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Evaluation of inclusion of hay, dampened hay, and silage in receiving diets of newly weaned beef calves

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ABSTRACT

Objective: The objective of this study was to evaluate the effects of receiving-diet roughage form and source on growth performance of newly received calves.

Materials and Methods: An oat crop was harvested as hay or silage and fed as oat hay (OH), dampened oat hay (OHW; 4:1 hay:water), or oat silage (SIL) as the roughage source in soybean hull–based receiving diets to 7-mo-old steer calves across 2 yr (replicates per treatment: yr 1 = 6; yr 2 = 7).

Results and Discussion: No differences in cumulative ADG ($P = 0.24$) or G:F ($P = 0.47$) were observed, but OH steers consumed less DM ($P = 0.02$) in yr 1. Cumulatively, no differences in ADG were observed in yr 2 ($P = 0.21$); however, SIL-fed steers consumed less DM ($P < 0.01$) than OH or OHW steers, which resulted in greater G:F ($P = 0.01$). The magnitude of change in proportion of larger particles (i.e., feed particles retained in a 12.7-mm screen) in the bunk from feed delivery to after the meal was almost 4-fold greater for OH than SIL in yr 1 ($P = 0.04$) and 3.5-fold greater in yr 2 ($P = 0.05$). As batch fraction (i.e., scale of 0 to 1 representing from which portion of the batch each pen's allotment of feed was derived) progressed, the proportion of larger particles delivered increased ($P < 0.01$).

Implications and Applications: Oat forage in silage form did not adversely affect acceptance of receiving diets for calves, and forage as silage resulted in more uniform feed mixing.

Key words: cattle, diet mixing, particle size, roughage source, silage

INTRODUCTION

One of the challenges confronting calves transitioning from rangeland or forageland grazing to a feedlot setting is the introduction of novel feedstuffs (Loerch and Fluharty, 1999). Adaptation to feedlot diets by newly received calves is an important aspect in the productivity and well-being of the calves. Improvements in performance during the receiving phase can often be maintained throughout subsequent feeding periods (Lofgreen et al., 1975; Lofgreen, 1987; Galyean et al., 1993). It is important for calves to increase DMI to minimize the time spent in a negative energy balance and to support immunity and growth. Harvested hay is often used as a roughage source for newly received calves as hay is a familiar feed to calves that have previously consumed forage. Ensiled feeds may be less desirable in receiving diets because of the unfamiliar smell and taste (Loerch and Fluharty, 1999; Preston, 2007). Ensiled feeds may require additional storage facilities and equipment costs, and silage quality can be readily diminished with improper storage or management (Johnson et al., 2002). However, ensiled feeds can decrease loss of fines due to wind and weather, do not require regular grinding events, and have inherent moisture, which can act as a diet conditioner, all of which are desirable for beef producers. The objective of this experiment was to evaluate the effects of hay, dampened hay, or silage as the roughage source in receiving diets on calf performance.

MATERIALS AND METHODS

All experimental protocols were approved by the South Dakota State University Institutional Animal Care and Use Committee (approval # 17-076E). These experiments were conducted over 2 consecutive years at the South Dakota State University Ruminant Nutrition Center (**RNC**).

The chronology of key events in both studies is presented in Table 1. Angus and Angus-based crossbred steer calves of approximately 7 mo of age (yr 1, n = 180; yr 2, n = 210) were sourced from 2 ranches in western South Dakota. Calves were weaned and transported approximately 580 km to the RNC near Brookings, South Dakota. Upon arrival at the feedlot, calves were placed into pens (10 steers per pen) and allowed access to water and long-stem grass hay overnight. The next morning calves were processed, which included obtaining individual BW, administering ear tags and vaccination for viral (Bovi-Shield Gold 5, Zoetis, Kalamazoo, MI) and clostridial diseases (Ultrabac 7, Zoetis), and treating for internal and external parasites

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Table 1. Chronology of key events in 2 receiving experiments

Item	Yr 1	Yr 2
Initial access to long-stem grass hay, d	1 to 3	1 to 2
First access to milled feed, d	3	2
Interim weight capture, d	16	14
Bunk sample collection, d	32 (all pens)	22 and 30 (replicates 1–3) 24 and 29 (replicates 4–7)
Total length of experiment, d	42	42

(Cydectin, Bayer, Shawnee, KS). Cattle were stratified by ranch of origin and processing BW and then randomly assigned to treatment and, subsequently, to pen replicate (yr 1 = 6 replicates per treatment; yr 2 = 7 replicates per treatment).

Treatments consisted of 3 diets that differed only in the form of oat forage included on a 40% DM basis in receiving diets. Forage forms included oat hay (**OH**), dampened oat hay (**OHW**; 4 parts hay:1 part water), or oat silage (**SIL**). Within year, forage was harvested from the same oat crop cutting from the same field. Oat silage was harvested with a forage harvester, chopped to a length of 1.9 cm (0.75 in), stored in a 4.3 × 3.0 m horizontal bunker silo without inoculant, and covered with a plastic tarp, which was weighted down with truck-tire sidewalls. Oat hay, stored as net-wrapped large round bales in a shed with a steel roof and open sides, was ground through an 8.9-cm (3.5 in) screen with a tub grinder (Haybuster Model 1130; DuraTech Industries International Inc., Jamestown, ND). Analyzed nutrient compositions of oat hay and oat silage are presented in Table 2. Composition of the receiving diets in yr 1 and yr 2 are presented in Table 3 and Table 4, respectively. Diets included soybean hulls and a pelleted supplement that was the carrier for added monensin, vitamins, and minerals. Additional protein was provided by soybean meal in yr 1 and by dried distillers grains in yr 2. All diets were formulated to exceed nutrient requirements of growing steers (NASEM, 2016).

