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Sustainable colostrum management and colostrum quality

Održivo upravljanje kolostrumom i kvalitet kolostruma

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ABSTRACT

This paper examines the sustainability of different calf production systems concerning colostrum nutrition and management, based on a review of available literature. The research aims to elevate calf production to a higher standard of hygiene, nutrition, and technological quality. The literature identifies several viable feeding options for newborn calves, including colostrum, enriched colostrum, and colostrum replacers. Evaluating the quality of colostrum and colostrum replacers used in calf nutrition is equally important. Factors such as price, availability, and convenience typically determine the ideal choice for each farm. Additionally, colostrum management plans must consider the economic and environmental sustainability of calf production systems. Recent studies have also emphasized the importance of colostrum's bioactive components, particularly understudied ones like leptin and adiponectin. These hormones may play a role in early regulation of energy balance, and appetite, and potentially in programming metabolic processes later in life. Although research on the role of miRNAs in bovine colostrum is still developing, it is clear that miRNAs contribute to the bioactivity of colostrum and play a vital role in supporting the health and development of newborn calves. Therefore, implementing effective colostrum management strategies and minimizing negative aspects of nutrition should be primary goals to enhance the sustainability of calf production systems.

Keywords: colostrum management, colostrum quality, colostrum replacers

ABSTRAKT

Svrha ovog rada je analiza održivosti različitih sistema proizvodnje teladi u pogledu ishrane i upravljanja kolostrumom na osnovu pregleda dostupnih podataka iz literature. Takođe, istraživanje je sprovedeno u cilju podizanja standarda proizvodnje teladi na viši nivo higijenskog, nutritivnog i tehnološkog kvaliteta. U literaturu su navedene mnogobrojne održive opcije hranjenja novorođene teladi, uključujući kolostrum, obogaćeni kolostrum ili zamene za kolostrum. Jednako je važno proceniti kvalitet kolostruma i zamene za kolostrum koji se koriste u ishrani teladi. Cena, dostupnost, i pogodnost su najčešće faktori koji određuju idealan izbor za svaku farmu pojedinačno. Planovi upravljanja kolostrumom takođe moraju uzeti u obzir i ekonomsku i ekološku održivost sistema za proizvodnju teladi. Nedavna istraživanja su takođe istakla važnost bioaktivnih komponenti kolostruma, posebno nedovoljno istraženih poput leptina i adiponektina. Ovi hormoni mogu igrati ulogu u ranoj regulaciji energetskog balansa, apetita, a verovatno i u programiranju metaboličkih procesa u kasnijem u životu goveda. Iako se istraživanja vezana za ulogu miRNA u goveđem kolostrumu još uvek razvijaju evidentno je da miRNA doprinose bioaktivnosti kolostruma i poseduju važnu ulogu u pogledu zdravlja i razvoja novorođene teladi. Stoga, primena odgovarajućih strategija upravljanja kolostrumom i minimiziranje negativnih aspekata ishrane treba da budu primarni ciljevi za poboljšanje održivosti sistema proizvodnje teladi.

Ključne reči: kolostrum menadžment, kvalitet kolostruma, zamene kolostruma

INTRODUCTION

Sustainability implies the improvement of agricultural production systems and management practices to produce high-quality products in sufficient quantities while ensuring economic viability and minimizing negative impacts on the external environment (Pelletier et al., 2008). There has also been a growing public demand for calf rearing based on sustainable principles in recent years. This implies a balance between environmental, economic, and social aspects. A crucial step in improving the sustainability of dairy and beef is to enhance the efficiency of the cow-calf sector. Improving genetic and reproductive efficiency, combined with optimizing nutritional management, could be a viable strategy to increase the sustainability and productivity of cattle systems (White et al., 2015). Management systems for raising calves can be organized in various ways, and numerous factors can influence their efficiency. Although breeders are working to improve dairy cows' main important production traits, they are still neglecting the issue of calf rearing, which is critical for future dairy and reproductive use. Therefore, they need to increase their awareness that improving colostrum quality is one way to increase profitability (Puppel et al., 2015). Improving the basic principles of colostrum feeding quality, quantity, and speed and newer methods such as extended colostrum feeding represents a significant opportunity. In bovine research, colostrogenesis is also an important topic that has been the subject of little attention and requires further study (Fischer-Tlustos et al., 2021). Furthermore, maternal nutrition during mid-to-late pregnancy has a strong influence on fetal intestinal development (Osorio, 2020).

