THE EFFECT OF ALFALFA AND CORNSTALK ROUND BALE PROCESSING TYPE ON ANIMAL PERFORMANCE, WASTAGE, PREFERENCE, AND MIXING CHARACTERISTICS

by

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Abstract

Seven experiments were conducted to evaluate the effect of alfalfa and cornstalk round bale processing type on animal performance, wastage, preference, and mixing characteristics. All bales were baled using a round baler (John Deere) that had the ability to cut forage being baled prior to wrapping. This machine processed all bales used in these experiments, with those termed conventional being baled with the cutter disengaged. In Exp. 1, 46 heifers (initially 270 kg BW) were used in a 27 d experiment with ADG being higher ($P < 0.01$) for heifers consuming precut alfalfa compared to conventional alfalfa in ring feeders. However, there was no difference in final BW ($P = 0.56$) between conventional and precut treatments. In Exp. 2, 46 heifers were used to show there was no ($P > 0.05$) difference in forage wastage from ring feeders between precut or conventional alfalfa. In Exp. 3, 26 beef heifers, (initially 305 kg) were used to show that there was no ($P = 0.48$) difference in the preference of conventional alfalfa or precut alfalfa when offered simultaneously in different ring feeders for 2 d. In Exp. 4, 75 bulls (initially 317 kg BW) were used to show that tub ground bales had smaller TMR particle size ($P = 0.01$) than TMR's with conventional or precut alfalfa bales. In Exp. 5, 60 heifers (initially 332 kg BW) were used to show that different discharge locations from each of the different cornstalk treatments had similar ($P > 0.11$) DM, CP, ADF, and NDF. Mixing time and fuel usage of a vertical mixer were evaluated in Exp. 6 and 7. In Exp. 6, bale mixing time was shorter ($P < 0.05$) for precut alfalfa compared to conventional alfalfa bales. Fuel usage per bale was lower ($P < 0.001$) for precut alfalfa bales compared to conventional alfalfa bales. In Exp. 7, precut cornstalk bale mixing time was shorter ($P < 0.001$) than conventional cornstalk bales. Fuel usage was similar ($P > 0.05$) among precut and conventionally-processed cornstalk bales. In conclusion, precutting alfalfa or cornstalk bales prior to net wrapping improved heifer performance and decreased mixing time and tractor fuel usage, but did not affect wastage and preference.

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CHAPTER 1 - The effect of round bale alfalfa processing type on heifer performance, forage wastage, and eating preference

Abstract

Three experiments were conducted to evaluate the effect of round bale alfalfa processing type on heifer performance, wastage, and preference when fed in ring feeders. All bales for the 3 experiments were baled with a round baler (John Deere) that had the ability to cut the material being baled prior to wrapping. This machine baled all bales used in these experiments; bales termed “conventional” were baled with the cutter disengaged. One field of alfalfa was used in mid-July in northeast Kansas. In Exp. 1, a total of 46 heifers (initially 270 kg BW) were used in a 27 d study to evaluate heifer performance; heifers were offered free choice alfalfa hay in a 2.4 m ring feeder that was either precut or in conventional form. Treatments were: 1) 1.5 × 1.2 m conventionally-baled alfalfa, and 2) 1.5 × 1.2 m precut alfalfa. There were 2 replicates per treatment. All heifers, regardless of treatment were fed 1.5 kg DM of wet corn gluten daily during the experimental. Average daily gain was higher (1.37 kg vs. 1.13 kg; $P < 0.01$) for heifers consuming precut alfalfa compared with conventional alfalfa. However, there was no difference in final BW (302.5 kg vs. 306.4; $P = 0.56$) between heifers fed conventional or precut treatments. Calculated DMI of alfalfa was not different (5.23 kg vs. 5.56 kg; $P = 0.70$) between precut and conventional treatments. In Exp. 2, 46 heifers were used to evaluate the effect of baling method on forage wastage from ring feeders; Exp. 2 was conducted concurrently with Exp. 1, and treatments were: 1) 1.5 × 1.2 m conventionally-baled alfalfa, and 2) 1.5 × 1.2 m precut alfalfa. Alfalfa wastage was raked daily for 5 d after the bale was placed in the ring feeder. There were a total of 4 pens, and wastage was collected on 3 subsequent 5-d periods for a total of 6 replications per bale type. There was no difference in DM alfalfa wastage ($P > 0.13$) between treatments for days 1, 3, 4, and 5. However, DM wastage for day 2 tended to be higher ($P = 0.10$) for the precut than for the conventional alfalfa. Overall, there was no difference ($P > 0.05$) between the two treatments. In Exp. 3, 26 beef heifers (initially 305 kg) were used to evaluate the preference for conventional vs. precut alfalfa offered simultaneously in different ring feeders for 2 d. Treatments were: 1) 1.2 × 1.2 m conventionally-baled alfalfa and 2) 1.2 × 1.2 m precut alfalfa. Two pens, each containing 13 heifers, were used with preference measured subsequently 3 times in 1 pen and twice in the other, thus there were 5 replicates per treatment. For heifer preference, there was no difference in calculated DMI between precut and conventional alfalfa (4.7 vs. 3.9 kg/d; $P = 0.48$). Feeding heifers precut vs. conventional alfalfa in ring feeders improved ADG, but did not influence wastage or eating preference based on bale type.

Key Words: alfalfa, growth, preference, wastage

Introduction

To maximize feed efficiency, harvested forages should be of high quality and easy to consume. Many factors affect forage quality, including moisture level at baling, compaction, bulk density, and maturity at harvest. Considerable losses in DM and nutrient value occur during field curing. To compensate for these losses, hay baled at or above 18% moisture should have less nutrient loss in the field (Buckmaster et al., 1989). However, hay baled at these moisture levels has the potential to heat during storage causing dry matter loss and nutrient degradation. Also, as particle length of forage decreases packing ability of forage increases, and bulk density of a bale increases. The greater compaction results in increased anaerobic activity and fermentation, which increases forage quality (Muck, 1988).

Other factors that affect efficiency include forage particle length, palatability, and feedstuff bulk density. Forage particle length plays an important role in digestion and animal performance; therefore, it is an important consideration it from harvest through feeding (Heinrichs et al., 1999). Chewing activities and sorting tendencies increase with greater particle length (Kononoff et al., 2003; Leonardi and Armentano, 2003). Decreasing particle length may result in reduced sorting. Less sorting results in better utilization of the forage and less wastage (Krause et al., 2002).

While particle length reduction is commonly practiced by grinding baled forage, nutrient losses are associated with this processing technique (Loya-Olguin et al., 2008). Therefore, precutting forage prior to baling may potentially eliminate grinding of forage prior to feeding and be beneficial for producers. Also, when feeding free choice in a ring feeder precutting forage may help reduce waste because the smaller particles fall within the ring and are not pulled out by the animals and thus subject to falling on the ground in the form of waste (Buskirk et al., 2003).

The objectives of these experiments were to determine whether precutting alfalfa during baling had an effect; 1) animal performance, 2) forage wastage, and 3) animal preference compared to conventional bales.

Materials and Methods

General

Experimental procedures were approved by the Kansas State University Institutional Animal Care and Use Committee.

One field of alfalfa was swathed and raked in mid-July in northeast Kansas. The conventional baling method used a round baler that fed alfalfa through the header and carried it by packer fingers into a baling chamber without further processing. The precut method fed alfalfa through the header of a round baler that had serrated knives in the inner 1 m that cut the alfalfa stems into 8 to 20 cm sections as the packer fingers moved them from the header to the baling chamber. Because there were no knives on the outer 15 cm of each side, the perimeter of the bale was composed of alfalfa that was of full stem length, which maintained bale structure for hauling or handling. Alfalfa bales for all 3 experiments were sampled with a Penn-State hay probe.

Experiment 1

A total of 46 heifers (initially 270 kg BW) were used to evaluate the effect of free choice alfalfa hay that was either precut or in conventional form on heifer performance in a 27 d study. The study was conducted at the Kansas State University Purebred Beef Research Unit. The treatments were 1.5 × 1.2 m conventionally-baled alfalfa and 1.5 × 1.2 m precut alfalfa. There were 4 pens of beef heifers used (2 pens of 10, 2 pens of 13) with 2 replications per treatment. Heifers were randomly allotted by weight and breed in a complete block design. The treatments were offered free choice in 2.4-m ring feeders. All heifers were fed 1.3 kg/d wet corn gluten. Each individual bale was weighed before being placed into the ring feeders. Heifers were weighed on 2 consecutive days at the beginning and end of the 27-d trial to determine starting and ending BW for calculation of ADG. To calculate individual DM alfalfa intake, the DM wastage by treatment (determined in Exp. 2) plus remaining orts were subtracted from the initial DM bale weights. This was then divided by the number of heifers in each respective pen for the calculated DM intake per head. Core samples were taken of each bale and combined to make one composite sample of each treatment. Chemical analysis of each composite sample was conducted for DM, CP, ADF, and NDF (AOAC, 1995).