On d 1, milled diets were top dressed on the long-stem hay to facilitate adaptation. Diets were mixed in a reel-type mixer (Roto-Mix 84-8; Roto-Mix, Dodge City, KS). Oat forage was the first ingredient added to the mixer. If the diet included added water, it was sprinkled directly onto the oat hay. The hay and water were allowed to mix for 30 s (approximately 2 full mixer revolutions). Pelleted supplement was then added to the mixer, followed by soybean hulls. Diets were allowed to mix for 4 min (20 full mixer revolutions). Three pens were fed out of each batch in yr 1, and either 3 or 4 pens were fed out of each batch in yr 2. Cattle were fed twice daily (approximately 0800 and 1500 h), and after the initial 14 d where intakes were programmed by management, bunks were managed according to a clean bunk management system (Pritchard and Bruns, 2003). Diets were formulated to be isoenergetic and provide 28 mg/kg monensin (Rumensin 90, Elanco Animal Health, Greenfield, IN). In yr 1, diets were reformulated on d 23 to adjust for decreasing CP content of the oat silage. Feed records were compiled weekly, or more frequently if necessary, and feed batching records and weekly ingredient assay values were used to calculate actual diet formulation and composition values. Feed samples were dried in a forced-air oven at 60°C until a constant weight was maintained to determine DM and then ground through a 1-mm screen (Thomas-Wiley Laboratory Mill Model 4, Thomas Scientific USA, Swedesboro, NJ). Ground samples were analyzed for DM (method no. 935.29; AOAC International, 2012), CP (Kjeldahl procedure; method no. 951.01; AOAC International, 2012), NDF and ADF (Goering and Van Soest, 1970), and ash content (method no. 942.05; AOAC International, 2012).

The initial BW used was the BW obtained during processing. Cattle were subsequently weighed on d 16 and

Table 2. Nutrient composition (DM basis) of oat forage sources over 2 yr

	Oat forage source[1]	
Item, %	OH	SIL
Yr 1		
n	6	6
DM, %	83.40	25.66
CP, %	11.97	10.70
NDF, %	67.34	65.94
ADF, %	42.88	43.85
Ash, %	10.64	11.11
Yr 2		
n	7	7
DM, %	88.69	31.94
CP, %	9.28	9.31
NDF, %	62.60	62.71
ADF, %	37.18	38.49
Ash, %	8.65	9.49

[1]OH = oat hay; SIL = oat silage. Within year, both forage sources were harvested from the same oat crop cutting from the same field.

Table 3. Diet formulations and composition for receiving calves in yr 1 as derived from weekly assays and batching formulas[1]

Item, % unless noted otherwise	Diet[2]		
	OH	OHW	SIL
3–22 d			
Soybean hulls	53.55	53.55	58.70
Oat hay	41.22	41.22	—
Oat silage	—	—	35.57
Pelleted supplement[3]			
Soybean hulls	3.09	3.09	3.38
Dry-rolled corn	0.53	0.53	0.58
Soybean meal	1.30	1.30	1.42
Salt	0.31	0.31	0.34
DM	85.97	78.15	48.27
CP	11.70	11.70	11.11
NDF	64.23	64.23	63.58
ADF	47.66	47.66	48.18
Ash	8.22	8.22	8.00
NE_m,[4] Mcal/kg	1.81	1.81	1.86
NE_g,[4] Mcal/kg	1.11	1.11	1.15
23–42 d			
Soybean hulls	51.39	51.39	47.27
Oat hay	40.33	40.33	—
Oat silage	—	—	43.32
Soybean meal	3.05	3.05	4.43
Pelleted supplement[3]			
Soybean hulls	3.09	3.09	2.93
Dry-rolled corn	0.53	0.53	0.51
Soybean meal	1.30	1.30	1.24
Salt	0.31	0.31	0.30
DM	84.59	76.90	44.49
CP	13.04	13.04	12.85
NDF	62.27	62.27	61.19
ADF	45.37	45.37	44.79
Ash	7.97	7.97	8.16
NE_m,[4] Mcal/kg	1.81	1.81	1.79
NE_g,[4] Mcal/kg	1.11	1.11	1.09

[1]All values except DM are reported on a DM basis.

[2]Roughage source in receiving diets consisted of oat hay (OH), dampened oat hay (OHW; 4:1 hay:water), or oat silage (SIL).

[3]Pelleted supplement contained monensin (28 mg/kg) and provided minerals and vitamins to exceed requirements of growing steers.

[4]Based on tabular feed values (Preston, 2016).

42 in yr 1 and on d 14 and 42 in yr 2. All individual BW were recorded in the morning before cattle were fed, approximately 17 h following the previous day's afternoon feeding.

