Mechanical and physical properties of composite panels manufactured from Chinese tallow tree furnish

Todd F. Shupe*
Leslie H. Groom*
Thomas L. Eberhardt
Timothy G. Rials*
Chung Y. Hse*
Thomas Pesacreta

Abstract

Chinese tallow tree is a noxious, invasive plant in the southeastern United States. It is generally considered a nuisance and has no current commercial use. The objective of this research was to determine the technical feasibility of using the stem wood of this species for particleboard, fiberboard, and structural flakeboard. Due to its rapid growth, Chinese tallow tree could be a leading raw material for bio-based composite panels. This preliminary study indicated that Chinese tallow tree can be successfully used for all three composite panel types to produce panels meeting various American National Standards Institute grades based modulus of rupture, modulus of elasticity, and internal bond.

A major change has occurred in the species composition of the forests of the southeastern United States. Chinese tallow tree (*Triadica sebifera* syn. *Sapium sebiferum*) has become a serious invasive species throughout this region. The 1990s forest inventory surveys revealed 1,035,000 forestland acres with at least 1.6 ft^2 basal area/ac ($\geq$1.0 in DBH/ac) in Chinese tallow tree for three regions: east Texas, Louisiana, and Mississippi. These Chinese tallow tree "occupied" forests contained 35,997,000 tons (2.562 tons/ac), an amount equivalent to 7.4 percent of the tree biomass in these forests (Rudis 2003).

Because it grows rapidly, has seeds rich in oils, abundant flowers, and colorful fall foliage, it has been widely planted as a potential crop and as an ornamental (Jones and McLeod 1990, Jubinsky and Anderson 1996, Bruce et al. 1997). Chinese tallow tree has become naturalized from the Gulf Coast of Texas to the Atlantic Coast of North Carolina (Jubinsky and Anderson 1996, Bruce et al. 1997, Grace 1998). This invasive exotic species is currently considered noxious by the USDA Natural Resources Conservation Service (2005), which indicates that it is considered a serious pest by the agency. It produces aboveground biomass at a significantly faster rate compared to most other tree species (Harcombe et al. 1993, Rockwood et al. 1993) and is able to establish a dense stand quickly.

The crooked stem prohibits the tree from being used for most conventional lumber applications. Shupe et al. (2005) studied the effect of sample location (vertical and horizontal)

The authors are respectively, Associate Professor, Louisiana Forest Products Development Center, School of Renewable Natural Resources, Louisiana State Univ. AgCenter, Baton Rouge, LA (tshupe@agcenter.lsu.edu); Project Leader and Research Scientist, USDA Forest Serv., Southern Res. Sta., Pineville, LA (lgroom@fs.fed.us; teberhardt@fs.fed.us); Professor/Director, Tennessee Forest Products Development Center, Univ. of Tennessee, Knoxville, TN (trials@utk.edu); Principal Wood Scientist, USDA Forest Serv., Southern Res. Sta. (chse@fs.fed.us); and Director, Microscopy Center, Univ. of Louisiana–Lafayette, Lafayette, LA (tcp9769@louisiana.edu). This paper (No. 06-40-0002) is published with the approval of the Director of the Louisiana Agri. Expt. Sta. This paper was received for publication in June 2005. Article No. 10077.
*Forest Products Society Member.
©Forest Products Society 2006.
Forest Prod. J. 56(6):64-67.

within three Chinese tallow trees on wood specific gravity (SG). They found the SG (ovendry conditions) to range from 0.48 to 0.61 within the tree stems.

However, it is possible that Chinese tallow tree may be able to provide high quality composite panel products. The fairly low density and light color of the wood should be advantageous attributes for composite panel production, particularly medium density fiberboard (MDF) and particleboard. Even though Chinese tallow tree currently lacks industrial utilization, given the abundant supply and rapid growth of this species, and its designation as a federally listed noxious species, the potential to utilize this species as an industrial raw material for composite products and a source of bio-based chemicals and energy is great.

