Effects of 9 Months of Weather Exposure on Slash Bundles in the Mid-South

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Abstract

With more interest in using woody biomass as an energy resource, the John Deere 1490D slash bundler is gaining in popularity for extracting logging residues from harvest sites. In the Mid-South, the winters are wet, and extraction from the forest is limited; therefore, energy facilities store up to 6 months of material to survive the reduced logging output. This study's goal was to determine if the slash bundles would be a good storage medium for wet winter storage. Five bundles from each of four different harvest sites were placed in open storage in southeastern Arkansas during July and inspected monthly through April. After the April inspection, a 5 percent sample was cut from each bundle and analyzed for British thermal unit (Btu) value per ovendry pound. The results indicated that the bundles would maintain their structural integrity through winter storage and that the Btu value per ovendry pound after the exposure was only slightly less than the average value used for wood (8,376 compared with 8,600). This would indicate that slash bundles would be a very good medium for storing these residues during the winter months.

With the push to use biomass as an energy resource, interest in using the John Deere 1490D slash bundler to collect in-forest residues has increased. Kerr (2009) reported that the supplier for a biomass-fueled power plant in East Texas plans to use six John Deere slash bundlers to collect postharvest residues. The power plant plans to maintain a 6-month supply of fuel as a cushion against wet weather when loggers have trouble getting material out of the woods.

In 2006, productivity studies were conducted using the John Deere 1490D in southeastern Arkansas (Patterson et al. 2008). This is a continuation of that previous study in that bundles from that study were exposed to the weather for 9 months. Bundles were weighed each month and inspected for durability. After 9 months, they were analyzed for their ovendry British thermal unit (Btu) content. The goal of this study was to determine the quality of the bundles as a storage medium to aid biomass-fueled plants to operate through the wet winter months in the Mid-South.

The Mid-South is a region in the south-central area of the United States made up of Arkansas, Mississippi, Louisiana, and East Texas (12 million acres of pine forest in the eastern part of Texas). The atmospheric conditions (high temperature and humidity) cause wood to deteriorate faster in this region compared to most of the other regions of the United States. In one study of southern pine deterioration, Sinclair (1979) divided the southern region of the United States into two areas for a decision model for utilizing beetle killed pine trees. His model was developed in the eastern coastal area, for which he defined three classes of dead southern pine trees: less than 2 months, 2 to 12 months, and 12 to 20 months (since foliage fade). To use his model for the Mid-South area, he recommended applying the prescriptions developed for trees dead for longer periods of time in the eastern coastal area to trees dead for shorter periods of time in this area because Mid-South conditions promote a more rapid rate of deterioration (Sinclair 1979).

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Slash Bundling System: John Deere 1490D Slash Bundler

The John Deere 1490D slash bundler is basically a bundling unit placed over the rear bogies of a John Deere 1410 eight-wheeled forwarder. The bundling unit is on a pivot so that it can be turned to the right or left for ease of loading. A boom mounted behind the control cab can reach out 32 feet and has a grapple on the end for gathering residue (Fig. 1; description taken from Patterson et al. 2008, with permission).

The normal operation of the bundler is as follows. The grapple grabs the residue, and the boom brings it to the in feed tray. Next to the in-feed tray are four feed rollers: bottom, each side, and top. The top roller is raised to allow the residue to be placed in the rollers. When the top roller is lowered and sensors determine that there is sufficient material to make a bundle, an automatic process is activated. The rollers force the material into a stationary compressor that then squeezes the material, greatly reducing its volume. A movable compressor slides up against the stationary compressor and compresses the material further. Once the movable compressor is compressed, the stationary compressor opens, and the movable compressor moves sideways, pulling the material while the feed rollers force more material into the first compressor. When the movable compressor reaches its travel limit, a ring of nine bailing twine spools (each spool starts with 9,600 ft of twine) spins around securing the bundle. As the bundle is forced out onto the out feed tray, a sensor determines its length, and when the desired length is reached, a hydraulic chain saw cuts it off, and the bundle falls to the ground (Fig. 2).

The bundles are approximately 2 feet in diameter. The length can be preselected from 6 to 16 feet by the operator. Sales representatives stated that the bundles weigh approximately 100 pounds per foot of length when produced immediately after harvest. For this study, 10-foot-long bundles were requested.

