Reconstituted versus dry alfalfa hay in starter feed diets of Holstein dairy calves: Effects on feed intake, feeding and chewing behavior, feed preference, and health criteria

S. Kargar* and M. Kanani

Department of Animal Science, School of Agriculture, Shiraz University, Shiraz 71441–65186, Iran

ABSTRACT

We investigated the effect of reconstitution of alfalfa hay on feeding and chewing behavior, sorting activity, and health status using 20 neonate Holstein male calves (3 d of age; 40.3 ± 1.30 kg of body weight) that were assigned randomly to 2 treatments, a starter feed containing either 10% dry (AH) or reconstituted alfalfa hay (RAH), each consisting of 10 calves. Alfalfa hay was reconstituted with water 24 h before feeding to achieve a theoretical dry mater (DM) content of 20%. Both starter diets had the same ingredients and nutrient compositions but differed in their DM content (90.9 vs. 66.6% DM for AH vs. RAH, respectively). Calves were weaned on d 50 and remained in the study until d 70. Reconstitution of alfalfa hay increased the percentage of particles retained on 8- and 1.18-mm sieves, but reduced feed materials retained on the bottom pan. Feeding RAH tended to increase meal frequency (preweaning) and increased meal duration (pre- and postweaning), and thereby increased time devoted to eating without affecting nutrient intake. Calves fed RAH tended to have lower eating rate during the pre- and postweaning periods. Tendencies to concurrent increase in rumination frequency and rumination duration in calves fed RAH increased time devoted to ruminating during the preweaning period; however, a tendency to longer rumination duration did not affect ruminating time during the postweaning period. Calves fed RAH spent less time resting and standing and more time drinking during the postweaning period. Non-nutritive oral behaviors were not affected by treatment during the pre- and postweaning period. Feeding RAH decreased sorting of particles retained on 8-mm sieve compared with AH; however, calves in both treatment groups sorted for particles retained on 8- and 1.18-mm sieves and against the feed materials retained on the

bottom pan. Crude protein and neutral detergent fiber intakes of particles retained on the both 8- and 1.18-mm sieves increased in calves fed RAH versus AH, with no changes in intake of nutrients retained on the bottom pan. Calves fed AH were more susceptible to develop diarrhea (odds ratio = 2.02) and pneumonia (odds ratio = 4.74) and thereby had lower chances of being treated. We found no difference between treatment groups for frequency and medication days of diarrhea; however, calves fed RAH experienced fewer days with diarrhea. Furthermore, frequency and number of days with pneumonia and administration of medication were greater for calves fed AH compared with calves fed RAH. Blood concentrations of total protein and globulin tended to be higher in calves fed RAH compared with calves fed AH. Overall, feeding RAH increased time devoted to eating by increasing meal frequency and meal duration but did not affect feed intake due to lower eating rate. Calves in both treatment groups exhibited feed sorting at the extent to which they balanced intake of nutrients and met their nutritional needs. Calves, in general, were healthy, but it seems that feeding a diet containing reconstituted alfalfa hay has a potential health-promoting effect, possibly through reducing diet dustiness and improving immune status.

Key words: dairy calf, diarrhea and pneumonia, forage reconstitution, sorting

INTRODUCTION

Growth performance of dairy calves early in life depends on adequate DMI of starter feed, which is crucial for reticulorumen development and allows calves to maintain BW gain through the transition from liquid to solid feed (Beiranvand et al., 2014; Pazoki et al., 2017; ZeidAli-Nejad et al., 2018). Therefore, starter feeds for calves are formulated to maximize palatability of feed and DMI (Beiranvand et al., 2014, 2016; Pazoki et al., 2017).

Feeding a TMR increases the distribution of DMI over the course of the day, increases time spent eating,

Received June 10, 2018.

Accepted September 7, 2018.

*Corresponding author: skargar@shirazu.ac.ir or skargar@wisc.edu

and decreases feeding rate and the amount of sorting against forage and for concentrate in replacement dairy heifers (146.2 ± 21.9 d of age; Greter et al., 2010). Therefore, the meal patterns of heifers consuming a TMR should, as in mature cows, result in intake of a more balanced diet and greater rumen buffering, thus contributing to improved rumen health. Data indicate that feeding a TMR to heifers from a young age not only has these immediate behavioral effects, but may also have longer-term benefits to these animals (Greter et al., 2010). However, dairy calves actively sort TMR against long forage particles and in favor of the smaller grain particles (rich in starch and energy; Miller-Cushon and DeVries, 2011), a pattern of feed sorting similar to that seen in dairy heifers or cows (Leonardi and Armentano, 2003; Greter et al., 2010; Kargar et al., 2013, 2014). Many factors affect feed sorting, such as feeding frequency (DeVries et al., 2005), higher or lower feed amount (Miller-Cushon and DeVries, 2010), forage-to-concentrate ratio and forage particle size (Leonardi and Armentano, 2003), and dietary moisture (Leonardi et al., 2005; Miller-Cushon and DeVries, 2009; Khan et al., 2014). Inconsistent results of dietary moisture have been reported in previous studies. Some investigators reported no difference (Khan et al., 2014), an increase (Miller-Cushon and DeVries, 2009), or a decrease (Leonardi et al., 2005) in feed sorting with increasing dietary moisture. Limited work has examined starter feed moisture that may influence feed sorting of young calves. Therefore, an investigation of feed sorting when calves are on starter feed containing reconstituted versus dry alfalfa hay is needed.

Earlier studies with dairy cows and older heifers revealed increased palatability (by improving texture or dilution of undesirable flavors) and DMI (Lahr et al., 1983; Teimouri Yansari and Primohammadi, 2009), prevented or reduced separation of ingredients (Leonardi and Armentano, 2003; Leonardi et al., 2005), and showed less dust (Arzola-Álvarez et al., 2010; Beiranvand et al., 2016) and lower feed losses due to wind (Khan et al., 2014; Beiranvand et al., 2016) when moisture content was increased by adding water; others, however, have reported either no effect (Thomas et al., 1961; Fish and DeVries, 2012) or decreased DMI (Khan et al., 2014) with increasing dietary moisture. Starter feed diets are usually provided as dry TMR to dairy calves (Beiranvand et al., 2014; Pazoki et al., 2017; ZeidAli-Nejad et al., 2018); it has been shown that dairy calves consumed more DMI when water was added to dry TMR to decrease DM content of diets from 90 to 50% (Beiranvand et al., 2016). The mechanism(s) by which DMI may be influenced by changing moisture levels of starter feed is not completely understood. Therefore, investigation of feeding behavior in dairy calves fed

starter diet containing reconstituted versus dry alfalfa hay may help to clarify the mechanism of reconstitution effects on feed intake. In addition, the literature does not indicate effects of moisture level of starter feed diet on prevention and medication of diseases (e.g., diarrhea and pneumonia) in milk-fed dairy calves. The objective of our study was to determine the effects of feeding reconstituted versus dry alfalfa hay on feed intake, feeding and chewing behavior, sorting activity, health status, and selected blood metabolites of Holstein dairy calves. We hypothesized that reconstitution of alfalfa hay would decrease feed sorting, increase DMI, and improve health status of Holstein dairy calves.

