from $42 to $119 per heifer ($1/d), depending mostly on seasonal variations in feed costs.

Reduction of involuntary culling rates in the herd helps reduce herd costs. Rogers et al. (1988) used dynamic programming to find the effect of optimum culling decisions on annual net revenue. Reduction of involuntary culling rates by 20% resulted in about a $22 improvement in annual net income per cow per year, and milk production performance had little effect on that value. Therefore, lowering involuntary culling rates is desirable because it reduces annual cow depreciation.

Van Arendonk (1988) also concluded that a reduction in rate of involuntary replacement allowed a higher voluntary replacement rate. This increased the financial advantage but it reduced the length of average herd life. Even though the increase in production of a cow within a herd increases the optimum average herd life, selection on milk production will not automatically result in longer average herd life of cows.

The review of literature and data available led to the formation of objectives for this study. Objectives were as follows:

- determine the frequency of respiratory and digestive disease for calves that were born and reared on the farm,
- determine relationships between disease occurrences and age at first calving,
- determine the impact of disease occurrence as calves on the probability of remaining in the herd through first lactation,
- determine the effect of disease occurrence on production in first lactation,
- determine associations between calfhood disease and disease in first lactation.

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Chapter 2
Introduction

In the mid-west region of the U.S. 36% of lactating dairy cows are replaced each year in herds with more than 100 cows (DRMS, Dairy Metrics). Over the past several years, costs of replacing these cows have varied from $1200 to more than $2000/heifer, offset by cull prices of $400 to $600/cow. Operating budgets indicate that approximately 20 to 25% of dairy operating expenses are attributed to the dairy heifer enterprise (VA Cooperative Extension). Therefore, it is economically important to minimize expenses of rearing dairy heifers and to reduce involuntary culling in the milking herd.

Digestive and respiratory diseases in calves are the two problems most common in rearing dairy heifers. In 1992, a survey of 921 dairy farms from the top 20 dairy states showed that respiratory disease afflicted 8.9% and digestive disease afflicted 27.2% of calves up to 8 wk of age (National Animal Health Monitoring System, 1994). A later study from the 21 top dairy states representing 85.5% of dairy cattle in the United States found that of calf deaths that occurred on dairy farms 62.1% were due to digestive disease and 21.3% were due to respiratory disease for unweaned heifers. For weaned heifers 12.3% of deaths was caused by digestive disease and 50.4% was due to respiratory disease (NAHMS 2002).

A common measure of efficiency in rearing Holstein heifers is for them to gain 0.7 kg/d to reach the onset of puberty at a body weight of 275 kg, which is approximately 43% of mature body weight (Little et al., 1981). This enables them to calve at 24 mo of age to optimize the balance of rearing expenses and future milk yield (Little et al. 1979). Calfhood disease has the potential to reduce daily gains and affect the age at first calving. Virtala et al. (1996) found that each week of pneumonia decreased body weight gain by 0.8 kg/d during the first 3 mo of life in 410 dairy calves in NY. Studies to determine the association between calfhood disease and morbidity and mortality of heifers through their first lactation have varied in their results. Some studies, such as Warnick et al. (1996), with 728 calves in 25 NY herds, found no relationship between calfhood disease categories with herd life. Britney et al. (1984) using 460 calves in two institutional herds also reported no difference in survival function, milk production or reproductive performance between healthy calves and those afflicted with respiratory, gastrointestinal, septicemia and 'other' diseases.

Conversely, Curtis et al. (1989) showed that dullness, which is an owner-diagnosed decline from a healthy appearance, within 90 d of birth increased the hazard rate for death after 90 d of age 4.3-fold above that for heifers without dullness, after adjusting for herd, season, and year of birth. Waltner-Toews et al. (1986) concluded that risk of pneumonia in individual calves increased by a factor of three while they also had scours.

Although calfhood disease can be detrimental to rate of growth, studies have shown no significant difference in milk production between cows that contracted diseases as calves and cows without incidence of calfhood disease (Britney et al., 1984; Hatch et al. 1974, Warnick et al. 1995).

Our study analyzed calves born in a single large dairy herd over a 3-year period. Whereas other studies have been successful in analyzing dairy heifers from several farms within a region, our data were from one large herd, involving 2556 cows reared under similar environmental and managerial conditions.

Objectives were to determine the frequency of respiratory and digestive disease for calves that were born and reared on the farm, and to determine relationships between disease occurrences and age at first calving. Heifers surviving to calving were analyzed to determine the impact of disease occurrence as calves on the probability of remaining in the herd through first lactation, as well as the effect of disease occurrence on production in first lactation. Calfhood disease frequencies were also utilized to determine an association between calfhood disease and disease in first lactation.

The dataset did not include body weights of calves; therefore, body weight gain during rearing could not be evaluated. There was also sparse information on heifers that left the herd before calving, so analysis of survival was limited to heifers that survived through calving and produced milk.

Materials and Methods

This study analyzed records of dairy cows reared on a large dairy in western Kansas. Data were obtained from both the dairy's records stored in PCDart, and DHI records retrieved from Dairy Records Management Systems (DRMS) in Raleigh, NC. PCDart records were updated on the farm on a daily basis with calfhood disease events recorded as they were treated. Monthly production data from the farm were processed by DRMS. Records for cows born between June 1998 and June 2001 were utilized for this study. The dataset received from DRMS was a complete record of all cows born in that interval that had subsequently calved. Variables were extensive in number and included production records for the life of the cow, as well as birth and calving dates, and reasons for leaving the herd. Variables kept and utilized in the study included cow index number, birth date, lactation number, reason left herd, age at first calving, first lactation 305-d milk, fat and protein, and average somatic cell count for the lactation. Accurate body weights were not available. In total, there was lactation information on 3016 heifer calves born in the 3-year period of this study.

The PCDart data provided health records for the calves and cows. A program named "Run 112" (DRMS, 2004) was utilized to extract all health information for each cow from the time of birth. Those data were imported into SAS. Variables kept from the health records included cow index number, occurrence and date of health or disease event, birth date, and lactation number. Most common diseases recorded for cows were mastitis, ketosis, and milk fever. There was calf health information for 4635 calves that were born in the 3-year time frame. Through SAS, the datasets were merged by cow index number so that one large data set was formed that included all the production and health records. The merged dataset was then edited to include only animals that had both lactation and calf health information such that all cows in the dataset had full health and production records from birth through first lactation. There were 2643 complete records after the datasets were merged, leaving 1992 calves that were lost before calving for reasons not stated, but presumably due to death and culling. The data were further edited to ensure that all records were accurate and free of error, which deleted 187 records, leaving 2556 cow records to be analyzed.

All health data were recorded by employees of the dairy and overseen by a head calf manager who was the same person for the years considered in this study. The clinical conditions of interest in the calf were digestive and respiratory diseases recorded when calves were treated for disease. To be recorded in this study, calfhood digestive disease was limited to treatment within the first 45 d of life, and respiratory disease occurrence was limited to the first year of life. The limitations were determined by frequency of occurrence of the diseases. After 45 d of age, digestive disease occurrence dwindled to nearly zero, and after 1 yr of age, the occurrence of respiratory disease was nearly zero, with an occasional occurrence thereafter. The number of occurrences of digestive and respiratory diseases prior to 45 d and 1 yr of age respectively are demonstrated in Figures 1 and 2.

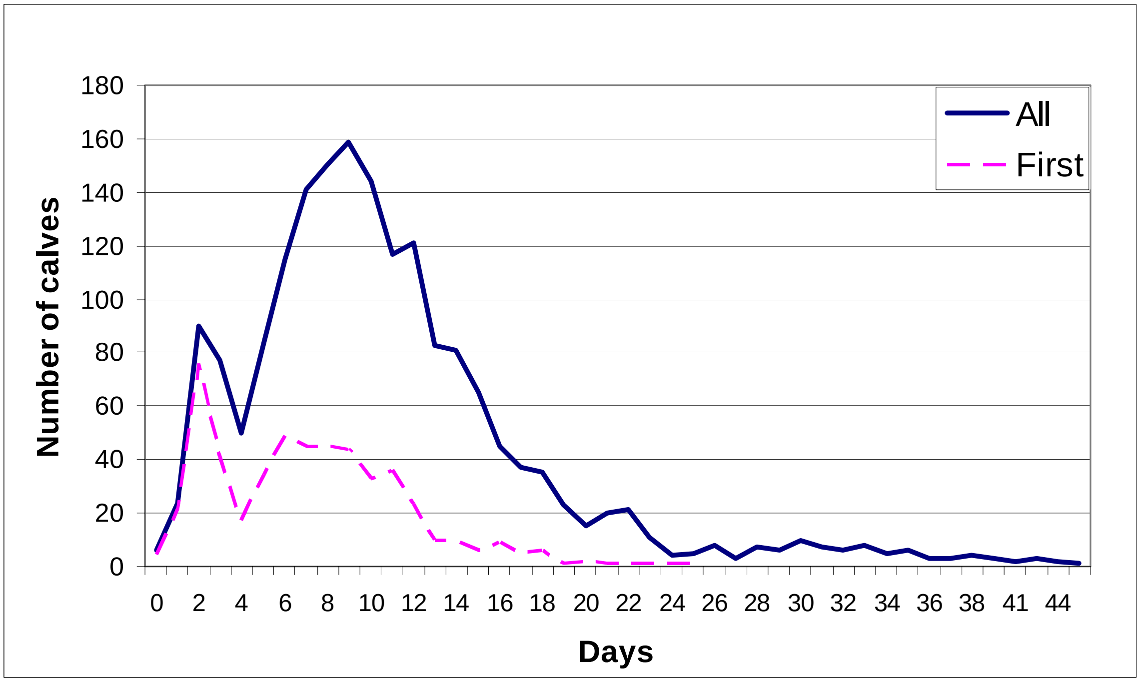

Figure 1. All and first occurrences of digestive disease from 0 to 45 d of age for 2556 calves.

