2022, Scienceline Publication
World's Veterinary Journal
World Vet J, 12(2): 123-127, June 25, 2022
ISSN 2322-4568
DOI: https://dx.doi.org/10.54203/scil.2022.wvj15

Forage for Pre-weaning Calves: An Update

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REVIEW ARTICLE
pii: S232245682200015-12
Received: 00 27 March 2022
Accepted: 18 May 2022

ABSTRACT

Forage nutrition for pre-weaning calves hosts numerous practical questions and on-farm challenges. The present review article aimed to update and address the biological consequences of forage provision to pre-weaned dairy calves. Health, nutrient intake (milk plus solid feed), and rumen development are the most important factors related to calf growth in pre- and post-weaning periods. A growing body of evidence suggests that the health and growth performance of dairy calves in the pre-weaning period are associated with their later performance as dairy cows. It seems that starter feeding strategies, including grain type, processing method, feed texture, and forage inclusion during the critical pre-weaning period may have profound effects on rumen function and calf performance. It is well understood that grain fermentation by-products are essential for increased growth and absorptive capacity of the rumen papillae. Forage provision as a part of a starter diet has been a topic of recent research. The rumen pH is the main factor altering the fate of fermentation and eventually animal health. In the pre-weaned calf, two major hypotheses exist regarding forage feeding. The first hypothesis describes that the rumen is not completely developed in pre-weaned calves and forage provision during this period might increase gut fill, and hence, decrease starter intake. It is believed that depressed starter intake may limit energy intake and finally suppress calf growth rate. The second hypothesis indicates that the rumen pH may decline as calves age and starter intake increases. Accordingly, forage inclusion in calf starter diets could prevent further rumen pH decline and subsequent negative consequences while improving starter intake and calf growth. Research data regarding these hypotheses are controversial. Many factors, such as milk feeding method, grain, forage type, and experimental conditions could affect calf responses to dietary forage. The current review focused on the biological consequence of forage provision to young calves to provide a practical framework for better use of forages in pre-weaned calves feeding programs.

Keywords: Forage, Growth, Pre-weaned calf, Rumen development

INTRODUCTION

Raising dairy heifers with a proper growth rate (800-900 g/d) for calving between 22-24 months of age is the main goal of commercial dairy heifer raising programs (Akins, 2016). Greater milk yield in the first lactation is partly attributed to higher growth rates in the early stages of life (Soberon et al., 2012). Reaching these goals is mainly dependent on calf feeding strategies during pre- and post-weaning periods. In the last two decades, most calf studies have focused on milk feeding strategies to increase the average daily gain (ADG) during the pre-weaning period. However, it should be considered that solid feed intake and the resulting rumen development are key factors determining calf growth in both pre- and post-weaning periods (Khan et al., 2016). Solid feed consumption in restricted milk-fed calves, has a critical role in supplying energy and protein to the growing calf. Also, in intensified milk-fed calves, enough starter feed intake is essential for successful weaning and post-weaning performance (Khan et al., 2011a). As a result, the quantity, quality, and chemical composition of starter feed provided to dairy heifers could affect their feed intake, rumen development, and subsequent performance.

In addition to concentrates (grain and protein supplements), forages in calf diets can influence rumen development and calf performance. It is believed that forage provision to young calves increases rumen muscularity, volume, and motility needed for optimal rumen development (Beiranvand et al., 2014). In terms of calf performance, feeding forages to pre-weaned calves may have controversial consequences. There is some evidence that forage inclusion in calf diets up to 5% limits feed intake and decreases the growth of calves from 28-56 d of age (Hill et al., 2008). In weaned calves, lower ADG was observed for calves fed 15% hay versus those fed 4.5 to 5% dietary roughage (Hill et al., 2009). In contrast, desirable ruminal pH and improved growth performance were observed when calves were fed different sources of forages as a free choice or mixed rations (Overvest et al., 2015; Omidi-Mirzaei et al., 2018). The contradictory results observed in such research can be partly attributed to the milk feeding method and the age at which the calves were

