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Failure of passive transfer and effective colostrum management in calves

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Colostrum is the first mammary secretion produced after calving. The ingestion of colostrum by the newborn calf is critical for its survival. Through colostrum, the dam transfers immunoglobulins and other factors important in disease protection, hormones, growth factors, and essential nutrients. The uptake of immunoglobulins from colostrum by the calf is referred to as passive transfer of maternal immunity. Failure of passive transfer (FPT) of colostrum immunoglobulins, generally accepted as a calf serum IgG concentration of <10 g/L, results in an increased incidence of disease and death.¹⁻⁴ The necessity for effective colostrum management has been well understood for over 30 years; however, failure of passive transfer of maternal immunity continues to be a problem.⁵⁻⁹ This issue of *Large Animal Veterinary Rounds* discusses the problem of FPT, the factors involved, and suggests management directions.

Colostrum composition

Immunoglobulins and other biologically active molecules are actively transported from circulation, and/or produced in the mammary tissue, to accumulate in the udder before parturition. Thus, the dam is able to transfer to the calf a concentrated formulation that provides defence against infectious diseases, contains factors important in growth and development, and is an important source of energy with which to start life.

Colostrum is constitutively different from milk. While dairies must withhold the first 6 milkings after calving from human consumption, the term, colostrum, is most appropriately used only for the first milk, while transitional milk is a better term for the subsequent milkings, since the constituents rapidly change in concentration. In particular, the levels of immunoglobulins decline precipitously following the initiation of postpartum milking.¹⁰

Colostrum contains many factors important in protection from microbial infection. Immunoglobulins are considered the most important defence factors present in colostrum, and are responsible for protection against both systemic and enteric diseases. Since immunoglobulins absorbed from colostrum circulate in the blood of the calf, they counteract any infection from spreading systemically. However, some of the immunoglobulins are "resecreted" from serum back into the intestine to provide local "enteric" immunity to prevent enteric diseases.¹¹ Most studies on the failure of passive transfer have concentrated on the level of immunoglobulins because they play such a crucial role in disease protection. However, the other components present in colostrum contribute to the health and well-being of the calf. In addition to the immunoglobulins, colostrum contains other antimicrobial factors including lactoferrin, lysozyme, and lactoperoxidase (Table 1).

Since colostrum is a rich source of many biologically active molecules, colostrum feeding has a variety of important effects on the clinical, metabolic, and endocrine status of calves.¹² Colostral hormones and growth factors stimulate protein synthesis, cell division, and growth; these processes are important in regulating the development of the gastrointestinal tract. Colostrum is much higher in fat than milk, and acts as a readily available source of energy. Delayed colostrum intake may reduce essential fatty acid and fat-soluble vitamin status, and impair synthesis of fatty acid binding protein. Diets deficient in fat and cholesterol, given early in life, can have lasting effects on fat absorption and intermediary lipid metabolism.¹³



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Table 1: Biologically active components of colostrum

Antimicrobial factors	Nutrients	Growth factors and hormones
Immunoglobulins	Fat	Insulin-Like Growth Factor I and II
Lysozyme	Lactose	Epidermal Growth Factor
Lactoferrin	Proteins	Transforming Growth Factor β
Lactoperoxidase	Vitamins	Growth hormone
Cytokines	Minerals	Insulin

Failure of passive transfer

Consequences

Increased neonatal morbidity and mortality from neonatal enteric, systemic, and respiratory diseases are well-accepted consequences of FPT.^{7,14-17} The consequences of FPT are not limited to the neonatal period, however. Effects on the incidence of disease and mortality are still seen at 2 months-of-age (Figure 1), and diminished long-term performance is demonstrated by decreased weaning weights in beef calves¹⁷ and decreased growth and milk production in dairy heifers.^{18,19}

