Colostrum Management and Factors Related to Poor Calf Immunity

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Take Home Messages

- Collect colostrum as soon as possible after calving and immediately feed it to the calf, temporarily store it in the fridge, or freeze it; do not store colostrum at room temperature.
- Measure colostrum quality (IgG content) on-farm – you need to know what you are feeding before you feed it.
- The colostrometer and the Brix refractometer are both good tools for indirectly measuring colostrum IgG concentration.
- Calves need to consume at least 100 g of IgG from colostrum in the first 6 hours of life to prevent failure of transfer of passive immunity.

Introduction

In the gestating dairy cow, maternal and fetal blood supplies are completely separate; therefore, there is no transfer of immunoglobulins, primarily immunoglobulin G (IgG), across the placenta from the dam to the fetus. As a result, calves are born with minimal immunological defenses against environmental pathogens. They must acquire immunity passively through the consumption of colostrum. If a calf does not receive an adequate amount of IgG from colostrum, it may suffer from failure of transfer of passive immunity (FTP). While FTP is not in itself a disease, it does predispose the calf to an increased risk of morbidity and decreased growth rate and lifetime milk production. By far the greatest factor contributing to mortality of pre-weaned calves is FTP, associated with 39 to 50% of pre-weaned calf mortality (Margerison and Downey, 2005). Failure of transfer of passive immunity is widespread, with a prevalence of 19% on US farms (Beam et al., 2009) and 37% on Ontario farms (Trotz-Williams et al., 2008). Failure of transfer of passive immunity is largely the result of insufficient IgG being consumed, and IgG consumption is related to the quality and quantity of colostrum consumed

and the timing of colostrum ingestion following calving. This paper discusses these factors and describes a study recently conducted in Alberta that identified calf management practices related to FTP.

■ Failure Of Transfer Of Passive Immunity

The presence of FTP in calves is usually determined using 1 of 2 methods: directly by measuring the concentration of IgG in the calf's serum using either an ELISA test or radial immunodiffusion (RID), or indirectly by measuring serum total protein (STP).

Serum IgG

It is commonly accepted that transfer of passive immunity is adequate when serum IgG concentration, measured by RID, is a minimum of 10 mg/mL. Calves with serum IgG greater than 10 mg/mL have significantly reduced risk of death compared to calves with lower serum IgG (Chelack et al., 1993). Serum IgG should ideally be determined between 12 and 24 hours after the calf has consumed its first colostrum meal. Before 12 hours, absorption of IgG across the gut is not complete and serum levels will still be low, and after 24 hours, serum IgG levels start to decline. Even though IgG content declines at a rate of approximately 2% per day, IgG concentrations in serum obtained within a week of birth are still considered indicative of the success or failure of transfer of passive immunity.

Serum Total Protein

The direct measure of serum IgG levels by RID is time-consuming and cannot be performed on-farm. An alternative is to use STP measured by refractometry as an indirect measure of IgG concentration. There is general agreement that the minimum STP concentration indicative of adequate immunity is 5.2 g/dL (52 mg/mL) but there is some variability around that value. Tyler et al. (1996) suggested that a range of 5.0 to 5.5 g/dL is an appropriate measure of adequate passive transfer. Although this range is generally useful, hydration status of the calf must be considered when using refractometry, as clinically ill dehydrated calves have elevated STP and can be misclassified as having adequate transfer of passive immunity. The correlation between STP and IgG concentration is not 100% because STP measures proteins other than IgG; however, the relationship is quite strong (correlation of up to 0.84; Tyler et al., 1996).

■ Colostrum Management

There are 5 major components to colostrum and its management that are key to a calf achieving adequate immunity: quality, cleanliness, quantity, timing of collection and feeding, and method of feeding.

Quality

Immunoglobulin G concentration tends to be used as the primary indicator of colostrum quality. Approximately 85-90% of the immunoglobulin in colostrum is IgG, with 80-90% of this being IgG1. During colostrogenesis, high concentrations of IgG are transported from the blood into the mammary glands through receptors on the alveolar epithelial cells (Godden, 2009).