Study Sites

The four study sites were located in southeastern Arkansas. The first study site was a clear-cut of a 57-year-old stand of loblolly pine that was harvested by conventional means. Some hardwoods, especially water oak, had invaded the stand during the final decades of stand growth. Hardwood pulpwood was recovered from the site as well as the pine sawlogs and pulpwood. Therefore, some hardwood residues were included along with the pine residues in the bundles. The second study site was a second thinning of a 26-year-old loblolly pine plantation harvested by conventional means. Again, some hardwood had invaded, resulting in the harvest of some hardwood pulpwood and hardwood residues in the bundles. The third study site was an 11-year-old loblolly pine plantation after first thinning by conventional logging methods. These trees had small branches and tops with large quantities of foliage. The fourth site was a 17-year-old loblolly pine plantation after first thinning with cut-to-length equipment. These trees (17 y old) were bigger than those in the third study site (11 y old) and smaller than those in the second study site (26 y old).

Methodology

Bundle moisture content and constituent analysis

Researchers from Mississippi State University obtained five bundles from each of the first three study sites and transported them to Starkville, Mississippi, for analysis (Steele et al. 2008). The bundles were placed on the ground in an open area for full exposure to the weather. One bundle from each study site was destructively sampled initially and then every 30 days until the end of the 4-month analysis. The initial moisture contents (dry basis) were 49.4, 81.1, and 127.3 percent for study sites 1, 2, and 3, respectively. After 1 month, the moisture contents were 13.5, 14.5, and 22.8 percent for study sites 1, 2, and 3, respectively. With lower temperatures and an increase in rain, the moisture contents after 4 months of exposure were 38.1, 46.2, and 69.9 percent for study sites 1, 2, and 3, respectively. Their moisture contents were based on one bundle per study site per month.

The researchers stated that the difference in needle content was the reason for the difference in moisture gain. Their analysis indicated that the needle content of the bundles were 3.4, 12.7, and 22.0 percent for study sites 1, 2, and 3, respectively. The stem and twig components were 93.0, 79.6, and 74.0 percent for study sites 1, 2, and 3,

Figure 1.—The John Deere 1490D slash bundler.

Figure 2.—The John Deere 1490D bundler unit in operation in a pine clear-cut in southeastern Arkansas.

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respectively. The remaining percentages of the ovendry volumes were classified as residuals and were made up of dirt, ant's nest, needle fragments, etc.

Bundle storage and evaluation

As the goal of this study was to determine if bundles are a good medium for outside winter storage of woody biomass in the Mid-South, the question arose as to when in the spring new bundles should be harvested from logging sites and bundles from the previous year would no longer be needed. In an earlier study, Patterson and Doruska (2005) found one of eight study stands underwater for the whole month of May, while the other seven stands were accessible. Based on this result and the experience of the research team, April was determined to be the beginning of the new harvest season in the Mid-South. Therefore, the exposure part of this study would run from July, when the bundles were made, until April—a total of 9 months.

Five bundles were transported from each of the four study sites to the University of Arkansas at Monticello campus. They were placed on sapling skids for ease of handling (Fig. 3). With the small diameter of the skids, there was very little airflow under the bundles; therefore, conditions should have been similar to being placed on the ground. Each month, each bundle was rolled on the skids in order to check for structural integrity and also to wrap cables around it to allow for handling. The cables were attached to crane-type load cell scales that had an accuracy of ± 1 pound. After lifting (Fig. 4), the bundle's weight was recorded, and then the bundle was placed on another set of skids. This way, the bundles were inspected in reverse order each month.

After the April inspection and weighing, a 5 percent sample (since the bundles were 10 ft long, a 6-in. section was 5%) was cut with a chainsaw from the center of each bundle. The sample material was gathered into plastic storage bins and taken to the laboratory, where the material was dried. After drying, lids were placed on the bins, and they were placed in dry storage.

A lawn-and-garden chipper was borrowed from the University's grounds crew to reduce the sample material to chips. The material was randomly removed from each bin and fed to the chipper in order to mix the material. The chipper had a box that collected the output of the chipper. As the chipper processed the material, it laid down layers of mixed material. After a sample was completed, the box was swept out onto a tarp that further mixed the material. The material was dumped from the tarp back into the storage bin.

A cutting mill with a 2-mm sieve was used to reduce the chipped material to a particle size suitable for the calorimeter. Again, the material was taken from the bins in a random manner for milling so as to mix the material as much as possible. After milling, the receiving vessel was shaken and dumped into the storage bin. The reason for all the random feeding and shaking was to arrive at a calorimeter sample that was a homogeneous mixture of all the material in the 5 percent sample taken from a bundle.

Five small samples totaling 1 to 1.5 pounds were randomly taken from each bin, placed in metal pans, and oven dried. The dried samples were placed in plastic zip-lock bags and taken to the calorimeter. Twenty calorimeter samples were taken from each bag. Twenty samples from 20 bundles resulted in 400 calorimeter tests completed for the study.