Colostrum consumption promotes the initiation of anabolic processes in numerous tissues, promoting organ development and postnatal body growth (Mann et al., 2020). Although immunoglobulins are only one of the many colostrum components essential for calf development, proper colostrum management is still considered the most important factor in reducing calf morbidity and mortality (Lorenz, 2021). Factors that affect the absorption of Ig molecules into the circulation include the rate at which the first colostrum is fed after birth, the bacterial contamination of the colostrum, and the metabolic status of the calf. The characterization of not only IgG, but also the hundreds of bioactive compounds in colostrum, and the elucidation of the mechanisms that control their synthesis are necessary for future investigations. It is critical to understand the degree of absorption and functionality of each bioactive component in colostrum and how it relates to health and long-term productivity (Fischer-Tlustos et al., 2021). Continuous monitoring is essential for colostrum management programs because it helps producers identify problems early and take appropriate action (Godden et al., 2019). Today, feeding practices on dairy farms tend to be based on perceived calf performance and the simplicity, efficiency, cost, or time effectiveness of their feeding practices compared to potential alternatives. There is also uncertainty about best practices for weaning calves (Palczynski et al., 2020). Breeders can support intestinal development and function in calves after an initial colostrum meal by feeding transition milk to newborn calves or diluting colostrum with milk or milk replacer (Pyo et al., 2020). Accordingly, recent studies have begun to reevaluate conventional milk replacer formulas, which can differ significantly in composition from whole milk (Niekerk et al., 2021).

This paper aims to discuss pre-weaning nutrition in terms of colostrum management and colostrum and colostrum replacer quality to determine the best way to maintain and sustain a healthy calf.

COLOSTRUM MANAGEMENT

Calf transition management, an essential part of livestock management, is concerned with maintaining calves' productivity, health, and well-being from birth to weaning. Colostrum management is the single most important factor influencing calf survival and health. The future of adult dairy cows, and most importantly, epigenetic programming, depends on colostrum management (Heinrichs and Heinrichs, 2011). Although progress has been made over the past 20 years, many dairy producers still have much room to improve their colostrum management practices, which will benefit animal performance and health (Godden et al., 2019). In the commercial dairy industry, calves and cows are separated within 24 hours. However, new research on extended suckling systems with part-time cow-calf contact, once-daily milking, and a pasture-based system showed the advantages of this system. Namely, calves that suckled dams gained weight faster and were therefore weaned two weeks earlier than commercial calves fed 8 L/day of milk. This system represents a promising alternative to separating calves from their mothers at the time of birth (Ospina Rios et al., 2023). The most critical time for calves is the first 2 weeks, when most falls occur, which may be due to digestive system disorders contributing to poor colostrum quality or poor husbandry (Puppel et al., 2015). Adequate transfer of passive immunity (TPI) in calves is associated with several colostrum management practices. Relevant practices include the amount of colostrum fed at the first meal, colostrum quality, bacterial contamination, time to the first colostrum feeding, and calf weight (Morin et al., 2021; Robbers et al., 2021).

Therefore, it is often recommended to monitor the apparent efficiency of immunoglobulin absorption in calves to evaluate overall colostrum management practices (Robbers et al., 2021; Lopez and Heinrichs, 2022). In newborn calves, not receiving colostrum in the first 24 hours after birth results in low levels of immunoglobulin G, β-carotene, and vitamin A, which can persist for weeks. This also affects the plasma patterns of fatty acids, essential amino acids, and glutamine/glutamate ratios (Blum and Baumrucker, 2002). When the calf is born, care must be taken to ensure that the calf receives a sufficient volume (3 litres) of high-quality colostrum (>50 mg per ml IgG) within the first two hours of life, which is critical for TPI (Shalloo et al., 2021). The length of time between birth and the first postpartum feed is important for the delivery of colostrum with sufficient immunoglobulin concentration (Ahmann et al., 2021). In research by Morin et al. (2021), adequate TPI was 2.6 times higher in calves receiving ≥2.5 L of colostrum at their first meal, 2.9 times higher in calves receiving colostrum at ≥24.5% Brix, and 1.6 times higher in calves receiving colostrum within 3 hours of birth than in calves not meeting these criteria.