MATERIALS AND METHODS

This study was performed from July 30 to October 21, 2017, at the Foudeh-Sepahan Agriculture and Animal Husbandry, Isfahan, Iran. All animal procedures were approved by the Animal Care Committee of Shiraz University by the Iranian Council of Animal Care (1995).

Calves, Treatments, and Management

Twenty neonatal male Holstein calves (3 d of age; 40.3 ± 1.30 kg of BW) were enrolled in the study. Calves were separated from their dams immediately after birth, weighed, and 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). Screened wood shavings with a minimum theoretical length cut of 50 mm were used to minimize dustiness in the housing environment. Bedding was refreshed every day and manure was removed daily to keep the pens visibly clean and dry. Calves consumed a total of 5.5 L of colostrum, with 3.5 L fed within 2 h of life and 2 L fed 8 h after the first feeding. On d 2 of life, calves received transition milk (4 L) in 2 equal meals (at 0900 and 1700 h). From d 3 onwards, calves were individually fed waste milk containing $2.93 \pm 0.23\%$ fat and $2.78 \pm 0.20\%$ CP in steel buckets in 2 equal meals (at 0900 and 1700 h). Calves were offered milk at 6 L/d from d 3 to 43, 4 L/d from d 44 to 46, and 2 L/d from d 47 to 49 of age. Calves were weaned on d 50 and remained on study until d 70.

Calves were assigned randomly to 1 of 2 treatments, a starter feed (mashed form) containing either 10% (DM basis) dry (**AH**) or reconstituted alfalfa hay (**RAH**), each consisting of 10 calves. Third-cut alfalfa hay at 50% flowering was chopped (particle size distribution: $15.4 \pm 0.5\%$ greater than 18 mm, $22.6 \pm 0.9\%$ between 8 and 18 mm, $31.4 \pm 1.1\%$ between 1.18 and 8 mm, and $30.6 \pm 1.0\%$ less than 1.18 mm, geometric mean particle 4.3 ± 0.15 mm) at a theoretical length of 30

mm using a harvesting machine with screen size regulator (Golchin Trasher Hay Co., Isfahan, Iran). Alfalfa hay was reconstituted (using tap water) 24 h before feeding by placing the required amount of dry hay into an industrial container (Iran Plast Co., Isfahan, Iran) and mixed thoroughly (every 6 h over a 24-h period) to achieve a theoretical DM content of 20%. The container was kept at ambient temperature under shade. Cereal grains (corn and barley), used in the starter feed, were ground using a hammer mill with a 2-mm screen (model 5543 GEN, Isfahan Dasht, Isfahan, Iran). Calves had free access to fresh and clean drinking water and TMR formulated according to NRC (2001), allowing at least 10% refusals.

Feed Sampling and Analyses

Samples of alfalfa hay ($n = 7$), treatment TMR ($n = 7$; pooled by treatment every 10 d over the study period), and individual refusals ($n = 4$; pooled by calf within treatment every 10 d starting on d 31 until the end of the study period) were gathered for particle size separation. Particle size distributions of the samples were measured using the Penn State Particle Separator [PSPS (The Pennsylvania State University, University Park; Kononoff et al., 2003); Nasco, Fort Atkinson, WI] equipped with 3 sieves (19, 8, and 1.18 mm) and a pan. This separated the particles into 4 fractions: long (>19 mm), medium (≥ 8 and <19 mm), short (≥ 1.18 and <8 mm), and fine (<1.18 mm) particles. After sieving, the DM concentration of each separated fraction was measured by drying at 100°C in a forced-air oven for 24 h (AOAC International, 2002; method 925.40). The physical effectiveness factor (**pef**) was determined as the DM proportion of particles retained on 2 sieves (**pef**_{>8}; Lammers et al., 1996) and on 3 sieves (**pef**_{>1.18}; Kononoff et al., 2003) of the PSPS, respectively. The physically effective NDF of 2 (**peNDF**_{>8}) and 3 sieves (**peNDF**_{>1.18}) were computed by multiplying the NDF concentration of the feed by the fraction on **pef**_{>8} and **pef**_{>1.18}, respectively.

Sorting Behavior and Chewing Activities

The sorting index was computed as the ratio of actual intake to expected intake for particles retained on each sieve of the PSPS (Leonardi and Armentano, 2003). The predicted intake of an individual fraction was computed as the product of the DMI of the total diet multiplied by the DM percentage of that fraction in the fed TMR. Values equal to 100% indicate no sorting, $<100\%$ indicate selective refusals (sorting against), and $>100\%$ indicate preferential consumption (sorting for). To test whether calves were sorting the diet for

each particle size fraction, 1 sorting value was generated per calf per 10 d starting on d 31 until the end of the study period.

Behavioral data, including eating, ruminating, resting, standing, lying, drinking, and non-nutritive oral behaviors (**NNOB**; when the animal licked any surface, tongue rolled, and so on), were recorded by direct observations of all the calves over a 12-h period (between 0900 to 2100 h) once per 3 consecutive days before weaning (d 37 to 39 of the trial) as well as once per 3 consecutive days after weaning (d 67 to 69 of the trial). All activities were noted every 5 min and each activity was assumed to persist for the entire 5-min interval between observations (Kargar et al., 2010, 2013, 2014). A period of eating was defined as at least 1 observation of eating activity occurring after at least 5 min without eating. Meal frequency was defined as the number of bouts during a 12-h period. The meal duration (min/meal) was calculated as the time from the beginning of the first feeding event until an interval between events and averaged for each calf. Intervals (min) between feeding events were calculated from the end of a feeding event to the beginning of the next and averaged for each calf. The meal size (grams of starter DMI during a 12-h period/number of meals during that period) was the total amount of starter DM ingested during each meal. The same procedure was used to calculate the rumination pattern.