Bunk samples were collected from each pen in both years to assess uniformity of mix and sorting by cattle. In yr 1, samples were collected on d 32 during the afternoon feed delivery. In yr 2, samples were collected during the morning feed delivery; pen replicates 1 through 3 of each treatment were sampled on d 22 and 30 and pen replicates 4 through 7 were sampled on d 24 and 29 (Table 1). At each bunk sampling event, samples were collected at the time of feed delivery and again after about 75% of feed was consumed. Bunk samples at the time of delivery were collected into a wooden sampling box placed in the middle of the bunk as feed was unloaded from the delivery wagon. Postmeal bunk samples were based on a visual assessment of when approximately 75% of delivered feed was consumed, independent of feed delivery sequence. Postmeal bunk samples were obtained by compositing four 15-cm (6-in) cross-sections of bunk contents at evenly spaced intervals along the length of the bunk. Immediately after postmeal sample collection, the weight of the remaining feed in the bunk was recorded to determine proportion of feed consumed. Upon collection, bunk samples were subjected to particle separation using a 12.7-mm (0.5-in) brass sieve (The W. S. Tyler Company, Mentor, OH). The weights of the material that passed through the sieve (smaller particles) and of the material that was retained (larger particles) were recorded. The DM content of the smaller and larger particle fractions was determined by drying in a forced-air oven at 60°C until a constant weight was maintained.

Blood was collected in yr 2 only, on d 2, 9, and 16 from sentinel steers (n = 3 steers per pen; 21 steers per treatment). Sentinel steers were selected from each pen based on initial BW. Initial BW was stratified for all steers in each pen. The third, fifth, and seventh ranked steers were selected from odd-numbered pen replicates, and second, sixth, and eighth ranked steers were selected from even-numbered pen replicates. Blood was collected via jugular venipuncture using 18-gauge needles and 10-mL vacuum-sealed tubes (Becton Dickinson, Franklin Lakes, NJ). Blood was allowed to clot for 24 h at 4°C and then centrifuged at 2,000 × g, and sera was harvested and stored frozen until subsequent metabolite analysis. Sera was analyzed for circulating concentrations of nonesterified fatty acids (**NEFA**) and albumin. Nonesterified fatty acids were quantified using a commercially available colorimetric assay [NEFA-HR(2); Wako Diagnostics, Richmond, VA] that converts NEFA to hydrogen peroxide by action of acyl-CoA synthetase, acyl-CoA oxidase, and peroxidase. Measurements of NEFA were performed in triplicate, and the intra- and inter-assay CV were 1.4 and 6.6%, respectively. Albumin was measured directly using a commercially available colorimetric assay (QuantiChrom DIAG-250; BioAssay Systems, Hayward, CA) that uses bromocresol green. Concentrations of albumin were measured in triplicate, and the intra- and inter-assay CV were 1.7 and 5.9%, respectively.

One steer from the OH treatment was removed from the experiment on d 31 in yr 2 for reasons unrelated to treatment. Data from this steer were included in the analysis up until the point it was removed from the study and excluded from cumulative performance. Animal performance and diet mixing data were analyzed using the Mixed Model procedure of SAS (SAS Institute Inc., Cary, NC) with fixed effects of treatment, year, and the interaction of treatment × year. Pen was considered to be the experimental unit for all analyses. All BW except initial BW were shrunk 4%. Blood metabolite data were analyzed specific for repeated measures, with fixed effects of treatment, time, and the treatment × time interaction, and pen serving as the experimental unit.

To evaluate effects of within-batch mix variation, each pen was assigned a batch fraction (**BF**) value (i.e., a scale of 0 to 1, with 0 being the beginning of batch offload and 1 being the final portion of batch offload). Batch fraction was calculated to represent from which portion of the batch each pen's allotment of feed was derived. This BF value was used to standardize feed batches manufactured for either 3 or 4 pens. For a 3-pen batch, BF values were 0.166, 0.500, and 0.833 for pen replicates 1 to 3, respectively. For a 4-pen batch, BF values were 0.125, 0.375, 0.625, and 0.875 for pen replicates 1 to 4, respectively. Effects of within-batch variation (to test mixing) were analyzed independent of treatment, with BF serving as a fixed effect. Linear and quadratic effects of within-batch mix variations within treatment were tested using equally spaced, polynomial orthogonal contrasts. The REG procedure was used to determine correlations between cumulative ADG, proportion of larger feed particles delivered, and BF. When $P \leq 0.05$, treatment means were separated using the LSMEANS statement with the PDIFF option.

Table 4. Diet formulations and composition for receiving calves in yr 2 as derived from weekly assays and batching formulas[1]

Item, % unless noted otherwise	Diet[2]		
	OH	OHW	SIL
Soybean hulls	49.76	49.76	50.17
Oat hay	40.51	40.51	—
Oat silage	—	—	40.02
Dried distillers grains	5.71	5.71	5.76
Pelleted supplement[3]			
Soybean meal	3.27	3.27	3.29
Calcium carbonate	0.45	0.45	0.46
Salt	0.30	0.30	0.30
DM	88.35	80.32	51.41
CP	13.16	13.16	13.20
NDF	58.55	58.55	58.50
ADF	39.15	39.15	39.63
Ash	7.23	7.23	7.58
NE_m,[4] Mcal/kg	1.81	1.81	1.81
NE_g,[4] Mcal/kg	1.11	1.11	1.12

[1]All values except DM are reported on a DM basis.

[2]Roughage source in receiving diets consisted of oat hay (OH), oat hay with added water (OHW), or oat silage (SIL).

[3]Pelleted supplement contained monensin (28 mg/kg) and provided minerals and vitamins to exceed requirements of growing steers.

[4]Based on tabular feed values (Preston, 2016).

