Starting Calves Off Right: Back to the Basics on Colostrum Management

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Take Home Messages

- Colostrum management on day one is the most critical management step in a calf's life in determining its health and longevity.
- Calves must be provided with large volumes of high quality colostrum early in life (< 2 hours of life) that has low bacterial contamination and is free of disease-causing pathogens.
- When quality of colostrum is low, supplementation with colostrum replacer is a viable option.
- Monitoring the colostrum program through measuring transfer of passive immunity is a requirement of sound colostrum management.
- Shift goals for passive immunity levels away from failed transfer to successful transfer of passive immunity, maximizing the number of calves in the excellent passive immunity category while minimizing the number of calves in the failed category.
- Colostrum is much more than just immunoglobulins (IgG), with the other components playing roles in development, thermoregulation, and disease resistance of the calf.
- Prolonged or extended feeding of some colostrum or transition milk after the first day of life can provide health and growth benefits to calves during the period that disease challenges are common.
- Use of colostrum as a therapeutic for calf disease, specifically diarrhea, is a promising area that requires further research.
- Good nutrition and management after colostrum feeding is critical for supporting health and welfare of calves and allowing the calves to reach their genetic potential.

Introduction

Dairy calves are both a by-product and a critical part of the dairy industry. Because dairy calves are commonly reared away from their dam, producers have the responsibility of providing proper care and management of their calves. Over the past few decades, the importance of calf care has received more focus as management practices change and long-term impacts of early life nutrition have become more evident. Although early life management is known to have short and long-term impacts on calf health and survival, room for improvement continues. The high rates of mortality (5%) and morbidity (38.1%) that calves face in the first two months of life are concerning from an animal welfare and productivity standpoint and also from an economic and sustainability standpoint (Urie et al., 2018).

The largest factor for impacting health and longevity of calves is proper colostrum management. Due to the type of placenta that cows have, immunoglobulins do not transfer across from the dam to the calf in utero, leaving newborn calves with an underdeveloped immune system and very susceptible to disease and mortality. Therefore, calves must consume and subsequently absorb immunoglobulins, specifically IgG, to obtain successful transfer of passive immunity (TPI). Successful TPI is not as simple as feeding colostrum to calves; there are multiple factors surrounding colostrum management that impact if calves will absorb an

adequate level of IgG to avoid failed transfer of passive immunity (FTPI). Well-managed colostrum feeding on day one and extending colostrum or transition milk feeding can help set calves up for a successful future, through helping them overcome disease and improving their development. This review will focus on the components of colostrum management, ways to ensure the feeding program is set up well and working, and the benefits of extending colostrum feeding post day one of life.

▪ Colostrum Components

It is common to think about immunoglobulins, specifically IgG, when colostrum is discussed because colostrum provides calves with passive immunity. Colostrum contains more than 100 times the immunoglobulins found in milk. Primarily IgG is focused on because it accounts for most immunoglobulins in colostrum (85-90%); however, IgM and IgA are also present in colostrum. The colostral IgG also has a local effect in the gastrointestinal tract (GIT) where it binds to pathogens to limit their adhesion and absorption. Additionally, IgG (majority IgG1) is absorbed across the 'open-gut' of the newborn calf to enter circulation and provide immediate protection as passive immunity (Carter et al., 2021). Due to this primary and important role IgG plays in the calf, colostrum management has focused on immunoglobulins.

However, colostrum is much more than just IgG, and the other components play roles in immunity, energy provision and biological processes such as hormone signaling. Additionally, the development and proper functioning of the calf's GIT is stimulated and supported by colostrum consumption (Hammon et al., 2014). A recent review outlines the quantities of some bioactives in colostrum compared to that in mature milk and discusses the benefit of these bioactives to the GIT (Table 1; Carter et al., 2021).

