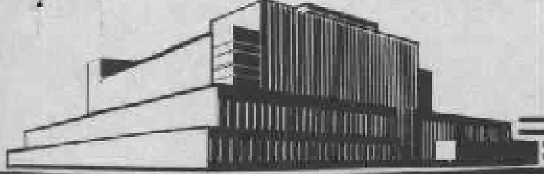
NEUTRAL SULFITE SEMICHEMICAL PULPING OF GUABA (*Inga vera*), YAGRUMO HEMBRA (*Cecropia peltata*), and EUCALYPTUS (*Eucalyptus robusta*) FROM PUERTO RICO

September 1958

No. 2127

INFORMATION REVIEWED
AND REAFFIRMED
1965



FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

NEUTRAL SULFITE SEMICHEMICAL PULPING OF GUABA (*Inga vera*), YAGRUMO HEMBRA (*Cecropia peltata*), AND EUCALYPTUS (*Eucalyptus robusta*) FROM PUERTO RICO[1]

By

E. L. KELLER, Chemical Engineer
R. M. KINGSBURY, Chemist
and
D. J. FAHEY, Technologist

Forest Products Laboratory,[2] Forest Service
U. S. Department of Agriculture

Summary and Conclusions

Eucalyptus (*Eucalyptus robusta*), guaba (*Inga vera*), and yagrumo hembra (*Cecropia peltata*) woods grown in Puerto Rico were pulped by the neutral sulfite process over a range in yield from 62 to 82 percent.

A low yield of pulp per cord of wood was obtained from yagrumo hembra, a hollow-stemmed light wood with a specific gravity of 0.29. The material cooked rapidly, however, giving unbleached pulps that approached the best of northern deciduous neutral sulfite pulps in quality. Removal of shives and dirt by centrifugal cleaning, followed by a conventional 3-stage bleach yielded 56 pounds of pulp per 100 pounds of wood. This pulp was converted into a bond paper of excellent brightness and appearance. Such pulp may also be well suited for glassine-type papers.

The eucalyptus was of medium density and showed average resistance to pulping compared with typical northern hardwood species. The resulting pulps had moderate strength and contained much more lignin than the yagrumo hembra pulps did at equal yield.

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[1] This report previously issued as a Pulp and Paper Division report of limited distribution.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

The guaba (specific gravity 0.62) was unusually dense, and so gave a large yield of pulp per cord of wood. The sodium sulfite requirement for cooking was rather high, and the cooking time was unusually long. These pulps were a little weaker than those prepared from eucalyptus. The lignin content for a given yield was 4 percentage points greater than that of pulps made from yagrumo hembra.

Because of their high lignin content, the eucalyptus and guaba pulps were not bleached. A mixture of the two woods was cooked to 74 percent yield and formed into a corrugating board that had good general strength and an excellent ring-crush resistance.

Introduction

Intensive cutting of the commercially valuable trees in Puerto Rico has left a large proportion of low-grade wood. A ready cash market for this material as pulpwood would encourage harvesting and promote reforestation of the low-fertility areas that are unsuited to more intensive agriculture. Problems of the local pulping industry in storing bagasse over the long season when freshly pressed cane is not available would also be relieved if a substitute source of fiber were at hand. However, the suitability for pulping and papermaking of those wood species, which are available in good supply, has never been demonstrated.

Three species of wood were accordingly shipped by the Tropical Research Center[3] to the Forest Products Laboratory for pulping studies. These woods were pulped by the neutral sulfite semichemical process over a range in yield from 82 to 62 percent. In this process, chips are cooked at temperatures of about 170° C. with a solution of sodium sulfite to which a small amount of sodium carbonate or sodium bicarbonate has been added. The cooked, softened chips are then reduced to fibers by mechanical means. This process has the advantages of low investment cost and the ability to operate economically on a smaller scale in contrast to the older processes. Relatively strong pulps are obtained from some broadleaved species. The material is used in a variety of products, from boards to various types of papers, such as printing, bond, and greaseproof papers.

Following preliminary pulping tests, a corrugating board was made from a mixture of two of the species, while bond paper was prepared from the third.

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[3] Forest Service, U. S. Department of Agriculture, Rio Piedras, P. R.

