Effect of bale feeder and forage on hay waste, disappearance, and sorting[1]

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ABSTRACT

Three feeders and 2 forage types were used in a 3 × 2 factorial treatment arrangement within a Latin-square design to evaluate forage feeding waste. A total of 48 spring-calving, gestating cows were stratified by age, BW, and BCS into 6 replicate pens with 8 cows per pen. Bale feeders evaluated were open ring with slanted feeding stations (OFD), sheeted lower section with slanted feeding stations and tapered sides (TFD), and sheeted lower and upper sections with straight feeding stations and a chain cone (CFD). Forages were alfalfa (Medicago sativa L.) haylage (AH) or tall fescue (Festuca arundinacea Schreb.) hay (FH). A forage × feeder type interaction ($P < 0.05$) was observed for percentage of bale wasted, where FH OFD was greatest (19.2%), FH TFD was intermediate (13.6%), and FH CFD (8.9%) was least ($P < 0.05$); however, FH CFD was not different ($P > 0.10$) from AH OFD (7.0%) or AH CFD (6.5%) but was greater than AH TFD (4.9%; $P < 0.05$). A feeder × forage × day interaction ($P < 0.01$) was observed for waste per day bale was offered. No difference ($P > 0.10$) was observed for percentage AH waste due to day or feeder. Fescue-hay waste was least ($P < 0.01$) in CFD at 24 and 48 h compared with OFD and TFD. At 96 h, TFD wasted the least ($P < 0.05$) for FH compared with CFD and OFD. The CFD feeder with lower-section sheeting reduced FH waste, whereas AH waste was not influenced by feeder design.

Key words: bale feeder, beef cattle, forage quality, hay waste

INTRODUCTION

Feed cost accounts for 63% of the annual cow cost and is the greatest variable influencing Midwest producers' profitability (Miller et al., 2001). In the last decade, hay production has decreased 11%, and hay prices have increased 77% (NASS, 2013). More efficient harvested-forage use can be achieved by reducing waste of large round bales during storage and feeding (Lechtenberg et al., 1974; Belyea et al., 1985; Baxter et al., 1986; Buskirk et al., 2003; Landblom et al., 2007). Improving the efficiency of forage use from harvest to feeding will be increasingly important as competition for land use between hay, pasture, biomass, and row-crop enterprises increases.

Large-round-bale feeders are the most adopted stored-forage feeding method for Oklahoma beef producers (Sexten, 2011). Bale-feeder design affects hay waste by altering agonistic interactions, entrance frequency (regular and irregular), and feeder occupancy (Buskirk et al., 2003). Ring feeders allow cattle to eat in a natural position preventing hay loss from frequent entrances (Buskirk et al., 2003). Cone-type feeders also reduce hay waste by providing a larger feeding area inside the feeder (Comerford et al., 1994; Buskirk et al., 2003). The effect of feeder design on waste associated with different forage types is unexplored. The experimental objective was to quantify hay waste by gestating beef cows using 3 bale-feeder designs and 2 forage types. We hypothesized tall fescue (*Festuca arundinacea* Schreb.) hay (**FH**) would result in greater waste than alfalfa (*Medicago sativa* L.) haylage (**AH**). Additionally, we hypothesized that cone-type feeders and feeder sheeting would reduce waste with FH but not AH.

MATERIALS AND METHODS

Treatments and Animal Management

Animal-use procedures were approved by University of Missouri Animal Care and Use Committee. Forty-eight spring-calving Simmental and Angus crossbred cows, 124 ± 8 d in

