An Investigation of Factors Affecting Wettability of Some Southern Hardwoods

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Abstract

Wettability of sanded and nonsanded transverse and tangential sections of 22 southern hardwood species were judged by measurement of contact angles using phenol-formaldehyde resins. As expected, contact angle values on transverse sections were higher than on tangential sections for both sanded and nonsanded surfaces. On sanded surfaces, hackberry had the highest mean contact angle (64.7"). and black oak had the lowest mean contact angle (50.1"). On nonsanded surfaces,. winged elm had the highest mean contact angle (59.1°), and sweetgum had the lowest mean contact angle (45.9°). In addition, 4 of the 22 species (southern red oak, sweetgum, white oak, and post oak) were selected to investigate the effect of ovendrying, air-drying, and freeze-drying on wettability. The mean transverse contact angle was 2.1° to 29.0° and 5.1° to 31.5° higher than radial and tangential values, respectively. The contact angle pattern typically displayed for a given species and plane was generally ovendry > air-dry > freeze-dry. The species pattern for most drying methods and planes was: sweetgum > white oak > post oak > Southern red oak. White oak and post oak gave similar contact angle values.

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Objectives

- investigate the wettability of 22 southern hardwood species;
- determine the effect of wood plane on wettability; and
- examine the effect of three drying methods on the wettability of four southern hardwoods.

Materials and methods

Twenty-two hardwood species were selected for this study The species common name, scientific name, and specific gravity are listed in Table 1. Ten trees with a diameter at breast height between 5.5 inches and 6.5 inches outside bark were selected for each species. The sampling locations were broadly distributed throughout that portion of each species. The sample range was the 1 l-state area extending from Virginia to northern Florida and west to Arkansas and eastern Texas. Only one tree of a particular species was cut at anyone location.

Sample preparation was similar to that previously described by Choong et al. (1974). We se-

lected 5.08-cm-thick disks that were removed at 1.8 m above ground for each tree. Three dowel-shaped samples were cut from each disk using a Greenlee plug cutter. The ends of the dowels were either perpendicular to the grain (transverse), or to the radial or tangential planes. This was to guarantee that the surface of the disks was that of one of the three primary structural directions. Also, this ensured that fluid movement would be in one of the three primary structural directions. It was not possible to distinguish heartwood and sapwood in some species. Therefore, the sampling proximity to the pith was the only assurance of avoiding sapwood.

Contact angle determination

Contact angle determination was accomplished with a microscope equipped with a goniometer eyepiece. The microscope tube was arranged horizontally. The specimen was placed on the stage, and a 0.05-ml droplet of phenol-formaldehyde (PF) resin (44% solids content) was applied with a pipette to the surface of the specimen. The contact angle was measured by rotating the goniometer eyepiece so that the hairline passed through the point of contact between droplet and veneer and was tangent to the droplet at that point. All measurements were made 5 seconds after the resin or water had been dropped.

Phase 1

Phase 1 was conducted with a commercial PF resin that contained 44 percent solids. Contact angle measurements were recorded on the transverse and tangential sections of 22 species. For each specimen, one of the transverse and tangential surfaces was sanded for 5 minutes with 100-grit sandpaper. The corresponding transverse and tangential surfaces on the same specimens were left unsanded. Therefore, each sample contained sanded and unsanded transverse and tangential surfaces.

Phase 2

Phase 2 was executed with laboratory-prepared PF resin.

Table 1.—*The 22* species studied and their specific gravities. *Specific gravity* data *taken from* Choong et al. (*1* 974).

Species	Scientific name	Specific gravity range
Blackjack oak	Quercus *marilandica* Muenchh.	0.70 to 0.86
White oak	Quercus *alba* L.	0.71 to 0.91
Hackbeny	*Celtis occidentalis* L.	0.51 to 0.70
American elm	Ulmus *americana* L.	0.52 to 0.64
Water oak	Quercus *nigra* L.	0.59 to 0.78
Black oak	Quercus velutina Lam.	0.65 to 0.85
Shumard oak	Quercus *shumardii* Buckl.	0.66 to 0.83
Northern red oak	*Quercus rubra* L.	0.65 to 0.80
Post oak	*Quercus stellata* Wangenh.	0.71 to 0.98
True hickory	*Carya* spp.	0.68 to 0.90
Southern red oak	*Quercus falcata* Michx.	0.62 to 0.88
Laurel oak	Quercus *laurifolia* Michx.	0.60 to 0.74
Red maple	*Acer rubrum* L.	0.49 to 0.60
White ash	*Fraxinus americana* L.	0.64 to 0.76
Green ash	*Fraxinus pennsylvanica* Marsh.	0.51 to 0.71
Sweetgum	*Liquidambar styraciflua* L.	0.46 to 0.57
Yellow-poplar	*Liriodendron tulipifera* L.	0.36 to 0.55
Sweetbay	*Magnolia* Virginia L.	0.38 to 0.55
Cherrybark oak	*Quercus falcata* var. *pagodaefolia* Ell.	0.63 to 0.82
Winged elm	*Ulmus alata* Michx.	0.62 to 0.77
Black tupelo	*Nyssa sylvatica* Marsh.	0.45 to 0.67
Scarlet oak	*Quercus coccinea* Muenchh.	0.64 to 0.85

[a] Specific gravity determined from longitudinal permeability samples, based on ovendry weight and dimensions.