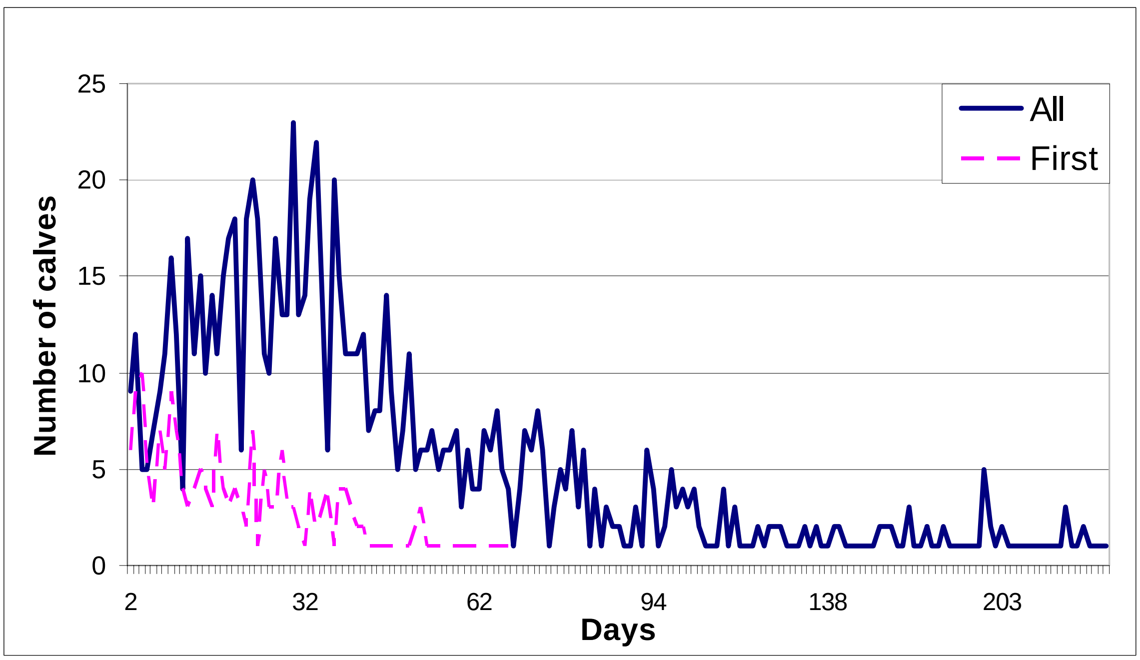

Figure 2. All and first occurrences of respiratory disease for the first year of life for 2556 calves.

Disease treatment for both digestive and respiratory disease was split into three categories: 0, 1, and > 1 occurrence for each disease per calf. An occurrence was denoted when a calf started a new treatment regimen for the ailment more than 7 d after the previous treatment. Most treatments lasted 3 d, but when two doses were administered within 7 d, it was classified as a "re-pull" and recorded as the same occurrence. In the lactating cows, clinical conditions of mastitis, milk fever, and ketosis were recorded when a cow was treated.

Of the 2556 cows available for analysis, 1791 acquired respiratory disease as calves, 1278 contracted digestive disease as calves, and 926 contracted both as calves. These numbers are further delineated in Table 2.

Table 2. Number of cows with digestive and respiratory disease as calves.

Respiratory disease[1]	Digestive disease[1]			
	0	1	2	Total
0	473	670	195	1338
1	223	397	151	771
2	69	187	191	447
Total	765	1254	537	2556

[1] Occurrence of disease, denoted as 0 = no occurrence, 1 = single occurrence, and 2 = two or more occurrences. Distinct occurrences must be at least 7 d apart.

Statistical Analyses

Age at First Calving

An analysis of variance was applied using the GLM procedure of SAS to determine the effects of disease occurrence in the calf, season of birth, and the effect of year and season of calving on age at first calving. The model was:

$$Y_{ijklm} = \mu + R_i + D_j + (RD)_{ij} + B_k + S_l + E_{ijklm}$$

Where

Y_{ijklm} = Age at first calving of cow m due to ith occurrence of calfhood respiratory disease and jth occurrence of calfhood digestive disease, season of birth k and year-season effect of calving l.

μ = overall mean,

R_i = effect of the ith occurrence of calfhood respiratory disease, i = 0, 1, >1,

D_j = effect of jth occurrence of calfhood digestive disease, j = 0, 1, >1,

$(RD)_{ij}$ = interaction of calfhood respiratory disease and digestive disease,

B_k = effect of season of birth, where Winter = December, January and February (k=1); Spring = March, April and May, Summer = June, July and August; Fall = September, October and November (k=4),

S_l = effect of year and season of calving, where Winter = December, January and February (l=1); Spring = March, April and May, Summer = June, July and August; Fall = September, October and November (l=4), and

E_{ijklm} = random error associated with each age at first calving for cow m.

Furthermore, age at first calving was categorized as less than 23 mo, 23 to 25 mo, and > 25 mo to determine whether calfhood diseases were distributed the same in each calving group (chi square test of independence).

Production

Effects of the occurrence of calfhood respiratory and digestive disease on first lactation actual milk yield (kilograms per day) were determined through the GLM procedure of SAS. The following model was used to estimate disease effects on first lactation milk, fat and protein production, and average somatic cell counts through 305 d of first lactation:

$$Y_{ijkl} = \mu + R_i + D_j + (RD)_{ij} + S_k + b_1A_l + b_2 (R_iA_l) + b_3 (D_jA_l) + b_4A_l^2 + b_5 (R_iA_l^2) + b_6(D_jA_l^2) + E_{ijkl}$$

Where

Y_{ijkl} = Milk yield of cow l due to i^{th} occurrence of calfhood respiratory disease and j^{th} occurrence of calfhood digestive disease, year and season of calving k, and day of age at first calving.

μ = overall mean,

R_i = effect of the i^{th} occurrence of calfhood respiratory disease, i = 0, 1, >1,

D_j = effect of j^{th} occurrence of calfhood digestive disease, j = 0, 1, >1,

$(RD)_{ij}$ = interaction of calfhood respiratory disease and digestive disease,

S_k = effect of year k^{th} year and season of calving, where Winter = December, January and February; Spring = March, April and May, Summer = June, July and August; Fall = September, October and November,

b_1A_l = linear effect of age at first calving for cow l calving at age A_l (days),

$b_2 (R_iA_l)$ = interaction of calfhood respiratory disease and the linear effect of age at first calving,

$b_3 (D_jA_l)$ = interaction of calfhood digestive disease and the linear effect of age at first calving,

$b_4 (A_l^2)$ quadratic effect of age at first calving,

$b_5 (R_iA_l^2)$ = interaction of calfhood respiratory disease and the quadratic effect of age at first calving,

$b_6 (D_jA_l^2)$ = interaction of calfhood digestive disease, and the quadratic effect of age at first calving, and

E_{ijkl} = random error associated with interactions.

The analysis utilized production records expressed per day, up to 305 d in milk for first lactation milk, fat, and protein.

Another estimate of disease effects on first lactation milk, fat and protein production, and average somatic cell count was calculated using the previous model without the effect of age at first calving in the model. This model was tried because of the possibility that age at first calving was influenced by respiratory and digestive disease as a calf. The same model (with age at calving) was also run substituting season of birth for year-season of calving. The seasons of birth and calving were too confounded to appear in the same model.

Mortality and Morbidity

For survival analysis we were interested in cows that left the herd prior to 305 d of their first lactation. From the 2556 cow records available, 439 cows left prior to 305 d in first lactation, 298 left in their first lactation after 305 d, and 1819 survived into a second lactation. Reasons cows left the herd and number of cows leaving are outlined in Table 3.

Table 3. Reasons cows left the herd prior to 305 d first lactation and the number of cows that left for each reason.

Reason cow left herd	Number of cows	Percent of total
Sold feet and legs	93	21.2
Sold low production	15	3.4
Sold reproduction problems	51	11.6
Sold injury or other	19	4.3
Died	121	27.6
Sold mastitis	73	16.6
Sold disease	66	15.0
Sold udder problems	1	0.0
Total	439	100.0

The Mixed procedure in SAS was first utilized to test data for a relationship between calfhood disease and survival in the first lactation prior to 305 d. The following model was used for morbidity statistics:

$Y_{ijkl} = \mu + R_i + D_j + (RD)_{ij} + S_k + E_{ijkl}$

Where

Y_{ijklm} = Survival time in days in herd through 730 d in first lactation, of cow l due to i^{th} occurrence of calfhood respiratory disease and j^{th} occurrence of calfhood digestive disease, and year-season of calving k.

μ = overall mean,

R_i = effect of the i^{th} occurrence of calfhood respiratory disease, i = 0, 1, >1,

D_j = effect of j^{th} occurrence of calfhood digestive disease, j = 0, 1, >1,

$(RD)_{ij}$ = interaction of calfhood respiratory disease and digestive disease,

S_k = effect of year and season of calving, where Winter = December, January and February; Spring = March, April and May, Summer = June, July and August; Fall = September, October and November, and

E_{ijkl} = random error associated with survival time of cow l.

Variable ps_simple was created so that when ps_simple = 0 it included only 0 occurrences of both respiratory and digestive diseases, ps_simple = 1 included strata where either respiratory or digestive disease occurrences equaled 1, and ps_simple = 2 included strata where either respiratory or digestive disease occurrences equaled 2. Variable timeinherd represents the time in days since first calving. If the cow exited the herd, timeinherd is recorded as the (age of exit (d)) minus (age at first calving (d)). If a cow did not exit the herd for death or cull reasons, her timeinherd was calculated using the last test date and she received a censor value of 1, otherwise her censor value was 0. Milklevel was created to split milk production into three categories based on milk per day up to 305 d in first lactation, 1 < 26 kg/d (bottom 25%) 2 = 26 to 34 kg/d (middle 50%) and 3 >34 kg/d (upper 25%). Milkdisease was created as a combination of the milklevel and ps_simple variables, so that; milkdisease = ((ps_simple x 10) + milklevel).

