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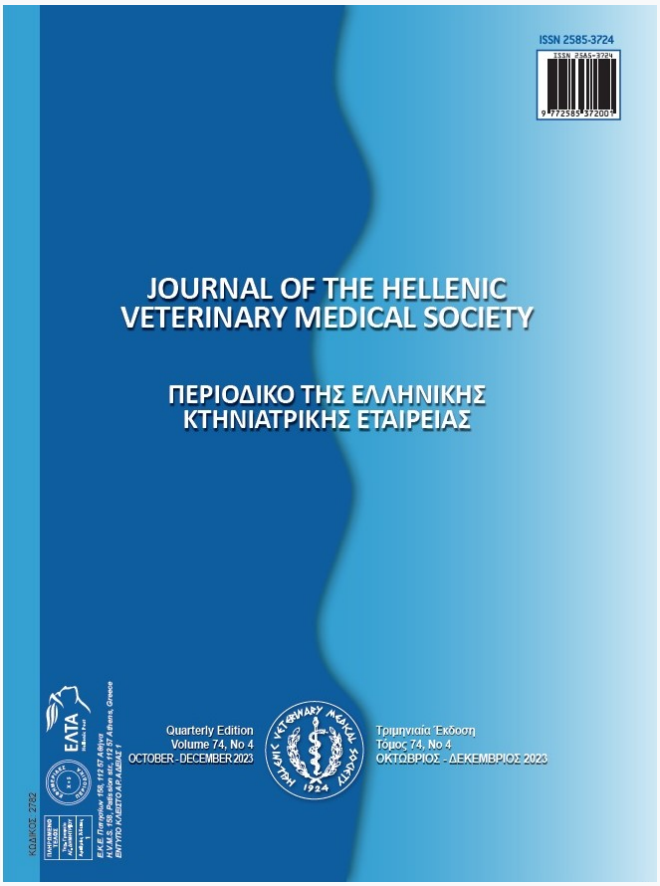

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Should Pre-Weaning Calf Diets Include Forage?

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ABSTRACT: The present review article aimed to update and address the biological consequences of forage supply to pre-weaned dairy calves. Early growth and development of a calf play a great role in lifelong performance of the animal. Comprehension of these stages is an important progress achieved in calf nutrition today. Health, milk-solid feed intake and rumen development are the most important factors related to calf growth in pre- and post-weaning periods. It is well understood that fermentation by-products of grain-based starter feeds are essential for increased growth and absorptive capacity of the rumen papillae. In pre-weaned calves, two major hypotheses exist regarding forage feeding. The first hypothesis suggests that the rumen is not fully developed in pre-weaned calves, and forage supply during this period might increase gut fill, thus decreasing starter intake. It is believed that depressed starter intake may limit energy intake and finally suppress calf growth rate. The second hypothesis indicates that rumen pH may decline as the calf ages and starter intake increases. Accordingly, forage supplementation into calf starter diets could prevent further rumen pH decline and subsequent negative consequences while improving starter intake and calf growth. Because research data regarding these hypotheses are controversial, there is no universally accepted standard for feeding calves with forage as a part of starter diets. Many factors, such as milk feeding method, grain, forage type and experimental conditions, could affect calf response to dietary forage. However, there is evidence that limited consumption of forage may be beneficial on rumen health and behavior of calves consuming highly processed (pelleted or finely ground) starter feed in the pre-weaning period.