Experiment 2

A total of 46 heifers were used to evaluate the effect of baling method on forage wastage from ring feeders, and Exp. 2 was conducted concurrently with Exp. 1. Treatment pens, and cattle were similar to those in Exp. 1. A 5-d collection period was conducted 3 times for a total of 6 replications per bale type. Prior to the start of each 5-d period, ring feeders and surrounding soil were scraped free of residual forage. Initial bale weights were recorded, and alfalfa wastage around the ring was collected every day at 0700 h for 5 d. Wastage was collected with a lawn rake from the feeder to a distance of 2.4 m around the feeder. Collection of manure was minimized, but could not be avoided in all circumstances. Wastage was collected and weighed every day. The entire amount of wastage collected by pen for the 5-d period was combined and sub sampled for analysis. After the 5th day, remaining orts were collected inside the ring feeders and weighed, to calculate wastage as a percentage. Individual bale core samples, and combined alfalfa wastage by collection period were analyzed for DM, CP, ADF, and NDF (AOAC, 1995).

Experiment 3

A total of 26 beef heifers (initially 305 kg BW) were used to evaluate the effect of free choice alfalfa hay that was either precut or in conventional form on heifer preference. The study was conducted at the Kansas State University Purebred Beef Research Unit. Heifers were allotted by weight and breed to utilize complete randomization in this study in 2 pens. There were 2 ring feeders per pen (2.4 m feeders), 1 contained the conventional treatment and 1 contained the precut treatment. Orts were collected and weighed every 2 days for calculation of DMI. Prior to the next 2-d period, feeder locations were moved within each pen so no carryover effect of feeder location would occur. The treatments were 1.2 × 1.2 m conventionally-baled alfalfa and 1.2 × 1.2 m precut alfalfa. During this study, all heifers were fed 1.5 kg/d wet corn gluten daily. All bales were weighed individually prior to being placed in 2.4-m ring feeders. Individual bale core samples were analyzed for analysis of DM, CP, ADICP, ADF, TDN, and mold spore counts. At the conclusion of the 2 d period DMI was calculated by subtracting the remaining orts from initial bale weight.

Statistical Analysis

Data were analyzed with the MIXED procedures of SAS. Pairwise comparison precut and conventional treatments were conducted. Main effects were considered significant at $P < 0.05$, with tendencies considered significant $P < 0.10$.

Results

Chemical Analysis

In Exp. 1 & 2, there were differences in chemical analysis between bales for the two treatments for DM, CP, ADF, and NDF (Table 1). The conventional treatment had a higher (79.5 vs. 79.1; $P < 0.01$) DM than the precut treatment. Crude protein was higher (20.6 vs. 17.7; $P < 0.04$) in the precut treatment than in the conventional treatment. Percentages for both ADF and NDF were higher (44.8 vs. 33.3 for ADF and 58.3 vs. 46.3 for NDF; $P < 0.03$) in the conventional treatment than in the precut treatment. In Exp. 2, chemical analysis of orts showed similar ($P > 0.90$) values for DM and CP, but higher ($P < 0.02$) ADF and NDF values for conventional alfalfa bales (Table 4). In Exp. 3, chemical analysis of the bales showed higher DM, TDN, and mold counts ($P < 0.04$) for the precut treatment than for conventional treatment. (Table 5). Also, CP and ADF were lower ($P < 0.04$) for the precut treatment compared with conventional alfalfa. There was no difference ($P > 0.10$) in ADICP between bale types.

Experiment 1

Initial BW of heifers was similar (271.9 kg vs. 269.3 kg; $P = 0.67$) in the conventional and precut alfalfa treatments (Table 2) as expected. Average daily gain was higher (1.37 kg vs. 1.13 kg; $P < 0.01$) for heifers consuming precut vs. conventional alfalfa. Calculated dry matter intake of alfalfa was not different (5.23 kg vs. 5.56 kg; $P = 0.70$) between treatments.

Experiment 2

There was no difference in alfalfa wastage ($P > 0.13$) between the treatments for d 1, 3, 4, and 5 (Table 3). However, wastage for d 2 tended to be higher ($P = 0.10$) in the precut treatment compared with conventional alfalfa. Overall there was no difference ($P > 0.05$) between the two treatments.

Experiment 3

For alfalfa bale type eating preference, there was no difference in DMI between precut and conventional alfalfa (4.7 vs. 3.9 kg/d; $P = 0.48$).

Discussion

Nutrient utilization of forages is important for optimum animal performance. Greater utilization of forages, specifically alfalfa, leads to better ruminal health and growth in ruminants when leaf loss is minimal. Processing method may affect leaf loss and nutrient quality of the hay (Loya-Olguin et al., 2008). When more leaf that is available, there is greater nutrient availability for optimizing growth. Understanding nutrient availability requires understanding the chemical analysis performed on specific forages.

In our study, the magnitude of improvement in ADG for heifers fed precut alfalfa was significant. This is challenging to fully explain, but there was a numerical, although not significant increase in DMI for heifers offered precut alfalfa. This combined with higher digestibility due to reduced particle length forage may have contributed to this effect. It is known that differences in feedstuff utilization can be attributed to improvements in hay quality or particle size length (Mertens and Ely, 1982). Although the conventionally-baled alfalfa in our study had a higher carbohydrate fraction because of higher NDF and ADF, more visual carmelization was evident among conventional bales. Research has shown that carmelization decreases digestibility when alfalfa is baled at 23% moisture (Montgomery et al., 1986).

In this study, differences in visual carmelization were observed between the two treatments that led to further investigation of the chemical analysis between the two baling methods in Exp. 3. In contrasts to Exp. 1, the chemical analysis of Exp. 3 showed that conventionally baled alfalfa had lower DM and greater CP compared with precut alfalfa bales. These differences were surprising because bales were harvested from the same field hours apart. Moreover, precut alfalfa bales in Exp. 3 had an increased mold count. We were not able to make specific conclusions relating to animal performance due to these higher mold counts because no difference in DMI was found. Also, the bales in Exp. 3 were smaller in size and no visual carmelization was seen.

Differences in preference can exist for forages from the same location. Fisher et al. (2002), evaluated the effects of harvest time (morning vs. afternoon) on alfalfa hay preference and found that hay harvested in the afternoon was higher in nutritive value and preferred over hay harvested in the morning.

The percent of wastage in this study was very low compared with other peer-reviewed research. Buskirk et al. (2003) determined that 6.1% DM of hay was wasted by using a ring feeder, whereas Ishler et al. (1993) showed that hay wastage in ring feeders was 8.0% DM. Other studies show that hay wastage ranges from 12.6 to 29.8 kg/d (Miller et al., 2001) or from 4.4 to 10.1 kg/d (Miller et al., 2007) for higher- or lower-quality hay, respectively. The ring feeders in the present study showed considerably less wastage (0.9 and 1.1% for conventional and precut, respectively) than any of these previous trials. This is possibly due to different forages being measured, and different diameters of round bales used in the various studies.

Variation in particle length has been shown to effect forage wastage (Brasche and Russell, 1988). The shorter particle length of precut alfalfa compared with conventional hay may result in more wastage. Moreover, the increased particle length of conventionally-baled alfalfa may lead to an increase in sorting behavior and wastage (Leonardi and Armentano, 2003). However, our research showed similar amounts of wastage for the precut and conventional alfalfa treatments. We conclude that forage wastage is not a concern when feeding precut alfalfa bales. In conclusion, feeding precut alfalfa bales increased heifer ADG, but did not have an effect on eating preference or forage wastage when fed in ring feeders.

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Figures and Tables

Table 1. Chemical analysis of alfalfa bales (Exp. 1 & 2)[1]

Item,	Conventional	Precut
DM, %	79.5	79.1
CP, %	17.7	20.6
ADF, %	44.8	33.3
NDF, %	58.3	46.3

[1]Chemical analysis of composite samples for each treatment.