Wood

One-quarter cord of peeled bolts of each species was received.

A disk was cut from each bolt that was used in the preliminary pulping experiments. These disks were measured for diameter and specific gravity. A darker center that resembled heartwood was apparent only in the eucalyptus. Since this darker wood was highly permeable to air the deposition of incrustants characteristic of heartwood was presumably light. The yagrumo hembra bolts had hollow noded centers. Samples of chips from each species were analyzed for chemical composition. Although the wood was stored at Madison in the shipping containers for two years before the experiments could be started, there was no evidence of decay.

Experimental

The bolts were reduced to standard chips 5/8 inch long and passed over a gyrating screen to remove sawdust and oversized material. The cooking liquor was prepared by dissolving technical grades of sodium bicarbonate and byproduct sodium sulfite. Details of the conditions used in cooking are included in the tabulated results.

Softened chips from the small preliminary digestions (which are designated in the tables by a "y" following the identification number) were fiberized in an 8-inch, single-rotating-disk refiner and further processed in a standard test beater to obtain the strength values. The testing methods followed the recommendations of the Technical Association of the Pulp and Paper Industry. Material from the larger "N" digestions, which was intended for conversion to paper and boards, was processed in a 36-inch, double-rotating-disk refiner.

The yagrumo hembra pulp prepared for bleaching was passed through a 3-inch centrifugal cleaner before it was chlorinated. The chemical requirements for bleaching two pulps, digestions 1408y and 5621N, were determined by small-scale bleaching tests using a conventional 3-stage chlorination, alkaline extraction, and hypochlorite process. About 55 pounds of the pulp from digestion 5621N were also bleached by a 3-stage process for papermaking. Because of the small amount of pulp available, however, the chlorination was done at low consistence and washing after chlorination was omitted to avoid loss of chlorine and fine material in the pilot bleaching equipment. Consequently, additional caustic soda was required to neutralize the acid formed during chlorination and to provide the usual alkalinity for extraction.

Discussion

Wood

The specific gravity of the eucalyptus wood was moderately high (table 1). The denser guaba matched the heavier North American oaks with a specific gravity of 0.62. Such high density causes a large yield of pulp per cord of wood purchased unless counteracted by a large content of lignin or water-soluble material which would be removed in cooking. The yagrumo, on the other hand, matched the lightest North American species with a specific gravity of only 0.293. In addition to the effect of low specific gravity, the weight of pulp obtained per cord of this light wood is further reduced by the large cavity in the stem. The weight of wood processed by a digester per day would be low with such a light wood because of the large volume taken up by a unit weight of chips.

Compared with typical North American broadleaved species, the woods were rather high in lignin content and low in pentosan content (table 1). This is quite common in tropical woods. The materials soluble in hot water were low, which is favorable toward obtaining a high yield of pulp. The wood fractions soluble in organic solvents were also small, but these may be greater in freshly cut wood. The 1 percent caustic soda solubilities were well below the average except for yagrumo hembra, which also contained the most material removable with organic solvents.

Cooking

For a yield of 75 percent of pulp on the weight of the wood, the eucalyptus required about 50 pounds more of sodium sulfite per ton of pulp than the yagrumo. In turn, the guaba required about 50 pounds more than the eucalyptus (table 2). The requirement in the case of guaba was large but not excessive, and it was partially offset because less sodium bicarbonate was needed to neutralize the acids released during cooking. The spread in the sodium sulfite requirement between yagrumo and the other species was narrower at lower yields. If comparisons are made at equal lignin contents in the pulps instead of at equal yields, the differences in chemical consumption between yagrumo and the other two are even greater.

Compared with northern deciduous species, the cooking time at maximum temperature required for a given result was unusually short for the yagrumo, but exceptionally long with the guaba. These differences in cooking time suggest that the species should not be mixed indiscriminately for all types of product, although it should be possible to produce an acceptable corrugating board from the mixed woods where segregation is impractical.