There are natural antimicrobial components, such as lactoferrin, lactoperoxidase and lysozyme that are in abundant quantities in colostrum compared with that in mature milk. These natural antimicrobial components work to limit the bacterial growth and protect calves from sepsis. Additional components that aid in immunity include cytokines, neutrophils and macrophages. High levels of oligosaccharides, specifically sialylated oligosaccharides, are also found in colostrum; these prohibit the binding of *E. coli* and rotavirus in the GIT and reduce GIT inflammation. Also, these oligosaccharides also act as prebiotics, providing an energy source for good gut bacteria and help develop the gut microflora, specifically beneficial species such as *Bifidobacteria* and *Lactobacillus*. (Carter et al., 2021; Fischer-Tlustos et al., 2021)

Table 1. Concentration of bioactives in colostrum and mature milk and the benefit to gut immunity and development.

Colostrum Bioactive		Concentration			Benefit to the Gastrointestinal Tract
		Unit	Colostrum	Mature Milk	
Immunoglobulin G		g/L	81	< 2	Primary immunity contributor through pathogen binding in intestinal mucosal membrane and passive immunity when absorbed into the circulatory system
Lactoferrin		g/L	1.84	0.1	Sepsis prevention in infants. Binds to iron, preventing excess growth of bacteria, such as *E. coli* and *salmonella.*
Lactoperoxidase		g/L	0.011-0.045	0.013-0.030	Inhibitory effects on bacterial metabolism through suppression of oxidation in proteins.
Lysozyme		µg/L	140-700	70-600	Cell lysis caused by hydrolysis of β linkages in the cell wall of Gram-positive and Gram-negative bacteria.
Insulin		µg/L	65	1	Promotes cell growth in the small intestine.
Insulin-like growth factor-I		µg/L	310	< 2	Stimulates intestinal cell growth and epithelial development.
Insulin-like growth factor-II		µg/L	150	1	Stimulates intestinal cell growth and epithelial development.
Oligosaccharides		g/L	1	< 0.2	Reduces gut permeability and promotes gut microflora development.
Fatty Acids		g/L	64	39	Improves thermoregulation capabilities. High levels of PUFA decreases oxidative stress by reducing the oxidants and reactive oxygen and nitrogen species.
Cytokines	IL-1 β	µg/L	845	3	Anti-inflammatory capabilities through the neutralization of pro-inflammatory molecules. Specifically, INF- γ amplifies the capacity of phagocytic cells.
	IL-6		75	< 0.2	
	TNF-α		925	3	
	INF-γ		260	0.2	

From an energy and metabolism standpoint, colostrum contains bioactives such as insulin, insulin-like growth factor-I (IGF-I) and insulin-like growth factor-II (IGF-II) that help with glucose absorption, growth, and development of the GIT. Colostral fat is another very important component; colostrum has a high level of fat compared with that in mature milk, and the specific fatty acid (FA) profile of colostral fat may play a role in thermoregulation. Newborn calves are born with brown adipose tissue (BAT) as their predominant fat reserve; however, the quantity is small, with only about 2% of their body weight (BW) being BAT (Silva and Bittar, 2019). The BAT is a critical component in thermoregulation in newborns, but with the small

amounts in calves at birth, calves have a very limited ability to thermoregulate. Colostral fat is thought to act as a substrate for calves to use their BAT to thermoregulate and help warm them up or cool them down in events of cold or heat-stress (Silva and Bittar, 2019). Additionally, colostral fat plays roles in metabolism and can help with immune response in the first few weeks of life (Fischer-Tlustos et al., 2021). Colostral fat clearly plays very important roles in the newborn calf, further stressing the importance of ensuring proper colostrum feeding to optimize performance and survival. Research is beginning to investigate aspects of the FA profile of colostrum and how specific FA impact the calf, such as how supplementing omega-3 fatty acids may help reduce inflammation (Opgenorth et al., 2020). However, more work is required to understand if the entire FA profile of colostral fat is required for the immune response and thermoregulation processes, or if supplementing with a similar FA profile would be sufficient. Recently, a trial investigated the impact on calf performance when calves were fed either a biological (full fat) level of colostral fat (22% fat) or a low level of colostral fat (5.7%). The researchers concluded calves fed the full fat colostrum had increased BW and growth rates at 90- and 127-day measurements and tended to have half the level of respiratory issues compared with calves fed the low fat colostrum (M. Nagorske, personal communication). This is an important area to understand further, because some colostrum replacers lack or have low quantities of colostral fat, which may negatively impact biological processes and calf health. Overall, the bioactives in colostrum all have some role in the development, metabolism, or immune system of a calf. It is important to understand the power of colostrum and the impact it has on short and long-term development and performance, as proper feeding of colostrum is not solely about acquiring successful TPI.