RESULTS AND DISCUSSION

Treatment diets in both years were formulated to be isonitrogenous and isocaloric. In yr 1, diets were reformulated on d 23 to adjust for numerically lesser CP concentration of oat silage (Table 3). Despite this lesser silage CP concentration, diet CP concentration from 3 to 22 d was not different ($P = 0.20$) between diets.

Animal Performance

Significant treatment × year interactions were detected ($P < 0.01$) for all of the growth performance measurements presented in Table 5, except for initial BW, G:F in period 2, and cumulative ADG and G:F. For these variables, main-effect LSM will be presented and discussed, and for all other variables, simple-effect LSM will be presented and discussed. During the initial 2 wk after arrival to the RNC, feed deliveries were managed to accommodate newly weaned calves by setting upper limits of allowable DMI. Briefly, cattle were allowed approximately 1-times maintenance energy intake (NASEM, 2016) on the first day milled feed was offered, and increases in feed offered were such that cattle were not allowed to surpass 2.3-times maintenance energy intake prior to d 14. In yr 1, the DM content of the oat silage was overestimated at the time of diet formulation. As a consequence, less feed was offered to the SIL calves for the 1 to 16 d period ($P \leq 0.01$). However, a treatment × year interaction ($P < 0.01$) was detected for ADG during period 1, where ADG did not differ across treatments during yr 1, but during yr 2, cattle fed SIL had a greater ADG than cattle fed OH or OHW ($P < 0.01$). Gain:feed also had a treatment × year interaction ($P < 0.01$) in that G:F was not different during yr 1, but within yr 2, calves fed SIL had a greater G:F than calves fed OH or OHW ($P = 0.01$).

A treatment × year interaction was detected ($P < 0.01$) for ADG during period 2. Within yr 1 ADG did not differ between OH and OHW treatments but was greater for calves fed SIL ($P = 0.03$); however, in yr 2, ADG was greater for calves fed OHW and lesser for cattle fed SIL ($P < 0.01$), with cattle fed OHW being similar to both. Although the improved performance in yr 1 by SIL-fed cattle during period 2 may initially appear to be compensatory growth, our hypothesis is that compensatory growth was unlikely in this case as the extent of restriction (i.e., 0.46 kg less DMI and 0.14 kg less ADG) for SIL cattle compared to OH or OHW cattle was minor and the length of restriction (i.e., 16 d) was quite short for true compensatory growth to occur.

Similar to ADG, a treatment × year interaction was noted for DMI ($P < 0.01$) in period 2. During yr 1, ADG

Table 5. Performance of calves fed receiving diets with different roughage sources[1]

	Yr 1[2]			Yr 2				*P*-value		
Item	OH	OHW	SIL	OH	OHW	SIL	SEM[2]	Year	Treatment	Treatment × year
Initial BW, kg	283	283	283	277	277	277	1.1	<0.01	0.99	0.99
Period 1										
ADG, kg	0.59	0.64	0.48	0.33	0.35	0.71	0.051	0.07	0.18	<0.01
DMI, kg	4.06[a]	4.11[a]	3.63[b]	4.14	4.18	4.13	0.017	<0.01	<0.01	<0.01
G:F	0.145	0.155	0.132	0.079	0.084	0.172	0.0182	0.03	0.11	<0.01
Period 2										
ADG, kg	0.90[a]	0.90[a]	1.06[b]	1.35[ab]	1.41[a]	1.27[b]	0.042	<0.01	0.60	<0.01
DMI, kg	6.15[a]	6.39[b]	6.72[c]	7.45[a]	7.46[a]	6.84[b]	0.067	0.03	<0.01	<0.01
G:F	0.147	0.142	0.158	0.181	0.185	0.185	0.0041	<0.01	0.31	0.41
Cumulative growth performance d 1–42										
ADG, kg	0.78	0.80	0.84	1.01	1.06	1.08	0.027	<0.01	0.27	0.92
DMI, kg	5.36[a]	5.52[b]	5.55[b]	6.34[a]	6.49[a]	5.94[b]	0.046	<0.01	<0.01	<0.01
G:F	0.146	0.145	0.151	0.159[a]	0.163[a]	0.182[b]	0.0045	0.06	<0.01	0.37

[a–c]Means within item and year with different superscripts differ ($P \leq 0.05$)

[1]All BW except initial BW are shrunk 4%. Roughage source in receiving diets consisted of oat hay (OH), dampened oat hay (OHW; 4:1 hay:water), or oat silage (SIL). Period 1 consisted of d 1 to 16 in yr 1 and d 1 to 14 in yr 2. Period 2 consisted of d 17 to 42 in yr 1 and d 15 to 42 in yr 2.

[2]Pooled SE of LSM.

was greater for cattle fed SIL and least for cattle fed OH, with OHW being intermediate ($P < 0.01$). Conversely, DMI for cattle fed during yr 2 did not differ for cattle fed OH or OHW but was lesser for cattle fed SIL ($P < 0.01$). Gain:feed was greater for cattle fed during yr 2 than yr 1 ($P < 0.01$), but it did not differ by treatment ($P = 0.31$).