Table 2. Effects of alfalfa bale type on heifer growth performance (Exp. 1)[1]

Item;	Conventional	Precut	Probability, *P* <	SEM
Initial BW, kg[2]	272	269	0.67	13.68
d 27				
ADG, kg	1.13	1.37	0.01	0.200
Calculated Forage DMI, kg[3]	5.24	5.56	0.70	1.814

[1]A total of 46 heifers were fed alfalfa hay processed by two different methods for 27 d.

[2]BW was determined by weighing heifers on 2 consecutive days at the beginning and end of the 27 d trial.

[3]DMI was estimated by subtracting remaining ort and calculated wastage weight (determined in Exp. 2), from initial bale weight.

Table 3. Effects of bale processing technique on hay wastage (Exp. 2)[1]

	Conventional	Precut	Probability, *P* <	SEM
Initial bale wt, kg[2]	398	426	0.01	8.7
Hay wastage, kg[3]				
d 1	1.97	2.66	0.14	0.960
d 2	1.16	2.37	0.10	1.480
d 3	0.71	0.70	0.97	1.011
d 4	0.45	0.24	0.16	0.304
d 5	0.26	0.14	0.29	0.567
Total	4.55	6.11	0.30	2.876

[1]A total of six replicates per treatment.

[2]DM basis; Bales were weighed at the beginning of each period.

[3]DM basis; Wastage was collected each morning at 0700 and weighed.

Table 4. Chemical analysis of alfalfa orts remaining in the ring feeder (Exp. 2)[1]

Item,	Conventional	Precut	Conventional vs. Precut	SE
DM, %	78.09	78.57	0.90	3.852
CP, %	20.02	20.07	0.96	1.015
ADF, %	44.21	36.14	0.001	1.824
NDF, %	54.91	49.42	0.02	2.069

[1]Mean of six sample each representing remaining alfalfa.

Table 5. Nutrient composition and intake of alfalfa hay by beef heifers (Exp. 3)[1]

Item,	Conventional [1]	Precut [1]	Probability, *P* <	SEM
DMI, kg/d[2]	3.9	4.7	0.48	2.46
Nutrient analysis,				
DM, %	82.2	84.1	0.002	0.31
CP, %	20.6	19.5	0.04	0.32
ADICP, %	1.1	1.4	0.13	0.12
ADF, %	31.4	29.6	0.03	0.50
NDF, %	54.5	50.8	0.01	1.21
Mold, spores/g	10,000	64,000	0.04	15588.0

[1]Five replicates per treatment.

[2]DMI was calculated by subtracting the weight of remaining orts from the initial bale weight.

CHAPTER 2 - COMPARISON OF FEEDING AND MIXING CHARACTERISTICS OF PRECUT, CONVENTIONAL, AND TUB GROUND ALFALFA OR CORNSTALKS IN A TOTAL MIXED RATION

Abstract

Two experiments were conducted to evaluate the feeding and mixing characteristics of precut, conventional, and tub ground alfalfa or cornstalks in a horizontal total mixed ration (TMR). All bales for both experiments were baled using a round baler (John Deere) that had the ability to cut the material being baled prior to wrapping. This machine baled all bales used in both experiments: conventional bales were baled with the cutter disengaged. In Exp. 1, 75 bulls (initially 317 kg BW) were used to evaluate the effects of varying alfalfa hay processing methods on TMR diet mix uniformity and feed refusal. The treatments were: 1) 1.5 × 1.2 m conventionally baled alfalfa, 2) 1.5 × 1.2 m precut alfalfa, and 3) 1.5 × 1.2 m conventionally baled alfalfa that was tub ground. There were 5 replicates per treatment with 5 blocks composed of 3 d each, for a total of 15 d. Rations were fed at an average of 2.3% of DM BW over the 15 d period. One treatment was randomly fed each day for each of the 3-d blocks. Samples were taken in the bunk at the first, middle, and last third of the discharge process for diet particle length and chemical analysis. Diet samples from the first third of the mixer discharge had a lower percentage ($P = 0.03$) and samples from the middle of the mixer discharge tended to have a lower percentage ($P = 0.07$) of forage > 12.7 mm than samples from the end of the mixer discharge. Additionally, TMR diets that contained tub-ground alfalfa had a lower percentage ($P = 0.01$) of forage > 12.7 mm than diets containing both conventional and precut alfalfa. Bale cores, discharge samples, and remaining orts were analyzed to compare DM, CP, ADF, and NDF. Diet chemical analysis revealed no ($P > 0.80$) mixer discharge site × bale type interactions. However, TMR had higher ($P < 0.05$) NDF when conventional vs. tub ground alfalfa was used. There was no chemical analysis difference comparing precut vs. conventional or tub ground alfalfa. However, diet samples taken from the last third of the discharge had greater ($P = 0.03$) ADF than diet samples taken during the first third of the mixer discharge. Additionally, diet samples taken from the last third had greater ($P = 0.03$) NDF, and samples taken from the middle third tended to have greater (*P* = 0.07) NDF than samples taken at the beginning third of the mixer discharge. Moreover, conventional bales had greater (*P* = 0.05) NDF, and tended to have greater (*P* = 0.08) ADF compared with bales that were tub ground. In this study, there were no residual feed refusals by any treatment. In Exp. 2, 60 heifers (initially 332 kg BW) were used to evaluate the effects of varying cornstalk processing methods on TMR diet uniformity and feed refusal. Rations were fed at an average of 2.4% of DM BW over the 15 d period. The treatments were: 1) 1.5 × 1.2 m conventionally baled cornstalks, 2) 1.5 × 1.2 m precut cornstalks, and 3) 1.5 × 1.2 m conventionally baled cornstalks that were later tub ground. All cornstalks treatments were used in a complete TMR prior to feeding. There were 5 replicates per treatment with 5 blocks composed of 3 d each, for a total of 15 d. One treatment was randomly fed each day for each of the 3-d blocks. Samples were taken in the bunk at the first, middle, and last third of the discharge process for chemical analysis. Orts remaining in the bunk after feeding were collected and weighed before the next feeding period. Bale cores, discharge samples, and remaining orts were analyzed for DM, CP, ADF, and NDF. Chemical analysis revealed no (*P* > 0.31) mixer discharge site × bale type interactions. The different cornstalk processing technique did not influence (*P* > 0.11). However, samples taken from the first third of the mixer discharge had lower (*P* = 0.02) DM and higher (*P* = 0.04) CP than samples taken during the last third of the mixer discharge. Samples taken during the middle third of the mixer discharge had lower (*P* = 0.01) ADF and NDF, higher (*P* = 0.01) CP, and a tendency for higher (*P* = 0.09) DM compared with samples taken at the end of the mixer discharge. For feed refusals, heifers refused similar (*P* > 0.25) amounts for all 3 treatments. There was no difference in chemical analysis of the refusals (*P* > 0.12) among different bale types. Precutting alfalfa or cornstalks in a TMR was similar in mixing characteristics as both unprocessed and tub ground alfalfa and cornstalks. However, discharge location does influence diet uniformity.

Key Words: alfalfa, cornstalk, discharge location, TMR

Introduction

Nutritionists and producers often assume that ingredients in a total mixed ration (TMR) are uniformly mixed (Pritchard and Stateler, 1997). However, many factors affect TMR homogeneity, including particle size, shape, density, and texture (Pfost, 1970). Specifically, research has shown that chewing activities and sorting tendencies increase with greater particle length (Kononoff et al., 2003; Leonardi and Armentano, 2003). Shorter particle lengths result in decreased ruminal pH and rumination duration (Krause et al., 2002). Thus, many operations use a time-intensive process to grind forages by breaking up round bales. This reduces forage particle length prior to adding the remainder of the ingredients for a TMR to reduce forage particle length variation in the TMR.

Currently, no peer-reviewed research has shown the effects of discharge site on ration uniformity. However, there is the potential for increased sorting or sifting of ingredients, which would result in increased differences in nutritional composition of samples taken throughout a TMR.

Previous research has shown that grain processing effects ration uniformity (Weichenthal et al., 1989; Robins, 1994). Preprocessing forages while baling may allow for optimal particle length for rumination and minimize particle sorting without having to process forages prior to mixing into a TMR. Thus, objectives of this study were to determine the effects of forage processing on 1) TMR mix uniformity at different discharge locations, 2) particle length throughout the mixing process by bale type, and 3) difference in feed refusals based on forage processing used in the TMR.

