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Invited review: Transitioning from milk to solid feed in dairy heifers

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ABSTRACT

Calves are born with a physically and metabolically underdeveloped rumen and initially rely on milk to meet nutrient demands for maintenance and growth. Initiation of solid feed consumption, acquisition of anaerobic microbes, establishment of rumen fermentation, expansion of rumen in volume, differentiation and growth of papillae, development of absorption and metabolic pathways, maturation of salivary apparatus and development of rumination behavior are all needed as the calf shifts from dependence on milk to solid feed. In nature and some production systems (e.g., most beef calves), young ruminants obtain nutrients from milk and fresh forages. In intensive dairying, calves are typically fed restricted amounts of milk and weaned onto starter feeds. Here we review the empirical work on the role of feeding and management during the transition from milk to solid feed in establishing the rumen ecosystem, rumen fermentation, rumen development, rumination behavior, and growth of dairy calves. In recent years, several studies have illustrated the benefits of feeding more milk and group rearing of dairy calves to take advantage of social facilitation (e.g., housing with peers or dam), and this review also examines the role of solid feed on rumen development and growth of calves fed large quantities of milk and reared under different housing situations. We conclude that the provision of high-starch and low-fiber starter feeds may negatively affect rumen development and that forage supplementation is beneficial for promoting development of the gut and rumination behavior in young calves. It is important to note that both the physical form of starter diets and their nutritional composition affect various aspects of development in calves. Further research is warranted to identify an optimal balance between physically effective fiber and readily degradable carbohydrates in starter diets to support development of a healthy gut and rumen, rumination behavior, and growth in young calves.
Key words: calf starter feed, dietary transition, neonatal growth, rumen development

INTRODUCTION

On many dairy farms, calves are separated from their dams at birth and reared artificially. Unfortunately, dairy calves are at a great risk of morbidity and mortality, especially during the milk-feeding period and the weeks after weaning (USDA, 2009). Many producers wean calves at a young age to reduce costs associated with feeding milk or milk replacer, but calves are born with a nonfunctional rumen and must initially rely exclusively on milk to meet the nutrient demands of maintenance and growth. A smooth transition from liquid to solid feed allows calves to consume and digest sufficient solid feed to support growth during and after weaning; this transition requires the physical and metabolic development of the rumen and coincides with the development of the salivary apparatus, rumination behavior, and several physiological adjustments at the gut, hepatic, and tissue levels (Baldwin et al., 2004; Khan et al., 2011a).

The nature of solid feed and the amount consumed can influence rumen development. Highly palatable “starter” feeds, containing easily fermentable carbohydrates, are thought to stimulate rumen development, including changes in the epithelium of the forestomach (Baldwin et al., 2004; Drackley, 2008). In contrast, calves reared by their dams in extensive housing systems (e.g., cow-calf operations) and young ruminants artificially reared in pastoral systems would not typically have access to starter feeds. Under forage-based livestock production systems, forage quality and availability determines the need for supplementary feeds (e.g., concentrate through creep feeding) to support growth of young ruminants. However, in nature and where permitted (e.g., pastoral systems or cow-calf operations), milk and pasture provide the majority of the stimulants and nutrients required for development and growth to young ruminants.

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Table 1. List of fiber sources, their physical form, and inclusion levels in the diets of calves evaluated in some studies

Class	Forage	Inclusion rate, % of DM	Physical form of forage	Age of calves, d	Reference
Legume hay					
	Alfalfa hay	66.7	Pelleted	7	Addanki et al., 1966
	Alfalfa hay	Ad libitum	Chopped	10	Anderson et al., 1982
	Alfalfa hay	25–50	Ground, long	35	Bull et al., 1965
	Alfalfa hay	20–70			Žitnan et al., 1998
	Alfalfa hay	Ad libitum	Chopped	8	Castells et al., 2012
	Alfalfa hay	25			Beharka et al., 1998
Grass hay					
	Orchardgrass	Ad libitum	Chopped	3	Khan et al., 2011b
	Grass hay	15–30	Chopped		Suárez et al., 2006a,b
	Grass hay	5–15	Chopped	5 or 56	Hill et al., 2008a
	Ryegrass hay, oats hay	Ad libitum	Chopped	8	Castells et al., 2012, 2013
	Grass hay	Ad libitum	Chopped	6–8	Kosiorowska et al., 2011
	Bromegrass hay	7.5–15	Chopped	5	Coverdale et al., 2004
Grass and legume blend					
	Alfalfa and timothy hay	67		3	Hibbs et al., 1956
	Alfalfa and grass hay	15			van Ackeren et al., 2009
	Grass legume silage	67		3	Conrad and Hibbs, 1956
Silage					
	Corn silage	30–60			Suárez et al., 2006a,b
	Corn silage	33.7		Birth	Block and Shellenberger, 1980
	Corn silage, triticale silage	Ad libitum		8	Castells et al., 2012
Straw					
	Barley, rye, wheat	5–60			Jahn et al., 1970
	Barley straw	15–30	Chopped	10	Suárez et al., 2006a,b
	Barley straw	Ad libitum	Chopped	8	Castells et al., 2012
Pasture/fresh grass					
	Pasture	Ad libitum		4	Pounden and Hibbs, 1949
	Pasture	Ad libitum			Conrad and Hibbs, 1956
	Ryegrass	Ad libitum		7	Phillips, 2004
Other fiber sources					
	Beet pulp	66.7	Pelleted	7	Addanki et al., 1966
	Beet pulp	30.3–91.3	Ground		Suárez et al., 2006a,b
	Corn cobs	56.7	Ground		Conrad and Hibbs, 1956
	Cottonseed hull	5–10		5 or 56	Hill et al., 2008a,b
	Soybean hulls	15.5–46.4	Pelleted		Suárez et al., 2006a,b
	Wood pulp fines	11		Birth	Block and Shellenberger, 1980
	Cottonseed hull	15		2	Hill et al., 2009

To our knowledge, no review has summarized research on the role of forage, concentrate, and feeding management on rumen development and performance of dairy calves during the transition from milk to solid feed. The current paper has 3 aims; first, to review the available literature on the role of solid feed and feeding management in establishing rumen fermentation; second, to understand how solid feeds affect the development of the digestive tract and rumination behavior; and third, to discuss how the nature of solid feed (concentrate and forage) and feeding management affect growth of dairy calves.

ROLE OF CONCENTRATE AND FORAGE IN ESTABLISHING RUMEN FERMENTATION

A list of fiber sources, their physical form, and inclusion levels in the diets of calves evaluated in selected studies is provided in Table 1. The effects of concentrate and forage on rumen development parameters (rumen weight and papillae growth, rumen motility and passage rate, rumen bacteria, rumen protozoa, fermentation end products, rumen pH, and buffering capacity) are summarized in Table 2.

Anaerobic Rumen Microbial System

At birth, young ruminants possess no anaerobic microbial population in the rumen. Establishment of rumen microbiota is necessary for the physiological development of the rumen and for the animal's ability to convert plant mass into products that can be utilized by the animal for maintenance and production (Jami et al., 2013). In adult ruminants, the rumen contains a complex anaerobic microbial ecosystem comprising various species of bacteria, protozoa, and fungi. During