Keywords: Forage; Growth performance; Pre-weaned calf; Rumen development

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INTRODUCTION

The early growth and development of a calf play a great role in the animal's lifetime performance. Comprehension of these stages is an important progress achieved in calf nutrition today (Heinrichs et al., 2017). The pre-weaning period provides a unique and unrepeatable opportunity to prepare calves for life. Therefore, the calf feeding program during this period focuses on the early development of the rumen and achieving high growth rates (Khan et al., 2016). In newborn calves, it has been known for years that butyrate is an important stimulator and regulator of ruminal epithelium growth and function (Castells et al., 2012). Producing higher rumen butyrate by feeding diets high in starch and sugars accelerates rumen development and results in a higher growth rate (Soltani et al., 2017). However, it was reported that feeding calves with diets rich in concentrate poses an increased risk of rumen acidosis, hyperkeratosis (Laarman and Oba, 2011) and papilla agglutination (Castells et al., 2012), and reduced production performance (Khan et al., 2016; Meale et al., 2017). These negative effects can be eliminated by adding fiber from different sources to the starter diet. There is substantial evidence that forage supplementation in calf diets increased chewing activity (eating and rumination), salivation and rumen pH, prevented hyper-keratinization, and supported rumen muscle development (Terre et al., 2013; Beiranvand et al., 2014; Hosseini et al., 2019; Gasiorek et al., 2020), improved the ruminal microbial development and the health of animals (NASEM, 2021), and reduced non-nutritive oral behaviors (Terre et al., 2013; Mirzaei et al., 2017). However, the lower energy content of forage compared with concentrate can reduce the energy density per unit of starter feed (Molaei et al., 2021), and may not adequately supply butyric acid (Hill et al., 2008). Contrarily to this negative effect of forage, in a recent study, Terler et al. (2022) observed that feeding young dairy calves such high-quality hay resulted in the same energy and nutrient intake and growth performance as in calves fed concentrate-rich starter feeds and enhanced ketogenesis and cholesterolgenesis around weaning. Furthermore, Poier et al. (2022) reported that feeding of high-quality hay enhanced butyrate concentration in the rumen without affecting health and stress parameters, as well as ruminal thickness as an indicator of rumen development.

Results of studies on rumen development and calf performance in the pre-weaning period are not consistent. Such inconsistencies are mainly attributed to differences in methods (source of forage, level, time and method of supplementation, physical form of forage and starter feed, milk feeding level) used in these studies (Imani et al., 2017; Diao et al., 2019). Therefore, since a universal standard has not been established on optimum forage requirements for calves, calf feeding recommendations for forage vary considerably from one region to another. For instance, in some countries such as the United States (USA), it is recommended to supply calves only with starter feed as solid feed during the pre-weaning period (BAMN, 2017), while in European Union countries, it is recommended to use a source of forage in addition to starter feed (Castel et al., 2012; Castel et al., 2013). However, in European Union countries, it has also been stated that forage feeding could be given up by adding textured starter feed to the calf starter (Kowalski et al., 2009; Terre et al., 2015; Strzetelski et al., 2014).

It is now recognized that optimizing calf rearing and feeding in the pre-weaning period offers an opportunity to improve long-term cow health, welfare, and performance. This supports the reassessment of the importance of the impact of solid feeds, especially forages, on calf performance. The aim of this review is to present the results of studies on the effect of dry forage on rumen development and calf performance in the pre-weaning period.

EFFECTS OF VARIOUS FORAGE SOURCES ON CALF PERFORMANCE

Supplementation of forage into the pre-weaning calf diets has long been discouraged because of its negative impacts on growth rate (Xiao et al., 2020). On the other hand, some studies indicated that several factors should be taken into consideration when assessing the impact of forage supply on calf performance (Imani et al., 2017; Diao et al., 2019). These factors, complicating comprehension of the forage use efficiency and the interpretation of the results, include the source, amount and particle size of forage, time of supply, feeding method and physical form of the starter feed.

Source and level of forage

Up until today, the primary focus of research on solid feed consumption in pre-weaning calf feeding has been comparing calves fed only with starter to those fed with both starter and forage (Terré et al., 2013; Hosseini et al., 2016; Takemura et al., 2019; Hosseini et al., 2019; Poczynek et al., 2020; Gasiorek et al., 2021; Ahmadi et al., 2022). Only a handful

of studies have compared different qualities of hay (e.g. alfalfa, grass, rye-grass, oat), straw, and silage forages (Castells et al., 2012; Movahedi et al., 2017; Omidi-Mirzaei et al., 2018; Kargar et al., 2019). In general, calves exhibit a preference for high-quality forage such as grass or alfalfa hay over low-quality forage like straw (Castells et al., 2012; Webb et al., 2014a; Omidi-Mirzaei et al., 2018). Due to the high neutral-detergent fiber (NDF) and acid-detergent fiber (ADF) content, the consumption of low-quality forage such as straw is relatively low. Low feed consumption (~5%) in straw-fed calves can enhance the rumen environment, stimulate starter feed consumption, and improve total dry matter (DM) consumption, ultimately enhancing feed conversion ratios (Movahedi et al., 2017). Conversely, high levels of forage DM consumption may lead to decreased digestibility and average daily gain (ADG) due to the limited capacity of the calf rumen (Hill et al., 2019). Adverse effects are observed when the ratio or consumption of high-quality forage, such as alfalfa, in total solid forage in DM exceeds 10% (Castells et al. 2012; Terré et al., 2013). Castells et al. (2012) found that calves consuming alfalfa hay (14%) had lower starter feed consumption, total DM consumption, and ADG compared to those consuming barley straw (5%), with the best performance observed in calves consuming oat straw (8%). However, Beiranvand et al. (2014) reported that calves consuming 10% alfalfa hay as part of total solid feed exhibited increased total DM consumption, ADG and final body weight as compared to those consuming 0 or 5% alfalfa hay. They also noted a shortened time to reach the starter DM consumption target at weaning (1 kg for 3 consecutive days). In another recent study, it was shown that increasing the alfalfa hay ratio to 7.5% improved rumen development without affecting calf performance (Ahmadi et al., 2022). Previous studies using straw as a source of poor-quality forage reported that straw consumption at 4% and 7.5% of total solid feed consumption tended to prolong rumination time, improve rumen environment, increase total solid feed consumption, and enhance ADG (Hosseini et al., 2019; Poczynek et al., 2020).

