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Abstract
Pulpwood is the primary product goal of limited commercial planting of eucalypts in Florida. Pulp yield and properties of four species for three product goals were investigated. NSSC pulping of three eucalypt species and a representative native hardwood mix showed substantially higher yields of pulp from the eucalypts with acceptable strength for corrugating medium. Yield of dissolving pulp from *Eucalyptus tereticornis* wood was slightly lower than from sweetgum. *Eucalyptus grandis, E. robusta,* and *E. camaldulensis* wood gave screened yields of kraft bleached grade equal to those of representative native hardwood controls at comparable kappa numbers. Strength of handsheets was inferior while brightness was superior to controls. *Eucalyptus tereticornis* gave substantially lower screened yields of kraft bleached grade pulp at equal or higher kappa numbers than the representative hardwood controls.

Yield and properties of pulp from eucalypt wood grown in Florida

E. C. Franklin

Eucalypts were first planted in Florida before the turn of this century. Homesteaders planted seedlings to quickly obtain shade and shelter from the intense seasonal winds. A few small stands volunteered from these early introductions, but natural reproduction by eucalypts has been extremely limited. In the early 1960's efforts to introduce exotic hardwood for timber production in southern Florida were intensified. The Florida Division of Forestry made extensive introductions and started developing commercial nursery techniques. The privately endowed Florida Forest Foundation was founded with the mission to develop a hardwood timber resource, particularly in southern Florida. Replicated trials were established with 67 species and 156 seed sources of eucalypts as well as other exotic species. Three or four species showed promise for fiber production, and in 1967 the Southeastern Forest Experiment Station, Forest Service, USDA, absorbed the Foundation's research program. In 1971, the Station entered into cooperative research agreements with several forest industries and landowners* to develop a commercial planting program for eucalypt pulpwood production in Gulf Coastal areas of the United States.

Primary selection emphasis in genetic improvement has been on growth rate, survival, and cold hardiness. Cold hardiness is of particular importance because subtropical Gulf Coastal areas have more severe frosts than comparable areas of Australia. Family plus individual tree selection has been practiced for one to three generations in those species proven most adaptable to Florida: *Eucalyptus grandis* Hill ex Maiden, *E. robusta* Sm., *E. camaldulensis* Dehnh, and *E. tereticornis* Sm. Progeny tested seed orchards now support commercial production of containerized planting stock. Because pulpwood was the primary product goal, it was necessary to investigate the pulping properties of the various species which are currently available for planting and further to characterize the properties of products made from this pulp. Samples were taken from 7- to 10-year-old plantation trees, 5 to 10 in. (12.7 to 25.4 cm) diameter, growing under typical commercial conditions in central and southern Florida.

RESULTS AND DISCUSSION

NSSC for Corrugating Medium

Three species of eucalypt trees, approximately 10 years old, (*E. camaldulensis, E. robusta,* and *E. tereticornis*) were pulped by the neutral sulfite semichemical process (NSSC) (Table I). Pulps were converted to corrugating medium with results generally equal to, or better than, with native hardwoods presently used. Under the same pulping conditions eucalypts gave 4–10% higher screened yields (o.d. wood basis)

Table I. Neutral Sulfite Semichemical Pulping of *Eucalyptus tereticornis, E. robusta,* and *E. camaldulensis*, Age Approximately Ten Years, for Corrugating Medium

	Furnish			
Property	*E. tereticornis*	*E. robusta*	*E. camaldulensis*	*Native hardwood*
Wood				
Density, lb/ft^3	36	28	33	29
Moisture, % o.d. wood	30	28	32	44
Pulp				
Kappa number, ml	38	37	38	36
Screened yield, % o.d. wood	75	74	74	67
Burst index[a]	36	48	45	40
Breaking length[a], $m \times 10^{-3}$	6.5	8.7	7.2	6.8
CMT[a,b], lb	19.5	19.5	22.0	18.5
Chlorine number	23.9	...	25.2	...
Residual total alkali	5.5	...	6.4	...

[a]CSF = 400 ml.
[b]Concora Medium Test for Crush Resistance.

*Cooperators are Buckeye Cellulose Corp., Perry, Fla.; Container Corp. of America, Fernandina Beach, Fla.; Hudson Pulp and Paper Corp., Palatka, Fla.; International Paper Co., Bainbridge, Ga.; ITT Rayonier, Fernandina Beach, Fla.; Lykes Bros., Inc., Tampa, Fla.; St. Regis Paper Co., Jacksonville, Fla.

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than native hardwood controls at comparable kappa numbers. Burst and tensile tests at the same freeness (CSF) levels were higher for *E. robusta* and *E. camaldulensis* than for native hardwood, but lower for *E. tereticornis*. Crush resistance, as measured by the Concora Medium Test (CMT) was higher for all eucalypt species than for native hardwood. *Eucalyptus tereticornis* and *E. camaldulensis* pulps appeared much rougher than those from the hardwood and *E. robusta* and required more refining to reach the same freeness levels.

