Substituting corn silage with reconstituted forage or nonforage fiber sources in the starter diets of Holstein calves: effects on performance, ruminal fermentation, and blood metabolites

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Abstract: We examined the effects of replacing corn silage (CS) with reconstituted alfalfa hay (AH) or beet pulp (BP) in the starter diet on the nutrient intake and digestibility, growth performance, rumen fermentation characteristics, selected blood metabolites, and health status in Holstein dairy calves. Newborn female calves ($n = 54$; 3 d of age; 39.8 ± 1.36 kg BW) were assigned randomly to 3 groups receiving starter diets containing CS [10% dry matter (DM) basis; CS diet] and reconstituted AH (10% DM, RAH diet) or BP (10% DM; RBP diet). The starter diets had the same nutrient composition and DM content. The calves were weaned on day 50 and the study continued until day 70. Nutrient intake, body weight (at weaning and at the end of the study), daily weight gain, feed efficiency, and body measurements (including heart girth, withers height, body length, body barrel, hip height, and hip width) were not affected by the diet ($P > 0.05$). Health-related variables including rectal temperature, fecal score, and general appearance score were not influenced by the diets ($P > 0.05$). During the postweaning period, apparent total tract digestibility of DM, organic matter, and crude protein were higher for

RBP ($P = 0.001$); however, digestibility of neutral detergent fiber was lower in RAH compared with CS or RBP ($P = 0.001$). Daily amount of nutrient digestibility did not change across the diets ($P > 0.05$). Rumen fluid pH and total volatile fatty acid concentration and profile were not different across the diets after weaning ($P > 0.05$). Calves fed RAH or RBP had higher blood concentration of β -hydroxy butyric acid compared with CS only before weaning ($P = 0.03$). Blood albumin concentration was higher for RBP compared with CS or RAH during the preweaning ($P = 0.006$) and overall ($P = 0.005$) periods; however, it was lower for CS compared with RBP after weaning ($P = 0.03$). Concentration of other blood variables including glucose, blood urea N, total protein, and globulin did not change across the diets ($P > 0.05$). Calves, in general, were healthy, and replacing CS with RAH or RBP in the starter diet had no beneficial effect on their feed intake or growth performance indicating that CS and reconstituted AH or BP can be used interchangeably in dairy calf starter diets until 70 d of age, allowing dairy producers more choices in selecting the feed ingredients.

Key words: alfalfa hay, beet pulp, dairy calf, reconstitution

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INTRODUCTION

Encouraging starter feed consumption is crucial to stimulate reticulo-rumen development in the young calf and create a smoother transition

from liquid to solid feed. This transition involves alterations in the gastro-intestinal tract because tissues must convert from reliance on glucose supplied from milk to the use of volatile fatty acids (VFA) as primary energy substrates (Baldwin et al., 2004). Therefore, starter feeds for calves are formulated to maximize palatability of feed and DM intake (DMI) as well as VFA production and allow calves to maintain weight gain through the transition from liquid to solid feed (Beiranvand et al., 2016, 2019; Mirzaei et al., 2017; Kargar and Kanani, 2019).

In recent years, many attempts have been made to increase DMI in dairy calves fed a total mixed ration (TMR) by moisturizing (Beiranvand et al., 2016, 2019) or reconstituting (Kargar and Kanani, 2019) starter feeds and feeding digestible source of nonforage fiber (Maktabi et al., 2016) or silage-based starter feeds (Mirzaei et al., 2016, 2017). Moisturizing the concentrate fraction of finely ground starter feed by adding water and decreasing DM content of dry TMR (10:90 forage [AH] to concentrate ratio) from 90% to 50% increased weight gain in dairy calves by increasing DMI and VFA (especially acetate and propionate) proportions (Beiranvand et al., 2016, 2019). Feeding a starter diet containing 10% dry vs. reconstituted AH and decreasing DM content of dry TMR from 91.2% to 83.8% nonsignificantly increased DMI (+24%; by increasing neutral detergent fiber [NDF] digestibility) and weight gain (+9%) in dairy calves during the preweaning period (Kargar and Kanani, 2019). Maktabi et al. (2016) reported higher feed intake, weight gain, and BW for dairy calves when adding 10% (vs. 0%) dry sugar BP to a starter diet. Recently, interest exists in providing silage-based TMR from early in life to dairy calves, which is a practical feeding strategy for the most dairy farmers, despite providing a more balanced and palatable source of nutrients for the developing young calves (Mirzaei et al., 2016, 2017). Feeding starter diets containing 15% CS (vs. 0%) or 15% CS vs. 15% dry AH increased feed intake, weight gain, and BW in dairy calves possibly due to reduced dustiness or higher palatability of the starter feed with increased dietary moisture (Mirzaei et al., 2016, 2017). However, it is not clear from those studies that how calves performed if they received starter feeds with similar moisture content to that of CS-based starter feeds.