The Lifetest procedure in SAS was to compute product-limit estimates of the survival distribution within each stratum used (ps_simple) and to test the equality of survival over the strata of respiratory and digestive disease occurrences. The Lifetest procedure was used to compare only the three new strata of ps_simple. The neg log of the survival distribution function can be examined to determine the distribution of the data as either exponential or Weibull. If the negative log survival function for disease produces linear curves that pass through the origin, then an exponential fit is recommended. If the log of the negative log graphs as parallel straight lines, then it fits a proportional hazards model. That being true, the Phreg procedure was used for a regression analysis of survival data based on the Cox proportional hazards model of SAS. In both Lifetest and Phreg data included not only cows that had left the herd, but also cows that survived beyond the study (censored data). The SAS statements for survival statistics were:

```
proc lifetest data=surv plots=(S,LS, LLS);
  time timeinherd*censor(1) ;
  strata ps_simple;
run;
```

```
proc phreg data=surv;
   model timeinherd*censor(1)= ps_simple;
   strata milklevel;
   output out=Pred survival=S ;
run;
```

The Phreg statements above fit a survival curve over time for each level of disease within each level of daily milk yield. That allows a determination of the effect of calfhood disease on survival after the effect of milk yield has been taken into account.

Frequency tables were used to analyze relationships among reasons for leaving herd and incidence of calfhood disease. A contingency table was constructed to test if the calfhood disease occurrences (0, 1, and 2) were distributed identically for each of the nine reasons cows left the herd in first lactation. Frequencies for disease occurrence as a cow and disease occurrence as a calf were computed in the same manner, looking at calfhood respiratory and digestive disease occurrence separately. Chi Squares tested the independence of removal reasons and disease occurrence.

An analysis of variance was applied using the GLM procedure of SAS to determine the effects of disease occurrence in the calf on morbidity. The association between respiratory disease and digestive disease was determined utilizing the following model:

$$Y_{ijk} = \mu + D_i + B_j + E_{ijk}$$

Where

Y_{ijk} = Calfhood respiratory disease code (Y = 0, 1, or 2) of cow k due to i^{th} occurrence of calfhood digestive disease, and season of birth j.

μ = overall mean,

D_i = effect of i^{th} occurrence of calfhood digestive disease, i = 0, 1, >1,

B_j = effect of season of birth, where Winter = December, January and February; Spring = March, April and May, Summer = June, July and August; Fall = September, October and November, and

E_{ijk} = random error associated with each calf's respiratory code.

The effect of calfhood respiratory disease on digestive disease was calculated by reversing Y and D in the model.

Results and Discussion

This section provides results and interpretation of the statistical analyses that were applied to the first lactation data outlined in Table 4. Data were not available on all cows for production variables of fat, protein and somatic cell count score. This is indicated by fewer than 2556 observations in Table 4 and is due to incomplete collection of data in the record system. Only 438 cows were treated for disease in first lactation, and exit age includes only the cows that left the herd (717). Analyses were run on available data for all variables. Frequencies for calfhood disease occurrence can be found in Table 2.

For the time period that production data were utilized, the herd increased in size from approximately 4000 to 8000 cows with an average rolling herd average of 10178 kg milk, 370 kg fat and 314 kg protein, and the herd had an average of 6215 cows.

Table 4. Means of variables.

Variable	N	Mean	Standard deviation	Minimum	Maximum
Respiratory [1]	2556	0.7	0.8	0	2
Digestive[1]	2556	0.9	0.7	0	2
Cow disease[2]	438	1.6	1.1	1	8
Days in milk	2556	339.7	141.8	9	1144
Exit age (d)	717	1046.3	216.1	608	1972
Time in herd (d)	2556	662.6	368.8	8	1519
Age at first calving (d)	2556	754.1	62.3	586	1127
Age at first calving (mo)	2556	24.8	2	19.3	37.1
Age at first calving (group)[3]	2556	2.2	0.7	1	3
Season of birth[4]	2556	2.7	1.1	1	4
Milk 305 d (kg)	2556	8368	3121	11	14912
Fat 305 d (kg)	1093	297	108	3	626
Protein 305 d (kg)	873	237	85	1	416
Milk (kg/d)	2556	29.5	8.2	0.7	50.2
Fat (kg/d)	1093	1.1	0.3	0.1	2.1
Protein (kg/d)	873	0.9	0.2	0.1	1.4
Average somatic cell count score	2385	2.6	1.5	0.1	9.6

[1] 0 = no occurrence, 1 = single occurrence, 2 = multiple occurrence.
[2] Numbers of occurrences of mastitis, ketosis and milk fever.
[3] 1 < 23 mo, 2 = 23 – 25 mo, 3 > 25 mo.
[4] Winter = December, January, February; Spring = March, April, May; Summer = June, July, August; Fall = September, October, November.

Age at First Calving

The ANOVA for age at first calving revealed that respiratory disease, the interaction of respiratory and digestive disease, season of birth, and the interaction between respiratory disease and season of birth were significant. The ANOVA table is in Appendix Table 1.

Age at first calving was influenced by respiratory disease, but in concert with digestive disease and season of birth (significant interactions). When respiratory disease was 0, there was a 0.28 mo increase in age at first calving as digestive disease increased from 0 to 2 (none to multiple occurrences). Similarly when respiratory disease was 1, the increase in digestive disease from 0 to 2 resulted in a 0.32 mo increase in age at first calving. These results are in Table 5 and Figure 3.

Table 5. Least squares means for age at first calving (AFC) by respiratory and digestive disease occurrence.

Respiratory disease[1]	Digestive disease[1]	AFCmo LSmean	Standard error
0	0	24.55	0.10
0	1	24.68	0.08
0	2	24.83	0.15
1	0	24.80	0.15
1	1	24.77	0.10
1	2	25.10	0.16
2	0	25.25	0.24
2	1	25.41	0.15
2	2	25.00	0.15

[1] 0 = none, 1 = one occurrence, 2 = multiple occurrences.

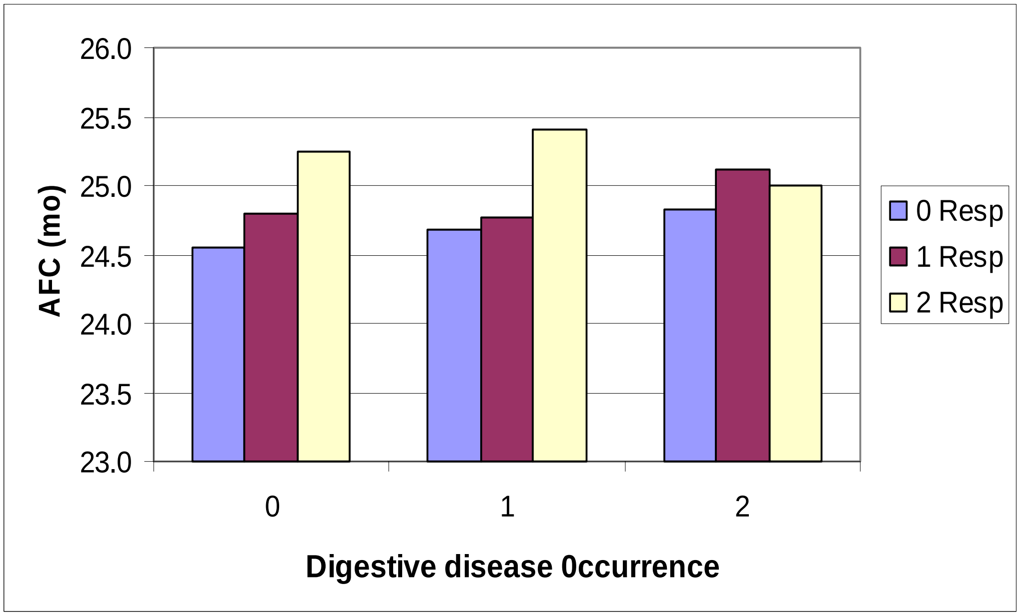

Figure 3. Least squares means illustrating interaction between digestive disease and respiratory disease for age at first calving in months. 0 = none, 1 = one occurrence, 2 = multiple occurrences.

As respiratory and digestive disease occurrence increased, the age at first calving increased. The age at first calving steadily increased for all disease levels, with only the multiple occurrences of both respiratory and digestive diseases falling lower than expected. Heifers were oldest at first calving, at or above 25 mo, when they had a history of multiple cases of respiratory disease.

The interaction of respiratory disease by season of birth (Table 6, Figure 4) resulted in a similar pattern for respiratory disease occurrences of 0 and 1. Spring births had the lowest age at first calving (23.9 mo), at 0 occurrences and winter births the highest (25.5) with a single occurrence. When respiratory disease occurrence was 2, however, fall births had the lowest age at first calving and spring births had the highest (25.4 mo). Spring calves that acquired more than one case of respiratory disease either matured more slowly or had a reproductive situation that delayed their conception by a month.

Table 6. Least squares means for age at first calving by respiratory disease occurrence and season of birth.

Respiratory Disease[1]	Season of Birth[2]	AFCmo LSmean	Standard Error
0	Spring	23.88	0.13
0	Summer	24.51	0.20
0	Fall	24.99	0.12
0	Winter	25.37	0.13
1	Spring	24.22	0.22
1	Summer	25.00	0.10
1	Fall	24.86	0.18
1	Winter	25.49	0.14
2	Spring	25.43	0.15
2	Summer	25.35	0.17
2	Fall	24.87	0.18
2	Winter	25.23	0.20

[1] 0 = none, 1 = one occurrence, 2 = multiple occurrences.
[2] Winter = December, January, February; Spring = March, April, May; Summer = June, July, August; Fall = September, October, November.