Colostrum IgG content varies widely within and between farms. Quigley et al. (2013) reported a range of 7 to 159 mg/mL on a single farm, and similar ranges have been found in other studies (Godden, 2009). Good quality colostrum should contain at least 50 mg of IgG per mL (Godden et al., 2009). Unfortunately, up to 35% of colostrum contains IgG below this value (Quigley et al., 2013), which makes measuring the quality of colostrum before feeding it absolutely essential to ensure calves receive an adequate amount of IgG. Pooling colostrum often decreases the concentration of IgG. Approximately 20% of dairy farms in the USA use pooled colostrum (Beam et al., 2009) and those that pool are 2.2 times more likely to have calves with FTP compared to those that do not pool.

Colostrum IgG content can be measured directly by RID, or indirectly using a colostrometer or a Brix refractometer. The colostrometer measures specific gravity, which is positively correlated with the total amount of protein in the colostrum, which in turn is correlated with IgG content. According to the calibration scale on the colostrometer, the cut point between “excellent” and “moderate” colostrum quality occurs between 49.8 mg/mL and 52.4 mg/mL (Fleenor and Stott, 1980); however, several studies have found that the colostrometer overestimates IgG content and that a minimum acceptable level should be between 60 to 80 mg/mL (Pritchett et al., 1994; Chigerwe et al., 2008a). Although it is relatively easy to use, the colostrometer does have some shortcomings. The colostrum must be measured at room temperature; at higher temperatures, IgG content will be under-estimated and at lower temperatures it will be overestimated. In addition, components of the colostrum such as non-IgG protein and fat can affect the specific gravity. Although dairy producers are familiar with the colostrometer, utilization is low; 4% of farms in Quebec were reported to use the colostrometer consistently (Vasseur et al., 2010).

The Brix refractometer measures total solids, whose concentrations are correlated with IgG content. Brix values for colostrum have been reported in the range of 12 to 37% with a mean of 24 - 26% (Bielmann et al., 2010; Quigley et al., 2013). Brix scores ranging from 20 - 23% have been reported to be roughly equal to an IgG concentration of 50 mg/mL (Chigerwe et al., 2008a; Bielmann et al., 2010). Unlike the colostrometer, the Brix refractometer is not sensitive to temperature and only requires a few drops of colostrum.

Cleanliness

Cleanliness refers to the absence of bacteria in colostrum; unfortunately, a large percentage of colostrum on commercial farms has high levels of bacteria, greater than 100,000 cfu/mL. Bacteria in colostrum have a negative impact on IgG absorption by the calf because they may bind IgG in the calf's small intestine or they may directly block the uptake of IgG by the intestinal cells (Godden, 2008). Bacteria in colostrum may also be pathogenic and cause diseases such as diarrhea. There are several management practices that should be followed to minimize bacterial contamination of colostrum:

- thoroughly wash your hands before milking the cow
- prepare the udder as you would before milking
- milk into a clean, sanitized bucket
- do not feed colostrum from known infected cows
- do not pool raw colostrum
- feed calves using clean, sanitized bottles or buckets and nipples
- do not let colostrum sit at room temperature – feed it, refrigerate it (use within 24 hours) or freeze it within one hour of collection

An effective method for reducing bacterial contamination of colostrum is pasteurization. Typical milk pasteurization temperatures are too high for pasteurizing colostrum; the IgG is partially destroyed by high temperatures and the colostrum tends to thicken. The recommended practice is to pasteurize colostrum at 60^{o}C for 60 minutes. Pasteurized colostrum stored in a clean, covered container in the refrigerator has a shelf life of 8 – 10 days. Studies have shown that calves fed pasteurized colostrum have significantly higher serum IgG levels than calves fed non-pasteurized colostrum (Johnson et al., 2007).

