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Effects of substituting grain with forage or nonforage fiber source on growth performance, rumen fermentation, and chewing activity of dairy calves

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ABSTRACT

The optimum level of fiber source supplementation in calf starter is beneficial for promoting rumen development and growth performance of young calves. This study evaluated the effects of replacing grain sources (mainly barley) with forage [alfalfa hay (AH)] or nonforage [beet pulp (BP)] fiber source on rumen parameters [pH, and short chain fatty acid (SCFA)], blood metabolites [glucose, and β-hydroxybutyrate (BHBA)], chewing activity (ruminating, eating, and total chewing), intake, and growth in pre- and postweaning dairy calves. Fifty-two male Holstein calves with 4 d of age and 41.7 ± 3.3 kg body weight (BW) were randomly assigned to 4 treatments. The 4 starters were formulated with similar crude protein [CP, 190 g/kg dry matter (DM)] and metabolizable energy value [(ME), 13.3 MJ/kg DM], but different in fiber sources and levels. Treatments were a basal starter with no fiber source [CON, 141 g neutral detergent fiber (NDF)/kg DM], or with 100 g AH/kg DM (AH-100, 171 g NDF/kg DM), 100 g BP/kg DM (BP-100, 171 g NDF/kg DM), and 200 g BP/kg DM (BP-200, 199 g NDF/kg DM). All the calves were offered 5 L of milk/d from d 3–45, and 2.5 L/d from d 46 until weaning on d 50. The study finished when calves were 70 d old. Compared with CON calves, calves in the AH-100 treatment tended to consume less starter feed, and exhibited significantly lower average daily gains (ADG), BW, and some structural growth measurements in overall period, calves in the BP-100 treatment tended to consume more starter, and had greater ADG, BW, and blood glucose in the pre-weaning period. Growth and feed intake were not affected during the postweaning period or with increasing the level of BP in the diet. Dietary treatment did not alter significantly total SCFA concentration or SCFA proportions on d 35. However, rumen molar proportion of acetate increased and that of butyrate decreased in calves fed either of fiber sources on d 70. Moreover, molar proportion of propionate and acetate to propionate ratio decreased in calves fed either the BP-100 or the BP-200 on d 70. Rumen pH, and eating and ruminating time were greater for calves receiving the AH-100 diet than those receiving the CON diet. Feeding either level of BP had no effect on chewing activity but tended to increase rumen pH during the preweaning period. No significant effect of AH supplementation was observed on BHBA although

Abbreviations: AH, alfalfa hay; BP, beet pulp; CON, starter with no fiber source control; AH-100, starter with 100 g AH/kg; BP-100, starter with 100 g BP/kg; BP-200, starter with 200 g BP/kg; ADF, acid detergent fiber; aNDF, neutral detergent fiber; peNDF, physically effective NDF; CP, crude protein; NFC, non-fiber carbohydrates; DM, dry matter; DMI, dry matter intake; ME, metabolizable energy; ADG, average daily gain; BW, body weight; BHBA, β-hydroxybutyrate; BUN, blood urea nitrogen; SCFA, short chain fatty acid.

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a decreasing trend was observed by supplementation of BP at the post-weaning period. In summary, chewing time, and rumen acetate and pH increased, but daily gain decreased as a result of supplementing 100 g AH/kg DM in the starter feed. Added NDF from BP source did not affect chewing activity but tended to increase preweaning rumen pH and growth performance (100 g BP/kg DM), and had no effect on theses parameters in the postweaning period.