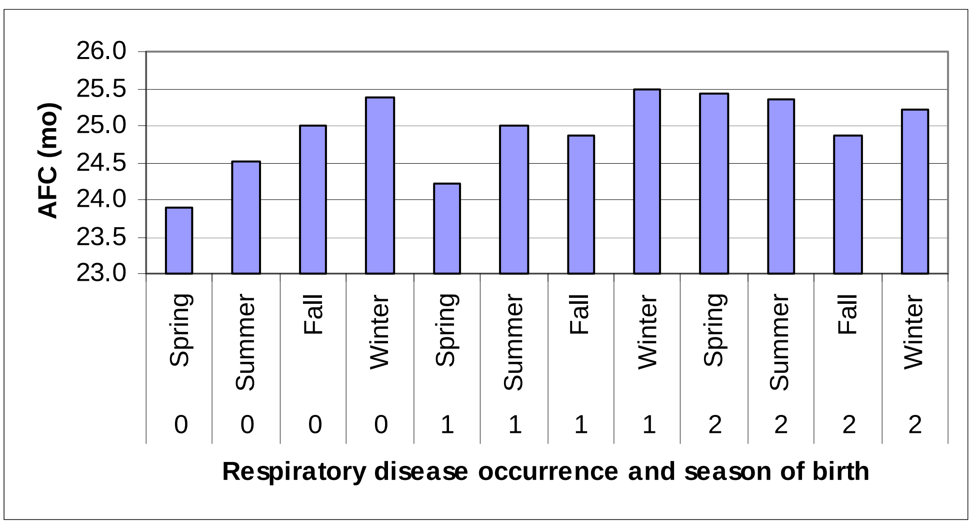

Figure 4. Season of birth and respiratory disease interaction effects on age at first calving (AFC). 0 = no occurrences, 1 = single occurrence, 2 = multiple occurrences. Winter = December, January, February; Spring = March, April, May; Summer = June, July, August; Fall = September, October, November.

These results may indicate that there were not only effects from season of birth, but season of breeding as well. With this herd, calves that were born in the spring became pregnant 14 mo later to calve at 2 yr of age, also in the spring. Multiple disease occurrences may have delayed maturity and breeding into the summer months when conception rates were low. Since all breeding information is not known with the data available, more research would be required to fully understand these results.

Overall, an increase in respiratory disease occurrence was accompanied by an increase in age at first calving. From 0 to 1 occurrences of respiratory disease there was an increase of 0.21 mo in age at first calving, and from 0 to 2 occurrences of respiratory disease, the increase was 0.53 mo. These results (Table 7 and Figure 5) are consistent with Van der Fels-Klerx et al. (2001), who found that calfhood pneumonia delayed first calving by 2 wk, with the range being from 0.1 to 0.9 mo.

Table 7. Effects of respiratory disease on age at first calving (AFC).

Respiratory disease[1]	AFCmo LSmean	Standard error
0	24.69	0.07
1	24.89	0.08
2	25.22	0.11

[1] 0 = no occurrences, 1 = single occurrence, 2 = multiple occurrences

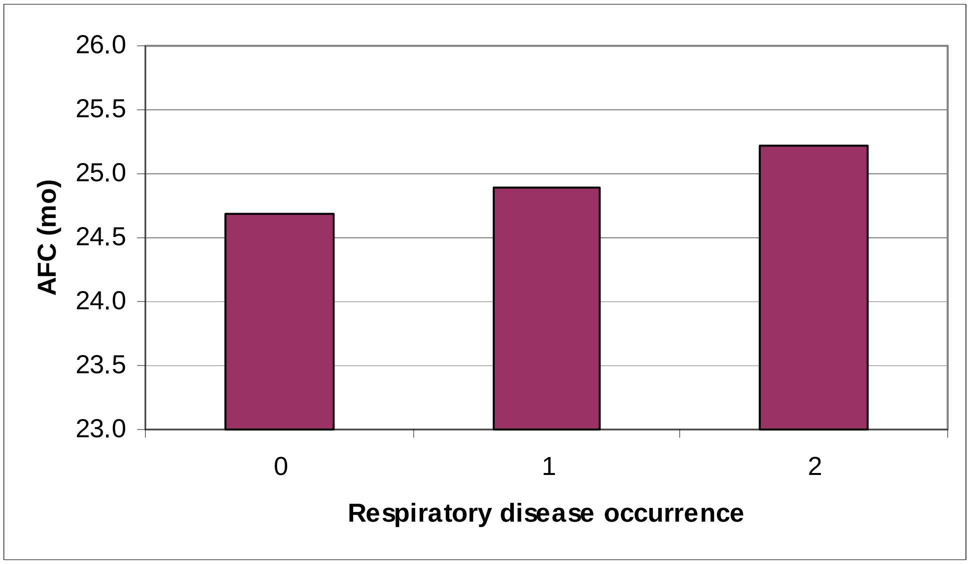

Figure 5. Least squares means for respiratory disease occurrence by age at first calving (AFC). 0 = none, 1 = one occurrence, 2 = multiple occurrences.

The effect of season of birth on age at first calving resulted in calves born in spring months having the lowest age at first calving of 24.51 mo. Calves born in winter months had the highest at 25.36 mo. Fall and summer births yielded approximately the same age at first calving of 24.9 mo. These averages, however, were impacted by multiple occurrence of respiratory disease as noted previously. These numbers are presented in Table 8 and Figure 6.

Table 8. Effects of season of birth on age at first calving (AFC).

Seasons[1]	AFCmo LSmean	Standard error
Winter	25.36	0.09
Spring	24.51	0.11
Summer	24.96	0.08
Fall	24.91	0.10

[1] Winter = December, January, February; Spring = March, April, May; Summer = June, July, August; Fall = September, October, November

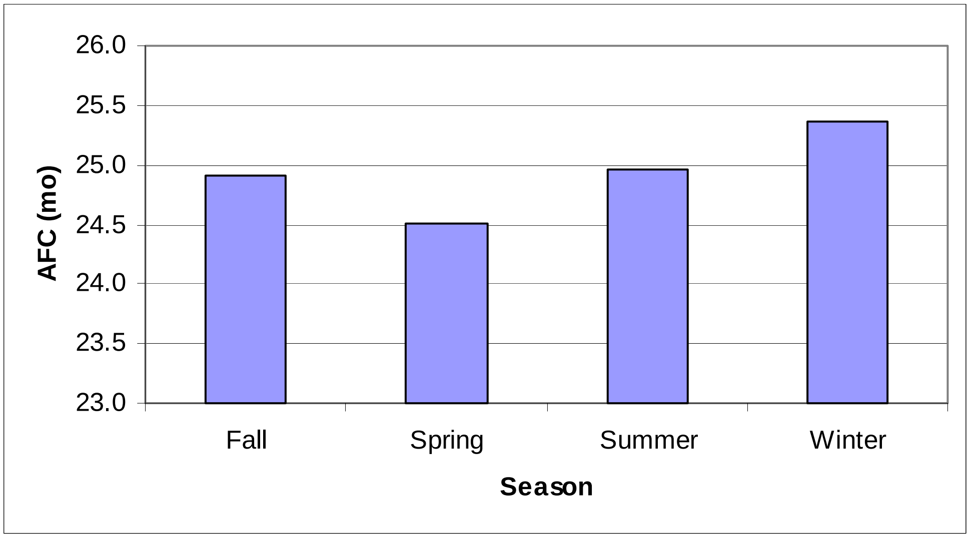

Figure 6. Effects of season of birth on age of first calving. Winter = December, January, February; Spring = March, April, May; Summer = June, July, August; Fall = September, October, November

When age at first calving was categorized as less than 23 mo, 23 to 25 mo, and > 25 mo, frequencies by respiratory disease indicated that calves with multiple respiratory occurrences calved more frequently at ages older that 23 mo and less frequently at less than 23 mo ($P < 0.01$). Calvings in the group between 23 and 25 mo and > 25 mo increased as respiratory disease occurrence decreased. These results are illustrated in Figure 7.

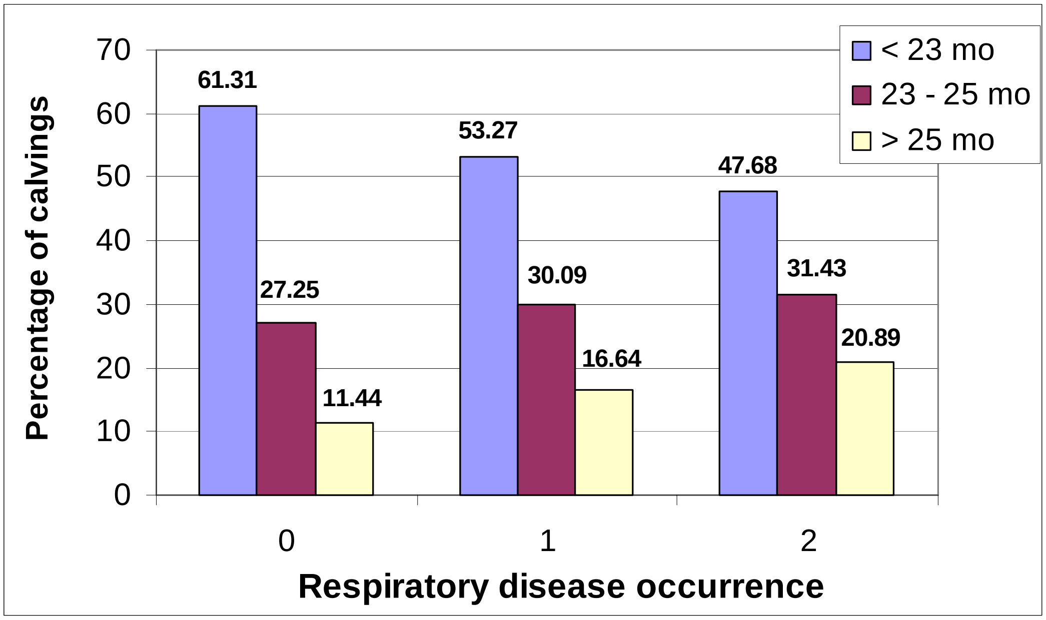

Figure 7. Percentage of calvings within respiratory disease occurrence. 0 = no occurrences, 1 = single occurrence, 2 = multiple occurrences.