Quantity

The amount of colostrum that should be consumed by the calf in the first 6 hours of life is a volume that supplies at least 100 grams of IgG, though some literature suggests that 150 to 200 grams is more appropriate (Chigerwe et al., 2008b). Consumption of more than 100 g of IgG in the first feeding results in a low prevalence of FTP, while inadequate colostrum intake has been associated with increased calf morbidity, decreased growth rate and reduced milk production as 1st lactation heifers. Because colostrum quality is not routinely measured on-farm, the current recommendation is to feed Holstein calves 4 L of colostrum as soon as possible after calving and Jersey calves 3 L. Calves should be fed an additional 2 L of colostrum within 8 - 12 hours of birth. Transition milk should be fed for another 2 - 3 days as it is very rich in nutrients and energy that will benefit the calf.

Timing of Collection and First Feeding

Colostrum collected more than 2 hours after the cow has calved is significantly lower in IgG than colostrum collected within a shorter time frame (Chigerwe et al., 2008b). As the cow produces milk after calving, the milk dilutes the colostrum, whose synthesis stops at calving; therefore, with increasing time post-calving that the cow is not milked, IgG concentrations steadily decrease. Ideally, cows should be milked within 2 hours of calving, and no later than 6 hours after calving.

In terms of when the calf should be fed, in a US survey, farms that administered the first colostrum feeding more than 4 hours after the calf was born were 2.7 times more likely to have calves with FTP than farms that fed the first colostrum within 4 hours (Beam et al., 2009). As maximal IgG absorption declines within hours of birth, calves should ideally be fed within the first 2 hours of birth, with the first feeding no later than 6 hours after calving (Godden, 2009).

Method of Feeding

Leaving the calf with the dam to suckle exclusively may result in inadequate voluntary consumption of colostrum within the critical 4-hour window and so contributes to the development of FTP (Trotz-Williams et al., 2008). Unfortunately this is still a common practice, with Ontario farms reporting that 50% of calves are left with the dam for 3 hours or less while 33% remain with the cow for 3 to 12 hours (Trotz-Williams et al., 2008). Beam et al. (2009) reported that 25% of farms in the US allow calves to obtain colostrum via suckling and 75% of calves are hand-fed with 89% of those calves being bottle-fed and the remaining fed via esophageal tube. The percentage of calves with FTP in that study was 61.4% in those that received colostrum via

suckling, 19.3% in those that were bottle-fed and 10.8% in those that were tube-fed.

When 2 L or less of colostrum is fed, bottle-feeding is the preferred method over tube-feeding. With tube-feeding, between 500 – 1000 mL of the colostrum stays in the reticulo-rumen for up to 3 hours, lengthening the time that the colostrum takes to reach the small intestine where absorption occurs. This delay in transport to the small intestine will result in lower amounts of IgG being absorbed and subsequent lower levels of IgG in the serum. When at least 3 L of colostrum is fed, there generally is no difference in the rate of FTP between bottle-fed and tube-fed calves.

■ Alberta Calf Management Study

We recently conducted a study that examined colostrum management practices, colostrum quality, and incidence of FTP on Alberta dairy farms. Thirteen farms from central Alberta were enrolled in the study between February and June of 2012. All farms had Holstein herds ranging in size from 60 to 300 lactating cows housed in free-stall barns. The producers collected samples of first milking colostrum or colostrum replacer, and IgG concentrations in the colostrum were then indirectly determined with a colostrometer and Brix refractometer, and directly by RID. Producers also completed a calf-management survey for each calf that asked questions pertaining to calving location and ease, and feeding methods and amounts. The farms were visited weekly, and height and body weight for each bull and heifer calf were measured at the initial visit, and heifers had these measurements taken weekly until 8 weeks of age. Weight was estimated with a heart girth measuring tape. Blood samples were taken from calves less than 7 days of age, and IgG and STP concentrations were determined. Multivariable analysis was then used to determine relationships between management practices and STP and serum IgG concentrations. In total, 199 bull calves and 556 heifer calves were sampled.

Colostrum Quality

Immunoglobulin G concentrations of the colostrum samples are shown in Table 1 and Figure 1.

Table 1. Quality measurements for maternal colostrum and colostrum replacer samples collected from 13 farms in central Alberta.