1. Introduction

Calves are born with a physically and metabolically underdeveloped rumen so that all, or essentially all their nutrient requirements are met by liquid feeds (milk or milk replacer). The quality of these feeds is preserved by a functional esophageal groove that allows the liquid feed to bypass the rumen . A smooth transition from liquid to solid feed (grain or forage) allow the calves to consume and digest sufficient solid feed to support growth during and after weaning (Khan et al., 2016). However, this transition requires 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 the rumination behavior (Baldwin et al., 2004; Khan et al., 2016). In nature, where calves are reared with their dam, milk and fresh forages provide the major portion of the nutrients required for the animal's development and growth. Under these rearing conditions, calves start grazing and ruminating at approximately 3 wk of age and regularly graze, and cattle wean their calves when they are approximately 8–10 months of age (Reinhardt and Reinhardt, 1981). However, in intensive dairying, highly palatable "starter" feed, which is relatively high in readily fermentable carbohydrates, is fed to stimulate dry feed consumption and rumen development (NRC, 2001; Drackley, 2008). Feeding readily fermentable carbohydrates, such as starch and sugar, to calves increases propionic and butyric acids in the rumen and improves ruminal epithelial development (Heinrichs and Lesmeister, 2004; Liu et al., 2016). Forage feeding has been discouraged, based on research showing lower starter intake and poorer weight gains in calves provided forage (Zitnan et al., 1998; Phillips, 2004). However, feeding forages stimulates rumen muscularization, enhances its volume and motility, promotes rumination, maintains the integrity and healthiness of the rumen wall, and reduces behavioral problems (Phillips, 2004; Castells et al., 2012; Montoro et al., 2013). On the other hand, consuming starter feeds containing a high proportion of grains, increase lactic acid production and reduce ruminal pH and microbial diversity, decrease rumen motility, and cause hyperkeratinization in pre-weaning calves (Kay et al., 1969; Greenwood et al., 1997). Hyperkeratinization in conjunction with rumen acidosis reduces the activity of rumen papillae needed for nutrient absorption (Greenwood et al., 1997). These may be the reasons reported in some recent studies underlying the improved ADG, DMI, and feed efficiency when forage is introduced in low-NDF starter feeds (Castells et al., 2012; Coverdale et al., 2004; Khan et al., 2011). However, adding forage to starter diets not only changes the fiber content but also has a diluting effect on energy concentration. Thus, the response of animal could be confounded by the effects of fiber (rumen fill and DMI) and energy concentrations. Calf starters should have a high energy density (13.7 MJ ME/kg DM) in order to cover the animal's maintenance needs and to allow for maximum ADG, especially during the first 2 months of life (NRC, 2001). Forage is less energy-intensive than calf starter feed because of its high NDF content and less digestibility. Hill et al. (2008) offered a low NDF starter diet (141 g/kg) in conjunction with different sources of fiber sources (up to 213 g NDF/kg) to young dairy calves and reported that adding low energy fibrous feeds to starters led to reduced ADG in calves weaned below 3 months of age. Beet pulp (BP) contains a high proportion of insoluble fibers (473 g NDF/kg) and is unique in its high concentration of neutral-detergent soluble fiber, especially pectic substances (235 g/kg) (NRC, 2001). Both fractions in beet pulp are highly digestible in the rumen, and they can be used to supply fermentable fiber in the diet (Bradford and Mullins, 2012). Moreover, beet pulp is often used to reduce the starch content in dairy cattle diets. Inclusion of beet pulp in lactation diets allows the formulation of high NDF diets of high energy density (Voelker and Allen, 2003). Offering BP in starter diet may assuage the negative effects of increased starch fermentation without increasing the filling effect of the diet to the level commonly observed with forage. However, the average effective value of NDF from nonforage was about 50 percent of that for NDF from forage (Mertens, 1997). The present study is dedicated to the evaluation of the potential benefits of supplementing BP in isocaloric starter feeds on rumen parameters, chewing activity, and performance of young milk calves. The results obtained from the fiber source of BP (100 and 200 g/kg DM) are compared with those of alfalfa hay (100 g/kg DM).

2. Materials and methods

2.1. Calves, diets, and management

A total of 52 male Holstein calves were separated from their dams immediately after birth, and kept in individual pens (1 × 2 m) bedded with wood shavings. Bedding was replenished and replaced every 24 or 48 h as required . All the calves received 3–4 L of colostrum within 2–6 h after birth. The study began when calves were 4 d old and 41.7 ± 3.3 kg of BW. On the 4th d, the calves were randomly assigned to 4 treatment s : control starter with no fiber sources (CON), a starter where