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INTERIOR COMPOSITE PANELS FROM UNDER-UTILIZED WOOD AND NON-WOOD SPECIES

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***Abstract**:*
Production of interior composite panels from under-utilized wood and non-wood species is getting more popular in many countries. Rice straw, jute, coconut fiber, oil palm and bagasse are only some of such resources that can be used to produce different types of interior composite panels including particleboard and medium density fiberboard (MDF). In addition to agricultural waste fibers, bamboo is also getting more attention from composite panels manufacturers in Asian countries as an alternative material. Invasive species such as eastern redcedar (Juniperus virginiana L.) in South Western states in the USA would also be considered as viable raw material to manufacture above products. The main objective of this study was to investigate both physical and mechanical properties of experimental panels manufactured from above raw materials. Both mechanical and physical properties of such panels were evaluated. Panels made 100% bamboo resulted in the best properties among the other samples. Having rice straw in the panels reduced both physical and mechanical properties of the samples. Manufacturing sandwich type of panels with fibers on the face layers while particle of the same type of material in the core improved overall surface quality of the specimens as compared to those made from single layer panels.

***Key words**: particleboard; fiberboard; eastern redcedar; bamboo.*

INTRODUCTION

Under-utilized species such as eastern redcedar (*Juniperus virginiana L.*) is widely distributed in Oklahoma. The greatest areas of expansion have been in the southwestern part of the state, characterized by an arid climate and rocky soils, and the northwestern part of the state, primarily open prairie land dissected by waterways. State biologists are now concerned that encroaching redcedar trees may someday take over the tall grass prairies in northern Oklahoma (Adams 1987, Bidwell *et al*. 2000, Hiziroglu 2002). Area of eastern redcedar in Oklahoma with the exception of the panhandle, exceeds three million hectares (Wittwer 1985). Use of low-quality eastern redcedar as a raw material in lumber manufacturing is not currently substantial due to its low value and irregular growth pattern (Hiziroglu 2002). Eastern redcedar is a problem to farmers and ranchers who often lose crop and pasture land to the species. The trees are generally considered water-stealing and space taking nuisance. Many wildlife species that need open range also are adversely affected by eastern redcedar. Currently the wood from eastern redcedar is also used for fence posts and novelty items, while the trees themselves are planted for shelterbelts and windbreaks.

Bamboo is one of the most diverse groups of plants in the grass family which belongs to the sub-family of Bambusoidae (Zhang and Yonglan 1988, Sumardi *et al*. 2005, Jenkins *et al*. 1995). It is widely recognized as an important non-wood forest resource due not only its excellent mechanical properties but also its high socioeconomic benefit. Currently, bamboo is still considered an under-utilized non-wood species, although it has additional limited use as scaffolding, furniture units, plywood, and flooring in Asian constructional industries (Ganapathy *et al*. 1992, Bai 1996, Chagtian 2002). One of the first bamboo composite panels was developed in 1940's in China (Ganapathy *et al*. 1992).

Although particleboard is also used as substrate for thin overlays its rough surface may create certain problems resulting in show through the thin films or direct finishing applications. Medium density fiberboard which is prime substrate product for furniture and cabinet manufacture is the most widely used interior type of panel in many countries. However overall cost of MDF is more expensive and has more complicated manufacturing process than that of particleboard. Combination of fibers and particles in the form of sandwich type of panel would possibly solve such cost problem. Experimental panels with a sandwich configuration were also manufactured from bamboo particles and fibers in this work. Since fibers were used on the face layers it is expected such panels would have not only smooth surface with thin layer of fibers on the face layers but also their overall properties would be enhanced.

The main objective of this study was to explore potential suitability of eastern redcedar in the form of whole-tree chipped raw material, in addition to bamboo and rice straw fiber resources to develop value-added interior panel products, namely particleboard, medium density fiberboard (MDF) and sandwich type panels having fibers on the face layers and the coarse particles in the core layer. Both basic physical and mechanical properties of experimental panels made from such resources were tested to find if these raw materials could be used to produce experimental panels with accepted properties.

MATERIALS AND METHODS

Low quality of eastern redcedar (*Juniperus virginiana* L.) trees with diameter breast height ranging from 13cm to 17cm were harvested in various locations in Oklahoma. All of the trees were chipped with branches and foliage using a commercial chipper before the chips were reduced into smaller particles using a laboratory-scale hammermill. The whole-tree furnish was dried to 3% moisture content in a one-cubic-meter capacity dryer. Bamboo (*Dendrocalamus asper*) clumps and rice straw were harvested in Khon Khen, Prachin Buri bamboo plantation in Thailand. Bamboo samples were reduced into chips using a commercial chipper before they were hammer milled for particle production.

Bamboo fibers were produced by employing a defibrator using a pressure of 0.75MPa, at a temperature of 160^{o}C for 1.5min. Fig. 1 illustrates laboratory defibrator. Later particles and fibers were dried in a kiln at a temperature of 80^{o}C until the furnish reached to 3% moisture content. Twenty and 50% rice straw fibers and particles were also added into the various types of panels to evaluate interaction between two types of materials. Later raw material was blended with urea formaldehyde (UF) having a solid content of 65.8% in a rotating drum type blender. Based on oven dry particle weight, 8% UF resin was applied using an atomizing spray gun.