Factors of Day One Colostrum Management

There are four factors to a colostrum management program that are important in helping avoid FTPI in calves. These factors are quickness, quantity, quality, and cleanliness, and all have recommendations that should be met. The recommendations for these factors are not arbitrary and are also not independent, as they all intertwine and if one is severely lacking, surpassing the recommendation in another still may not prevent FTPI. These ‘gold standard’ recommendations for colostrum programs are based on calves achieving successful TPI. Historically the cut-off for TPI was defined as serum levels of IgG ≥ 10 g/L, which was estimated to be achieved through providing calves 150 to 200 g of IgG early in life. However, from recent knowledge of improved morbidity levels from achieving a greater level of passive immunity, which will be discussed later in this paper, this IgG minimum has doubled. The goal is to achieve excellent TPI (≥ 25 g/L of serum IgG; see category descriptions later in the paper) to reduce the level of disease; this means calves should be fed a minimum of 300 g of IgG within the first two hours of life, or 400 g of IgG in the first 24 hours of life (Lombard et al., 2020). With high morbidity levels threatening the health and welfare of calves, farm economics and public perception of the dairy industry, it is crucial we shift away from avoiding FTPI and shift towards maximizing the percentage of calves that can obtain this excellent TPI level to help reduce morbidity levels. This movement of the goalpost for passive transfer can seem drastic when you look at doubling the recommended grams of IgG fed but can be met if all factors of colostrum management are refined and optimized.

Quality

One of the main factors that impacts the grams of IgG fed to calves is the quality of colostrum. Typically, quality of colostrum is referred to as grams of IgG per litre, and good quality has been defined as > 50 g/L of IgG (Godden et al., 2019). An easy on-farm measurement of quality is measuring the Brix percentage of colostrum using either an optical or digital refractometer. Brix and IgG concentration measured through the gold standard radial immunodiffusion (RID) analysis correlate well together (r = 0.75), making Brix % a good on-farm management tool. Typically, 50 g/L of IgG correlates to 21-22% Brix (Bielmann et al., 2010; Quigley et al., 2013), and is the minimum recommended cut-off. However, this cut-off was developed when avoiding FTPI was the goal, rather than the new goal of achieving excellent TPI. This raises the question of potentially increasing this minimum Brix % to ensure calves are getting a larger IgG dose via colostrum. Recent work conducted in Quebec supports the concept of increasing the Brix cut-off; calves that were fed colostrum that was ≥ 24.5% Brix were 2.9 times more likely to have successful TPI (Morin et al., 2021). Previous cut-offs for quality colostrum around 22% Brix were established by comparing Brix with IgG

concentration determined by RID to achieve 50 g/L, rather than levels to avoid FTPI. Therefore, it is probable that the Brix cut off should be 24-25 % to avoid FTPI, rather than 22%, which also aligns with the increase in IgG required for excellent TPI. Additionally, feeding a higher level of Brix % colostrum is more critical when one of the other factors is lacking, such as a lower quantity fed or extended time to feeding. Many factors can influence colostrum quality, such as parity, breed, dry cow diets, dry period length, vaccination protocols and seasons (see Godden et al., 2019 review). Therefore, it is important that all colostrum be measured for quality using a refractometer before feeding every calf. An option when quality is lacking is to supplement or enrich the low-quality colostrum with a colostrum replacer to allow the use of low-quality colostrum while maintaining similar TPI levels (Williams et al., 2014; Lopez et al., 2020). Additionally, assessing thickness and color of colostrum is not an accurate way of determining quality, and for a small investment, measuring colostrum quality using a refractometer can help calves achieve excellent TPI levels and provide peace of mind to producers.