Health Criteria

Calf health was monitored daily by a veterinarian, unaware of the treatments, during the preweaning period (d 1 to 49). Rectal temperature was recorded daily between 1300 to 1400 h using a digital thermometer (model FT 15/1; Beurer GmbH, 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 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 recorded daily based on a 1 to 5 system while calves were in individual pens (Pazoki et al., 2017). Rectal temperature was categorized as number of days with temperature $\geq 40^{\circ}\text{C}$; fecal score (1 to 5 scale) was categorized as number of days with fecal score ≥ 3 ; and general appearance (1 to 5) was categorized as number of days with general appearance score ≥ 2 . These categories were denoted as days with abnormal rectal temperature, fecal score, and general appearance and evaluated by the veterinarian to confirm diarrhea and pneumonia diagnoses. Calves with diarrhea or pneumonia were treated with stan-

standard procedures prescribed by the veterinarian. Calves with diarrhea received water-based oral rehydration salt solution (4 L/d per calf in 2 equal meals for 3 consecutive days; Sepid Dehdasht Co., Tehran, Iran) and neomycin sulfate (one 500-mg bolus/d per calf for 3 consecutive days; Tolide Darouhai Dami Co., Tehran, Iran). Nonresponding individuals were treated for 3 more days with amoxicillin (Betamox L. A.; 6 mL per calf on d 1 and 3; Norbrook Laboratories Ltd., Newry, UK) and meloxicam (Rheumocam 2%; 6 mL per calf on first 2 d; Chanelle Pharmaceutical Manufacturing Ltd., Loughrea, Ireland). To treat pneumonia, calves were administered oxytetracycline (Tenaline 20% L. A.; 8 mL per calf on d 1 and 3; Ceva Santé Animale, Libourne, France), florfenicol (F-nex 300; 6 mL per calf for 3 consecutive days; Razak Laboratories Co., Karaj, Iran), and flunixin meglumine (Flunixin 5%; 5 mL per calf for 3 consecutive days; Razak Laboratories Co.). Nonresponding individuals were treated for 5 more days with ampicillin [Ampivil 1g; 2 times daily (12-h intervals) for 3 consecutive days and then 1 time daily for 2 consecutive days; Daanapharma Co., Tabriz, Iran] and flunixin meglumine (Flunixin 5%; 5 mL per calf for the first 3 consecutive days; Razak Laboratories Co.). In the case of nonresponse to the 2 applied protocols, the veterinarian did not continue medication with additional protocol. No animal died during the study period.

Blood Sampling and Analyses

Blood samples were gathered 4 h after the morning feeding into vacuum serum separator tubes containing clot activator on the starting day of study (72-h post-birth; to assess passive transfer status by measuring total protein; Table 8) and every 10 d thereafter during the preweaning period and immediately placed on ice. 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 kept immediately at -20°C for next analyses. The concentrations of blood metabolites were spectrophotometrically (UNICCO, 2100, Zistchemi, Tehran, Iran) measured using commercially available kits [Pars Azmoon Co., Tehran, Iran; Catalogue Numbers: total protein (1-500-028) and albumin (1-500-001)] according to the manufacturer's instructions (Kargar et al., 2015). Globulin concentrations were computed by subtracting albumin from total protein.

Statistical Analyses

Data were checked for normality before analyses using the UNIVARIATE procedure (SAS 9.4, SAS

Institute Inc., Cary, NC). Data (blood variables) that were not normally distributed were transformed logarithmically. Data on nutrient intake (d 1 to 49, 50 to 70, and 31 to 70), sorting activity (d 31 to 70), actual particle size fraction intakes for CP and NDF (d 31 to 70), and blood variables (d 1 to 49) were subjected to ANOVA using the MIXED procedure of SAS with time (day) as repeated measures. The effects of diet, time, and diet by time interaction were considered as fixed and calf as a random effect. Autoregressive covariance structure (type 1) was the best fit for these data as determined by the lowest Bayesian information criterion. Data on meal and rumination patterns and chewing behavior were analyzed using the same model without the time effect. Sorting values were transformed into a difference from 100% and tested against the null hypothesis that the difference was zero using *t*-tests within PROC MIXED of SAS. Furthermore, data for particle size distribution, pef, peNDF of experimental TMR, and geometric mean particle size were analyzed by including diet as fixed effect and period as a random effect. Least squares means for time and diet $\times$ time effects were separated using a Tukey adjustment when the overall F-test was $P \leq 0.05$. Trends were declared when $0.05 < P \leq 0.10$.

Models for occurrence of diarrhea (≥ 3), pneumonia, need for medication, rectal temperature ($\geq 40^\circ\text{C}$), and general appearance (≥ 2) were tested by logistic regression using a binomial distribution in the GLIMMIX procedure in SAS. Odds ratio was used to compare the likelihood for calves on each experimental diet to experience any event. Frequency and duration of diarrhea, pneumonia, administration of medication, and number of days with pneumonia, diarrhea (≥ 3), rectal temperature ($\geq 40^\circ\text{C}$), and general appearance (≥ 2) were tested with a Poisson distribution using the GENMOD procedure of SAS (version 9.4).

RESULTS

Diet Characteristics and Particle Size Distribution

The ingredient composition and chemical analysis of dry TMR are presented in Table 1. Both starter feed diets in the present study had the same ingredients and nutrient compositions; however, reconstitution of alfalfa hay decreased DM content of dry TMR from 91.2% in AH to 83.8% in RAH. Data on particle size distribution of alfalfa hay and TMR are presented in Table 2. Regardless of treatment, no particles were retained on the top sieve of the PSPS (>19 mm). The percentage of particles retained on the second (8–19 mm) and third (1.18–8 mm) sieves were greater for RAH than for AH, resulting in greater $\text{pef}_{>8}$ and $\text{pef}_{>1.18}$ ($P = 0.001$),

Table 1. Ingredients and chemical composition of the basal diet

Item	Value
Ingredient composition (% of DM)	
Alfalfa hay	10.0
Corn grain, ground	60.0
Barley grain, ground	5.5
Soybean meal	22.0
Vitamin and mineral mixture ¹	0.8
Calcium carbonate	1.2
Salt	0.5
Chemical composition (% of DM, unless noted)	
DM	91.2
CP	19.7
NFC ²	55.3
NDF	16.0
Ether extract	3.5
Ash	5.4
Calcium ³	0.7
Phosphorus ³	0.4
ME, ³ Mcal/kg of DM	3.1
NE _M , ³ Mcal/kg of DM	2.3
NE _G , ³ Mcal/kg of DM	1.8

¹Contained per kilogram of supplement: 1,000,000 IU of vitamin A, 12,500 IU of vitamin E, 16 g of Zn, 12 g of Mn, 3.5 g of Cu, 120 mg of I, 120 mg of Co, and 80 mg of Se.

²NFC = 100 - (CP + NDF + ether extract + ash) (NRC, 2001).

³Calculated from NRC (2001).

peNDF_{>8} and peNDF_{>1.18} ($P = 0.001$), and geometric mean particle size (1.8 vs. 1.5 mm; $P = 0.001$). As expected, reconstitution of alfalfa hay decreased (53.0 vs. 61.1%; $P = 0.001$) the feed materials retained on the bottom pan (<1.18 mm).