The sandwich type samples with fibers on the face layers and the particles in the core layer were also manufactured using the above set up. The core of the panels had homogeneous mix of 95% bamboo and 5% rice straw as filler using 8% urea formaldehyde resin. Fibers of both type of raw material were used at the same ratios for the face layers of the panels using 10% urea formaldehyde. Mats were compressed at a temperature of 165^{o}C and a pressure of 5MPa for 5 minutes in a computer controlled press. Average target density of the panels ranged from 0.65g/cm^3 to 0.80g/cm^3. No wax or any other additives was used for the panel manufacture. A total of 40 panels with a target thickness of 1.0cm were manufactured from different raw materials and their combinations.

Fig. 1
Laboratory type defibrator used for fiber production.

Panels were conditioned in a climate room with a temperature of 20°C and a relative humidity of 65% for about two weeks before any tests were carried out. Modulus of elasticity, modulus of rupture, and internal bond strength properties were tested on an Instron Testing Machine Model-22, 5500-R equipped with a load cell capacity of 5,000kg. Two and six samples were cut from each panel for bending and internal bond strength tests, respectively.

Surface roughness of the samples was also evaluated using a portable stylus type equipment, Hommel T-500 profilometer. Eight specimens with a size of 5cm by 5cm were randomly taken from each type of panel for roughness measurements. The profilometer equipment consisted of a main unit with a pick-up drive which has a skid-type diamond stylus with a 5-µm tip radius and 90° tip angle. The stylus traverses the surface at a constant speed of 1mm/sec over a 12.0-mm tracing length. The vertical displacement of the stylus is converted into electrical signals by a linear displacement detector before the signal is amplified and converted into digital information. Various roughness parameters such as average roughness (R_a), mean peak-to-valley height (R_z), and maximum roughness (R_{max}) can be calculated from the digital information. Definition of these parameters is discussed in detail in previous studies (ANSI 1999, Hiziroglu *et al*. 1996, Mummery 1993). Four random measurements were taken from each side of the samples to evaluate their roughness characteristics. Analysis of variance was used for statistical analysis of the data from the tests.

RESULTS AND DISCUSSION

The results of both mechanical and physical properties of the panels made from eastern redcedar are displayed in Table 1. Average MOE, MOR, and IB for eastern redcedar samples were 2277MPa, 12.48MPa, and 0.76MPa, respectively. A previous study found that MOE and MOR of whole-tree chipped particleboard samples ranged from 2273MPa to 16.10MPa (Hiziroglu 2002). Based on ANSI A 28.1 1725MPa , 11.02MPa, and 0.40MPa are minimum requirements for MOE, MOR, and IB of particleboard panels for M-1 grade, respectively (ANSI 1999). It seems that foliage content in the furnish did not influence adversely mechanical properties of the samples.

Table 1

Properties of panels made from Eastern redcedar (Numbers in parenthesis are coefficient of variation.)

Species	MOE (MPa)	MOR (MPa)	IB (MPa)	TS (%)	Surface roughness (µm)		
					R_a	R_z	R_{max}
ERC	2270 (12.11)	12.48 (10.21)	0.76 (12.21)	16	17.64 (0.25)	67.87 (0.17)	130.20 (0.26)

Two - and 24 - hour water soaking resulted in thickness swelling ranging from 15 to 17 percent. Although no wax was used in the panels, none of the samples crumbled nor any separation between particles was observed even after drying the specimens at a room temperature for two months following the water soaking. Oil in eastern redcedar and high extractive content may have acted similar to wax which is normally used for a typical particleboard manufacture. Eastern redcedar had an average R_a value of 17.64µm. In a typical commercially manufactured particleboard could have R_a values ranging from 3µm to 6µm (Hiziroglu1996). Therefore, roughness measurements of the samples suggest that surface quality of all of the panels was found to be very rough and not ideal for thin overlaying applications as substrate.

Results of bending properties of different types of panels made from bamboo are illustrated in Fig. 2. Medium density fiberboard samples had an average MOE and MOR values of 2273MPa and 28.66MPa, respectively. In previous studies showed that bamboo particleboard had 2420MPa and 22.57MPa for above properties (Hiziroglu *et al*. 2005, Li *et al*. 2004, Chow *et al*. 1993). In the case of sandwich type panels MOE and MOR values of the samples ranged from 1287MPa to 1910MPa and 13.77MPa to 26.30MPa depending on panel density. American National Standards ANSI-A 208 minimum MOE and MOR requirement for medium grade MDF for interior applications are 1400MPa and 14MPa, respectively (ANSI 1999). It seems that panels manufactured in this study, including sandwich type panels satisfied MOR strength requirements for general used based on ASTM standard.