<u>Production</u>

The model that included digestive and respiratory disease and their interaction, along with year-season of calving instead of season of birth, was used to analyze 305 d first lactation milk yield (kg/d) due to its higher R-square value of 0.075. The R-square implies that 4.4% of the variation in milk yield was explained by the model, as opposed to 1.6% for the model that included season of birth. Obviously, both R-squares were low and prediction of milk from calfhood disease was not precise.

Although none of the results were significant, the P value for respiratory disease was approaching significance at 0.11, and milk yield was 0.23 kg/d less for 0 occurrences compared to 1 occurrence, and 1.08 kg/d less comparing 0 to multiple occurrences. Appendix Table 2 and Table 9 demonstrate these results. These findings agree with the findings of Britney et al. (1984) who found no difference between diseased groups for respiratory, gastro-intestinal, and disease-free groups per completed lactation. Warnick et al (1995) agreed with these findings as well, stating that there was no significant detrimental effect of owner-diagnosed calfhood disease on first lactation milk production.

Table 9. Effects of respiratory disease on milk yield[1]

Respiratory disease[2]	Milk kg/d LSmean	Standard error
0	29.3	0.31
1	29.1	0.36
2	28.2	0.48

[1] Not significant (p = 0.11).
[2] 0 = no occurrences, 1 = single occurrence, 2 = multiple occurrences.

Fat production was not significantly influenced by any factor in the analyses; the ANOVA is in Appendix Table 3.

Protein yield (kg/d) was affected by respiratory disease occurrence, such that calves having none or one occurrence of digestive disease yielded 0.05 kg/d more protein than those with multiple occurrences. These results are in Table 10, Figure 8, and the ANOVA table in Appendix Table 4

Table 10. Effects of respiratory disease on protein yield.

Respiratory disease[1]	Protein kg/d LSmean	Standard error
0	0.85	0.02
1	0.87	0.02
2	0.80	0.02

[1] 0 = no occurrences, 1 = single occurrence, 2 = multiple occurrences.

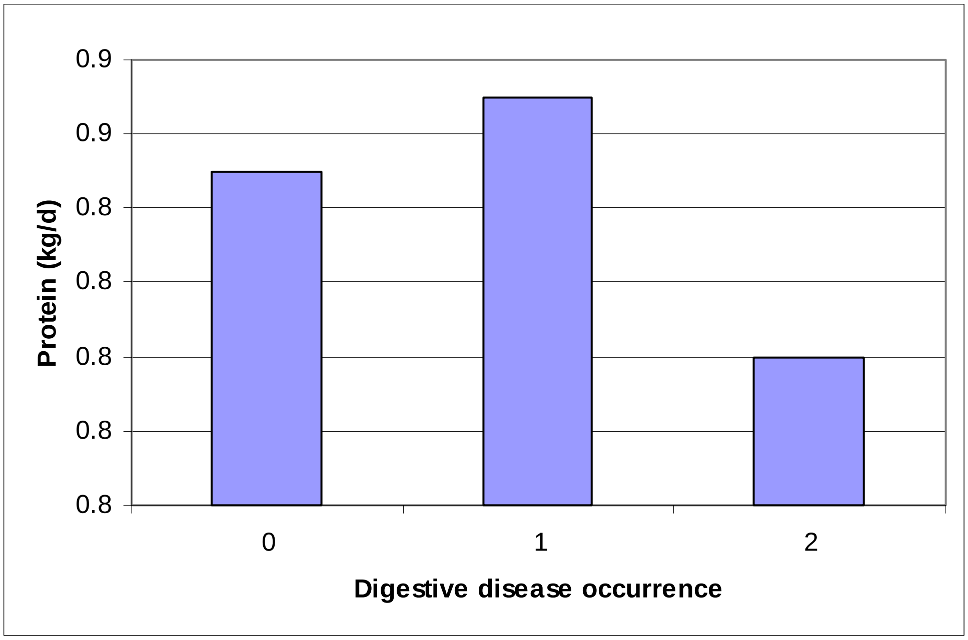

Figure 8. Effects of respiratory disease on protein yield.

There was no significant effect of calfhood disease on average SCC for first lactation. The ANOVA table results are in Appendix Table 5.

Mortality and Morbidity

A mixed model analysis of days in milk at death or culling revealed that there was no association between calfhood digestive and respiratory disease and survival in first lactation through 305 d. Although not significant the results are shown in Table 11. The difficulty with this analysis is that it does not account for cows surviving past 305 d, known as censored data.

Table 11. Analysis of respiratory and digestive disease variance by time in herd for cows leaving the herd before 305 d.

Effect	DF	F Value	Pr > F
Respiratory	2	0.42	0.65
Digestive	2	0.06	0.93
Respiratory * Digestive	4	0.55	0.70
Year and season of Calving	14	39.66	< 0.0001

The Lifetest procedure of SAS determined variables of importance for further investigation. The number of cows that left the herd by 730 d after first calving and those surviving in each stratum for each variable are in Tables 13 – 16. Overall, 72% survived past 730 d from first calving. Of the disease categories, lowest survival was for multiple occurrences and averaged about 66% survived. Low milk per day had a large negative effect on survival, dropping below 40% for low milk and multiple disease occurrences.

Table 12. Number of censored and uncensored values for respiratory disease.

Stratum	Respiratory disease[1]	Total	Number failed[2]	Number censored[3]	Percent censored
1	0	1338	353	985	74
2	1	771	213	558	72
3	2	447	151	296	66
Total		2556	717	1839	72

[1] 0 = no occurrences, 1 = single occurrence, 2 = multiple occurrences.
[2] Left the herd prior to 730 d after first calving.
[3] Survived 730 d after first calving.

Table 13. Number of censored and uncensored values for digestive disease.

Stratum	Digestive disease[1]	Total	Number failed[2]	Number censored[3]	Percent censored
1	0	765	195	570	75
2	1	1254	336	918	73
3	2	537	186	351	65
Total		2556	717	1839	72

[1] 0 = no occurrences, 1 = single occurrence, 2 = multiple occurrences.
[2] Left the herd prior to 730 d after first calving.
[3] Survived 730 d after first calving.

Table 14. Number of censored and uncensored values for combined disease occurrence.

Stratum	Disease occurrence[1]	Total	Number failed[2]	Number censored[3]	Percent censored
1	0	473	115	358	76
2	1	1290	331	959	74
3	2	793	271	522	66
Total		2556	717	1839	72

[1]0 Disease = no disease occurrence, 1 Disease = one occurrence of respiratory, digestive or both, 2 Disease = two or more occurrences of at least one disease.

[2] Left the herd prior to 730 d after first calving.

[3] Survived 730 d after first calving.

Table 15. Number of censored and uncensored values for milk and disease categories.

Stratum	Milk level	Disease level[1]	Total	Number failed[2]	Number censored[3]	Percent censored
1	Low	0	93	49	44	47
2	Low	1	308	174	134	44
3	Low	2	228	139	89	39
4	Medium	0	216	34	182	84
5	Medium	1	560	114	446	80
6	Medium	2	371	90	281	76
7	High	0	164	32	132	81
8	High	1	422	43	379	90
9	High	2	194	42	152	78
Total			2556	717	1839	72

[1]0 Disease = no disease occurrence, 1 Disease = one occurrence of respiratory, digestive or both, 2 Disease = two or more occurrences of at least one disease.

[2] Left the herd prior to 730 d after first calving.

[3] Survived 730 d after first calving.

The Phreg procedure of SAS determined the significance of respiratory disease, digestive disease, disease occurrence combined and milk level by disease occurrence, each in a separate analysis (Table 12).

The Phreg analysis generates survival rate functions that are the probabilities a cow will survive until a specified time in the herd after first calving. For these results, "survived" refers to animals that remained in the herd. They did not die, nor were they culled. Of the 2556 cows included in the survival statistics, 807 cows did not have an opportunity to reach 730 d due to late dates of calving. Although they were in the herd for less than 730 d, they were still alive at the end of the study.

Table 16. Survival parameter estimates from Phreg procedures.[1]

Variable	DF	Parameter estimate	Standard error	Chi-Square	Pr > ChiSq	Hazard ratio
Respiratory	1	0.10	0.05	5	0.03	1.11
Digestive	1	0.13	0.05	6	0.01	1.14
Combined disease occurrence	1	0.17	0.05	10	0.00	1.18
Disease occurrence within milk	1	0.08	0.05	2	0.14	1.08

[1] Each variable was analyzed in a separate Phreg analysis.

The relationship between respiratory and digestive disease on survival rate was similar (Figure 9). Minor deviations were present at 0 and 1 occurrence of the disease, which led to an increased survival rate for 0 and 1 occurrence of digestive disease compared to respiratory disease. Overall there was a 5 % advantage in probability of surviving through 305 d and 730 d with 0 occurrences of respiratory disease compared to 2 or more occurrences. Zero occurrences of digestive disease had a 5 % advantage at 305 d and a 7 % advantage at 730 d compared to 2 or more occurrences.