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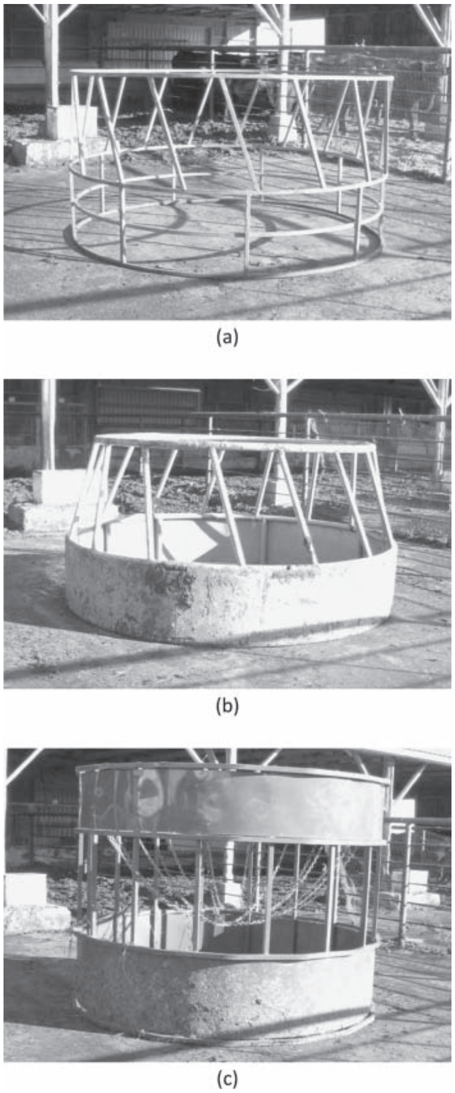

Figure 1. Round-bale feeder designs: (a) OFD = open ring with slanted feeding stations (Hay Ring; Hatton Vermeer Sales LLC, Auxvasse, MO), (b) TFD = sheeted lower section with slanted feeding stations and tapered sides (Double Slant Hay Feeder; Sioux Steel Co., Sioux Falls, SD), and (c) CFD = sheeted lower and upper sections with straight feeding stations and a chain cone (Hay Hopper; Action Signs and Billboards, Chandler, MN).

gestation, were used in a 3 × 2 factorial treatment arrangement within a 6 × 6 Latin-square design. Three bale-feeder designs and 2 forage types were used to evaluate the effect of bale feeder and forage type on hay waste and DMI. The 6 combinations of bale feeder and forage type were applied to 6 pen replicates in each of the 6 periods. Periods were 12 d in length. Cows were stratified by age (4 ± 2.5 yr), BW (517 ± 68.8 kg), BCS (5.5 ± 0.42 units; Wagner et al., 1988), and ultrasound-measured fat thickness over the 12th rib (0.4 ± 0.16 cm) into 6 replicates with 8 cows per replicate. Each replicate was randomly assigned to 1 of 6 concrete pens (16.6 × 7.3 m) with 4.5 m of linear bunk space. Facilities included barns open to the south with an uncovered 8.8 × 7.3 m hay-sampling pad, and the remainder of the pen was covered by roof and bedded with sawdust. Replicates remained in pens, and bale feeder and forage type rotated to different pen replicates upon completion of each 12-d sampling period.

Bale-Feeder Design

The 3 bale-feeder designs are shown in Figure 1. Open feeders (**OFD**) had no lower- or upper-section sheeting and measured 2.4 m in diameter and were 1.2 m tall (Hay Ring; Hatton Vermeer Sales LLC, Auxvasse, MO). Feeding spaces for OFD (n = 17) were 41 cm wide and 65 cm tall, and bars were angled at 73°. Tapered feeders (**TFD**) had 0.5 m of straight lower-section sheeting and measured 2.4 m in diameter at the bottom and 2.1 m in diameter at the top and were 1.2 m tall (Double Slant Hay Feeder; Sioux Steel Co., Sioux Falls, SD). Dividing bars in the TFD feeder were angled at 74° with a 46-cm-wide and 66-cm-tall feeding space (n = 15). Cone feeders (**CFD**) were 2.3 m in diameter and 1.7 m tall and had 0.6 m of lower-section sheeting, 0.5 m of upper-section sheeting, and a 16-chain cone spaced at 41 cm (Hay Hopper; Action Signs and Billboards, Chandler, MN). Dividing bars in the CFD feeders were angled at 90° with a feeding space (n = 16) 41 cm wide and 69 cm tall.

Forage Type and Sampling

Two forage types were used to evaluate the interaction of bale feeder and forage. Alfalfa haylage was harvested May 18, 2012, (first cutting) and ensiled as plastic-wrapped bales. Tall fescue hay was harvested June 19, 2012, (first cutting) and barn stored until experiment initiation. Alfalfa-haylage bales were 1.5 m wide, 1.1 m in o.d., and weighed 364 ± 34 kg (DM basis), and FH bales were 1.5 m in width, 1.5 m in diameter, and weighed 546 ± 45 kg (DM basis). Bale DM and forage nutritional value were determined from 3 core samples (Hayprobe, Hart Machine Co., Madras, OR) collected from each bale before feeding (Table 1). Bales were oriented horizontally in the feeder and removed from storage no greater than 5 d before feeding.