One of the barriers to Chinese tallow tree utilization is the fear that the successful development of an industrial use for the species will encourage people to cultivate the already noxious species. Accordingly, most past research emphasis on this species has been on eradication, not utilization. However, if Chinese tallow tree wood performs well as the sole furnish type for composite panels, it should also perform well when mixed with other species. Oriented strandboard is commercially produced from mixed hardwoods and previous research has shown that structural flakeboard can be successfully produced from mixed hardwood species (Shupe et al. 2001). Accordingly, as a mixed species stand is harvested, available Chinese tallow tree could be collected and utilized without adversely affecting product quality. Moreover, the successful development of commercial uses for this species might be able to aid in underwriting the costs associated with controlling the species. The objective of this research was to determine the technical feasibility of producing structural flakeboard, particleboard, and fiberboard using Chinese tallow tree wood as the furnish.

Material and methods

Three Chinese tallow trees with a diameter of breast height (DBH) ranging from 8.1 to 12.1 inches were randomly selected from a mixed hardwood forest in Rapides Parish, Louisiana. The trees were bucked into 8-foot-long bolts and converted into flakes with a laboratory disk flaker. The bark was manually removed using draw knives and discarded prior to conversion into flakes.

Three panels were produced for each particular condition of each panel type. Three specimens were tested in bending parallel to the panel length for modulus of rupture (MOR) and modulus of elasticity (MOE) from each panel for each panel type. Other tests included internal bond (IB), linear expansion (LE), and thickness swell (TS) and were performed in accordance with ASTM D1037 (ASTM 1993). Four IB specimens were cut from the ends of failed bending specimens for each panel of each panel type. Physical property tests were only performed using flakeboard samples. The LE values were measured after ovendry-vacuum-pressure-soak (ODVPS) treatment. A special optical linear micrometer as described by Suchsland (1970) was used for measuring LE. All panels were stacked on edge for 24 hours prior to cutting test specimens.

Flakeboard

The flakes measured approximately 3 inches long, 3/4-inch wide, with a thickness of 0.015 inch. All flakes were dried to a mean moisture content (MC) of 3 percent before a common, commercial phenol-formaldehyde (PF) resin (51% solids content) was applied at 3.5 percent based on ovendry furnish weight. Three panels were produced without wax and three additional panels were fabricated with 1 percent wax. The wax contained 50 percent solids content. The press times for panels with and without wax were 7.5 and 7.0 minutes, respectively. The panel target density was 42 pcf. Panels measuring 22 inches by 40 inches by 0.5 inch were pressed at 340°F with a hot-press time of 7.5 and 7.0 minutes for panels with and without wax, respectively and a press closing time of 30 seconds to stops.

Particleboard

The sawdust generated from felling the trees and preparing disks for other studies was collected and used as the furnish for the particleboard study. The particles were not classified based on size. Particles were dried to an MC of 0 percent and sprayed with 8 percent of a urea-formaldehyde (UF) resin (65% solids), based on furnish ovendry weight, which increased the particle MC from near 0 to 2.84 percent. No wax was applied. The same drum blender and resin sprayer was used to prepare each mat. The drum blender was carefully cleaned between groups to avoid cross contamination. Panels were manufactured at a target density of 45 pcf. Two panels were pressed simultaneously with each press cycle. All particleboard panel types were replicated four times. Mats were hand-felted and randomly oriented in a 17- by 19-inch forming box for a target thickness of 1/2 inch. The hot-press schedule consisted of reduction of initial pressure after 2 minutes and gradual relief of pressure during the last minute of the 4.5-minute press cycle. The platen temperature was 340°F.

Fiberboard

Flakes were reduced to particle size in a laboratory disk refiner. The refiner was adjusted to a narrower clearance and water was injected to reduce particles to fibers. Fibers were sprayed with a UF resin at 8 percent based on the ovendry weight of the wood particles.

The UF resin was 65 percent solids and increased the furnish MC from near 0 to 9.2 percent. Resin was applied in a similar manner for the fibers. No wax was applied. Resin was applied in a 50-gallon drum equipped with air injection to keep the fibers in suspension and optimize resin distribution. The same drum and resin sprayer was used to prepare each mat. The drum was carefully cleaned between groups to avoid cross contamination. Panels were manufactured at a target density of 44 pcf. One panel was pressed for each press cycle. All fiberboard panel types were replicated three times. Mats were hand-felted and randomly oriented in a 14- by 14-inch forming box for a target thickness of 1/2 inch. The hot-press schedule consisted of reduction of initial pressure after 2 minutes and gradual relief of pressure during the last minute of the 5.0-minute press cycle. The platen temperature was 430°F.