	N	Mean	Minimum	Maximum
Brix, %	572	24.3	6.8	52.6
IgG by colostrometer, mg/mL	519	82.3	0.0	140.0
IgG by RID, mg/mL	462	63.7	8.3	128.6

For the colostrometer, 73 out of 519 (14.1%) were samples below 50 mg/ml while for the RID-measured IgG data, 136 out of 462 samples (29.4%) were below 50 mg/mL.

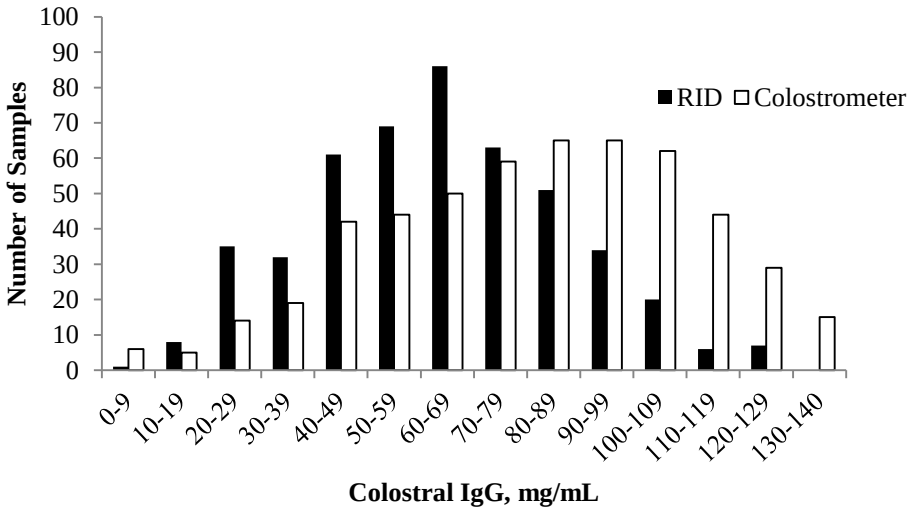

Figure 1. Distribution of RID and colostrometer-determined IgG concentrations of maternal colostrum and colostrum replacer samples.

The Brix refractometer data ranged from 6.8 to 52.6% Brix with a mean of 24.3% (Figure 2).

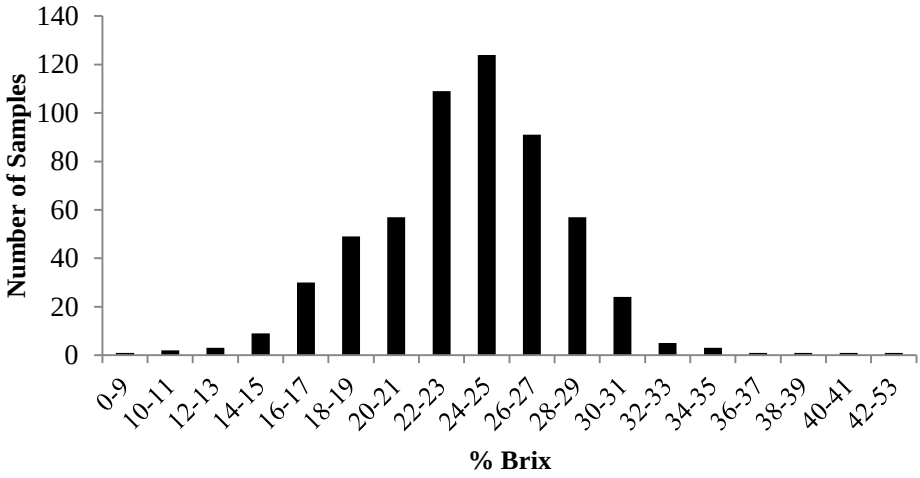

Figure 2. Distribution of colostrum samples analyzed with a digital Brix refractometer.

In terms of factors that impacted colostrum quality, cows in their 3rd or higher lactation had significantly higher colostral IgG (69.5 mg/mL) compared to 2nd parity (59.8 mg/mL) and 1st parity dams (62.2 mg/mL). Season, or month of birth, did not affect colostral IgG concentrations.