Table 1. Forage nutrient composition determined by near-infrared spectroscopy

Item, % of DM	Tall fescue	Alfalfa
DM	92.0	41.0
CP	7.5	17.0
NDF	66.6	49.4
ADF	36.4	34.4
Ash	10.5	9.1

Cows were acclimated to combinations of feeder and forage type at period initiation to minimize effects associated with modifying feeding positions or changing forage types because treatment combinations within pen changed each period. One bale of FH was provided for acclimation to feeder design for 96 h. Two AH bales were provided for acclimation for 72 h each. The additional AH bale during acclimation was provided to maintain 12-d periods.

Following acclimation orts and debris were removed from the feeding pad and a new bale was introduced for collection. Waste was collected at 24, 48, 72, and 96 h following new FH-bale introduction, and AH waste collection and samples were taken at 24, 48, and 72 h following bale introduction due to less DM per bale. After initial bale-waste and orts collection was complete, orts were removed from the feeder, weighed, and sampled. After orts were removed, a new bale was introduced for replication.

Waste was considered forage outside of the bale ring, and orts were forage remaining in the feeder. Waste was divided into contaminated and clean forage subgroups. Clean forage was classified as manure- and urine-free forage. Contaminated forage was contaminated with urine or manure that could not be sorted out during sampling. When possible, manure was sorted from a sample before sampling, but some contamination was unavoidable. Waste subgroups were weighed and subsampled for DM, CP, NDF, ADF, and ash determination. Total waste forage-quality estimates were composited as a weighted mean of clean and contaminated forage for calculations and statistical analysis.

The length of the experiment was 72 d with 24 h fasted BW, BCS, and 12th-rib fat depth measured at the beginning and end of experiment. Fasted BCS were assigned on a 1-to-9 scale (Wagner et al., 1988) by 2 experienced evaluators (data not shown).

Forage samples were immediately dried at 55°C for 72 h, ground through a 5-mm screen in a Wiley Mill (Model 4, Thomas Scientific, Sweedesboro, NJ), subsampled, and ground through a 1-mm screen using a 1093 Cyclotech Mill (Tecator, Eden Prairie, MN). Wet chemistry methods were used for DM (dried 12 h at 100°C), CP (% of N × 6.25; FP-428 LECO Corporation; St. Joseph, MI), NDF and ADF (Ankom Tech Corp., Fairport, NY), and ash (combusted 8 h in a muffle furnace at 500°C) for approximately half the samples to generate prediction equations. Samples were then placed in glass vial and analyzed using a FOSS XDS monochromator XM-1000 fitted with an XDS rapid content analyzer XM-1100 (FOSS NIRSystems Inc., Laurel, MD). Resulting correlation coefficients for DM, CP, NDF, ADF, and ash predictions were 0.88, 0.99, 0.90, 0.89, and 0.85, respectively.

Supplementation

Each cow was fed 1 kg of supplemental DM daily consisting of 42% dried distillers grains with solubles, 24.7% wheat middlings, 24.4% ground corn, and 8.9% mineral and vitamin premix for the duration of the experiment. Three pens received 200 mg per cow per day monensin (Rumensin 90; Elanco Animal Health, Greenfield, IN) within the supplement, and 3 pens received no monensin. Monensin was randomly assigned to pen and was fed for the duration of the experiment.

Statistical Analysis

Combinations of feeder and forage type were randomly assigned to pen within a period. The effects of monensin supplementation were nested within pen and could not be separated from pen effects in this analysis, because combinations of feeder and forage type were not replicated within a period.

Separate analyses were conducted to evaluate treatment means and repeated measures. Analysis 1 of treatment means was performed as a 6 × 6 Latin-square design. Treatments were arranged as a 3 × 2 factorial (feeder = 3, forage = 2). Columns represented 6 pens, and rows represented 6 periods. Pen was the experimental unit, and bale within period was considered a pseudo-replicate. Analysis 2 parameters were analyzed as a 6 × 6 Latin-square design with repeated measurement over time. The main plot contained the effect of column, row, and treatment combinations (forage, feeder, forage × feeder). The subplot contained the effects of time and all interactions with forage and feeder. The 96-h measures were analyzed without forage effects because FH was the only forage measured at 96 h. Analysis 3 was similar to analysis 2 except forage nutritional parameters were analyzed as a function of bale-feeding-system components (bale, waste, and orts) rather than over time. All differences were determined using Fisher's least significant difference from the LSMEANS statement in PROC MIXED of SAS 9.3 (SAS Institute Inc., Cary, NC). Treatments were considered different at $\alpha \leq 0.05$.