Proper storage and handling of colostrum is essential to maintaining its quality. Colostrum should be refrigerated or frozen immediately after collection to prevent bacterial growth and preserve its nutritional properties. The process of colostrum freezing did not affect the colostrum's immune and dietary qualities, except for the fat content, which is gradually reduced (Luiza et al., 2020). On the other hand, heating colostrum before feeding is a management strategy used to reduce bacterial contamination and the potential for transmission of infectious agents from dam to calf through milk. A proven method for maintaining adequate flow characteristics and effectively reducing or eliminating bacteria is to use a longer heating process (60 minutes) at a lower temperature (60 °C) (Mann et al., 2020; Robbers et al., 2021). The disadvantage of this approach is that certain colostrum components are destroyed or reduced in concentration or viability, such as IgA, insulin, insulin-like growth factors (IGF), complement proteins, enzymes, and somatic cells (Mann et al., 2020). Both freezing and heating of colostrum kill the majority of colostral leukocytes (Godden et al., 2019). On the other hand, freeze/thaw of colostrum has little or no effect on IgG concentrations as long as thawing is done au bain-marie and the temperature does not exceed 40 °C (Robbers et al., 2021). The influence of treatment methods such as freezing and thawing is highly dependent on the procedure and does not necessarily lead to a reduction in immunoglobulin concentration (Ahmann et al., 2021). In addition, Mann et al. (2020) reported that calves fed heat-treated colostrum had less colostrum insulin and a prolonged rise in insulin concentrations after feeding. There were differences in thirty-eight proteins between calves fed raw colostrum and those fed heat-treated colostrum. Calves fed heat-treated colostrum had increased serum insulin and incretin gastric inhibitory polypeptide but decreased several glycolysis- or glycogenolysis-related enzymes.

It is also important to prioritize how calves are nursed after birth as a key management strategy. Gamsjäger et al. (2021) evaluated two colostrum management strategies on cow-calf operations using an oro-oesophagal tube (OET) feeder and nipple battle. The results showed that using an oro-oesophagal tube (OET) feeder, feeding a moderate volume of 1.4 L of colostrum within 60 minutes of birth is recommended for high-risk calves because calves nursed sooner than calves fed smaller or larger volumes of colostrum. When feeding a smaller volume (1 L), the nipple bottle (NB) should be preferred over the OET based on the statistically significantly shorter latency to stand and nurse compared to calves fed the OET or a combination of NB+OET. Failing to consume the entire volume provided by the NB may indicate a lack of overall vigour. These calves had statistically significantly longer latencies to stand and nurse and should be closely monitored. The factors influencing the quantity and Ig transfer are complex, and newer ones, such as genetics, have not been adequately studied (Ahmann et al., 2021). Furthermore, colostrum management research must incorporate new management practices more responsive to animal welfare standards.

COLOSTRUM QUALITY

The quality of bovine colostrum is critical to the health and well-being of newborn calves (Blum and Baumrucker, 2002). Colostrum contains various nutrients and immune-enhancing bioactive compounds such as immunoglobulins, lactoferrin, lysozyme, lactoperoxidase, alpha-lactalbumin, beta-lactoglobulin, and essential vitamins and fatty acids. Variables such as breed, productivity, parity, feeding intensity, season of the year, colostrum yield, and/or production system may affect the concentration of the compounds mentioned above (Puppel et al., 2019; Ahmann et al., 2021). According to a study by Luiza et al. (2020) genetic group and parity did not influence passive immunization and colostrum quality. However, prepartum management had a significant effect on colostrum quality. Similarly, Osorio (2020) emphasized that stressors experienced by the mother in the later stages of pregnancy not only affect colostrogenesis but also undermine proper fetal intestinal development. This limits the newborn's ability to absorb nutrients, bioactive compounds, and immunity (i.e., immune cells, cytokines, and immunoglobulins) from colostrum. As the newborn calf must digest and absorb nutrients from milk or milk substitutes, these adverse effects interfere with intestinal maturation and passive immunity necessary for the establishment of a mature postnatal mucosal immune system.

