United States Department of Agriculture

Forest Service

Forest Products Laboratory[1]

Research Note

FPL-0241

Should Whole-Tree Chips for Fuel Be Dried Before Storage?

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Abstract

Whole-tree chips deteriorate more rapidly than do clean, debarked chips and present a greater hazard for spontaneous ignition when stored in outdoor piles. To prevent ignition, the chips can be stored for only short periods of time and the frequent rotation of the storage piles results in high handling costs. Drying the chips prior to storage will prevent deterioration and heating, provided the chips are stored under cover. In many cases, the costs of drying can be recovered when the chips are burned for fuel. In these instances, drying and covered storage is the least expensive method for maintaining an inventory of whole-tree chips to be used as fuel.

Introduction

Chips produced from the entire above-ground portion of trees, bole, bark, branches, and foliage are called whole-tree chips. Such chips are presently being used for fuel in several heating and power plants. This use is expected to greatly increase in the near future.

When using whole-tree chips as fuel or as pulpwood, it will, no doubt, be necessary to store some of the chips. The rate of deterioration of whole-tree chips in storage is usually found to be significantly greater than that for clean, debarked chips. This Note discusses past findings on pile storage of whole-tree chips, advantages of drying for storage, and relative costs.

Background

In a laboratory-scale storage study, Zoch et al. found aspen whole-tree chips to evolve much more heat and to lose ovendry weight six times faster than clean, debarked chips (*24*).[2] Moran reported that the decay rate for mixed hardwood whole-tree chips (mainly oak) stored in an outside pile was roughly three times that for clean, debarked chips (9). Springer et al. found that the rate of weight loss was significantly greater for southern pine whole-tree chips than for clean, debarked chips (*18*), but that the rates were nearly identical for mixed hardwood (mainly oak) whole-tree chips and clean, debarked chips (*17*). However, for both pine and mixed hardwood chips, the whole-tree chips evolved significantly more heat than did the clean, debarked chips.

That bark and foliage are responsible for the generally increased rate of deterioration of whole-tree chips has been demonstrated in the studies of Gislerud and Gronlien (*4,5*). They placed nylon mesh bags containing foliage, bark, whole-tree chips, and clean, debarked chips in outside piles of whole-tree chips and determined ovendry weight losses after storage. Weight loss during storage increased

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] Italicized numbers in parentheses refer to Literature Cited at the end of the report.

in the order: clean, debarked chips < whole-tree chips < bark < foliage. Foliage losses were roughly ten times as high as those for clean, debarked chips.

Because of the increased rate of deterioration of whole-tree chips and the associated increased rate of heat evolution, it would be expected that piles of whole-tree chips would be more susceptible to spontaneous ignition than similar-sized piles of clean, debarked chips. That this is indeed true was demonstrated by a chip pile fire and a subsequent chip pile study at the Mead Corporation pulpmill at Chillicothe, Ohio (*1*). In 1973, Mead began using small quantities of mixed hardwood whole-tree chips and storing them in the chip pile together with mixed hardwood clean, debarked chips. The whole-tree chips were not uniformly blended with the clean chips but were simply spread on the pile as they were received. In 1974, the quantities of whole-tree chips in the pile increased substantially. It was estimated, however, that the whole-tree chip content of the pile never exceeded 8 percent at any time. Due to space limitations in the woodyard, it was impossible to use the chips in the order in which they were received. Chips at the bottom were in the pile for as long as 18 months. In January 1975, a serious chip pile fire broke out. The pile at that time contained about 50,000 tons of green chips.

Mead had never experienced a chip pile fire previously and, in an effort to understand the causes, set up a chip pile monitoring study. A new chip pile containing about 30 percent mixed hardwood whole-tree chips and with a maximum height of about 36 feet was constructed and temperatures in the pile were monitored with thermocouples. Within 10 days of pile completion, a maximum temperature of 206° F was observed. Temperatures then decreased and leveled off at about 135° F. One month after the first temperature rise, another began. At 41 days after pile completion, a maximum temperature of 215° F was observed and then, after a brief pause, the maximum temperature rose to 239° F on the 49th day. Since chip pile temperatures above about 180° F are considered to indicate a high probability of spontaneous ignition, immediate action was then taken to cut down the pile and use the chips. This pile contained only 30 percent whole-tree chips; a pile containing 100 percent whole-tree chips would be expected to evolve more heat and thus reach dangerously high temperatures even faster. From this study, it appears that piles of whole-tree chips or piles containing significant quantities of whole-tree chips will be very susceptible to spontaneous ignition. Based on this study, Mead adopted a policy of using whole-tree chips on a "first in-first out" basis and requiring that the chips be stored for no longer than 20 days. There are other published reports of spontaneously ignited fires occurring in chip piles containing barky (*2*) or whole-tree chips (*13*).

