J. Dairy Sci. 101:1–9
https://doi.org/10.3168/jds.2018-14583

Relationships between starch concentration of dry feed, diet digestibility, and growth of dairy calves up to 16 weeks of age

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ABSTRACT

Our objective was to examine the potential relationship between starch concentration of dry feed and growth performance of young dairy calves via mixed-effects model analyses. A database was developed from 6 published studies conducted at the Nurture Research Center, Provimi (Brookville, OH), from 2008 to 2017 that included 18 dietary treatments and 372 calves at 0 to 8 wk of age in 5 nursery trials and 26 dietary treatments and 660 calves at 8 to 16 wk of age in 8 grower trials. The dry feeds ranged from 10.1 to 53.3% starch, 12.1 to 45.3% neutral detergent fiber, and 2.7 to 3.0 Mcal/kg of metabolizable energy [dry matter (DM) basis]. In all nursery trials, with increasing starch concentration in starter, average daily gain (ADG), hip width change, and starter intake linearly increased. In all grower trials, as starch concentration of dry feed increased, ADG, hip width change, and ADG/DM intake linearly increased; DM intake and DM intake/body weight were unaffected. In addition, the calves at 6 to 16 wk of age had greater digestibility of DM and crude protein with increasing starch concentration of dry feed. As indicated by meta-regression analysis, growth responses to starch concentration were influenced by metabolizable energy concentration in dry feed fed to the calves up to 16 wk of age. Changing starch from 23 to 43% on a DM basis (a typical range in the US industry) was predicted to increase ADG and hip width change by 5.8 and 5.0%, respectively, for calves at 0 to 8 wk of age and by 9.6 and 11.2%, respectively, for calves at 8 to 16 wk of age. Positive linear relationships between starch concentration of dry feed with DM digestibility, ADG, and hip width change reflect the importance of starch in the diets of young dairy calves.
Key words: performance, calf, starter, mixed-effects model

INTRODUCTION

Young calves face tremendous physiological and metabolic challenges during the transition from milk-fed preruminants to functional ruminants. Appropriate nutrition management for calves is thus essential in successful rearing programs for dairy producers. Dry (starter) feed consumption initiates and promotes rumen development. It is suggested that relatively high concentrations of readily fermentable carbohydrates adequate in digestible fiber should be included in starter diets to support fermentation necessary for proper ruminal tissue growth (NRC, 2001). In recent years, extensive research has been carried out to examine the effect of varying the source and content of carbohydrate and fiber in starter with addition of different sources and varying amounts of forage (Kosiorowska et al., 2011; Terré et al., 2013; Maktabi et al., 2016) on rumen development, health, and growth performance of calves with the aim of defining the solid feed feeding strategies for pre- or postweaning calves.

Starch supplied mostly by cereal grains represents a large fraction of calf starter diets. Readily fermentable starch in the starter diet fed to calves is fermented in the rumen to produce short-chain fatty acids and, consequently, stimulate rumen development (Kosiorowska et al., 2011). However, high starch intake might result in low rumen pH (Kristensen et al., 2007). Low rumen pH could further induce SARA. It has been reported that adding forage to starter diets improved rumen pH (Kim et al., 2016) and ADG of dairy calves (Terré et al., 2013). Nevertheless, increasing the amount of dietary NDF via addition of fiber in the starter diet, hay provision, or a combination of both would likely reduce the proportion of starch and energy concentration of the diets. This might be a reason why it has also been reported that added hay and cottonseed hulls reduced ADG of dairy calves (Hill et al., 2008a). So far, little information is available regarding the optimal starch concentration of dry feed for obtaining the best rumen development and growth performance. Analyses reported herein are based on data collated from the previous studies, conducted in Nurture Research Center, Provimi (Brookville, OH), in which male Holstein

Received February 12, 2018.
Accepted March 28, 2018.
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calves were fed dry feed with different starch concentrations. The objective of this study was to examine potential relationships between starch concentration of dry feed and growth performance and nutrient digestibility of dairy calves.

MATERIALS AND METHODS

Calves used in all studies were cared for by acceptable practices as described in the previous or current editions of the Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS, 2010).