Results and Discussion

With the passing of time, the bundles began to flatten and become more oval instead of round in shape. This made it more difficult to roll the bundles for inspection and weighing. In real storage situations, the bundles would be stacked on top of each other, causing them to flatten even more, but this would tend to make the stack more stable. With the monthly handling, only one bundle started to lose its structural integrity, with the twine starting to slip.

The weather during the summer and early fall was very hot and dry. This caused the bundles to lose moisture and weight. With the lower temperatures and increased rainfall during the late fall and winter, the bundles gained back some of the moisture and weight (Fig. 5). The average monthly temperatures and monthly rainfall for the time frame of the study (National Oceanic and Atmospheric Administration 2009) are shown in Figures 6 and 7. The average moisture contents of the 5 percent samples cut from

Figure 3.—Study bundles from pine harvest sites in southeastern Arkansas placed on skids for observation and weighing.

Figure 4.—Weighing slash bundle from pine harvest site in southeastern Arkansas with a crane scales and cables to determine weight change due to exposure.

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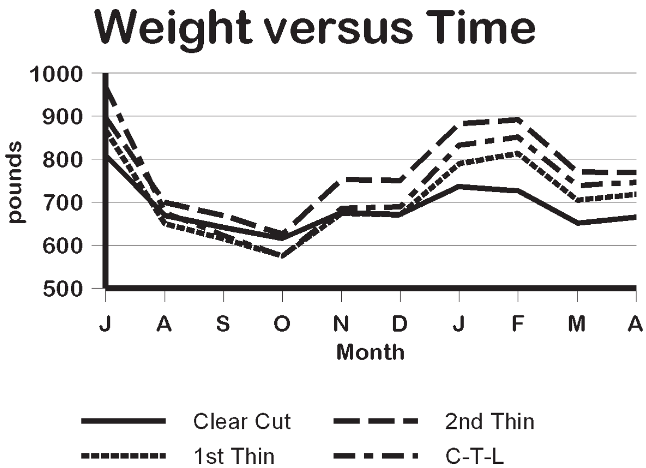

Figure 5.—Average weight of five bundles from each harvest study site from each monthly weighing from July 2006 through April 2007.

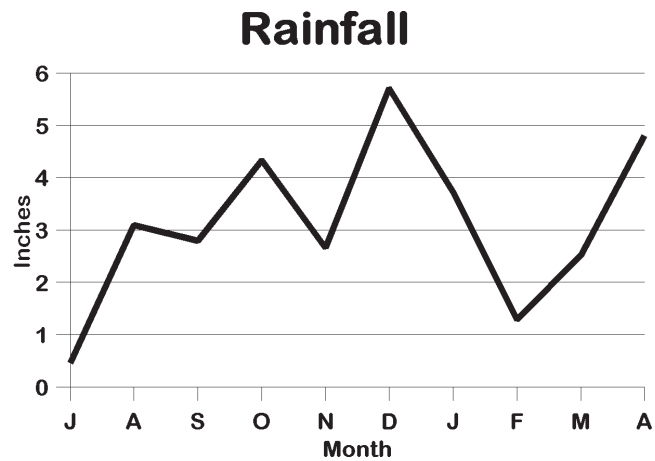

Figure 7.—Monthly rainfall from July 2006 through April 2007 in Monticello, Arkansas, the location of this research.

the center of the bundles after 9 months were 30.1, 77.5, 93.3, and 108.9 percent for study sites 1, 2, 3, and 4, respectively.

The weight and weather information is presented in line graph form to illustrate how the bundle weight change followed but lagged behind the weather change. If bundles are to be sold on a weight basis, this weather information would indicate that for bundles prepared in the summer, bundle delivery to the buyer must be occur as quickly as possible to maximize return. But if the bundles were made during the late fall and winter, there would not be as much urgency in bundle delivery. This hygroscopic nature of wood is causing some people to propose the sale of woody biomass based on the bone-dry Btu value and not weight.

When the calorimeter data was analyzed, it was noted that one bundle had a statistically significant lower Btu value (7,730) than the other bundles. Further investigation revealed that this bundle had a much higher ash percentage than the others. Most of the bundles had an ash content of 2 to 4 percent, while all the samples from this bundle had an ash content of 13 to 14 percent. It had been noted during the study that after each sample firing for this bundle, the crucible had a large amount of sand remaining in it. The ash values of the other bundles were averaged and subtracted from the ash content of the subject bundle to estimate the weight of the extra sand. The extra ash/sand weight was subtracted from the sample weight, and the new sample weight was used to recalculate the Btu per pound value (8,740). It is theorized that in pushing the residue into a pile in a corner of the landing, the skidder pushed dirt and sand up into the pile, and the slash bundler captured the sand with the slash in making this bundle. Because this is an aspect that the other bundles do not have, this bundle was removed from the study.

