Assessing the degradability of a soybean hull-based baling twine

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Incorporating soybean hulls into twine increased ruminal degradability compared to traditional plastic twine, with higher soyhull content leading to greater breakdown. While soyhull-incorporated twine is not as degradable as sisal twine, results highlight the potential for developing safer baling material for livestock.

Summary

This study investigates the ruminal digestibility of a newly developing twine made with polylactic acid and soybean hulls as a safer alternative to conventional polypropylene twine. Using in-situ rumen incubation in cannulated Jersey steers, results showed higher degradation in the rumen with greater inclusion of soybean hulls. Traditional plastic twine showed no breakdown, indicating its resistance to digestion. These findings suggest that incorporating agricultural byproducts like soybean hulls into baling materials may reduce health risks to cattle.

Introduction

The use of baling twine in the livestock industry for forage management is a common practice. Conventional twine materials often contain synthetic plastics, like polypropylene, due to their durability. These materials can pose risks to animal health and the environment. Twine that is not properly disposed of can be ingested by cattle, resulting in gastrointestinal blockages, reduced feed intake and, in severe cases, death.

In response to these issues, there is a growing interest in developing alternative twine materials that can both maintain bale storage and be safer for livestock if ingested. Agricultural byproducts, such as soybean hulls, may offer a solution for biodegradable and digestible materials that could be used in twine. Soybean hulls are rich in highly digestible neutral detergent fiber (NDF) and are already a feedstuff that can be utilized in cattle diets (Lyu et al., 2022).

The objective of this study was to evaluate the digestibility of a newly formulated soybean hull-based twine when ingested by cattle. This work aims to provide preliminary insights into incorporating plant-based materials into baling products that reduce health risks and environmental impacts while maintaining practical functionality on the farm.

Procedures

The experimental procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee (IACUC#A21018). Two mature, cannulated Jersey steers were used to conduct an in-situ experiment. The steers were housed individually and fed a grass hay diet.

Experimental twine material was made of a biodegradable polylactic acid (PLA) polymer, which is produced from corn starch, with 0%, 10%, 20% and 30% soyhulls (SH) by weight (SH-0, SH-10, SH-20 and SH-30). Twine samples were produced through an extrusion process of a uniform blend of SH powder with PLA and a small amount of compatibilizer, a chemical agent added to enhance bonding between SH and PLA.

Each PLA/SH combination, a positive control (alfalfa), a negative control (commercial polypropylene twine) and an alternative product (sisal twine), was incubated ruminally in each steer. Twine samples were prepared by cutting materials into 5-gram portions. Alfalfa was ground through a 2-mm screen. Approximately 5 g of each sample, in triplicate, were sealed in in-situ bags (10 × 20 cm, Ankom Technology, Macedon, NY) using a heat sealer for each time point. Each time point also included triplicate blank bags. All samples were placed in mesh laundry bags, each containing the full set of incubation treatments for one time point. The mesh laundry bags were presoaked in water for 20 minutes and allowed to drip dry prior to insertion into the rumen. A large rock was placed in each bag to anchor it at the bottom of the rumen below the hay mat.

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Samples were incubated for 0, 24, 72, 120 and 168 hours (0, 1, 3, 5 and 7 days), placed in reverse order to allow for all bags to be pulled simultaneously. After incubation, each mesh laundry bag was rinsed carefully in a bucket to remove large particulate matter from the outside of the bags. The heat-sealed in-situ bags were then removed from the mesh bag and washed in a portable washing machine. All samples were agitated for 1 minute, drained and spun for 2 minutes; this cycle repeated five times. Each time point was washed separately due to limited space in the machine. Bags were then dried in a forced-air oven at 55 degrees Celsius for 48 hours, placed in a plastic bag and transferred to a desiccator. Once removed, samples were allowed to equilibrate to room conditions for at least 3 hours before recording equilibrated dry weights. Disappearance was calculated as loss in sample weight divided by initial sample weight using triplicate incubations. Final bag weights containing samples were corrected for changes in weight of empty incubated bags.