RESULTS AND DISCUSSION

Results for waste, orts, and disappearance are shown in Table 2. A forage × feeder interaction ($P < 0.01$) was observed for percentage of bale wasted, with FH OFD (19.2%) being the greatest ($P = 0.02$), FH TFD intermediate (13.6%), and FH CFD (8.9%) least ($P < 0.01$). However, FH CFD was not different ($P > 0.15$) from AH OFD (7.0%) or AH CFD (6.5%) but was greater than ($P = 0.03$) AH TFD (4.9%). These results agree with previous research where cone-type feeders reduced grass-hay waste (Comerford et al., 1994; Buskirk et al., 2003; Sexten, 2011; Sparks et al., 2013). In this experiment, CFD resulted in 35% less waste than TFD. This amount is less than that reported by Buskirk et al. (2003) and Sparks et al. (2013), where cone feeders resulted in 43 to 50% less mixed-grass-hay waste than a sheeted feeder. The flexible (chain) CFD used in the current experiment compared with the solid (steel bar) cone in previous research may allow for increased waste in cone feeders. The lower-section sheeting on the TFD feeder resulted in 29% less waste compared with OFD, which is similar to 39% reported by Sexten (2011).

Estimates of tall-fescue waste are similar to those reported by Sexten (2011), who measured grass-hay waste in open, sheeted, and cone feeders at 21, 13, and 6%, respectively, with similar waste-collection methods, forage nutritional value, and feeder stocking density to the current experiment. However, FH waste estimates from the current experiment are approximately twice those of Buskirk et al. (2003), who measured waste of alfalfa and orchardgrass hay at 3.5 and 6.1% for cone and sheeted feeders, respectively. Multiple vari-

Table 2. Effect of forage type and bale feeder on hay waste, orts, and disappearance (DM basis)

	Forage and feeder treatment[1]									
	Alfalfa			Tall fescue				*P*-value[3]		
Item	CFD	TFD	OFD	CFD	TFD	OFD	SEM[2]	Forage	Feeder	Forage × feeder
n	12	12	12	12	12	12				
Bale wt, kg	366	353	373	554	553	541	23.1	<0.01	0.90	0.61
Waste,[4] % bale	6.5[cd]	4.9[d]	7.0[cd]	8.9[c]	13.6[b]	19.2[a]	1.7	<0.01	<0.01	<0.01
Orts,[5] % bale	7.1[c]	10.2[bc]	8.8[bc]	18.1[a]	13.5[ab]	8.3[c]	1.8	<0.01	0.09	0.02
DMI,[6] % bale	86.5	84.9	84.2	73.0	72.9	72.5	2.2	<0.01	0.82	0.91
DMI,[7] % BW	2.32	2.18	2.30	2.21	2.20	2.15	0.11	0.24	0.63	0.52

[a–d]Within a row, means without common superscript differ, $P \leq 0.05$.

[1]Alfalfa = alfalfa (*Medicago sativa* L.) haylage; Tall fescue = tall fescue (*Festuca arundinacea* Schreb.) hay. OFD = open ring with slanted feeding stations (Hay Ring; Hatton Vermeer Sales LLC, Auxvasse, MO); TFD = sheeted lower section with slanted feeding stations and tapered sides (Double Slant Hay Feeder; Sioux Steel Co., Sioux Falls, SD); and CFD = sheeted lower and upper sections with straight feeding stations and a chain cone (Hay Hopper; Action Signs and Billboards, Chandler, MN).

[2]Standard error of least squares means.

[3]Forage, feeder, and forage × feeder interaction significance level.

[4]Forage waste expressed as a percentage of initial DM bale weight.

[5]Orts expressed as a percentage of initial DM bale weight.

[6]DMI calculated as initial bale weight minus waste and orts, expressed as percentage of initial DM bale weight.