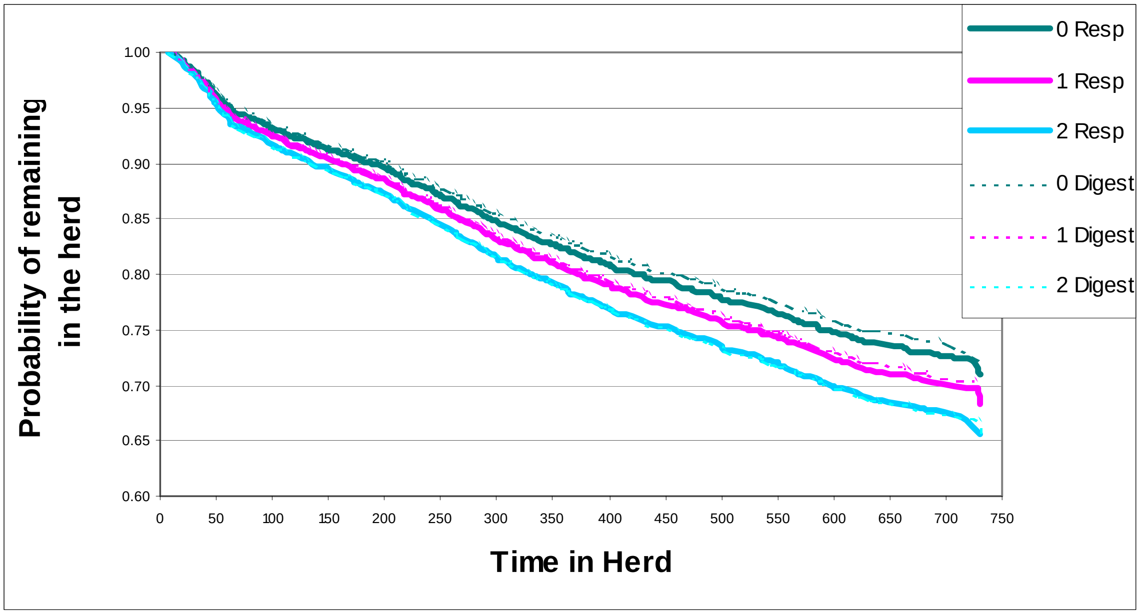

Figure 9. Effects of respiratory and digestive disease occurrences on the probability of remaining in the herd through 730 d in first lactation. 0 = no occurrence, 1 = single occurrence, 2 = multiple occurrences.

The results for the overall disease occurrence (respiratory and digestive combined, Figure 10) were similar to results for respiratory and digestive disease alone. While 2 or more occurrences of either disease had the same survival rate function, the survival rate function for a single occurrence and no occurrence was higher for the combined disease occurrence than each disease occurrence alone. At 305 d there was a 5% advantage for 0 verses 2 occurrences of disease, and at 730 d there was an 8% advantage for 0 occurrences.

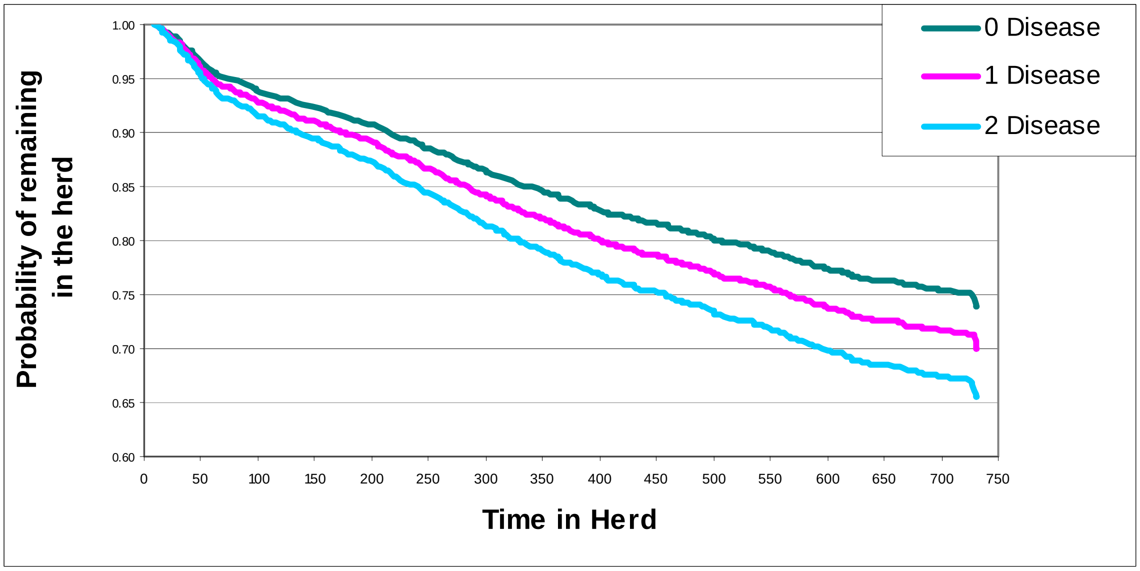

Figure 10. Effects of combined disease occurrence on the probability of remaining in the herd through 730 d in first lactation. 0 Disease = no disease occurrence, 1 Disease = one occurrence of respiratory, digestive or both, 2 Disease = two or more occurrences of at least one disease.

Milk production influenced the survival function estimate through 730 d in first lactation (Figure 11). For all three tiers of milk production, as disease occurrence increased from 0 to 1 the probability of remaining in the herd decreased. The greatest difference existed for the low 25% of producing cows. While the medium and high producing cows did not show much decline over time in the probability of remaining in the herd, the lowest producing cows declined exponentially in the probability that they would survive to 730 d. Cows medium and high in milk survived to 730 d at a rate of about 80%, whereas the low producing cows were approaching 40% survival. The impact of the combined diseases on survival was more variable for the low producing cows. For all milk levels, as time increased, the differences in survival among disease frequencies began to deviate, with the low producing cows showing the largest deviation, about 6 percentage points advantage in survival for no disease compared to multiple occurrences as calves.

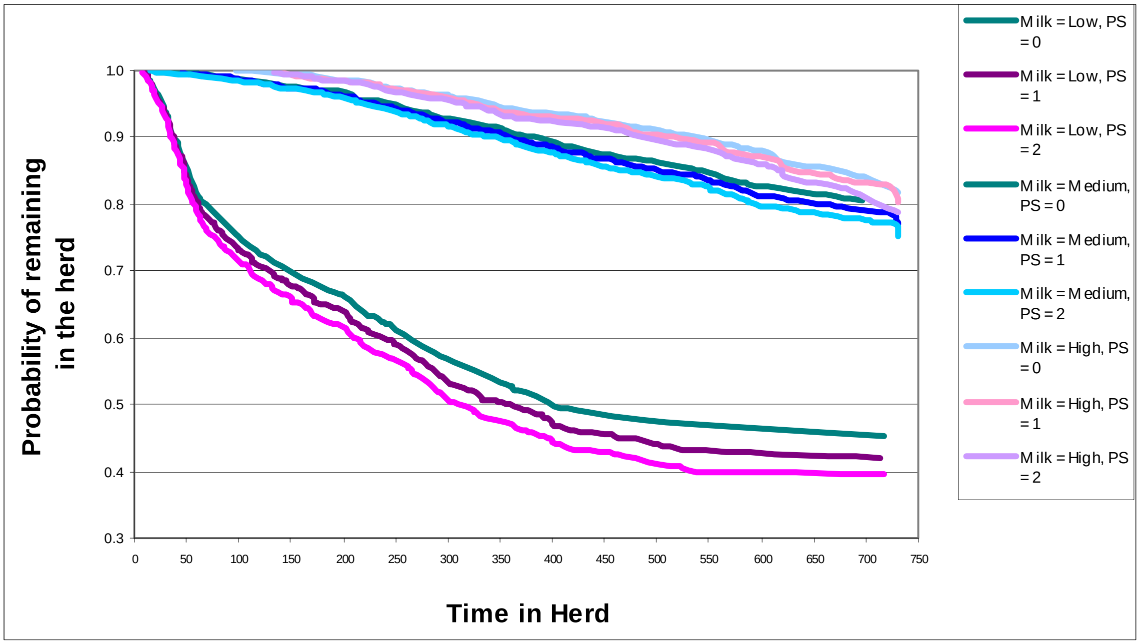

Figure 11. Effects of disease occurrence and milk level on the probability of remaining in the herd through 730 d in first lactation. 0 PS = no disease occurrence, 1 PS = one occurrence of respiratory, digestive or both, 2 PS = two or more occurrences of at least one disease. Milk level; Low < 26 kg/d, Medium = 26 – 34 kg/d, High > 34 kg/d.

Table 17 relates the occurrences of disease in first lactation (mastitis, milk fever, and ketosis) with digestive disease occurrences as calves. The majority of cows had one or two disease occurrences in first lactation. No disease as a calf or multiple occurrences as a calf both projected the same frequencies of disease as a cow. Probability of a larger chi-square was 0.14, indicating similar occurrence of disease as a cow regardless of calfhood disease in first lactation.

Table 17. Effect of calfhood digestive disease on cow health in first lactation.[1]

Cow disease occurrences	Digestive disease 0	1	2	Total
1	77	136	64	277
2	22	48	25	95
3	6	17	12	35
4	7	4	6	17
5	3	2	3	8
6	3	0	2	5
8	1	0	0	1
Total	121	212	112	438

[1] Chi square test of independence, p = 0.14.
[2] Occurrence in first lactation of mastitis, ketosis, and milk fever.

The relationship of cow disease and calfhood respiratory occurrences was similar to that of digestive disease (Table 18). The major difference is that most had no respiratory disease as calves. Again, the chi-square (p = 0.45) indicated that respiratory disease did not affect disease occurrence in the first 305 d of first lactation.

Table 18. Effect of calfhood respiratory disease on cow health in first lactation.[1]

Cow disease occurrences[2]	Respiratory disease 0	1	2	Total
1	150	83	44	277
2	55	24	16	95
3	16	12	7	35
4	9	8	0	17
5	7	1	0	8
6	4	1	0	5
8	1	0	0	1
Total	247	131	67	438

[1] Chi square test of independence, p = 0.45.
[2] Occurrence in first lactation of mastitis, ketosis and milk fever.

Of the cows that survived through 305 d of their first lactation, 17% contracted 2 or more occurrences of respiratory disease as calves, whereas of those that were culled or died, 21% had contracted multiple cases of respiratory disease as calves, a 24% increase. For no occurrence of respiratory disease, 3 percentage units more cows survived in the herd through their first lactation. These results are shown in Table 19 and Figure 12.