Materials and Methods

General

Experimental procedures were approved by the Kansas State University Institutional Animal Care and Use Committee. One field of alfalfa was swathed and raked in mid-July in northeast Kansas. The conventional baling method utilized a round baler that fed forage through the header and carried by packer fingers into a baling chamber without further processing. The precut method fed forage through the header of a round baler that had serrated knives in the inner 1 m which cut the alfalfa stems into 8 to 20 cm sections as the packer fingers moved the forage from the header to the baling chamber. Because there were no knives on the outer 15 cm of each side, the perimeter of the bale was composed of forage that was of full stem length, which maintained bale structure for hauling or handling. Alfalfa (Exp. 1) and corn stalk (Exp. 2) bales were sampled using a Penn-State hay probe. For both experiments, there were 5 replicates per treatment with 5 blocks composed of 3 d each, for a total of 15 d. One treatment was randomly fed each day for each of the 3-d blocks. Prior to the start of each experiment, conventional bales were unrolled on a concrete slab. Precut bales were broken apart by being raised to approximately 5 m with a tractor grapple fork and dropped onto concrete. Tub-ground bales were ground with a Haybuster H-1000 (DuraTech Industries International, Inc., Jamestown, ND) using a 5.08 cm screen. All forage was collected and stored in a covered commodity shed until it was used in the experiments. A TMR was created and ingredients were added in the following order 1) wet corn gluten feed, 2) steam flaked corn, 3) vitamin and trace mineral premix, and 4) designated bale type (Table 1). The TMR was mixed with an engaged horizontal mixer (Forage Express, Roto-Mix, Dodge City, KS). After all ingredients were included in the mixer, the power take-off speed was set at 540 revolutions per minute and ran for 3 min. During the 15-d feeding, plastic containers (30 cm × 20 cm × 15 cm) were placed at the first, middle, and last third of the bunk line. The plastic containers were removed from the bunk line after the TMR was fed. Sub samples from each container were collected, placed in a plastic bag, and stored for further lab analysis. Total mixed ration quantity was increased with each subsequent block. Orts remaining in the bunk were collected and weighed before the next feeding period for determination DM feed refusal. Bale cores, discharge samples, and remaining orts were analyzed to compare DM, CP, ADF, and NDF (AOAC, 1995). To calculate average DM intake, DM refusals was subtracted from initial DM of the TMR and divided by total number of animals. Animals were weighed on 2 consecutive days to compose a single mean for each d 0 and 15 for determination of weight change during the 15-d experimental period.

Experiment 1

A total of 75 bulls (initially 317 kg BW) were used to evaluate the effects of varying alfalfa hay processing methods on TMR particle length at different discharge locations. One field of alfalfa was swathed and raked on a single day in mid-July, 2008 in northeast Kansas. Alfalfa was baled with three different processing methods, which served as the three treatments. The treatments were: 1) 1.5 × 1.2 m conventionally baled alfalfa, 2) 1.5 × 1.2 m precut alfalfa, and 3) 1.5 × 1.2 m conventionally baled alfalfa that was later tub ground. Rations were fed at an average of 2.33% of DM BW over the 15-d period. The average DMI for the 15 d feeding period was 7.4 kg/animal each day. Average final BW for the 15 d feeding period was 340 kg, and ADG was 1.5 kg/d. Ingredient DM inclusion rate was 60% alfalfa, 32% wet corn gluten, 4.09%

steam flaked corn, and 3.91% vitamin trace mineral premix. Diet particle length was determined by measuring the geometric mean of the percentage amount of forage remaining on the top 2 screens (> 12.7 mm), the overall geometric mean length, and geometric standard deviation (ASAE Standard S424.1).

Experiment 2

A total of 60 heifers (initially 332 kg BW) were used to evaluate the effects of cornstalk processing methods on forage particle size length and heifer growth performance. In mid-October 2009, a portion of a cornstalk field in northeast Kansas was cut with a flail shredder (John Deere 27) and raked (Darf 17 wheel v-hay rake) on a single day. The cornstalks were either conventionally baled or precut baled. The treatments were: 1) 1.5 × 1.2 m conventionally baled cornstalks, 2) 1.5 × 1.2 m precut cornstalks, and 3) 1.5 × 1.2 m conventionally baled cornstalks that were later tub ground. Rations were fed at an average of 2.45% of DM BW over the 15 d period. The average DMI for the 15-d feeding period was 8.13 kg/animal each day. Final average BW for the heifers was 357 kg, and ADG for the entire 15-d feeding period was 1.6 kg/d. Ingredient DM inclusion rate was 45% cornstalks, 44.95% wet corn gluten, 6.14% steam flaked corn, and 3.91% vitamin trace mineral premix.

Statistical Analysis

Data was analyzed with the MIXED procedures of SAS. Individual bale was considered the experimental unit. Main effects were considered significant when $P < 0.05$, and tendencies when $P < 0.10$. Contrasts were used to compare differences in bale processing method.

Results

Experiment 1

Diet samples from the beginning third of the mixer discharge had a smaller ($P = 0.03$) percentage, and samples taken from the middle third of the mixer discharge tended to have a smaller ($P = 0.07$) percentage of forage length of the TMR (> 12.7 mm) compared to samples from the last third of the mixer discharge (Tables 2 and 3). Additionally, TMR diets containing tub ground alfalfa had a smaller ($P = 0.01$) percentage of forage length of the TMR (> 12.7 mm) than both the conventional and precut bale types. Samples taken from different discharge positions or bale types had similar ($P > 0.23$) geometric mean lengths and standard deviations.

Chemical analysis revealed no ($P > 0.80$) mixer discharge site × bale type interactions. The different alfalfa processing technique did not influence ($P > 0.28$) TMR DM and CP percentages (Tables 4 and 5). Discharge location first third vs. middle third was not different ($P > 0.17$) for ADF, and tended to be higher ($P = 0.07$) in percentage NDF. Samples taken from the last third of the discharge had greater ($P = 0.03$) ADF and NDF than samples taken at the beginning third of the mixer discharge. Compared with samples taken at the beginning third of the discharge, samples taken from the last third had similar ($P > 0.44$) ADF and NDF levels. Moreover, conventional bales had greater ($P = 0.05$) NDF, and tended to have a greater ($P = 0.08$) percentage of ADF than tub-ground bales.

Experiment 2

Chemical analysis revealed no ($P > 0.32$) mixer discharge site × bale type interactions. Different discharge locations from each of the different cornstalk treatments had similar ($P > 0.11$) DM, CP, ADF, and NDF. Total mixed ration samples taken from the beginning of the mixer discharge had lower ($P = 0.02$) DM and higher ($P = 0.04$) CP levels compared with samples taken at the end of the mixer discharge (Tables 6 and 7). Samples taken during the middle of the mixer discharge had lower ($P = 0.01$) ADF and NDF percentages, higher ($P = 0.01$) CP levels, and a tendency for higher ($P = 0.09$) DM levels, than samples taken at the end of the mixer discharge.

Heifer DM refusal was similar ($P > 0.25$) among all 3 treatments (Table 8). Chemical analysis of the refusals revealed similar ($P > 0.12$) levels of DM, CP, ADF, and NDF among the TMR with different processed bale types.

Discussion

Ideally, diets are mixed so ingredients are evenly distributed. However, smaller particles filter to the bottom of mixers throughout the mixing process (Vegricht et al., 2007). In a TMR, over-mixing can cause concentrates and micro-ingredients to sort to the bottom of the mixer (Kammel, 1998). Generally, forages are processed to create a shorter particle length so the diet can be more uniformly mixed. If the proportions of these ingredients are not mixed properly, ingredients will not be discharged in an even mix, resulting in inappropriate levels of nutrients being delivered to animals (Behnke, 1996). Processing of forages such as alfalfa can result in leaf loss and thus decreased forage value (Loya-Olguin et al., 2008). It was assumed after looking at the chemical analysis by discharge location that particles at the bottom of the mixer were smaller than those at the top. Alfalfa bales that were further processed by tub grinding had a smaller particle length compared with conventional alfalfa bales, which was expected. Interestingly, there were no differences in particle length between conventional or precut alfalfa bales. This suggests that precutting stems to shorter lengths at the time of baling did not significantly affect final TMR particle size.

Although numerical differences were seen, the reduction in particle length was not as great as with traditional tub grinding. This may be due to the forage not being cut as short as for traditional tub grinding. Also, the outer portion of the precut bales was not cut; thus, a portion of the precut treatments was actually of conventional length.

Analyzed nutrient levels reveal varied concentrations throughout the mixer. The ADF and NDF values correlate with increased forage concentrations in the TMR. These concentrations were highest at the end of the mixer discharge and with conventional alfalfa or cornstalk bales, suggesting that more forage was present in these conditions. Additionally, DM and CP levels were highest at the beginning of the mixer discharge or in tub-ground bales. This indicates that a higher level of the concentrates and wet corn gluten was present in these conditions.