Alfalfa hay, CS, and BP are commonly utilized in ruminant diets in many dairy-producing areas of the world including Iran (Maktabi et al., 2016; Mirzaei et al., 2017; Beiranvand et al., 2019). The majority of dairy farms in Iran are using BP in

reconstituted form with similar moisture content (75–80%) to that of CS (Kargar et al., 2013, 2014); therefore, there would be a potential for CS to be used interchangeably in dairy calf starter feeds if DMI or nutrient digestibility is maintained or increased. Limited information is available on how feeding reconstituted AH- or BP-based starter feeds affect the performance of dairy calves compared with CS-based TMR when fed at the level ($\leq 10\%$ of dietary DM) to avoid gut fill effect (Imani et al., 2017). The main goal of this study was to investigate the effect of replacing CS with reconstituted AH or BP in starter feeds containing similar moisture (15.6%, on average) or NDF (16.8%, on average) levels. We hypothesized that DMI and weight gain in dairy calves fed reconstituted AH or BP would be comparable with those of dairy calves fed CS within targeted levels of NDF (16–18%) in starter diets, which is important for maintaining feed intake and digestibility (Beiranvand et al., 2016, 2019). To this end, we measured the nutrient intake and digestibility, growth performance, rumen fermentation, blood metabolites, and health status in Holstein dairy calves.

MATERIALS AND METHODS

Animals, Management, and Diets

All the animal procedures (protocol # 9431401) were approved by the Animal Care Committee of Shiraz University by the Iranian Council of Animal Care (1995). Fifty-four female Holstein calves (3 d of age; 39.8 ± 1.36 kg BW) were housed in a naturally ventilated barn with wood shavings-bedded pens ($2.9 \times 1.1 \times 1.8$ m; length $\times$ width $\times$ height). Bedding was replaced every 24 h and manure was removed daily to keep the pens visibly clean and dry. Calves fed a total of 5.5-liter colostrum with 3.5-liter fed within 2 h of life and 2 liter fed 8 h after the first feeding. Calves received transition milk (4 liters; on day 2 of life) or waste milk (from day 3 onward) in two equal meals (at 0900 and 1700 h). Milk (not pasteurized and contained 2.93% fat and 2.78% crude protein [CP]) was provided at 6 liters/d from days 3 to 43, 4 liters/d from days 44 to 46, and 2 liters/d from days 47 to 49 of age. Calves were weaned on day 50 and remained on study until day 70.

Calves were assigned randomly to 1 of the 3 dietary treatments ($n = 18$ per treatment), including 1) starter feed diet containing 10% (on DM basis) CS (CS diet), 2) starter feed diet containing 10% reconstituted AH (RAH diet), and 3) starter feed

diet containing 10% reconstituted BP (RBP diet; Table 1). Alfalfa hay was chopped (particle size distribution: $14.5 \pm 0.6\%$ greater than 18 mm, $24.9 \pm 1.2\%$ between 8 and 18 mm, $29.6 \pm 1.0\%$ between 1.18 and 8 mm, and $31.0 \pm 1.0\%$ less than 1.18 mm, and geometric mean particle 4.3 ± 0.12 mm) with a theoretical length cut of 30 mm, using a harvesting machine with screen size regulator (Golchin Trasher Hay Co., Isfahan, Iran). Particle size distribution of CS was as $20.6 \pm 1.0\%$ greater than 18 mm, $60.6 \pm 1.3\%$ between 8 and 18 mm, $18.8 \pm 1.0\%$ between 1.18 and 8 mm, and $0.0 \pm 0.0\%$ less than 1.18 mm, and geometric mean particle $12.1 \pm$

1.6 mm. The particle size of AH (3–5 mm as mean geometric) and CS (12–15 mm as mean geometric) was in ranges used in the majority of dairy farms in Iran (Kargar et al., 2013, 2014). Alfalfa hay and BP were reconstituted using tap water a day before feeding by placing the required amounts of dry AH or BP into an industrial container (Iran Plast Co., Isfahan, Iran; kept at ambient temperature under shade) and mixed thoroughly (4 times over a day) to obtain a theoretical DM content of 20% (because CS had this DM content). Calves had free access to fresh and clean drinking water and TMR formulated according to the National Research Council (NRC, 2001).

Table 1. Ingredients and chemical composition (% of dry matter unless otherwise noted) of the experimental diets