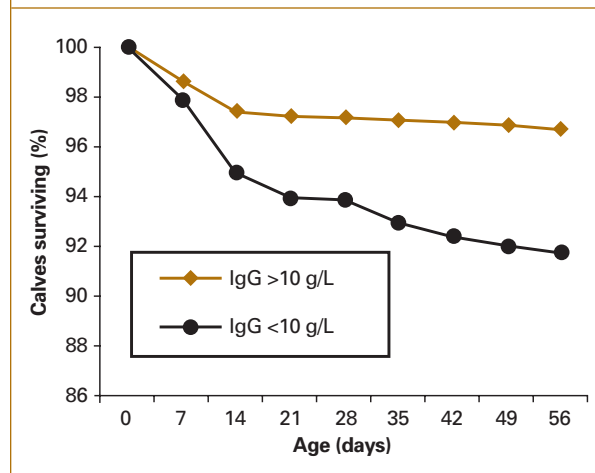
Measurement of FPT

The assessment of passive transfer has typically been done by the measurement of immunoglobulin concentration in the serum of calves, 24 to 48 hours after birth. The serum immunoglobulin concentration that is indicative of FPT is affected by the disease outcomes used to assess calf health, the management factors affecting calf health, and the method of immunoglobulin measurement. When death from septicemia is used as the clinical outcome, the serum immunoglobulin levels associated with diminished risk vary between 1 g/L,²⁰ 5 g/L,^{7,15,16} and 8 g/L.²¹ Alternatively, if serious morbidity or mortality associated with diarrhea is considered as an outcome, the levels needed for decreased risk are higher, ranging between 7.5 g/L,²⁰ 8 g/L,^{22,23} 10 g/L,¹⁵ and 16 g/L.^{9,23} While calves with serum immunoglobulin levels in excess of 16 g/L had the lowest risk of disease, the greatest difference in risk occurred between groups of calves with serum immunoglobulin levels less than or greater than 8 g/L.²³

Some of the differences in the reported protective levels of serum immunoglobulins may be attributable to management factors. For example, the levels of pathogen challenge to which the calf is subjected result in differences in the serum immunoglobulin levels necessary to confer a low risk of disease.⁷

As well as the variables in disease outcome, some of the differences in “protective” levels of serum immunoglobulins among studies also relate to the methods used to measure the immunoglobulin concentration. The zinc sulphate turbidity test (ZST) used in several studies^{7,9} provides only an estimate of the immunoglobulin concentration. One of the most reliable tests for measuring bovine IgG is the radial immunodiffusion

Figure 1: Failure of passive transfer affects calf mortality to 8 weeks of age. Serum IgG concentration was measured in blood samples from 2,177 dairy heifers collected between 24 and 48 h after birth. Over 40% of the calves had less than 10 g/L serum IgG. These calves were more likely to get sick and die over the 8-week monitoring period. (1992 National Dairy Heifer Evaluation Project, NAHMS, USDA:APHIS:VS.)



NAHMS = National Animal Health Monitoring System
 USDA = United States Department of Agriculture
 APHIS = Animal and Plant Health Inspection Service
 VS = Veterinary Service

(RID) assay. The RID test can be accurate and reproducible when utilized by experienced technical personnel; however, accuracy also depends upon the validity of the antisera and standards used in the assay.²⁴

The published data support the concept that the greater the level of serum immunoglobulin achieved in the calf the less the risk of disease, but it is not possible to precisely determine a minimum level of serum immunoglobulin consistent with a decreased risk of serious disease, given the differences among the various studies, ie, outcomes assessed, methods of IgG measurement, and influence of management factors. However, as a rule of thumb, calves with serum IgG levels <10 g/L are at a high risk for disease and this level can be used as a definition for failure of passive transfer.

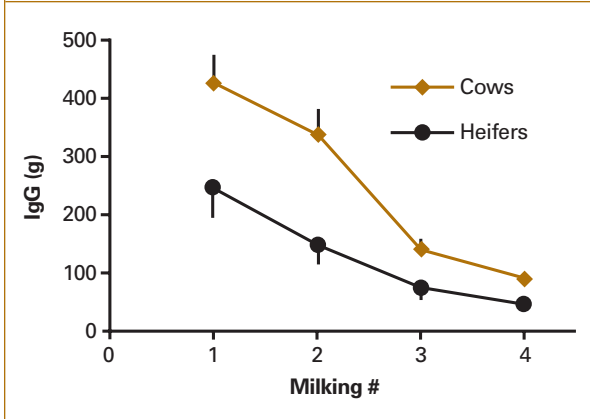
Prevalence

In spite of the well-recognized consequences of FPT, the number of calves that fail to receive adequate levels of colostrum protection is remarkably high. FPT occurred in 41% of dairy calves born in the USA (serum immunoglobulin levels <10g/L; National Dairy Heifer Evaluation Project, NAHMS, 1993). Even in well-managed beef and dairy operations, over 25% of calves have serum immunoglobulin levels less than the recommended levels of 8-10 g/L.³ Given the prevalence and serious consequences of FPT, veterinarians need to help producers understand the factors that influence effective passive transfer.

