ABSTRACT

Large round bales of hay stored uncovered outdoors can result in changes in forage quality and mold growth which can influence dry matter intake (DMI) by livestock. The objective of this study was to evaluate hay waste and cattle preference of large round bales wrapped with plastic twine, net wrap, and B-Wrap after long-term, outdoor storage. Large round bales of alfalfa (Medicago sativa L) hay (n=24) were stored outdoors for 15 months in plastic twine, net wrap, and B-Wrap. After the storage period, round bales were fed in a switchback design to 18 Angus cow-calf pairs. Pairs had ad libitum access to three round bales, one of each wrap-type, in individual feeders for 48-hour periods (n=8 periods). Feeders were weighed and waste surround feeders was collected at 24 and 48 h to calculate DMI. Alfalfa cultivar did not affect forage quality ($P > 0.05$). The concentrations of crude protein (CP), acid detergent lignin (ADL), acid detergent fiber (ADF), and neutral detergent fiber digestibility (NDFD48) were similar across wrap types ($P > 0.05$). However, neutral detergent fiber (NDF) was different ($P = 0.03$) between twine (49%) and B-Wrap (46%). Mold counts differed between wrap-types ($P < 0.0001$). Twine and net wrap bales had the highest mold count at $7.1 \times 10^6$ and $4.7 \times 10^6$ CFU/g,
respectively, while B-Wrap had lower counts at $4.8 \times 10^4$ CFU/g. Total DMI, and DMI during the first 24 hours, were greater in B-Wrap bales compared to twine wrapped bales indicating the cattle preferred hay wrapped in B-Wrap. These results confirm wrap-type influenced forage quality and mold counts in outdoor stored hay, which in turn impacted cattle preference at the time of feeding.

INTRODUCTION

Large round bales are a common way to harvest, store and feed livestock hay throughout the United States. However, the quality of large round bales is known to deteriorate during outdoor storage. This deterioration is mostly concentrated to the outer layer which is most exposed to weather (Belyea et al., 1985; Russel et al., 1990; Collins et al., 1987; Shinners et al., 2009 and 2013). Specifically, moisture from rainfall and snow can result in the loss of soluble nutrients, the subsequent concentration of insoluble plant fibers, the growth of mold, and repugnant odors (Russel et al., 1990; Collins et al., 1987; Scudamore et al., 1998; Shinners et al., 2009). These factors can reduce livestock dry matter intake (DMI) and result in feeding losses (Belyea et al., 1985; Russell et al., 1990; Undi et al., 1996).

Several storage methods have been studied to determine their impact on DMI and associated livestock feeding losses. Belyea et al. (1985) determined round bales stored outdoors and covered had less storage and feeding losses compared to bales stored outdoors uncovered. Cattle wasted 12% to 15% of covered round bales compared to 25% of uncovered round bales (Belyea et al., 1985). Additionally, Russell et al. (1990) found that outdoor stored round bales wrapped in net wrap resulted in 16% to 25% greater DMI by sheep compared to round bales wrapped with twine. More recently, Shinners et al. (2013) evaluated cattle preference after round
bales were stored in different wrap-types, processed, and fed in bunkers. They found that shredded round bales wrapped with B-Wrap were preferred over net wrapped bales stored outdoors without cover and had equal preference to net wrapped bales stored indoors (Shinners et al., 2013). However, research is needed to evaluate hay waste and cattle preference when feeding unprocessed, or whole, large round bales harvested and wrapped with different wrap-types. Therefore, the objectives of this research were to determine hay waste and cattle preference of large round bales wrapped with plastic twine, net wrap, and B-Wrap after long-term, outdoor storage.

**MATERIALS AND METHODS**

Round bales used in the current study were previously utilized in a research trial investigating the effect of wrap-type on dry matter (DM) loss and forage quality of round bales in outdoor storage (Reiter et al., 2019). After treatment difference were confirmed during the storage period, round bales were transported to the Rosemount Research and Outreach Center in Rosemount, MN. Starting on 3 October, 2018 round bales were fed to cattle to determine the effect of wrap-type on cattle preference and hay waste.

