ABSTRACT

This study is an attempt to investigate the use of eastern redcedar (Juniperus virginiana L.) in a whole-tree chipping process to manufacture a commercial single-layer particleboard. Redcedar chips with and without foliage were used to manufacture 36 experimental particleboard panels with two density levels. The panels were tested for mechanical strength and dimensional stability properties according to the procedures defined by ASTM D-1037. Average modulus of elasticity and modulus of rupture values for static bending, internal bond strength, and thickness swelling tests were found to be comparable to those of commercial particleboards manufactured from different species. Panel properties, with the exception of internal bond strength, from the two types of chips were not statistically different at the 95 percent confidence level. Panels made with foliage had 13 percent lower internal bond strength values than those of panels made without foliage. Based on the findings in this study, it appears that whole-tree chipped eastern redcedar can be used to manufacture particleboard without having any adverse influence on panel properties.

Eastern redcedar (Juniperus virginiana L.) is one of 13 juniper species native to the United States. It is a small evergreen tree, commonly 10 to 35 feet tall with a pyramidal shape that becomes more round with age. Redcedar leaves come in two types; one type is scale-like, dull pointed, closely appressed to the twig and about 1/16 inch long; the other leaves are awl-like about 1/4 to 1/2 inch long pointing away from the twig (11). Eastern redcedar is not a true cedar but a member of the Juniper genus. Its distinctive bright red and brown heartwood is moderately soft.

Eastern redcedar grows on many soils and under varying climatic conditions. This adaptability has enhanced redcedar’s recent spread into areas where it was formerly rare or absent. It is also one of the most widely distributed indigenous conifers in Oklahoma. A 1993 survey found that there were 30 million ft.³ of redcedar in 18 eastern Oklahoma counties, namely Delaware, Mayes, Adair, Cherokee, Sequoyah, Latimer, Pushmata, McCurtain, Atoka, Coal, Bryan, Muskogee, McIntosh, Haskell, Le Flore, Pittsburgh, Choctaw, and Ottawa (3).

Range-grown eastern redcedar is certainly poor quality which makes this species inefficient as a raw material for lumber manufacturing. Many wildlife species that need open range also are affected negatively by eastern redcedar. Currently it is considered a nuisance in Oklahoma, and many of the state’s farmers are eligible for government subsidy payments to clear their land of redcedar. The wood from eastern redcedar is often used for fence posts, novelty items, or for lining chests, wardrobes, mailboxes, birdhouses, and closets due to its fragrance and ability to repel moths. The trees themselves may be planted for shelterbelts, windbreaks, and/or soil conservation.

Wood composition panels such as particleboard are commodity products manufactured in great quantities in the United States and are primarily used in the furniture industry (6). Currently there are several manufacturers in the United States that use roundwood of eastern redcedar to produce flakeboard. Also whole-tree chipped furnish of mixed species is used by various companies to manufacture particleboard panels.
The use of low quality eastern redcedar in Oklahoma to manufacture particleboard appears to have economical and environmental advantages. Whole-tree particleboard manufacturing can make use of a majority of the redcedar's anatomy, including the bark, small limbs, and even the needles. This process would provide an alternative method to convert a potentially costly land management problem into a value-added product. To our knowledge, there has been no other study investigating the feasibility of manufacturing particleboard from whole-tree chipped eastern redcedar. Therefore, the objective of this study is to use eastern redcedar as raw material for laboratory-made particleboard and to test the properties of such panels to determine if they are similar to particleboard made from other species.

Assessment of Raw Material in Oklahoma

The availability of eastern redcedar in Oklahoma has been on the rise over the last two decades. According to a 1996 report by Bidwell et al. (3), the number of acres invaded by eastern redcedar and Ashe juniper (Juniperus ashei) increased from 3.5 million acres in 1985 to over 6 million acres in 1994. The greatest areas of expansion have been in the southwestern part of the state, characterized by an arid climate and rocky soil, and the northwestern part of the state, primarily open prairie land dissected by waterways. In fact, state biologists are now concerned that encroaching redcedars may someday take over the tall grass prairies in northern Oklahoma.

