New Concepts in Calf Nutrition: The First Week of Life

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Take Home Messages

- The high rates of calf morbidity and mortality during the first weeks of life are largely due to digestive disorders and diseases; therefore, implementing a sound colostrum and milk feeding program is critical.
- Early (< 2 hours after birth) feeding of colostrum via nipple bottle or esophageal tube feeder is recommended; IgG absorption will not be compromised if a large volume of colostrum (~3 L) is tube-fed.
- Feeding colostrum earlier in life not only increases blood concentrations of IgG but may also have a positive effect on beneficial gut bacterial populations compared with feeding colostrum later than 6 hours after birth.
- Colostrum contains more than just IgG: it also contains high concentrations of prebiotic oligosaccharides, fatty acids, insulin, and antimicrobial compounds.
- Transition milk contains elevated levels of beneficial compounds and feeding transition milk can lead to improved intestinal development.
- The majority of farms only feed up to 4 L of milk per day during the first week of life, resulting in compromised body weight gain (up to an extra 400 g/d) compared with calves fed 8 to 10 L of milk per day.
- Calves can be fed up to 4 L of milk per meal two times per day without compromising insulin sensitivity provided that feeding large volumes of milk starts during the first week of life.
- Milk replacer is high in lactose and low in fat compared with whole milk. Research is needed to evaluate how this may affect gut health and development when large volumes of milk replacer are fed.

Introduction

Preweaned calves suffer from the highest rates of mortality (5 to 6.4%) and morbidity (34%) during the first two months of life (Urie et al., 2018; Winder et al., 2018). Specifically, digestive disorders are the most common reported cause of morbidity and mortality, accounting for 48% of sick calves and 32% of deaths, with most cases occurring before 2 weeks of age (Urie et al., 2018). This has severe consequences for the Canadian dairy industry because these disorders not only cause concern from an animal health and welfare standpoint but can also be costly to producers. Digestive disorders can often be prevented and mitigated through well-developed nutritional and health management programs. Although preweaned calf management has improved over the past decades, mortality and morbidity incidence has only decreased by 4.5% and 2.8%, respectively, since 2007 (NAHMS), demonstrating that we still have much to learn as to how early life nutrition can mitigate the incidence of preweaning sickness and death. Therefore, this paper will focus on how calf gut health is influenced by colostrum, transition milk, and whole milk or milk replacer (MR) feeding during the first week of life.

▪ The First Days of Life

Colostrum and Passive Transfer

The structure of the bovine placenta prohibits passive transfer of IgG from the dam to the calf *in utero*. Consequently, the neonatal calf is born without a fully developed immune system and, thus, relies on immunoglobulin-rich colostrum to establish immunity. To ensure passive transfer, it is important to feed newborn calves an adequate volume of colostrum (~3 to 4 L) containing more than 50 g of IgG/L and a total bacterial count less than 100,000 cfu/mL (McGuirk and Collins, 2004). Timing of colostrum feeding is also critical because the absorption of IgG decreases linearly as the calf ages, with calves fed later than 12 hours after birth being at high risk for illness and death (Stott et al., 1979). Although these four 'golden rules' of colostrum feeding are well-known and practiced by approximately 67% of Canadian dairy producers (Winder et al., 2018), failure of passive transfer (FPT, serum IgG < 10 g/L) still occurs on 6.4 to 12.1% of farms (Shivley et al., 2018; Winder et al., 2018). High rates of FPT are associated with increased calf morbidity and mortality, costing up to C$87 per calf (Raboisson et al., 2016). Moreover, feeding inadequate amounts of colostrum to a calf results in reduced milk production during her first and second lactations (DeNise et al., 1989; Faber et al., 2005). Multiple factors are associated with FPT, including relying on the dam to provide colostrum, not assessing colostrum quality before feeding, and infrequently walking the barn during the night causing colostrum feeding to be delayed by at least 6 hours after birth (Vasseur et al., 2010).

