J. Dairy Sci. 98:1–11
http://dx.doi.org/10.3168/jds.2014-9144

Rumen fermentation, blood metabolites, and growth performance of calves during transition from liquid to solid feed: Effects of dietary level and particle size of alfalfa hay

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ABSTRACT

This study evaluated the effects of particle size (PS) and dietary level of alfalfa hay (AH) on rumen fermentation parameters, blood metabolites, eating behavior, and growth performance in dairy calves during transition from liquid to solid feed. Sixty newborn dairy calves (41 ± 2.5, kg of body weight) were used in a 2 × 2 factorial arrangement with the factors dietary AH level (medium, 12.5%, or high, 25%, on DM basis) and PS (fine = 1 mm or medium = 3 mm, as geometric means) of AH. Hence, the dietary treatments were (1) medium level of AH with fine PS (M-FPS), (2) medium level of AH with medium PS (M-MPS), (3) high level of AH with fine PS (H-FPS), and (4) high level of AH with medium PS (H-MPS). Particle size of AH did not affect total DMI (TDMI) during the preweaning period, although TDMI was greater for calves fed MPS than in those fed FPS during the postweaning and overall periods. Calves fed MPS spent more time eating solid feed and ruminating and less time on nonnutritive oral behaviors compared with FPS calves. The dietary level of AH did not affect behavioral parameters. Average daily gain of calves was not affected by dietary treatment before weaning. During the postweaning and overall periods, average daily gain was greater in calves fed MPS than in those fed FPS at the 25% AH level, but this effect was absent with 12.5% AH. Furthermore, the rumen pH values on d 35 and 70 of the study were greater for MPS than for FPS, regardless of the dietary level of AH. Effects of AH level, PS, and their interaction did not affect blood glucose concentrations in developing calves. These results indicate that feed intake, feeding behavior, rumen fermentation parameters, and blood β-hydroxybutyrate concentration may be affected by rations differing in forage PS; thus, providing calves with MPS can improve calf performance and reduce their nonnutritive oral behaviors.
Key words: alfalfa hay, particle size, dairy calf

INTRODUCTION

Physical and metabolic development of the reticulorumen in young calves is the prerequisite to their transition from a preruminant milk diet to a solid diet based on grain forage (Drackley, 2008). Although rumen development in young calves is affected by many factors (Baldwin et al., 2004), it is mainly dictated by the amount and nature of the solid feed offered (Khan et al., 2011). Development of the rumen epithelium is triggered by the VFA produced during microbial fermentation of ingested solid feed in the rumen (Baldwin et al., 2004). Development of rumen musculature, rumen movements, and the capacity of the rumen are influenced by the physical stimuli provided by the bulk of the ingested material (Beharka et al., 1998).

Cereal-based starter diets generally contain higher levels of fermentable carbohydrates than forages, which provide greater amounts of VFA to stimulate rumen papillae when they ferment in the rumen (Lesmeister and Heinrichs, 2004; Khan et al., 2008). Ingestion of forage provides bulk in the rumen and thereby promotes rumen musculature and helps maintain the integrity of the rumen epithelium in developing calves (Beharka et al., 1998; Beiranvand et al., 2014b). Forage provision to young calves is generally discouraged because forage is less energy intensive and digestible compared with starter diets, and could, therefore, delay rumen epithelial development and suppress growth in young ruminants (Stobo et al., 1966; Hill et al., 2008, 2009). Furthermore, the guidelines of National Research Council (NRC, 2001) do not include any recommendations for fiber provision for developing calves. However, recent studies have demonstrated beneficial effects of

Received November 23, 2014.
Accepted April 21, 2015.
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feeding forage (grasses and legumes) early in life on rumen fermentation (Castells et al., 2013; Terré et al., 2013), rumen pH (Laarman and Oba, 2011), rumen development, feed consumption, and growth performance (Khan et al., 2011; Castells et al., 2012; Montoro et al., 2013; Beiranvand et al., 2014b). Furthermore, Castells et al. (2013) reported increased expression of a VFA transporter (mono-carboxylate transporter 1) in the rumen epithelium of calves that had access to forage compared with calves fed pelleted starter without forage. Previous studies (Castells et al., 2013; Beiranvand et al., 2014a,b) have shown enhanced concentrate intake and growth performance in young calves supplemented with forage. Particle size (**PS**) of the dietary forage affects the rumen environment, with high amounts of long and coarse forage resulting in decreased intake because of gut fill in dairy cows (Mirzaei et al., 2015). This may also apply to dairy calves, especially because of the limited capacity of their reticulorumen (Beharka et al., 1998; Godden et al., 2009).