Quantity

The other main factor that impacts TPI in calves through directly impacting the amount of IgG fed is quantity of colostrum fed. The recommendation is to feed 10-12% of the calf's BW in colostrum for the first feeding, which equates to 3 – 4 L for a Holstein calf and 2 – 3 L for a Jersey calf. This provides calves high levels of IgG when their efficiency of absorption is maximized early in life. Providing large volumes of colostrum at the first feeding can increase serum IgG levels, average daily gain (ADG), and milk production in the first two lactations (Godden et al., 2019). Although this one high volume feeding typically prevents FTPI if quality is sufficient, calves benefit from a second feeding to increase IgG levels (Fischer-Tlustos et al., 2021), specifically a second feeding in the first 12 hours of life (Hare et al., 2020). This is likely due to an increased IgG mass fed through two feedings while the gut is still permeable to IgG, suggesting a minimum of two feedings of colostrum should be completed within 12 hours.

Quickness

There are two aspects to timing when it comes to colostrum management: timing of milking and timing of feeding. The timing of milking in relationship to calving is important to maximize the bioactive amounts in colostrum. As time progresses, colostrum quality (g/L of IgG) decreases; cows milked at two hours after calving have the highest colostrum quality compared with cows milked at 6, 10 or 14 hours after calving (Moore et al., 2005). Additionally, as time progresses bioactive concentrations decrease, likely due to dilution of colostrum with mature milk (Carter et al., 2021), stressing the importance of adapting milk procedures to incorporate cows soon after parturition. The other part of timing is how quickly the calf is fed. This is related to gut closure of the newborn calf. The calf's gut is permeable to large molecules like IgG when the calf is born; this is referred to as an 'open gut'. As time progresses the gut closes and its ability to absorb IgG decreases rapidly and is estimated to be fully closed at 24 hours of life. The maximum apparent efficiency of absorption (AEA) occurs immediately following birth. The AEA can be calculated based on serum IgG levels, calf BW and the quality (g/L of IgG) and volume of colostrum fed. In general, AEA is a way of assessing how well the calf absorbed the quantity of IgG fed. The AEA varies between calves, with 69% of calves falling between 21 and 40% AEA, but AEA will range between 7.7% to 59.9% (Halleran et al., 2017). Fischer et al. (2018) indicated a large drop in AEA between feeding colostrum within the first hour of life (51.8%) compared with six hours (35.6%) and 12 hours (35.1%). This not only indicates the importance of quickness in feeding but indicates that maximum absorption occurs at birth and the decrease in AEA may not be as linear as once thought, considering no AEA difference was detected between 6 and 12 hours. With the large AEA drop between the first hour of life and six hours, the first feeding of colostrum should be < 2hours after birth of the calf. Additionally, earlier colostrum feeding results in quicker colonization of beneficial gut bacteria such as Bifidobacterium spp. and Lactobacillus spp., which can aid in gut health (Fischer et al., 2018).

A management practice that can help with the timing of feeding is the use of an esophageal tube feeder. Historically, it was thought that tubing calves their colostrum resulted in reduced IgG absorption. Although there is some evidence of this, the volume that is being fed via esophageal tube must be considered because this colostrum will enter the forestomaches before it enters the abomasum and small intestine where it will then be absorbed. One study investigated IgG absorption differences when bottle or tube

feeding colostrum and concluded that if the volume is sufficient (≥ 3 L), the IgG levels of the calves were similar (Desjardins-Morrissette et al., 2018). Because tube feeding allows colostrum to be administered quickly, it is a sufficient method of colostrum administration if done properly with clean equipment.

Cleanliness

Bacterial contamination of colostrum dramatically reduces colostrum quality and absorption because the bacteria may bind to the IgG in the gut and may also block the absorption of IgG across the intestine, reducing passive immunity. Additionally, the bacteria can be absorbed into the circulatory system, leading to disease. The recommendations for bacteria levels are < 100,000 colony-forming units (cfu)/mL total plate count and less than 10,000 cfu/mL total coliform count (Godden et al., 2019); however, these are quite high recommendations, and it is best to aim for lower bacteria levels. Many colostrum samples will exceed these levels of bacterial contamination, ultimately reducing IgG absorption and potentially making calves sick if fed. Contamination can occur during colostrum harvesting, storage and feeding. It is important that good milking procedures are followed, with all collection, storing and feeding equipment properly cleaned and sanitized, as these are common sources of bacterial contamination. If storing colostrum for a later date, cool the colostrum down as quickly as possible (within the hour), and place it in the refrigerator for a maximum of two days or freeze it immediately. Bacteria multiply extremely quickly in warm temperatures, meaning the bacteria level will double in freshly milked colostrum in only 20 minutes, so the colostrum needs to be fed or cooled and stored immediately after collection. Additionally, when thawing or heating colostrum, you need to ensure that it is not rushed, and overheating is avoided. If colostrum exceeds 60ºC, denaturation of IgG can occur; therefore, the water bath to thaw or heat colostrum should be below this temperature and should be changed frequently to maintain its temperature. Another thing to consider for cleanliness is the presence of pathogens that are of concern in the herd, such as *E. coli, Salmonella sp.,* and *mycobacterium avium paratuberculosis* (MAP- causative agent of Johne's disease). If you have diseases of concern in your herd or specific cows that you know are positive for a disease of concern, consider discarding their colostrum, using a colostrum replacer, or investing in a pasteurizer.