No large-scale, economically viable use has been established for eastern redcedar in Oklahoma and the trees are generally considered a water-stealing, space-taking nuisance. Population growth and land development, among other factors, have limited the size of open land areas and thus resulted in decreased numbers of controlled burns to regulate redcedar infestation. Landowners try to control redcedar on their land using removal methods such as spraying with chemicals, chaining, and cutting. Chemical application is a common method for managing areas of small and young tree growth, but it is not practical for large trees. Chaining is a method in which a large anchor chain is dragged between two bulldozers in a U-shaped pattern to catch the trees, generally those less than 8 feet in height, and pull them out by their roots. For areas with trees larger than 8 feet high, cutting by means of chain saws, rotary saws, or hydraulic shears is the most common methods for tree extraction. Large areas of very small trees and seedlings may also be controlled through regular cutting via brushhog mowers.

Methods used for removing redcedar in Oklahoma have varied according to the landscape and intended use of the redcedar. In much of western Oklahoma, where redcedars may be intermittently distributed throughout grasslands, the trees are generally too small for lumber manufacturing. Therefore, prescribed burns are the standard means of redcedar removal. In eastern Oklahoma, where redcedar trees have grown to larger heights in drainage systems and mixed woods regions, the trees are large enough to provide usable lumber and the amount of undergrowth and other vegetation makes burns more difficult to control. In this case the preferred method for extracting the trees is most often by the use of chain saws.

The costs for these extraction methods also vary by landscape and tree density. Utilizing 1989 costs and custom rate prices, Stritzke and Bidwell (8) found considerable differences in extraction costs for trees larger than 8 feet on acres with varying levels of trees per acre. For land with an average of 8 such trees per acre, cutting costs varied from $2.25/acre for using a rotary saw or hydraulic shears to $5.28/acre for total tree extraction including roots using a hydraulic grapple. Chain saw costs were approximately $2.56/acre on the lower end of the spectrum. However, using an average number of 154 such trees per acre from their survey, the costs for chain saw extraction grew considerably to $32.34/acre. On the other hand, costs were estimated as $15.55/acre and $16.50/acre for rotary saw or hydraulic shear and a hydraulic grapple, respectively. Besides the costs of extracting the trees, landowners in Oklahoma are still faced with the problem of piling and burning the trees, or otherwise removing them from their property.

Market Potential for a Red-Cedar Particleboard Operation

The demand for particleboard for furniture indicates a favorable market environment for products manufactured from the pleasantly aromatic eastern redcedar. According to the U.S. Census Bureau, the United States has 108 establishments capable of manufacturing various types of reconstituted wood products such as particleboard, oriented strandboard, and medium density fiberboard (9). These establishments utilized over $2.9 billion in materials to manufacture almost $5.3 billion of reconstituted wood products in 1997. U.S. manufacturers utilized approximately 12.3 million tons of chips, slabs, edgings, sawdust, planer shavings, and other woodwaste in manufacturing these products. This is up from 10.1 million tons recorded by the 1992 Economic Census, further indicating the growing demand for products manufactured from lumber mill by-products and other items generally considered to be woodwaste.

Oklahoma had only four reconstituted wood products manufacturers, which are all located in the eastern part of the state. These two establishments utilized $13.1 million in materials, primarily oak, pine, and hickory, to manufacture approximately $20.7 million of products in 1997. The only states bordering Oklahoma with reconstituted wood products manufacturers are Arkansas with 5 establishments and Texas with 19 establishments (9,10). Both states' processors utilize primarily pine and mixed hardwood species as a raw material to manufacture particleboard, oriented strandboard, and fiberboard.

There have been no formal feasibility assessments to determine the economic viability of a particleboard facility exclusively utilizing redcedar in Oklahoma, and the issue is briefly addressed in this study. Such assessment will be a separate economic study relying upon updated information on Oklahoma redcedar dispersion, manufacturing facility and equipment costs, labor requirements, utility requirements, and a marketing study.