Nutrient Intake and Sorting Behavior

Reconstitution of alfalfa hay did not affect nutrient intake (DM, CP, and NDF) from starter feed (Table 3). Calves fed RAH sorted less for medium-length particles on the second sieve of the PSPS than for calves fed AH (107.9 vs. 114.2%; $P = 0.03$); however, reconstitution of alfalfa hay did not affect sorting of particles retained on the third sieve ($P = 0.71$) and bottom pan ($P = 0.23$). Irrespective of the type of dietary treatment fed, calves sorted for medium- and short-length particles on the second and third sieves of the PSPS and against the feed materials retained on the bottom pan. Reconstitution of alfalfa hay did not affect CP ($P = 0.46$) and NDF ($P = 0.67$) intakes of the feed materials retained on the bottom pan. However, CP and NDF intakes of particles retained on the both 8- and 1.18-mm sieves increased in calves fed RAH versus AH.

Meal and Rumination Patterns and Chewing Behavior

During the preweaning period, intermeal interval and meal size were not affected by treatment (Table 4); however, meal frequency (5.2 vs. 3.9; $P = 0.08$) and meal length (9.4 vs. 7.5 min; $P = 0.05$) increased and eating rate tended to decrease (7.1 vs. 9.7 g of starter DM/min; $P = 0.09$) with reconstitution. During the preweaning period, reconstitution of alfalfa hay tended

Table 2. Physical characteristics of alfalfa hay and experimental diets measured using the Penn State particle separator¹

Item	Alfalfa hay	Diet ²		SEM	P-value: Diet
		AH	RAH		
% of DM retained on sieves					
19 mm	15.4	0.0	0.0	—	—
8 mm	22.6	3.3 ^b	4.4 ^a	0.19	0.001
1.18 mm	31.4	35.6 ^b	42.6 ^a	0.39	0.001
Pan	30.6	61.1 ^a	53.0 ^b	0.47	0.001
pef _{>8} ³	0.38	0.03 ^b	0.04 ^a	0.001	0.001
pef _{>1.18} ³	0.69	0.39 ^b	0.47 ^a	0.004	0.001
peNDF _{>8} , % ³	17.3	0.5 ^b	0.7 ^a	0.03	0.001
peNDF _{>1.18} , % ³	31.7	6.2 ^b	7.5 ^a	0.07	0.001
Xgm, ⁴ mm	4.3	1.5 ^b	1.8 ^a	0.01	0.001
SDgm, ⁵ mm	3.6	2.2	2.3	—	—

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

¹Particle length variables were measured using the Penn State particle separator (The Pennsylvania State University, University Park; Kononoff et al., 2003).

²AH = starter feed containing 10% dry alfalfa hay; RAH = starter feed containing 10% reconstituted alfalfa hay.

³pef_{>8} and pef_{>1.18} = physical effectiveness factor determined as the proportion of particles retained on 2 sieves (Lammers et al., 1996) and on 3 sieves (Kononoff et al., 2003), respectively; peNDF_{>8} and peNDF_{>1.18} = physically effective NDF determined as NDF content of TMR multiplied by pef_{>8} and pef_{>1.18}, respectively.

⁴Geometric mean particle size, calculated according to ASAE (1995; method S424.1).

⁵Geometric SD of particle size, calculated according to ASAE (1995; method S424.1).

Table 3. Nutrient intake, sorting index¹, and particle size intake as influenced by feeding dry (AH) versus reconstituted alfalfa hay (RAH) to Holstein dairy calves

Item	Diet (D) ²		SEM	P-value		
	AH	RAH		D	Time (T)	D × T
Starter feed DMI, g/d						
Prewaning (d 1 to 49)	341	420	60.1	0.39	0.001	0.60
Postweaning (d 50 to 70)	2,040	2,152	110.2	0.52	0.001	0.22
d 31 to 70	1,355	1,447	91.9	0.42	0.001	0.31
Starter feed CP intake (d 31 to 70), g/d	267	285	18.1	0.49	0.001	0.30
Starter feed NDF intake (d 31 to 70), g/d	217	232	14.7	0.40	0.001	0.23
Sorting index, %						
19 mm	—	—	—	—	—	—
8 mm	114.2 ^{a*}	107.9 ^{b*}	1.90	0.03	0.001	0.28
1.18 mm	101.8 [*]	101.9 [*]	0.24	0.71	0.001	0.36
Pan	98.2 [*]	97.7 [*]	0.26	0.23	0.001	0.40
CP intake, g/d						
19 mm	—	—	—	—	—	—
8 mm	10 ^b	13 ^a	0.6	0.006	0.001	0.23
1.18 mm	96 ^b	123 ^a	7.0	0.01	0.001	0.14
Pan	161	149	10.9	0.46	0.001	0.34
NDF intake, g/d						
19 mm	—	—	—	—	—	—
8 mm	8 ^b	11 ^a	0.5	0.004	0.001	0.28
1.18 mm	78 ^b	100 ^a	5.6	0.01	0.001	0.19
Pan	131	121	8.8	0.67	0.001	0.39

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

¹Sorting % = $100 \times (\text{actual particle size fraction DMI} / \text{predicted particle size fraction DMI})$. Values equal to 100% indicate no sorting, <100% indicate selective refusals (sorting against), and >100% indicate preferential consumption (sorting for). Particle size determined by the Penn State particle separator (Kononoff et al., 2003), which separates the particles in 4 fractions: long (>19 mm), medium (<19 but >8 mm), short (<8 but >1.18 mm), and fine (<1.18 mm). Data are averaged over 10 d for each 10-d period for 10 calves per treatment.

²AH = starter feed containing 10% dry alfalfa hay; RAH = starter feed containing 10% reconstituted alfalfa hay.

* $P \leq 0.05$; sorting values differ from 100%.

to increase the number of ruminating bouts per 12 h (7.1 vs. 5.4; $P = 0.08$) and rumination duration (16.8 vs. 13.9 min; $P = 0.09$) but not rumination interval. During the postweaning period, meal length increased (9.9 vs. 8.1 min; $P = 0.02$) but eating rate tended to decrease (14.2 vs. 23.6 g of starter DM/min; $P = 0.07$) due to reconstitution. Reconstitution of alfalfa hay did not affect the number of rumination bouts per 12 h and rumination interval, but tended to increase rumination duration (16.6 vs. 14.9 min; $P = 0.08$) during the postweaning period.

During the preweaning period, time spent eating (48.7 vs. 30.1 min; $P = 0.01$) and ruminating (117.4 vs. 78.0 min; $P = 0.04$) increased in calves fed RAH compared with calves fed AH (Table 5). However, reconstitution did not affect time spent resting, standing, lying, drinking, and NNOB during the preweaning period. During the postweaning period, time spent eating (83.7 vs. 59.6 min; $P = 0.01$) and drinking (8.3 vs. 5.3 min; $P = 0.05$) increased but time spent resting (59.4 vs. 78.0 min; $P = 0.04$) and standing (136.2 vs. 159.0 min; $P = 0.03$) were decreased by reconstitution. However, times spent ruminating, lying, and NNOB were unaffected by reconstitution during the postweaning period.