In Exp. 1, bulls were fed increasing levels of TMR every 3 d. The increase was intended to entice more feed refusal. Rations were fed at an average of 2.3% of DM BW over the 15-d period. However, we were not able to create refusals over the 15-d for bulls fed at this BW. This may have been due to feeding high quality forage where DMI will increase compared to feeding lower quality forage (NRC, 2000).

In Exp. 2, heifers were fed at 2.4% of DM BW. Cornstalks are known to have low digestibility levels, whereas increased stalk length is known to decrease intake (Klopfenstein et al., 1987). In contrast, results from our study showed there was no difference in the amount of precut, conventional, or tub ground TMR refusals. Average DMI for the heifers was adequate for their BW (NRC, 2000). Because there was no difference in chemical analysis of the remaining orts, there was no indication that any more or less sorting of ingredients occurred because of initial cornstalk bale feeding type.

In summary, there was more ingredient segregation when TMR diets included conventional or precut bales rather than tub-ground forage. This segregation was evident from the increased DM and CP and decreased ADF and NDF concentrations at the beginning of the mixer discharge compared with the end. Precutting forages results in responses similar to those for conventionally baled forages at the dietary inclusion levels and conditions in these experiments.

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Figures and Tables

Table 1. Ingredient composition of diet (Exp. 1 and 2; DM basis)

Ingredient, % DM basis	Exp. 1	Exp. 2
Alfalfa hay	60.00	-
Cornstalks	-	45.00
Wet corn gluten feed	32.00	44.95
Steam flaked corn	4.09	6.14
Premix[1]	3.91	3.91
Total	100.00	100.00
Calculated composition		
DM, %	76.74	70.85
NEm, Mcal/kg	1.48	1.54
NEg, Mcal/kg	0.90	0.95
CP, %	17.11	14.00
Ca, %	1.25	0.76
P, %	0.49	0.55

[1]Provided (per kg of diet) 1,963 IU of vitamin A; 1,309 IU of vitamin E; 7.5 ppm Co; 593.8 ppm Cu; 37.1 ppm I; 0.10% K; 3,564.4 ppm Mg; 17.81% NaCl; 0.44% S; 14.8 ppm Se; 3,560.4 ppm Zn; 0.033 g Monensin, and 0.0099 g Tylosin.

Table 2. Effects of alfalfa bale type on diet particle length (Exp. 1)[1]

	Bale type									
	Conventional			Precut			Tub ground			
Item;	First third	Middle third	Last third	First third	Middle third	Last third	First third	Middle third	Last third	SE
Fraction top 2 screens, %[2]	19.9	21.4	26.1	15.6	17.5	23.7	3.7	2.6	5.6	3.08
Geometric mean length, mm	6.9	7.1	8.4	5.3	5.6	7.3	3.1	2.9	3.2	1.03
Geometric SD, mm	4.5	5.1	6.1	4.0	4.3	5.7	2.9	2.8	2.9	0.42

[1]45 samples of the complete diet were analyzed. (ASAE Standard S424.1)

[2] Collected particle > 12.7 mm.

Table 3. Probabilities of effects of alfalfa bale type on diet particle length (Exp. 1)[1]

	Probability, $P <$						
Item;	First third vs. Middle third	First third vs. Last third	Middle third vs. Last third	Conventional vs. Precut	Conventional vs. Tub ground	Precut vs. Tub ground	Site × Type
Fraction top 2 screens, %[2]	0.75	0.03	0.07	0.16	0.01	0.01	0.90
Geometric mean length, mm	0.83	0.96	0.79	0.50	0.28	0.68	0.91
Geometric SD, mm	0.91	0.66	0.74	0.72	0.41	0.24	0.26

[1]Samples of the complete diet were analyzed. (ASAE Standard S424.1)

[2]Collected particle > 12.7 mm.

Table 4. Effects of alfalfa bale type and discharge site on total mixed ration composition (Exp. 1)[1]

	Bale type									
	Conventional			Precut			Tub ground			
Item, %;	First third	Middle third	Last third	First third	Middle third	Last third	First third	Middle third	Last third	SE
DM	72.3	70.6	70.8	68.5	70.6	72.4	72.7	73.0	73.0	2.53
CP	23.4	23.8	23.7	24.7	23.9	23.5	24.1	24.2	24.6	0.74
ADF	23.2	25.3	26.0	22.3	23.8	24.9	22.5	23.1	23.6	1.21
NDF	39.8	42.6	42.1	39.9	41.1	42.2	39.2	39.8	40.3	1.07

[1]15 d of feeding different alfalfa bale types on discharge location in a total mixed ration chemical analysis.

Table 5. Probabilities of effects of alfalfa bale type or discharge site on ration composition (Exp.1)[1]

	Probability, *P* <						
Item, %;	First third vs. Middle third	First third vs. Last third	Middle third vs. Last third	Conventional vs. Precut	Conventional vs. Tub ground	Precut vs. Tub ground	Site × Type
DM	0.91	0.66	0.74	0.72	0.41	0.24	0.86
CP	0.83	0.96	0.79	0.50	0.28	0.68	0.80
ADF	0.16	0.03	0.43	0.25	0.08	0.53	0.95
NDF	0.07	0.03	0.71	0.63	0.05	0.14	0.85

[1]Probabilities of 15 d of feeding different alfalfa bale types on discharge location in a total mixed ration.

Table 6. Effects of cornstalk bale type or discharge site on ration composition (Exp. 2)[1]

	Bale type									
	Conventional			Precut			Tub ground			
Item %;	First third	Middle third	Last third	First third	Middle third	Last third	First third	Middle third	Last third	SE
DM	67.6	69.5	73.7	70.0	68.8	71.8	68.6	70.6	69.9	1.16
CP	12.6	13.1	11.8	12.2	12.5	11.1	12.6	12.7	12.2	0.45
ADF	28.2	27.0	28.3	28.6	26.1	31.8	28.2	27.6	29.9	1.45
NDF	51.6	50.0	53.7	54.6	49.8	56.7	53.3	53.3	54.7	1.78

[1]15 d of feeding different cornstalk bale types on discharge location in a total mixed ration chemical analysis.

Table 7. Probabilities of effects of cornstalk bale type or discharge site on ration composition[1]

	Probabilities, *P* <						
Item, %;	First third vs. Middle third	First third vs. Last third	Middle third vs. Last third	Conventional vs. Precut	Conventional vs. Tub ground	Precut vs. Tub ground	Site × Type
DM	0.49	0.02	0.09	0.98	0.65	0.67	0.32
CP	0.41	0.04	0.01	0.12	0.92	0.14	0.86
ADF	0.23	0.17	0.01	0.41	0.55	0.83	0.60
NDF	0.15	0.21	0.01	0.19	0.18	0.97	0.56

[1]Probabilities of 15 d of feeding different cornstalk bale types on discharge location in a total mixed ration chemical analysis.

Table 8. Refusal composition according to cornstalk bale type or discharge site (Exp. 2)[1]

	Bale type				Probability, *P* <		
Item;	Conventional	Precut	Tub ground	SE	Conventional vs. Precut	Conventional vs. Tub ground	Precut vs. Tub ground
DM, %	65.7	72.5	72.5	4.48	0.30	0.30	1.00
CP, %	5.1	5.1	4.9	0.32	0.97	0.55	0.58
ADF, %	50.6	51.2	49.4	1.05	0.71	0.42	0.24
NDF, %	76.7	77.7	79.2	1.07	0.53	0.13	0.35
DM refusal, kg	23.6	25.0	18.2	14.44	0.81	0.33	0.25

[1]Refusal DM and chemical analysis of 15 d of feeding cornstalk bales in a TMR.