Cumulatively, from d 1 to 42, ADG was greater for cattle fed during yr 2 than yr 1 ($P < 0.01$), but ADG was not affected by treatment ($P = 0.27$). Conversely, there was a year × treatment interaction for cumulative DMI ($P < 0.01$). In yr 1, SIL- and OHW-fed cattle had greater DMI than OH cattle ($P = 0.02$). During yr 2, OH- and OHW-fed cattle had greater ADG than cattle fed SIL ($P < 0.01$). Differences in dietary NDF or effective NDF can be associated with DMI of feedlot cattle, with greater dietary NDF or effective NDF sometimes resulting in increased DMI as a proportion of BW (Galyean and Defoor, 2003). Although we did not measure effective NDF in the current study, dietary NDF concentrations did not differ among treatments ($P \geq 0.70$), and thus, we did not expect differences in DMI. Furthermore, when the oat hay was baled, leaf drop during baling was not assessed, so we are unsure whether leaf drop and could have affected the NDF of the oat hay.

Gain:feed tended to be greater for cattle fed during yr 2 than yr 1 ($P = 0.06$), although no differences among treatments were detected in yr 1 ($P = 0.47$). During yr 2 G:F was greater for SIL-fed cattle than cattle fed OH or OHW ($P < 0.01$).

Little data exist regarding the use of the same crop harvested in both its dry and ensiled forms in receiving-cattle diets. When growing steers were fed dry or ensiled alfalfa, Merchen et al. (1986) reported silage-fed steers had greater ADG and numeric improvements in G:F compared with hay-fed cattle. Additionally, steers grown for 196 d on a grass silage–based diet consumed less DM but with no difference in ADG compared with grass hay–fed cattle (Petit and Flipot, 1992b), despite the similar DM digestibility (Petit and Flipot, 1992a). However, Dennis et al. (2012) fed growing heifers grass harvested as either dry hay or baleage (high-moisture baled and stretch-wrapped grass hay). They reported hay-fed heifers had increases in ADG (13%) and DMI (5%) with a tendency for increased G:F compared with baleage-fed heifers. Verbič et al. (1999) reported that microbial protein supply per unit of DMI was greater in growing lambs fed grass hay than in those fed grass silage. This may be a result of sheep being more responsive to changes in MP supply and a greater amount of fermentation end-products (i.e., organic acids) in grass silage from the ensiling process, which would not contribute as a source of energy for rumen microbes and may explain increases in ADG for hay- versus silage-fed animals. Lack of differences in the current study, taken together with conflicting reports from the available literature, indicate that ensiled forages may serve as suitable alternatives for dried hays of a similar crop in receiving-calf diets.

Blood Metabolites

To assess the ability of each diet to minimize time spent in a negative energy balance, sera concentrations of NEFA were measured in yr 2 on d 2, 9, and 16. No treatment ×

day interactions were observed for sera metabolite data ($P \geq 0.66$; Table 6). Sera concentrations of NEFA were elevated on d 2 compared with d 9 and 16 ($P < 0.01$), which was expected of calves that had been weaned on the truck and transported 580 km. These results are in agreement with results from Knowles et al. (1999) and Marques et al. (2012), who observed greater NEFA concentrations in newly received cattle following transportation. Increased circulating NEFA on d 2 suggests that these cattle were responding to stresses of transportation and depressed caloric intake during these initial days of the receiving phase. Increases in DMI from d 2 to 9 and 16 would promote a more positive energy balance and, thus, less need for mobilized body energy stores, which would explain why NEFA concentrations returned to baseline levels at these time points. In the current study, initial sera NEFA concentrations following entry into the feedlot were greater than those in cattle from the same sources previously received to the RNC on oat forage–based diets (Mueller et al., 2011). However, length of time after weaning can affect NEFA concentrations, and a significant proportion of the calves used by Mueller et al. (2011) were weaned before shipping, whereas in the present study calves were weaned onto the truck. No differences in NEFA concentration were observed among treatments ($P = 0.18$). No effects of forage source ($P = 0.50$) or day ($P = 0.31$) were observed on sera concentrations of albumin, which can serve as an indicator of protein status in cattle (Payne et al., 1970; Moriel and Arthington, 2013). Blood concentrations of albumin and total protein can spike well above baseline levels following transportation but return to near baseline levels within 48 h (Knowles et al., 1999), which would be near to the first time point at which albumin concentrations were measured in the current study. Therefore, these calves most likely returned to normal albumin concentrations prior to our blood collection, and this might explain why no effect of time was detected.

Bunk Sampling

After 75% of delivered feed was consumed, OH and OHW bunks contained almost 2-fold greater proportions of larger particle mass compared with SIL ($P = 0.01$). Consequently, the percentage change in the proportion of larger particles from delivery to 75% consumption was over 3.5-fold greater for OH compared with SIL ($P = 0.05$). Using this metric, it appears that using SIL in receiving diets reduces the degree to which cattle can physically sort smaller and larger particles in the bunk. Similar reductions in sorting have been reported in dairy cattle diets, when alfalfa silage replaced alfalfa hay (Leonardi and Armentano, 2003). Using silage rather than dry hays in receiving-calf diets may help provide a more consistent supply of nutrients to each individual animal within the pen by reducing diet sorting.

A tendency for an interaction was detected for the proportion of larger particles retained on a 12.7-mm screen ($P = 0.07$; Table 7), in that during yr 1, at the time of delivery, the SIL treatment contained a greater proportion of larger particle mass (i.e., the mass of particles retained in a 12.7-mm screen) compared with the OH treatment ($P < 0.01$), with the OHW treatment being intermediate. In yr 2, the OH and SIL were similar and lesser than the OHW. Even though SIL was processed to a shorter length (1.9 vs. 8.9 cm), the difference in larger particle mass during yr 1 may have been caused by the increased moisture in SIL and OHW (Tables 3 and 4), in that a greater amount of fines could adhere to larger particles in the diets with greater moisture.

