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Effects of Pre-Cutting Round Alfalfa Hay Bales on Forage Quality and Processing Time

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Abstract

Round hay balers with knives that cut the hay as it enters the baling chamber reduce the particle size upon baling, and eliminate the need for a tub grinder. The objective of this study was to evaluate the effects of a round hay baler with knives on forage quality of alfalfa hay at baling and after storage, and the effects of the processing method on nutrient composition and particle size distribution. Alfalfa hay was baled (560 M Megawide HC2, John Deere, Moline, IL) with knives every 4 inches (CUT; theoretical length of cut) or without knives (NORM). At baling and after 6 months of uncovered storage, bales were weighed, measured, and 10 core samples were obtained for nutrient analysis. Cores were separated into outer 6 inches and inner 6- to 18-inch segments to determine the depth of spoilage. After storage, particle size was reduced to approximately 4 inches using a mixer wagon for CUT (CUT-MIX) or a tub grinder for NORM (NORM-GRIND). Compared with NORM, CUT increased bale weight and density. Core depth interacted with storage timepoint whereby acid detergent fiber (ADF) concentration increased more for outer than inner cores from baling to the end of storage, with similar effects for lignin and 240-hour undigestible NDF. Compared with NORM, CUT increased concentrations of aNDF organic matter, ADF, and lignin, and decreased relative forage quality (RFQ). The CUT-MIX treatment increased time to reduce particle size, but decreased processing shrink by 6.1% compared with NORM-GRIND. Additionally, when compared with NORM-GRIND, CUT-MIX increased fiber content and decreased fiber digestibility, which may have been due to sampling error from longer particle size. In summary, CUT produced larger, more dense bales and increased fiber content slightly, and CUT-MIX decreased processing shrink but increased fiber content with additional longer particles after processing, which could be advantageous for physically effective fiber in ruminant diets. Further work should continue to evaluate leaf loss during baling, and options for processing and incorporating pre-cut hay into diets.

Keywords

density, shrink, round bale, particle size, grinding

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Effects of Pre-Cutting Round Alfalfa Hay Bales on Forage Quality and Processing Time

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Summary

Round hay balers with knives that cut the hay as it enters the baling chamber reduce the particle size upon baling, and eliminate the need for a tub grinder. The objective of this study was to evaluate the effects of a round hay baler with knives on forage quality of alfalfa hay at baling and after storage, and the effects of the processing method on nutrient composition and particle size distribution. Alfalfa hay was baled (560 M Megawide HC[2], John Deere, Moline, IL) with knives every 4 inches (CUT; theoretical length of cut) or without knives (NORM). At baling and after 6 months of uncovered storage, bales were weighed, measured, and 10 core samples were obtained for nutrient analysis. Cores were separated into outer 6 inches and inner 6- to 18-inch segments to determine the depth of spoilage. After storage, particle size was reduced to approximately 4 inches using a mixer wagon for CUT (CUT-MIX) or a tub grinder for NORM (NORM-GRIND). Compared with NORM, CUT increased bale weight and density. Core depth interacted with storage timepoint whereby acid detergent fiber (ADF) concentration increased more for outer than inner cores from baling to the end of storage, with similar effects for lignin and 240-hour undigestible NDF. Compared with NORM, CUT increased concentrations of aNDF organic matter, ADF, and lignin, and decreased relative forage quality (RFQ). The CUT-MIX treatment increased time to reduce particle size, but decreased processing shrink by 6.1% compared with NORM-GRIND. Additionally, when compared with NORM-GRIND, CUT-MIX increased fiber content and decreased fiber digestibility, which may have been due to sampling error from longer particle size. In summary, CUT produced larger, more dense bales and increased fiber content slightly, and CUT-MIX decreased processing shrink but increased fiber content with additional longer particles after processing, which could be advantageous for physically effective fiber in ruminant diets. Further work should continue to evaluate leaf loss during baling, and options for processing and incorporating pre-cut hay into diets.