Energy Required for Fiberizing

Each of the two larger scale digestions, yagrumo hembra cooked to 68 percent yield and the guaba-eucalyptus mixture cooked to 74 percent yield, was reduced to pulp by a single pass through the refiner fitted with Bauer C-914 plates. The lower yield pulp required slightly less than 10 horsepower days of energy per ton of air-dry pulp, while the pulp from mixed woods consumed 18 horsepower days. These requirements would probably be moderately lower in mill operation. The respective freenesses were 450 and 540 milliliters.

Chemical Properties of the Pulps

The high lignin contents of the eucalyptus and guaba pulps were in keeping with the high lignin contents of the raw woods (tables 1 and 3). While pulps from such species can be bleached to high brightness, the low yield of pulp and the high chemical costs would make the product relatively expensive. The yagrumo with a lignin content of 10 percent at a relatively high yield of 69 percent, coupled with good strength, makes the species more suitable for use in bleached papers. In spite of a low proportion of pentosans in the pulps, the beating times shown in table 4 were comparable to those of similar pulps from northern species.

Properties of the Unbleached Pulps

The general pulp strength increased normally as the cooking time was extended (table 4). In strength, the yagrumo hembra pulps approached those of aspen, which makes about the best quality neutral sulfite semichemical pulp of all the North American hardwoods cooked by this process. The folding endurance was especially good. Standard test sheets obtained from the yagrumo hembra were considerably denser than those obtained from the other two species.

Pulps from the other two woods had moderate strength. Such pulps commonly show a sharp increase in strength, if they are cleaned to remove shives and dirt and then fully bleached. Because of their high lignin content, however, the preparation of bleached pulps in these instances would not be overly attractive. On the other hand, full advantage could be taken of their excellent stiffness, which is characteristic of hardwood neutral sulfite semichemical pulps, by converting the unbleached material into corrugating board.

The eucalyptus and guaba pulps had a desirable property uncommon among hardwoods cooked by this process in that their maximum tearing resistance developed at a lower freeness than usual. This gave a greater tearing strength over the normal freeness range than usually would be associated with the other strength characteristics.

The yagrumo hembra gave the brightest of the unbleached pulps by a margin of from 10 to 20 points. The general level of brightness among these species was so low, however, that even the best could not be used to any extent in writing or printing papers without bleaching treatment.

Properties of Corrugating Boards

Nine-point corrugating board was made on the experimental paper machine with pulp made from equal parts of eucalyptus and guaba chips that had been cooked to a yield of 74.3 percent. According to the data in table 4, the strength of the mixed pulp was slightly lower than the average strength of these two species cooked separately to the same yield. Table 5 lists the properties of boards formed at headbox freenesses of 480 and 430 milliliters. The 50-milliliter reduction in freeness obtained by jordaning the pulp furnish increased the general strength properties appreciably. The boards had adequate strength, but did not equal, in some respects, similar boards prepared on the experimental machine from a commercial aspen neutral sulfite semichemical furnish that had given a high-grade product in mill operation. Additional improvement in strength could be obtained, if desired, by further refining or by cooking to a lower yield. The yield to which the aspen semichemical pulp had been cooked is estimated to be close to 80 percent.

In corrugating board, the most important qualities are stiffness and resistance to flat crush when converted to the final product. The stiffness, as measured by the ring-compression test, of the boards made from Puerto Rican woods, was much superior to that of the aspen board. The flat-crush resistance was also good.

Bleaching

The results of the bleaching experiments given in table 6 show that the total chlorine requirements for bleaching the yagrumo hembra pulps (about 1.4 pounds of chlorine per pound of lignin) were about the same as those for neutral sulfite semichemical pulps of the same yield and lignin content made from North American hardwoods. The bleached pulps were essentially free of dirt and partially bleached shives. The pulp bleached in the pilot plant also showed a normal increase in strength compared with the unbleached pulp.

Properties of Bleached Papers

An attractive, bright bond paper was formed from bleached pulp prepared from yagrumo hembra. Because the amount of material was insufficient for experimentation on the paper machine, the properties reported in table 7 must not be considered to be the optimum. Indeed, from the high quality shown by test sheets made from the bleached pulp (table 4), it is evident that considerably greater strength could be obtained. Papers made entirely from bleached deciduous neutral sulfite pulps, however, are characteristically low in opacity, and certain other properties do not equal the best properties of sulfite bond papers. For these reasons, it is customary to use a mixed furnish, which contains a substantial amount of coniferous fibers, to make writing and printing papers. Suitable pulps for such blending are readily available on the open market.

