Health and Immune Function of Dairy Calves

Ken Leslie

Department of Population Medicine, University of Guelph, Guelph, ON N1G2W1
Email: keleslie@uoguelph.ca

▪ Take Home Messages

- Many dairy producers have substantial losses associated with difficult calvings, including both stillbirths and health problems in calves that survive the calving event. A large proportion of these losses can be prevented with appropriate management of calving.
- Despite improved knowledge concerning management of colostrum feeding, actual rates of success of passive transfer still need considerable improvement.
- Bovine Respiratory Disease (BRD) is a major health problem in raising dairy replacement heifers. Although most calves survive the initial episode of BRD, just having this problem has profoundly negative effects on future performance and survival.
- Prevention of BRD through colostrum management, environmental control and successful vaccination programs is an important goal for raising replacement heifers.
- Enhanced nutritional programs for improved growth and prevention of disease should be implemented.
- Recording birth and weaning weights shows promising results for management decision-making and heifer selection.
- Dairy producers should provide growth, disease and survival information to genetic improvement organizations. Substantial long-term improvement in calf health is distinctly possible through genetic selection.
- Significant improvement in the efficiency of rearing replacement heifers is possible through better health and growth, reductions in age at first calving, and greater lifetime survival.

Introduction

Dairy producers are faced with some unique and formidable challenges for successful rearing of calves. An understanding of these challenges, and of the various determinants of disease, is essential for the implementation of appropriate preventive measures. For example, vaccination is often a common and useful strategy to generate immunity prior to exposure to a given disease agent. However, in newborn calves, a number of challenges result from their unique characteristics. Newborn calves are immunologically naïve. In addition, calves generally have weak or slow immune responses when exposed to infectious pathogens. For this reason, calves depend on passive (maternal) antibodies absorbed from colostrum to help prevent disease. Although these antibodies are crucial for early survival of the calf, they can significantly suppress an active immune response to vaccination.

Given this challenging situation, dairy producers should have a basic understanding of the risk factors for early calfhood disease, steps to improve the neonatal immune system, and a number of effective management practices to improve health and growth. This paper will outline a series of management programs and measures to achieve these goals, such as assistance at calving, colostrum management, pre-weaning feeding programs, and genetic improvement for health.

Management of Calving

The process of calving can be a traumatic and hazardous event in the life of a calf. Dystocia is defined as a difficult or abnormal calving due to a prolonged unassisted parturition process, or due to a prolonged or severe assisted calf removal (Mee, 2008). The prevalence of difficulty at calving in dairy cattle has increased over time as breeding programs have focused largely on production traits, and have coincidentally resulted in cows producing calves that are relatively larger compared to their dams (Mee, 2008). The most common cause of dystocia is excessively large calf birth weight and a resulting mismatch of fetal-maternal size, especially at first calving (Lombard et al., 2007). The threshold for calf bodyweight in Holsteins lies between 42 and 45 kg. If calf weight increases above 45 kg, the rate of dystocia increases significantly (Johanson and Berger, 2003). The stress effects of a difficult calving greatly increase the risks of illness and death in young dairy calves. Lombard et al. (2007) reported that health effects of a difficult calving account for almost 50% of all calf deaths. A comprehensive study to document calf losses in North America has reported that 15.9% of calves die before weaning (USDA, 2007). The first losses (8.1%) result from events that occur during calving. These losses are classified as stillbirths. The remaining deaths (7.8%) are associated with health problems caused by pathogens acquired after birth, most commonly manifested as diarrhea and respiratory problems leading to calf death. There is now abundant evidence that calves that have experienced trauma from a difficult calving often have reduced newborn viability, resulting in an increased risk of having health problems and death.

Management of calving on most modern dairy herds in North America is aimed at maintaining a healthy and fertile cow after the calving event. A large number of stillbirth deaths are attributed to trauma, suggesting either inappropriate timing of assistance or excessive force during delivery. Excessive trauma is commonly found (25%) in calves delivered using normal traction. When excessive force is applied during the delivery process, trauma inflicted can affect several body systems. For example, rib and spinal fractures are a common occurrence. Bleeding around the kidneys is a useful indicator that a spinal fracture has occurred. Other frequent findings after birth trauma include fractures of the jaw, congestion around the brain, liver rupture and many other injuries. Calf deaths from these problems often occur from 24 hours to several days later. Since these events are very common, a large percentage of traumatic injuries sustained during calving remain undetected and are not recorded.

