

Industrial harvesting of corn stover as a biomass feedstock

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Introduction

Harvesting corn stover as a biomass feedstock is a growing practice within the Midwest US. Corn stover harvesting generally occurs soon after corn grain harvest is complete and ahead of fall tillage or fertilization. Corn stover is generally baled to create high density packages that can be transported efficiently. Both round bales and square bales can be formed depending on the end use. Round bales are generally more suitable for lower volume uses like animal bedding while large square bales are preferred for industrial uses like cellulosic biofuels.

This report provides an overview of the basic machinery systems used in corn stover production. While applicable to any end use of corn stover, this report is specifically aimed at industrial corn stover production which will supply cellulosic biorefineries.

Windrowing

Windrowing involves collecting corn stover into concentrated strips in a field to facilitate collection by a baler. Three primary methods exist to windrow corn stover; combine windrow, rake, and stalk chopping windrower.

Combine windrowing is achieved by disengaging the spreaders on the back of a combine and allowing the material other than grain (MOG) to drop directly onto the ground behind the combine. This creates a concentrated windrow directly behind the combine at the time of grain harvest. In typical corn production this will produce a windrow with approximately 0.75 ton/acre of material.

Two types of rakes provide viable windrowing options in corn stover. Bar rakes use rotating parallel bars with mounted teeth to convey material into a center windrow (Figure 1). Wheel rakes use rotating wheels with attached teeth to sweep corn stover into a center windrow as well. Both can be optionally configured to be hydraulically powered which give the operator more control over the speed and flow of material across the rake.

The corn stover harvest rate can be controlled by changing the height of the rake off the ground. Rakes will generally produce corn stover windrows between 1.25 – 2 tons/acre under normal operations. Care should be taken to ensure that the rake teeth never touch the ground and maintain appropriate clearance off the ground in order to minimize the amount of soil contamination that is entrained in the windrow.



Figure 1. Hydraulically powered bar rake forming a corn stover windrow.

Windrowing stalk choppers use a series of rotating knives to chop or shred corn stalks. Stalk choppers are commonly used in many areas of the corn belt to help break down stalk material particularly in continuous corn production. The windrowing stalk chopper is modified to include an auger along the rear of the windrower which conveys shredded material to a central discharge area (Figure 2). Depending on the model, the windrow discharge

may be located at the center or the end of the stalk chopper.

Like rakes, the harvest yield from stalk choppers can be adjusted by changing the clearance between the chopping knives and the ground. Because the stalk choppers have less opportunity to engage the soil, the soil contamination or ash level of corn stover produced with a stalk chopper is generally less than with a raked windrow.



Figure 2. Side discharge windrowing stalk chopper forming a corn stover windrow.

Baling

Balers are used to convert loose corn stover windrows into densified packages that can be transported throughout the supply chain. Round balers and large square balers can be used, although industrial corn stover production favors large square balers because of their higher productivity level and the handling advantages of large square bales over round bales.

Round balers are common throughout the majority of the Midwestern US. The dimensions of round bales vary based on the specific equipment model used, but for corn stover production round bales generally are 5 feet wide and have diameters ranging from 5.5 – 6 feet. Round balers can require up to 75 PTO horsepower. For adequate drawbar power and to maximize the productivity of the baler it is recommended that a tractor with 120+ horsepower be used for industrial baling operations. High density round balers with chopping pretreatment can achieve bale densities of 10 lb/ft³.

Large square balers are less common across the grain belt, but are widely used in regions of the US that are active in commercial forage production (Figure 3). Large square bales offer advantages in their stacking and transportation characteristics which make them the preferred baling platform for high volume applications. Three models of large square balers are available. The most common model produces a 3 ft by 4 ft bale cross section. The length of the bale is controlled by the operator although the industry standard length is 8 ft. Two other models which produce a 3 ft by 3 ft and a 4 ft by 4 ft cross section bale are also available. For most industrial applications, the 3 ft by 4 ft baler is preferred because it can achieve higher bale densities and the bales can be legally stacked three high on a semi-trailer which creates effectively a 9 ft high transportation package. High density balers, which have only been on the market since 2010, can produce bale densities of over 12 lb/ft³ in optimal crop conditions.



Figure 3. Three foot by four foot large square baler used in corn stover production.

Large square balers require considerably more power than round balers. High density and high capacity large square balers typically list a minimum of 180+ horsepower on manufacturer's literature. Baler speed in corn stover is often higher than in hay crops due to the lower per acre yield of corn stover. Due to the higher travel speeds and increased motion resistance of the baler in soft Midwestern soils, a minimum of 250 horsepower is recommended for corn stover baling.

For industrial scale corn stover supply chains, the bale density and bale length should be closely monitored to ensure the bale characteristics match the end user requirements. Higher density and appropriate length bales will minimize how many individual bales are created. Fewer bales with higher density will reduce transportation and storage costs.

Similar to the windrowing machinery, the pickup on the baler should be accurately set to maximize the amount of the windrow that is collected while minimizing the amount of soil that is swept into the bale. Baler pickup tines should never come into contact with the ground. Operators should check this setting regularly to ensure high quality biomass production.

Single Pass Harvesting

Single pass harvesting involves creating baled corn stover simultaneously during grain harvest (Figure 4). This is achieved by towing a baler behind a combine and directly baling all MOG directly out of the combine before the material hits the ground. By direct baling the corn stover, soil contamination is eliminated and a much higher percentage of cobs are captured in the bale. Single pass baled corn stover has an average ash content of 3.5% which is equivalent to the structural ash of corn stover. Currently single pass balers are being marketed commercially by AGCO and Tuthill Drive Systems.

Harvest rates with single pass baling equipment vary significantly based on the combine header configuration. When using a standard grain header, harvest rates of only 0.7 tons/ac are achievable with a high percentage of cobs in the baled fraction. High take rate headers including row crop headers can increase the harvest rate significantly. Additionally, changing the vertical position of the combine header can increase the biomass collection rate. Production single pass baling systems with these appropriate header modifications have been shown to produce harvest rates of up to 2 tons/ac.



Figure 4. AGCO single pass combine producing corn stover bales simultaneously with corn grain harvest.

Towing a single pass baler will generally reduce the combine productivity by up to 30% when harvesting at 2 tons/ac. The loss of productivity is associated both with the additional draft force required by the combine to tow the baler through the field as well as the additional power to thresh the corn grain and additional biomass. Under typical harvest conditions, this reduction will often not impact the overall field productivity unless grain handling is completely optimized.

Bale Collection

Once corn stover bales are produced they should be collected and moved off the field as quickly as possible to allow for subsequent fall field operations. Multi-bale collection wagons exist for round bales and large square bales. These wagons are typically tractor drawn and hydraulically powered to lift and carry individual bales. Models for large square bales are normally equipped with a hydraulically powered lift table which is used to stack bales at the edge of the field. Self-propelled models are also available.



Figure 5. Round bale collection wagon used to move round bales from a field to a storage facility.



Figure 6. Large square bale collection wagon used to collect bales and create a field stack.

Conclusions

- Industrial corn stover production includes three unique machinery activities; windrowing, baling, and bale collection.
- Stalk chopping windrowers generally produce higher quality corn stover (lower ash content) that is best suited for use in cellulosic biofuels industry.
- Large square bales offer better handling and transportation characteristics for high volume biomass than round bales.
- To maximize the productivity of large square balers, tractors with greater than 250 horsepower are required.
- Bale collection wagons can efficiently collect bales within a field.