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weaned. Since milk and solid feed intakes are negatively correlated, feeding different amounts of milk or milk replacer may affect calf response to dietary fiber. On the other hand, as calves age, feed intake increases over time; hence, the duration of the pre-weaning period and weaning time could affect nutrient intake. It can be hypothesized that differences in the duration of solid feed intake may alter the rumen environment, causing different metabolic responses. Additionally, it has been reported that forage source, level, and feeding methods as well as the physical form of the starter diet affect rumen development and calf performance (Diao et al., 2019). Consequently, calf response to dietary fiber is not arbitrary and depends on a variety of nutritional factors. It is important to note that forage intake and rumen pH are interrelated. Thus, forage provision may play a critical role in stabilizing rumen pH and promoting optimal rumen health and calf performance (Terre et al., 2015).

Rumen pH is an important factor affecting the host ruminant health and performance (Laarman et al., 2011). It seems that the ruminal acidosis during pre-weaning and weaning transition periods occurs in a way similar to dairy cows (Galsinger et al., 2020). Moreover, its signs are also similar. Providing forages depending on their source, level (5-15%, in general), and method of feeding has the potential to modulate rumen pH and promote starter intake and growth of pre-weaned calves (Imani et al., 2017). However, in a study investigating the physical form of the starter feed on calf performance, significant amounts of fine starter particles were reported as the main factor affecting intake and ADG (Bateman et al., 2009). It has been recommended that to prevent rumen parakeratosis and bloat, 75% of starter particle size should exceed 1190 µm in diameter (Porter et al., 2007). The variability of rumen pH and occurrence of ruminal acidosis in response to different dietary treatments can be more complicated given that salivary glands are not completely functional in young calves (Khan et al., 2016). For example, parotid glands' ability to produce sufficient amounts of saliva is still low even by 4 weeks of age (Kay, 1960). Consequently, the age at which forages are provided to the calves may be an important factor influencing their metabolic and productive responses. Overall, new studies suggest that fibrous sources such as oat hay provision to pre-weaned calves can improve rumen fermentation parameters, allowing calves to pass the weaning transition successfully (Gasiorek et al., 2020).

Because calf performance in the pre-weaning period is associated with post-weaning growth performance and later dairy herd productivity, the physiological effects of forage feeding on the digestive tract of pre-weaned calves will be reviewed in this article also. Determining optimal types, levels and particle sizes of forages offered in the pre-weaning period requires much future research.

DIETARY FIBER, RUMEN PHYSIOLOGY, AND CALF GROWTH

Weaning is an important period in a dairy calf's life in which milk dependency is disrupted and calves have to meet their energy and protein requirements through solid feed consumption. Calves suffer much from the weaning distress unless the digestive tract adapts properly to ferment and assimilate solid feeds eaten before weaning (Baldwin et al., 2004). Rumen development is a key factor in allowing calves to wean successfully (Nikkhah and Alimirzaei, 2022). Just after birth, the rumen is inactive, but it undergoes extensive metabolic and physical changes over time by initiating solid feed consumption. The type, physical form, and chemical composition of concentrates and forages offered to calves can differently affect rumen development and fermentation patterns. However, in general, starter feeds rich in grains stimulate the rumen epithelium and papillae growth, leading to increased absorptive capacity (Baldwin et al., 2000). Stimulatory effects of grain feeding on the rumen epithelial growth are related to their fermentation end-products profile. It has been shown that volatile fatty acids (VFA; mainly butyric, propionic, and acetic acids) produced by the ruminal anaerobic metabolism are responsible for the proliferation and differentiation of the rumen papillae (Warner et al., 1956). Amongst VFAs, butyric acid is exclusively metabolized in the rumen epithelial cells and is considered a major promoter of papillae differentiation (Baldwin et al., 2004). Butyric acid accompanied by propionic and acetic acids have a direct role in the expression of enzymes involved in the rumen epithelial cells' growth and differentiation (Connor et al., 2013). With these findings, pre-weaning calves can benefit from feeding high grain diets. On the other hand, in a study conducted to evaluate the rumen mucosal absorptive capacity, increased acid absorption was observed when the solution pH decreased from 7.5-8 to 5-5.5 (Sutton et al., 1963). Starch sources and levels in starter diets as well as feed processing methods could affect molar proportions of VFA in the rumen, resulting in altered rumen pH (Lesmeister and Heinrichs, 2004). The accumulation of fermentation products and subsequent lower ruminal pH increases rumen fluid osmolality, causing bacterial death and finally decreased feed intake (Carter et al., 1990). In addition, lower ruminal pH can impair rumen motility and induce papillae keratinization, resulting in lower blood flow to the rumen papillae, and thus, decreased nutrient absorption (Khan et al., 2016).