CHAPTER 3 - COMPARISON OF MIXING CHARACTERISTICS OF PRECUT AND CONVENTIONAL ALFALFA AND CORNSTALK ROUND BALES IN A VERTICAL MIXER

Abstract

Two experiments were conducted to compare the mixing characteristics of precut or conventionally processed alfalfa and cornstalk round bales. All bales for both experiments were baled using a round baler (John Deere) that had the ability to cut the material being baled prior to wrapping. This machine was used in both experiments; with conventional bales were baled with the cutter disengaged. Mixing time was measured as the time from when the bale entered the vertical mixer (12 m^3 Roto-Mix Vertical Express, Dodge City, KS) until the bale core was broken apart. Fuel usage (L/h) level was recorded every 20 s of mixing time in Exp. 1 and every 10 s in Exp 2 from the computer display and averaged. Fuel usage per bale was then calculated. In Exp. 1, one field of alfalfa was swathed and baled as (1) 1.5 × 1.2 m precut bales, (2) 1.5 × 1.2 m conventional bales, (3) 1.8 × 1.2 m precut bales, and (4) 1.8 × 1.2 m conventional bales. There were 8 replicates for treatments 1 to 3 and 7 replicates for treatment 4. Mixing time was shorter ($P < 0.05$) for precut than for conventional bales, regardless of bale size (72 vs. 142 s for 1.5 × 1.2 m and 110 vs. 237s for 1.8 × 1.2 m, respectively). The large bales had increased fuel usage on both a liter per hour and liter per bale basis ($P < 0.001$). Fuel usage for the 1.5 × 1.2 m precut bale was lower ($P < 0.05$) than for the 1.5 × 1.2 m conventional bale (7.48 vs. 8.00 L/h, respectively), but was similar between bale types for the 1.8 × 1.2 m bales (9.23 vs. 9.14 L/h, respectively). Fuel usage per bale was lower ($P < 0.001$) for precut than for conventional regardless of bale size (0.15 vs. 0.31 L/bale for 1.5 × 1.2 m and 0.28 vs. 0.60 L/bale for 1.8 × 1.2 m, respectively). In Exp. 2, one field of cornstalks was swathed, brush hogged, or flail shredded and baled; treatments were: (1) conventionally baled brush hog, (2) precut baled brush hog, (3) conventionally baled flail shredded, (4) precut baled flail shredded, (5) conventionally baled swathed, and (6) precut baled swathed. All bales were 1.5 × 1.2 m. There were 8 replicates for treatments 1 to 3 and 5 to 7 and 7 replicates for treatment 4. Mixing time was decreased ($P < 0.05$) for the precut bales compared with the rush hog conventional bales (39.8 vs. 85.5 s, respectively). Mixing time for flail shredded and swathed precut bales were shorter ($P < 0.001$) than conventional bales. Bales processed with a brush hog had decreased ($P < 0.01$) mixing time compared with shredded bales but not ($P > 0.05$) swathed bales. Flail shredded bale mixing time was less ($P < 0.02$; 39.9 and 64.6 vs. 39.6 and 83.5 s for precut and conventionally processed bales, respectively) than for swathed bales. Fuel usage (L/h) for mixing was similar ($P > 0.05$) among precut and conventionally processed bales of each harvest method. Shredded bales tended ($P = 0.06$) to use less fuel than swathed bales. Bales harvested by brush hog had fuel usage similar ($P = 0.86$) to shredded bales. Bales harvested by swather had increased ($P = 0.04$) mixing fuel usage compared with brush hog harvested bales. Fuel usage (L/bale) for precut cornstalk bales was lower ($P < 0.01$) than for conventional bales. Shredded bales used less ($P < 0.02$) fuel than brush hog and swathed cornstalk bales. Using a precut method of baling forage decreased mixing time and fuel usage per bale.

Key Words: alfalfa, cornstalk, fuel usage, mixing time

Introduction

The goal of ruminant nutrition is to deliver the ideal level of nutrients to individual animals (Behnke, 1996a). Properly mixing and distributing nutrients throughout a ration can be equally as important as including them in the formulation. Many factors, including forage type, particle length, and mixer type affect the homogeneity of total mixed rations (TMR). Particle size plays an important role in digestion and animal performance, therefore particle size is an important consideration from harvest through feeding (Heinrichs et al., 1999). An increase in particle size results in a less uniform distribution of nutrients throughout the mix (Buckmaster and Muller, 1992). Consequently, chewing activities and sorting tendencies increase with greater particle length (Kononoff et al., 2003; Leonardi and Armentano, 2003). Particle length of forage is a physical characteristic that affects intake, rumen retention time, and gut passage rate of ruminant animals. In addition, diets with a high proportion of forages have the lowest uniformity in a TMR (Vegricht et al., 2007). Many operations use processed forage to reduce particle length. Thus, round bales are simply placed in vertical mixers to break apart the bale prior to adding the remainder of the ingredients for a TMR. This approach can be time consuming but is rationalized as a necessary step in improving forage utilization. Voluntary DMI increases when forage particle size is decreased by grinding and pelleting (Allen, 1996). Shorter particle lengths results in decreased ruminal pH and rumination duration (Krause et al., 2002). Cows have decreased rumination time and buoyant digesta in the rumen under conditions in which total amounts of forage or particle size of the forage are reduced (Heinrichs et al., 1999). Diet preparation time and energy use affects productivity and profitability of many operations. Decreasing mixing time may save money through decreased fuel usage and opportunity costs, but animal performance and feed efficiency can suffer if rations are not mixed properly. Therefore, it is important to mix rations adequately and efficiently.

Typically, alfalfa hay or cornstalks are cut by various types of machines and baled in full particle length. This method generally requires producers to further process bales into shorter particle lengths before using the bales in a TMR, either by tub grinding or placing into a vertical mixer where the bale is broke apart and goes through particle length reduction before the remainder of ingredients are added. A prototype baler has been developed to cut the stems prior to bale wrapping to reduce overall particle length, thus potentially eliminating the need to further process the forage before using it in a TMR.

The objectives of this study was to determine: the effects of precut and conventional alfalfa and cornstalk bales on 1) mixing time in a vertical mixer, 2) initial cut type of cornstalks on mixing time, and 3) tractor fuel usage while mixing.

Materials and Methods

General

One field of alfalfa was swathed and raked in mid-July in northeast Kansas. In the conventional baling method, alfalfa or cornstalks were fed through the header of a round baler and carried by packer fingers into a baling chamber without further processing. In the precut method, alfalfa or cornstalks were fed through the header of a round baler that had serrated knives in the inner 1 m which cut the forage stems in 8 to 20 cm sections as the packer fingers moved it from the header to the baling chamber. Because there were no knives on the outer 15 cm of each side, the perimeter of the bale was composed of forage that was of full stem length, which maintained bale structure for hauling or handling.

Experiment 1

A total of 31 alfalfa round bales were used to evaluate differences in mixing time of alfalfa baled with various techniques (precut vs. conventional) or in different bale sizes (small, 1.5 × 1.2 m vs. large, 1.8 × 1.2 m). A single field of alfalfa was used in mid-July in northeast Kansas. Treatments were: 1) 1.5 × 1.2 m precut bales, 2) 1.5 × 1.2 m conventional bales, 3) 1.8 × 1.2 m precut bales, and 4) 1.8 × 1.2 m conventional bales. There were 8 replicates per treatment, with the exception of the 1.8 × 1.2 m conventional alfalfa bales, which had 7 replicates. Core samples were taken from each bale to make a composite sample of each treatment that was analyzed for DM, CP, ADF, and NDF (AOAC, 1995).

Each bale was raised to 5 m by a loader tractor and dropped into a 12 m^3 vertical double screw mixer (Vertical Express, Roto-Mix, Dodge City, KS) that was engaged. The power take-off (PTO) speed was set at 540 revolutions per minute during the mixing process. Mixing time was measured as the time from when the bale entered the mixer until the bale core was broken apart. Fuel usage was determined with the factory-installed on-board computer display in the tractor. Fuel usage (L/h) was measured every 20 s of mixing time, averaged with fuel usage by bale, and then calculated.

Experiment 2

A total of 46 cornstalk round bales were used to evaluate differences in mixing time of cornstalks baled with various techniques and cutting methods. In mid-October portions of 1 field of corn stalks in northeast Kansas were prepared with 3 cutting methods: New Holland 116 swather (swathed), Model John Deere 27 Flail Shredder (shredded), and Model HX 15 Batwing Mower (brush hog). After each cutting method was performed, cornstalks were raked (Darf 17 wheel v-hay rake) and then precut or conventionally baled. All bales were 1.5 × 1.2 m. Treatments were: 1) conventionally baled brush hog, 2) precut baled brush hog (Model HX 15), 3) conventionally baled flail shredded, 4) precut baled flail shredded (John Deere 27), 5) conventionally baled swathed, and 6) precut-baled swathed (New Holland 116). Core samples were taken from each bale to make a composite sample of each treatment that was analyzed for DM, CP, ADF, and NDF (AOAC, 1995).

Each bale was raised to 5 m by a loader tractor and dropped into the same double screw mixer used in Exp. 1 that was engaged. The power take-off speed was 540 revolutions per min.