Factors influencing passive transfer

Calves fail to receive sufficient maternal colostrum for a variety of preventable management-associated reasons, such as

Figure 2: Colostral IgG mass is affected by parity and time after parturition. Colostrum volume and IgG concentration were determined for 24 cows and 11 heifers over the first four milkings. The IgG mass was calculated, and the mean (\pm S.E.) is shown. (Adapted from Chelack et al., 1993.¹⁰)



delays in colostrum administration. In addition, there are many unavoidable circumstances in which sufficient high-quality maternal colostrum is not available to the calf. These factors are categorized and discussed in terms of maternal, calf, environment, and management components.

Maternal factors

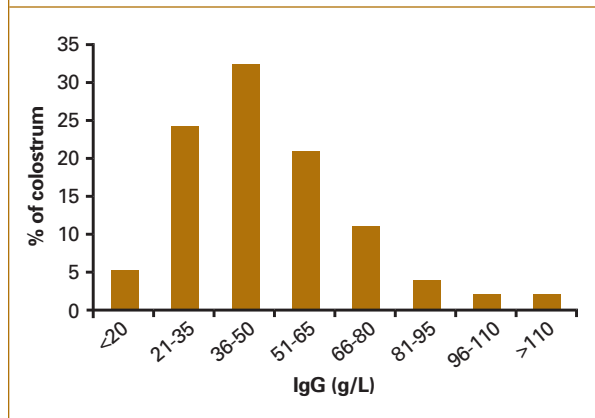
A crucial factor influencing the success of passive transfer is the mass of immunoglobulins supplied by the dam (the immunoglobulin mass is a function of the volume and immunoglobulin concentration of the colostrum).²⁵⁻³⁰ There are age, breed, and individual cow differences in the concentration of immunoglobulin and the volume of colostrum produced.¹ In a survey of 919 colostrum samples from a single dairy, the IgG concentration varied from < 20 g/L to > 110 g/L (Figure 2).³¹ The immunoglobulin concentration decreases with each milking and heifers produce less immunoglobulin than multiparous cows (Figure 3).¹⁰ In addition, the concentration of immunoglobulin in the colostrum is negatively correlated with the volume of milk produced;³¹ therefore, very high-producing cows may have poor quality colostrum even at the first milking.³²

The maternal diet can affect colostrum volume, composition, and transfer. Poor nutrition reduces the volume of colostrum produced.³³ Absorption of immunoglobulins may be reduced when cows are fed restricted amounts of energy and protein.³⁴

Other maternal factors contributing to FPT include multiple births, poor teat conformation, colostrum leaking from the udder, and a short dry period. Good mothering abilities increase serum immunoglobulin levels in calves.³⁵

Vaccination of cows is an important management technique to raise the level of protection against specific diseases. The veterinarian, with knowledge of the incidence of certain diseases on the farm, can incorporate a specific vaccination protocol as part of the herd health program.

Figure 3: Frequency distribution of IgG concentration in colostrum. First milking colostrum samples ($n=919$), obtained from cows on a single dairy, were analyzed for IgG concentration. (Adapted from Pritchett et al. 1991.³¹)



Calf factors

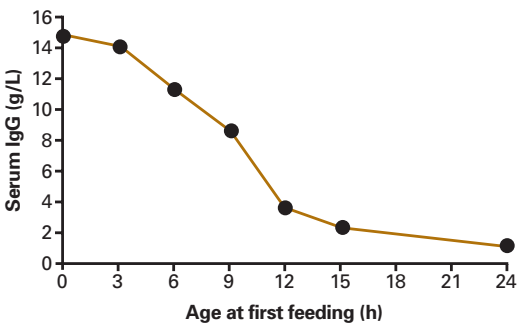
The effectiveness of passive transfer is dependent upon the ability of the calf to transport immunoglobulin from the colostrum into the bloodstream, as well as, the amount of immunoglobulin available for transport.