White and Deluca have studied the outdoor storage of bark and sawdust and concluded that longterm outside storage is feasible and may be very practical (23). Their test piles were, however, so small that pile temperatures remained below the danger point. Larger piles would have, no doubt, attained dangerously high temperatures. Because of the danger of spontaneous ignition, many pulp mills limit the height of their piles of clean debarked chips. Mills in the Southeast, using southern pine, often limit pile height to less than 25 feet. Mills on the West Coast, using Douglas-fir and other western species, limit pile height to 50 feet (*10*).

Storage Methods

Some possible methods for inhibiting the deterioration and associated heat evolution of whole-tree chips might be:

Storage under anaerobic conditions

Chemical treatment prior to storage

Drying the chips and storing under some type of shelter

Anaerobic Conditions

Anaerobic (oxygen-free) conditions are easily established in the laboratory, but difficult to attain under actual use conditions. Covering a large chip pile with polyethylene film might be a reasonable possibility; however, establishing nearly oxygen-free conditions inside the enclosure would probably be difficult. A laboratory study involving covering a small 4-foot-high pile of aspen chips with polyethylene film showed that it was possible to inhibit heating and deterioration under laboratory conditions where only about 1 percent oxygen was present within the enclosure (*3*). With 4 to 5 percent oxygen present, deterioration was essentially the same as in the open air. Maintaining an oxygen level at 1 percent or below in a large covered chip pile would probably be very difficult due to tears in the film caused by the wind and other factors. Several years ago, a number of log storage piles were covered with black polyethylene film in an effort to preserve the southern pine logs by establishing and maintaining anaerobic conditions (*8*). It was found to be very difficult to maintain oxygen levels as low as 1 percent. One of the test piles contained a pocket of about 1,600 cubic feet of chips at its center. When dismantled after 16 months, the logs showed little deterioration, whereas chip deterioration was about what would be expected in an uncovered pile. Thus, this method, although seemingly adequate for log storage, would not greatly reduce chip deterioration. Based on this trial, it is thought that large-scale anaerobic storage of chips is impractical.

Chemical Treatment

A great amount of effort has gone into the development of chemical treatments for preservation of outdoor-stored wood chips (*15,16*). To date, no practical, cost-effective treatment has been developed which will inhibit heat evolution in the storage pile for long periods of time.

Thus, chemical treatment is not at present a practical method for preservation of outdoor-stored whole-tree chips.

Dried and Covered

It is well known that wood dried below its fiber saturation point (20 to 24 pct moisture content (MC), wet basis (*19*)) is not subject to bacterial or fungal attack. Drying also kills any living wood cells and thus, a storage pile of adequately dried wood chips will not deteriorate or evolve a significant amount of heat. To keep the chips, especially the top chips, in an outdoor pile from rewetting due to rainfall, it would be essential to shelter or cover the pile in some fashion. Covering the pile using polyethylene film might be effective in this case, because it would only be necessary to keep rainfall off the chips and not to make an air-tight enclosure. This storage method has been considered for use with clean, debarked pulp chips. It was, however, thought to be too expensive, since the cost of drying and of covering the chips was much higher than the usual monetary losses incurred in storing untreated and unprotected chips. Losses due to spontaneous combustion were not considered because the probability of spontaneous ignition in clean, debarked chips stored according to accepted industrial procedures is low (*10*). Although not cost effective for clean, debarked chips, drying and covered storage may be cost effective for the storage of whole-tree chips, especially those to be used for fuel.

Advantages of Drying

In recent years, the advantages of drying wet sawdust, bark, and other types of "hogged fuel" prior to burning have been studied (*6*). Drying the fuel resulted in increased heat release per unit of fuel and a consequent reduction in the quantity of fuel required for a given energy output. When flue gas is used for drying, it is claimed that the savings will pay for the capital costs of a dryer in just a few years (*11,20*). Drying the fuel also results in several additional benefits:

Increased furnace capacity

Increased furnace efficiency

Reduced quantity of stack gases

Reduced particulate emissions

In recent tests, the steam output from a boiler was almost doubled in going from 63 percent MC hogged fuel to 28 percent MC fuel (*6*). In addition, particulate emissions from the stack were reduced from about 0.3 grain per standard cubic foot to less than 0.1. The flue-gas flow rate was the same in both cases.

In many instances, it is cost effective to dry wet bark, sawdust, or hogged fuel when using these wood residues to replace fossil fuels in existing boilers modified to accept such fuels (*6,21*). In situations where a new boiler installation for burning 100 percent wood residue fuel is being considered, the economic justification for drying is in some doubt (*21,22*). Where emission control equipment is required, installation of a dryer, together with a smaller boiler and less complex emission control equipment, will probably be as economically justifiable as installation of a larger boiler for burning wet fuel and large-sized, more complex, more efficient emission control equipment.