Pasteurizing colostrum is becoming more popular on farm, and if feeding raw maternal colostrum, investing in a pasteurizer should be considered. Pasteurizing colostrum should be completed at 60ºC for 60 minutes to reduce bacterial contamination and inactivate disease-causing pathogens while minimizing denaturing of IgG. Feeding pasteurized colostrum can increase AEA likely due to lower levels of bacteria interfering with the IgG in the gut, reduce the risk of diarrhea, and promote GIT colonization of beneficial gut bacteria compared with feeding raw maternal colostrum (Godden et al., 2019). However, pasteurizers need to be managed well and calibrated frequently. If the quality of colostrum is poor before pasteurization, it will still be poor after. Pasteurization will not make gold out of garbage and the colostrum still needs to be tested for quality and bacteria level still needs to be considered. Also, if temperature is high, denaturation of IgG can be severe (up to 58.5 % in large batches; Godden et al., 2003). The effect of heat treatment on the other bioactives in colostrum is an area that needs more research. The temperature should be monitored frequently when pasteurizers are at the maximum temperature. Samples of batches of colostrum can be taken before and after pasteurization and monitored for IgG concentration to determine if the pasteurizer is running too hot and denaturing IgG. Although Brix % of colostrum is a good way to measure colostrum quality on-farm, measuring it before and after pasteurization will not indicate if the IgG are being denatured. Brix is a measure of total solids and not a direct measure of active IgG; therefore, if IgG denaturation is a concern, submitting pre- and post- pasteurization samples for IgG analysis through RID is recommended. Overall, pasteurizers are not a solution to poor management of colostrum and should be optimized to help programs when feeding maternal colostrum.

▪ Calves at Increased Risk for FTPI

Although the above recommendations for the quality, quantity, quickness, and cleanliness will likely result in TPI for most calves, there are still calving situations that create calves that are high risk for FTPI. Calves that experience stress, whether in utero, during birth or shortly after parturition, are susceptible to reduced AEA. Undergoing a long and difficult birth commonly results in postnatal respiratory acidosis in calves and is associated with a decrease in IgG absorption for the first 12 hours of life (Godden et al., 2019). Calves

born under cold-stress conditions or after having a hard calving tend to have reduced vitality and will likely consume lower amounts of colostrum; therefore. they may require manually feeding (Murray and Leslie, 2013). Additionally, when born in heat or cold-stress situations, calves need to have colostrum administered immediately to allow thermoregulation to occur. Calves that are born from a dam that experienced heat-stress in her final trimester have an in-utero programming effect occur that reduces their ability to absorb IgG, while also reducing the dam's IgG concentration in colostrum (Dado-Senn et al., 2020). These calves will also go on to produce less milk in the first two lactations; therefore, it is critical they also do not experience FTPI (Dado-Senn et al., 2020). Additionally, as hours pass before colostrum feeding, calves are at an increased risk of FTPI. Therefore, calves that have extended time to feeding or are born overnight and found the next morning require high volumes of very high quality of colostrum to help overcome the decrease in AEA that occurs as time progresses. Calves that are at a higher risk of FTPI should have a separate colostrum protocol in place that provides them with higher quantities of IgG since their absorption capacity may be compromised. Feed these calves with very high-quality maternal colostrum (25-30% Brix) in large volumes or with a colostrum-derived replacer to eliminate bacterial contamination and ensure calves are fed quickly.