According to blister tests and measurements of the resistance of test sheets to penetration by turpentine, bleached yagrumo hembra pulps may be well suited for the making of glassine-type papers. Favorable results were obtained on test sheets made from pulp beaten to a Schopper-Riegler freeness of 140 milliliters.

Table 1.--Properties of three Puerto Rican woods (Shipments 4024, 4073B, 4073A)

Specific gravity[1]	Bolt diameter	Heartwood volume	Lignin content	Holocellulose content	Alphacellulose content	Pentosan content: Gravimetric	Pentosan content: Volumetric	Alcohol-benzene solubility	Ether solubility	1 percent sodium hydroxide solubility	Hot water solubility	Ash content
	In.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
EUCALYPTUS (*Eucalyptus robusta*)												
0.490	3.5	[2]40.6	27.5	66.6	47.7	16.2	12.3	2.1	0.27	12.2	2.5	0.5
GUABA (*Inga vera*)												
.620	5.6	(3)	28.0	66.2	49.6	17.3	13.3	2.3	.30	11.3	2.4	.2
YAGRUMO HEMBRA (*Cecropia peltata*)												
.293	5.4	(3)(4)	24.9	67.6	46.4	17.4	13.5	3.1	.56	15.4	2.4	.7

[1] Moisture-free weight, green volume.

[2] Judged to be heartwood from the color; air permeability unusually high for heartwood.

[3] Heartwood not apparent.

[4] Hollow center equal to 11.5 percent of the area of the sample disks.

Table 2.--Neutral sulfite semichemical pulping of three Puerto Rican woods

Digestion No.[1]	Chemicals charged to digester: Sodium sulfite: Concentration	Sodium sulfite: Amount per 100 pounds of wood[2]	Sodium bicarbonate: Concentration	Sodium bicarbonate: Amount per 100 pounds of wood[2]	Liquor charged per 100 pounds of wood[2]	Maximum temperature	Time at maximum temperature	pH of spent liquor	Na_2SO_3 content of spent liquor	Yield of unscreened pulp
	Gm. per l.	Lb.	Gm. per l.	Lb.	Gal.	°C.	Hr.:Min.		Gm. per l.	Percent
EUCALYPTUS (*Eucalyptus robusta*)										
1412y	31.6	10.2	19.5	6.5	40	170	0:11	7.1	10.9	82.5
1407y	38.8	12.8	19.0	6.3	40	170	1:00	7.7	10.7	78.7
1406y	52.6	17.3	19.1	6.3	40	170	3:10	8.0	10.0	70.9
1413y	67.4	22.3	19.4	6.5	40	180	2:15	8.6	10.0	63.6
GUABA (*Inga vera*)										
1388y	49.1	12.8	23.1	6.2	32	170	1:38	7.9	10.4	81.6
1387y	65.8	17.4	23.4	6.2	32	170	4:10	8.0	10.5	74.8
1411y	79.8	21.0	20.7	5.5	32	180	2:57	8.4	9.9	67.4
1410y	96.3	25.6	20.8	5.5	32	180	3:45	8.6	10.1	62.1
EQUAL PARTS OF EUCALYPTUS AND GUABA BY CHIP VOLUME										
5620N	51.4	15.4	20.6	6.2	36	175	2:20	....	10.6	74.3
YAGRUMO HEMBRA (*Cecropia peltata*)										
1418y	21.0	9.7	17.1	7.8	55	160	[3]3:00	7.1	9.9	83.4
1409y	30.1	13.7	13.2	6.1	55	170	:45	6.8	10.1	73.7
1408y	40.3	18.4	13.7	6.3	55	170	2:45	7.2	10.3	68.8
1417y	53.7	24.2	14.8	6.8	55	180	3:00	7.5	10.1	61.8

[1] Digestions made in indirectly heated tumbling digesters with the chips lightly steamed for 0.5 hour before adding the cooking liquor; 2.5 hours to maximum temperature; pH measured at room temperature.

[2] Moisture-free basis.

[3] 2.25 hours to 160° C.