Thus, when considering the use of whole-tree chips for fuel, it will probably be profitable to dry the chips in most instances prior to burning, even in situations where no storage is contemplated. Drying costs, therefore, need not be considered to be storage costs, provided that the stored chips are kept in a dry condition. To accomplish this, the outside stored chips must be covered or sheltered from rain and snow. Shelter costs will, of course, be a storage expense.

Protection of Chips from Precipitation

Wood dried below its fiber saturation point will not attain MC's above that point unless wetted by water. Thus, any type of shelter to protect the dried chips from precipitation will serve to maintain them in a dry condition. Any type of rigid structure such as a silo or shed is several times more expensive per ton of stored chips than is simply covering the chips with heavy polyethylene film. Based on published data (*7*) it is estimated that the cost of reinforced polyethylene film for covering a chip pile will be about \$2 per ton of dry chips. This cost and the cost involved in putting the film over a pile, securing it in place, and finally removing it are true storage costs. The installation cost for covering a pile with polyethylene film is roughly estimated to be \$1 per ton of chips stored (ovendry basis). The cost of removing the film at the end of storage will be somewhat less. Thus, the total cost of covering chips with reinforced polyethylene film should be somewhat less than \$4 per ton of chips (ovendry basis). In locations with little or even moderate precipitation, it may not be necessary to cover the dried chips. The influence of rain and snow on uncovered piles of dried chips should be studied.

Storage Costs

Any power or heating plant requires a certain inventory of fuel on hand at all times. If whole-tree chips were used as the fuel source, the required inventory could be held as either dried, covered chips or as fresh, moist, uncovered chips. The fresh chips would have to be rotated frequently to prevent spontaneous ignition. Dry covered chips could be kept in storage for many months and incoming chips sent directly to the dryer and then the furnace. Because fresh, moist, uncovered chips need rotation every 20 days, whereas dry covered chips can be held for more than 6 months, the cost of handling the fresh chips will be greater than the cost of covering the dry chips with reinforced polyethylene film.

In 1962, Ritcey made a survey of the costs of handling chips into and out of storage piles (*12*). The costs varied widely from mill to mill, but averaged about \$0.50 per ton (ovendry basis) into storage and about the same cost for removal from storage. Allowing for increases in efficiency of handling and adjusting costs upward for inflation, it would today, undoubtedly, cost at least \$1.50 to handle 1 ton of chips (ovendry basis) into and out of a storage pile. Storage of a given inventory of fresh, moist, uncovered chips for 6 months would then require $\frac{180}{20} = 9$ complete rotations of the chips; the cost based on an ovendry ton of inventory would be $9 \times \$1.50 = \$13.50$ per ton. Dry covered storage for 6 months would cost about \$4 per dry ton for the polyethylene cover plus \$1.50 for putting the chips into and taking them out of the pile, for a total of about \$5.50 per dry ton. Dry covered storage will thus be the least expensive way to maintain the required inventory of whole-tree chips. The maximum time that dry covered chips can be held in storage without significant losses occurring should be determined, as storage cost will be inversely proportional to length of storage.

In many instances, when dry chips are burned for fuel, the drying costs will be entirely recovered. No drying cost recovery takes place when dried chips are pulped and, indeed, the dried chips may cause problems in pulping. Drying and covered storage is probably not a cost-effective method for maintaining an inventory of pulp chips. The greatest monetary losses in storage of clean, debarked pulp chips are for southern pine chips and amount to about $4 per ton of initial ovendry wood substance in 6 months of pile storage (*14*). Drying and covering costs would greatly exceed this loss. For pulp chips, the best procedure would be to pulp green whole-tree chips immediately and to store the required inventory as clean, debarked chips.

Conclusions

Because of the danger of spontaneous ignition, fresh, moist, whole-tree chips can be stored in outdoor piles for only short periods of time. Maintaining a given inventory of such chips in storage thus requires that the chips be rotated frequently and, as a result, handling costs are very high. The ignition hazard can be eliminated by drying the chips and maintaining them in a dry condition. In many instances, drying costs can be entirely recovered when whole-tree chips are burned for fuel. The cost of maintaining an inventory for fuel purposes in these cases is thus simply the cost of providing a cover for the dry chips and of moving the chips into and out of storage. This method is much less expensive than frequent rotation of moist chips.