- mole ratio of formaldehyde to phenol: 1.85;
- mole ratio of sodium hydroxide to phenol: *0.45;*
- viscosity: *250* cps;
  solids content: 4 1%; and
- pH: 12.0

Conclusions

Phase 1

- Significant wettability differences existed between species (Tables 2–4).
- Transverse values were typically higher than tangential values on both sanded and unsanded surfaces.

Phase 2

- Significant wettability differences existed on the transverse, radial, and tangential sections for the four species.
- Transverse values were typically higher than radial and tangential.
- Air-dried samples on average had the highest contact angles, and freeze-dried samples usually gave the lowest contact angle values (Table 5).

Table 2.—Mean contact angle values for 22 southern hardwood species ***oh*** the ***transverse and tangential faces.*** Specimens were tested in the air-dry condition, and the surface was sanded.

	Sanded surface					
Species	Transverse surface[a]	COV	Tangential surface[a]	COV	Transverse − Tangential	Mean
		(%)		(%)		
Blackjack oak	62.0 (ABCD)	(8.0)	62.3 (A)	(4.4)	-0.3	62.2
White oak	68.3 (A)	(5.3)	S8.S (ABCDE)	(5.2)	9.8	63.4
Hackberry	67.6 (A)	(4.7)	61.7 (AB)	(4.3)	-0.1	64.7
American elm	59.3 (CD)	(8.4)	55.3 (CDE)	(5.7)	4.0	57.3
Water oak	68.3 (A)	(3.6)	58.5 (ABCDE)	(3.0)	9.8	63.4
Black oak	51.2 (E)	(8.9)	49.0 (F)	(9.0)	2.2	50.1
Shumard oak	56.5 (DE)	(12.0)	53.6 (DEF)	(5.9)	2.9	55.1
Northern red oak	63.5 (ABC)	(4.4)	57.9 (ABCDE)	(6.6)	5.6	60.7
Post oak	62.2 (ABCD)	(8.8)	55.3 (CDE)	(5.7)	6.9	58.8
Hickory	63.1 (ABCD)	(5.4)	61 .O (ABC)	(4.7)	2.1	62.1
Southern red oak	62.3 (ABCD)	(9.6)	56.3 (BCDE)	(6.6)	6.0	59.3
Laurel oak	66.7 (AB)	(4.9)	60.9 (ABC)	(5.9)	5.8	63.8
Red maple	60.0 (BCD)	(5.9)	53.4 (EF)	(7.3)	6.6	56.7
White ash	63.5 (ABC)	(6.8)	57.5 (ABCDE)	(6.1)	6.0	60.5
Green ash	62.3 (ABCD)	(5.9)	60.4 (ABC)	(3.9)	1.9	61.4
Sweetgum	60.1 (BCD)	(8.3)	56.6 (ABCDE)	(8.9)	3.5	58.4
Yellow-poplar	65.0 (ABC)	(4.28	57.5 (ABCDE)	(9.2)	7.5	61.3
Sweetbay	68.0 (A)	(4.8)	59.6 (ABCD)	(4.5)	a.4	63.8
Cherrybark oak	60.3 (BCD)	(3.9)	S9.S (ABCD)	(3.9)	0.8	59.9
Winged elm	58.9 (CD)	(6.4)	59.0 (ABCDE)	(6.2)	-0.1	59.0
Black tupelo	62.0 (ABCD)	(5.5)	58.0 (ABCDE)	(8.3)	4.0	60.0
Scarlet oak	62.2 (ABCD)	(3.9)	55.8 (BCDE)	(9.7)	6.4	59.0

[a] Each mean value represents 24 observations. Letters in parentheses represent Scheffé groupings. Species with similar letters are not statistically different at a = 0.05. Species comparisons were made within a particular surface (either transverse or tangential).

Table 3.—*Mean* contact angle valuesfor 22 southern hardwood species on the transverse **and** tangentialfaces. Specimens were tested in the air-dry condition, and the surface was not sanded.