Results and discussion

The mean mechanical and physical properties for all three panel types are presented in **Table 1**. The ovendry wood SG was determined to be 0.49. The actual panel density values were converted to SG values (not shown) and then divided by the wood SG. The compaction ratio for the particleboard (1.47) and fiberboard samples (1.45) was greater than that of the flakeboard samples (ca. 1.26). It is generally considered necessary to achieve a compaction ratio of 1.3 in order to promote good bonding (Maloney 1977). The bonding of Chinese

Table 1. — Mean mechanical and physical properties for flakeboard, particleboard, and fiberboard panels produced using Chinese tallow tree wood furnish.[a]

Panel type	Resin content	Target density	Actual density	CR	MC	IB	MOR	MOE	WA	LE[b]	TS[b]
	(%)	(pcf)	(pcf)		(%)		(psi)	(1,000 psi)	------------------(%)------------------		
Flakeboard (no wax)	3.5	40	38 (1.4)[c]	1.24	4.5 (0.20)	81.4 (0.81)	3,522 (0.51)	347.9 (0.85)	138.9 (1.24)	0.075 (3.29)	20.1 (3.10)
Flakeboard (with wax)	3.5	40	39 (0.8)	1.29	4.4 (0.21)	96.3 (0.76)	4,078 (0.44)	384.0 (0.37)	122.1 (1.19)	0.067 (2.29)	13.8 (3.29)
Particleboard	8.0	45	45 (2.1)	1.47	4.9 (0.25)	116.3 (0.90)	3,445 (0.48)	499.8 (0.30)	--	--	--
Fiberboard	8.0	45	44 (1.8)	1.45	4.8 (0.16)	48.2 (0.70)	3,362 (0.44)	342.7 (0.30)	--	--	--

[a]CR = compaction ratio (actual panel density/wood density); MC = moisture content; IB = internal bond; MOR = modulus of rupture; MOE = modulus of elasticity; WA = water absorption; LE = linear expansion; TS = thickness swelling.
[b]Values measured by ovendry-vacuum-pressure-soak treatment.
[c]Values in parentheses are coefficients of variation (%).

tallow tree wood should not present any specific problems related to the extractives or inherent cell wall chemistry functionality (Eberhardt et al. 200_).

The mean internal bond (IB) of the particleboard samples was enhanced by the high compaction ratio and high resin content of 8.0 percent. Preliminary data, not shown, indicated that lower resin contents were unsuccessful at generating adequate IB results. The fiberboard samples had the same resin content and nearly identical actual panel density as that of the particleboard samples. However, the fiberboard IB was substantially lower than that of the corresponding particleboard IB samples. This difference is thought to be largely attributable to the differences in furnish geometry. Pugel et al. (1989) reported an approximately 50 percent decrease in mean IB when comparing particleboard to fiberboard using similar southern pine mature wood furnish, panel density, and resin content. The fiberboard samples did satisfy the IB requirement for LD-2 grade particleboard, and the particleboard samples met the IB requirement for M-3 grade particleboard as specified by ANSI A208-1-1999 (ANSI 1999). However, all composite panel types failed to yield IB values that satisfied the requirements for ANSI grade H-1 panels (**Fig. 1**).

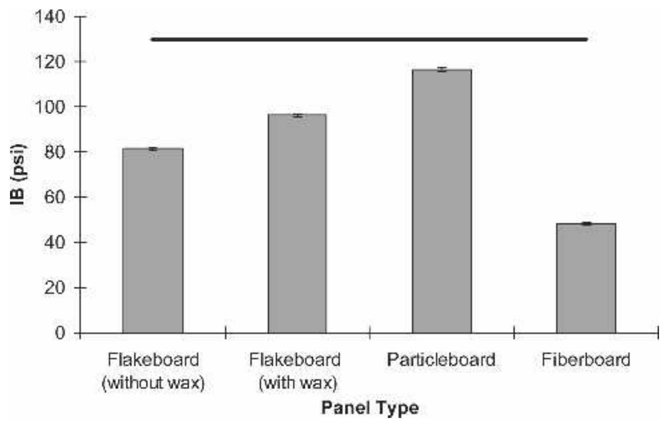

Figure 1. — Mean IB values for flakeboard, particleboard, and fiberboard made from Chinese tallow tree furnish. The horizontal line denotes the ANSI H-1 grade standard for particleboard based on ANSI A208.-1999. The vertical error bars represent one standard deviation..