Ingredient composition	Diet ¹		
	CS	RAH	RBP
Ground corn grain	54.0	54.0	54.0
Ground barley grain	10.1	10.1	10.1
Soybean meal	23.0	23.0	23.0
Corn silage ²	10.0	–	–
Reconstituted alfalfa hay ³	–	10.0	–
Reconstituted sugar beet pulp ⁴	–	–	10.0
Vitamin and mineral mixture ⁵	1.0	1.0	1.0
Calcium carbonate	1.3	1.3	1.3
Salt	0.6	0.6	0.6
Chemical composition			
Dry matter (DM)	84.7	84.1	84.4
Crude protein (CP)	19.9	20.3	20.0
Nonfibrous carbohydrate (NFC) ⁶	52.7	53.8	54.6
Neutral detergent fiber (NDF)	17.6	16.7	16.1
Ether-extract (EE)	3.6	3.3	3.2
Ash	6.2	6.0	6.1
Calcium ⁷	0.65	0.76	0.71
Phosphorous ⁷	0.38	0.38	0.36
Metabolizable energy, ⁷ Mcal/kg of DM	3.08	3.06	3.11
Net energy for maintenance, ⁷ Mcal/kg of DM	2.31	2.30	2.33
Net energy for growth, ⁷ Mcal/kg of DM	1.75	1.75	1.77
Geometric mean particle size, mm	2.0	1.8	1.7

¹CS = starter diet containing 10% corn silage; RAH = starter diet containing 10% reconstituted alfalfa hay; and RBP = starter diet containing 10% reconstituted beet pulp.

²Corn silage consisted of (DM basis) 20.6% DM, 91.2% OM (organic matter), 11.5% CP, 20.5% NFC, 54.7% NDF, 4.5% EE, and 8.8% ash.

³Alfalfa hay consisted of (DM basis) 94.3% DM, 93.3% OM, 14.7% CP, 31.1% NFC, 45.6% NDF, 2.0% EE, and 6.7% ash.

⁴Sugar beet pulp consisted of (DM basis) 94.6% DM, 92.7% OM, 11.7% CP, 39.9% NFC, 40.1% NDF, 1.0% EE, and 7.3% ash.

⁵Contained per kilogram of supplement: 975,000 IU of vitamin A, 750,000 IU of vitamin D, 1,800 IU of vitamin E, 143 g of Zn, 76 g of Mn, 48.6 g of Cu, 19.5 g of Se, 18.4 g of Fe, 8 g of Ca, and 1.3 g of Co.

⁶NFC = $100 - (\text{CP} + \text{NDF} + \text{EE} + \text{Ash})$ (NRC, 2001).

⁷Calculated from NRC (2001).

Sampling and Laboratory Analyses

Amounts of feed delivered and refused were recorded daily at 0900 h for each calf to compute the starter intake. Samples of CS, AH, BP, and treatment TMR were taken every 10 d during the study period. The DM concentration of pooled samples was determined by drying at 100 °C in a forced-air oven for 24 h (AOAC International, 2002; method 925.40). The samples were ground to pass a 1-mm screen in a Wiley mill (Ogawa Seiki Co., Ltd., Tokyo, Japan) and analyzed in duplicates for CP using Kjeldahl method (Kjeltec 1030 Auto Analyzer, Tecator, Höganäs, Sweden; AOAC International, 2002; method 955.04), ether extract (EE; AOAC International, 2002; method 920.39), ash (AOAC International, 2002; method 942.05), and NDF using a heat stable α -amylase (100 $\mu\text{L}/0.5$ g of sample) and sodium sulfite (Van Soest et al., 1991). The nonfibrous carbohydrate (NFC) component was computed as $100 - (\text{CP} + \text{NDF} + \text{EE} + \text{Ash})$ (NRC, 2001).

Calves were weighed at birth, on day 3 postbirth and every 10 d thereafter before the morning feeding using an electronic balance, and average daily gain (ADG; kg of BW/d) was computed as the difference between BW taken every 10 d apart divided by 10. Feed efficiency was calculated as kg of weight gain/total DM intake (milk DM + starter feed DM). Body measurements including the heart girth (circumference of the chest), withers height (distance from base of the front feet to the withers), body length (distance between the points of shoulder and rump), body barrel (circumference of the belly before feeding), 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 measured at the start of the study and every 10 d thereafter

as described by Kargar and Kanani (2019). Health related variables (rectal temperature, fecal score, and general appearance) were monitored daily during the preweaning period (days 1–49). Rectal temperature was measured daily between 1300 and 1400 h using a digital thermometer (Model FT 15/1; Beurer GmbH Söflinger Str. 218, 89077 Ulm, Germany) placed in the rectum for 1 min. Fecal score (1 = normal; 2 = soft to loose; 3 = loose to watery; 4 = watery, mucous, and slightly bloody; and 5 = watery, mucous, and bloody) and the calf's general appearance (1 = normal and alert; 2 = ears drooped; 3 = head and ears drooped, dull eyes, slightly lethargic; 4 = head and ears drooped, dull eyes, lethargic; and 5 = severely lethargic) were measured daily based on a 1 to 5 system while the calves were in individual pens (Kargar and Kanani, 2019).