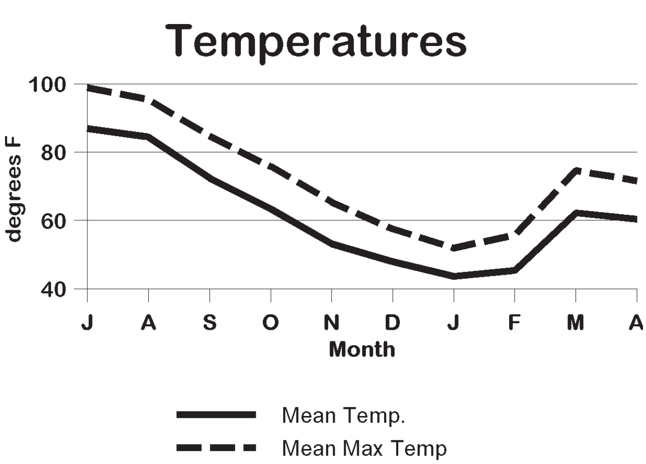

Figure 6.—The mean monthly temperatures and the mean monthly maximum temperatures from July 2006 through April 2007 in Monticello, Arkansas, the location of this research.

The average Btu per ovendry pound value for the remaining 19 bundles was 8,376. Statistical analysis indicated that there was no significant difference in the Btu values between bundles from different study sites. The average Btu per ovendry pound values for bundles from each study site were 8,388, 8,324, 8,419, and 8,374 for sites 1, 2, 3, and 4, respectively (Table 1). These results would indicate that the bundles lost very little of their fuel value during the 9 months of exposure to the weather since the most common value for wood is 8,600 Btu per ovendry pound (Patterson and Zinn 1990). When using bundles as a fuel source, moisture content appears to be the major item of concern.

The ash contents of the samples from the 19 remaining bundles were within the expected range (Table 1). The ash content was higher for the bundles from smaller trees (sites 3 and 4), which had more bark and foliage because of smaller limbs, than for the bundles from mature trees (site

Table 1.—Results of calorimeter tests showing mean Btu values per ovendry pound and percent ash content of slash bundles from each of four southern pine harvest sites in southeastern Arkansas after 9 months of exposure to the weather.

Study site	*n*	Mean (SD) Btu per ovendry pound	Mean % ash sample weight
1. Mature clear-cut	100	8,388 (127)	0.8
2. Second thinning	80	8,324 (216)	2.1
3. First thinning	100	8,419 (160)	3.4
4. Cut to length	100	8,374 (199)	2.8

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1). Studies have shown that bark produces four times the amount of ash as wood (Patterson and Zinn 1990).

The high sand content of the removed bundle brings another concern to the forefront. When discussing the use of bundles as a fuel source, noncombustible content such as sand may add weight and increase the seller's profits, but it is only trouble otherwise. This material is detrimental to the processing equipment at the plant. It can cause excessive wear and breakage, resulting in extra maintenance costs. If the residue must be pushed into a pile at the landing to await the slash bundler, care should be exercised to keep dirt and sand out of the pile. If sales are based on energy value instead of weight, then the seller will be transporting something that is of no value. The per bone-dry pound value of the rejected bundle was reduced by 1,000 Btu (7,730 vs. 8,740) because of the sand.

Conclusions

The goal of this study was to determine if slash bundles would be a good storage medium for winter biomass storage in the Mid-South. With monthly inspections over a 9-month period, the bundles maintained their structural integrity, indicating that they would remain physically sound. The calorimeter tests indicated that the bundles appeared not to lose their fuel value after 9 months of exposure. Calorimeter tests of energy potential were not conducted at the beginning of the study because it was desired to keep the bundles intact. The average value normally used for wood is 8,600, and the average of the 20 bundles was 8,376. Therefore, it can be concluded that the slash bundles from the John Deere 1490D are a good storage medium to aid biomass-fueled plants to make it through the wet winter months in the Mid-South.

If the bundles were placed in storage under roof, the bundles would tend to air dry to the equilibrium moisture content (EMC) for the area. In the Mid-South, the EMC is between 17 and 20 percent (dry basis). Shrinkage usually does not start until the moisture content drops below 30 percent; therefore, minimal shrinkage would occur, and the integrity should not be compromised.

The results of this study are relevant to the Mid-South region. There have been studies conducted on the slash bundler in the northwestern part of the United States (Rummer et al. 2004). The environmental conditions there are colder (frozen) in the winter and drier in the warm weather as compared with the Mid-South. Based on the current study, it is anticipated that the results in other areas of the South, where environmental conditions are less conducive to deterioration, would be even better.

Acknowledgments

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