Another consequence of forced extraction of the fetus is the premature rupture of umbilical vessels. With early umbilical cord rupture, calves have an inability to regulate respiration, leading to a diminishing oxygen supply and the rapid development of asphyxia and respiratory acidosis. This situation results from lack of ability to breathe after termination of blood oxygenation from the placenta, intense and prolonged labor contractions, and trauma during forced extraction. The prolonged lack of oxygen results in the production of lactic acid and leads to acidosis. Eventually, this lack of oxygen can cause edema, bleeding, liver damage and death. Furthermore, if uterine fluids get into the lungs, it can also result in pneumonia. Severely acidotic calves had a 52% decrease in colostrum intake, and a 35% decrease in serum immunoglobulin G (IgG) levels (Besser et al., 1990). It is very evident that severe acidosis compromises newborn calf survival.

The ability of calves to maintain their body temperature during early life is an important adaptive response. It has been shown that following a difficult birth, calves have may have an impaired response to environmental stress, such as cold temperature conditions. After a delivery requiring a mechanical calf puller, calves were less able to withstand cold stress as compared to calves born without assistance, with minor manual assistance or by cesarean section (Bellows and Lammoglia, 2000). Autopsy findings of calves that died later than a few hours after birth, but less than eight days later, showed typical signs of cold injury and starvation. The lower heat production and drop in rectal temperature found in stressed calves may be due to decreased mobilization of body fats and low levels of plasma thyroid hormone.

It is logical that pain, discomfort and inflammation, following a difficult calving, may interfere with the normal physiological and behavioral status of newborn calves, including temperature regulation and the motivation to consume feed. It has been shown that consumption of colostrum in calves with fetal distress is reduced by up to 74% during the first 12 hours after birth (Vermorel et al., 1989). Studies have indicated that calves that have experienced a difficult calving have reduced or delayed intake of colostrum at birth. Thus, failure of passive transfer in these calves may result from merely the failure to get up and drink in a timely manner.

Dairy producers can make meaningful improvements in calf health and performance by focusing on management interventions to reduce the frequency of difficult calving, and by appropriate assistance at the calving event.

■ Colostrum Management

Newborn calves do not have meaningful levels of immunoglobulins when they are born, so they need to acquire passive immunity from their dam shortly after birth in order to survive. High levels of IgG that are present in colostrum are essential for development of a calf’s immunity and for protection against disease in early life (Chase et al., 2008; Waldner and Rosengren, 2009). A calf’s ability to absorb large immunoglobulin molecules from the gut is limited to the first hours of life, and by 6 hours after birth this absorptive capacity is already diminished by 50%. This means it is crucial that colostrum is provided as soon as possible after birth, allowing the opportunity for the calf to acquire the greatest mass of maternal IgG possible.

Colostrum management and successful passive transfer of maternal antibodies have long been emphasized for their role in prevention of early calfhood disease. Various studies have shown associations between failure of passive transfer (FPT) and an increased frequency of calfhood disease (Waldner and Rosengren, 2009). For example, the probability of BRD increases as the serum concentrations of maternal IgG in the calf decrease (Van Donkersgoed et al., 1993; Waldner and Rosengren, 2009).

There have been vast improvements in our understanding of appropriate colostrum management and how to achieve success of passive transfer (Godden, 2008). These improved techniques involve the timing of colostrum delivery, the volume and quality of colostrum, and the prevention of bacterial contamination. It is also very useful to regularly monitor success of passive transfer by assessment of calf serum total protein between days 1 and 6 of age. Nevertheless, recent studies continue to report high rates of failure of passive transfer in the dairy industry (Furman-Fratczak et al., 2011; Trotz-Williams et al., 2008). Considerable improvement is clearly obtainable by implementing appropriate colostrum management practices.

■ Newborn Calf Management

There are a number of management practices and procedures for newborn and young dairy calves that have documented research results showing improved health and performance. These practices include disinfection of the navel cords, treatment with injectable selenium and vitamin E and provision of an appropriate environment. Interestingly, some of these practices have declining rates of implementation, even though the costs and effort are minimal. For example, for reasons that are not documented, it is estimated that less that 10% of dairy producers in eastern Canada administer injectable selenium and Vitamin E to newborn calves, whereas more than 90% of beef cow-calf herds utilize this easy and inexpensive preventive program. Dairy producers should continuously re-assess their management programs to ensure that cost-effective practices are being implemented.