The majority of studies examining the timely feeding of colostrum and its effect on passive transfer were conducted more than 25 years ago. To our knowledge, a study by Fischer et al. (2018a) was the first to determine how a delay in colostrum feeding using current colostrum recommendations affects passive transfer in the neonatal calf. Importantly in this study and in contrast to past research, colostrum IgG concentration and volume fed were standardized by feeding a pooled colostrum source that contained 62 g of IgG/L at 7.5% of birth body weight. It was hypothesized that delaying the colostrum meal would linearly reduce passive transfer. As expected, calves fed within 1 hour of birth had a 28% increase in the maximum blood IgG concentration (25.5 mg/mL) reached compared with calves fed at 6 hours and 12 hours (18.4 mg/mL). However, contrary to expectations, calf blood IgG concentrations did not differ between calves fed at 6 or 12 hours. These results suggest that there may be a critical time point between birth and 6 hours of life whereby the ability of the small intestine to absorb IgG diminishes to a 'point of no return'. Interestingly, calves fed colostrum at 12 hours after birth still achieved successful passive transfer in this study. This is likely because of the consumption of adequate volumes of high-quality colostrum; calves received an average of 3.2 L of colostrum or a total mass intake of 197 g of IgG. Colostrum IgG concentrations can widely vary on farm, from 7.1 to 159 mg/ml, with 16 to 22.6% of samples containing less than 50 mg/ml (Quigley et al., 2013; Shivley et al., 2018). Therefore, although all calves in this study (Fischer et al., 2018a) had adequate passive transfer, the authors do not recommend waiting until 6 hours after birth or later to feed colostrum because the on-farm variation in IgG will increase the risk for FPT and, consequently, preweaning morbidity and mortality.

In addition to the importance of the quickness, quality, quantity and cleanliness of colostrum feeding, the method by which colostrum is fed can also impact the success of passive transfer. Specifically, calves fed colostrum directly from suckling the dam, a nipple bottle, or an esophageal tube feeder had FPT rates of 61%, 19%, and 10%, respectively (Besser, 1991). Tube feeding on-farm is an appealing strategy because it takes only a matter of minutes (~1 to 5 minutes for 3 L of colostrum; Hare et al., unpublished data; Desjardins-Morrissette et al., 2018) compared with bottle feeding that can average 18 minutes per meal (Desjardins-Morrissette et al., 2018). Although tube feeding is a time efficient method, there is a concern that colostrum entering the rumen via tube feeding impedes emptying of IgG into the small intestine for absorption thereby reducing the efficiency of IgG absorption and serum IgG concentration. Decreased serum IgG concentrations have been observed when small volumes of colostrum are tube-fed; however, these studies did not assess abomasal emptying rate (the rate at which the colostrum meal empties into the intestine from the abomasum). To investigate this, Desjardins-Morrissette et al. (2018) fed 3 L of colostrum, containing acetaminophen as a marker for abomasal emptying, via esophageal tube or nipple bottle and found that abomasal emptying rates and blood IgG concentrations of newborn calves did not differ between feeding methods. The authors suggested from their results and others (Godden et al., 2009) that feeding a small volume (e.g., 1.5 L) of colostrum results in a larger proportion (approximately 26%) of the meal remaining in the rumen and decreases IgG absorption compared with feeding a large volume (e.g., 3 L) feeding, where only 13% of the meal would remain in the rumen and thus there would be negligible differences in passive transfer. Therefore, if a calf is tube-fed a sufficient volume (≥ 3 L) of good-quality colostrum, this method should result in adequate passive transfer of immunity.