Health Criteria and Blood Variables

Table 6 presents the logistic models for the occurrence of elevated rectal temperature ($\geq 40^\circ\text{C}$), general appearance score ≥ 2 , diarrhea (score ≥ 3), pneumonia, and needs for medication during the pre-weaning (d 1 to 49) period. The occurrence of elevated rectal temperature was not affected by reconstitution. Reconstitution of alfalfa hay decreased the occurrence of general appearance score ≥ 2 ($P = 0.007$), diarrhea ($P = 0.007$), and pneumonia ($P = 0.01$). Likewise, the chance of administration of medication for diarrhea and pneumonia increased in calves fed RAH compared with calves fed AH.

Table 7 presents the Poisson regression for the frequency and number of days with elevated rectal temperature ($\geq 40^\circ\text{C}$), general appearance (score ≥ 2), diarrhea (score ≥ 3), and pneumonia, as well as medicated days for both diarrhea and pneumonia. We observed no difference between treatments for the number of days with elevated rectal temperature; however, number of days with general appearance (score ≥ 2) decreased (0.3 vs. 1.7 d; $P = 0.001$) in calves fed RAH compared with calves fed AH. Frequency and medication days of diar-

Table 4. Meal and rumination patterns as influenced by feeding dry (AH) versus reconstituted alfalfa hay (RAH) to Holstein dairy calves

Item	Diet ¹		SEM	<i>P</i> -value: Diet
	AH	RAH		
Preweaning (d 37 to 39)				
Meal				
Bouts/12 h	3.9	5.2	0.51	0.08
Length, min	7.5 ^b	9.4 ^a	0.62	0.05
Interval, min	177.1	129.1	23.31	0.89
Eating rate, g of starter DM/min	9.7	7.1	1.03	0.09
Meal size, g of starter DM	71.9	66.5	9.07	0.67
Rumination				
Bouts/12 h	5.4	7.1	0.63	0.08
Length, min	13.9	16.8	1.14	0.09
Interval, min	119.4	84.6	16.24	0.28
Postweaning (d 67 to 69)				
Meal				
Bouts/12 h	7.4	8.5	0.57	0.16
Length, min	8.1 ^b	9.9 ^a	0.48	0.02
Interval, min	89.2	74.8	6.89	0.12
Eating rate, g of starter DM/min	23.6	14.2	3.46	0.07
Meal size, g of starter DM	189.3	138.1	26.48	0.19
Rumination				
Bouts/12 h	7.6	7.7	0.54	0.92
Length, min	14.9	16.6	0.66	0.08
Interval, min	79.8	76.9	5.62	0.92

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

¹AH = starter feed containing 10% dry alfalfa hay; RAH = starter feed containing 10% reconstituted alfalfa hay.

rhea were not affected by reconstitution, but duration of diarrhea decreased (2.4 vs. 4.7 d; $P = 0.01$) in calves fed RAH compared with calves fed AH. Frequency (0.1 vs. 0.4; $P = 0.001$) and number of days (0.3 vs. 1.4 d;

$P = 0.001$) with pneumonia and medicated days ($P = 0.001$) decreased in calves fed RAH compared with calves fed AH.

Initial blood concentration of total protein was not affected by treatment (9.13 g/dL; Table 8). Blood concentrations of total protein (8.54 vs. 7.77 g/dL; $P = 0.09$) and globulin (4.58 vs. 3.67 g/dL; $P = 0.06$) tended to be higher for calves fed RAH than for calves fed AH. However, concentrations of albumin and albumin-to-globulin ratio were not affected by treatment.

Table 5. Chewing behaviors (min/12 h) and times devoted to resting, standing, lying, drinking, and non-nutritive oral behaviors (NNOB) as influenced by feeding dry (AH) versus reconstituted alfalfa hay (RAH) to Holstein dairy calves

	Diet ¹			<i>P</i> -value: Diet
Item	AH	RAH	SEM	
Prewaning (d 37 to 39)				
Eating time	30.1 ^b	48.7 ^a	4.93	0.01
Ruminating time	78.0 ^b	117.4 ^a	13.06	0.04
Resting time	156.6	122.4	17.59	0.18
Standing time	139.6	135.9	7.78	0.73
Lying time	261.8	243.9	19.40	0.52
Drinking time	10.1	12.0	1.29	0.32
NNOB	43.5	39.5	6.57	0.67
Postweaning (d 67 to 69)				
Eating time	59.6 ^b	83.7 ^a	5.83	0.01
Ruminating time	111.3	123.5	8.38	0.32
Resting time	78.0 ^a	59.4 ^b	6.08	0.04
Standing time	159.0 ^a	136.2 ^b	7.04	0.03
Lying time	274.4	282.6	11.38	0.62
Drinking time	5.3 ^b	8.3 ^a	1.02	0.05
NNOB	32.1	26.1	4.69	0.37

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

¹AH = starter feed containing 10% dry alfalfa hay; RAH = starter feed containing 10% reconstituted alfalfa hay.

DISCUSSION

Increased moisture has been shown to diminish dustiness (Arzola-Álvarez et al., 2010; Beiranvand et al., 2016) and to prevent or decrease separation of ingredients (Leonardi and Armentano, 2003; Leonardi et al., 2005) of dry TMR and, therefore, to increase TMR uniformity and adhesiveness (Khan et al., 2014; Beiranvand et al., 2016). Accordingly, in the present study, the increased percentage of particles retained on the second and third sieves of PSPS and the decreased feed materials retained on the bottom pan in RAH may be attributed to the increased moisture due to the reconstitution of alfalfa hay.

In contrast to our hypothesis, increasing moisture level of TMR through the reconstitution of alfalfa hay did not encourage significant DMI in dairy calves. Ad-

Table 6. Logistic models for rectal temperature ($\geq 40^{\circ}\text{C}$), general appearance (≥ 2)¹, diarrhea (≥ 3)², pneumonia, and medication occurrence during the preweaning (d 1 to 49) period as influenced by feeding dry (AH) versus reconstituted alfalfa hay (RAH) to Holstein dairy calves

Variable and comparison	Coefficient	SEM	Odds ratio ³	95% CI	P-value
Rectal temperature (AH vs. RAH)	0.5808	0.43	1.78	0.75, 4.23	0.18
General appearance (AH vs. RAH)	1.6826	0.62	5.37	1.56, 8.49	0.007
Diarrhea occurrence (AH vs. RAH)	0.7066	0.26	2.02	1.20, 3.40	0.007
Pneumonia occurrence (AH vs. RAH)	1.5564	0.63	4.74	1.35, 6.59	0.01
Medication occurrence					
Diarrhea (AH vs. RAH)	-0.7066	0.26	0.49	0.29, 0.83	0.007
Pneumonia (AH vs. RAH)	-1.5564	0.63	0.21	0.06, 0.73	0.01

¹Where 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.