Furthermore, Fischer-Tlustos et al. (2021) noted that it is known that changes in diet and management practices during the dry period affect the overall composition of colostrum. However, the specific mechanisms controlling the occurrence of different colostral immune and bioactive components are still not clear. Some other research has shown that parity significantly increases the amount of protein and total solids and decreases the amount of fat in colostrum from Holstein cows. The time between calving and colostrum collection had a significant negative effect on fat, protein, and total solids content, as well as a positive effect on lactose content. In addition, colostrum yield had a significant negative effect on protein and total solid content (Soufleri et al., 2021). Furthermore, cows with three or more lactations and colostrum collected within the first 2 hours after parturition had a significant effect on colostrum quality with a Brix value above 22% (Morin et al., 2021; Lichtmannsperger et al., 2023). Both colostrum quantity (≥2 L) and quality (≥22% Brix) are protective factors against failure of transfer passive immunity (FTPI), and there was a strong association between calf diarrhoea and FTPI in the first three weeks of calf life (Lichtmannsperger et al., 2023).

It is considered that total protein (TP) concentrations in poor-quality colostrum are <5.8 g/dL, good 5.8 g/dL, and excellent <6.2 g/dL. IgG is found in poor-quality colostrum at <18 g/L, good: at 18 to <25 g/L, and excellent at ≥25 g/L. Serum IgG and TP concentrations decline over the first 16 days of life, and this decline is associated with TPI classification on the first day of life (Correa et al., 2022). Delhez et al. (2021) recommend the immunochromatographic rapid test as an appropriate on-farm method for direct serum IgG measurement and assessment of TPI status in calves. According to them, this will contribute to timely interventions in the management of calves with inadequate TPI, especially for the identification of calves with poor TPI (serum IgG < 10 mg/mL). The rapid test showed better performance than the Brix refractometer. In addition, the relationship between colostrum bacterial load and calves' TPI levels has not been sufficiently studied (Uyama et al., 2022). Many calves could be at risk of receiving poor-quality colostrum, particularly in terms of microbial contamination (Asgari et al., 2022). Morin et al. (2021) found that the median bacterial contamination distribution (interquartile range) in the first colostrum meal was 14,000 cfu/mL (3,000-83,000 cfu/mL) for total plate count (TPC) and 0 cfu/mL (0–1,000 cfu/mL) for total coliform count (TCC). The incidence of FPTI was very low in the study of Asgari et al. (2022) due to the high level of IgG in colostrum and the adequate amount of colostrum fed in the first hours after birth. However, only 37.3% of fresh colostrum met all quality indicators, including IgG concentration, TPC and TCC. In addition, 50, 5.9 and 4% of the colostrum samples were positive for *Staphylococcus* spp., *Salmonella* spp. and *Mycobacterium paratuberculosis*, respectively.

Bioactive components of colostrum

Colostrum, as mentioned, has many properties, such as being nutritional, energetic, protective, and also laxative (Puppel et al., 2019). Extensive research has been devoted to the study of colostrum quality and management, particularly concerning the transfer of maternal IgG to the newborn calf. Despite the vital role of the remaining components of colostrum and transition milk for the infant animal, they have not received the same level of attention (Silva et al., 2024a). The bioactive components in colostrum may act as mediators in the passive transfer of immunity, protect against pathogens, contribute to cellular differentiation and growth, and potentially act as maternal-offspring signalling molecules. The most studied bioactive components to date are immunoglobulins (especially IgG), growth factors (especially IGF-I and IGF-II), and fatty acids (especially n-3 and n-6 fatty acids) (Silva et al., 2024a). For successful calf rearing, it is necessary to characterize IgG and the numerous bioactive compounds in colostrum and to elucidate the mechanisms that control their synthesis (Fischer-Tlustos et al., 2021). The gastrointestinal tract of newborns is somewhat permeable immediately after birth, which could allow the absorption of larger molecules such as insulin-like growth factor (IGF-I) and insulin. However, this permeability decreases rapidly within the first hours to days of life, limiting the window for such absorption. The extent to which these molecules can be absorbed intact and remain biologically active in the circulation, rather than being degraded by digestive processes, remains a topic of investigation (Godden et al., 2019). There is also a lack of research on some components, such as many hormones whose concentrations in colostrum are not known, as well as the role of nucleic acids, enzymes, cytokines, and amino acids in newborns. Most, if not all, of these components, appear to be important for the neonatal calf, as some of them have significantly higher concentrations in colostrum and transition milk compared to whole milk (Silva et al., 2024a).