Colostrum and Gut Development

While it is well known that colostrum feeding greatly influences IgG concentrations, it can also stimulate the secretion of gut hormones. Of the many hormones stimulated, glucagon-like peptide (GLP)-1 and GLP-2 are of high interest. Glucagon-like peptide-2 is known to stimulate gut development, while GLP-1 stimulates insulin release, resulting in increased uptake of glucose for energy use by peripheral tissues. Prior to the study conducted by Desjardins-Morrissette et al. (2018), no research had reported GLP-1 and GLP-2 concentrations in newborn calves. No effect on GLP-1 or GLP-2 was found by feeding colostrum via bottle or tube-feeder, indicating that both feeding methods were effective in promoting the release of gut hormones. Nutrients, such as fats and carbohydrates, stimulate secretion of GLP-1 and GLP-2 within the intestine. Therefore, feeding colostrum, which is high in fat, caused large increases in the concentrations of these hormones in the blood (Desjardin-Morrissette et al., 2018). In addition, Inabu et al. (2018) demonstrated that GLP-1 and GLP-2 concentrations were lower in calves that were not fed colostrum until 12 hours after birth compared with those in calves fed immediately after birth. These findings demonstrate that the release of beneficial gut hormones is stimulated by colostrum feeding and that delayed feeding suppresses the amount of GLP released, potentially compromising intestinal development in the neonate.

In terms of macronutrients, protein initially appears to be the predominant energy source in colostrum for the calf, but it is unlikely that the majority of protein in colostrum is fully digestible because of the presence of compounds in colostrum that inhibit protein digestion (McGrath et al., 2016). Additionally, the newborn calf gut is relatively inefficient at digesting and absorbing protein. We recently conducted a review of our lab’s data and determined that fat supersedes protein as the major energy source in colostrum, providing an estimated 63% of the approximate digestible energy supply compared with protein supplying an estimated 25%. Fat in colostrum is essential for fueling the metabolism of the newborn calf and for thermoregulation. It is also involved in hormonal signalling and inflammatory and immune responses. Furthermore, supplementing the colostrum fed to neonatal calves with fish and flax oils, which are high in omega-3 fatty acids (FA), has prolonged benefits in terms of antioxidant status and immune response (Opgenorth et al., 2019). These compounds are naturally elevated in colostrum compared with whole milk (Hare et al., 2019), highlighting that colostrum contains numerous factors apart from IgG that will promote calf health.

The newborn gut is a complex environment and hosts numerous microbial species. Gut microbiota fundamentally influence early life gut development and maturation, including the metabolism of otherwise indigestible compounds, the development of the immune system, and the overall physiology of the calf. The establishment of a healthy microbial community within the gut is also associated with overall calf health and disease outcomes, with certain fecal bacteria positively correlated with weight gain and negatively correlated with diarrhea incidence (Oikonomou et al., 2013). Feeding colostrum is critical in establishing beneficial gut microbiota populations and not feeding colostrum can result in a decreased abundance of total bacteria in the small intestine (Malmuthuge et al., 2015). For this reason, the study in which colostrum feeding was sequentially delayed after birth (Fischer et al., 2018a) also investigated the effect of this practice on gut microbial populations. Calves fed colostrum at 12 hours tended to have lower amounts of *Bifidobacteria* and *Lactobacillus,* which are well known for their beneficial role in the newborn gut microbiome, associated with the colon mucosa at 2 days of life. These results indicate that preventing the immediate establishment of beneficial early life bacteria by delaying the first colostrum feeding may have an impact on calf intestinal microbiota. Unfortunately, this study cannot answer whether or not this affects the ability of the gut to respond to future pathogenic challenges later in life and requires further research.