Table 3.--Chemical analysis of neutral sulfite semichemical pulps made from Puerto Rican woods.

Digestion No.	Yield of pulp	Lignin content	Holo-cellulose content	Alpha-cellulose content	Pentosans (volumetric) content
	Percent	Percent	Percent	Percent	Percent
EUCALYPTUS (*Eucalyptus robusta*)					
1407y	78.7	19.1	70.8	57.2	11.6
1406y	70.9	15.3	74.9	61.8	11.8
1413y	63.6	12.1	79.5	67.3	11.9
GUABA (*Inga vera*)					
1387y	74.8	18.4	72.0	59.5	12.6
1411y	67.4	13.3	77.4	65.0	12.7
1410y	62.1	9.4	81.1	69.0	13.2
YAGRUMO HEMBRA (*Cecropia peltata*)					
1409y	73.7	14.0	78.3	63.4	12.8
1408y	68.8	9.8	81.7	66.2	13.2
1417y	61.8	6.2	87.1	70.5	13.4

Table 4.--Physical properties of neutral sulfite semichemical pulps made from Puerto Rican woods

Digestion No.	Yield of unscreened pulp	Pulp brightness (G.E. equivalent)	Bursting strength		Tearing resistance		Breaking length		Folding endurance		Sheet density		Beating time from 500- to 250-milliliter freeness[1]
			500-milliliter freeness[1]	250-milliliter freeness[1]	500-milliliter freeness[1]	250-milliliter freeness[1]	500-milliliter freeness[1]	250-milliliter freeness[1]	500-milliliter freeness[1]	250-milliliter freeness[1]	500-milliliter freeness[1]	250-milliliter freeness[1]	
	Percent	Percent	Pts. per lb. per rm.[2]	Pts. per lb. per rm.[2]	Gm. per lb. per rm.[2]	Gm. per lb. per rm.[2]	Meters	Meters	Double folds	Double folds	Gm. per cc.	Gm. per cc.	Minutes
					EUCALYPTUS (*Eucalyptus robusta*)								
1412y	82.5	31.3	0.26	0.49	0.61	0.70	2,700	4,800	1	10	0.39	0.49	24
1407y	78.7	29.2	.32	.59	.70	.78	3,500	5,800	2	27	.38	.53	24
1406y	70.9	30.3	.32	.74	.77	.94	3,400	6,900	2	85	.39	.61	20
1413y	63.6	32.3	.41	.88	1.04	1.11	4,150	7,100	5	230	.39	.60	21
					GUABA (*Inga vera*)								
1388y	81.6	33.3	.27	.46	.64	.72	2,400	4,100	2	11	.38	.51	21
1387y	74.8	36.5	.34	.62	.75	.77	2,950	5,500	3	32	.40	.55	17
1411y	67.4	36.8	.33	.73	.85	.90	3,400	6,500	5	74	.40	.59	22
1410y	62.1	37.5	.47	.82	.96	.89	3,950	6,700	10	95	.44	.61	16
					EQUAL PARTS OF EUCALYPTUS AND GUABA BY CHIP VOLUME								
5620N	74.3	....	.25	.56	.70	.87	2,800	5,600	3	27	.38	.52	21
					YAGRUMO HEMBRA (*Cecropia peltata*)								
1418y	83.4	48.7	.29	.51	.82	.84	3,040	5,450	4	55	.45	.60	17
1409y	73.7	48.2	.63	.84	.98	.78	5,700	8,200	140	590	.62	.74	17
1408y	68.8	48.5	.63	.93	1.09	.85	6,100	9,000	145	630	.64	.76	13
1417y	61.8	48.5	.62	1.02	1.25	.93	6,000	8,800	170	720	.63	.82	16
					FULLY BLEACHED PULP FROM YAGRUMO HEMBRA								
5621N	[3]56	85.0	....	1.26	....	.94	....	9,550	....	1,370	....	.92	....

[1] Canadian Standard freeness. Interpolated values from standard beater test.

[2] Ream of 500 sheets, 25 by 40 inches.

[3] Estimated yield after cleaning and bleaching. Yield before cleaning and bleaching = 68.4 percent.