We hypothesized that PS of alfalfa hay (**AH**) in the diet with rapidly degradable starch, as in barley grain, may have the potential to modify rumen conditions and to improve the performance of dairy calves. Hence, 2 levels of PS (fine and medium) were combined with 2 levels of AH (12.5 and 25% of dietary DM) in forage-supplemented diets to investigate their interaction on feed intake, rumen fermentation parameters, feeding behavior, and growth performance in dairy calves.

MATERIALS AND METHODS

The experiment was conducted on a local dairy farm (Ghiam Esfahan Plantation and Domesticated Co., Isfahan, Iran). All the calves were cared and managed according to the guidelines of Iranian Council of Animal Care (1995).

Calves, Management, and Treatments

Sixty 3-d-old Holstein male dairy calves (41 ± 2.5 kg of BW) were separated from their dams, weighed, and moved to individual pens (1.2 × 2.5 m) bedded with sawdust that was renewed every 48 h. The animals were fed 3 to 4 L of colostrum within 2 to 6 h after birth. Colostrum feeding continued for the first 2 d of life. Calves were fed whole milk (4 L/d), at a rate of 10% of BW, containing 3.22 ± 0.11% fat, 2.96 ± 0.07% CP, 4.92 ± 0.05% lactose, and 11.77 ± 0.15% TS in steel buckets twice daily at 0900 and 1700 h from d 3 to 47, followed by morning feeding (2 L/d) from 47 to 50 d of age before being weaned on d 51 of age.

The calves were randomly assigned (n = 15 per treatment) in a 2 × 2 factorial arrangement to a medium (12.5% on DM basis) and a high dietary level of AH (25% on DM basis) with a fine (1 mm; geometric mean) or medium PS (3 mm; geometric means). Calves were assigned to 1 of 4 treatments: (1) medium level of AH with fine PS (**M-FPS**), (2) medium level of AH with medium PS (**M-MPS**), (3) high level of AH with fine PS (**H-FPS**), and (4) high level of AH with medium PS (**H-MPS**). The ingredient and chemical composition of the experimental diets are shown in Table 1. All the diets were formulated and to be isoenergetic and isonitrogenous according to the Cornell Net Carbohydrate and Protein System version 5.1 (Fox et al., 2000). For the first 16 d, all calves received the starter diet without forage provision. From d 16 onward, AH was mixed with finely ground concentrates and provided as a TMR. Starter containing AH (TMR) was fed ad libitum to permit at least 10% orts (i.e., the portion of the starter not consumed over a 24-h period), and TMR feed refusal from each individual calf was collected at 0800 h. Calves had ad libitum access to water and starter throughout the study. Before the experiment, AH was chopped (Golchin Trasher Hay Co., Isfahan, Iran) to obtain fine (1 mm, geometric mean) and medium (3 mm, geometric mean) PS. At least 6 representative samples were collected from each PS and used for analyzing PS distribution of AH by the Penn State Particle Separator (PSPS; Table 2). Geometric mean PS was calculated as described by the American Society of Agricultural Engineers (ASAE, 1996; method S424.1).

Sampling

Intakes of calf starter (forage and starter feed, as TMR) and total DMI (milk, starter feed, and forage) were measured daily and BW were recorded weekly during the preweaning (wk 1 to 7), postweaning (wk 8 to 10), and overall periods (wk 1 to 10). Amounts of feed offered and refused were recorded daily for each individual calf. Preweaning, postweaning, and overall means of total DMI (milk solids, starter feed), ADG, and feed efficiency (kg of BW gain/kg of total DMI) were also calculated.

Body measurements at weaning (d 51) and at the end of the study (d 71), including body length (distance between the points of shoulder and rump), body girth (the measurement of the distance around the belly over the part of the back before morning feeding), withers height (distance from base of the front feet to the withers), heart girth (circumference of the chest), hip height (distance from base of the rear feet to hook bones), and hip width (distance between the points of hook bones), of the calves were performed according to the method described by Khan et al. (2007).