Upon ingestion of colostrum, the immunoglobulins are absorbed by the epithelial cells of the gut through a nonselective pinocytotic mechanism and transferred to the lymphatics and bloodstream. Since this mechanism begins to decline in effectiveness after birth, a number of studies have examined the effect of the age at which the colostrum is fed. The absorption coefficient of calves fed at 20 hours postpartum is less than half that of calves fed at 2 hours-of-age.³⁶ Therefore, while there is evidence of a transfer of immunoglobulins for up to 24-hours postpartum,³⁷ the degree of transfer is minimal by this time (Figure 4). Consequently, in calves fed 1 L of colostrum at 6-hour intervals beginning at different times postpartum, only calves fed colostrum before 6 hours attained serum immunoglobulin levels > 10 g/L.⁴ The success of passive transfer is, therefore, highly dependent upon how soon after birth the calf receives colostrum.

Another consequence of the transport mechanism is that if bacteria are ingested prior to colostrum, those bacteria will be transported across the epithelial barrier resulting in septicemia.³⁸ This is another reason for the calf to receive colostrum as soon as possible after birth. The capacity of the macromolecular transport mechanism is limited; thus, immunoglobulin absorption is more efficient when the concentration of immunoglobulin as a percentage of total protein in colostrum is higher.³⁹

The newborn calf's requirement for colostral immunoglobulin mass is approximately 80-150 grams,^{36,40} if the calf is fed within the first 2 hours after birth. Since the absorbed IgG is distributed in the plasma volume, which is related to the size of the calf, small birth weight calves require 80 - 120 g of immunoglobulin, while high birth weight calves require 120 -

Figure 4: Uptake of IgG decreases rapidly after birth. The serum IgG concentration was determined in calves fed 1 L of colostrum at six-hour intervals starting at seven different ages. (Adapted from White, 1993.⁴¹)



150 g to achieve 10g/L serum immunoglobulin concentration. Since small birth weight calves consume only 0.5 to 1.0 litres/feeding, while high birth weight calves consume 1.0 to 2.0 litres/feeding,^{26,30} colostrum immunoglobulin concentrations of >60 g/L are required to deliver the required immunoglobulin mass in these volumes during the first critical hours of life. Other calf factors that may compromise passive transfer include weakness, competition for teats, and the metabolic state of the calf. The metabolic state of the calf can be affected by premature delivery, dystocia, anoxia, or acidosis.^{4,41,42}

Environment

Cold temperatures reduce the rate of immunoglobulin absorption by calves, but not final serum immunoglobulin levels;⁴³ however, they may affect passive transfer since calves may be slower to stand and suckle voluntarily.⁴⁴ Heat stress affects the cow, reducing colostrum levels of IgG and IgA, fat, lactose, protein, and energy.

Management Factors

Management can affect passive transfer success through the method of colostrum feeding, the length of the dry period, milking prior to parturition, and overcrowding. There is a higher prevalence of FPT in calves born in a stanchion-stall or pen, compared to calves born in box stalls.⁶

While some reports²⁵ indicate nursing, either natural or via a nipple bottle, is the best method to administer colostrum, others do not demonstrate an advantage to natural suckling over tube feeding.⁴⁵ With natural nursing, the volume consumed cannot be determined, making it difficult for the farmer to predict the success of transfer. Higher volumes can be administered by esophageal tube, so that adequate immunoglobulin mass can be transferred, even if colostrum IgG concentration is suboptimal. Since the capacity of the neonatal calf rumen is estimated to be about 400 mL, the large volumes result in “spill over” into the abomasum, an effect similar to the closure of the

esophageal groove that occurs with the suckling reflex.⁴⁶ In one study, the administration of larger volumes resulted in lower absorption of immunoglobulin.²⁶ However, in these experiments, calves were fed very large volumes of colostrum (10% of body weight or 4–5 L). The question of the benefits of suckling versus tube feeding may be largely academic since the vast majority of calves that are hand-fed are allowed to suckle. Only 2.3 % of calves in the 1992 NAHMS National Dairy Heifer Evaluation Project were fed by esophageal tube. Therefore, it is advisable that colostrum meet the needs of the calf in the volume that a calf would normally suckle (≤ 2 L).