In adult dairy cows, adequate dietary fiber is required for preventing durable rumen pH decline and acidosis. Although the actual need for dietary fiber has not yet been determined well in young calves, forage provision is recommended to avoid acidosis (McBurney et al., 1983; Castells et al., 2012). Additionally, it has been illustrated that the severity of sub-acute ruminal acidosis can be mitigated by including small amounts of forages in calf diets (Laarman et al., 2011). In another study, increased ruminal pH in pre- and post-weaning periods was reported by feeding forages

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(Khan et al., 2011b). Dietary fiber, especially from forage sources, potentially promotes chewing activity and saliva flow to the rumen which can neutralize protons produced in the rumen and increase ruminal pH (Lin et al., 2018). In addition to the modulatory effect of dietary fiber on rumen pH, forage provision impacts rumen muscularity and physical structure (Heinrichs, 2005). In this regard, larger particle size and higher amounts of dietary effective fiber increase rumen motility. Overall, rumen maturation from metabolic and physical perspectives is essential for subsequent calf growth and development in the post-weaning period.

The growth performance of young calves may be affected by dietary fiber. As discussed above, calves respond differently to forage provision depending on starter feeds and forages' chemical as well as physical features. Interaction of dietary forage with other diet ingredients may cause differences in calf performance. For instance, the supplemental fat source may interact with dietary forage (Karimi et al., 2021). Calves fed soybean oil containing 51% linoleic acid (C18:2) had the lowest starter intake and ADG during the pre-weaning period. Decreased feed intake and growth rate reported in studies concerning forage provision to pre-weaned calves may be associated with gut fill and limited energy intake (Xiao, 2020). It seems that the time at which forages are included in the diet could influence calf performance. In a recent study conducted to determine the optimal time of forage feeding, results indicated that the provision of wheat straw on d 21 had a significant effect on calves weaning body weight (Ghahremani et al., 2021). Forage provision should be considered with starter feed particle size, as well. It seems that forage effects can be more profound when starter feed is too fine and readily fermentable in the rumen, which can elevate acid production and reduce the rumen pH. In a recent study, starter intake decreased by including forage in whole corn grain-based starters, implying that forage provision may be more effective when diet ingredients are finely ground (Gholizadeh et al., 2021). More research is needed to understand how much roughage should be included in the dairy calf diet and what the best forage particle sizes are for pre- and post-weaning calves.

CONCLUSION

A successful post-weaning performance is dependent on proper rumen development in the pre-weaning period. Providing forages to young calves may promote rumen development needed for optimal feed intake, rumination, and nutrient absorption. The level and particle size of forage supplied to the young calf should be orchestrated in accordance with the gain source in the starter diet. These will require future research to be optimally determined.

DECLARATIONS

Acknowledgments

The authors thankfully acknowledge Behroozi Dairy Farm's management (Tehran, Iran) for providing field and research facilities and support for the study.

Authors' contribution

The authors contributed equally to this work including conceptualization, review strategic contemplation, writing development, editing, and revising. Akbar Nikkhah led the project.

Competing interests

None.

Ethical considerations

Ethical considerations (e.g., plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy) have been made by the authors.

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