During the postweaning period, 8 fecal grab samples per calf were gathered via rectal palpation at 3-h intervals (1200, 1500, 1800, 2100, 2400, 0300, 0600, and 0900 h) by rotating the sampling times over the 4-d collection period. Samples were collected from the same 10 calves randomly selected per treatment on days 64 (1200 and 2400 h), 65 (1500 and 0300 h), 66 (1800 and 0600 h), and 67 (2100 and 0900 h), frozen daily, mixed on an equal wet weight basis, and subsampled for analysis. Samples were dried at 60 °C for 72 h and ground through a 1-mm screen in a Wiley mill (Ogawa Seiki Co., Ltd., Tokyo, Japan). Total tract nutrient digestibility was determined by measuring acid insoluble ash as an internal marker in the feed (corrected for refusals) and fecal samples according to Van Keulen and Young (1977).

Rumen fluid was collected 3 h after morning feeding on day 65 by a stomach tube fitted to a vacuum pump. Rumen fluid pH was determined immediately after the samples were collected using a mobile pH meter (HI 8318; Hanna Instruments, Cluj-Napoca, Romania) calibrated before each reading. Samples were squeezed through 4 layers of cheesecloth and 8 mL of the rumen fluid was acidified with 2 mL of 25% meta-phosphoric acid and stored at –20 °C until analyzed for VFA by gas chromatography (Kargar et al., 2012).

Blood samples were collected 3 h after morning feeding into vacuum serum separator tubes containing clot activator on the initiation of the experiment and every 10 d thereafter during the study. Samples were centrifuged immediately at $3,000 \times g$ for 20 min at 4 °C, and 1.5 mL of serum was transferred into 2-mL microtubes and stored at –20 °C for subsequent analyses. Blood variables

were quantified spectrophotometrically (UNICCO, 2100, Zistchemi, Tehran, Iran) using commercially available kits [Pars Azmoon Co., Tehran, Iran; Catalogue Numbers: glucose (1-500-017), blood urea N (BUN; 1-400-029), total protein (1-500-028), and albumin (1-500-001)] according to the manufacturers' instructions. Globulin concentration was calculated by subtracting albumin from total protein concentrations. Concentration of beta-hydroxy butyric acid (β HBA) was determined using a commercial colorimetric kit (Randox Laboratories Ltd., Ardmore, UK) with a Technicon-RA 1000 Auto-analyzer (DRG Co., Marburg, Germany).

Statistical Analyses

Feed intake, ADG, feed efficiency, skeletal growth, and blood variables (normalized by logarithmic transformation) were analyzed for three discrete periods as preweaning (days 1–49), postweaning (days 50–70), and overall (days 1–70) periods. Data on growth performance, rectal temperature, and blood variables were analyzed using the MIXED MODEL procedure (SAS Institute, 2013) as follows:

$$Y_{ijklm} = \mu + \text{Calf}_i + \text{Diet}_j + \text{Time}_k + (\text{Diet} \times \text{Time})_{jk} + \beta (X_i - \bar{X}) + E_{ijkl} + e_{ijklm},$$

where Y_{ijklm} is the dependent variable; μ is the average experimental value; Calf_i is the random effect of calf; Diet_j is the fixed effect of experimental diets j (j = CS, RAH or RBP); Time_k is the fixed effect of 1- or 10-d period k (k = number of 1-d or 10-d period); $(\text{Diet} \times \text{Time})_{jk}$ represents the effect of the interaction between diet and time; $\beta (X_i - \bar{X})$ designates the covariate variable, where the β is the regression coefficient relating covariate factor to the variable measured, X_i is the covariate factor for the i th factor, and $\bar{X}$ is the overall mean of covariate factor; E_{ijkl} is the sampling error; and e_{ijklm} is the error term.

Data on fecal score and calf general appearance score were analyzed using the GLIMMIX procedure. In both models (MIXED and GLIMMIX), the effects of diet, time, and diet by time interaction were considered as fixed and calf as a random effect. Time (1- or 10-d period) was modeled as a repeated measurement by using an autoregressive covariance structure (Type 1) which was determined by the lowest Akaike information criterion. Initial BW, skeletal measurements, and blood variables were considered as covariate for the weight (weaning and final BW), skeletal growth, and blood variables analyses, respectively.

Least squares means for dietary effects were separated using Tukey's adjustment whenever the overall F -test was $P \leq 0.05$. Trends were declared at $0.05 < P \leq 0.10$.

Data on BW, nutrient digestibility, and rumen fermentation characteristics were subjected to ANOVA according to the following model:

$$Y_{ij} = \mu + \text{Diet}_i + e_{ij},$$

where Y_{ij} is the dependent variable; μ is the average experimental value; Diet_i is the effect of experimental diets i ($i = \text{CS, RAH or RBP}$); and e_{ij} is the error term.

RESULTS

Nutrient Intake, Growth Performance, and Health Criteria

There was no interaction between diet and time on nutrient intake, growth performance, body measurements, and health-related variables (Tables 2 and 3). Replacing CS with reconstituted AH or BP did not influence nutrient intake, ADG, feed efficiency, BW (at weaning or at the end of the study), or skeletal growth during the all studied periods ($P > 0.05$). Irrespective of the dietary treatment, nutrient intake increased with advancing age (Time effect: $P = 0.001$); however, total EE intake, due to milk consumption, was higher during the pre- vs. post-weaning period (0.11 vs. 0.08 kg/d; Time effect: $P = 0.001$). As calves grew older, their ADG and skeletal growth increased (Time effect: $P = 0.001$). Health-related variables (rectal temperature, fecal score, and general appearance score) were not influenced by treatment ($P > 0.05$).