Insulin and insulin-like growth factor

Much of the discussion centres on the growth factors' potential in colostrum to enter the bloodstream of newborns unaltered and have systemic effects upon ingestion. Insulin and insulin-like growth factor (IGF)-I are essential for development and growth. In addition to acting as a direct growth hormone mediator, IGF-I is essential for cell growth and development. Conversely, insulin has anabolic effects on various tissues and is necessary for glucose metabolism (Soufleri et al., 2021). According to Playford and Weiser (2021), high levels of insulin-like growth factors (IGFs) in colostrum may facilitate the anabolic-reparative effects of the gut. High concentrations of growth factors and nutrients in colostrum, both nutritive and non-nutritive, enhance intestinal growth and function and improve the ability of the neonatal gastrointestinal tract to absorb nutrients. In addition, colostrum feeding, likely as a result of improved glucose status, leads to higher postprandial plasma glucose concentrations in neonatal calves through increased glucose absorption (Hammon et al., 2013). Intestinal carbohydrase activity in neonatal calves showed a gradual increase in proximal jejunal lactase activity and a concomitant decrease in ileal isomaltase activity with insulin supplementation. Consequently, colostrum insulin promotes gastrointestinal growth while down-regulating the expression of insulin signalling pathway mRNA. This has a beneficial effect on energy metabolism by enhancing lactose catabolism and increasing glucose availability. Moreover, regarding macroscopic intestinal development, the mass of dry rumen tissue decreased linearly when insulin was added to the colostrum. Furthermore, the supplementation resulted in a linear increase in the density of dry tissue in the duodenum (g dry matter/cm), while also showing a tendency to increase the weight of dry tissue in the duodenum (Hare et al., 2023). Another study reported that the season of parturition and sex had a significant effect on key insulin characteristics in newborn Holstein calves. The amount of milk produced during pregnancy, the duration of lactation, and the prepartum dry period are strongly correlated with insulin characteristics. However, it remains unclear whether changes in insulin modifications early in life have long-term effects on metabolism (Kamal et al., 2015). Some other studies have reported that calves fed high levels of colostrum had improved nutrient absorption and increased IGF-I production internally in the calf's liver. Plasma IGF-I and IGF-binding protein (IGFBP) concentrations are significantly dependent on the time of first colostrum feeding. It was shown that the IGFBP-2/IGFBP-3 ratio was higher and plasma IGF-I and insulin concentrations were lower when the first colostrum feeding was delayed by 24 h. Conversely, there were no changes in IGF-I and IGFBP in neonatal calves at 7 days, suggesting that they recovered quickly from immediate postnatal food deprivation (Mann et al., 2020). Pyo et al. (2020) observed that Holstein bull calves feeding colostrum and a mixture of colostrum and whole milk (1:1) promoted small intestinal maturation. On the other hand, calves feeding whole milk showed transient decreases in IGF-1 and glucagon-like peptide (GLP-2), with the latter followed by recovery. The authors also suggested that neonatal calves may be receiving inadequate amounts of nutrients due to current industry practices.