The static bending properties of the panels are presented in **Table 1**. The MOR and MOE for the flakeboard samples were surprisingly good, particularly considering the low panel density and resin content used. All sample groups performed very well for bending strength and satisfied the MOR requirements for H-1 grade particleboard (**Fig. 2**). The flakeboard samples with wax and particleboard were the only two samples groups to meet the ANSI requirements for H-1 grade particleboard based on MOE (**Fig. 3**). The other groups were very near the threshold and can likely satisfy the requirement with very minimal enhancement of a key processing variable such as resin content or panel density.

The flakeboard dimensional stability properties are shown in **Table 1**. The mean values are quite good and comparable to mixed hardwood panels made in an earlier study using similar techniques (Shupe et al. 2001). As expected, the addition of wax improved dimensional stability. However, what was less expected was the improvement the wax had on the mechanical properties of all panel types. It has been previously reported that wax can improve the IB of particleboard (Talbott and Maloney 1957, Hann et al. 1962). It should be noted that most researchers have found that a wax content over 2 percent can have an adverse effect on panel properties (Gatchell et al. 1966). Although excessive wax will hinder bond formation

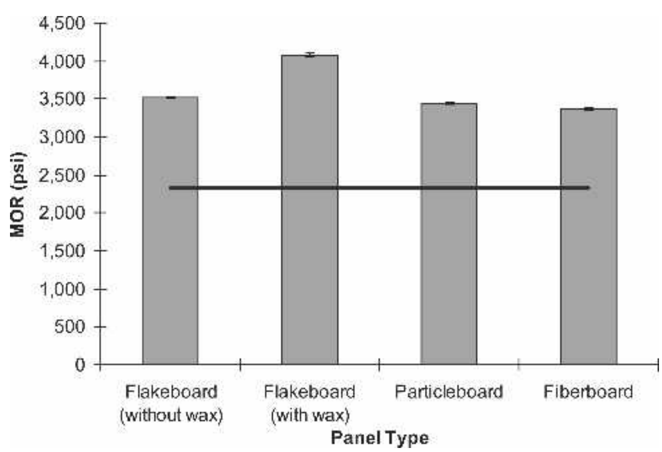

Figure 2. — Mean MOR values for flakeboard, particleboard, and fiberboard made from Chinese tallow tree furnish. The horizontal line denotes the ANSI H-1 grade standard for particleboard based on ANSI A208.1-1999. The vertical error bars represent one standard deviation.

(Kelley 1977), a moderate level of approximately 1 percent can result in a small increase in panel density and enhance the overall effect of compaction ratio on mechanical properties. In this study, the flakeboard panels with wax had a slightly

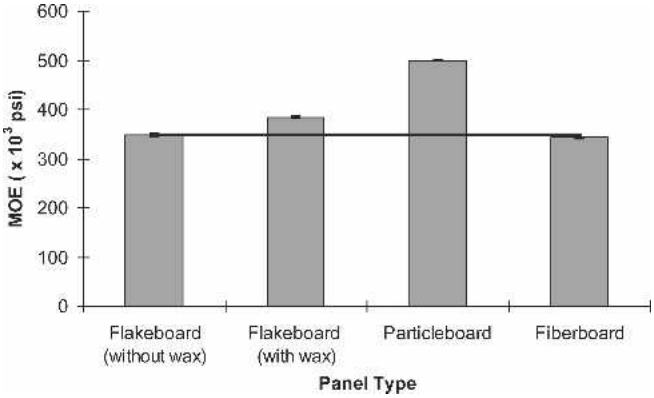

Figure 3. — Mean MOE values for flakeboard, particleboard, and fiberboard made from Chinese tallow tree furnish. The horizontal line denotes the ANSI H-1 grade standard for particleboard based on ANSI A208.1-1999. The vertical error bars represent one standard deviation.

higher compaction ratio and panel density than the corresponding panels without wax. These differences are suspected to be largely responsible for the differences in mechanical properties.

Conclusions

This study was undertaken to determine the technical feasibility of using Chinese tallow tree wood furnish for particleboard, fiberboard, and structural flakeboard. This preliminary study indicated that Chinese tallow tree can be successfully used for all three composite panel types to produce panels meeting various ANSI grades based on MOR, MOE, and IB.