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Introduction

The use of round hay bales in livestock feeding in North America is common, either through animals eating directly from the bale or caretakers incorporating hay into mixed diets delivered to the animals. If hay from round bales is to be incorporated into diets and delivered to animals, it must be disassembled to facilitate ease of mixing and to reduce particle size for stimulation of feed intake in high forage diets limited by gut fill. A common method for round bale disassembly is the use of tub grinders, which rapidly break down the bale and reduce hay particle size. While this method is relatively quick and effective, there are several drawbacks. First, a large amount of shrink occurs as high-value components of the feed drift away as small fragments into the environment, especially on windy days. Secondly, the ground hay typically is stored outdoors and exposed to moisture and wind for extended periods of time until it can be fed, with estimated losses incurred up to 20%. Finally, the use of a tub grinder requires specialized equipment, either purchased or contracted, creating an additional expense per ton of feed offered to the animal. The energy requirements of grinding also increase energy costs to reduce particle size.

Round hay balers with vertical knives reduce the particle size of hay before entering the baling chamber, which potentially eliminates the need for tub grinders to break apart round bales before incorporation into animal diets. Hay produced in this manner is widely referred to as precut or presliced hay and provides unique feed management possibilities to prevent forage losses during preparation for mixed ration delivery. While precut hay baler models have been available from various equipment manufacturers for over two decades, little peer-reviewed data are available on forage produced in this manner. The data that are available focus on animal feeding behavior and production performance, forage quality, and fermentation of wrapped precut hay bales, and bale characteristics and power requirements for bale production.

In hay production, an estimated dry matter (DM) loss of 25% may occur between harvest and feeding, so maximizing nutrient retention from harvest to feed delivery is critical to ensure the nutritional requirements of the animal are met cost-effectively. Nutrient loss occurs from harvest through feeding of round hay bales, and precutting bales may eliminate the need for tub grinding. The objectives of this study were to 1) assess the effect of precutting alfalfa hay on forage quality at baling and after storage, and 2) determine the effects of post-storage processing method determined by bale production system on forage quality. We hypothesized that precutting alfalfa hay would have minimal impacts on forage quality at baling and through storage, and that precut bales would retain more nutrients during processing with a mixer wagon due to less leaf loss to the environment compared with grinding bales.

Experimental Procedures

This trial was conducted on four farms in south central Nebraska in the summer and winter of 2019 as a split-split-plot design. A John Deere 560 M Megawide HC[2] (John Deere Corporation, Moline, IL) was used to produce round alfalfa bales of either first or second cutting, with two farms for each cutting. Bales were produced using vertical knives spaced 4 inches apart between the pickup and the baling chamber (CUT) or with the knives retracted to produce a normal bale (NORM) and each treatment was

applied to alternate bales as the baler moved through the field. Knives were not present on the outer 6 inches of the baler to preserve bale stability. There were 6 bales of each treatment produced on each farm for a total of 48 bales. Time to bale and wrap each bale was recorded. Before bales were moved, 4 diameter measurements were recorded for each end of the bale and 4 length measurements were recorded on each side. The diameter and length measurements were averaged, respectively, to calculate bale volume. Bales were weighed individually and stored uncovered in rows for 5 to 6 months. Bale measurements and weights were recorded again after storage.

Core samples were obtained from each bale at baling and after storage. Ten core samples were obtained randomly from the sides of each bale before and after storage using an 18-inch hay probe. Core samples were split into sections representing the outer 6 inches of the core, and the inner 6 to 18 inches of the core. Core depth sections from 2 bales of the same treatment at each farm were composited into one sample for analysis. All samples were analyzed for chemical composition using near-infrared spectroscopy.

After post-storage core samples and measurements were obtained, bales were subjected to different particle size reduction strategies based upon baling treatment. The NORM bales were ground individually in a tub grinder with a 4- to 6-inch screen and ground hay was deposited directly into a twin-screw mixer wagon (NORM-GRIND; XLRation 2580, Helm Welding Limited, Lucknow, Ontario). Time to grind the entire bale was recorded. The CUT bales were individually placed in the mixer wagon and mixed until the long particles were approximately the same length as the longest particles for NORM-GRIND (approximately 4 inches; CUT-MIX). Time to reduce the particle size to the desired length in the mixer wagon was recorded and the weight was recorded on the wagon scales. After particle size reduction, the wagon was used to deposit each bale in a windrow, and subsamples were obtained for nutrient analysis and particle size distributions.