Table 19. Frequency of cows that calved and remained through 305 d by respiratory history as calves.[1]

	Respiratory disease as a calf[2]			
	Number			
	0	1	2	Total
Survived 305d	1117	645	355	2117
Dead or culled	221	126	92	439
	Percent			
Survived 305d	84	84	79	
Dead or culled	16	16	21	
Total	100	100	100	

[1] Chi square test of independence, p = 0.007.
[2] 0 = no occurrence, 1 = single occurrence, 2 = multiple occurrences.

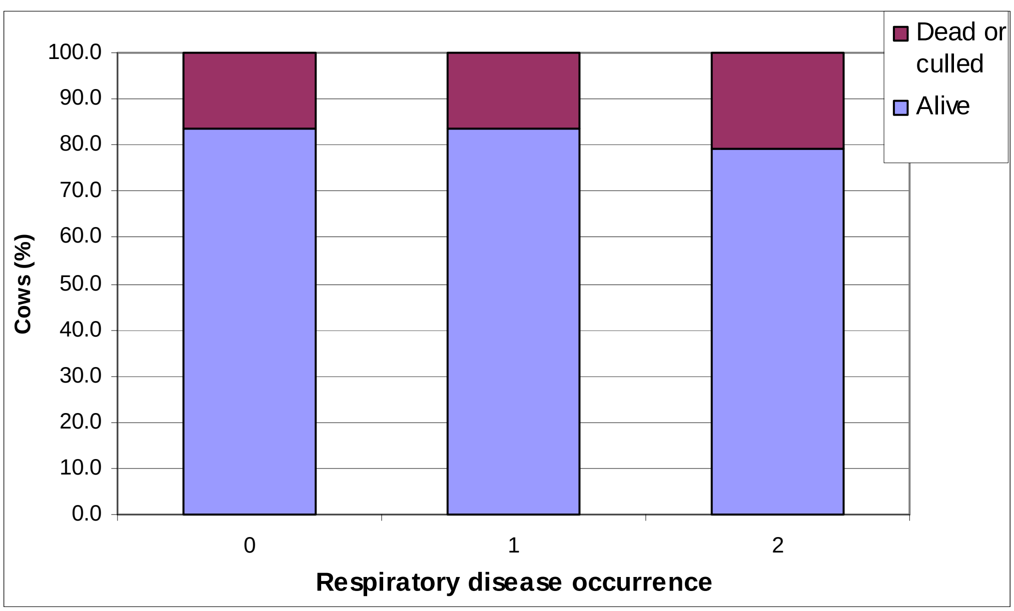

Figure 12. Survival status of cows through 305 d in first lactation by respiratory disease as calves. 0 = no occurrence, 1 = single occurrence, 2 = multiple occurrences.

Frequencies revealed that for both respiratory and digestive disease, the group with 2 occurrences as calves had a higher percentage of cows that had left the herd than cows that survived in the herd through the first lactation. When comparing 2 occurrences with 0 or 1, there was a greater percentage of cows alive than had left the herd for 0 and 1 occurrence for both respiratory and digestive disease.

Frequencies of cows that left the herd compared with cows that survived through 305 d of their first lactation showed a disadvantage of 5 percentage units (25%) if they had contracted 2 or more occurrences of digestive disease as calves. For no occurrence of calfhood digestive disease 2 percentage units more cows survived through their first lactation. These results are in Table 20 and Figure 13.

Table 20. Frequency of cows that calved and remained through 305 d by digestive history as calves.[1]

	Digestive Disease as a Calf[2]			
	Number			
	0	1	2	Total
Survived 305d	644	1045	428	2117
Dead or culled	121	209	109	439
	Percent			
Survived 305d	84	83	80	
Dead or culled	16	17	20	
Total	100	100	100	

[1] Chi square test of independence, p = 0.001.
[2] 0 = no occurrence, 1 = single occurrence, 2 = multiple occurrences.

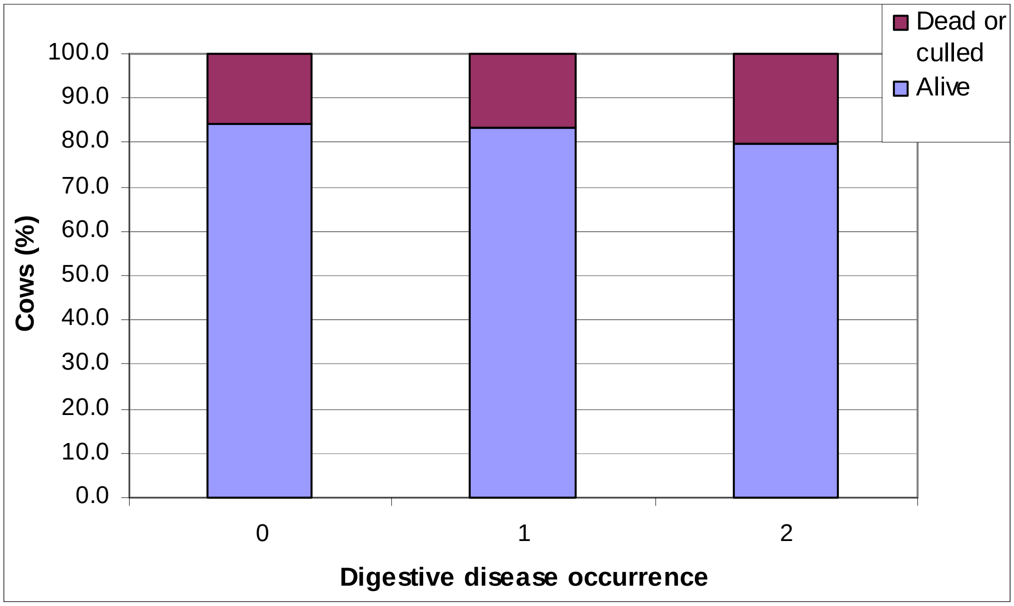

Figure 13. Status of cows through 305 d in first lactation that had digestive disease as calves. 0 = no occurrence, 1 = single occurrence, 2 = multiple occurrences.

Frequencies of reasons that cows left the herd prior to 305 d in first lactation differed significantly for digestive disease occurrence. The most outstanding result was being sold for mastitis, where 62% of the animals sold had one occurrence, and 15% had two or more occurrences of respiratory disease. The frequencies revealed that approximately 50% of the cows afflicted with at least one occurrence of mastitis had one occurrence of calfhood digestive disease. These results indicate that cows that acquired calfhood digestive disease and survived into first lactation, acquired mastitis to a degree that was detrimental to the cow's survival in the milking herd.

As calfhood disease occurrence of either respiratory or digestive disease increased from 0 to 2, there was a 10.2% increase in percentage units of cows leaving the herd in the first lactation. Therefore, as calfhood disease increased to 2 or more occurrences, the percentage of cows that left the herd in each occurrence group increased. These results are illustrated in Table 21 and Figure 14.

Table 21. Percent of cows calving that survived through first lactation by combinations of respiratory and digestive disease as calves.[1]

Respiratory disease[2]	Digestive disease[2]	Percentage	
		Survived	Left herd
0	0	75	25
0	1	74	26
0	2	64	36
1	0	73	27
1	1	74	26
1	2	65	35
2	0	67	33
2	1	65	35
2	2	64	36

[1] Chi square test of independence, p = 0.003.
[2] 0 = no occurrence, 1 = single occurrence, 2 = multiple occurrences.

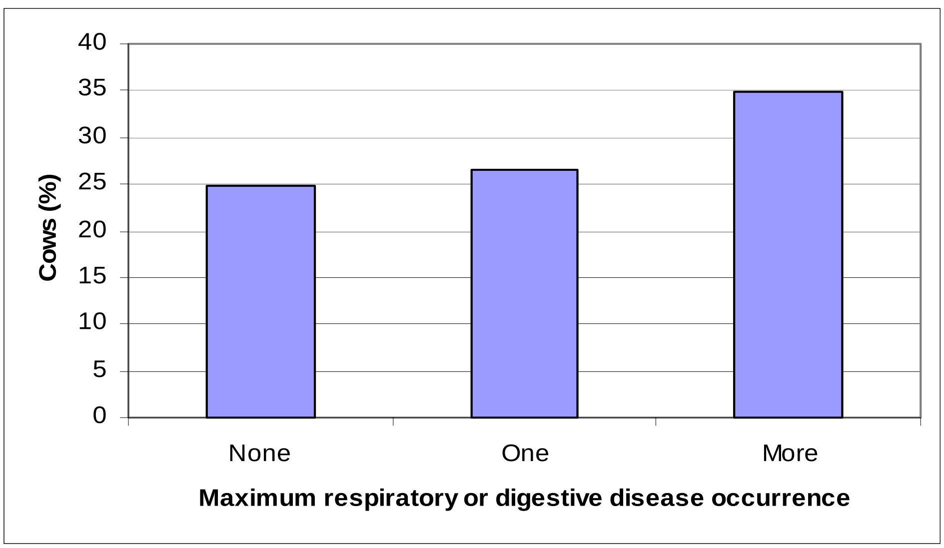

Figure 14. Percentage of cows calving that failed to survive first lactation, allocated by maximum occurrence of calfhood disease. None = no disease occurrence, One = one occurrence of respiratory, digestive or both, More = two or more occurrences of at least one disease.

Although calfhood respiratory and digestive disease seemed to cause a higher removal rate in first lactation, there was no particular reason for removal that was related to respiratory or digestive disease. Reasons for leaving the herd are shown in Table 22 and Table 23.

Table 22. Percentage of cows that left the herd in first lactation by reason and respiratory disease occurrence.[1]

Reason left herd	Respiratory disease 0	1	2	% Total	Number left herd
Feet and legs	44	33	23	100	106
Low production	42	42	16	100	19
Reproduction	48	34	18	100	202
Injury or other	54	23	23	100	26
Died	54	29	17	100	157
Mastitis	55	20	25	100	128
Disease	43	28	29	100	94
Udder problems	60	20	20	100	5

[1] Chi square test of independence, p = 0.28.
[2] 0 = no occurrence, 1 = single occurrence, 2 = multiple occurrences.