There was a treatment × year interaction ($P = 0.02$; Table 7) for the proportion of larger particle mass remaining in the bunks after cattle had consumed about 75% of the feed delivery. Year 1 did not differ across treatments ($P = 0.47$), whereas within yr 2, cattle fed OH and OHW had a greater proportion ($P = 0.01$) of larger particles

Table 6. Blood metabolites over time of calves fed diets with different roughage sources (yr 2)[1]

	Diet[2]				*P*-value		
Day	**OH**	**OHW**	**SIL**	**SEM**	**Treatment**	**Day**	**Treatment × day**
Nonesterified fatty acids, mmol							
2	0.65	0.60	0.58				
9	0.30	0.30	0.29	0.024	0.18	<0.01	0.66
16	0.35	0.31	0.33				
Albumin, g/dL							
2	2.97	3.08	2.98				
9	2.94	3.12	2.85	0.150	0.59	0.42	0.90
16	3.09	3.13	3.16				

[1]Sentinel steers (n = 3 per pen).

[2]Roughage source in receiving diets consisted of oat hay (OH), dampened oat hay (OHW), or oat silage (SIL).

Table 7. Effect of roughage source[1] and added water on feed particles retained in a 12.7-mm screen on d 32 in the afternoon feed delivery (yr 1)

	Yr 1			Yr 2				*P*-value		
Item, % of total	OH	OHW	SIL	OH	OHW	SIL	SEM	Year	Treatment	Treatment × year
Larger particles[2]										
At delivery,[3] %	16.9[a]	21.1[b]	26.0[c]	12.7[a]	15.6[b]	12.7[a]	1.26	0.04	<0.01	0.05
After meal,[3] %	38.0	40.0	33.7	35.8[a]	40.3[a]	19.1[b]	5.72	0.12	0.18	0.02
Change, %	123.3[a]	86.3[ab]	31.6[b]	191.5[a]	164.6[ab]	52.7[b]	21.16	0.07	0.04	0.28
DM consumed,[4] %	81.6[a]	77.3[ab]	69.3[b]	75.4	74.7	70.8	2.26	0.48	0.20	0.02
Elapsed time, min	36	35	39	47	62	65	2.0	<0.01	0.29	0.48

[a–c]Means within a row and year with different superscripts differ ($P < 0.05$).

[1]Roughage source in receiving diets consisted of oat hay (OH), dampened oat hay (OHW; 4:1 hay:water), or oat silage (SIL).

[2]Larger particles = feed particles that are retained in a 12.7-mm screen.

[3]Percentage of total DM.

[4]Percentage of DM offering that had been consumed at postmeal bunk sample collection.

remaining in the bunk after a meal than cattle fed SIL. Although the oat silage was processed to a shorter length than the oat hay, it also has inherent moisture, which may allow fine feed particles to adhere to the silage and remain with the larger feed particles.

There was no treatment × year interaction ($P = 0.28$) detected for the change in the proportion of larger particle mass from delivery to 75% consumption (i.e., effect of sorting). There was a tendency for the change in the proportion of larger particle mass from delivery to 75% consumption to be greater for yr 2 than for yr 1 ($P = 0.07$). Moreover, a treatment effect was also detected ($P = 0.04$) in each year where the percentage change in the proportion of larger particle mass from delivery to 75% consumption was almost 4-fold greater for OH compared with SIL, and the percentage of total feed consumed at postmeal sample collection was greater for OH ($P = 0.01$) than for SIL, with OHW being intermediate. However, with subjective visual appraisal used to determine when to collect bunk samples, some variability in the amount of