Immediately prior to feeding, round bales were weighed using axel weigh pads (Locosc, Ningbo, China) and cored four times with a 47-cm hay probe (Penn State Forage Sampler, University Park, PA) to determine dry matter (DM), forage quality, and mold and yeast counts. Hay core samples were dried in a forced-air oven at 60°C for 48 h to determine DM. Samples were then ground through a 6-mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ) followed by a 1-mm screen in a Cyclotec (Foss, Eden Prairie, MN). Ground samples were mixed thoroughly, and subsamples were analyzed using near infrared reflectance spectroscopy (NIRS)
to determine crude protein (CP), ether extract, crude fiber, ash, and NFE (Dairy One, Ithaca, NY). Additionally, samples were scanned using NIRS (Model DA 7200; Perten Instruments, Springfield, IL) with calibration equations developed in Minnesota to estimate CP, NDF, ADF, NDFD48, and ADL. Hay core subsamples to determine mold counts were analysis by a commercial lab (DHIA Laboratories, Sauk Centre, MN).

All experimental procedures were conducted according to those approved by the University of Minnesota Committee on Animal Use and Care (1808-36268A). Eighteen Angus cow-calf pairs were housed in a 24 × 34 m cement pen, which included a 10 × 34 m covered area. Calves were approximately 33 ± 11 days old at the initiation of the trial. Throughout the trial, the pairs had ad libitum access to water and loose mineral (Rain and Wind All Season, Purina, St. Louis, MO). Individual cow bodyweight (BW) and body condition score (BCS; Spitzer, 1986) were recorded at the start and conclusion of the 17-day trial. Round bales were fed in a switchback design where periods were blocked by alfalfa cultivar. Bales were rotated in a repeating Latin square design so that the wrap-type locations were not repeated in consecutive periods. Bales were individually fed in 2.4 ×1.1 m skirted round bale feeders (Priefert, Mount Pleasant, TX). All feeders were retrofitted with a welded bottom plate to facilitate moving and weighing the bales once fed. Feeders were placed approximately 6.7 m apart in the covered area of the pen and cattle were allowed ad libitum access to all feeders. For each 48-hour period (n=8), three round bales, one from each wrap type within an alfalfa cultivar, were fed. At hours 24 and 48, the entire feeder was weighed using axel weigh pads (Locosc, Ningbo, China) to determine DMI. No other feedstuffs were offered during the 17-day trial; however, a bedding pack of chopped straw was maintained in the uncovered section of the pen.
Each day, hay waste was collected from the perimeter of the feeders. Hay waste was defined as hay on the ground outside of the feeders. After hay waste was removed, the area around each feeder was scraped clean by hand then power swept using a skid loader broom attachment (SE Series Hopper Broom, Spartan Equipment, Joppa, MD) to minimize contamination with manure, although contamination was inevitable. Therefore, contaminate hay waste was rinsed with water to remove manure before drying. All hay waste was dried in a forced-air oven at 60°C until a constant weight was achieved to determine DM. After 48 hours, hay remaining in the feeders (orts) was removed, and new bales were fed. Percent hay waste was calculated as the total amount of daily hay waste divided by the amount of hay fed, minus orts (Martinson et al., 2012). Dry matter intake was calculated as the amount of hay fed, minus orts and total hay waste, and was used to determine preference.

Forage quality, DMI and hay waste data were analyzed using the MIXED procedure of SAS (version 9.4; SAS Institute Inc., Cary, NC). Individual bales were the experimental unit, and statistical significance was set at $P \leq 0.05$. Forage quality response variables included bale moisture content, CP, NDF, ADF, ADL, NDFD48, and mold counts. Mold counts were log transformed to meet analysis of variance assumptions; data were back transformed for presentation. Forage quality response variable models included alfalfa cultivar, wrap-type, period, and alfalfa cultivar $\times$ wrap-type interaction as fixed effects, while bale replicate was included as a random effect. The model for response variables hay waste and DMI included wrap-type, feeder placement, and period as fixed effects at each collection time, 24 and 48 h. For categorical effects (e.g. wrap-type), means separations were performed on significant effects using Tukey’s HSD test. To assess the relationship between DMI and forage quality, partial Pearson correlation coefficients were calculated between DMI and the forage quality for mold.
counts using the REG procedure of SAS (version 9.4; SAS Institute Inc., Cary, NC). Changes in animal BW and BCS over the experimental period were evaluated using a two sample t-test using PROC TTEST in SAS (version 9.4; SAS Institute Inc., Cary, NC).