An abundance of bioactive molecules is present in colostrum, but these molecules have taken a backseat to the widely discussed IgG. One the key families of bioactive compounds are oligosaccharides (OS), which are considered to be one of the major prebiotic compounds in colostrum that aid in establishing beneficial gut microbiota after birth. Oligosaccharides are small polymers of indigestible simple sugars composed of a lactose core. In bovine colostrum and milk more than 70% of OS contain sialic acid, a nine-carbon sugar with an acidic charge. This is in contrast to humans, where 50 to 70% of OS in colostrum and milk contain fucose, a neutral six-carbon sugar, and only 5 to 15% contain sialic acid. To date, over 50 bovine OS have been detected, with 3'siayllactose (3'SL) being the most abundant OS and present in colostrum at concentrations 15 times greater than in whole milk (Fischer-Tlustos et al., 2020). Recently, Fischer et al. (2018b) demonstrated that bovine heat-treated (HT; 60^{o}C for 60 minutes) colostrum had higher concentrations of free OS compared with fresh colostrum, likely due to their cleavage from glycoconjugate structures during the HT process. Subsequently, when calves were fed HT colostrum, they had a higher prevalence of *Bifidobacteria* in the small intestine at 6 hours of life compared with calves fed fresh colostrum (Malmuthuge et al., 2015). The correlation between high concentrations of free OS in HT colostrum and *Bifidobacteria* in the calf gut suggests that OS may be a key compound in mediating the early establishment of beneficial bacteria. Bovine OS have also been shown to inhibit common pathogens implicated in calf diarrhea and positively influence the immune system. Furthermore, the sialic acid portion of bovine OS may enhance the uptake of IgG by the intestine (Gill et al., 1999). This finding may explain the high abundance of sialylated OS in bovine colostrum because the uptake of IgG is one of the most important factors in promoting the health and survival of the neonatal calf. Due to the high rate of digestive disorders in dairy calves and societal pressure to reduce antibiotic use in the agricultural industry, the potential benefits of these naturally produced compounds on calf health warrant further research. However, studies at the calf level are lacking and future research should explore the specific mechanisms by which OS exert beneficial effects on the newborn calf gut.

In addition to the aforementioned bioactive molecules, colostrum contains high levels of growth factors, hormones, cytokines, enzymes, nucleotides, and antimicrobial components (Blum and Hammon, 2000; McGrath et al., 2016). These components enhance the calf's ability to fight infection, as well as promote growth and gut development. For example, Blum and Hammon (2000) reported that insulin concentrations in colostrum are 65 times greater than in whole milk. Insulin has positive effects on the development of the neonatal gut, including promoting gastrointestinal cell proliferation and increasing intestinal mass and enzyme activity. Similar to insulin, insulin-like growth factor 1 (IGF-1) in colostrum can also stimulate intestinal cell proliferation, while antimicrobial compounds, such as lactoferrin and lactoperoxidase, help to maintain a healthy gut environment. Therefore, although the multitude of potentially beneficial compounds in colostrum have been overlooked during the past few decades, it is clear that colostrum has a much larger role in calf development than simply providing IgG.

Transition Milk

Many of the aforementioned bioactive compounds are not only elevated in colostrum but are also present at higher concentrations in transition milk (TM; defined as milkings 2 to 5) than in whole milk (Table 1). For instance, the major bovine OS, namely 3'SL, 6'sialyllactose (6'SL), and 6'sialyllactosamine (6'SLN) are higher in TM than in whole milk (Fischer-Tlustos et al., 2020). Furthermore, TM has elevated proportions of omega-3 and omega-6 FA (Hare et al., 2019), nucleotides (Gill et al., 2011), IGF-1, and insulin compared with whole milk (Blum and Hammon, 2000). Unfortunately, after feeding colostrum many producers transition calves directly onto whole milk or MR, which is a stark contrast to calves naturally consuming TM from the dam. Due to this common practice, most dairy calves miss out on the potential benefits of TM. Research has demonstrated that calves fed TM after the initial colostrum feeding have lower odds of being assigned a poor eye/ear score (Conneely et al., 2014). Similarly, calves that consume a 1:1 colostrum:whole milk mixture (to simulate TM) after the initial colostrum feeding may have increased production of GLP-1 (Inabu et al., 2019) that, as previously discussed, can have beneficial effects on energy use. Furthermore, a study by Pyo et al. (2020), in which the same simulated TM was used, determined that calves fed colostrum or the 1:1 colostrum:whole milk mixture for 3 days after birth had increased small intestinal surface area and cell proliferation in certain intestinal segments compared with calves consuming only whole milk, suggesting that TM feeding promotes intestinal development. Importantly, the simulated TM promoted intestinal development to the same degree as providing solely colostrum for 3 days, despite the nutrient and bioactive compound concentrations being lesser. Therefore, feeding fresh or frozen TM to calves is a possible strategy producers can implement to promote gut development. An additional solution is to feed a mixture of colostrum and whole milk, or even whole milk mixed with a colostrum replacer product, to achieve this goal. Unfortunately, research regarding the feeding of TM to calves is lacking and future studies should investigate the roles of potential bioactive compounds in TM that may assist in proper gut development.