Leptin and adiponectin

Several studies have examined leptin and adiponectin in colostrum. Leptin and adiponectin are two hormones that regulate energy balance, appetite, and metabolism. While adiponectin increases insulin sensitivity and has anti-inflammatory effects, leptin is primarily associated with appetite suppression and increased energy expenditure (Hammon et al., 2013). Furthermore, adiponectin is a hormone that belongs to a group known as adipokines, of which white adipose tissue is a major source (Sauerwein and Häußler, 2016; AL-Thuwaini, 2022). It has multiple functions in livestock, including lipid metabolism, energy regulation, immunity, and insulin sensitivity, with energy metabolism and ovarian function being the most important. The function of adiponectin depends on its interactions with its receptors, such as AdipoR1 and AdipoR2. These receptors (AdipoR1 and AdipoR2) are found in several tissues, including adipose tissue and skeletal muscle. They are also expressed in the hypothalamus, pituitary, and gonadotropin-releasing glands (AL-Thuwaini, 2022). According to Kesser et al. (2015), placental transfer of adiponectin to the bovine fetus is unlikely, and calves have very low blood concentrations of the protein at birth. The postnatal increase in circulating adiponectin in newborn calves depends on colostrum intake. Numerous functions of adiponectin are associated with growth, lactation, and overall health, making it relevant to both dairy and beef production systems, but quantitative data on bovine adiponectin protein have only recently been published in the literature (Sauerwein and Häußler, 2016). Recent studies suggest that adiponectin enhances skeletal muscle growth through interaction with the p38 mitogen-activated protein kinase (p38-MAPK) pathway, thereby influencing carcass traits such as marbling, ribeye muscle area, and carcass fat thickness. More importantly, it appears to be related to mammalian fertility, as adiponectin is located on the hypothalamic-pituitary-gonadal (HPG) axis, which is involved in mammalian reproductive functions.

However, the physiological action of adiponectin in livestock remains to be elucidated (AL-Thuwaini, 2022). Recent studies showed that umbilical cord blood concentrations of adiponectin, leptin, visfatin, and IGF-1 were associated with calf birth weight. Besides that, adiponectin, leptin, and IGF-1 were present in both venous and cord blood and these factors may regulate each other, but there was no significant correlation between calf birth weight and venous blood adiponectin, leptin, and IGF-1 (Shen et al., 2019). Kizil et al. (2023) noted that the mode of delivery had no significant effect on irisin, asprosin, leptin, adiponectin, and IGF-1 levels in maternal and fetal blood. The higher levels of all hormones in cord blood suggest that these hormones may have important functions in fetal life. Besides that, AL-Thuwaini (2022) noted that the relationship between genetic polymorphisms in the ADIPOQ gene and reproductive traits in livestock has not received much attention. The regulation of phenotypic traits related to the adiponectin gene suggests that this gene is fundamentally linked to several phenotypic traits in livestock.

MicroRNAs

Increasing attention is also being paid to other bioactive substances such as lactoferrin, oligosaccharides, and microRNAs (Silva et al., 2024a). Colostrum has a high nutrient content and strengthens immunity, but it also contains bioactive substances transferred from mother to child, such as molecular instructions or signals. MicroRNAs (miRNAs) are short, non-coding RNA molecules that can regulate gene expression at the transcriptional level. They are thought to act as key regulators of various biological and developmental processes (Van Hese et al., 2020; Benmoussa et al., 2020). As a complex fluid, milk is enriched in different miRNAs, which may not all survive processing and may be specifically secreted by mammary epithelial cells and other cell types. Each miRNA exists in different isomeric forms in all biological samples, called isomiRs (Benmoussa et al., 2020). These compounds influence the postnatal maturation of the gut, including the differentiation and functional development of the intestinal epithelium after ingestion (Osorio, 2020; Chen et al., 2016), as well as systemic immune functions (Lorenz, 2021; Ylioja et al., 2019). Colostrum contains more miRNAs than mature milk, with immune and developmental miRNAs being prominent (Van Hese et al., 2020). Milk exosomes are a rich source of microRNAs (miRNAs) that are protected from degradation (Sun et al., 2015). Thus, microRNAs (miRNAs) are encapsulated in different extracellular vesicle (EV) subsets that protect them from the extracellular milieu and the harsh conditions of the gastrointestinal tract during digestion (Benmoussa et al., 2020).