Colostrum supplementation

Traditionally, neonatal calves suspected of colostrum deficiency have been supplemented with stored or frozen dairy colostrum. Dairy cows produce far more colostrum than their own calves can use. The excess can be safely stored at 4°C for 24 hours or frozen for up to a year. The colostrum is best divided into 1 or 2 L packages for ease of thawing. However, frozen colostrum purchased from dairies has been found to contain widely variable and often inadequate amounts of immunoglobulin.⁴⁷ One reason may be that while the first 6 milkings post-partum are considered “colostrum” from the dairy marketing point of view, adequate immunoglobulin levels are generally found only in the first 1 or 2 milkings.^{10,29} Frozen colostrum has other disadvantages, eg, the requirement for large amounts of freezer storage space and the inconvenient time required for thawing prior to use. There is also a significant risk for the transmission of infectious diseases associated with the use of untreated colostrum, particularly, the mycobacteria.⁴⁸

There are several dried bovine colostrum supplement/replacer products that are commercially available, derived from cheese whey, slaughterhouse blood/serum, or dairy colostrum. These products offer the advantages of being easy to use, stable, of defined quality, and heat-treated for safety. The disadvantages include the relative expense compared with frozen colostrum, the low immunoglobulin and nutrient levels in some products, poor palatability of some products, and inadequate heat treatment of some products (disease risk). In addition, blood and whey protein-derived products may lack other beneficial nonimmunoglobulin colostrum factors.

Historically, there has been a problem with the immunoglobulin content of some of these products.⁴⁷ In more recent years, the immunoglobulin claims of commercially available products have increased, but supplementing maternal colostrum with colostrum replacement products does not always improve calf serum immunoglobulin levels.^{32,49-51} This raises questions regarding whether factors other than immunoglobulin mass are important in achieving normal serum immunoglobulin levels when these products are used. In one study, calves were fed maternal colostrum or one of 3 commercially available colostrum supplements.⁵² While all calves received in excess of 100 g of immunoglobulin, only the

calves fed maternal colostrum achieved serum immunoglobulin levels >8 g/L. These results contrast with our studies that have shown effective absorption of dried, reconstituted colostrum; calves fed 120 g of immunoglobulin, either spray-dried reconstituted or thawed colostrum, achieved the same serum immunoglobulin levels, both >12 g/L.¹⁰ Further, calves fed dried colostrum achieved protective levels of antibodies to bovine pathogens, including viruses such as bovine viral diarrhoea virus (BVDV).⁵³

The failure of effective absorption of some dried colostrum supplements may be partially due to the high percentage of nonimmunoglobulin proteins present in the products. The addition of 37 g/L of albumin to colostrum containing 42 g of IgG/L diminished the rate of absorption of the immunoglobulins from 59% to 36%; thus, decreasing the serum immunoglobulin levels achieved in the calves from >9 g/L to <7 g/L.³⁹ Since the absorptive capacity of the intestinal epithelial cells in the neonate is relatively nonselective and finite, it is likely that high levels of nonimmunoglobulin proteins compete with the absorption of the immunoglobulins and diminish the percentage absorbed. Good quality maternal colostrum is estimated to be over 20% immunoglobulin on a dry matter basis (50 g of IgG in 1 litre containing 21% dry matter);^{2,10} colostrum replacers/supplements should contain similar immunoglobulin levels to ensure effective absorption.

Other factors may also impact upon the absorption of colostrum immunoglobulins. The most important, from the perspective of commercial colostrum supplements/replacers, may be the presence of high levels of colostrum trypsin inhibitors that prevent trypsin-mediated digestion of the immunoglobulin molecules.^{54,55} One study showed that the addition of soybean trypsin inhibitor to normal colostrum increased IgG absorption by 16% and IgM absorption by 30%.⁵⁶ Colostrum replacers/supplements manufactured from noncolostral sources may not contain the high levels of trypsin inhibitors normally present in colostrum. Therefore, the immunoglobulins in these products may be susceptible to proteolytic degradation and fail to be absorbed.