There are also studies reporting that forage consumed as 10-25% of total solid DM consumption did not negatively affect or increased calf performance. Nemati et al. (2016) observed a linear increase in total DM consumption and ADG of calves supplemented with 0, 12.5 and 25% chaffed alfalfa hay. Gasiorek et al. (2021) indicated that increasing supplementation of chaffed triticale hay into pelleted starter feed from 10% to 15% did not have any adverse effects on calf performance and rumen fermentation. Daneshvar et al. (2015) conducted a study on whether gradual milk feeding together with forage supply would improve performance, finding that 15% alfalfa hay supplementation into starter rations improved the performance of dairy calves. However, it is widely believed that the increase in ADG and live weight (LW) in calves fed with high levels of forage may be attributed to greater rumen filling (Mirzaei et al., 2015). On the other hand, Terler et al. (2022) conducted a study in which quality forage (11.2 ME/MJ/kg DM, 210g CP/kg DM, 455g NDF/kg DM) was used as the sole solid feed source in pre-weaning period, and no decrease was observed in calf performance values. Researchers found similar DM consumption, ADG and post-weaning LW in calves fed with 100% high-quality forage as the sole solid feed source compared to those fed with a 70:30 mixture of starter and forage. In a similar study by Poier et al. (2022), it was determined that feeding with high-quality hay instead of concentrate-rich starter feeds improved rumination and the ruminal fermentation profile without affecting ruminal pH and systemic and stress health variables. In light of these data, there is a need for further investigation of the relationship between intestinal fullness and ADG.

Recently, there has been increased interest in studies incorporating silages into pre-weaning calf rations because of their widespread availability on dairy farms and their lower cost as compared to dry forage (Kehoe et al., 2021). The majority of these studies focused on maize silage (Overest et al., 2016; Mirzaei et al., 2017; Kehoe et al., 2019), while others focused on alfalfa silage (Khan et al., 2020) and triticale silage (Castells et al., 2012, 2013). Until today, only a few studies have compared silages with other forage types in terms of calf performance (Castells et al., 2012; Overvest et al., 2016; Mirzaei et al., 2017). Castells et al. (2012) found that triticale silage increased total DM consumption and ADG as compared to calves fed with alfalfa hay; however, such beneficial effects were not observed compared to barley straw, rye-grass or oat hay. Kargar et al. (2019) indicated that replacing maize silage (10%) with alfalfa hay or sugar beet pulp in starting diets had no beneficial effect on feed consumption or growth performance. These three sources of forage could be used interchangeably, providing producers with more options for choosing feed ingredients. On the other hand, lower DM consumption,

lower weaning weight and weak rumen development were observed in calves consuming fermented feeds as the sole solid feed source compared to calves fed with only starter feed (Khan et al., 2020) or starter feed plus forage (Overvest et al., 2016). Some studies show that adding silage to calf rations during the pre-weaning period had either no effect or a positive effect on performance compared to calves fed only with starter feed (Castells et al., 2012; Mirzaei et al., 2017). Further research is needed to detail the effects of different types of silage on calf feeding, behavior and performance during weaning and the practices of providing silage to calves on the farm.

Based on these research results, a minimum level of forage is critical to improve the rumen environment and raise healthy calves. Therefore, it may be recommended to use low quality forage in the pre-weaning period and to limit the consumption level to approximately 5% on the basis of DM.