Table 5.--Properties of corrugating boards made from equal parts of eucalyptus and guaba woods from Puerto Rico[1]

Properties	Mixed Puerto Rican woods: Not jordaned	Mixed Puerto Rican woods: Jordaned	Average of aspen corrugating boards[2]
Machine run No.	4879	4880	....
Headbox freeness (Canadian Standard). milliliter	480	430	410
Weight. pounds per 1,000 square feet	25.9	26.2	26.3
Thickness. mils	9.8	9.2	7.5
Density. grams per cubic centimeter	.51	.55	.68
Bursting strength:			
Mullen. points	40.1	50.4	53.5
Unit. points per pound per ream[3]	.44	.55	.59
Tearing resistance. grams per pound per ream[3]	.74	.79	.87
Folding endurance. double folds	15	53	50
Tensile strength. pounds per inch of width	35.1	39.5	38.9
Ring compression[4]			
Machine direction. pounds	64.2	69.1	53.5
Cross machine direction. pounds	44.3	49.0	40.7
Flat crush resistance[5]. pounds per square inch	[6]20.3	[6]32.6	26.2

[1]Cooked to 74.3 percent yield.

[2]Made at Forest Products Laboratory from commercial pulp.

[3]Ream of 500 sheets, 25 by 40 inches.

[4]Test specimen 1/2 by 6 inches.

[5]Area of circular test specimen, 5 square inches, A-flute corrugation.

[6]Flutes poorly formed.

Table 6.--Bleaching experiments on *Cecropia peltata* neutral sulfite semichemical pulps

Digestion No.	1408Y		5621N		
Bleach No.	**4040**	**4041**	**4104**	**4105**	**4108**
Stage 1, chlorine					
Amount applied......percent	12.0	12.0	11.0	11.0	12.5
Amount consumed.....percent	11.8	11.8	10.9	10.9	12.4
Temperature.............°C.	25	25	25	25	25
Consistence.........percent	2	2	2	2	1.3
Duration.............hours	1	1	1	1	1
pH..........................	1.6-1.5	1.6-1.5	2.2-1.9	2.2-1.9	1.5-1.4
Stage 2, caustic soda					
Amount applied......percent	2.0	2.0	2.0	2.0	[1]7.3
Temperature.............°C.	40	40	40	40	30
Consistence.........percent	10	10	10	10	1.3
Duration.............hours	1	1	1	1	1
pH..........................	11.7-11.1	11.7-11.1	11.7-11.1	11.7-11.1	11.3-11.1
Stage 3, calcium hypochlorite					
Amount applied.....percent[2]	2.0	2.8	1.5	2.5	1.5
Amount consumed....percent[2]	1.8	2.5	1.5	2.3	1.3
Temperature.............°C.	37	37	37	37	37
Consistence.........percent	10	10	10	10	10
Duration.............hours	4	4	1.7	4	4
pH..........................	10.0-9.0	10.4-9.0	9.5-9.0	9.4-8.7	9.8-9.0
Brightness...........percent	84.6	86.8	76.5	83.5	85.0

[1]Applied on unwashed chlorinated pulp and includes alkali required to neutralize acid formed during chlorination.

[2]Calculated as available chlorine.

Table 7.--Properties of 20-pound bond paper made from yagrumo hembra neutral sulfite semichemical pulp[1]

Headbox freeness (Canadian Standard)...........milliliter:	220
Basis weight....................................pounds[2]:	48.7
Thickness..mils:	3.1
Density.......................grams per cubic centimeter:	.87
Bursting strength.............points per pound per ream[2]:	.39
Tearing resistance.............grams per pound per ream[2]:	.98
Folding endurance..........................double folds:	19
Tensile strength................pounds per inch of width:	17.7
Penetration (castor oil)........................seconds:	119
Air resistance..........seconds per 100 cubic centimeters:	227
Opacity (contrast-ratio)........................percent:	78.8
Brightness.....................................percent[3]:	87.9
Ash content.....................................percent:	4.6

[1]Estimated yield of cleaned bleached pulp was 56 percent of the weight of the wood.

[2]Ream size: 500 sheets, 25 by 40 inches.

[3]G. E. equivalent obtained on a Hunter reflectometer.