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Influence of particle size and packaging on storage dry matter losses for switchgrass

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ARTICLE INFO

Article history:
Received 21 July 2014
Received in revised form
24 November 2014
Accepted 12 December 2014
Available online 7 January 2015

Keywords:
Dry matter loss
Lignocellulosic biomass
Packaging
Particle size
Storage
Switchgrass

ABSTRACT

The objective of this study was to estimate the storage dry matter (DM) losses for switchgrass bales that were preprocessed using an industrial baler technology prior to storage with three particles sizes of feedstock and two types of bale wraps. Mixed models were used to test difference in DM losses across the particle sizes, wrap materials, and storage days. Response functions were also estimated to determine DM losses for each particle size and wrap material at storage over time. DM losses were found to be different across particle size, wrap material, and storage period. Specifically, the DM losses were lower when the particle size of switchgrass baled decreased from full length to less than two centimeters. The results show switchgrass bales stored at the smallest particle size had lower DM losses than bales stored at the full length of feedstock. Also, applying additional film wrap that completely covers the net wrapped bale reduced DM losses relative to bales wrapped only in net. Furthermore, storage DM losses of preprocessed switchgrass bales increased linearly with days in storage. Our findings suggest that applying both net and film wrap to switchgrass bales composed by a particle size less than two centimeters can reduce DM losses during storage. Economic analysis indicates the price of switchgrass was also important in the choice of storage method for switchgrass. The results provide valuable insight into improving feedstock logistics and the feasibility of the advanced biofuels industry.

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http://dx.doi.org/10.1016/j.biombioe.2014.12.009
0961-9534/

1. Introduction

Development of an advanced biofuel industry is a major focus of United States energy policy. The Renewable Fuel Standard under the Energy Independence and Security Act of 2007 mandated 136 billion L yr^{-1} of biofuels to be available by 2022, with 79 billion L yr^{-1} from lignocellulosic biomass (LCB) [1]. LCB energy crops are an important component of the mandate given concerns about the effects of the corn ethanol industry on the environment [2,3], agroecosystems [4], and food prices [5–7]. Moreover, LCB production is anticipated to promote growth and diversification of rural economies [8,9]. However, several technical barriers related to the logistics of LCB feedstock directly impact storage and delivery costs and are important factors impeding the commercialization of the LCB industry in the United States [10,11]. The development of innovative technologies designed to improve the efficiency of collection, storage, and transportation of LCB feedstock and thereby reducing feedstock cost has gained much attention in the literature [12].

An important factor influencing the cost of feedstock LCB feedstock delivered to a conversion facility is dry matter (DM) losses during storage [13]. After feedstock is stored, DM losses may cause substantial reductions in both feedstock quantity and quality, which decreases efficiency of LCB storage and increases feedstock cost for conversion facilities [14–21]. Increased LCB feedstock production to offset storage losses could increase greenhouse gas emissions in LCB feedstock supply chain [22]. Thus, assessing storage DM losses of LCB feedstock processed by alternative and/or innovative technologies in feedstock logistics system is important. Such knowledge is relevant in improving efficiency of the LCB feedstock logistics and reducing the cost of producing LCB biofuels.

Larson et al. [23] evaluated the feasibility of using a new commercial stretch-wrap baler, BaleTech 3 (BT3), to compact chopped switchgrass (*Panicum Virgatum* L.) into a large round bale for outdoor storage. The large round bale has similar dimensions to an agricultural round bale but with potentially lower dry matter losses during storage. The bale is wrapped in two layers of a proprietary high strength mesh net and two layers of a proprietary high tensile strength stretch film that completely sealed the bale. The film around the bales is virtually impervious to UV rays, which allowing bales to be stored in outdoor for extended periods of time. The technology has the potential to provide an anaerobic storage environment that can mitigate DM losses during storage [23]. The findings in Larson et al. [23] suggest that BT3 could be a lower cost alternative for the harvest, storage, and transport of LCB using large round bale or large rectangular bale hay technologies. While Larson et al. [23] provided insight into the economics of potentially improving efficiency of LCB feedstock collection and handling with BT3, their study did not use moisture content or DM data of switchgrass bales processed with BT3 to evaluate the feasibility of the technology.

Further research on the impacts of new storage technologies such as BT3 on storage DM losses is needed. Also, analysis on the cost of the storage technology that compares the value of the feedstock saved by reducing DM losses with the costs of protection provided by the technology is important to the industries utilizing the LCB. This research particularly focused on the relationship between the storage DM losses of LCB and two factors in the BT3 storage technology: i) particle size of feedstock and ii) bale wrap method. Chaoui and Eckhoff [24] hypothesized that particle size of feedstock in storage may influence the level of storage DM losses. They posited that larger particle sizes were more desirable for outdoor storage than smaller particle sizes because the smaller particle sizes were more likely to be eroded due to wind or rain. Currently, there is a lack of empirical studies that evaluate the effects of particle size on storage DM losses for LCB feedstock. In addition, the aerobic and anaerobic storage environment resulting from different packaging/wrap materials affects DM losses during storage [25,26]. Anaerobic storage of LCB may reduce storage DM losses relative to aerobic storage methods but may be more costly to implement. The optimal storage method for LCB feedstock considering particle size and storage wrap (e.g., aerobic or anaerobic) should consider the trade-offs in the value of foregone storage DM losses with more protection and the cost of protective inputs [15].

Thus, the two objectives of this study were: 1) to evaluate the influence of particle size of feedstock and bale wrap on storage DM losses for switchgrass that was preprocessed using the BT3 technology prior to storage, and 2) to assess the trade-offs in the value of foregone storage DM losses with more protection and the cost of the protective wrap provided by the BT3 technology. Our data were collected from a 225-day storage experiment conducted in Tennessee USA where switchgrass is considered to be a primary candidate for LCB production [27]. The results will help improve efficiency and reduce costs for the bioenergy processors in the Southeast.

2. Literature review

Studies on large round and rectangular hay bale technologies have shed light on the outdoor storage losses of LCB feedstock. First, Sanderson et al. [20] ascribed disparities in storage losses between two studies conducted in different time periods, but at similar locations, as being due to differences in weather. LCB exposure to variations in temperature and humidity, precipitation, and ultraviolet rays during storage increased losses during storage.

Second, bale shape (large rectangular versus large round) and wrapping method of the bale during storage has been shown to influence storage losses. For example, large twine-wrapped round bales have lower losses than large twine-wrapped rectangular bales [14,15,17]. This is likely because the circular shape facilitates the shedding of water away from bales. Mesh-wrapped large round bales had lower DM losses than twine-wrapped large round bales [21]. Mesh-wrapped bales may have a more uniform shape during storage, which may explain the lower DM losses [22]. Although a large rectangular bale has the potential for higher outdoor storage losses, its larger throughput capacity and a more desirable shape