Particle size and processing of forage

Forage particle size significant effects chewing activity and rumen fermentation in calves (Nemati et al., 2015; Mirzaei et al., 2015). It has also been demonstrated that forage particle size can influence the effective fiber requirement of dairy calves. Mirzaei et al. (2015) highlighted the impact of alfalfa particle size on the performance and rumen development of calves fed with finely ground starter feeds. They found that alfalfa hay with a longer particle size (5.04 mm on average) increased starter feed consumption and weaning weight compared to 8% alfalfa hay with a medium particle size (2.92 mm on average). Indications suggest that calves prefer long-particle forage (Webb et al., 2014a), and it may be effective in preventing stereotypical behaviors in calves. A study using grass hay as a forage source showed that increasing particle length from 2 mm to 3-4 cm reduced non-nutritive mouth behaviors and improved nutrient digestibility (Montoro et al., 2013). Another study reported that, compared to short-particle alfalfa hay (thin: 2 mm, long: 3 to 4 cm), long-particle alfalfa hay was more advantageous in promoting rumen development (Norouzian et al., 2014). In contrast to long-particle forages, low-level short-particle forages may not have the potential to increase rumen capacity, motility and development (Tamate et al., 1962). Additionally, feeding calves with rations containing finely chopped hay (2 mm) may increase feed selection and cause unbalanced nutrient consumption after weaning (Miller-Cushon et al., 2013). However, there are also studies reporting that the particle size of forage did not affect ruminal fermentation. Suarez-Mena et al (2015; 2016) suggested that increasing the particle size of the starting diet by adding different lengths of oats or straw had no effect on rumen fermentation and calf development. Omidi-Mirzaei et al. (2018) reported that supplementation of different particle sizes (alfalfa hay: short = 1.96 mm or long = 3.93 mm; wheat straw: short = 2.03 mm or long = 4.10 mm) into calf diets increased rumination time, but starter feed DM consumption, ADG and feed conversion ratios did not differ. Bagheri et al. (2021) indicated that wheat straw supplied separately from the starter feed increased starter feed consumption, rumen pH and welfare of calves, but wheat straw particle size had no effect on these parameters. On the other hand, although pelleting of forages has been suggested as a strategy to prevent gastrointestinal fullness, no beneficial effects of pelleting of forages on rumen function or performance have been detected (Jahani-Moghadam et al., 2015; Suarez-Mena et al., 2016; Molaei et al., 2021). These results indicate that an optimal standardization of forage size to support rumen development has not yet been defined.

Initial time of forage supply

In general, although there is scientific evidence that pre-weaning forage supply stimulates rumen development, the optimal time remains unclear. The emergence of rumination behavior in calves can also be evaluated as a key marker for rumen development. The age of the first rumination was reported to start at 3-6 weeks of age for calves fed with pelleted concentrate feed (Porter et al., 2007; Ghassemi Nejad et al., 2012; Khan et al., 2016) and the second week of life for calves fed with a coarsely chopped alfalfa-meadow grass mixture (Swanson and Harris, 1958). However, Jami et al. (2013) suggested that cellulolytic bacteria were present in the rumen from the age of 3 days, and therefore, forage added to the ration at a very early age would be beneficial. In numerous studies, the highest performance and fastest rumen development were obtained from calves fed with forage from week 2 rather than week 4 or week 6 (Hosseini et al., 2016; Lin et al., 2018; Chen et al., 2021). Hosseini et al. (2016) reported that calves fed with alfalfa hay at 2 weeks of age improved feed consumption, ADG and rumination as compared to calves fed with forage at the 4th or 6th weeks of life. In another study, it was reported that adding oat straw to calf diets at the 2nd or 6th weeks before weaning improved DM consump-

tion, rumination, rumen pH, decreased non-nutritive oral behaviors, and supported healthy rumen development; productivity and rumen development were better in calves supplied with oat straw from the 2nd week (Lin et al., 2018). Improvement of rumen fermentation, keeping rumen pH at optimal levels and decreasing the amount of rumen NH_3-N by increasing the acetate/propionate ratio provides significant advantages in terms of growth performance and satisfactory rumen fermentation. Thus, Chen et al. (2021) reported that supplying calves with oat straw from one week of age increased body weight, ADG, starter feed consumption, rumen pH value, acetate/propionate ratio, and decreased rumen NH_3-N concentration, thus improving growth performance and rumen fermentation, and also improving calf welfare by increasing rumination time and decreasing abnormal behavior durations. Contrary to these findings, according to the results of some studies comparing the effects of forage supply time, alfalfa hay or oat hay supplied at 3 days (Gahremani et al., 2021), 2nd or 3rd week of age (Wu et al., 2018) did not affect ADG and rumen development. On the other hand, although further research is needed, there is also evidence showing that consuming different feed sources in the early stages of life could support the acceptance of new feeds in the later stages of life and positively affect the ability to adapt to feed changes, due to the effect of forage on cognitive development of the calf (Horvath et al. Miller-Cushon, 2019).