Although the scale on the colostrometer indicates that 50 mg/mL is the cut point for poor vs. good quality colostrum, our data indicate that the colostrometer over-estimates IgG content and that 80 mg/mL should be considered the cut point for good quality colostrum. This is in line with other groups who recommend cut points of 60 - 80 mg/mL (Mechor et al., 1991; Pritchett et al., 1994; Chigerwe et al., 2008a). In terms of the Brix, our data suggest that 23% is the minimum acceptable value. Although suggestions in the literature range from 20 to 23% Brix (Chigerwe et al., 2008a; Bielmann et al., 2010; Quigley et al., 2013), it is in the best interest of the calf to use a high cut point.

Calf Measurements

According to STP analysis, 44.2% of calves had FTP as 334 of 755 samples fell below the 5.2 g/dL cut point. For the RID analysis, 210 of 755 or 27.8% had FTP (serum IgG < 10 mg/mL; Figure 3).

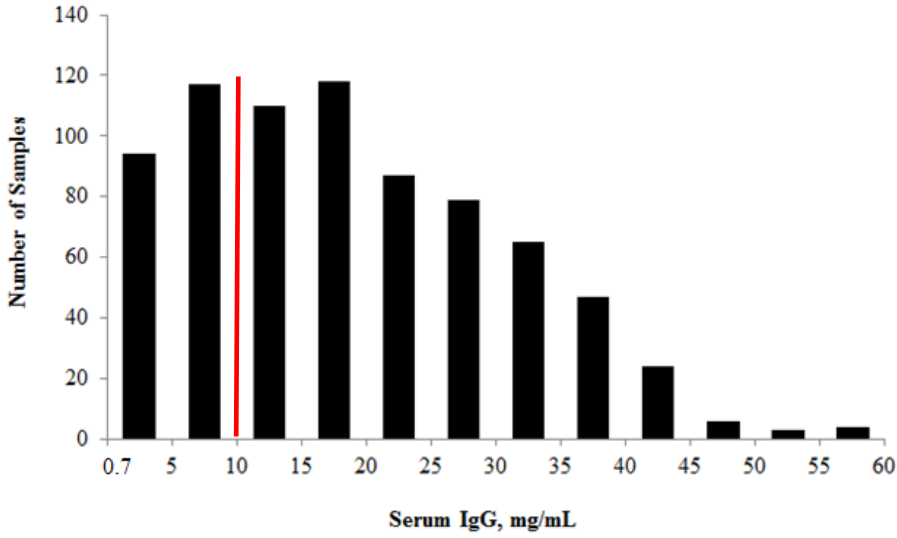

Figure 3. Distribution of serum IgG analysed by RID. The line represents the cut point for failure of transfer of passive immunity.

Table 2 shows the management factors that were related to STP concentrations. The type of colostrum fed from 6 to12 hours of life and type of milk fed after colostrum were important categorical predictors of STP concentrations. As well, for every unit increase in IgG (mg) consumed in the first 6 hours of life, STP increased by 0.002 g/dL ($p < 0.01$).

Table Error! No text of specified style in document.**. Variables associated with serum total protein in 704 dairy calves**

Variable	STP (CI[1]), g/dL
Type of colostrum fed from 6-12 hours	
Other cow colostrum	6.1[a] (5.6-6.6)
Dam colostrum	5.9[a] (5.6-6.2)
Not fed	5.9[a] (5.7-6.2)
Colostrum replacer	5.5[a] (4.9-6.1)
Supplement	5.2[b] (4.5-5.9)
Pooled colostrum	5.4[ab] (4.7-6.1)
Type of milk fed after colostrum	
Waste milk, sale milk, and colostrum replacer	6.7[a] (5.7-7.7)
Sale milk	5.4[b] (5.1-5.7)
Waste milk	5.2[b] (4.8-5.6)
Waste and sale milk	5.2[b] (4.9-5.5)

[1]95% confidence interval

Superscripts with the same letters indicate no significant difference ($p > 0.05$)

The final multivariable analysis for serum IgG is shown in Table 3. Feeding frozen colostrum or a combination of fresh and frozen resulted in the highest serum IgG levels. Colostral IgG concentration was significantly associated with serum IgG ($p < 0.01$); for each unit increase in colostral IgG, serum IgG increased by 0.2 mg/mL. For each mg of IgG consumed from 6 to 12 hours, serum IgG increased by 0.02 mg/mL ($p < 0.04$).