Nutrient Digestibility and Rumen Fermentation Characteristics

Feeding RBP increased apparent total tract digestibility of DM, organic matter, and CP compared with CS or RAH during the postweaning period ($P = 0.001$; Table 4). Apparent total tract digestibility of NDF was higher for CS and RBP compared with RAH ($P = 0.001$); however, digestibility of NFC and EE was not influenced by treatment ($P > 0.05$). Daily amounts of digested nutrients were not changed across treatment groups ($P > 0.05$). Rumen fluid pH and total and individual (acetate, propionate, butyrate, valerate, and iso-valerate) VFA concentrations were not influenced by treatment during the postweaning period ($P > 0.05$).

Blood Biochemical Attributes

Blood metabolites including glucose, BUN, total protein, and globulin and albumin to globulin ratio were not affected by treatment (Table 5). Blood concentration of β HBA was higher for calves fed reconstituted AH or BP compared with calves fed CS during the preweaning period ($P = 0.03$). Calves fed reconstituted BP had higher blood concentration of albumin compared with calves fed CS or reconstituted AH during the preweaning and overall periods. During the postweaning period, blood concentration of albumin was higher for calves fed reconstituted BP compared with calves fed CS ($P = 0.03$).

DISCUSSION

By reconstitution, DM content of RAH and RBP diets reached to that of CS (84.4%, on average; Table 1). At the same levels of moisture (15.6%, on average) and NDF (16.8%, on average), DMI was not affected by diet emphasizing that starter feeds with relatively low NDF contents (16–18%) are recommended to maintain feed intake (Beiranvand et al., 2016, 2019). Due to similar DMI and daily amounts of digested nutrients in the present study, weight gain, feed efficiency, BW (at weaning and at the end of the trial), and frame size were not affected by treatment. Unlike to our results, feeding starter diets containing 15% CS vs. 15% dry AH increased DMI, ADG, BW, and body length in dairy calves possibly due to improved uniformity, adhesiveness, and palatability and diminished dustiness of the moist starter (Mirzaei et al., 2017). When diets containing 32% alfalfa meal, 17% cottonseed hulls or 34% BP were fed, Murdock and Wallenius (1980) reported no difference in feed efficiency but a decrease in feed intake and BW gain (a tendency) in calves fed BP when compared with calves fed cottonseed hulls under 3 mo old; however, calves fed BP and alfalfa meal had a similar feed intake and weight gain. Maktabi et al. (2016) observed no difference in DMI but tendencies for improvement in weaning BW and hip height and also an improvement in weight gain and feed efficiency (a tendency) in dairy calves before weaning (day 50 of age) when adding 10% (vs. 0%) dry BP to a starter diet; however, they reported no differences in DMI, ADG, final BW (day 70 of age), and skeletal growth after weaning but a reduction in feed efficiency between 0% and 10% dry BP diets.

Forage fiber is either relatively less digestible than nonforage fiber or has a slower passage rate (Firkins, 1997). Beet pulp contains high

Table 2. Nutrient intake of Holstein dairy calves as influenced by feeding corn silage or reconstituted alfalfa hay and beet pulp