Since fibrolytic enzymes of the rumen are not fully active until 3-4 weeks after birth (Anderson et al., 1987), early exposure to solid feeds may be beneficial for rumen development and microbial colonization of calves (Diao et al., 2019). Therefore, it is recommended to include forage in calf diets as early as the 2nd week and even immediately after birth to improve DM consumption and ADG (Hosseini et al., 2016; Lin et al., 2018; Horvath and Miller-Cushon, 2019; Chen et al., 2021).

Mode of supply

There are no definitive recommendations on how forage should be supplied to calves for optimal growth and development. Including forage in the total mixed ration (TMR) or supplying it in a separate feeder may affect the feed consumption and performance of the calves. Straw bedding should not be considered as a forage supply method, as calves may consume contaminated bedding and cause health problems. Satisfactory scientific data on the comparison of the effects of forage supply methods on calf growth performance and rumen fermentation are limited. To promote the consumption of adequate, balanced and complete ration and to maintain rumen health, it is common practice to provide various feedstuffs as a TMR. However, it is recommended that forage be served separately from the starter feed so that the calves do not learn the forage separation behavior at an early age (Miller-Cushon and DeVries, 2011; Miller-Cushon et al., 2013). Also, mixing forage and starter can raise some problems as it ignores individual differences in forage consumption seen in pre-weaning calves (Webb et al., 2014b). Therefore, offering forage and starter feed ad libitum can allow calves to choose the amount of feed they want and get the most benefit from each feed source. In a meta-analysis study (Imani et al., 2017), it was reported that providing calves with forage separately increased starter feed consumption and ADG as compared to TMR. Castell et al. (2012) observed that when forages were presented ad libitum and separately from starter feed, they consumed approximately 5% of forages and increased DM consumption and ADG. Conversely, there are studies reporting that forage feeding did not always lead to better performance. Indeed, Gasiorek et al. (2020) and Engelking et al. (2020) did not observe any significant differences between two feeding methods (mixed and separate) in terms of DM consumption and growth performance. This was probably due to the low (10%) forage content of the mixed diet used in both studies.

Physical form of starter feed

Properties of pre-weaning starter feed (ie. type of carbohydrate, physical form of starter feed) and digestibility can affect calf DM and energy consumption. The majority of commercial starter feeds are in pelleted physical form and formulated with high levels of non-fiber carbohydrates (NFC) to support calf rumen development and performance. Commercial starter feeds, which are widely available and finely ground, can reduce rumen pH (Laarman and Oba, 2011) and lead to rumen parakeratosis (Imani et al., 2017). Considering these issues, 75% of the particles in the initial diet should exceed 1190 μm in diameter (Porter et al., 2007). Textured starter feeds are fermented more slowly and are less likely to lower rumen pH than finely ground, heat-treated and/or pelleted starters (Hill et al., 2012). Therefore, providing forage to calves fed with textured starter feed may adversely affect growth and feed consumption, which may slow down rumen development. There are many

textured starters available in the markets and it is difficult to predict whether these feeds will optimize rumen development. Therefore, chaffed forage together with a pelleted starter may offer an alternative to prevent abnormal growth of rumen epithelium without using a texturized starter (Castells et al., 2012; Terre et al., 2015; Imani et al., 2017). Recently, Toledo et al. (2020) found that growth performance and ruminal and intestinal development were increased in calves fed with a small particle pelleted starter feed and grass hay from the age of 21 days. On the other hand, Leao et al. (2020) indicated that 5% of grass hay together with started feed in different forms did not affect starter feed consumption, animal performance, rumen pH, rumen ammonia nitrogen and organic acids, the weight of internal organs (% of empty body weight) and calf gastrointestinal system development.

CONCLUSION

Although providing forage to calves in the pre-weaning period is still a controversial practice, considering the physical stimulation effect of forage and the benefits it provides to rumen development and adequate rumination, it is considered as an important issue to be offered in amounts that do not suppress the intake of starter feed. Therefore, calves should have starter feed consumption and access to water from 3 days of age and it is recommended that forage should also be supplied in separate feeders at the same time. It is recommended that the forage consumption during this period should not exceed 5% of the total solid feed DM consumption. It is also reported that lower quality forage was a better option. Calves fed with pelleted starter formulations can benefit from the buffering effect of forage. It is thought that calves fed with textured starter grain did not need forage.

CONFLICT OF INTEREST

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of paper.

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