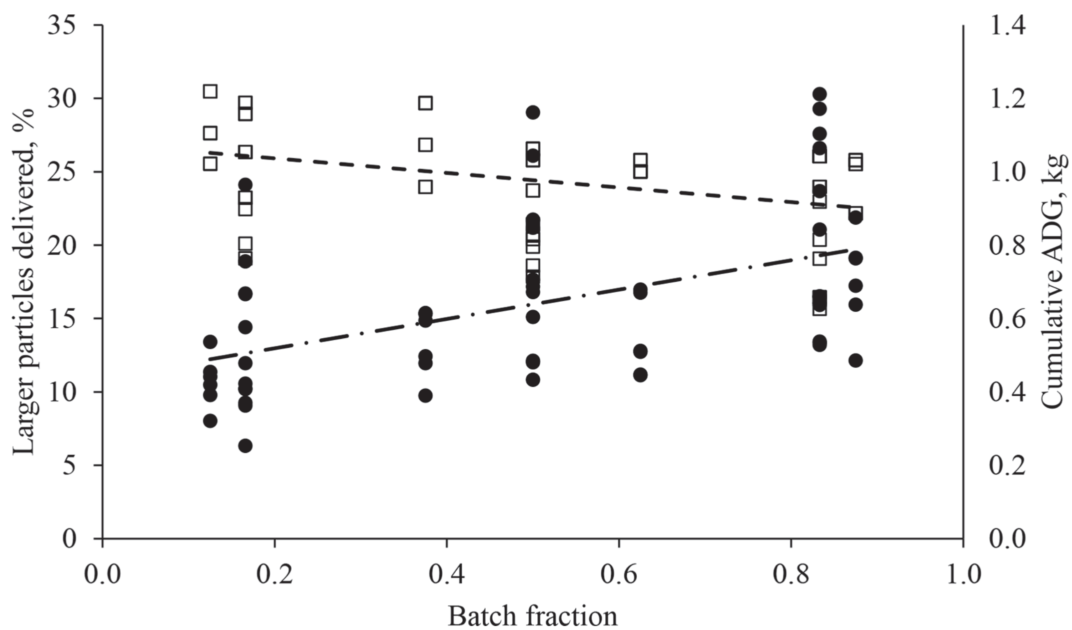

Figure 1. The effect of batch fraction (BF; i.e., a scale of 0 to 1 representing from which portion of the batch each pen's allotment of feed was derived) on the proportion of larger particles (i.e., feed particles retained on a 12.7-mm screen) delivered to the bunk and cumulative steer ADG. Larger particles delivered (●; – · –) = 9.9958(BF) + 10.974; $r^2 = 0.23$. Cumulative ADG (□; - - -) = −0.1986(BF) + 1.0763; $r^2 = 0.15$.

Table 8. Influence of diet and load distribution on feed particles passing through a 12.7-mm screen (yr 1)

	Batch fraction[2]				*P*-value	
Item[1]	**0.166**	**0.500**	**0.833**	**SEM**	**Linear**	**Quadratic**
OH						
n	2	2	2			
Larger particles[3]						
At delivery,[4] %	11.09	19.46	20.10	2.504	0.08	0.30
After meal,[4] %	24.35	40.37	49.19	6.719	0.08	0.69
Change, %	114.2	107.6	148.1	40.97	0.60	0.67
OHW						
n	2	2	2			
Larger particles						
At delivery,[4] %	15.55	19.66	27.95	1.542	0.01	0.35
After meal,[4] %	21.26	42.75	56.01	4.495	0.01	0.51
Change, %	35.3	123.0	100.6	33.52	0.26	0.27
SIL						
n	2	2	2			
Larger particles						
At delivery,[4] %	21.50	27.57	28.94	1.898	0.07	0.39
After meal,[4] %	26.69	36.91	37.52	5.435	0.25	0.52
Change, %	28.9	35.8	30.1	31.09	0.98	0.88

[1]Roughage source in receiving diets consisted of oat hay (OH), dampened oat hay (OHW; 4:1 hay:water), or oat silage (SIL).

[2]Batch fraction = scale of 0 to 1 to represent from which portion of the batch each pen's allotment of feed was derived. 0.166 = first pen delivered out of 3-pen batch; 0.500 = second pen delivered out of 3-pen batch; 0.833 = third pen delivered out of 3-pen batch.

[3]Larger particles = feed particles that are retained in a 12.7-mm screen.

[4]Percentage of total DM.

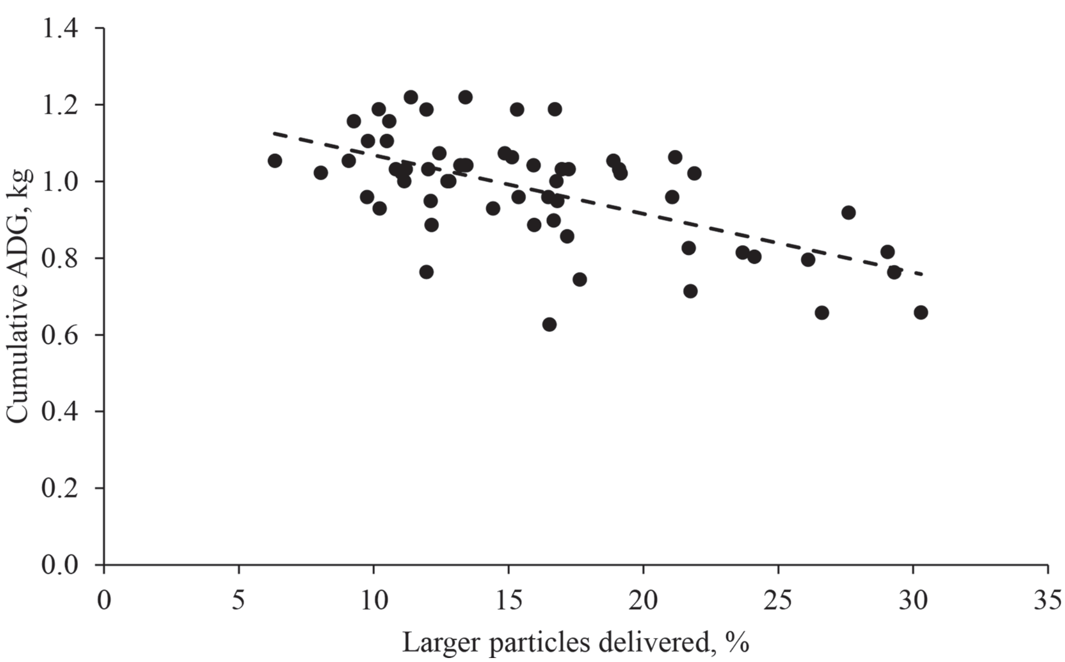

Figure 2. Effect of the proportion of larger particles (i.e., feed particles retained on a 12.7-mm screen) delivered to the bunk on cumulative ADG (yr 1 and 2 data combined). Cumulative ADG = −0.0153(Larger particles delivered) + 1.2211; $r^2 = 0.37$.