There is currently no reported price listing for redcedar in Oklahoma, due in part to this species status as a pest and the overwhelming availability of virtually free redcedar. However, if landowners make use of state and federal programs to remove redcedar trees from their property, the costs of delivered inputs to a centralized particleboard facility may be only the transportation costs.
Using a cost of $1.85 per load mile for a tractor-trailer with the capacity of 40,000 pounds, and assuming an average of 100 miles to a centralized facility, the costs of obtaining inputs could be as little as $185 in addition to a nominal loading and unloading fee for a 20-ton delivery (5). For most of central and western Oklahoma, transportation would not be impeded by hills or road conditions as one might expect with a logging operation in eastern Oklahoma.

Should eastern redcedar become viewed as a marketable commodity in the future, however, the viability of a particleboard plant would hinge on its ability to gauge the price of its inputs. To develop a rough estimated cost of delivered redcedar in central Oklahoma, the following assumptions were made by the authors:

- Harvesting an average of seventy-seven 8-foot redcedar trees per acre (half the average per-acre quantity from the Stritzke and Bidwell (8) study) in the procurement region with bottom basal area of 8 inches and a top basal area of 1 inch.
- Chain saw extraction of the redcedar trees.
- An average transport of 100 miles to a centralized particleboard manufacturing facility.
- Estimated weights of 50 pounds per cubic foot of redcedar.
- Transportation costs of $1.85 per load mile with a maximum load of 40,000 pounds.

Further, it was assumed that chain saw extraction of the trees costs $21.56/acre ($0.28/ tree), as compared to the $32.34/acre for extracting 154 trees from each acre ($0.21/tree) (8). Also, costs for loading the trees is assumed to be included in either the extraction or shipping costs.

By the Smalian formula, the cubic feet retrieved from each tree in this scenario is 3.01, or 231.92 ft.3/acre, even without considering the additional mass from small limbs and foliage that could be used in manufacturing redcedar particleboard. Assuming a weight of 50 pcf, each tree is providing 150.6 lb./tree, or 11,596.2 lb./acre. A fully loaded truck with a capacity of 40,000 pounds would carry the equivalent of 3.45 acres worth of harvested redcedar trees. Given the assumed transportation costs of $1.85 per load mile and the average distance to the facility of 100 miles, the costs would be $259.38 per delivered load, or $32.42 per 100 ft. Utilizing the whole-tree would lower the input costs, as the redcedar limbs and foliage would increase the volume of usable furnish obtained per tree and contribute to the quantity of redcedar delivered to a centralized facility.

**Panel Manufacturing and Testing**

Three eastern redcedar trees with an average of 10.3-inch diameter at breast height were harvested in Goldsby, Oklahoma. Two of the trees were limbed and only their trunks were chipped while the third tree was chipped with branches and foliage using a commercial chipper after they were bucked into smaller segments. The chips were reduced into particles using a laboratory-type hammermill without screening. Later the furnish was dried to 5 percent moisture content in a 30-ft.3 capacity dryer.

Urea-formaldehyde resin with a solids content of 65.8 percent was used as binder for the panels. The furnish for each panel was mixed with 7 percent resin based on overdried particle weight in a rotating drum type mixer for 5 min-
utes. No wax was used in this process. Thirty-six single-layer mats with dimensions of 20 by 22 by 0.5 inches were manually formed in a frame prior to pressing. Panels were made with average target density levels of 0.65 g/cm$^3$ and 0.75 g/cm$^3$. Formed mats were pressed in a computer-controlled press at a temperature of 385°F and a pressure of 780 psi for 5 minutes. Average press closing times were 14 and 17 seconds for low and high density panels, respectively (4.7).

Test samples were prepared based on ASTM D-1037 specifications and conditioned at a temperature of 70°F and 55 percent relative humidity before any tests were carried out (2). Modulus of elasticity (MOE) and modulus of rupture (MOR) were determined on a Titus Universal system and a Conten tensile tester was employed for internal bond strength (IB) tests. Density profiles of the panels were also determined using an x-ray density profilometer. Table 1 and Figure 1 show the experimental design and a typical density profile of the panels.