Table 23. Percentage of cows that left the herd in first lactation by reason and digestive disease occurrence.[1]

Reason left herd	Digestive disease 0	1	2	% Total	Number left herd
Feet and legs	22	49	29	100	106
Low production	47	32	21	100	19
Reproduction	30	42	28	100	202
Injury or other	19	42	39	100	26
Died	32	44	24	100	157
Mastitis	24	53	23	100	128
Disease	24	54	22	100	94
Udder problems	0	40	60	100	5
Total number of occurrences	765	1254	537		

[1] Chi square test of independence, p = 0.19.
[2] 0 = no occurrence, 1 = single occurrence, 2 = multiple occurrences.

Analyzing only information for cows that left the herd prior to 305 d, rather than those who were in milk beyond 305 d, revealed that respiratory disease did not significantly affect the reason the cow left the herd (Table 24).

Table 24. Percentage of cows that left the herd prior to 305 d in first lactation by reason and respiratory disease occurrence.[1]

Reason left herd	Respiratory disease 0	1	2	% Total	Number left herd
Feet and legs	20	48	32	100	93
Low production	50	33	27	100	15
Reproduction	35	33	31	100	51
Injury or other	16	42	42	100	19
Died	35	45	20	100	121
Mastitis	23	62	15	100	73
Disease	24	53	23	100	66
Udder problems	0	100	0	100	1
Total number of occurrences	1338	771	447		

[1] Chi square test of independence, P = 0.19
[2] 0 = no occurrence, 1 = single occurrence, 2 = multiple occurrences.

Digestive disease had an effect on reason the cow left the herd prior to 305 d in first lactation. The percentages of cows that left for each reason by digestive disease are outlined in Table 25. Those that seem least related to calfhood digestive problems were low production, reproduction, and died. Mastitis, disease, and udder problems were prevalent in cows that had one digestive occurrence and injury or other was high for multiple occurrences as calves. Reasonable explanations are not apparent.

Table 25. Percentage of cows that left the herd prior to 305 d in first lactation by reason and digestive disease occurrence.[1]

Reason left herd	Digestive disease 0	1	2	% Total	Number left herd
Feet and legs	21	47	32	100	93
Low production	40	33	27	100	15
Reproduction	35	33	32	100	51
Injury or other	16	42	42	100	19
Died	35	45	20	100	121
Mastitis	23	62	15	100	73
Disease	24	53	23	100	66
Udder problems	0	100	0	100	1

[1] Chi square test of independence, p = 0.04.
[2] 0 = no occurrence, 1 = single occurrence, 2 = multiple occurrences.

To determine more precisely the relationship between respiratory and digestive disease, analyses of variance were run on each, with the other as an independent categorical variable. In both models, season of birth was held constant to remove effects of seasons unfavorable to calf health.

The ANOVA revealed that as digestive disease occurrence increased, the rate of respiratory disease also increased. Least squares means for digestive occurrences are in Table 26, and are illustrated in Figure 15. When digestive disease occurrence increased from 0 to 1, the respiratory disease occurrence increased from 0.49 to 0.63, and from 0 to 2 digestive disease occurrences, there was an increase from 0.49 to 1.01 in respiratory disease. The ANOVA is in Appendix Table 6.

Table 26. Digestive disease effects on respiratory disease.

Digestive disease[1]	Respiratory disease LSmean	Standard error
0	0.49	0.03
1	0.63	0.02
2	1.01	0.03

[1]0 = no occurrence, 1 = single occurrence, 2 = multiple occurrences.

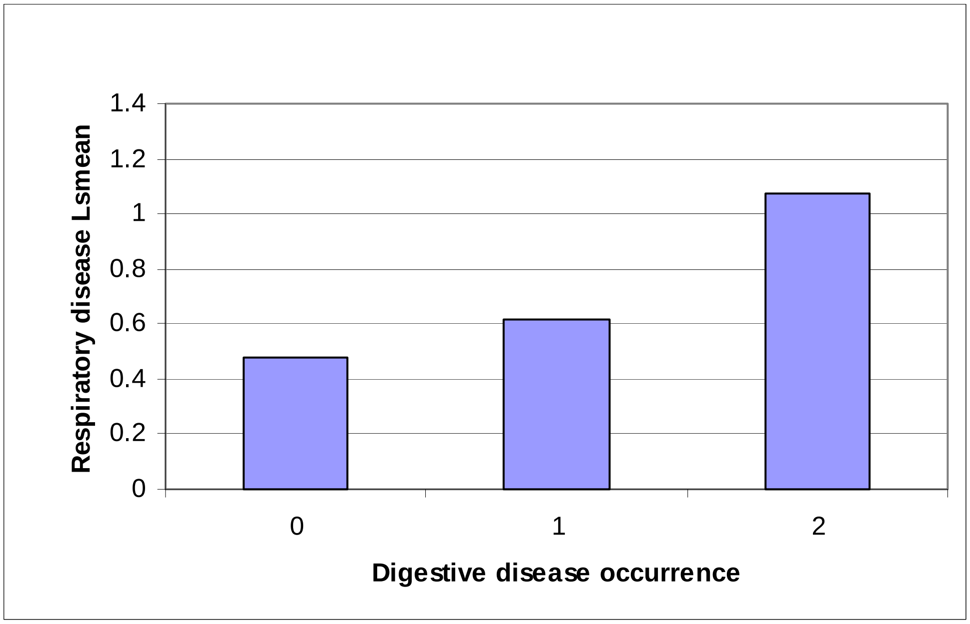

Figure 15. Respiratory means for digestive disease occurrences. 0 = no occurrence, 1 = single occurrence, 2 = multiple occurrences.

The results showed that calfhood respiratory disease was significantly associated with calfhood digestive disease, so that calves treated for digestive disease were more susceptible to respiratory disease. These results are consistent with Waltner-Toews et al. (1986), who found the risk of pneumonia in individual calves increased by a factor of three if they had scours. Also, Curtis et al. (1988) found that calves with scours had a relative risk value of 2.5 for respiratory disease.

Conclusions

Calfhood respiratory and digestive diseases are costly from a calf mortality and treatment standpoint and tend to make calves more susceptible to additional occurrences of either type of disease. Occurrence of calfhood disease only increased age at first calving by an average of 2 wk, but heifers born in the spring calved 2 mo later when they had acquired a disease as calves. Whereas an increase in respiratory disease depressed protein production slightly, there was no effect on 305 d milk, fat yield, somatic cell count score or survival rates in first lactation. Cows with zero occurrences of calfhood disease had a 5% greater chance of surviving 305 d and an 8% great chance of remaining in the herd 730 d than cows with 2 or more occurrences of calfhood disease. Calfhood disease led to an increase in culling for mastitis and other diseases, but there was no effect on occurrence of mastitis, ketosis or milk fever during first lactation.

Although illness should always be of concern, this study indicated that managers should be especially concerned with illness in calves born in the spring months, which led to a delay in calving by as much as 2 mo. While calves that made it into the milking herd suffered minimal production consequences from calfhood disease occurrences, there was a decrease in the probability of remaining in the herd after affliction with disease as a calf.

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Appendix

Appendix Table 1. Analysis table for age at first calving.

Source	DF	Mean square	F Value	Pr > F
Respiratory	2	36.88	9.21	< 0.0001
Digestive	2	1.48	0.37	0.69
Respiratory * digestive	4	8.33	2.08	0.08
Season of birth	3	46.04	11.49	< 0.0001
Respiratory * season	6	26.04	6.50	< 0.0001
Digestive * season	6	2.47	0.62	0.72
Residual	2532	4.01		

Appendix Table 2. Analysis table for milk production.

Source	DF	Mean square	F Value	Pr > F
Respiratory	2	143	2.20	0.11
Digestive	2	6	0.09	0.91
Respiratory * digestive	4	46	0.71	0.59
Year and season of calving	14	415	6.40	<0.0001
Residual	2530	164257		

Appendix Table 3. Analysis table for fat yield.

Source	DF	Mean square	F Value	Pr > F
Respiratory	2	0.09	1.12	0.33
Digestive	2	0.23	0.30	0.74
Respiratory * digestive	4	0.17	2.26	0.06
Year and season of calving	15	0.34	4.36	< 0.0001
Residual	1007	0.14		

Appendix Table 4. Analysis table for protein yield.

Source	DF	Mean square	F Value	Pr > F
Respiratory	2	0.20	5.37	0.005
Digestive	2	0.01	0.23	0.79
Respiratory * digestive	4	0.03	0.81	0.52
Year and season of calving	15	0.22	5.94	< 0.0001
Residual	801	0.04		

Appendix Table 5. Analysis table for somatic cell count score.

Source	DF	Mean square	F Value	Pr > F
Respiratory	2	0.01	0.00	0.99
Digestive	2	1.96	0.92	0.40
Respiratory * digestive	4	3.35	1.56	0.18
Year and season of calving	38	6.52	3.05	< 0.0001
Error	2288	2.14		

Appendix Table 6. Analysis table for respiratory disease.

Source	DF	Mean square	F Value	Pr > F
Digestive	2	42.24	78.71	< 0.0001
Season of birth	3	5.05	9.42	< 0.0001
Error	2498	0.54		

Vita

Katherine Rossini

After graduating from Staten Island Technical High School in 1998, I left my hometown of Staten Island NY and went to Virginia Tech to work on my Bachelor's degree. I earned a degree in Dairy Science with a minor in Chemistry from Virginia Tech and graduated in 2002. While an undergraduate I was an active member of Phi Sigma Pi National Honor Fraternity. After my Bachelor's degree was completed, I began work on my Master's degree in Dairy Science Management at Virginia Tech, and completed my studies in 2004.