Mixing time was measured as the time from when the bale entered the mixer until the bale core was broken apart. Fuel usage (L/h) was measured every 10 s of mixing time, averaged with fuel usage by bale, and then calculated.

Statistical Analysis

Data was analyzed with the MIXED procedures of SAS. Bale was the experimental unit. The level of probability at which the main effects were considered significant was $P < 0.05$, tendencies were considered at $P < 0.10$. Contrasts comparing bale size and type were evaluated.

Results

Experiment 1

The 1.5 × 1.2 m alfalfa DM bales were lighter ($P < 0.001$) than 1.8 × 1.2 m bales, as expected (Table 1). There was no difference in DM weight ($P > 0.10$) between the precut and conventionally processed bales. Bale mixing time was shorter ($P < 0.05$) for precut than for conventional, regardless of bale size (72 vs. 142 s, for 1.5 × 1.2 m and 110 vs. 237s, for 1.8 × 1.2 m, respectively). The large bales had increased fuel usage on both a liter per hour and liter per bale basis ($P < 0.001$). Fuel usage for the 1.5 × 1.2 m precut bale was lower ($P < 0.05$) than for the 1.5 × 1.2 m conventional bale (7.48 vs. 8.00 L/h, respectively), but was similar ($P > 0.10$; 9.23 vs. 9.14 L/h, respectively) between bale types for the 1.8 × 1.2 m bales types. Less fuel ($P < 0.001$) was used for precut vs. conventional alfalfa bales. Also, the 1.5 × 1.2 m alfalfa bales used less fuel per bale ($P < 0.001$) than the 1.8 × 1.2 m bales.

Experiment 2

Cornstalk bale weights were similar ($P > 0.05$) among treatments (Table 2). Brush hog 1.5 × 1.2 m precut bale mixing time was decreased ($P < 0.05$) compared with brush hog 1.5 × 1.2 m conventional bales (39.8 vs. 85.5 s, respectively). Flail shredded and swathed precut bale mixing time was less ($P < 0.001$) than for conventional bales. Bales harvested with a brush hog had decreased ($P < 0.01$) mixing time compared with shredded bales, with swathed bales being intermediate. Finally, flail shredded bale mixing time was less ($P < 0.02$) than for swathed bales.

Tractor fuel usage was similar ($P = 0.20$) among precut and conventionally processed bales regardless of harvest method. However, swathed bales had increased ($P = 0.04$) tractor fuel usage compared with bales harvested by brush hog and tended to have increased ($P = 0.06$) fuel usage compared with bales harvested by shredding. Bales harvested with a brush hog had fuel usage similar ($P = 0.86$) as shredded bales. Fuel usage per bale was less ($P < 0.01$) among precut compared with conventionally processed bales for each harvest method. Bales harvested with the brush hog used more fuel per bale ($P = 0.02$) than shredded bales but showed similar ($P = 0.33$) fuel usage per bale compared with swathed bales. Bales processed with the shredder used less fuel per bales ($P < 0.002$) than swathed bales.

Discussion

The goal of mixing a TMR is to produce feed that has uniformly distributed nutrients with as little nutrient destruction as possible (Rippel et al., 1998). Just as important, properly mixed feed improves animal performance (Castle et al., 1979; Heinrichs et al., 1999). However, mixing time and the associated fuel usage depend on a variety of factors. Mixing time is affected by mixer design and changes in material including differences in particle size and bulk density (Behnke, 1996b). For many years, producers have preprocessed forage for to achieve the most uniform mix possible and increase the portion of forage that is rapidly degradable in the rumen (Roberge et al., 1998). Overmixing a TMR wastes both time and fuel and can cause nutrient segregation or physical breakdown (Kammel, 1998; Townsend, 2000).

Previous research has shown that preprocessing forages with the precut method may decrease the physical breakdown of nutrients compared with tub grinding (Loya-Olguin et al., 2008). However, Loya-Olguin et al. (2008) used large square bales rather than the prototype round bales used in this experiment. Although nutrient breakdown was not directly measured in our studies, the preprocessed forages used in our studies may have this same advantage. Producers who mix TMR rations without tub grinding the forage often use a vertical mixer to break apart round bales before adding the other ingredients. This can be a time-consuming process depending on forage type and bale size (Kammel, 1998). Preprocessing bales could reduce mixing time. In our study, mixing time ranged from 72 to 237 s (Exp. 1) and 59 to 85 s (Exp. 2). In fact, our data showed a reduction of approximately half the time required for bale destruction which may lead to increased on-farm time efficiency. Using the precut baling method reduced fuel usage per bale during the mixing period and; thus may potentially decrease the cost of mixing a TMR.

The observed reduction in fuel usage was due to the shorter particle length of the forage in precut bales, which required less time and power to break apart. Alfalfa stems are smaller in diameter and less fibrous than cornstalk stems. This allows alfalfa bales to be baled tighter than cornstalk bales, as indicated by their heavier weights compared with cornstalk bales of the same size. Furthermore, decreased particle size results in greater bulk density of diets (Teimouri Yansari et al., 2004). Thus, bales of longer particle length require more time and fuel to achieve complete break-up.

In summary, precut bales may potentially allow producers to eliminate traditional preprocessing methods such as tub grinding while maintaining the advantage of feeding forages with shorter particle lengths. Precut forage bales required less time to break up in a vertical mixer and less fuel per bale to mix.

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Figures and Tables

Table 1. Effects of alfalfa bale type on weight, mixing time, and fuel usage[1]

	Bale size					Probability, *P* <	
	1.5 × 1.2 m		1.8 × 1.2 m			Precut vs.	1.5 × 1.2 m vs.
Item	Precut	Conventional	Precut	Conventional	SE	Conventional	1.8 × 1.2 m
Weight, kg[2]	486[a]	490[a]	771[b]	775[b]	8.8	0.64	0.001
Mixing time, s	72[a]	142[b]	110[ab]	237[c]	19.5	0.001	0.003
Fuel usage							
Tractor, L/h	7.48[a]	8.00[b]	9.23[c]	9.14[c]	0.158	0.16	0.001
Bale, L	0.15[a]	0.31[b]	0.28[b]	0.60[c]	0.046	0.001	0.001

[1] n = 31 alfalfa bales (treatments 1-4, n=8; treatment 4, n=7).

[2] Bales were on an as fed basis.

[abc] Means within a row without a common superscript differ $P < 0.05$.

Table 2. Effects of cornstalk bale type on weight, mixing time, and fuel usage[1]

	Bale type							Probability, *P* <			
Harvest type:	Brush hog		Shredded		Swathed			Precut vs. Conv.	Brush hog vs. Shredded	Brush hog vs. Swathed	Shredded vs. Swathed
Item / Bale type:	Precut	Conv.[2]	Precut	Conv.[2]	Precut	Conv.[2]	SE				
Weight, kg[3]	445[b]	429[ab]	441[a]	419[a]	433[a]	437[a]	12.1	0.09	0.41	0.81	0.56
Mixing time, s	39.8[a]	85.5[c]	39.9[a]	64.6[b]	39.6[a]	83.5[c]	5.33	0.001	0.01	0.77	0.02
Fuel usage											
Tractor, L/h	10.84[ab]	10.36[b]	10.86[ab]	10.49[b]	11.73[a]	11.21[ab]	0.446	0.20	0.86	0.04	0.06
Bale, L/h	0.12[c]	0.25[a]	0.12[c]	0.19[b]	0.13[c]	0.26[a]	0.012	0.01	0.02	0.33	0.02

[1] n = 46 cornstalk bales (treatments 1-4 & 6, n = 8, treatment 5, n = 7).

[2] Conventionally-processed bales.

[3] Bales were on an as fed basis.

[abc] Means within a row without a common superscript differ $P < 0.05$.