▪ Updated Recommendations for Monitoring Colostrum Programs

Ensuring the factors of colostrum management are followed will help reduce the incidence of FTPI and increase the TPI levels in calves. When calves experience FTPI, they have reduced growth and feed efficiency, are more susceptible to disease and death, and have reduced lactation performance and increased culling risk (Godden et al., 2019). Historically, the threshold for FTPI was developed around reducing mortality rates and was found to be < 10 g/L of serum IgG when measured between 24 and 48 hours. However, recently calf experts came together to investigate a four-category system to classify TPI levels, presented in Table 2.

Table 2. Updated recommendations for passive immunity levels when measured between 24 and 48 hours of life

Category	% of calves in each category	Serum IgG (g/L)	STP (g/dL)	% Brix of Serum
Poor (FTPI)	**< 10**	**< 10**	**<5.1**	**< 8.1**
Fair	**~20**	**10 – 17.9**	**5.1 – 5.7**	**8.1 – 8.8**
Good	**~30**	**18 – 24.9**	**5.8 – 6.1**	**8.9 – 9.3**
Excellent	**> 40**	**≥ 25**	**≥ 6.2**	**≥ 9.4**

These updated recommendations were developed to be achievable and to reduce morbidity and mortality rates. Calves in the excellent category had the lowest percent of morbidity compared with all other categories, suggesting that having a dichotomous pass versus fail monitoring system should be changed to reduce the disease calves experience (Lombard, 2020). As indicated in Table 2, there are a few ways of measuring TPI in calves through sampling their serum. Serum total protein (STP) and serum Brix are indirect, easy on-farm measurements when feeding maternal colostrum that offer producers, consultants and veterinarians ways of monitoring colostrum programs. However, when feeding colostrum replacer, STP and serum Brix are unreliable measurements and IgG concentration must be assessed directly through RID analysis conducted in a laboratory setting. As seen in Figure 1 (Lopez et al., 2021), STP and IgG levels in serum of calves fed colostrum replacers are not well correlated, likely due to different manufacturing and nutritional compositions of the different products.

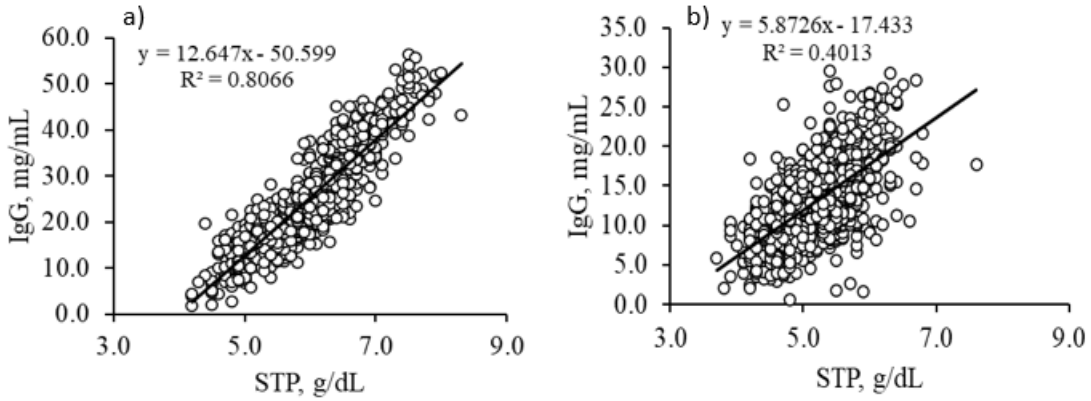

Figure 1. Linear regression relationship between serum total protein (STP) and serum IgG for 927 calves fed maternal colostrum (panel a) or 1,258 calves fed colostrum replacer (panel b).