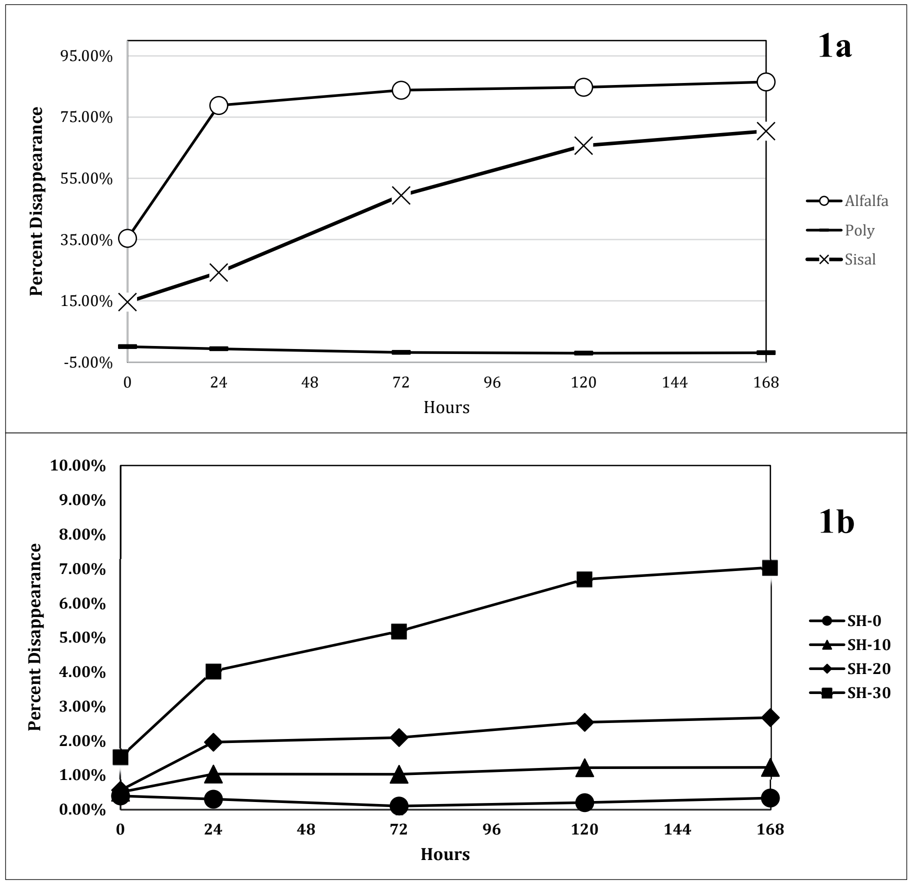

Figure 1. Comparison of degradation rates of alfalfa, sisal twine, commercial polypropylene twine (Poly) (1a) and comparing PLA/soyhull twine degradation rate (1b).

$$Disappearance = \frac{W_{initial} - (W_{incubated} - (W_{bag} - Blank\ correction))}{W_{initial}}$$

Results and Discussion

Alfalfa exhibited rapid degradation, with disappearance exceeding 80% by 72 hours and plateauing near 90% (Figure 1a). The fast rate of degradation reflects alfalfa's rich content of rumen-fermentable nutrients such as NDF, which are readily available to ruminal microbes (Van Soest, 1994). Sisal twine, which contains plant-based fibers, also demonstrated significant degradation, increasing steadily over time and reaching nearly 70% disappearance at 168 hours. The upward trend in disappearance suggests that sisal is able to be digested in the rumen environment. In contrast, the commercial polypropylene (Poly) was undegraded across all time points, with values near zero degradation, showing its resistance to microbial breakdown. This result is as expected due to its resistance to degradation (Shah et al., 2008).

Across all time points, SH-30 showed the greatest disappearance of PLA twines, reaching approximately 7% by 168 hours (Figure 1b). Lower SH levels resulted in less degradability, while SH-0 (no soyhulls) showed minimal degradation, similar to the Poly. These results indicate that incorporating SH into twine could enhance the breakdown of material by ruminal microbes due to the presence of plant-derived organic matter. Although the PLA/SH composites had greater degradation than Poly, degradability was less than that of the sisal twine, suggesting that further formulations could be developed to improve degradation of the SH twine in the cattle digestive tract.

Degradation rate and half-life provide more insights into how the PLA/SH twine breaks down in the rumen (Figure 2). The degradation rate increases nonlinearly with increasing soyhull content. SH-0, representing pure PLA twine, did not degrade, while SH-30 had the fastest rate at approximately 0.06%/hour; this is still slow compared to alfalfa (8.60%/hour) and sisal (0.88%/hour), indicating higher microbial activity and availability. The estimated half-life of the degradable fraction (the amount of

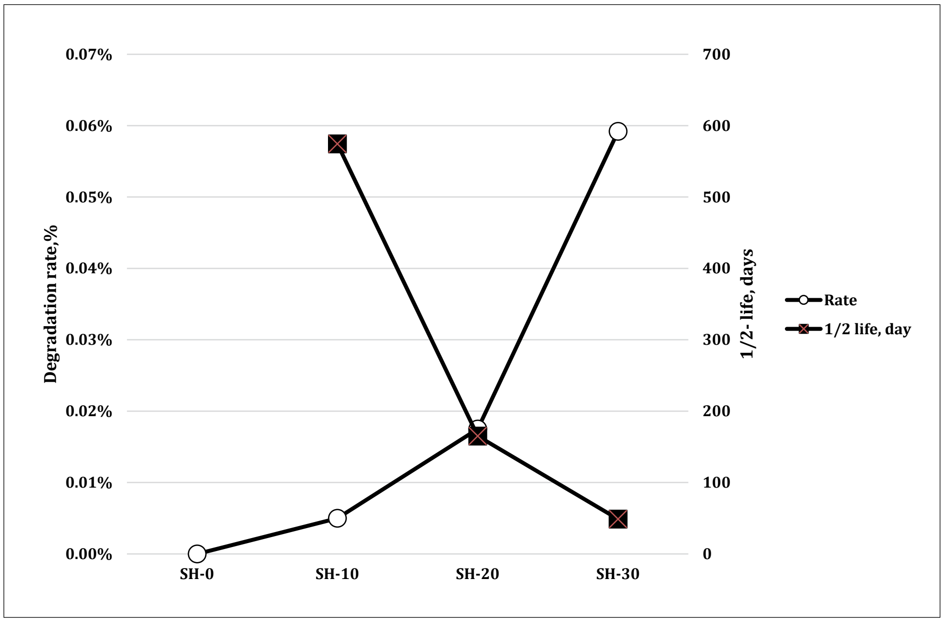

Figure 2. Ruminal degradation rate. Effect of soyhull content on the disappearance rate (%) of PLA-based twine materials in rumen incubation. A nonlinear increase in disappearance rate was observed as soyhull content increased with SH percentage.

time it takes for half of the material to degrade) decreased with increasing SH content but was still quite long. SH-10 had a half-life exceeding 575 days, while the half-life of SH-30 dropped to below 49 days. These findings suggest that the structural and nutritional contribution of SH within the PLA twine can improve overall disappearance and increase degradation efficiency.

Acknowledgments

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