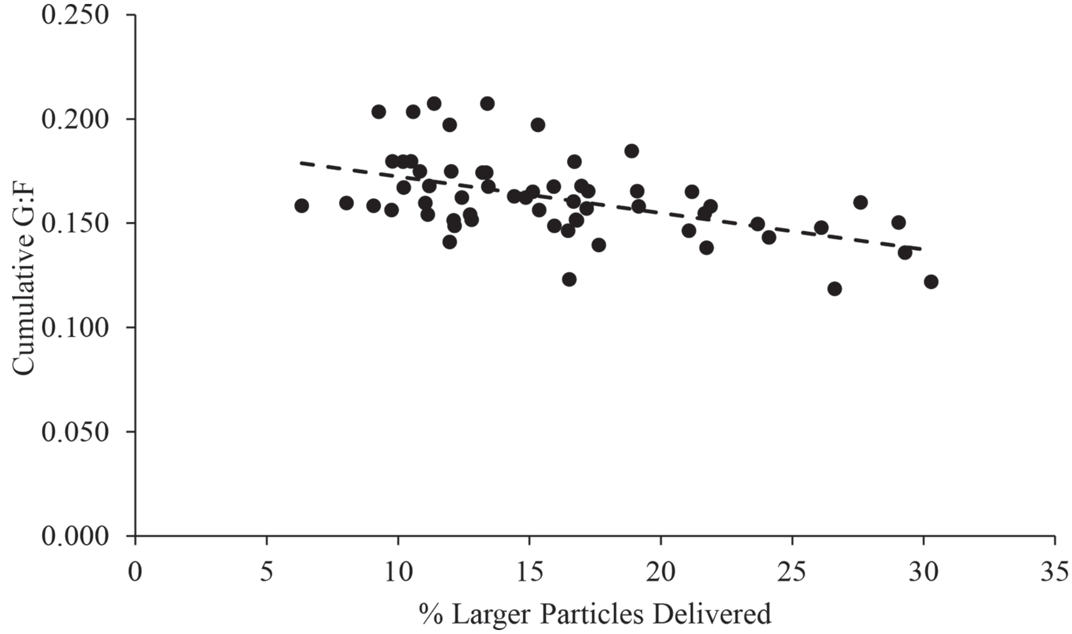

Figure 3. Effect of the proportion of larger particles delivered to the bunk on cumulative G:F (yr 1 and 2 data combined). Cumulative G:F = −0.0017(Larger particles delivered) + 0.1898; $r^2 = 0.27$.

feed remaining in the bunk was expected. It is unclear how differences in the percentage of feed consumed at postmeal sample collection could have influenced the proportion of larger particles remaining in the bunk.

Not only were we interested in measuring the effects of different roughage sources on diet integrity, but we were also interested in the effect they have on mixing quality within a batch of feed. In yr 1, each batch of feed was prepared for 3 pens of cattle. In yr 2, cattle were fed from either 3- or 4-pen batches. The proportion of larger particle mass in delivered feed tended ($P = 0.08$; Table 8) to linearly increase with BF (i.e., as the batch was offloaded) in the OH. Similarly, the proportion of larger particle mass in the OHW increased linearly with BF ($P = 0.01$). The proportion of larger particle mass also tended to increase with BF in the SIL ($P = 0.07$) but at a lesser magnitude than in the OH or OHW. It is important to note that these changes in diet composition from initial to final feed offload were unexpected as these changes were indiscernible upon visual appraisal of the diets. Postmeal proportions of larger particle mass tended to linearly increase with BF in the OH treatment ($P = 0.08$) and was linearly increased in the OHW ($P = 0.01$) treatment, with no difference in the SIL treatment ($P = 0.25$).

We combined data from yr 1 and yr 2 together and regressed the proportion of larger particles delivered to the bunk against BF. We found that as BF increased (i.e., as the batch was offloaded), the proportion of larger particles being delivered also increased ($P < 0.01$; Figure 1). Ideally, the proportion of larger particles would be similar throughout batch offload. It appears that we were not achieving optimal mixing conditions to provide uniform particle distribution throughout the batch. Cumulative ADG linearly decreased ($P < 0.01$; Figure 1) as BF increased. Using the proportion of larger particle mass as a proxy for the proportion of roughage in the diet, it follows that as proportionally more roughage was offloaded later in the batch, the diet energy density would concomitantly decrease, thus the performance of those cattle would be less than those fed early in the batch. It appears that variations in diet mixing that are not recognizable by visual appraisal can affect cattle performance. Additionally, when we regress cumulative ADG of all pens of cattle in both years against the proportion of larger particle mass delivered to the bunk, we find that cumulative ADG is negatively correlated ($P < 0.01$; $r^2 = 0.37$; Figure 2) with increasing proportion of larger particle mass. Cumulative G:F is also negatively correlated with increasing proportion of larger particle mass ($P < 0.01$; $r^2 = 0.27$; Figure 3).

APPLICATIONS

No detectable aversion to fermented feed was observed among naïve receiving calves. Cumulative calf performance was generally unaffected by roughage source except for increased G:F for silage-fed calves in yr 2. Receiving diets containing silage reduced the extent of sorting from the time feed was delivered until approximately 75% of feed was consumed. Changes in the proportion of larger particle mass were detected from the beginning to the end of batch offload, despite being indiscernible by visual appraisal. These variations in diet mixing across a batch affected cattle performance. Generally, dampening the dry hay was intermediate to OH and SIL with regard to animal growth performance and diet mixing and integrity characteristics. The observations from this study indicate that SIL is an acceptable alternative for OH in receiving-calf diets.

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