If any type or amount of colostrum replacer is fed in the first day of life, blood samples should be sent to a lab for RID testing as this is an accurate way of determining IgG for these calves and is the gold standard of IgG analysis. Additionally, STP and serum Brix % should only be used on a population basis, measuring a group of calves rather than an individual only. Although RID and STP results are ~80% correlated, there is still room for error, meaning indirect measurement of IgG through STP or serum Brix % can misclassify calves Therefore, if STP results and calf health and performance are not aligning, samples should be submitted for RID analysis to ensure colostrum is not an issue. Recently, Cantor et al. (2022) investigated the impact of sampling time and classification level of TPI for calves during the first seven days of life. They concluded that IgG TPI level should only be measured between 24 hours to three days after colostrum feeding to avoid misclassification of TPI level due to the rapid degradation of IgG in the blood. Also, as TPI level recommendations are based on sampling blood at 24 to 48 hours, caution should be used when sampling after two days of life, as STP and IgG correlation can be variable and decrease over time, and dehydration levels impact STP values.

Prolonged Colostrum or Transition Milk Feeding

It is clear colostrum feeding is important for health and performance of young calves. However, as previously mentioned, calves continue to face high levels of morbidity and mortality during the preweaning phase. Digestive issues (i.e., diarrhea) and respiratory issues (i.e., pneumonia) are the two main causes of disease in young calves accounting for 56% and 33%, respectively (Urie et al., 2018). Diarrhea and pneumonia both have negative impacts on short-term welfare and performance and long-term production and economics. When calves experience diarrhea, they are more susceptible to other diseases, experience reduced ADG, and may experience death as a result. Long-term, calves that experience diarrhea have an increased number of inseminations to achieve pregnancy and can have over a 300 kg reduction in their first lactation milk yield (Carter et al., 2021). Additionally, when calves experience a respiratory event, they also have reduced ADG and increased risk of being culled before calving and may have reduced production in the first lactation (Buczinski et al., 2021). It is evident that disease plays a huge role in economics and efficiencies on a dairy; therefore, opportunities to help reduce disease events, severity, and duration, and improve growth during the preweaning phase are needed to improve welfare and sustainability of the dairy industry.

Beyond the economics and welfare aspect, the use of antimicrobials is a growing industry and societal concern. Antimicrobials are often reached for in events of diarrhea, although they can upset the gut microbiota early in life and can kill off both pathogenic and beneficial bacteria, causing a GIT dysfunction (Carter et al., 2021). In some rearing situations, antimicrobials are provided to all calves prophylactically, which is an even greater concern. With the disease and death pressures calves face, and the need to reduce antimicrobial use, natural prevention and therapeutic options are necessary.

Benefits of extended feeding of transition milk or colostrum

Over the past decade, interest in the composition of colostrum and transition milk (milkings 2 to 6 after calving; typically, 1 to 4 days post-partum) and how feeding it can impact the calf has increased. Transition milk contains high levels of bioactive compounds compared with that in mature milk and is likely to have a beneficial impact on the calf's gut development and health, as calves would naturally consume this if raised alongside their dam. Feeding transition milk after initial colostrum feedings can lower the odds of being scored with an abnormal eye or ear and nasal score (Conneely et al., 2014), and can reduce the duration of diarrhea (Kargar et al., 2021), compared with feeding whole milk directly after colostrum. Additionally, feeding 2 L of pasteurized transition milk that is mixed with 4 L of whole milk per day for the first three weeks of life can improve BW in the preweaning phase and ADG in the postweaning phase (Kargar et al., 2021). These results indicate that additional transition milk feedings after colostrum can provide short-term health and performance benefits and a prolonged advantage in growth.

Although transition milk is advantageous to feed, it can often be a difficult thing to collect, store and implement into a feeding program compared with first milking colostrum. An alternative to feeding transition milk is feeding small amounts of maternal colostrum mixed with milk or milk replacer to mimic this transition milk. Some researchers mimic transition milk by feeding 50% of a meal in milk or milk replacer, and 50% of the meal with maternal colostrum (Pyo et al., 2020; Van Soest et al., 2020). Others have investigated a smaller dose for the first two weeks of life (Kargar et al., 2020b). Additionally, feeding a 50:50 mixture of colostrum and milk for the first three days of life improved ability of the calf to absorb nutrients by increasing villi length and surface area of the small intestine (Pyo et al., 2020). Additionally, feeding a 50:50 mixture of transition milk and milk replacer from day 2 – 4 of life improved growth and reduced signs of inflammation in calves (Van Soest et al., 2020). Producers may have a difficult time identifying these positive outcomes of feeding transition milk for a few extra days of life because many benefits are occurring within the development of the digestive system. Nevertheless, if feeding transition milk can be managed well, it may make for more efficient and healthier calves,