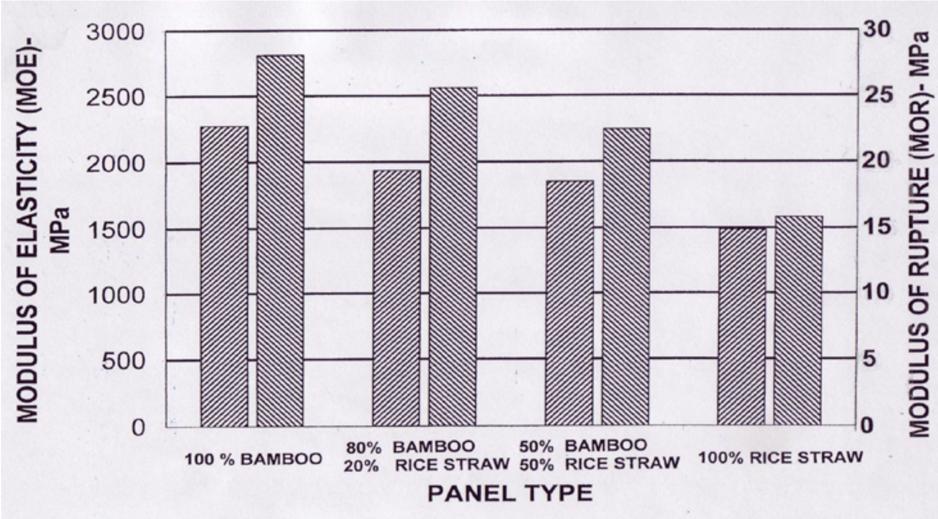

Fig. 2
Bending properties of the panels made from bamboo and rice straw.

Internal bond strength of the samples followed the similar trend of bending properties of the panels. Overall IB strength values of the samples ranged from 0.51MPa to 0.84MPa. Thickness swelling of the MDF and sandwich type samples was found to be acceptable based on the standards. Panels made from 100% bamboo fibers had 7.84% thickness swelling as a result of 2-hr water soaking. Corresponding value for sandwich type panels was 9.98% with lower density level. Using rice straw furnish as filler in the panels reduced strength properties of the samples as illustrated in Fig. 3. In general single-layer particleboard with rough surface are not used for thin overlays as substrate for cabinet and furniture manufacture. Average roughness value of bamboo particleboard was within the range of 19µm. However both MDF and sandwich type panels resulted in much smoother surface with and average R_a values ranging from 5.08µm to 7.50µm.

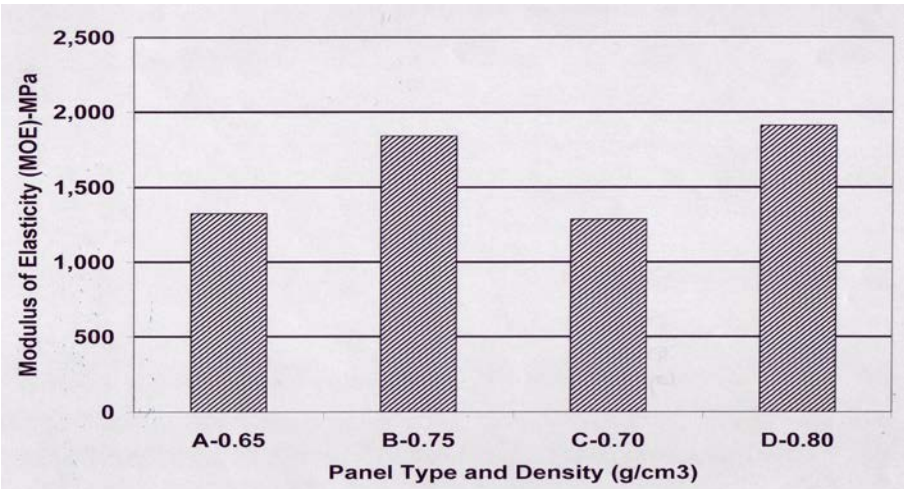

Fig. 3
Average modulus of elasticity values of the sandwich type panels made from bamboo and rice straw.

It appears that having only 20% rice straw fiber in face layers of three-layers panels did not influence significantly their surface characteristics. Panel density was found to be one of the important parameters controlling surface quality. Samples had better surface roughness with their increasing density which can be related to compactness of face layers. Based on the roughness measurement it is expected that both types of panels having fibers on the face layers can be used as substrate for even ultra thin overlay papers without having any show through effect.

CONCLUSIONS

This study briefly reviewed some of the initial findings of experimental work related to manufacture of different types of interior composite panels from eastern redcedar, bamboo and rice straw. In the light of preliminary results of the study such underutilized and non-wood species can be used to produce interior composite panels with accepted physical and mechanical properties. It appears that manufacturing composites from bamboo would provide a profitable and marketable interior panel products in many Asian countries. Using eastern recedar which is an invasive species could provide some alternative benefit to solve ecological problem in Oklahoma and surrounding states with a possibility of conversion of this resource into panel products as value-added panels.

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