Table 1. Levels of bioactive molecules in colostrum (milking 1), transition milk (milkings 2 to 5) and whole milk (milking 12)[1].

	Milking					
Bioactive compound[2]	1	2	3	4	5	12
IgG, g/L	94.1	39.3	13.9	6.1	3.4	1.2
Fat content, g/milking	371.2	335.4	376.2	441.8	511.6	523.4
Omega-6 FA, %	4.2	3.1	3.5	3.1	3.0	2.7
Omega-3 FA, %	0.63	0.43	0.48	0.40	0.38	0.35
Omega 6:3 ratio	7.1	7.4	7.6	7.9	8.2	7.8
3'SL, μg/mL	592.4	304.9	171.2	99.3	67.0	41.2
Total SA-OS, μg/mL	1065.2	569.3	317.2	186.0	134.5	76.0
Nucleotides, μmol/dL	258.7	86.4	174.4	-	133.8	15.6

[1]IgG, fat content, 3'SL, and total SA-OS concentrations are reported in Fischer-Tlustos et al. (2020); Omega-3 and -6 concentrations and the omega 6:3 ratio are reported in Hare et al. (2019); nucleotide concentrations are reported in Gill et al. (2011).
[2]FA = fatty acids; 3'SL = 3'sialyllactose; SA-OS = sialylated oligosaccharides.

The First Week of Life

Milk Feeding

After consuming colostrum and TM for the first 1 to 3 days of life, calves begin consuming whole milk or MR. Typically, calves are either fed large (≥ 8 L, 67% of Canadian producers) or small (≤ 6 L, 33% of Canadian producers) volumes of milk (Winder et al., 2018). Conventional feeding programs aim to encourage early starter intake by limiting milk consumption to 10% of body weight (BW), which is roughly 4 to 6 L of milk/day or 600 to 750 g of MR powder/day. By decreasing milk intake, early starter intake is promoted and rumen development is enhanced (Khan et al., 2016). In turn, calves are thought to be less susceptible to health and production challenges during weaning. However, research has shown that calves suffer from hunger when milk is restricted, demonstrating compromised animal welfare. In contrast, feeding an elevated plane of milk nutrition (20% of BW; ≥ 8 L of milk or 1.2 kg of MR powder per day) improves animal welfare because starvation-associated behaviours are reduced. Recent studies show positive outcomes from feeding larger volumes of milk, including increased BW gain, the potential to produce more milk during lactation, improved mammary development, and reduced age at first calving (Vasseur et al., 2010; Soberon et al., 2012). Yet, producers still limit calves to only 10% of BW (4 to 6 L) per day during the first week of life and gradually transition calves to higher amounts of milk (8 to 10 L) throughout weeks 2 and 3 of life. A Quebec survey (Vasseur et al., 2010) showed that the majority of farms feed only 4 L of milk per day during the first week after birth. At this time, starter intake is negligible and all metabolizable nutrients are consumed directly from milk. Maintenance requirements alone equal ~3 L of milk per day; therefore, feeding only 4 L largely restricts energy for growth. This is typically why we see depressed weight gain (e.g., only up to 400 g/day) when calves are limit-fed milk at 10% BW. Haisan et al. (2019) showed that all calves (n = 26) offered large volumes of milk were able to consume over 8 L/day and up to 10 L/day using an automated calf rail during the first week of life, resulting in an average daily gain (ADG) up to 800 g/day, whereas calves limit-fed 5 L/day only gained up to 400 g/day during this period. While feeding up to 10 L/day of milk during the first week may seem daunting to producers because of the perceived economic inefficiency, it is a feasible strategy to incorporate an elevated plane of nutrition and can be considered as an investment in the replacement herd's future productivity.