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

³The odds ratio (OR) indicates the probability of either having elevated rectal temperature ($\geq 40^{\circ}\text{C}$), general appearance (≥ 2), diarrhea (≥ 3), pneumonia, or needing medication for the AH vs. RAH diet. If the OR is >1 , the AH diet in the comparison is more likely to have elevated rectal temperature ($\geq 40^{\circ}\text{C}$), general appearance (≥ 2), diarrhea (≥ 3), pneumonia, or to be medicated than the RAH diet by a factor of the difference above 1. If the OR is <1 , the AH diet has a lower probability of occurrence than the RAH diet.

dition of water to hay or changing the moisture level of haylage by drying did not affect DMI in dairy heifers (Thomas et al., 1961). Adding water to high-forage (60%) TMR to obtain a DM content less than 65% tended to decrease DMI in dairy heifers (Khan et al., 2014). Addition of water to reduce DM content of dry TMR (containing 10% alfalfa hay and 90% concentrate) from 90 to 50% increased DMI in summer-exposed dairy calves (Beiranvand et al., 2016). Differences in reported results might be attributed to differences in feed composition (e.g., dietary forage source and levels), environmental conditions (e.g., temperature and humidity), moisture levels and methods used to manipulate moisture (e.g., adding water to concentrate or hay), and different animal age groups (calf vs. heifer; Khan et al., 2014; Beiranvand et al., 2016).

Regardless of the type of dietary treatment fed, calves sorted for the particles retained on second and third sieves of PSPS and against the feed materials retained on the bottom pan. Miller-Cushon and DeVries (2011) reported that calves fed hay during the preweaning period primarily sorted for forage particles when switched to a TMR (containing 40% hay and 60% concentrate), but established a preference for sorting against forage particles and for grain particles within a month after this alteration in diet. A preliminary sorting for forage has been connected to feed familiarity and developing sorting skills (Miller-Cushon and DeVries, 2011). However, calves in the present study were fed TMR from birth, which may indicate that the observed sorting activity was not due to feed neophobia or a lack of the requisite motor skills to obtain fine particles.

Table 7. Poisson regression for days with rectal temperature ($\geq 40^{\circ}\text{C}$) and general appearance (≥ 2)¹, and frequency and duration of diarrhea (≥ 3)², pneumonia, and days medicated during the preweaning (d 1 to 49) period as influenced by feeding dry (AH) versus reconstituted alfalfa hay (RAH) to Holstein dairy calves

Item	Diet			P-value: Diet
	AH	RAH	SEM	
Days with rectal temperature ($\geq 40^{\circ}\text{C}$)	1.6	0.9	0.30	0.17
Days with general appearance (≥ 2)	1.7 ^a	0.3 ^b	0.46	0.001
Diarrhea				
Number of calves diagnosed at least once for diarrhea	9/10	8/10	—	—
Frequency, times diagnosed	1.1	1.0	0.32	0.75
Duration, d	4.7 ^a	2.4 ^b	0.18	0.01
Medicated, d	4.2	4.0	0.16	0.77
Pneumonia				
Number of calves diagnosed at least once for pneumonia	3/10	1/10	—	—
Frequency, times diagnosed	0.4 ^a	0.1 ^b	0.80	0.001
Duration, d	1.4 ^a	0.3 ^b	0.45	0.001
Medicated, d	1.4 ^a	0.3 ^b	0.45	0.001

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

¹Where 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.

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

Table 8. Blood variables (g/dL) during the preweaning period (d 1 to 49) as influenced by feeding dry (AH) versus reconstituted alfalfa hay (RAH) to Holstein dairy calves

Item	Diet (D)		SEM	P-value		
	AH	RAH		D	Time (T)	D × T
Initial total protein	8.56	9.70	0.620	0.23	—	—
Total protein	7.77	8.54	0.241	0.09	0.95	0.63
Albumin	4.10	3.97	0.090	0.47	0.33	0.15
Globulin	3.67	4.58	0.254	0.06	0.87	0.66
Albumin:globulin	1.39	0.88	0.223	0.19	0.89	0.67

Calves are capable of developing the emergence and persistence, but not the pattern, of sorting skills from a young age, and these skills are determined by nutritional demands, rumen function, or their motivation to chew and ruminate (Costa et al., 2016). Because calves are thought to learn through physiological postingestive feedback mechanisms (Provenza, 1995), our findings indicate that calves fed AH and RAH from birth learn to balance nutrient intake (CP and NDF measured in the present study) in ways that support growth and alleviate the effects of lower rumen pH, which was substantiated by similar final BW (87.4 vs. 92.8 kg for AH vs. RAH, respectively; SEM = 3.25 and $P = 0.26$) and rumen fluid pH during the preweaning (5.62 vs. 5.73 for AH vs. RAH, respectively; SEM = 0.14 and $P = 0.57$) and postweaning (5.70 vs. 5.60 for AH vs. RAH, respectively; SEM = 0.09 and $P = 0.45$) periods between treatment groups (Kargar and Kanani, 2019). Despite this, calves may be sorting for longer particles because of feeding a high-corn or high-starch diet, and sorting was exacerbated in the dry AH treatment because of a greater need to buffer as peNDF was shifted due to water addition.

Feed intake is a function of both meal size and meal frequency, determined by satiety and hunger, respectively (Allen et al., 2009; Kargar et al., 2013, 2014). In the present study, a higher meal frequency (25%) together with a longer meal duration (20%) in calves fed RAH resulted in calves spending more time eating (min/12 h) compared with calves fed AH during the preweaning period. Despite an increase in meal frequency and eating time, DMI did not change, which may be attributed to slower eating rate in calves fed RAH. The slower eating rate in calves fed RAH may reflect that calves fed AH ate feed easier than that of calves fed RAH. This observation may be substantiated by greater NDF intake from particles retained on the second and third sieves of PSPS in calves fed RAH versus AH (Kargar et al., 2010); however, overall NDF intake was similar between treatment groups. Moisture can increase bulkiness of feed, which could reduce feeding rate due to slower passage rate (satiety; Neel et al., 1995). Rumen

capacity in young calves was considerably reduced compared with larger weaned heifers and mature cows, so satiety may have been reached quicker with bulkier feed. Another explanation is that keeping reconstituted AH at ambient temperature might result in fermentation, a drop in pH, and a rise in forage heat because it was allowed to sit for 24 h before feeding, thereby reducing eating rate (Thomas et al., 1961; McLeod et al., 1970). However, we did not measure these variables during the study period to substantiate the observed effect. Similar to eating time, a higher rumination frequency (24%) and longer rumination duration (17%) resulted in increased time spent ruminating in calves fed RAH. The increase in time devoted to rumination in RAH relative to AH may be, in part, due to greater selective consumption of NDF (Kargar et al., 2013, 2014). However, time spent eating and ruminating decreased when reconstituted alfalfa hay was fed to dairy cows (Teimouri Yansari and Primohammadi, 2009) or was not affected when water was added to TMR to reduce DM content of diets from 78 to 40% (Lahr et al., 1983). During the postweaning period, calves fed RAH had a longer meal duration (18%) and thereby a longer eating time compared with calves fed AH, with no changes in DMI between treatment groups, indicating a slower eating rate in calves fed RAH. Due to the higher eating time, calves fed RAH spent less time resting during the postweaning period. The reason for a decrease in time devoted to standing and an increase in drinking time in calves fed RAH is not clear. Beiranvand et al. (2016) observed a tendency for a linear increase in time devoted to standing in dairy calves with increasing moisture level of starter diets. To our knowledge, no similar published data on the effect of reconstituted alfalfa hay on the feeding behavior of dairy calves are available for comparison.