Item ¹	Diet (D) ²			SEM	P-value		
	CS	RAH	RBP		D	Time (T)	D × T
Starter DM intake, kg/d							
Prewaning (days 1–49)	0.30	0.39	0.46	0.08	0.30	0.001	0.14
Postweaning (days 50–70)	2.07	2.10	2.40	0.17	0.32	0.001	0.19
Overall (days 1–70)	0.81	0.88	1.01	0.10	0.34	0.001	0.12
Starter intake, % of birth BW							
Prewaning (days 1–49)	0.76	0.97	1.15	0.17	0.28	0.001	0.13
Postweaning (days 50–70)	5.27	5.25	6.04	0.42	0.30	0.001	0.17
Overall (days 1–70)	2.05	2.19	2.55	0.24	0.33	0.001	0.14
Total DM intake, kg/d							
Prewaning (days 1–49)	0.99	1.08	1.14	0.07	0.31	0.001	0.12
Postweaning (days 50–70)	2.07	2.10	2.40	0.17	0.32	0.001	0.18
Overall (days 1–70)	1.30	1.37	1.50	0.10	0.35	0.001	0.14
Total DM intake, % of birth BW							
Prewaning (days 1–49)	2.52	2.72	2.86	0.17	0.39	0.001	0.11
Postweaning (days 50–70)	5.27	5.25	6.04	0.42	0.30	0.001	0.16
Overall (days 1–70)	3.30	3.44	3.77	0.25	0.39	0.001	0.12
Total ME intake, Mcal/d							
Prewaning (days 1–49)	3.99	4.29	4.48	0.22	0.30	0.001	0.11
Postweaning (days 50–70)	6.45	6.50	7.52	0.53	0.26	0.001	0.15
Overall (days 1–70)	4.69	4.92	5.35	0.31	0.32	0.001	0.11
Total CP intake, kg/d							
Prewaning (days 1–49)	0.20	0.22	0.23	0.01	0.31	0.001	0.15
Postweaning (days 50–70)	0.40	0.41	0.46	0.03	0.35	0.001	0.18
Overall (days 1–70)	0.26	0.27	0.30	0.02	0.35	0.001	0.13
Total EE intake, kg/d							
Prewaning (days 1–49)	0.11	0.11	0.11	0.002	0.52	0.001	0.19
Postweaning (days 50–70)	0.08	0.07	0.08	0.006	0.62	0.001	0.17
Overall (days 1–70)	0.10	0.10	0.10	0.003	0.44	0.001	0.17
NDF intake, kg/d							
Prewaning (days 1–49)	0.05	0.06	0.07	0.01	0.47	0.001	0.11
Postweaning (days 50–70)	0.35	0.34	0.37	0.02	0.64	0.001	0.14
Overall (days 1–70)	0.14	0.14	0.16	0.01	0.62	0.001	0.13
NFC intake, kg/d							
Prewaning (days 1–49)	0.16	0.22	0.26	0.04	0.25	0.001	0.14
Postweaning (days 50–70)	1.12	1.16	1.35	0.09	0.20	0.001	0.13
Overall (days 1–70)	0.44	0.48	0.57	0.05	0.24	0.001	0.15

¹DM = dry matter; BW = body weight; Total DM intake = milk DM + starter feed DM; ME = metabolizable energy; CP = crude protein; EE = ether-extract; NDF = neutral detergent fiber; and NFC = non-fibrous carbohydrate.

²CS = starter diet containing 10% corn silage; RAH = starter diet containing 10% reconstituted alfalfa hay; and RBP = starter diet containing 10% reconstituted beet pulp.

quantities of NDF and neutral detergent soluble fiber (mainly pectin; [NRC, 2001](#)). The NDF in BP is digested more rapidly than forage NDF since the extent of lignification of BP fiber is markedly low ([Bhatti and Firkins, 1995](#)). Pectin is also digested more quickly than NDF and starch, but produces less lactate and has a propensity for acetate vs. propionate production in the rumen ([Marounek et al., 1985](#); [Maktabi et al., 2016](#)); however, in the present study, no changes in molar concentrations of acetate or propionate were observed. The

NDF digestibility of grasses is often greater than that of legumes ([Oba and Allen, 1999](#)). The higher NDF digestibility in CS vs. RAH may be attributed, in part, to CS prefermentation as it can decrease the ruminal digestion lag time and thereby increase the NDF digestibility ([Pasha et al., 1994](#)). The other explanation is that perhaps because of longer particle size in CS vs. RAH the passage rate was slower giving more time for bacteria to digest fiber. Furthermore, due to higher ratio of lignin to fiber in legumes vs. grasses ([Kuoppala et al.,](#)

Table 3. Body weight, average daily gain, feed efficiency, skeletal growth and health status of Holstein dairy calves as influenced by feeding corn silage or reconstituted alfalfa hay and beet pulp