One of the major concerns centred around feeding larger volumes of milk is that it is difficult to implement on-farm because of labour constraints unless an automated feeding system is used. Producers who aim to provide more milk without automated feeding often feed large volumes of milk per feeding, generally in two meals daily. With this, there is concern regarding abomasal overflow of milk into the rumen, abomasal inflammation and lesions, and reduced insulin sensitivity due to a large amount of glucose being supplied during a short period of time. However, a recent study from Norway (Ellingsen et al., 2016) demonstrated that calves allowed free access to milk consumed between 5 to 7 L per meal without any overflow into the rumen. Regarding insulin sensitivity, Bach et al. (2013) showed that calves fed 8 L of milk/day from 2 weeks of life onward released more insulin to control blood glucose than calves fed 6 L of milk/day. In contrast, MacPherson et al. (2018), fed calves 8 L per day over two or four meals, beginning at the first week of life, and found no differences in insulin sensitivity between groups during a glucose tolerance test. Calves fed only two meals per day had a decreased rate of abomasal emptying indicating that the slower delivery of nutrients, namely glucose, from the abomasum to the intestine may have regulated insulin response. It may be important to begin feeding large volumes of milk during the first week of life because this may be a critical developmental window in which the calf adapts to consuming high levels of milk; however, the long-term effects of this practice on calf development and metabolism are unknown.

Whole milk vs. Milk Replacer

Another controversial topic in terms of milk feeding are the benefits and disadvantages of feeding whole milk vs. MR. Producers generally feed MR because the calf receives a known and consistent nutrient supply, and it is clean and convenient. However, the macronutrient composition of the majority of MR do not resemble that of whole milk, which is plausibly more suited to the calf's needs. Most MR today contain more lactose (45 vs. 35%) and less fat (18 vs. 30%) compared with whole milk (Figure 1). Considering that approximately 60% of calves are fed MR or a combination of MR and whole milk (Urie et al., 2018), more research on how this practice affects calf gut health is needed. High lactose inclusion in MR could negatively affect glucose homeostasis, resulting in high blood glucose and insulin that may eventually lead to the development of insulin resistance. Additionally, high lactose concentrations increase the osmolality of MR (400 to 600 mOsm/L) relative to whole milk (300 mOsm/L; Figure 1). The high osmolality of MR can increase intestinal permeability, potentially disturbing gut mucosal structure and function (Wilms et al., 2019). However, recent work by Welboren et al. (2019b) found that feeding high lactose MR tended to decrease intestinal permeability, which may decrease the risk of pathogens or toxins entering the body. From this conflicting research, it is clear that more research is required to identify calf metabolic and intestinal development responses as calves are progressively fed larger volumes of milk replacer.