[7]Percentage of calculated midpoint BW.

ables likely contribute to differences in waste observations between the 2 experiments. Buskirk et al. (2003) used high-quality alfalfa and orchardgrass hays, potentially reducing waste compared with low-quality FH. Additionally, in the current experiment 8 cows used each feeder and the feeding system was not continuous, as orts were removed and measured for each bale. Buskirk et al. (2003) allowed 20 cows to use each feeder and offered bales continuously for 7 d. Greater feeder stocking rate increases competition among cows, potentially reducing waste by limiting feeder entry and exit and reducing the nonfeeding time cattle are exposed to the bale.

As cows consume hay the feeding space increases within the feeder; removing orts for each bale in this experiment reduced the amount of time relative to intake when the feeding space within the feeder would be the greatest. Continuous feeding would minimize the overestimation of waste attributed to feeding area within the feeder.

Reductions in AH waste compared with FH waste may be attributed to differences in bale size, density, moisture level, or forage nutritional value. Previous research suggests moisture level does not influence grass-hay waste. Comerford et al. (1994) observed no difference in feeding waste of dry bales (90% DM) compared with silage bales (40% DM) harvested from the same forage lot. The effect of bale size on hay waste during feeding has not been previously studied. Schultheis and Hires (1982) reported that pusher head gates requiring cattle to reach for forage reduced waste. In the present experiment AH bales were smaller in mass and diameter than FH bales and feeder size was constant, suggesting cows had to reach further into the feeder to prehend the AH, potentially reducing waste. Hay-waste estimates for AH has not been reported. The amount of orts and waste appear to be inversely related for FH but not for AH. For AH, both orts and waste remained constant.

Calculated forage DMI as a percentage of BW was not different ($P = 0.63$) because of feeder, which agrees with results by Buskirk et al. (2003). Dry matter intake as a percentage of initial bale was less ($P < 0.01$) for FH (72.8%) compared with AH (85.2%) because of differences in waste and orts. Calculated forage DMI was not different ($P = 0.24$) due to forage type. Forage DMI was expected to be greater for AH than FH because of greater ($P < 0.001$) cell-wall content of FH (66.6% NDF) compared with AH (49.4% NDF) and the effect of cell wall on digestibility and voluntary forage intake (Jung and Allen, 1995; Allen, 1996). Forage digestibility was not measured in the current experiment, so direct conclusions of forage digestibility on voluntary intake could not be made. Alfalfa-haylage DMI could be underestimated in this experiment because of greater forage moisture content; waste may be more likely to become contaminated or be classified as contaminated.

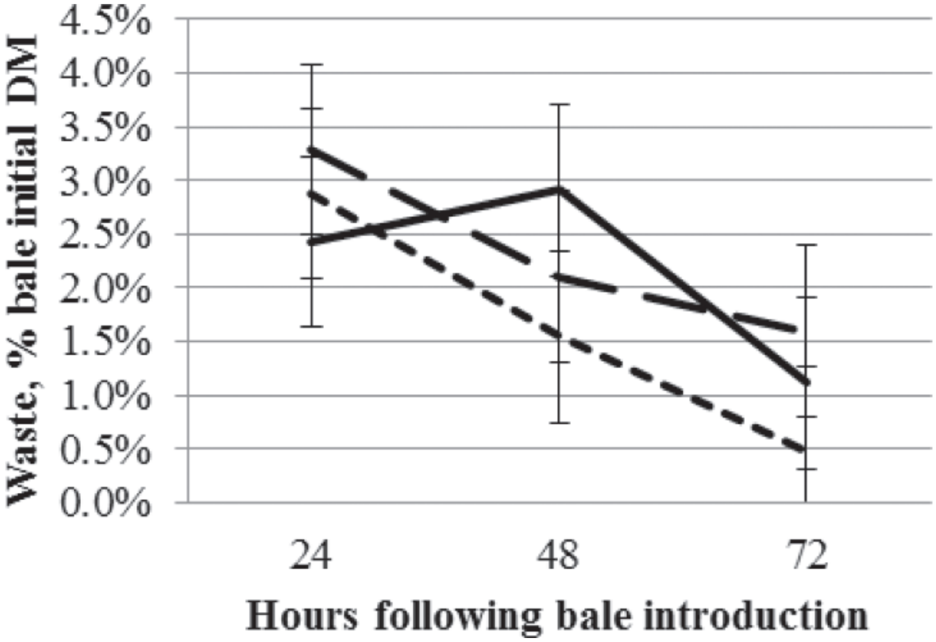

Figure 2. Least squares means of alfalfa-haylage waste by feeder design during 24-h feeding periods. OFD = open ring with slanted feeding stations (long-dashed line; Hay Ring; Hatton Vermeer Sales LLC, Auxvasse, MO), TFD = sheeted lower section with slanted feeding stations and tapered sides (short-dashed line; Double Slant Hay Feeder; Sioux Steel Co., Sioux Falls, SD), and CFD = sheeted lower and upper sections with straight feeding stations and a chain cone (solid line; Hay Hopper; Action Signs and Billboards, Chandler, MN). Feeder × forage × day interaction, $P < 0.01$. No difference ($P > 0.05$) due to feeder or day.