Wang et al. (2018) found that a total of 25 core miRNAs were differentially expressed during lactation compared to non-lactation, and these miRNAs were involved in epithelial cell terminal differentiation and mammary gland development. In addition, putative differentially expressed genes were significantly enriched in fatty acid (FA) metabolism, amino acid biosynthesis, ketone body synthesis and degradation, and unsaturated FA biosynthesis. Biological processes related to protein metabolism, lipid metabolism, and mammary gland development were enriched for some of the identified miRNAs, suggesting that they may play critical roles in regulating milk protein and fat traits in dairy cattle (Cui et al., 2020). In a study by Özdemir (2020), functional enrichment analysis revealed that miRNAs expressed in Holstein milk were mainly associated with milk synthesis, whereas those in colostrum were mainly involved in immune pathways. On the other hand, in Doğu Anadolu Kirmizisi (DAK) milk regulates milk fat and protein metabolism.

Yun et al. (2021) confirmed that immune-related miRNAs (miR-30a-5p, miR-22-3p, and miR-26a) are commonly present in cow colostrum and mature milk. Colostrum from cows with a high body condition score (BCS) contained less miR-486, which is associated with altered glucose metabolism. In addition, colostrum from cows with elevated serum-free fatty acids (FFA) contained less miR-885, which may be associated with liver function during the transition period. The fat content of the mother's diet appears to significantly influence the expression of miRNAs in milk and neonates.

The likely relationship between diet and maternal miRNA expression provides a potential avenue for optimizing miRNA expression and improving neonatal maturation (Van Hese et al., 2020). The importance of miRNAs in neonatal health is clear, and it is also clear that these molecules are highly expressed in colostrum; however, it is not clear whether their action is dependent on uptake into the bloodstream or whether they can act in the gastrointestinal tract (Silva et al., 2024a). Furthermore, the mechanisms by which most of the differentially expressed miRNAs regulate milk quality remain unclear and require further validation (Wang et al., 2018).

COLOSTRUM REPLACERS

Colostrum supplements and replacers are specially formulated products designed to provide essential nutrients to calves when maternal milk is unavailable or insufficient (Godden et al., 2018). They were developed primarily to provide supplemental Ig, and data on the efficacy of colostrum supplements and replacers is still inconsistent (Cabral et al., 2013). The most appropriate milk replacer depends on many factors, including individual calf needs, cost, availability, and farm conditions. It should also provide controlled weight gain, replace as much milk in the calf's diet as possible, and maintain high microbiological standards. A milk substitute could be made entirely from dried skim milk or whey products (except those that are salted) and contain all milk proteins and a specific set of available amino acids. Dried whey, lactose whey, and whey protein concentrates are examples of whey products. The animal and vegetable fats that are part of milk replacers have some specific characteristics. Therefore, the evaluation should be based on methods for determining the average diameter of fat globules, the fatty acid composition, and the initial oxidation state of fats (Kharitonov et al., 2021).