■ Prevention of Bovine Respiratory Disease

Bovine respiratory disease (BRD) is one of the most important illnesses that affect dairy replacement heifer calves during the first 3 months of life. Together with neonatal calf diarrhea, these diseases are the most common infectious causes of morbidity and mortality in young dairy cattle (USDA, 2007). BRD has serious consequences for the individual calf, both during and beyond calfhood. Understanding the incidence, risk factors and impacts of disease will assist in the development of effective and economical control measures for this important health problem.

Long-Term Impacts of BRD

Dairy producers often perceive the major costs of calfhood disease to be veterinary services, medication, labour, and death loss at the time of the BRD event. However, long-term costs include decreased growth, delayed age at first calving (AFC), premature culling, and reduced lifetime profit (Waltner-Toews et al., 1986; Heinrichs et al., 2005; Gulliksen et al., 2009, Stanton et al., 2012; Bach, 2011). For heifers treated for BRD before 90 days of age, first calving was delayed by 6 months (Correa et al., 1988). More recently, it has been confirmed that AFC is significantly increased with the occurrence of BRD compared to heifers that had no disease (Bach, 2011; Stanton et al., 2012). Also, the percentage of heifers calving before 24 months is higher when there were no occurrences of BRD. An increasing number of days of treatment with antibiotics in the first 4 months of life tended to increase AFC (Heinrichs et al., 2005). Recent research suggests that BRD has an impact on the probability of surviving to first calving, and the probability of having a difficult delivery at the first calving (Stanton et al., 2012). Overall, it is likely that BRD has negative impacts on reproductive performance and survival, mediated through impaired growth.

Vaccination of the Dairy Calf

As described in the Introduction of this paper, one of the major challenges in calf rearing is the need for a large amount of maternal immunoglobulins for protection against disease. Yet, this situation leads to the subsequent dilemma of delayed capacity to respond to vaccination. In other words, for a period of time, when the level of maternal IgG has diminished, but the level of antibodies generated by the calf itself has not yet reached a sufficiently protective level, there is increased susceptibility to disease. To make the situation worse, this time often coincides with the age when calves may undergo stresses associated with management practices, such as weaning, moving, co-mingling, and dehorning. The level of maternal antibodies that is sufficient to protect against disease, and the level that is low enough to be permissive for succesful immunization are depicted in Figure 1.

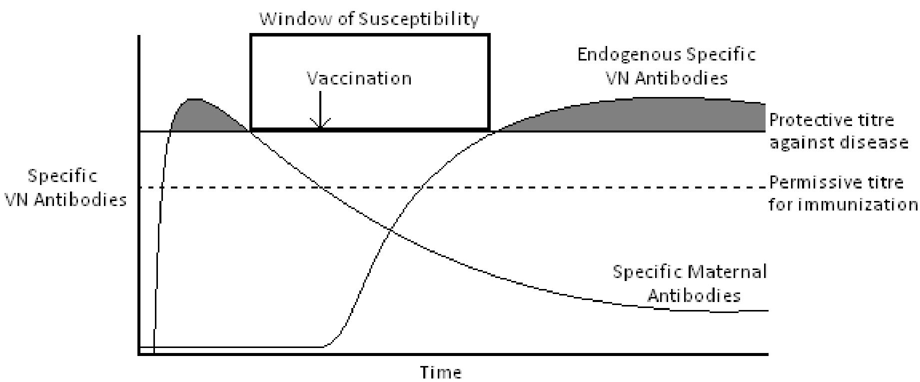

Figure 1. Levels of specific antibodies in a calf over time, starting at birth. The shaded areas represent the periods when antibody titers are above a protective level. Adapted from Chase et al., 2008.

Over time, the maternal antibody level will decrease until it is below a protective level (Chase et al., 2008). As it continues to decrease, it drops below the level which inhibits vaccination. When calves are vaccinated after the maternal antibody titer is below this permissive titer, they are able to mount a specific antibody response. The period of time, between when the specific maternal antibody titer drops below protective levels and when the calf's own antibodies due to vaccination reach protective titers, is referred to as the window of susceptibility (Chase et al., 2008)

The ideal circumstance would be to provide continuity of immunity, whereby calves would generate an adaptive immune response prior to the decline of maternal antibodies to below protective levels. Vaccination is one method to induce an adaptive immune response. However, if maternal antibodies are present in sufficient quantity, or if the calf's immune system is not sufficiently mature, there may be little detectible response to vaccination. Until recently, identifying the opportune time to vaccinate young animals that possess varying levels of maternal antibodies, using the existing commercial vaccine products, has been a formidable challenge. Recently, a temperature sensitive intranasal vaccine product, approved for use in the first week of life, shows promise for protection of pre-weaned dairy calves against the major infectious agents causing BRD in dairy calves.