Yields by NSSC pulping were generally higher for eucalypts, even though the permanganate and chlorine numbers were comparable. Higher yields from eucalypts are reasonable, considering that they have lower lignin and higher holocellulose contents than native hardwoods.

Eucalypt pulp, even after refining in a small disk refiner, has substantially more shives than the hardwood controls. Eucalypt pulps also required more beating energy to reach the same freeness levels as the hardwood. After reaching the same freeness levels, the appearance was the same as the native hardwood with only a slightly darker color. Total residual alkali analysis indicated that *E. tereticornis* had slightly higher chemical demand than the *E. camaldulensis*, but results were not conclusive. The higher average density of the eucalypts indicated that their use could increase the pulping capacity of a mill.

Eucalypt pulps had higher initial tensile and CMT values and maintained this advantage over the hardwood during the beater runs. *Eucalyptus tereticornis* proved to yield the poorest pulps, falling below the native hardwood in tensile strength and never developing comparable burst strength. All curves indicated that eucalypt pulps developed equal strength at higher freeness levels to those of native hardwood. This higher freeness may offset the slightly higher energy required to meet the same freeness mentioned earlier. Bulk of the eucalypt pulps was generally higher than that of native hardwood. In addition, no increase in water drop was noted when the pulps were aged on a hot plate. These two facts indicate that eucalypt pulps should be more absorbent than pulps from native hardwoods.

Results of this trial indicated that all three species of eucalypts tested produced NSSC pulps generally equal or superior to native hardwood furnish. *E. robusta* and *E. camaldulensis* yielded stronger pulps with lower chemical consumption than did *E. tereticornis*. The generally superior pulping properties of the eucalypts compared to native hardwood could be expected to increase overall production through increased yield and pulping capacity at higher machine speeds.

Kraft Process for Dissolving Pulp

Average results of three kraft runs of *E. tereticornis* for dissolving pulp gave screened yields lower (32 vs. 35%) than comparable runs with sweetgum (*Liquidambar styraciflua* L.), even though *E. tereticornis* had slightly higher density (Table II). Brightness and alpha cellulose content did not differ significantly from those of sweetgum pulp. With the kraft process, *E. tereticornis* pulp had substantially higher lignin content than that from sweetgum (Table II).

To facilitate filtration testing, eucalypt pulp was blended with a standard pine pulp (V-68) in equal proportions. This was done to avoid problems with pressing short-fibered pulps. The blend was tested against a pure sample of pine standard V-68 pulp. Eucalypt samples shredded quite easily, which resulted in lower power requirements than those from the pine. Eucalypt samples had substantially higher viscose viscosity and did not swell as well as pine when mixed with caustic, and therefore had lower filtration values (Table II). Slightly modified processing conditions may be needed for eucalypt pulps.

Kraft Process for Bleached Grade Paper Pulp

Several trials using conventional kraft pulping processes have been done by four companies on one or more of four eucalypt species (Table III). Eucalypt wood of all species had equal or higher densities than native hardwood controls used by mills in the southeastern Gulf Coast region. *Eucalyptus tereticornis* and *camaldulensis* had the highest densities, averaging about 32 lb/ft^3, while *E. grandis* and *E. robusta* averaged 28 lb/ft^3, a value similar to that of the native hardwood. Moisture contents were generally higher than the two

Table II. Kraft Pulping of *Eucalyptus tereticornis* Sm. Wood for Dissolving Pulp by Buckeye Cellulose Corp.

Property	Furnish: *E. tereticornis*	*Sweetgum*[a]
Wood		
Density, lb/ft^3	31	29
Moisture content, % o.d. wood	54	46
Pulp		
Kappa number[b], ml	9	?
Screened yield, % o.d. wood	32	35
Brightness, %	92	94
Alpha cellulose, %	96	94
Lignin, %	0.35	0.24
Viscose viscosity, sec	74[c]	53[d]
Viscose filtration, g	806[c]	900[d]

[a]*Liquidambar styraciflua* L.
[b]TAPPI 40 ml.
[c]50% eucalypt blended with 50% pine standard V-68.
[d]100% pine standard V-68.

Table III. Pulping of Wood from Four Species of Eucalypts, With and Without Bark, for Bleached Grade Kraft Pulp by Four Companies

Company	Species	Wood density, lb/ft^3	Pulp moisture, % o.d. wood	Pulp yield, % o.d. wood	Kappa number, ml
Buckeye Cellulose Corp.	*E. tereticornis*	31	54	43	14
	Control[a]	29	46	46	11
Hudson Pulp and Paper Corp.	*E. camaldulensis* Dehnh.	33	55	45	12
	E. camaldulensis[b]	32	56	43	16
	E. grandis Hill ex Maiden	28	50	45	12
	E. robusta Sm.	28	48	48	13
	E. tereticornis	34	42	39	13
	E. tereticornis[b]	33	49	42	20
	Control[a]	...	46	47	11
International Paper Co.	*E. tereticornis*	34	49	43	12
ITT Rayonier	*E. tereticornis*	31	50	39	13
	E. tereticornis	30	51	36	15
	Control	...	...	48	12

[a]Representative hardwood furnish.
[b]With bark.