RESULTS AND DISCUSSION

Forage Quality

Alfalfa cultivar did not affect forage quality ($P > 0.05$). With the exception of ADL and NDFD48, these results were anticipated as others have found similarities in CP, NDF, and ADF between reduced-lignin and conventional alfalfa cultivars (Getachew et al., 2011; Li et al., 2015; Grev et al., 2017; Peterson et al., 2018). Although other researchers have found differences in ADL and NDFD48 between reduced-lignin and conventional alfalfa cultivars at harvest (Mertens and McCaslin, 2008; Weakley et al., 2008; Undersander et al., 2009; Li et al., 2015; Grev et al., 2017), no one has investigated whole bale differences between cultivars after long-term, outdoor storage. These results suggest that forage quality differences observed between reduced-lignin and conventional alfalfa at harvest may be lost after long-term outdoor storage.

The concentrations of CP, ADL, ADF, and NDFD48 were similar across wrap types ($P > 0.05$; Table 1). However, NDF was different between the wrap-types ($P = 0.03$). Neutral detergent fiber was greatest in bales wrapped in twine (49%) compared to B-Wrap (46%), while net wrap intermediary (48%; Table 1). These results agree with previous work that showed NDF values tend to be higher, or more concentrated, in twine and net wrap bales compared to B-Wrap after storage outdoors (Shinners et al., 2013; Reiter et al., 2019). Shinners et al. (2013) found an 8% increase in NDF in net wrapped bales compared to B-Wrap, while Reiter et al. (2019) found a 16% to 23% increase in NDF in net and twine wrapped bales. Forage quality of storage hay is
important, as elevated NDF concentrations can limit DMI in cattle due to decreased palatability and increased rumen fill (Dado and Allen, 1995).

*Mold Counts*

Mold counts differed between wrap-types ($P < 0.0001$). Twine and net wrap bales had the highest mold count at $7.1 \times 10^6$ and $4.7 \times 10^6$ CFU/g, respectively, while B-Wrap had lower counts at $4.8 \times 10^4$ CFU/g (Table 1). Several researchers have reported visual observations of mold growth in round bales stored outside; however, this is the first study to quantify the impact of wrap-type on mold quantity (Russell et al., 1990; Harrigan and Rotz, 1994; Shinners et al., 2009; 2010). Current recommendations for the maximum inclusion of mold in livestock rations indicate values of $< 5 \times 10^5$ CFU/g being considered safe, $5 \times 10^5$ to $1 \times 10^6$ CFU/g being relatively safe, $> 1 \times 10^6$ CFU/g should be fed with caution, and $> 5 \times 10^6$ CFU/g should not be fed to livestock (Adams et al., 1993). According to these recommendations, hay wrapped in B-Wrap and stored outdoors for 15 months was considered safe to feed livestock, hay wrapped in net wrap should have been fed with caution, and hay wrapped in twine wrap bales should not have been fed. However, no illnesses or adverse health issues were observed in cow-calf pairs throughout the experimental period.

*Cow Bodyweight and Body Condition*

Cow BW and BCS did not differ throughout the trial ($P \geq 0.20$). On average, cows weighed $692 \pm 46$ kg at the start of the experiment (3 October 2018) and weighed $711 \pm 46$ kg 17 days later when the trial ended. Average cow BCS (Spitzer, 1986) was $6.4 \pm 0.3$ at the start of the trial and $6.7 \pm 0.4$ at the conclusion.

*Hay Waste, Dry Matter Intake and Cattle Preference*
There were no differences in hay waste collected at 24 hours, 48 hours, or total hay waste between the wrap-types \((P = 0.55)\). Mean total hay waste was 2.2, 2.5 and 2.9% in twine, net wrap and B-Wrap. Wrap-type affected DMI during the first 24 hours and total DMI \((P = 0.02; P = 0.03\), respectively\), but not after 48-hours \((P = 0.22; Table 2)\). During these times, cows consumed more hay from B-Wrap bales compared to twine bales. Net wrapped bales were always similar to the other wrap-types. These results agree with previous findings of greater DMI of bales stored in breathable films similar to B-Wrap (Shinner et al., 2013). However, Shinner et al. (2013) also observed differences in cattle DMI between hay stored outdoors, wrapped in breathable films and net wrap bales, then processed and fed to cattle. The absence of differences in DMI after 48 hours is likely a result of cows consuming a majority of the hay they preferred in the first 24-hours, then consuming the remaining hay more equally.