Because of its rapid growth, Chinese tallow tree could be a leading raw material for bio-based composite panels. The relatively low wood density and high compaction ratio add to its utilization potential. Moreover, anecdotal evidence suggests that buyers of MDF and particleboard prefer bright colored panels, therefore the light color of Chinese tallow tree wood may be advantageous

Further research is ongoing to ascertain other critical panel properties of Chinese tallow tree. The tree utilization potential of this species cannot be realized until its basic anatomical, chemical, mechanical, and physical properties are understood. Current research is being conducted toward this end.

Literature cited

American National Standards Institute. (ANSI). 1999. Particleboard standard ANSI. A208.1-1999. Composite Panel Assoc., Gaithersburg, MD.

American Society for Testing and Materials (ASTM). 1993. Standard test methods for evaluating properties of wood-base fiber and particle panel materials. ASTM D 1037. Vol. 04.10. ASTM, West Conshohocken, PA.

Bruce, K.A., G.N. Cameron, and P.A. Harcombe. 1997. Introduction, impact on native habitats, and management of a woody invader, the Chinese tallow tree, *Sapium sebiferum* (L). Rob. Natural Areas J. 17: 255-260.

Eberhardt, T.L., X. Li, T.F. Shupe, and C.Y. Hse. 200_. Chinese tallow tree (*Sapium sebiferum*) utilization: Characterization of extractives and cell wall chemistry. Holzforschung (in review).

Gatchell, C.J., B.G. Heebink, and F.V. Hefty. 1966. Influence of component variables on properties of particleboard for exterior use. Forest Prod. J. 16(4):46-59.

Hann, R.A., J.M. Black, and R.F. Blomquist. 1962. How durable is particleboard? Forest Prod. J. 12(12):577-584.

Grace, J.B. 1998. Can prescribed fire save the endangered coastal prairie ecosystem from Chinese tallow invasion? Endangered Species Update 15:70-76.

Harcombe, P.A., G.N. Cameron, and E.G. Glumac. 1993. Above-ground net primary productivity in adjacent grassland and woodland on the coastal prairie of Texas. J. Veg. Sci. 4:521-530.

Jones, R.H. and K.W. McLeod. 1990. Growth and photosynthetic responses to a range of light environments in Chinese tallow tree and Carolina ash seedlings. Forest Sci. 36:850-862.

Jubinsky, G. and L.C. Anderson. 1996. The invasion potential of Chinese tallow-tree (*Sapium sebiferum* Roxb.) in the southeast. Castaenea 61: 226-231.

Kelley, M.W. 1977. Critical literature review of relationships between processing parameters and physical properties of particleboard. FPL GTR-10. USDA Forest Serv., Forest Prod. Lab., Madison, WI. 64 pp.

Maloney, T.M. 1977. Modern Particleboard and Dry-Process Fiberboard Manufacturing. Miller-Freeman Pub., Forest Prod. Soc., Madison, WI

Pugel, A.D., E.W. Price, and C.Y. Hse. 1989. Composites from southern pine juvenile wood. Part 1. Panel fabrication and initial properties. Forest Prod. J. 40(1):29-33.

Rockwood, D.L., N.N. Pathak, and P.C. Satapathy. 1993. Woody biomass production systems for Florida. Biomass and Bioenergy 5:23-34.

Rudis, V.A. 2003. Status of Chinese tallow (*Triadica sebifera*) from USDA FS forest inventory and analysis forest resource surveys of selected southern states (Draft). USDA Forest Serv., Southern Res. Sta., Starkville, MS. 4 pp.

Shupe, T.F., C.Y. Hse, and E.W. Price. 2001. Technical feasibility of structural flakeboard made from mixed hardwoods and cypress from northern Florida. Forest Prod. J. 51(1):62-64.

__________, L.H. Groom, and T.L. Eberhardt. 2005. Basic wood properties of Chinese tallow tree. Unpublished data. Louisiana State Univ. AgCenter, Baton Rouge, LA.

Suchsland, O. 1970. Optical determination of linear expansion and shrinkage of wood. Forest Prod. J. 20(6):26-29.

Talbott, J.W. and T.M. Maloney. 1957. Effect of several production variables on the modulus of rupture and internal bond strength of board made of green Douglas-fir planer shavings. Forest Prod. J. 7(10):395-398.

USDA Natural Resources Conservation Service 2005. Plants database. http://plants.usda.gov.