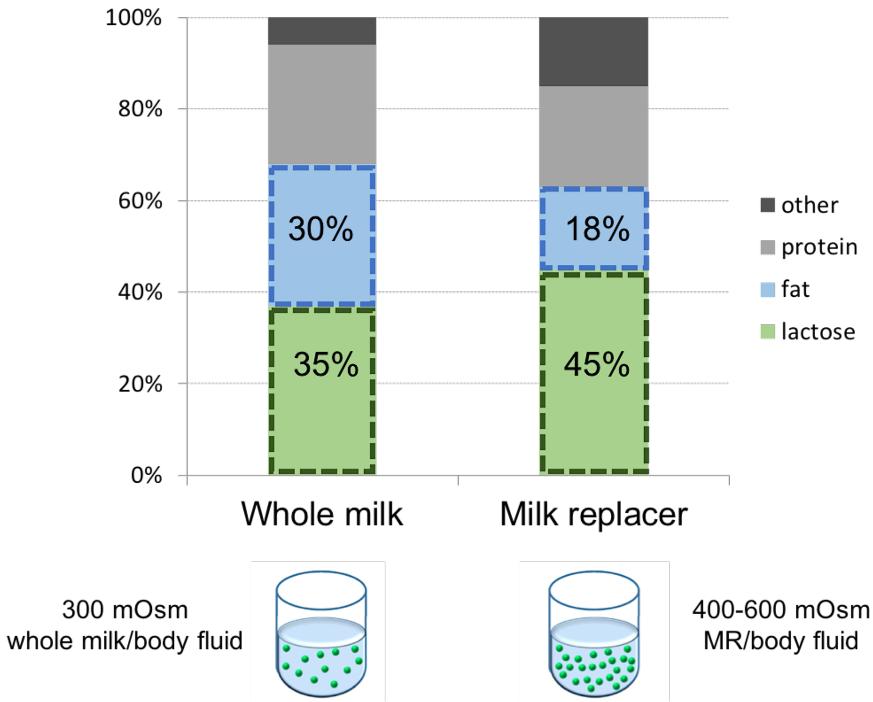

Figure 1. The macronutrient composition (%DM) and osmolality (mOsm) of whole milk and milk replacer (MR).

In addition to high amounts of lactose in MR possibly disturbing calf development, the low levels of fat may also be of concern. High fat consumption is essential for calves during the first week of life because it is crucial for providing energy and assists in thermoregulation. Moreover, increased fat inclusion in liquid feed decreased mortality in preweaned calves (Urie et al., 2018), further demonstrating that this is a critical macronutrient promoting young calf health and survival. Welboren et al. (2019a) showed that feeding 6 L of MR with low lactose and high fat content (HF) twice daily during the first week of life tended to delay abomasal emptying compared with feeding a high lactose and low fat (HL) MR. This may be beneficial in delaying the digestion of protein and fat from MR to allow for better absorption of nutrients and may have positive effects on glucose regulation. The calves fed the HF MR also experienced a lesser rise in glucose and insulin concentrations, although insulin sensitivity was unaffected. Unfortunately, milk fat is not commonly used in MR for economic reasons, with animal-based fats being widely used, including tallow and lard, as well as plant-based coconut, canola, and palm kernel oil. Whole milk lipids appear as globules that are emulsified in the aqueous phase of milk and are coated with bipolar materials, called the milk fat globule membrane (MFGM). The lipid droplets in the fat mixtures used in MR do not contain MFGM but are instead coated with casein and whey molecules from skim milk – a stark contrast to the bipolar molecules that make up whole milk MFGM. The MFGM structure in whole milk potentially plays a role in digestion, lipid metabolism and delivery of lipids to the gut, where they may play a critical role in protection and maturation. Providing MR void of MFGM may have consequences on calf gut development and maturation but has not been thoroughly investigated. Furthermore, milk fat contains medium- to long-chain saturated FA, while many of the plant-based fats used in MR contain high levels of polyunsaturated FA. Feeding high polyunsaturated FA sources can result in poorer growth and nutrient digestibility, and increased occurrences of diarrhea compared with feeding MR that more closely resembles the FA profile of whole milk (Jenkins et al., 1985). To date, there is little research investigating how current MR macronutrient composition, namely the high inclusion of lactose and low amount of fat, affects calves fed elevated planes of nutrition. Future research is needed to evaluate the specific mechanisms by which MR formulations directly affect calf gut barrier function, development, and overall health.

▪ Conclusion

Nutritional management during the first week of life can largely affect calf health, gastrointestinal development and growth performance, and may influence future productivity. Aside from ensuring passive transfer, it is clear that feeding colostrum and transition milk can exert beneficial effects on gut development and maturation. This may occur directly through the action of bioactive molecules, such as OS, fatty acids, and antimicrobial compounds, and indirectly by stimulating the production of gut hormones. In addition, maximizing nutrient intake from whole milk or milk replacer during the first week of life is essential to support growth because starter intake is negligible. There is currently a large knowledge gap as to how the typical macronutrient composition of MR affects calf gut development and health when larger volumes are provided. More research is needed regarding the potential benefits and long-term effects of colostrum, transition milk, and whole milk or MR feeding in order to make confident and informed decisions to promote optimal calf growth, health and productivity during the calf's first week of life.

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