**CONCLUSION**

After 15 months in outdoor storage, B-Wrap bales had lower amounts of NDF and mold compared to twine tied bales. Total DMI, and DMI during the first 24 hours, were greater in B-Wrap bales compared to twine tied bales indicating the cattle preferred hay wrapped in B-Wrap. Net wrapped bales resulted in similar forage quality and DMI to both B-Wrap and twine wrapped bales. These results confirm wrap-type influenced forage quality and mold counts in outdoor stored hay, which in turn impacted cattle preference at the time of feeding. These results will help producers make research-based decision related to harvesting, storing, and feeding hay to beef cattle.
ACKNOWLEDGEMENTS

This project was funded in part by Midwest Forage Association, John Deere, and Tama Inc.

LITERATURE CITED


Table 1. Forage quality and mold counts of alfalfa hay stored outdoors for 15 months and wrapped in twine, net, or B-Wrap.

<table>
<thead>
<tr>
<th></th>
<th>Wrap-Type</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Twine</td>
<td>Net</td>
<td>B-Wrap</td>
<td>SEM</td>
<td></td>
</tr>
<tr>
<td>CP (% DM)</td>
<td>14.5</td>
<td>14.7</td>
<td>14.8</td>
<td>0.3</td>
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<tr>
<td>NDF (% DM)</td>
<td>49.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>47.8&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>46.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>ADF (% DM)</td>
<td>33.5</td>
<td>32.4</td>
<td>31.2</td>
<td>0.7</td>
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<tr>
<td>ADL (% DM)</td>
<td>6.0</td>
<td>6.0</td>
<td>6.4</td>
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<td>NDFD48 (% NDF)</td>
<td>44.8</td>
<td>46.4</td>
<td>46.9</td>
<td>0.8</td>
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<tr>
<td>Mold count (CFU/g)</td>
<td>7.1 x 10&lt;sup&gt;6&lt;/sup&gt; a</td>
<td>4.7 x 10&lt;sup&gt;6&lt;/sup&gt; a</td>
<td>4.8 x 10&lt;sup&gt;4&lt;/sup&gt; b</td>
<td>0.8</td>
<td></td>
</tr>
</tbody>
</table>

<sup>ab</sup> Means within quality parameter without common superscripts differ (<i>P</i> < 0.05)
Table 2. Dry matter intake (DMI, kg) of alfalfa hay stored outdoors for 15 months, wrapped in twine, net or B-Wrap and fed to 18 lactating Angus cows.

<table>
<thead>
<tr>
<th>Wrap-type</th>
<th>24 hr</th>
<th>48 hr</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twine</td>
<td>4.2\textsuperscript{a}</td>
<td>6.4</td>
<td>10.7\textsuperscript{a}</td>
</tr>
<tr>
<td>Net Wrap</td>
<td>5.8\textsuperscript{ab}</td>
<td>5.5</td>
<td>11.4\textsuperscript{ab}</td>
</tr>
<tr>
<td>B-Wrap</td>
<td>7.9\textsuperscript{b}</td>
<td>5.5</td>
<td>13.4\textsuperscript{b}</td>
</tr>
</tbody>
</table>

\textit{ab} Means within a column without common superscripts differ ($P < 0.05$)

DMI

\begin{tabular}{lccc}
\hline
Wrap-type & 24 hr & 48 hr & Total \\
\hline
Twine & 4.2\textsuperscript{a} & 6.4 & 10.7\textsuperscript{a} \\
Net Wrap & 5.8\textsuperscript{ab} & 5.5 & 11.4\textsuperscript{ab} \\
B-Wrap & 7.9\textsuperscript{b} & 5.5 & 13.4\textsuperscript{b} \\
SEM & 0.81 & 0.40 & 0.64 \\
\hline
\end{tabular}