In the present study, calves fed AH compared with calves fed RAH had a higher probability of having diarrhea and pneumonia and a lower chance of being treated during the preweaning period. The lower chance of treatment was because a number of calves in the AH group did not respond to the 2 applied

medication protocols and no further medications was applied; despite this fact, health criteria were still recorded. We observed no difference between treatment groups for frequency and medication days of diarrhea; however, calves fed RAH had fewer days with diarrhea. Furthermore, frequency and number of days with pneumonia and administration of medication were greater for calves fed AH compared with calves fed RAH. Pneumonia, a disease of the lungs, is the result of a complex interaction between the calf, its own resilience to disease and immunity, viral and bacterial pathogens, the environment (e.g., dust), and concurrent disease (Waltner-Toews et al., 1986; Perez et al., 1990; Taylor et al., 2010). Dust can interact with pathogens (which can be present in a normal calf's nose and throat) to gain access to the lower lung and cause pneumonia. Accordingly, we hypothesized that calves fed AH (due to having a dry nature and finer particles; Tables 1 and 2) in the present study had more dust around nose-space and therefore developed pneumonia more frequently than calves fed RAH. We assumed that calves fed RAH in the present study had a stronger immune state than calves fed AH and thereby experienced fewer days with diarrhea and pneumonia as well as faster recovery from disease. This effect was substantiated by an increase in indicators of immune system activity (e.g., blood total protein and globulin) in the present study and those greater concentrations in calves fed RAH may depict an immune response. Fresh-cut hay or pasture and salt (as a supplement) are recommended to feed dairy calves to avoid diarrhea during the preweaning period (Maas, 1999). Hydration increases availability and cation exchange capacity of forage for some macrominerals, including Ca, Mg, and K (Van Soest, 1994). In immune cells, divalent cations (e.g., Ca and Mg) have important roles as second messengers to regulate intracellular signaling pathways. In addition, monovalent cations (e.g., Na and K) mainly regulate the membrane potential, which indirectly controls the influx of Ca and immune cell signaling (Feske et al., 2015). Alfalfa contains greater concentrations of K and Ca (NRC, 2001), so we assumed that reconstitution increased availability of K and Ca for RAH calves, improved their immune state, and thereby decreased duration of medication. Another explanation is that calves fed RAH versus AH had a slower eating rate with similar intake, and therefore fewer days with diarrhea in calves fed RAH might be reflective of passage rate and not sickness. However, calves, in general, were healthy, but more studies with a greater number of animals per groups are required to confirm these explanations. Due to a greater incidence rate of pneumonia and longer recovery period from diarrhea and pneumonia, calves fed AH had a greater

chance to be seen in the statement that general appearance score is ≥ 2 .

CONCLUSIONS

In summary, feeding RAH to dairy calves increased time spent eating by increasing meal frequency and meal duration but did not affect DMI due to lowering eating rate. Regardless of type of dietary treatment fed, calves presented feed sorting to the extent that balanced intake of nutrients and met their nutritional needs. Calves in general were healthy but it seems that feeding a TMR diet containing reconstituted alfalfa hay has a potential health promoting effect, possibly through reducing diet dustiness and improving immune status.

ACKNOWLEDGMENTS

The authors thank Shiraz University (Shiraz, Iran) for providing suitable experimental conditions. The authors express their kind appreciation to the farm staff at Foudeh-Sepahan Agriculture and Animal Husbandry (Isfahan, Iran) for diligent animal care; to Mehdi Mirzaei (Arak University, Arak, Iran), Yadollah Moharrami, Naser Dadkhah, and Ali Agha-Tehrani (Foudeh-Sepahan Agriculture and Animal Husbandry, Isfahan, Iran), and Abolfazl Soltani (University of Tehran, Karaj, Iran) for their help in conducting this experiment.

REFERENCES

- Allen, M. S., B. J. Bradford, and M. Oba. 2009. Board-invited review: The hepatic oxidation theory of the control of feed intake and its application to ruminants. *J. Anim. Sci.* 87:3317–3334.
- AOAC International. 2002. Official Methods of Analysis. 17th ed. AOAC International, Arlington, VA.
- Arzola-Álvarez, C., J. A. Bocanegra-Viezcá, M. R. Murphy, J. Salinas-Chavira, A. Corral-Luna, A. Romanos, O. Ruiz-Barrera, and C. Rodríguez-Muela. 2010. Particle size distribution and chemical composition of total mixed rations for dairy cattle: Water addition and feed sampling effects. *J. Dairy Sci.* 93:4180–4188.
- ASAE (American Society of Agricultural Engineers). 1995. Method of determining and expressing fineness of feed material by sieving. Method S424.1. Page 461 in ASAE Standards 1995. ASAE, St. Joseph, MI.
- Beiranvand, H., G. R. Ghorbani, M. Khorvash, A. Nabipour, M. Dehghan-Banadaky, A. Homayouni, and S. Kargar. 2014. Interactions of alfalfa hay and sodium propionate on dairy calf performance and rumen development. *J. Dairy Sci.* 97:2270–2280.
- Beiranvand, H., M. Khani, S. Omidian, M. Ariana, R. Rezvani, and M. H. Ghaffari. 2016. Does adding water to dry calf starter improve performance during summer? *J. Dairy Sci.* 99:1903–1911.
- Costa, J. H. C., N. A. Adderley, D. M. Weary, and M. A. G. von Keyserlingk. 2016. Short communication: Effect of diet changes on sorting behavior of weaned dairy calves. *J. Dairy Sci.* 99:5635–5639.