Data were analyzed with mixed models in JMP (SAS Institute, Cary, NC). Grinding time, grinding shrink, and post-processing factors were analyzed as a completely randomized design. Bale dimensions, weight, density, and post-processing factors were analyzed as a split-plot design, while pre-processing nutrient analysis was analyzed as a split-split-plot design with treatment as the whole plot, storage period as the sub-plot, and core depth as the sub-sub-plot. Significance was declared at $P < 0.05$, and tendencies were declared at $P < 0.10$.

Results
Baling and Storage
The CUT increased bale weight and density compared with NORM ($P < 0.001$), and despite an increase in baling time for CUT because of the greater mass ($P = 0.01$), there was no evidence of a difference for baling rate ($P = 0.74$). A minor, yet significant ($P < 0.001$) increase in bale length for CUT may have been due to increased internal pressure after baling. Using a precutting system on a farm can enhance efficiency by decreasing the number of bales produced and decreasing the space needed for storage. It could also decrease the time spent wrapping bales since fewer bales would be produced overall.

There was no evidence of a difference between treatment for crude protein ($P = 0.31$), but CUT increased neutral detergent fiber (NDF), ADF, and lignin compared with NORM ($P < 0.01$). This increase in fiber content, albeit numerically small, also increased undigestible NDF ($P \leq 0.01$). Considering the lack of difference between treatments for CP content, it is unclear why there was an increase in fiber components, and a resulting decrease in digestibility for CUT. We would anticipate that a loss of leaves due to the pre-cutting process would reduce CP with a concomitant increase in fiber components. The hay in this study was relatively lower quality, so leaf loss may not have been noticeable by evaluating crude protein alone.

There was an interaction between core depth and storage time for ADF and lignin ($P < 0.01$) whereby both variables increased more for the outer portions of the bale over the storage period than for inner portions. Additionally, 240-h NDF digestibility decreased more for outer layers than inner layers over the storage period ($P = 0.001$). The NDF content also decreased over the storage period. These data confirm the effects of bale exposure to the elements during the storage period, where moisture contributes to the deterioration of the outer portions of the hay bale, leaching soluble nutrients and decreasing the fiber digestibility.

Bale Processing

The CUT-MIX combination increased the time to reduce particle size, and the processing rate compared with NORM-GRIND ($P < 0.001$). However, the CUT-MIX decreased the processing shrink for total pounds of DM lost and as a percentage of the total bale weight ($P < 0.001$). The reduced shrink of total DM and as a percent of bale weight for CUT-MIX compared with NORM-GRIND has the potential to save producers significant money. Because of the nature of the study design, it is difficult to determine the effects of the baling treatments vs. the processing treatments individually. However, these combinations are indicative of on-farm scenarios in which this technology can be utilized.

Despite the reduction in shrink for CUT-MIX during processing, it increased NDF, ADF, and lignin content compared with NORM-GRIND ($P < 0.001$), which is the opposite of the anticipated results. This also reduced NDF digestibility and increased undigestible NDF ($P < 0.01$). It is not clear why this occurred, but it may be a factor of the differences in particle size distribution between treatments. The CUT-MIX had more particles on the top screen compared with NORM-GRIND ($P < 0.001$), but the opposite was the case for the shortest particles ($P < 0.001$). The use of tub grinders is much more aggressive, resulting in a finer product. While we cannot separate the effects of the baling treatment and processing method in this study, it appears that the NORM-GRIND created a much finer product that had more flowability and was easier to sample compared with CUT-MIX. We hypothesize that the greater percentage of longer particles for CUT-MIX allowed the finer particles to fall through the windrow matrix when the hay was touched for sampling, thus resulting in the greater particle size on the top screens and increased fiber content overall. The increase in longer particles with CUT-MIX may be advantageous in scenarios where diets with adequate physically effective fiber cannot be achieved.