Colostrum is essential for the newborn calf to receive early immune protection. However, colostrum quality varies widely between and within farms. As a result, it can be a challenge to ensure that the calf receives the Ig required for optimal growth (Cabral et al., 2013). Urakawa et al. (2024) investigated the effect of feeding milk colostrum (MC) versus colostrum replacer (CR) on the immunological status, growth, and health of pre-weaned Japanese Black calves. Their results showed that calves fed CR had delayed immune activation and were more likely to fail to transfer passive immunity. Furthermore, continuous feeding of CR may compromise calf performance and increase the risk of early-life bacterial infections, resulting in lower disease resistance, higher infection rates, and reduced carcass weights. Conversely, MC increases populations of various immunocompetent cells that may reduce infection rates and improve weight gain. In a study conducted by Lopez et al. (2020), no significant difference was found in the average daily weight gain, various health indicators, or the final measurements of hip width, withers height, or body weight in calves that were fed either low-quality maternal colostrum enriched with colostrum replacer IgG (LMC-CR), a commercial whey-based CR, or MC. According to the authors, calves fed CR had a higher apparent absorption efficiency (AEA) than calves fed MC. Similarly, Ahmadi et al. (2021) concluded that growth rate, body frame development, and incidence of diarrheal disease were not different between Hanwoo calves fed lacteal-derived colostrum replacer or natural bovine colostrum (from Holstein cows). In other studies, the total serum protein (TSP) concentrations measured up to 72 hours were higher in calves fed maternal colostrum. In addition, calves receiving MC and formulated transition milk (FTM) had higher glucose concentrations during the preweaning period. On the other hand, colostrum fortified with CR at 25% Brix decreased plasma lactate concentrations. The authors concluded that fortifying mid-quality colostrum could be an alternative in situations where high-quality colostrum is scarce; however, feeding 4 L/day of FTM for only 3 days after colostrum feeding showed no additional benefit (Silva et al., 2024b). Quigley et al. (2002) evaluated the benefits of feeding young Holstein bull calves with a colostrum supplement (CS) containing defibrinated bovine plasma or a CR containing an immunoglobulin concentrate prepared by concentrating the immunoglobulin IgG fraction of bovine plasma. The plasma IgG concentration in the first 24 hours after calves were born and fed CR indicated a successful transfer of passive immunity. Both the IgS from CS and CR were readily absorbed by newborn calves. Other studies have investigated whether supplementation of low- and high-quality MC with bovine-dried CR can achieve adequate serum IgG levels. In newborn calves, supplementing low-quality colostrum with bovine-dried CR can increase serum IgG levels to sufficient levels within 24 hours. However, the researchers emphasized that more research is needed to determine how the composition of fortified colostrum affects IgG absorption in high-quality MC (Lopez et al., 2020). Kharitonov et al. (2021) analyzed the qualitative indicators of colostrum and milk replacers. It was found that some of the physicochemical properties of milk replacers need additional control, i.e., the concentration of immunoglobulins, the polypeptide, and the amino acid profile of the protein component. Also, the primary milk sanitary and hygienic indicators should be controlled using various approaches, e.g., thermal inactivation or fermentation of colostrum with *Acidophilus bacillus*, which reduces the number of pathogens. Only by controlling colostrum quality and using high-quality whole milk replacers can farmers achieve rapid weight gain, early calving, high productivity, and prolonged lactation. In terms of hepatic glycogen concentration, it increased much more when MC was fed instead of a milk-based colostrum replacer. In addition, formula-fed calves typically had higher first-pass glucose uptake in their splanchnic tissue. Neonatal calves consuming colostrum have higher plasma glucose levels and an improved energy status, which increases insulin secretion and accelerates the stimulation of anabolic processes. This has been demonstrated by enhanced postnatal somatotrophic axis maturation in newborn calves (Hammon et al., 2013). Liermann et al. (2020) tested the hypothesis that energy metabolism and its endocrine regulation would differ during the first 10 days of life in calves fed pooled colostrum or milk-based formula. It was shown that formula-fed calves had lower plasma immunoglobulin, haptoglobin, leptin, adiponectin, IGF, and insulin-binding protein (IGFBP)-4 concentrations than colostrum-fed calves. Conversely, formula-fed calves had transiently elevated plasma concentrations of urea, insulin, glucagon, triglyceride, and cholesterol on the first day of feeding. In addition, absorption of colostral leptin and adiponectin may influence insulin sensitivity in neonatal calves, but further studies are needed to substantiate the influence of colostral leptin and adiponectin on insulin sensitivity after birth. Furthermore, some results suggest that the level of milk replacer feeding in early life affects the number and physiology of granulosa cells later in life. This could affect the entire reproductive lifespan initiated by entering puberty in cattle (Röttgen et al., 2023)

CONCLUSION

A comprehensive review of colostrum management strategies underscores the need for an effective program to ensure passive immunity in calves, which results in improved health and growth performance. Colostrum, the first milk given to newborns, is rich in bioactive components that support neonatal health and development. Research in this area highlights the importance of immunoglobulins (Ig) and growth factors, but there remains a critical need to further investigate the role of adiponectin, leptin, and microRNAs. MicroRNAs (miRNAs) play crucial roles in various biological processes, including immune regulation and development, and have been found in higher concentrations in bovine colostrum than in bovine milk. Further studies are necessary to fully elucidate the functions and mechanisms of action of miRNAs in bovine colostrum. Numerous studies have been conducted to determine the best management approaches for feeding colostrum. Feeding high-quality colostrum replacers may be justified when colostrum quality is poor. In contrast, the use of low-quality colostrum replacers can lead to poor health and stunted growth in newborn calves.

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