There is a need for commercially available, safe, and effective colostrum supplements/replacers for calves. When choosing a replacer, the important features to examine are:

- IgG content: Bovine colostrum replacer/supplements should contain a sufficient mass of immunoglobulin (>120 g) in a volume that a normal calf could be expected to consume within 6 hours (<2 L). To ensure effective absorption of the immunoglobulins, the product should be 20% immunoglobulin.
- Treatment to eliminate the pathogens (pasteurization)
- Antibody function tested
- Source: A product derived from colostrum provides nonimmunoglobulin factors.

Summary

Failure of passive transfer is a preventable condition with important consequences on calf health. Some general recommendations for colostrum feeding can be developed under the basic tenants of feeding the calf as soon as possible after birth with sufficient high-quality colostrum to provide adequate immunoglobulin and nutrients, to optimize immunoglobulin uptake, and to prevent migration of pathogens through the intestinal wall. The best practices for feeding colostrum to achieve maximal benefits may be summarized as:

- Timing: “The sooner the better.” Feed calf within 6 hours of birth. Time is of the essence; if the calf will not suckle, it is better to use an esophageal feeder than let time pass.

- Immunoglobulin Mass: “More is better” Feed at least 120 g of immunoglobulin, as early as possible. More is required if the entire amount is not consumed before 12 hours-of-age. Colostrometers, which are inexpensive hydrometers used for measuring the specific gravity of colostrum, may be used to estimate the colostrum immunoglobulin concentration. If maternal colostrum is not sufficient, supplement with high-quality, frozen dairy colostrum, or commercial colostrum supplements with high IgG levels (>60 g/L).

- Manage the calf to facilitate health: “Mothering” promotes absorption of factors from the colostrum, and can be simulated by rubbing the calf and keeping it clean, warm, and dry. Keep calf in an isolated, dry, draft-free environment.

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References

1. Aldridge B, Barry F, Adams MA. Role of colostrum transfer in neonatal calf management: failure of acquisition of passive immunity. *The Compendium on continuing education for the practicing veterinarian* 1992;14:265-269.
2. Besser TE, Gay CC. The importance of colostrum to the health of the neonatal calf. *Vet Clin North Am Food Anim Pract* 1994;10:107-17.
3. Perino LJ. A guide to colostrum management in beef cows and calves. *Vet Med Food Animal Practice* 1997;75-82.
4. White DG. Colostral supplementation in ruminants. *The Compendium on continuing education for the practicing veterinarian* 1993;15:335-342.
5. Fallon RJ, Harte FJ. The occurrence of diarrhoea in calves under different management systems. *Ann Rech Vet* 1983;14:473-8.
6. Filteau V, Bouchard E, Fecteau G, et al. Health status and risk factors associated with failure of passive transfer of immunity in newborn beef calves in Quebec. *Can Vet J* 2003;44:907-913.
7. Hancock DD. Assessing efficiency of passive immune transfer in dairy herds. *J Dairy Sci* 1985;68:163-83.
8. McDonough SP, Stull CL, Osburn BI. Enteric pathogens in intensively reared veal calves. *Am J Vet Res* 1994;55:1516-20.
9. White DG, Andrews AH. Adequate concentration of circulating colostrum proteins for market calves. *Vet Rec* 1986;119:112-4.
10. Chelack BJ, Morley PS, Haines DM. Evaluation of methods for dehydration of bovine colostrum for total replacement of normal colostrum in calves. *Can Vet J* 1993;34:407-412.
11. Besser TE. Concentrations of passively acquired IgG1 antibodies in the intestinal lumen of the neonatal calf. *Vet Immunol Immunopathol* 1993;38:103-12.
12. Hadorn U, Hammon H, Bruckmaier RM, et al. Delaying colostrum intake by one day has important effects on metabolic traits and on gastrointestinal and metabolic hormones in neonatal calves. *J Nutr* 1997;127:2011-23.