Item	Diet (D) ¹			SEM	P-value		
	CS	RAH	RBP		D	Time (T)	D × T
Body weight, kg							
Initial (day 1)	39.1	40.0	40.2	1.36	0.85	—	—
Weaning (day 49)	65.6	69.0	70.1	2.14	0.33	—	—
Final (day 70)	87.8	90.5	92.1	2.68	0.70	—	—
Average daily gain, kg/d							
Prewaning (days 1–49)	0.54	0.59	0.61	0.04	0.37	0.001	0.15
Postweaning (days 50–70)	1.11	1.08	1.10	0.07	0.96	0.001	0.63
Overall (days 1–70)	0.69	0.72	0.74	0.04	0.59	0.001	0.41
Feed efficiency ²							
Prewaning (days 1–49)	0.55	0.55	0.54	0.02	0.94	0.001	0.19
Postweaning (days 50–70)	0.54	0.51	0.46	0.04	0.11	0.25	0.97
Overall (days 1–70)	0.53	0.53	0.49	0.02	0.61	0.001	0.13
Heart girth, cm							
Prewaning (days 1–49)	88.1	88.6	88.0	0.54	0.69	0.001	0.33
Postweaning (days 50–70)	100.2	100.5	101.5	1.01	0.64	0.001	0.47
Overall (days 1–70)	91.5	92.0	91.9	0.64	0.88	0.001	0.38
Withers height, cm							
Prewaning (days 1–49)	82.7	82.8	83.3	0.38	0.52	0.001	0.87
Postweaning (days 50–70)	89.6	89.6	90.7	0.76	0.50	0.001	0.44
Overall (days 1–70)	84.7	84.8	85.4	0.45	0.48	0.001	0.96
Body length, cm							
Prewaning (days 1–49)	48.2	48.1	48.6	0.32	0.46	0.001	0.93
Postweaning (days 50–70)	55.5	55.6	56.6	0.67	0.45	0.001	0.18
Overall (days 1–70)	50.3	50.3	50.9	0.38	0.39	0.001	0.82
Body barrel, cm							
Prewaning (days 1–49)	94.8	95.9	95.8	1.23	0.81	0.001	0.37
Postweaning (days 50–70)	118.2	121.1	123.6	2.53	0.37	0.001	0.18
Overall (days 1–70)	101.6	103.1	103.7	1.65	0.68	0.001	0.20
Hip height, cm							
Prewaning (days 1–49)	87.2	87.3	87.5	0.43	0.87	0.001	0.78
Postweaning (days 50–70)	94.7	94.8	95.6	0.66	0.54	0.001	0.68
Overall (days 1–70)	89.3	89.5	89.8	0.45	0.72	0.001	0.86
Hip width, cm							
Prewaning (days 1–49)	16.1	16.4	16.3	0.12	0.37	0.001	0.17
Postweaning (days 50–70)	19.3	19.6	19.9	0.28	0.27	0.001	0.89
Overall (days 1–70)	17.0	17.3	17.4	0.16	0.37	0.001	0.32
Health status (days 1–49)							
Rectal temperature, °C	38.9	39.0	38.9	0.03	0.51	0.001	0.39
Fecal score ³	1.13	1.11	1.14	0.01	0.68	0.001	0.93
General appearance score ⁴	1.01	1.01	1.00	0.003	0.51	0.001	0.96

¹CS = starter diet containing 10% corn silage; RAH = starter diet containing 10% reconstituted alfalfa hay; and RBP = starter diet containing 10% reconstituted beet pulp.

²Feed efficiency was calculated by dividing average daily gain by average total DM intake (milk DM + starter feed DM).

³Where 1 = normal; 2 = soft to loose; 3 = loose to watery; 4 = watery, mucous, and slightly bloody; and 5 = watery, mucous, and bloody.

⁴Where 1 = normal and alert; 2 = ears drooped; 3 = head and ears drooped, dull eyes, slightly lethargic; 4 = head and ears drooped, dull eyes, lethargic; and 5 = severely lethargic.

2009), the lower NDF digestibility in RAH vs. CS would be related to a greater lignin to fiber ratio (Brown et al., 2018). The amounts of digested nutrients were similar across treatment groups, which was substantiated by similar rumen fluid pH and total VFA concentration and profile (Table 4).

Accordingly, our data do not support an effect of forage or nonforage fiber sources on feed intake, nutrient digestibility, and growth performance, indicating that CS, RAH, and RBP can either be used in the starter diet formulation based on their availability and relative costs.

Table 4. Apparent total tract nutrient digestibility and rumen fermentation characteristics of Holstein dairy calves as influenced by feeding corn silage or reconstituted alfalfa hay and beet pulp

Item	Diet (D) ¹			SEM	<i>P</i> -value
	CS	RAH	RBP		D
Apparent total tract nutrient digestibility					
Postweaning (days 64–67)					
DM					
%	76.7 ^b	79.6 ^b	83.0 ^a	0.82	0.001
kg/d	1.72	1.70	2.11	0.21	0.19
OM					
%	77.6 ^b	80.2 ^b	83.5 ^a	0.82	0.001
kg/d	1.65	1.62	2.01	0.19	0.20
CP					
%	72.5 ^b	75.4 ^b	80.4 ^a	1.15	0.001
kg/d	0.32	0.32	0.40	0.03	0.17
NFC					
%	84.9	87.5	87.9	1.23	0.22
kg/d	1.03	1.03	1.26	0.11	0.25
NDF					
%	67.3 ^a	59.0 ^b	68.6 ^a	1.05	0.001
kg/d	0.25	0.20	0.27	0.02	0.14
EE					
%	86.0	88.7	89.3	2.93	0.70
kg/d	0.07	0.07	0.08	0.007	0.54
Rumen fermentation characteristics					
Postweaning (day 65)					
pH	5.54	5.56	5.67	0.16	0.82
Total volatile fatty acid, mM	99.85	101.55	99.98	3.52	0.98
Acetate, mM	41.00	38.38	44.29	2.98	0.72
Propionate, mM	46.99	51.13	44.72	2.93	0.13
Butyrate, mM	8.48	9.37	7.93	1.13	0.70
Valerate, mM	2.90	2.33	2.76	0.29	0.42
Iso-valerate, mM	0.47	0.34	0.28	0.11	0.47

DM = dry matter; OM = organic matter; CP = crude protein; NFC = nonfibrous carbohydrate; and NDF = neutral detergent fiber.