- DeVries, T. J., M. A. G. von Keyserlingk, and K. A. Beauchemin. 2005. Frequency of feed delivery affects the behavior of lactating dairy cows. *J. Dairy Sci.* 88:3553–3562.
- Feske, S., H. Wulff, and E. Y. Skolnik. 2015. Ion channels in innate and adaptive immunity. *Annu. Rev. Immunol.* 33:291–353.
- Fish, J. A., and T. J. DeVries. 2012. Short communication: Varying dietary dry matter concentration through water addition: Effect on nutrient intake and sorting of dairy cows in late lactation. *J. Dairy Sci.* 95:850–855.
- Greter, A. M., K. E. Leslie, G. J. Mason, B. W. McBride, and T. J. DeVries. 2010. Effect of feed delivery method on the behavior and growth of dairy heifers. *J. Dairy Sci.* 93:1668–1676.
- Iranian Council of Animal Care. 1995. Guide to the Care and Use of Experimental Animals, Vol. 1. Isfahan University of Technology, Isfahan, Iran.
- Kargar, S., G. R. Ghorbani, V. Fievez, and D. J. Schingoethe. 2015. Performance, bioenergetic status, and indicators of oxidative stress of environmentally heat-loaded Holstein cows in response to diets inducing milk fat depression. *J. Dairy Sci.* 98:4772–4784.
- Kargar, S., G. R. Ghorbani, M. Khorvash, E. Kamalian, and D. J. Schingoethe. 2013. Dietary grain source and oil supplement: Feeding behavior and lactational performance of Holstein cows. *Livest. Sci.* 157:162–172.
- Kargar, S., G. R. Ghorbani, M. Khorvash, A. Sadeghi-Sefidmazgi, and D. J. Schingoethe. 2014. Reciprocal combinations of barley and corn grains in oil-supplemented diets: Feeding behavior and milk yield of lactating cows. *J. Dairy Sci.* 97:7001–7011.
- Kargar, S., and M. Kanani. 2019. Reconstituted versus dry alfalfa hay in starter feed diets of Holstein dairy calves: Effects on growth performance, nutrient digestibility, and metabolic indications of rumen development. *J. Dairy Sci.* 102:4051–4060. <https://doi.org/10.3168/jds.2018-15153>.
- Kargar, S., M. Khorvash, G. R. Ghorbani, M. Alikhani, and W. Z. Yang. 2010. Short communication: Effects of dietary fat supplements and forage:concentrate ratio on feed intake, feeding, and chewing behavior of Holstein dairy cows. *J. Dairy Sci.* 93:4297–4301.
- Khan, M. A., A. Bach, L. Castells, D. M. Weary, and M. A. G. von Keyserlingk. 2014. Effects of particle size and moisture levels in mixed rations on the feeding behavior of dairy heifers. *Animal* 8:1722–1727.
- Kononoff, P. J., A. J. Heinrichs, and D. R. Buckmaster. 2003. Modification of the Penn State forage and total mixed ration particle separator and the effects of moisture content on its measurements. *J. Dairy Sci.* 86:1858–1863.
- Lahr, D. A., D. E. Otterby, D. G. Johnson, J. G. Linn, and R. G. Lundquist. 1983. Effects of moisture content of complete diets on feed intake and milk production of cows. *J. Dairy Sci.* 66:1891–1900.
- Lammers, B. P., D. R. Buckmaster, and A. J. Heinrichs. 1996. A simple method for the analysis of particle sizes of forage and total mixed rations. *J. Dairy Sci.* 79:922–928.
- Leonardi, C., and L. E. Armentano. 2003. Effect of quantity, quality, and length of alfalfa hay on selective consumption by dairy cows. *J. Dairy Sci.* 86:557–564.
- Leonardi, C., F. Giannico, and L. E. Armentano. 2005. Effect of water addition on selective consumption (sorting) of dry diets by dairy cattle. *J. Dairy Sci.* 88:1043–1049.
- Maas, J. 1999. Preventing calf diarrhea. *California Cattleman*. Accessed Sep. 7, 2018. http://ucanr.edu/sites/UCCE_LR/files/151979.pdf.
- McLeod, D. S., R. J. Wilkins, and W. F. Raymond. 1970. The voluntary intake by sheep and cattle of silages differing in free-acid content. *J. Agric. Sci.* 75:311–319.
- Miller-Cushon, E. K., and T. J. DeVries. 2009. Effect of dietary dry matter concentration on the sorting behavior of lactating dairy cows fed a total mixed ration. *J. Dairy Sci.* 92:3292–3298.
- Miller-Cushon, E. K., and T. J. DeVries. 2010. Feeding amount affects the sorting behavior of lactating dairy cows. *Can. J. Anim. Sci.* 90:1–7.
- Miller-Cushon, E. K., and T. J. DeVries. 2011. Effect of early feed type exposure on diet-selection behavior of dairy calves. *J. Dairy Sci.* 94:342–350.
- Neel, J. P., E. C. Prigge, and E. C. Townsend. 1995. Influence of moisture content of forage on ruminal functional specific gravity and passage of digesta. *J. Anim. Sci.* 73:3094–3102.
- NRC. 2001. Nutrient Requirement of Dairy Cattle. 7th rev. ed. Natl. Acad. Sci., Washington, DC.
- Pazoki, A., G. R. Ghorbani, S. Kargar, A. Sadeghi-Sefidmazgi, J. K. Drackley, and M. H. Ghaffari. 2017. Growth performance, nutrient digestibility, ruminal fermentation, and rumen development of calves during transition from liquid to solid feed: Effects of physical form of starter feed and forage provision. *Anim. Feed Sci. Technol.* 234:173–185.
- Perez, E., J. P. T. M. Noordhuizen, L. A. van Wuijkhuise, and E. N. Stassen. 1990. Management factors related to calf morbidity and mortality rates. *Livest. Prod. Sci.* 25:79–93.
- Provenza, F. D. 1995. Postingestive feedback as an elementary determinant of food preference and intake in ruminants. *J. Range Manage.* 48:2–17.
- Taylor, J. D., R. W. Fulton, T. W. Lehenbauer, D. L. Step, and A. W. Confer. 2010. The epidemiology of bovine respiratory disease: What is the evidence for predisposing factors? *Can. Vet. J.* 51:1095–1102.
- Teimouri Yansari, A., and R. Primohammadi. 2009. Effect of particle size of alfalfa hay and reconstitution with water on intake, digestion and milk production in Holstein dairy cows. *Animal* 3:218–227.
- Thomas, J. W., L. A. Moore, M. Okamoto, and J. F. Sykes. 1961. A study of factors affecting rate of intake of heifers fed silage. *J. Dairy Sci.* 44:1471–1483.
- Van Soest, P. J. 1994. Nutritional Ecology of the Ruminant. 2nd ed. Cornell University Press, Ithaca, NY.
- Waltner-Toews, D., S. W. Martin, and A. H. Meek. 1986. Dairy calf management, morbidity and mortality in Ontario Holstein herds. III. Association of management with morbidity. *Prev. Vet. Med.* 4:137–158.
- ZeidAli-Nejad, A., G. R. Ghorbani, S. Kargar, A. Sadeghi-Sefidmazgi, A. Pezeshki, and M. H. Ghaffari. 2018. Nutrient intake, rumen fermentation and growth performance of dairy calves fed extruded full-fat soybean as a replacement for soybean meal. *Animal* 12:733–740.