13. Blum JW, Hadorn U, Sallmann HP, et al. Delaying colostrum intake by one day impairs plasma lipid, essential fatty acid, carotene, retinol and alpha-tocopherol status in neonatal calves. *J Nutr* 1997;127:2024-9.
14. Davis CL, Drackley JK. Colostrum. *The Development, Nutrition, and Management of the Young Calf*. Ames, Iowa: Iowa State University Press; 1998; Ch. 13: 179-206.
15. McGuire TC, Pfeiffer NE, Weikel JM, et al. Failure of colostrum immunoglobulin transfer in calves dying from infectious disease. *J Am Vet Med Assoc* 1976;169:713-8.
16. Rea DE, Tyler JW, Hancock DD, et al. Prediction of calf mortality by use of tests for passive transfer of colostrum immunoglobulin. *J Am Vet Med Assoc* 1996;208:2047-9.
17. Wittum TE, Perino LJ. Passive immune status at postpartum hour 24 and long-term health and performance of calves. *Am J Vet Res* 1995;56:1149-54.
18. DeNise SK, Robison JD, Stott GH, et al. Effects of passive immunity on subsequent production in dairy heifers. *J Dairy Sci* 1989;72:552-4.
19. Robison JD, Stott GH, DeNise SK. Effects of passive immunity on growth and survival in the dairy heifer. *J Dairy Sci* 1988;71:1283-7.
20. Penhale WJ, Christie G, McEwan AD, et al. Quantitative studies on bovine immunoglobulins. II. Plasma immunoglobulin levels in market calves and their relationship to neonatal infection. *Br Vet J* 1970;126:30-7.
21. Fecteau G, Van Metre DC, Pare J, et al. Bacteriological culture of blood from critically ill neonatal calves. *Can Vet J* 1997;38:95-100.
22. Perino LJ, Sutherland RL, Woollen NE. Serum gamma-glutamyltransferase activity and protein concentration at birth and after suckling in calves with adequate and inadequate passive transfer of immunoglobulin G. *Am J Vet Res* 1993;54:56-9.
23. Perino LJ, Wittum TE, Ross GS. Effects of various risk factors on plasma protein and serum immunoglobulin concentrations of calves at postpartum hours 10 and 24. *Am J Vet Res* 1995;56:1144-8.
24. Li-Chan EC, Kummer A. Influence of standards and antibodies in immunochemical assays for quantitation of immunoglobulin G in bovine milk. *J Dairy Sci* 1997;80:1038-46.
25. Stott GH, Marx DB, Menefee BE, et al. Colostral immunoglobulin transfer in calves. IV. Effect of suckling. *J Dairy Sci* 1979;62:1908-13.
26. Stott GH, Marx DB, Menefee BE, et al. Colostral immunoglobulin transfer in calves. III. Amount of absorption. *J Dairy Sci* 1979;62:1766-73.
27. Stott GH, Marx DB, Menefee BE, et al. Colostral immunoglobulin transfer in calves II. The rate of absorption. *J Dairy Sci* 1979;62:1766-73.
28. Stott GH, Marx DB, Menefee BE, et al. Colostral immunoglobulin transfer in calves I. Period of absorption. *J Dairy Sci* 1979;62:1632-8.
29. Stott GH, Fleenor WA, Kleese WC. Colostral immunoglobulin concentration in two fractions of first milking postpartum and five additional milkings. *J Dairy Sci* 1981;64:459-65.
30. Stott GH, Fellah A. Colostral immunoglobulin absorption linearly related to concentration for calves. *J Dairy Sci* 1983;66:1319-28.
31. Pritchett LC, Gay CC, Besser TE, et al. Management and production factors influencing immunoglobulin G1 concentration in colostrum from Holstein cows. *J Dairy Sci* 1991;74:2336-41.
32. Morin DE, McCoy GC, Hurley WL. Effects of quality, quantity, and timing of colostrum feeding and addition of a dried colostrum supplement on immunoglobulin G1 absorption in Holstein bull calves. *J Dairy Sci* 1997;80:747-53.
33. Logan EF. The influence of husbandry on colostrum yield and immunoglobulin concentration in beef cows. *Br Vet J* 1977;133:120-5.
34. Hough RL, McCarthy FD, Kent HD, et al. Influence of nutritional restriction during late gestation on production measures and passive immunity in beef cattle. *J Anim Sci* 1990;68:2622-7.