¹CS = starter diet containing 10% corn silage; RAH = starter diet containing 10% reconstituted alfalfa hay; and RBP = starter diet containing 10% reconstituted beet pulp.

^{a-c}Means within a row with different superscripts are significantly different ($P \leq 0.05$).

The lack of treatment effect on health-related variables (rectal temperature, fecal score, and general appearance score) is in line with other reports (Mirzaei et al., 2017); however, Maktabi et al. (2016) reported a tendency for lower fecal score in calves fed 10% (vs. 0%) dry BP before weaning. In the present study, all the calves were healthy with no clinical symptoms of systemic disease or mortality other than diarrhea and very few pneumonia occurrences throughout the experiment.

Due to similar DMI and daily amounts of digested nutrients, the findings of the present trial indicated that replacing CS with RAH or RBP had no significant effects on metabolic indicators of rumen development (including concentrations of blood glucose, β HBA, and BUN) in young calves; however, the reason for decreased concentration of β HBA in calves

fed CS before weaning is unknown. This might be attributed, in part, to a nonsignificant decrease in feed intake in CS compared with RAH (–90 g/d) or RBP (–160 g/d) during the preweaning period. The progressive increases in starter DMI and blood β HBA and a decrease in blood glucose with advancing age are indicative of increasing rumen development and function by calves on all starter diets during the study period (Baldwin et al., 2004). The reason for increased concentration of albumin in calves fed RBP is unclear. Higher blood albumin concentration is generally attributed to higher protein intake or skeletal muscle breakdown (Pluske et al., 2018). However, in the present study, neither CP intake nor blood BUN concentration was affected by treatment.

Calves in general were healthy and replacing CS with RAH or RBP did not affect the overall feed

Table 5. Blood variables of Holstein dairy calves as influenced by feeding corn silage or reconstituted alfalfa hay and beet pulp

Item	Diet (D) ¹			SEM	P-value		
	CS	RAH	RBP		D	Time (T)	D × T
Glucose, mg/dL							
Prewaning (days 1–49)	94.46	101.79	101.22	2.76	0.16	0.001	0.15
Postweaning (days 50–70)	81.98	87.68	83.49	3.75	0.55	0.005	0.32
Overall (days 1–70)	90.93	97.55	96.16	2.50	0.19	0.001	0.14
βHBA ² , mmol/L							
Prewaning (days 1–49)	0.04 ^b	0.06 ^a	0.06 ^a	0.005	0.03	0.001	0.40
Postweaning (days 50–70)	0.25	0.21	0.18	0.03	0.28	0.42	0.60
Overall (days 1–70)	0.10	0.10	0.09	0.01	0.79	0.001	0.26
BUN ³ , mg/dL							
Prewaning (days 1–49)	25.56	20.71	21.06	1.87	0.17	0.004	0.45
Postweaning (days 50–70)	19.14	20.09	19.74	1.90	0.94	0.53	0.34
Overall (days 1–70)	23.76	20.58	20.73	1.51	0.30	0.002	0.51
Total protein, g/dL							
Prewaning (days 1–49)	6.24	6.18	6.48	0.22	0.54	0.83	0.49
Postweaning (days 50–70)	5.79	6.10	6.46	0.40	0.39	0.46	0.32
Overall (days 1–70)	6.09	6.17	6.47	0.20	0.28	0.83	0.59
Albumin, g/dL							
Prewaning (days 1–49)	3.14 ^b	3.03 ^b	3.53 ^a	0.09	0.006	0.36	0.40
Postweaning (days 50–70)	2.96 ^b	3.32 ^{ab}	3.36 ^a	0.12	0.03	0.41	0.24
Overall (days 1–70)	3.09 ^b	3.11 ^b	3.49 ^a	0.08	0.005	0.42	0.33
Globulin, g/dL							
Prewaning (days 1–49)	3.04	3.15	3.00	0.27	0.93	0.97	0.24
Postweaning (days 50–70)	2.66	2.92	3.06	0.47	0.77	0.39	0.46
Overall (days 1–70)	2.89	3.13	3.03	0.24	0.84	0.90	0.36
Albumin: globulin							
Prewaning (days 1–49)	1.56	1.12	1.26	0.21	0.44	0.98	0.49
Postweaning (days 50–70)	1.52	1.26	1.14	0.33	0.67	0.37	0.47
Overall (days 1–70)	1.60	1.14	1.21	0.19	0.28	0.99	0.53

¹CS = starter diet containing 10% corn silage; RAH = starter diet containing 10% reconstituted alfalfa hay; and RBP = starter diet containing 10% reconstituted beet pulp.

²βHBA = β-hydroxy butyric acid. BUN = blood urea N.

³BUN = blood urea N.

intake and thereby growth performance and metabolic indications of rumen development measured as ruminal VFA and selected blood metabolites (including glucose, βHBA, and BUN). In general, CS can be replaced with RAH or RBP without adverse effect on feed intake and growth performance based on availability and feed competitive costs.

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