■ Promoting Growth to Weaning

The term "accelerated feeding" has typically referred to enhanced nutrition as compared to conventional (restricted) feeding. As an example, it would mean using a milk replacer with 26% protein rather than 20%, a mixing ratio of 170 grams per liter rather than 125, and feeding volumes of five liters rather than four liters per day. Using higher protein levels, mixing ratios, and volumes results in greater weight and stature at weaning compared to conventional feeding. However, in recent years, accelerated feeding has taken on a new meaning, thanks to some old and some new milk delivery systems. These systems enhance the calf's feeding experience by allowing individual calves to achieve their biological growth, in addition to meeting their physiological and behavioral needs. Free access feeding is the new approach for accelerated feeding, because free access systems mimic more closely nature's way and complement group housing. Accelerated milk-feeding includes greater daily intakes, of dry matter, nutrients, and volumes, as compared to conventional restricted feeding. (Anderson, 2011).

Accelerated colostrum-feeding (rapid overfilling of the forestomachs) has become a relatively common practice. Actually, dairy producers and their advisors have become so focused on achieving success of passive transfer that they may have become desensitized to the potential physical or metabolic harm that providing 4L of colostrum at one time may have (Anderson, 2011). Enhanced early nutrition may lessen the importance of FPT and hasten a return to practical and safe volumes for colostrum feeding. New mixing and feeding guidelines for milk replacers recommend that calves be fed 2.0% of their body weight as milk replacer powder, that mixing ratios be 15% solids for moderate- and high-protein milk replacers, and that calves be fed greater volumes per day.

In addition to more nutrients, feed delivery systems that mimic nature's way of suckling enhance a calf's feeding experience. Feeding systems for preserved milk allow calves free access to simulate normal suckling patterns, and to attain normal biological growth. For preserved milk, the systems may be simple barrels with nipples or milk lines with gravity flow or pump assist. Automated feeders may be programmed for restrictive, accelerated or free access feeding. In general, automated feeders require enhanced management skills compared to conventional feeding systems. Automated feeders provide easy access to useful records and may be programmed for gradual weaning. It is clear that substantial improvements in health and performance of replacement heifers can be achieved with these systems.

▪ Measuring Birth and Weaning Weights

Weight gain during early life may have effects on future milk production. Heifers in a research herd that had a pre-weaning average daily gain (ADG) of 0.91kg/day produced 612kg more milk in their first lactation compared to their herd-mates that gained less, and pre-weaning growth explained 20% of variation in first lactation milk yield (Van Amburgh, 2008). In a Scandinavian study, energy corrected milk was associated with ADG between weaning and first service, with heifers that gained more than 0.74kg/day producing more than calves that gained less than 0.60g/day (Svensson and Hultgren, 2008). These authors cautioned that maximal early growth may not be optimal. Lean versus fat body weight gain may have different impacts on future milk yield. A body condition score of greater or equal to 3.2 at first service was associated with lower milk production than scores less than 2.9 (Svensson and Hultgren, 2008). Rapid gain that results in over-conditioning is not desirable, thus the protein and energy concentrations of heifer rations should be appropriately balanced to promote optimal gains in lean body weight and frame size. In summary, a meta-analysis of research investigating the association between pre-pubertal growth and first lactation milk yield found an optimal ADG of approximately 800g/day (Zanton and Heinrichs, 2005).

It is interesting that the cow-calf industry has widely accepted, and adopted, the collection and recording of both birth weights and weaning weights of their calf population for management and genetic progress purposes. Recent research from the dairy industry emphasizes the usefulness of this information as it relates to long-term performance and survival in dairy cattle (Bach, 2011). Advanced and automated systems to collect and use this information for dairy calves in North America should be explored.