Species	Nonsanded surface					
	Transverse surface'	cov	Tangential surface[a]	cov	Transverse - Tangential	Mean
		(%)		(%)		
Blackjack oak	52.6 (DEFG)	(9.0)	47.4 (ABCDE)	(11.4)	5.2	50.0
White oak	59.6 (BCDE)	(6.8)	51.5 (AB)	(8.9)	8.1	55.6
Hackberry	58.5 (BCDEF)	(10.1)	48.0 (ABCD)	(11.9)	10.5	53.3
American elm	52.1 (EFG)	(7.6)	43.0 (ABCDE)	(13.9)	9.1	47.6
Water oak	63.0 (ABC)	(5.5)	46.3 (ABCDE)	(12.0)	16.7	54.7
Black oak	54.8 (CDEFG)	(11.8)	44.7 (ABCDE)	(10.9)	9.6	50.0
Shumard oak	61.3 (ABC)	(6.9)	43.0 (ABCDE)	(17.3)	18.3	52.2
Northern red oak	61.1 (ABCD)	(8.9)	44.7 (ABCDE)	(11.2)	16.4	52.9
Post oak	58.6 (BCDEF)	(9.4)	38.2 (E)	(17.4)	20.4	48.4
Hickory	62.0 (ABC)	(8.7)	49.8 (AB)	(11.9)	12.2	55.9
Southern red oak	57.5 (BCDEFG)	(11.6)	49.8 (AB)	(11.9)	7.7	53.7
Laurel oak	56.2 (BCDEFG)	(10.2)	43.4 (ABCDE)	(14.8)	12.8	49.8
Red maple	62.9 (ABC)	(5.7)	39.9 (DE)	(12.8)	23.0	51.4
White ash	64.5 (AB)	(8.5)	44.3 (ABCDE)	(10.7)	20.2	54.4
Green ash	61.0 (ABCD)	(8.5)	47.2 (ABCDE)	(11.3)	13.8	54.1
Sweetgum	49.6 (G)	(10.1)	42.2 (BCDE)	(10.2)	7.4	45.9
Yellow-poplar	54.9 (CDEFG)	(9.5)	40.2 (CDE)	(13.9)	14.7	47.6'
Sweetbay	50.6 (FG)	(10.3)	44.7 (ABCDE)	(14.2)	5.9	47.7
Cherrybark oak	64.2 (AB).	(9.5)	52.3 (A)	(10.0)	11.9	58.3
Winged elm	68.6 (A)	(5.3)	49.5 (ABC)	(5.1)	19.1	59.1
Black tupelo	55.3 (CDEFG)	(9.6)	46.6 (ABCDE)	(12.5)	8.7	51.0
Scarlet oak	57.6 (BCDEFG)	(8.3)	46.0 (ABCDE)	(15.9)	11.6	51.8

[a] Each mean value represents 24 observations. Letters in parentheses represent Scheffé groupings. Species with similar letters are not statistically different at a = 0.05. Species comparisons were made within a particular surface (either transverse or tangential).

Table 4.—*Summarized* analysis of variance of the effect of 22 species and surface preparation on contact angle.

sov	df	Contact angle P—value
Species	21	0.0198[a]
Sand	1	0.0001[b]
Species x sand	21	0.0001[b]

[a] Denotes significance at a = 0.05.
[b] Denotes significance at a = 0.05.

Table 5.—*Mean* contact angle values of four southern hardwoods. Specimens were ovendried, air-dried, or freeze-dried prior to contact angle determination on *all* three planes of the wood. Each **mean value represents 30** observations. *There were 10* observations per sample.

	Ovendried					
Species	Transverse	cov	Radial	cov	Tangential	cov
		(%)		(%)		(%)
Southern red oak	53.3	(6.0)	51.2	(7.8)	-18.3	(4.9)
Sweetgum	98.0	(8.9)	69.1	(7.8)	66.5	(3.8)
White oak	71.2	(4.7)	57.2	(4.8)	56.4	(9.5)
Post oak	68.7	(4.8)	59.9	(8.7)	59.8	(9.4)
	Air-dried					
Species	Transverse	cov	Radial	cov	Tangential	cov
Southern red oak	55.2	(13.4)	46.4	(6.8)	47.7	(3.0)
Sweetgum	88.3	(9.3)	63.2	(4.4)	64.3	(6.8)
White oak	78.9	(5.0)	62.3	(4.6)	60.9	(5.5)
Post oak	72.2	(2.6)	58.5	(3.3)	58.4	(5.1)
	Freeze-dried					
Species	Transverse	cov	Radial	cov	Tangential	cov
Southern red oak	48.3	(9.0)	39.8	(5.9)	41.9	(7.2)
Sweetgum	73.5	(6.2)	55.6	(13.1)	62.2	(4.6)
White oak	68.3	(6.1)	63.3	(4.2)	55.5	(7.0)
Post oak	63.0	(4.9)	56.3	(6.1)	58.1	(7.8)