Although there are clear benefits to calf gut development when feeding transition milk or mimicking transition milk with maternal colostrum for a few days of life, the properties of colostrum bioactives may provide benefits over a longer period. Kargar et al. (2020b) showed that feeding pasteurized maternal colostrum (700 g/d) for the first two weeks of life resulted in reduced days with diarrhea, pneumonia, and high temperatures, and improved postweaning ADG and final BW. An alternative to using maternal colostrum is supplementing in a dried colostrum-derived replacer to avoid opportunities for error in managing raw transition milk or colostrum and ensure consistency in components day to day. Mimicking transition milk with colostrum replacer has been shown to reap the same benefits of improved growth and reduced inflammation compared with feeding transition milk (Van Soest et al., 2020). Offering calves 70 g/d of a colostrum-derived replacer (10 g of IgG) for 14 days improved feed intakes and growth and reduced diarrhea events and treatments (Berge et al., 2009). More recently, Chamorro et al. (2017), concluded that feeding 150 g (32 g of IgG) of colostrum replacer for 14 days can reduce abnormal fecal, respiratory, attitude and navel scores while reducing antibiotic use. Overall, there are gut development, health, and economic benefits to feeding transition milk or colostrum after the first day of life. However, research to date has primarily focused on calves fed lower planes of nutrition (~4-6 L/d) and understanding how these extended colostrum feeding programs can impact calves fed higher planes of nutrition is an area of interest as more producers shift towards this practice due to the benefits in health and production.

Opportunities for Colostrum as a Therapeutic

As indicated, the use of colostrum or colostrum replacer as a prophylactic treatment for the first 14 days of life seems promising to help reduce health issues and promote growth while reducing antimicrobial use. The use of hyperimmune colostrum, created by exposing dams to specific pathogens to ensure high levels of antibodies for that pathogen in her colostrum, has been used in the past for diarrhea treatment in humans, mice, and calves (Carter et al., 2021). Although a viable option, economically and from a welfare standpoint it is not likely sustainable or overly efficacious, as calf diarrhea is multifactorial, and calves are often faced with more than one pathogen. Cantor et al. (2021) used drinking behavior (reduction in drinking speed or intake) from day 14 to 50 to identify calves that may be experiencing a health event. These calves were

then fed a meal of 125 g of milk replacer or 125 g of colostrum replacer for three days. The authors concluded that calves fed the colostrum replacer meal had reduced odds of getting bovine respiratory disease and lung consolidation in the following weeks. Recently, Carter et al. (2022) investigated the efficacy of colostrum as a diarrhea treatment for calves and concluded feeding a 50:50 mixture of milk replacer and colostrum replacer for four days or eight milk feedings helped calves get over diarrhea more quickly and improved their growth rates, compared to keeping diarrhetic calves on milk replacer. These are promising results that indicate colostrum may be a good option as a therapeutic when there are early disease symptoms however, further work is needed to identify dosing, timing, and duration of these treatments to get optimal results.

Summary

When thinking about colostrum, we need to continue to shift away from solely focusing on IgG. Further exploration of the different bioactives in colostrum and the role they play in the calf is required. Focusing on ensuring day one colostrum management is done properly, with all calves consuming adequate volumes of quality colostrum in the first few hours of life is the most important area of calf management to promote health and performance both short and long-term. However, the focus on colostrum feeding shouldn't end after two feedings on day one, and some level of transition milk or colostrum should be fed for an extended period. There are promising results and interest in using colostrum to treat health events, specifically diarrhea, which would be beneficial to the calf, producer, and sustainability of the industry. Although colostrum is the most important step in calf care, and extended feeding of colostrum can help calves overcome disease challenges and optimize their growth and GIT development, milk and solid feed nutrition, housing conditions and management of calves all play a role in calf performance. Setting calves up for success through good colostrum management is the first step, but certainly not the last, and guaranteeing adequate nutrition and management are provided thereafter will ensure the calves are thriving, and ultimately will generate better milk cows for the future herd.

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