Table 3. Variables associated with serum IgG in 704 dairy calves

Variable	Serum IgG (CI[1]), mg/mL
Fresh or frozen colostrum fed from 0-12 hours	
Fresh and frozen	29.3[a] (25.4-33.2)
Frozen	29.2[a] (24.2-34.3)
Fresh	24.3[b] (21.6-27.0)
Colostrum replacer	24.7[ab] (19.5-30.0)
Type of milk fed after colostrum	
Waste, sale, and milk replacer	37.1[a] (27.3-46.9)
Sale milk	25.2[b] (21.5-28.8)
Waste and sale milk	22.8[b] (20.1-25.5)
Waste milk	22.5[b] (20.5-24.5)

[1]95% confidence interval

Superscripts with the same letters indicate no significant difference ($p > 0.05$)

Regarding calf body weight (BW), for each kg increase in initial BW, there was a 0.49 kg increase in BW at week 8 ($p < 0.01$). There was also a relationship between STP and BW; for every g/dL increase in STP, BW at 8 weeks increased by 1.65 kg. The final multivariable analysis of BW at week 8 is shown in Table 4. Calves that were tube-fed had the lowest BW at 8 weeks of age. Calves born from mature cows, and calves born in the summer months had the highest 8-week BW.

Table 4. Variables associated with body weight (BW) at 8 weeks in 380 heifer calves

Variable	BW at week 8 (kg)
Method of feeding from 0 to 6 hours	
Bottle	74.5[a] (72.1-77.0)
Left with dam	72.2[a] (67.6-76.8)
Not fed	71.8[ab] (59.1-84.6)
Bucket	71.0[ab] (65.3-76.6)
Tube	66.0[b] (61.3-70.7)
Parity of dam	
3+	73.30[a] (69.5-77.1)
2	70.34[b] (66.6-74.1)
1	69.65[b] (66.0-73.3)
Month of birth	
May	75.40[a] (71.5-79.3)
June	73.29[a] (69.4-77.2)
April	71.50[b] (67.6-75.4)
February	70.83[b] (66.9-74.8)
March	70.13[b] (66.0-74.2)
July	71.95[a] (67.6-76.3)

[1]95% confidence interval
Superscripts with the same letters indicate no significant difference ($p > 0.05$)

Disease incidence and mortality over the first 8 weeks of life are shown in Table 5. Diarrhea was the primary disease observed.

Table 5. Rates of morbidity and mortality of calves

Event	Calves (n)	Calves (%)
Death	12/465	2.6
Respiratory	33/466	7.1
Diarrhea	50/465	10.8

For each kilogram increase in BW in week 1, probability of death decreased by 13% ($p < 0.06$). The odds ratio (OR) of death for calves that were either not fed from 0 to 6 hours, or fed by tube, compared to bottle-fed was 59.8 and 8.7, respectively. The mean risk of mortality for calves that were not fed within 6 hours of birth was 32.7%. The OR of having diarrhea for calves not born in an individual calving pen was 2.97 compared to calves born in an individual calving pen that was cleaned before birth. The OR of having at least one event of respiratory disease was 98.2 for calves that received no colostrum from 6 to 12 hours compared to calves fed a colostrum supplement, and 15.9 compared to calves fed their own dam's colostrum.

Conclusion

The high rate of FTP on North American dairy farms indicates that there is room for improvement in the care and management of neonatal calves. Central to this is colostrum management, which centres around quality, quantity, cleanliness, timing of collection and feeding, and testing. Test the quality of the colostrum before you feed it, because if you don't know what you are feeding, you may be limiting your calf's potential without even knowing it.

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