35. Selman IE, McEwan AD, Fisher EW. Absorption of immune lactoglobulin by newborn dairy calves. Attempts to produce consistent immune lactoglobulin absorptions in newborn dairy calves using standardised methods of colostrum feeding and management. *Res Vet Sci* 1971;12:205-210.
36. Kruse V. Absorption of immunoglobulin from colostrum in newborn calves. *Anim. Prod.* 1970;12:627-638.
37. Marx DB, Stott GD. Analysis of censored data for such as colostrum immunoglobulin transfer in calves. *J Dairy Sci* 1979;62:1819-24.
38. Corley LD, Staley TE, Bush LJ, et al. Influence of colostrum on transepithelial movement of *Escherichia coli* 055. *J Dairy Sci* 1977;60:1416-21.
39. Besser TE, Osborn D. Effect of bovine serum albumin on passive transfer of immunoglobulin G1 to newborn calves. *Vet Immunol Immunopathol* 1993;37:321-7.
40. Todd AG, Whyte PB, Carroll PD. A comparison of serum immunoglobulin concentrations in neo-natal calves fed substitute colostrums. *Aust Vet J* 1993;70:154-5.
41. Boyd JW. Relationships between acid-base balance, serum composition and colostrum absorption in newborn calves. *Br Vet J* 1989;145:249-56.
42. Besser TE, Szenci O, Gay CC. Decreased colostrum immunoglobulin absorption in calves with postnatal respiratory acidosis. *J Am Vet Med Assoc* 1990;196:1239-43.
43. Olson DP, Papsian CJ, Ritter RC. The effects of cold stress on neonatal calves. II. Absorption of colostrum immunoglobulins. *Can J Comp Med* 1980;44:19-23.
44. Rogers GM, Capucille DJ. Colostrum management: keeping beef calves alive and performing. *Compend Contin Educ Pract Vet* 2000;22:6-13.
45. Adams GD, Bush LJ, Horner JL, et al. Two methods for administering colostrum to newborn calves. *J Dairy Sci* 1985;68:773-5.
46. Chapman HW, Butler DG, Newell M. The route of liquids administered to calves by esophageal feeder. *Can J Vet Res* 1986;50:84-7.
47. Haines DM, Chelack BJ, Naylor JM. Immunoglobulin concentrations in commercially available colostrum supplements for calves. *Can Vet J* 1990;31:36-37.
48. Streeter RN, Hoffsis GF, Bech-Nielsen S, et al. Isolation of *Mycobacterium paratuberculosis* from colostrum and milk of subclinically infected cows. *Am J Vet Res* 1995;56:1322-4.
49. Abel Francisco SF, Quigley JD, 3rd. Serum immunoglobulin concentrations after feeding maternal colostrum or maternal colostrum plus colostrum supplement to dairy calves. *Am J Vet Res* 1993;54:1051-4.
50. Mee JF, O'Farrell KJ, Reitsma P, et al. Effect of a whey protein concentrate used as a colostrum substitute or supplement on calf immunity, weight gain, and health. *J Dairy Sci* 1996;79:886-94.
51. Hopkins BA, Quigley JD, 3rd. Effects of method of colostrum feeding and colostrum supplementation on concentrations of immunoglobulin G in the serum of neonatal calves. *J Dairy Sci* 1997;80:979-83.
52. Garry FB, Adams R, Cattell MB, et al. Comparison of passive immunoglobulin transfer to dairy calves fed colostrum or commercially available colostrum-supplement products. *J Am Vet Med Assoc* 1996;208:107-10.
53. Cortese VS, West KH, Hassard LE, et al. Clinical and immunologic responses of vaccinated and unvaccinated calves to infection with a virulent type-II isolate of bovine viral diarrhoea virus. *J Am Vet Med Assoc* 1998;213:1312-9.
54. Sandholm M, Honkanen-Buzalski T. Colostral trypsin-inhibitor capacity in different animal species. *Acta Vet Scand* 1979;20:469-76.
55. Quigley JD, 3rd, Martin KR, Dowlen HH. Concentrations of trypsin inhibitor and immunoglobulins in colostrum of Jersey cows. *J Dairy Sci* 1995;78:1573-7.
56. Quigley JD, 3rd, Martin KR, Dowlen HH, et al. Addition of soybean trypsin inhibitor to bovine colostrum: effects on serum immunoglobulin concentrations in Jersey calves. *J Dairy Sci* 1995;78:886-92.

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