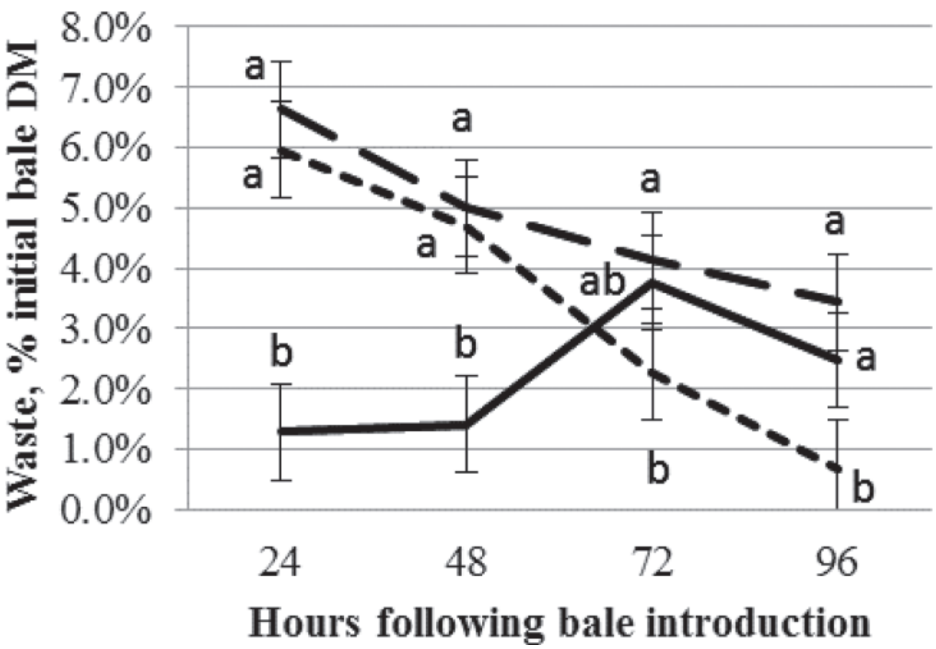

Figure 3. Least squares means of fescue-hay waste by feeder design during 24-h feeding periods OFD = open ring with slanted feeding stations (long-dashed line; Hay Ring; Hatton Vermeer Sales LLC, Auxvasse, MO), TFD = sheeted lower section with slanted feeding stations and tapered sides (short-dashed line; Double Slant Hay Feeder; Sioux Steel Co., Sioux Falls, SD), and CFD = sheeted lower and upper sections with straight feeding stations and a chain cone (solid line; Hay Hopper; Action Signs and Billboards, Chandler, MN). Feeder × forage × day interaction, $P < 0.01$. [a,b]Different letters indicate means within day differ, $P < 0.05$.

Waste per day is presented in Figures 2 and 3. A feeder × forage × day interaction ($P < 0.01$) was observed for waste per day bale was in the feeder. No difference ($P > 0.10$) was observed for percentage AH waste due to day or feeder. Fescue hay waste was less ($P < 0.01$) in CFD at 24 and 48 h compared with OFD and TFD, which were not different ($P > 0.10$). The TFD tended ($P < 0.08$) to waste less FH at 72 h and wasted the least ($P < 0.05$) FH at 96 h compared with CFD and OFD, which were not different ($P > 0.10$). No difference between the TFD and OFD at 24 and 48 h suggests the TFD feeder design was not as effective at reducing waste when forage DM availability was greatest. However, the TFD feeder resulted in less waste at 72 and 96 h because of lower-section sheeting. Differences in FH waste at 24 and 48 h explain the waste-reducing feature of CFD feeders. Suspending the bale in CFD provided greater feeding space inside the feeder, thus cows were able to eat in a natural grazing position inside the feeder, reducing hay waste (Buskirk et al., 2003). Providing feed at ground level (grazing-like position) reduces forage waste by reducing feed-tossing behavior compared with providing feed in an elevated bunk (Albright, 1993).