Conclusions

Producing round alfalfa hay bales using a pre-cutting mechanism increased bale mass and density. The CUT treatment significantly increased the content of NDF, ADF, and lignin compared with NORM, but the magnitude of differences was small. During processing, CUT-MIX decreased DM shrink compared with NORM-GRIND, but it increased fiber content and reduced digestibility of the hay, while altering the particle size distribution. The increase in fiber content after processing may have been influenced by sampling error due to different particle size distribution between treatments. Further work should be conducted to determine the cause of the increased fiber content for CUT bales, and additional options for incorporating CUT bales into total mixed rations should be evaluated.

Table 1. Effects of a pre-cutting hay baler on round alfalfa bale baling efficiency, bale weight, density, dimensions, and shrink over a 5- to 6-month storage period

| | Treatment | | Storage | | | P-value | | |
Item	Cut	Normal	Begin	End	SEM	Trt	Storage	Trt × storage
Baling time, seconds	60	54	-	-	3.7	0.01	-	-
Baling rate, lb DM/min	1,361	1,346	-	-	118.5	0.74	-	-
Bale characteristics								
Weight, lb DM	1,279	1,131	1,253	1,158	43.5	<0.001	<0.001	0.14
Length, in	62.9	62.1	62.5	62.5	0.09	<0.001	0.81	0.34
Diameter, in	64.9	64.9	65.4	64.3	1.71	0.74	<0.001	0.59
Volume, ft^3	121	119	122	118	6.2	0.01	<0.001	0.82
Density, lb DM/ft^3	10.6	9.6	10.3	9.9	0.37	<0.001	<0.001	0.10
Storage shrink, lb DM	108	84	-	-	26.2	0.02	-	-
Storage shrink, %	7.9	7.0	-	-	1.82	0.16	-	-

DM = dry matter. Trt = treatment.

Table 2. Effect of a pre-cutting baler, core depth, and storage timepoint on alfalfa bale chemical composition, quality, and digestibility[1]

| Item[1] | Treatment | | Core depth | | Storage | | SEM | P-value[2] | | | | |
	Cut	Normal	Inner	Outer	Begin	End		Trt	Core	Storage	Core × storage	Trt × storage
Bale DM%	89.5	89.5	89.8	89.3	90.5	88.6	1.36	0.96	0.01	0.02	0.06	0.46
Crude protein, %	18.8	19.0	19.0	18.8	18.9	18.9	1.07	0.31	0.10	0.36	0.98	0.70
ADF, %	38.2	37.6	37.4	38.4	37.0	38.8	0.48	<0.01	<0.001	<0.001	<0.01	0.41
NDF, %	45.4	44.8	44.9	45.4	44.4	45.9	0.81	<0.01	0.06	<0.001	0.64	0.64
NDFom, %	41.9	41.3	41.4	41.7	40.7	42.4	0.95	<0.01	0.25	<0.001	0.71	0.61
Lignin, %	8.7	8.5	8.5	8.7	8.4	8.9	0.10	<0.01	<0.001	<0.001	<0.001	0.47
Ash, %	11.1	10.8	10.9	11.1	11.1	10.9	0.38	0.32	0.18	0.39	0.08	0.77
ADICP, % DM	0.8	0.8	0.8	0.9	0.8	0.9	0.04	0.36	<0.001	<0.001	<0.001	0.02
ADICP, % CP	4.5	4.4	4.3	4.6	4.1	4.8	0.21	0.08	<0.001	<0.001	<0.001	0.05
NDFD-30h, % NDF	41.1	41.6	41.4	41.3	41.4	41.3	0.70	0.08	0.53	0.41	0.69	0.47
NDFD-48h, % NDF	47.7	48.5	48.1	48.1	48.3	47.9	0.57	0.08	0.98	0.50	0.43	0.77
NDFD-120h, % NDF	49.2	50.0	49.8	49.4	49.9	49.3	0.50	0.06	0.30	0.26	0.20	0.98
NDFD-240h, % NDF	51.2	51.5	51.6	51.1	50.7	52.0	0.80	0.10	0.10	0.11	0.001	0.89
uNDF-30h, % DM	26.7	26.2	26.3	26.6	26.0	27.0	0.47	0.01	0.08	<0.001	0.60	0.48
uNDF-120h, % DM	23.1	22.4	22.6	23.0	22.2	23.3	0.51	<0.01	0.10	<0.001	0.28	0.87
uNDF-240h, % DM	22.2	21.7	21.7	22.2	21.3	22.6	0.52	0.01	0.03	<0.001	0.01	0.76
TTNDFD, % NDF	31.7	32.3	32.8	31.3	33.5	30.6	0.94	0.08	<0.001	<0.001	<0.001	0.49
RFV	121	124	124	121	126	119	3.0	<0.01	0.01	<0.001	0.18	0.57
RFQ	112	117	115	114	118	111	3.2	0.02	0.27	0.001	0.55	0.70