CHAPTER 4 - THE EFFECT A NUTRIENT BALANCE OF A COMMERCIAL FEEDLOT ON THE AMOUNT OF RECOVERABLE N AND P FROM THE FEEDLOT PEN SURFACE

Abstract

The ability to develop a nutrient balance for livestock operations is important for maintaining a long-term sustainable production system with current and future environmental regulations. The objectives of this experiment were to determine the nutrient balance of a commercial feedlot and to determine the amount of recoverable N and P from the feedlot pen surface. A commercial feedlot with a capacity of approximately 35,000 in south central Kansas was used for this experiment from November 2005 to May 2006. The average number of head and body weight per pen were 66 and 434.5 kg, respectively. Each pen had a total area of 1,920 m^2, which calculated to an average square meter of 29.1 per head. Intake of N and P was calculated based on daily feed delivery per pen as well as the analyzed nutrient level of the diet. Excretion of N and P was determined by subtraction of retained nutrients from intake nutrients. The N intake for cattle in the experiment was calculated to be 210.7 g/hd/d (SD = 29.8). Based on the assumed N retention of 28 g/hd/d, 13.3% of the N fed was retained by the animal. In addition, it was calculated that 135.6 g/hd/d (SD = 26.6) of N was lost or non-recovered, which represents 74.2% of the amount of N that was excreted. The P intake for cattle in the experiment was calculated to be 33.0 g/hd/d (SD = 4.3). Based on the assumed P retention of 6.5 g/hd/d, 19.7% of the P fed was retained by the animal. Also, it was calculated that 8.8 g/hd/d (SD = 4.7) of P was lost or non-recovered, which represents 33.3% of the amount of P that was excreted. In summary, significant amounts of nutrient excretion relative to nutrient intake levels occur in feedlot cattle. This coupled with subsequent losses of excreted nutrients from the pen surface, particularly N, needs to be further addressed to capture more nutrients in manure for increased value.

Key words: environment, feedlot, nutrients

Introduction

The ability to develop a nutrient balance for a livestock operation is important for maintaining a long-term sustainable production system with current and future environmental regulations (Van Horn et al., 1996). Producers invest considerable amount of financial resources in the input of nutrients onto the farm, which are primarily feed and livestock. When animals leave the farm, they retain a portion of the feed nutrients they consumed, but the majority of feed nutrients is not retained by the animal and is excreted (Owens and Gardner, 2000). Once excreted, certain compounds in the manure volatilize which lowers the manure nutrient concentration and in turn diminishes the economic value of the manure as fertilizer (Olk et al., 2008). Many factors are likely to affect the nutrient removal levels from a beef feeding operation. There are three major factors effecting nutrient levels; weather, ration characteristics, and management (Kissinger et al., 2007). Weather can influence the amount of moisture and the degree of the soil mixed with manure. Ration formulation can impact the total amount of nutrients in the manure. Management implications can greatly affect how much of the manure is harvested or what is used for the maintenance of the pen. The summer months result in more volatilization than winter due to high microbial activity. P excreted tends to collect on the pen surface, rather than runoff into holding ponds, unlike N. This variation in runoff can lead to difficulties in the N-to-P ratio when applying the manure to crops (Koelsch and Lesoing, 1999). In addition, these volatile compounds can create air quality concerns. Operations designated as Concentrated Animal Feeding Operations (CAFO's) must develop nutrient management plans to provide documentation that the manure produced will be applied at agronomic rates for environmental protection. Thus, understanding the nutrient balance of a livestock operation is critical in developing whole-farm manure management plans. The objectives of this experiment were to: 1) determine the nutrient balance of a commercial feedlot; and 2) determine the amount of recoverable N and P from the feedlot pen surface.

Materials and Methods

A commercial feedlot with a capacity of approximately 35,000 in south central Kansas was used for this experiment from November 2005 to May 2006. Within the feedlot, 8 adjoining pens were used for data collection. Both heifers and steers were used in the experiment, as well as cattle at different weights and feeding durations for each group. The average number of head and body weight per pen were 66 and 434.5 kg, respectively. Each pen had a total area of 1,920 m^2, which calculated to an average of 29.1 m^2 per head.

Daily logs were kept for each pen. Data included head count, ration ID, and amount of feed delivered. Data was also provided on starting and ending weight for each group of cattle which were housed in the pens. This data was used to determine the number of cattle-days the pens were occupied during the entire experiment.

Samples of all rations fed during the experiment were taken at the bunk for analysis of DM, N, and P (AOAC, 1995). Analyses of the rations allowed for daily calculations of N and P intake by animal. Diets were based on steam-flaked corn, corn silage, alfalfa hay, and wet distiller's grains and the proportions of each varied depending on stage of feeding.

Before the start to the experiment, all pens were cleaned uniformly following the standard protocol of the feedlot. At the conclusion of the experiment, pens were individually cleaned and weights of removed manure were recorded by pen. All manure removed from the 8 pens was hauled to a common storage area and piled together. A total of 15 manure samples (approximately 13.6 kg total) were then taken from combined piled manure representing all 8 pens. This composite sample was mixed thoroughly and sub-sampled. A total of 4 sub-samples were collected and analyzed at a commercial laboratory for Kjeldahl N and P. The 4 sub-sample analyses were averaged to determine the mean concentration of nutrients in the collected manure.

All calculations were completed on a per animal basis within pen. Results are presented as grams per head per day (g/hd/d; Tables 1 and 2) as the average of the 8 pens in the experiment. Intake of N and P was calculated based on daily feed delivery per pen as well as the analyzed nutrient level of the diet. Values of N and P retention are referenced from values obtained from Kissinger et al. (2007) in a large scale nutrient balance study representing six feedlots in Nebraska (N = 28.0 g/hd/d; P = 6.5 g/hd/d). Excretion of N and P were determined by subtraction of retained nutrients from intake nutrients. The N and P per day in manure were determined from the actual manure analysis and volume of manure collected by pen. The amount of N and P lost was determined by subtracting the amount excreted from the amount in the collected manure. Also, the standard deviation for each calculated value was determined.

Results and Discussion

The N intake for cattle in the experiment was calculated to be 210.7 g/hd/d. Based on the assumed N retention of 28 g/hd/d, 13.3% of the N fed was retained by the animal. In addition, it was calculated that 135.6 g/hd/d of N was lost or non-recovered, which represents 74.2% of the amount of N that was excreted.

The percentage loss of N recovery can mainly be explained through the volatilization of N from the feedlot surface and secondarily from runoff during rain events or not recovering all N in the manure from the pen surface (Powers and Van Horn, 2000). N in the ammonia form can volatilize and contribute to decreased air quality, increased odor, and reduced economic value of the manure for fertilizer (Rotz, 2004). The P intake for cattle in the experiment was calculated to be 33.0 g/hd/d. Based on the assumed P retention of 6.5 g/hd/d, 19.7% of the P fed was retained by the animal. Also, it was calculated that 8.8 g/hd/d of P was lost or non-recovered, which represents 33.3% of the amount of P that was excreted. This level of P loss was higher than previously published values and was not expected to be this high due to the fact that P is not volatile (Klopfenstein and Erickson, 2002).

Kissinger et al. (2005) showed that less than 100% of P excreted is removed in the manure. For P, the percentage loss of P recovery must be due to unaccounted runoff losses, mixing manure with soil after precipitation events and the potential of inconsistent scraping depths at the start or at the conclusion of the experiment.

During the entire experiment, a total of 21.7 cm of rainfall was recorded. However, 10.3 cm was received during the last 45 days of the experiment. With wet conditions present during the last portion of the study, challenges in obtaining complete manure removal at the end of the study may have occurred, which could have underestimated the recovery of total manure, especially P. Significant amounts of nutrient excretion relative to nutrient intake levels occur in feedlot cattle. This coupled with subsequent losses of excreted nutrients from the pen surface, particularly N, needs to be further addressed.

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Figures and Tables

Table 1. N balance of a commercial feedlot[1]

Item,	Mean	SEM
N intake, g/hd/d	210.7	29.8
N retained, g/hd/d	28.0[a]	-
N excreted, g/hd/d	182.7	29.8
N manure, g/hd/d	47.1	14.4
N lost, g/hd/d	135.6	26.6
N lost, % of excreted	74.2	7.6

[1]Represents 8 pens in a 35,000 capacity feedlot from November 2005 through May 2006.

[a]Referenced value from Kissinger et al. (2007).

Table 2. P Balance of a Commercial Feedlot[1]

Item,	Mean	SEM
P intake, g/hd/d	33.0	4.3
P retained, g/hd/d	6.5[a]	-
P excreted, g/hd/d	26.5	4.3
P manure, g/hd/d	17.6	5.4
P lost, g/hd/d	8.8	4.7
P lost, % of excreted	33.3	18.5

[1]Represents 8 pens in a 35,000 capacity feedlot from November 2005 through May 2006.

[a]Referenced value from Kissinger et al. (2007).

Table 3. Manure analysis of a Commercial Feedlot[1]

Item,	Mean
DM, %	
N	
Kjeldahl N, %	0.013
Ammonia N, %	0.033
Organic N, %	0.010
P, %	0.005
Ca, %	0.022
K, %	0.016

[1]Represents manure from 8 pens in a 35,000 capacity feedlot from November 2005 through May 2006.

[a]Referenced value from Kissinger et al. (2007).