**RESULTS AND DISCUSSIONS**

Table 2 displays the results of both mechanical and physical tests of the panels manufactured from eastern redcedar. Type B panels, with an average density of 0.75 g/cm$^3$ and made from non-foliage furnish, gave the highest bending and IB strength values among the three types of the panels. Average values of MOE, MOR, and IB for these Type B panels were 364,571 psi, 2,557 psi, and 214 psi, respectively. Average target density of Type A and Type C panels were 0.65 g/cm$^3$. However, Type A panels were manufactured from non-foliage furnish while Type C panels contained foliage. The average MOE, MOR, and IB values for Type C panels were 329,651 psi, 1,848 psi, and 148 psi, respectively. Although no wax was used in the panels, none of the samples crumbled nor was there any separation between particles observed even after drying of the specimens at room temperature for about 1 month following the water soaking. Mechanical properties of both types were not statistically different at the 95 percent confidence level.

MOE, MOR, and IB strength of Type B panels were found to be significantly different than those of Types A and C at the 95 percent confidence level. This could be related to the density difference between the panels rather than foliage content, since Types A and C did not show any significant difference in their mechanical properties. It appears that foliage content in the furnish did not adversely influence overall strength of the panels.

MOE and MOR values of the panels made from foliage furnish were only 4 and 9 percent lower than those of the non-foliage panels, as can be observed from Figure 2. The furnish was not screened to eliminate any bark or needles during the panel manufacturing. It appears that if a certain percentage of foliage was screened from the furnish, these minor reductions in mechanical properties could have been reduced. The highest IB strength reduction due to foliage in the raw material was 13 percent (Fig. 3).

Two- and 24-hour water soaking resulted in thickness swelling ranging from 19 to 23 percent as shown in Figure 4. Based on statistical analysis, no significant difference was determined between thickness swelling values of the samples made from the two types of furnish. Although no wax was used in the panels, one of the samples crumbled nor was any separation between particles observed even after drying of the specimens at room temperature for about 1 month following the water soaking.

One of the characteristics of eastern redcedar is the oil content of the wood, which averages between 3.8 and 4.0

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**TABLE 2. — Test results for particleboard made from Eastern redcedar.**

<table>
<thead>
<tr>
<th>Test name</th>
<th>Board from furnish without foliage (type-A)$^a$</th>
<th>Board from furnish without foliage (type-B)$^b$</th>
<th>Board from furnish with foliage (type-C)$^c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOE (psi)</td>
<td>346,386 (54,014)$^a$</td>
<td>364,571 (52,112)$^b$</td>
<td>329,651 (32,034)$^c$</td>
</tr>
<tr>
<td>MOR (psi)</td>
<td>2,344 (541)$^a$</td>
<td>2,557 (402)$^b$</td>
<td>1,848 (335)$^c$</td>
</tr>
<tr>
<td>IB strength (psi)</td>
<td>172 (24)$^a$</td>
<td>214 (11)$^b$</td>
<td>148 (26)$^c$</td>
</tr>
<tr>
<td>2-hr. thickness swelling (%)</td>
<td>20 (2.6)$^a$</td>
<td>19 (5)$^b$</td>
<td>20 (1.8)$^c$</td>
</tr>
<tr>
<td>24-hr. thickness swelling (%)</td>
<td>23 (3.7)$^a$</td>
<td>24 (4.5)$^b$</td>
<td>22 (2)$^c$</td>
</tr>
</tbody>
</table>

$^a$ Density = 0.65 g/cm$^3$.
$^b$ Density = 0.75 g/cm$^3$.
$^c$ Numbers in parentheses are standard deviations.

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![Figure 2. — MOE and MOR of the samples.](image-url)
percent (1). This oil may have acted similar to a wax that is normally added for typical particleboard manufacturing.

**CONCLUSIONS**

This study investigated the use of eastern redcedar whole-tree chips in particleboard manufacturing. It appears that both physical and mechanical properties of the panels are comparable to panels made from other species. Foliage content in the panels did not reduce their properties substantially. Based on the results of this study, low quality redcedar trees have potential as whole-tree chipped furnish for manufacturing particleboard. This process would provide a value-added economic incentive to convert a costly land management problem into marketable particleboard panels.

In further studies, the manufacturing and strength comparisons of single- and three-layer panels from screened particles could give a better understanding of redcedar panel properties. Three-layer panels could improve not only panel properties but also surface characteristics of the panel to be used as a substrate for thin overlays.

**LITERATURE CITED**