Table IV. Properties of Bleached Grade Kraft Pulp from Four Species of Eucalypts Grown in Southern Florida[a]

Mill species	*Burst, %*	*Tear, units*	*Brightness, %*	*Opacity, %*
Hudson Pulp and Paper Co.				
E. camaldulensis Dehnh	70	93	...	...
E. camaldulensis[b]	66	97	...	...
E. grandis Hill ex Maiden	62	70	87	...
E. robusta Sm.	59	85	86	...
E. tereticornis Sm.	37	82	82	...
E. tereticornis[b]	27	78	81	...
Control[c]	59	96	79	...
International Paper Co.				
E. tereticornis	148	100	88	...
ITT Rayonier				
E. tereticornis	76	130	92	82
E. tereticornis[b]	74	130	93	82
Control	100	171	91	72

[a]Results are at 300 ml CSF except for Hudson *E. tereticornis* which is at 400 ml CSF.
[b]With bark.
[c]Representative hardwood furnish.

controls although preprocess handling procedures can cause this parameter to vary widely.

Pulp yields of control samples were very consistent, averaging 47%. Debarked *E. robusta* was the only wood with pulp yields exceeding the controls. Debarked *E. camaldulensis* and *E. grandis* were second to *E. robusta,* with yields a couple of points below the controls at comparable kappa numbers. Pulp yields of debarked *E. tereticornis* were somewhat variable, averaging 5–8 points below the controls. When bark was not removed, *E. camaldulensis* showed a 4-point reduction below the controls while *E. tereticornis* showed a 2-point increase in one case and a 12-point reduction in another. In both, reduction below the yield of bark-free wood was 2 to 3 points. One consistent result of pulping with bark was a higher consumption of chemicals and thus a less complete cook under conditions similar to that of bark-free wood. This was reflected by the consistently high kappa numbers for runs which included bark.

The advantage of including bark was a general increase in tear factor through the addition of the longer bark fiber to the pulp. Of the important pulp properties, burst and tear strength were most variable (Table IV). In general, the *E. camaldulensis* pulp without bark developed very high burst without substantial loss in tear. When bark was included, the *E. camaldulensis* pulp exceeded the controls in both burst and tear strength. *Eucalyptus robusta* and *E. grandis* pulps developed burst values in excess of the controls at 300 ml CSF, but tear values were 11 and 26 points below the controls, respectively. Thus tear strength of these two pulps was deficient in this trial. Burst values for *E. tereticornis* were consistently well below the controls while corresponding tear values were slightly below to substantially above comparable controls. Inclusion of bark with the *E. tereticornis* wood did not substantially affect burst or tear strength in these trials.

Brightness of eucalypt pulps was uniformly better than controls at equal or slightly higher bleaching costs under comparable conditions. In one trial, opacity of handsheets from *E. tereticornis* pulps, with and without bark, was 10 points higher than that of the controls (Table IV).

SUMMARY

Neutral sulfite semichemical (NSSC) process gave pulp yields from *E. tereticornis, E. robusta,* and *E. camaldulensis* substantially higher than those from native hardwood furnish at comparable kappa numbers. Strength properties of test sheets indicated slight inferiority for *E. tereticornis* and slight to moderate superiority for *E. robusta* and *E. camaldulensis.* Preliminary results showed yields of dissolving pulp from *E. tereticornis* to be slightly lower than those from native sweetgum. Brightness and alpha cellulose levels were comparable. The easily shredded *E. tereticornis* pulp had lower filtration values than the controls.

Debarked *E. grandis, E. robusta,* and *E. camaldulensis* wood gave screened yields of kraft bleached paper grade pulp equal to those of representative native hardwood furnish at comparable kappa numbers. Strength properties of handsheets were generally inferior to those of native hardwood controls. Brightness of bleached pulp was equal or superior to native hardwood controls at equal or slightly higher processing costs.

Debarked *E. tereticornis* wood gave substantially lower screened yields of kraft bleached paper grade pulp at equal or higher kappa numbers than native hardwood furnish. Strength properties of handsheets were variable, with burst factor being generally lower and tear factor being equal to or higher than native hardwood furnish. Brightness of bleached pulp was superior to that of native hardwood furnish as was opacity of handsheets. Costs for bleaching were somewhat higher for *E. tereticornis* than for native hardwoods. When bark was included with chips from *E. camaldulensis* and *E. tereticornis,* screened yields of bleachable-grade kraft pulp were lower at substantially higher kappa numbers, reflecting increased chemical consumption. Tear strength was equal to or slightly higher, while burst strength was equal to or slightly lower than those of samples without bark. Changes in brightness and opacity were insignificant for *E. tereticornis* with bark.

While the general conclusions seem to be well supported by the data, comparisons between tests by different companies must be tempered with caution because of differences in control lots, processing details, and product standards.

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