"Feeding space" can be defined as the area allowed for feeding inside the feeder and is measured as the distance between the newly introduced bale and the feeder. Feeding space inside OFD and TFD feeders was approximately 0.45 and 0.38 m, respectively, at new FH bale introduction. The feeding space inside CFD was measured as the feeder diameter because the bale was suspended in the chain. Greater FH waste at 24 and 48 h for TFD and OFD suggests feeding space was inadequate for cows to feed naturally inside the feeder, increasing entrance frequency and waste. The CFD feeder resulted in increased FH waste at 72 and 96 h because the bale was no longer suspended by the CFD and the lower-section sheeting had filled with forage. The TFD feeder

Table 3. Effect of forage type on nutritive value in initial bale, waste, and orts

Item, % DM	Forage[1]						SEM[2]	*P*-value[3]		
	Alfalfa			Fescue						
	Bale	Waste	Orts	Bale	Waste	Orts		Forage	Component	Forage × component
CP	17.0[a]	16.1[b]	14.7[c]	7.2[d]	7.4[d]	7.4[d]	0.39	<0.01	<0.01	<0.01
ADF	34.4[c]	37.9[b]	40.7[a]	36.4[b]	33.7[c]	38.0[b]	0.69	<0.01	<0.01	<0.01
Ash	9.1[c]	10.1[b]	8.9[c]	10.5[ab]	10.9[ab]	11.0[a]	0.29	<0.01	0.03	0.04

[a–d]Within a row, means without common superscripts differ, $P \leq 0.05$.

[1]Alfalfa = alfalfa (*Medicago sativa* L.) haylage; Fescue = fescue (*Festuca arundinacea* Schreb.) hay. Bale = bale core samples; Waste = waste grab samples composited by mass; Orts = orts grab samples.

[2]Largest standard error of least squares means.

[3]Forage, component, and forage × component interaction significance level.

resulted in less waste than OFD at 72 and 96 h because of sheeting retaining more forage inside the feeder, once space was available for cows to comfortably feed inside the feeder. Lower-section sheeting of the feeder reduces waste when forage remaining in the feeder is no longer in bale form later in the feeding period.

Sorting of plant parts, as indicated by composition, was not different ($P = 0.46$) because of feeder; however, there was a forage × component interaction ($P < 0.01$; Table 3). Sorting was evident with AH as there was a reduction in CP and an increase in ADF for waste and orts compared with initial bale. There was no evidence of selective leaf consumption for FH as CP was not different for initial bale, waste, or orts. However, a reduction in FH waste ADF was observed, suggesting FH waste contained a greater leaf concentration. These results agree with those of Buskirk et al. (2003), where OM, NDF, and ADF were lower in waste of dry alfalfa and orchardgrass hay. Greater leaf-waste proportions are a product of leaf shattering during feeding, which is less likely to occur with wet forage. Our results disagree with those of Leonardi et al. (2005), who saw a decrease in sorting with addition of water to a 40% forage diet. Devries et al. (2007) reported sorting against NDF but to a greater extent in a 50%-forage than a 62%-forage diet. Increased sorting in AH compared with FH could be explained by less orts for AH (32.2 kg) compared with FH (74.7 kg), forcing cows to sort the remaining forage. Differences in sorting may be a product of greater leaf and stem distinction in the legume haylage compared with the cool-season-grass hay.

IMPLICATIONS

As hypothesized, feeder design influenced FH waste to a greater extent than AH waste. The OFD feeder resulted in the greatest FH waste, TFD was intermediate, and CFD resulted in the least FH waste. Alfalfa-haylage waste was not different due to feeder and ranged from 5 to 7%. Tall fescue–hay waste ranged from 9 to 19%, suggesting feeder choice is an important economic decision when feeding dry, low-quality, large round bales. The CFD and TFD feeders reduced FH waste 54 and 29%, respectively. Stored-forage use efficiency can be improved in traditional hay-feeding systems using feeders equipped with lower-section sheeting or sheeting and cone-shaped bale-suspension capabilities. Further research is needed to determine effects of moisture level, forage nutritional value, bale size, feeding-period length, and feeder stocking density on stored-forage utilization.

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