▪ Genetics of Calf Survival

Genetic selection for improved health and longevity is a major goal of dairy cattle breeders. Yet, little attention has been paid to the genetic components of calf health and survival. Nevertheless, death of youngstock represents a on-going concern among breeders of dairy cattle in Canada and the United States. Currently, Canada and the US only genetically evaluate mortality for the first 24 and 48 hours of life, respectively, to calculate a trait also known as 'stillbirth' (Philipsson et al., 1979; Berger et al., 1998). Furthermore, stillbirth is recorded exclusively on a voluntary basis in both countries. It has been speculated that the difference in susceptibility at different ages may indicate that different genes are responsible for pre and post-weaning mortality (Hansen, 2003). The improvement of the additive genotype of calves would be permanent and cumulative across generations. For this improvement to occur, additive genetic variation for mortality needs to exist. In a review on selection for disease resistance by Shook (1989), it was concluded that more genetic and economic studies on calfhood mortality are needed for making decisions on the use of this trait in breeding programs (Shook, 1989). To date, few genetic studies on calf mortality have been carried out, and for the most part these efforts have examined primarily preweaning mortality (Cundiff et al., 1986; Erf et al., 1990; Hansen et al., 2003).

Recent research has shown that genetic variance exists between sires for survival of calves after weaning through the growing period (Heringstad et al., 2008; Henderson et al., 2011). Furthermore, associations between proofs for survival and proofs for routinely evaluated traits in Canada and the US were found to be significant for a number of traits. Specifically, a large number of proofs for conformation traits were significantly correlated with the survival proofs. Although the heritabilities reported in these studies are relatively low, genetic variability is sufficient for selection to be implemented, if recording of survival to weaning, to breeding age, and prior to first lactation was available on a large number of animals. Furthermore, calf and heifer survival traits add important economic value to the overall profitability of a dairy herd. It is clear that dairy producers should work with genetic improvement organizations to implement a standardized method to record these traits on a national scale.

▪ Conclusions

Approximately 20% of the cost of production for dairy producers is spent rearing replacement heifers (Donovan et al., 1986; Fetrow, 1988). The return on this investment is not fully realized until at least the end of the first lactation (Bach, 2011), making it economically vital that heifer calves reach maturity and enter the milking herd. Yet, despite significant advancements and changes in calf management programs, calf mortality remains unacceptably high. It is evident that management changes have not succeeded in reducing calf mortality as expected, suggesting that there may be a genetic component to morbidity and mortality. Genetic selection for disease resistance, as well as improved perinatal and postnatal survival, could reduce the incidence of disease and overall calf mortality.

Bovine respiratory disease has significant effects on reduced performance and survival. Reduced weight gain and increased AFC also have negative impacts on a heifer’s lifetime profitability. In the end, BRD has important negative implications for the individual animals, as well as the dairy operation’s overall productivity and profitability.

This goal of this paper was to cover a series of management programs and measures, such as assistance at calving, colostrum management, pre-weaning feeding programs, and genetic improvement for health.

■ References

Anderson, N.G. 2011. Practical aspects of accelerated feeding to dairy calves. The AABP Proceedings. 44:88-100.

Bach, A. 2011. Associations between several aspects of heifer development and dairy cow survivability to second lactation. J. Dairy Sci. 94:1052-1057.

Bellows, R., and M. Lammoglia. 2000. Effects of severity of dystocia on cold tolerance and serum concentrations of glucose and cortisol in neonatal beef calves. Theriogenology 53:803-813.

Berger, P., J. Thompson, and C. Sattler. 1998. Preliminary investigations on the feasibility of a stillbirth evaluation for the USA. Interbull Bull. 18:28–30.

Besser, T.E., O. Szenci, and C.C. Gay. 1990. Decreased colostral immunoglobulin absorption in calves with postnatal respiratory acidosis. J. Am. Vet. Med. Assoc. 196:1239-1243.

Chase, C. C. L., D. J. Hurley, and A. J. Reber. 2008. Neonatal immune development in the calf and its impact on vaccine response. Vet. Clin. North Am. Food Anim. Pract. 24:87-104.

Correa, M. T., C. R. Curtis, H. N. Erb, and M. E. White. 1988. Effect of calfhood morbidity on age at first calving in New York Holstein herds. Prev. Vet. Med. 6:253-262.

Cundiff, L. V., M. D. MacNeil, K. E. Gregory, and R. M. Koch. 1986. Between- and within-breed genetic analysis of calving traits and survival to weaning in beef cattle. J. Anim. Sci. 63:27–33.

Donovan, G. A., I. R. Dohoo, D. M. Montgomery, and F. L. Bennett. 1998. Associations between passive immunity and morbidity and mortality in dairy heifers in Florida, USA. Prev. Vet. Med. 34:31–46.

Erf, D. F., L. B. Hansen, and R. R. Neitzel. 1990. Inheritance of calf mortality for Brown Swiss cattle. J. Dairy Sci. 73:1130–1134.