Literature Cited

1. Boggan, J. A.
   1977. How Mead Papers learned to use whole-tree chips for bleached pulp. Pulp and Pap. 51(14):110-113.
2. Cole, A. H.
   1972. Chip pile fire. Pulp and Pap. Mag. Can. 73(C):137-140.
3. Feist, W. C., E. L. Springer, and G. J. Hajny.
   1971. Encasing wood chip piles in plastic membranes to control chip deterioration. Tappi 54(7):1140-1142.
4. Gislerud, O., and H. Gronlien.
   1977. Storage of whole-tree chips—A storage experiment with chips from thinnings . . . Norsk Institutt for Skogforskning Rapport 1/77. Oslo, Norway.
5. Gislerud, O., and H. Gronlien.
   1978. Storage of whole-tree chips of gray alder—A storage experiment at Meraker Smelteverk A/S. Norsk Institutt for Skogforskning Rapport 1/78. Oslo, Norway.
6. Johnson, Robert C.
   1975. Some aspects of wood waste preparation for use as fuel. Tappi 58(7):102-106.
7. Ku, Jesse C. Z., and Denis Bevan.
   1977. Outdoor bulk storage for hydrophilic materials. Chem. Eng. 84(18):69-74.
8. McKee, J. C., and J. W. Daniel.
   1966. Long term storage of pulpwood in sealed enclosures. Tappi 49(5):47A-50A.
9. Moran, J. S.
   1975. Kraft mill experience with whole-tree chips. [TAPPI Annu. Meet., N.Y. Feb. 1975.] TAPPI, Atlanta, Ga.
10. National Fire Protection Association.
    1973. Outdoor storage of wood chips. Natl. Fire Prot. Assoc. Bull. No. 46A, NFPA, Boston, Mass.
11. Porter, S. M., and R. W. Robinson.
    1976. Waste fuel preparation system. No. P-76-14 Proc. Symp. Energy and Wood Prod. Ind. [Atlanta, Ga., Nov. 15-17, 1976.] p. 72-79. For. Prod. Res. Soc., Madison, Wis.
12. Ritcey, Glenn C.
    1962. Application of pneumatic handling to the pulp and paper industry. Pulp and Pap. Mag. Can. 63(C):T116-T125.
13. Southern Pulp and Paper Manufacturer.
    1977. Virginia-Carolina discusses chip handling and coating operations at Richmond meeting. South. Pulp Pap. Manuf. 40(2):56,58.
14. Springer, E. L.
    1978. Losses during storage of southern pine chips: the case for stand-by storage. Tappi 61(5):69-72.

15. Springer, E. L., M. Benjamin, W. C. Feist, L. L. Zoch, Jr. and G. J. Hajny. 1977. Chemical treatment of chips for outdoor storage: Evaluation of sodium . . . Tappi 60(2):88-91.

16. Springer, E. L., W. C. Feist, L. L. Zoch, Jr., and G. J. Hajny. 1977. Evaluation of chemical treatments to prevent deterioration of wood chips during storage. Tappi 60(2):93-97.

17. Springer, E. L., S. E. Knowles, W. C. Feist, L. L. Zoch, Jr., and G. J. Hajny. 1980. Chemical treatment and storage of hardwood whole-tree chips in pile simulators. To be published in Tappi.

18. Springer, E. L., L. L. Zoch, Jr., W. C. Feist, G. J. Hajny, and R. W. Hemingway. 1978. Storage characteristics of southern pine whole-tree chips. *In* Complete Tree Utilization of Southern Pine. p. 216-223. Charles W. McMillin, ed. For. Prod. Res. Soc., Madison, Wis.

19. Stamm, A. J. 1964. Wood and Cellulose Science. Ronald Press, N.Y. p. 155.

20. Thompson, S. 1978. Drying bark for efficient burning. [Millyard Oper. Tech. Group Meet., Atlanta, Ga., Jan. 19, 1978.] Thompson Dehydrating Co., Topeka, Kans.

21. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 1978. Final Report, Forest Residues Energy Program. USDA, For. Serv. N.C. For. Exp. Stn., St. Paul, Minn.

22. Vanelli, L. J., and W. B. Archibald. 1976. Economics of hog fuel drying. No. P-76-14 Proc. Symp. Energy and Wood Prod. Ind. [Atlanta, Ga., Nov. 15-17, 1976.] p. 59-62. For. Prod. Res. Soc., Madison, Wis.

23. White, Marshall S., and Peter A. Deluca. 1978. Bulk storage effects on the fuel potential of sawmill residues. For. Prod. J. 28(11):24-29.

24. Zoch, L. L., Jr., E. L. Springer, and G. J. Hajny. 1976. Storage of aspen whole-tree chips under laboratory conditions. USDA For. Serv. Res. Pap. FPL 288. For. Prod. Lab., Madison, Wis.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1980-651-111/35