[1]Determined by near-infrared spectroscopy (Rock River Laboratory, Inc., Watertown, WI).
[2]Interactions for treatment × core and the three-way interaction of main effects all lacked significance and are not reported in this table.
DM = dry matter. Trt = treatment. ADF = acid detergent fiber. NDF = neutral detergent fiber. NDFom = neutral detergent fiber as a % of organic matter. ADICP = acid detergent insoluble crude protein.
NDFD = NDF digestibility. uNDFD = undigestible NDF. TTNDFD = total track NDF digestibility. RFV = relative feed value. RFQ = relative forage quality.

Table 3. Effect of the combination of baling and processing methods (CUT-MIX vs. NORM-GRIND) on the chemical composition and particle size distribution of alfalfa hay

Item	Treatment		SEM	*P*-value
	CUT-MIX	NORM-GRIND		
DM, %	91.5	91.1	0.36	0.06
CP, %	19.1	19.6	1.26	0.06
ADF, %	41.5	40.3	0.57	<0.001
NDF, %	48.6	47.0	0.96	<0.001
NDFom, %	45.1	43.3	1.05	<0.001
Lignin, %	9.9	9.4	0.14	<0.001
Ash, %	11.1	11.0	0.38	0.93
ADICP, % DM	1.2	1.1	0.05	<0.01
ADICP, % CP	6.3	5.9	0.39	<0.001
NDFD-30h, % NDF	39.7	41.1	0.92	<0.001
NDFD-48h, % NDF	44.6	47.0	0.62	<0.001
NDFD-120h, % NDF	46.9	48.7	0.98	0.001
NDFD-240h, % NDF	49.0	50.8	1.30	<0.01
uNDF-30h, % DM	29.3	27.7	0.49	<0.001
uNDF-120h, % DM	25.8	24.1	0.93	<0.001
uNDF-240h, % DM	24.8	23.2	1.08	<0.001
TTNDFD, % NDF	28.7	29.7	0.94	0.03
RFV	109	114	3.0	<0.001
RFQ	95	105	3.3	<0.001
Processing time, min/bale	11.0	3.6	1.53	<0.001
Processing rate, lb DM/min	121	408	79.1	<0.001
Processing shrink, lb DM[3]	20.1	73.2	6.24	<0.001
Processing shrink, % DM[3]	1.6	8.1	0.95	<0.001
Particle size[2]				
Screen 1, % total DM	35.1	13.7	1.58	<0.001
Screen 2, % total DM	20.3	19.6	1.14	0.04
Screen 3, % total DM	13.3	16.6	0.65	<0.001
Pan, % total DM	31.2	49.9	1.82	<0.001

[1]Determined by near-infrared spectroscopy (Rock River Laboratory, Inc., Watertown, WI).
[2]Screen sizes were 19 mm, 8 mm, and 4 mm, respectively.
[3]Does not include data from one farm due to issues with operating the tub grinder.
CUT-MIX = precutting during baling followed by mixer wagon processing. NORM-GRIND = no precutting during baling followed by tub grinder processing. DM = dry matter. CP = crude protein. ADF = acid detergent fiber. NDF = neutral detergent fiber. NDFom = neutral detergent fiber as a % of organic matter. ADICP = acid detergent insoluble crude protein. NDFD = NDF digestibility. uNDFD = undigestible NDF. TTNDFD = total track NDF digestibility. RFV = relative feed value. RFQ = relative forage quality.