Database

Data used to examine the potential relationships between starch concentration of dry feed and other variables were collected from the published studies (Hill et al. 2008a,b, 2012, 2016; Suarez-Mena et al., 2011; Dennis et al., 2017), which were conducted at the Nurture Research Center, Provimi, located in southwest Ohio, from 2008 to 2017. The database consisted of 3 subdata sets: (1) nursery (0–8 wk of age; 5 trials including 18 dietary treatments), (2) grower (calves 8–16 wk of age; 8 trials including 26 dietary treatments), and (3) digestibility [nutrient digestibility measured in post-weaned calves at 6–16 wk of age (trial 1 in Suarez-Mena et al., 2011) and grower at 8 to 16 wk of age (Hill et al., 2016)]. Across all trials, results reported the effect of varying starch concentration in calf starter either alone or blended with chopped grass hay (Table 1).

All calves were Holstein males initially less than 1 wk of age and were housed in 1.2 m × 2.4 m individual pens in a curtain-sided, naturally ventilated barn with no added heat. The pens were separated by wire-mesh panels, and the coarse rock, tile-drained floor was bedded with straw. Milk replacer was diluted with water to 12 to 15% (g/L) DM before feeding. Milk replacer was fed to the nursery calves at a rate of 0.454 kg/d (Hill et al., 2008b) or 0.681 kg/d (Hill et al., 2008a; Suarez-Mena et al., 2011) on an as-fed basis, divided equally into a.m. and p.m. feedings for 25 d followed by only the a.m. feeding (once daily, in the morning) at half the total daily amount of the previous milk replacer on d 26 to 28. However, 2 rates of milk replacer (as-fed basis) were fed to the nursery calves in the study of Dennis et al. (2017): (1) 0.66 kg of DM fed in equal amounts twice daily (a.m. and p.m. feeding) for 39 d followed by 0.33 kg of DM fed once daily (a.m. feeding) for 3 d; and (2) 0.87 kg of DM for 5 d and 1.08 kg of DM for 37 d fed in equal amounts twice daily and then 0.43 kg of DM fed once daily (a.m. feeding) for 7 d. Starter and water were offered for ad libitum intake throughout the nursery trial. For all grower trials, calves were randomly assigned to pens with approximately 6.5 m^2 of outside pen space and 0.9 to 1.35 m^2 of inside pen space per calf. Inside pen space was bedded with straw, and there was no added heat. Pen size varied, with 4 calves per pen in some trials (Hill et al., 2012, 2016; Dennis et al., 2017) but 6 calves per pen in the others (Hill et al., 2008a,b; Suarez-Mena et al., 2011). In the grower trials, calves were fed starter either alone or blended with chopped grass hay (Table 1) for ad libitum intake with unrestricted access to water. Detailed management practices, including vaccines or specific treatment applications in each individual trial, could be found in the original studies (Table 1). Mean, standard deviation, and minimal and maximal values for all major selected variables are in Table 2.

Statistical Analysis

In all trials, treatment means of ADG, hip width change, and other dependent variables were used to examine the overall effects of varying starch concentrations across all trials in each of 3 subdata sets. There were several studies (Hill et al., 2012, 2016; Dennis et al., 2017) in which most of the trials were conducted in an experimental design with factorial arrangement of treatments (Table 1). Based on the treatment structure in those trials, an independent comparison of dietary treatments was constructed. Each comparison was considered specifically as a "trial" being included in the statistical model for further analysis, which would be the most appropriate way to detect true response resulting only from varying starch concentration in the diets. Potential relationships between dependent variables such as ADG and starch concentration in dry feed were examined among trials in each of 3 subdata sets using the PROC MIXED model in SAS (SAS Institute Inc., 2012). The model was

$$Y_{ij} = B_0 + B_1X_{ij} + s_i + b_{1i}X_{ij} + e_{ij},$$

where i is the 1, 2, . . ., trials; j is the 1, 2, . . ., n_i observations within trial i; B_0 is the overall intercept among trials (fixed effect); B_1 is the slope of Y on X among trials (fixed effect); X_{ij} is the value of variable X for the jth observation in trial i; s_i is the random intercept effect of trial i; b_{1i} is the random slope effect of Y on X in trial i; and e_{ij} is the error term, assumed to be N (0, σ^2). Trial was considered to be a random effect (St-Pierre, 2001), and significance was declared at $P < 0.05$.

In the mixed-effects model, there are both fixed (intercept and slope) and random (intercept and slope)