Furman-Fratczak, K., A. Rzasa, and T. Stefaniak. 2011. The influence of colostral immunoglobulin concentration in heifer calves' serum on their health and growth. J. Dairy Sci. 94:5536–5543.

Godden S. 2008. Colostrum management for dairy calves. In Dairy Heifer Management, Veterinary Clinics of North America: 24(1):19-38.

Gulliksen, S., K. Lie, T. Loken, and O. Osteras. 2009. Calf mortality in Norwegian dairy herds. J. Dairy Sci. 92:2782-2795.

Hansen, M., P. Madsen, J. Jensen, J. Pedersen, and L. G. Christensen. 2003. Genetic parameters of postnatal mortality in Danish Holstein calves. J. Dairy Sci. 86:1807–1817.

Heinrichs, A. J., B. S. Heinrichs, and O. Harel. 2005. A prospective study of calf factors affecting age, body size, and body condition score at first calving of Holstein dairy heifers. J. Dairy Sci. 88:2828-2835.

Henderson, L., F. Miglior, A. Sewalem, D. Kelton, A. Robinson, and K. E. Leslie. 2011. Estimation of genetic parameters for measures of calf survival in a population of Holstein heifer calves from a heifer raising facility in New York State. J. Dairy Sci. 91:461-470.

Heringstad, B., Y. M. Chang, D. Gianola, and O. Osteras. 2008. Short communication: Genetic analysis of respiratory disease in Norwegian red calves. J. Dairy Sci. 91:367-370.

Johanson, J. and P. Berger. 2003. Birth weight as a predictor of calving ease and perinatal mortality in Holstein cattle. J. Dairy Sci. 86:3745-3755.

Lombard, J. E., F. B. Garry, S. M. Tomlinson, and L. P. Garber. 2007. Impacts of dystocia on health and survival of dairy calves. J. Dairy Sci. 90:1751-1760.

Mee, J. F. 2008. Prevalence and risk factors for dystocia in dairy cattle: A review. Vet. J. 176: 93-101.

Philipsson, J., J. L. Foulley, J. Lederer, T. Liboriussen, and A. Osinga. 1979. Sire evaluation standards and breeding strategies for limiting dystocia and stillbirth. report of an EEC/EAAP working group. Livest. Prod. Sci. 6:111–127.

Shook, G. E. 1989. Selection for disease resistance. J. Dairy Sci. 72:1349–1362.

Stanton, A. L., D. F. Kelton, S. J. LeBlanc, J. Wormuth, and K. E. Leslie. 2012. The impact of respiratory disease and a preventative antibiotic treatment on growth, survival, age at first calving, and milk production of dairy heifers. J. Dairy Sci. *(in press).*

Svensson, C. and J. Hultgren. 2008. Associations between housing, management, and morbidity during rearing and subsequent first-lactation milk production of dairy cows in southwest Sweden. J. Dairy Sci. 91:1510-1518.

Trotz-Williams, L. A., K. E. Leslie, and A. S. Peregrine. 2008. Passive immunity in Ontario dairy calves and investigation of its association with calf management practices. J. Dairy Sci. 91:3840-3849.

USDA. 2007. Part 1: Reference of Dairy Cattle Health and Management Practices in the United States, 2007. NAHMS Dairy 2007:1-128.

Van Amburgh, M. 2008. Early life management and long-term productivity in dairy calves. Dairy Health Management Certificate Program Proceedings pp. 1-8.

Van Donkersgoed, J., C. S. Ribble, L. G. Boyer, and H. G. Townsend. 1993. Epidemiological study of enzootic pneumonia in dairy calves in Saskatchewan. Can. J. Vet. Res. 57:247-254.

Vermorel, M., J. Vernet, C. Dardillat, Saido, C. Demigne, and M. Davicco. 1989. Energy metabolism and thermoregulation in the newborn calf; Effect of calving conditions. Can. J. Anim. Sci. 69:113-122.

Waldner, C. and L. B. Rosengren. 2009. Factors associated with serum immunoglobulin levels in beef calves from Alberta and Saskatchewan and association between passive transfer and health outcomes. Can. Vet. J. 50:275-281.

Waltner-Toews, D., S. W. Martin, and A. H. Meek. 1986. Dairy calf management, morbidity and mortality in Ontario Holstein herds. 3. Association of management with morbidity. Prev. Vet. Med. 4:137-158.

Zanton, G. I. and A. J. Heinrichs. 2005. Meta-analysis on effects of prepubertal ADG of Holstein heifers on first-lactation production. J. Dairy Sci. 88:3860-3867.