HIGH-YIELD SULFATE AND SODA SEMICHEMICAL PULPS FROM SELECTED SOUTHERN HARDWOODS AND SOUTHERN YELLOW PINE FOR THE PRODUCTION OF PAPERBOARDS

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HIGH-YIELD SULFATE AND SODA SEMICHEMICAL PULPS FROM SELECTED SOUTHERN HARDWOODS AND SOUTHERN YELLOW PINE FOR THE PRODUCTION OF PAPERBOARDS[1]

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Abstract

Seven southern hardwoods of widely different physical and chemical characteristics and a sample of Southern yellow pine for comparison have been reduced at the Forest Products Laboratory to pulps of high yield by the sulfate and the soda semichemical processes. For these experiments the customary pulpwood chips were digested with about one-half the total chemicals, at about half the concentration, as commonly employed in the commercial operation of the sulfate process. As a result, the chemicals were almost completely consumed, and a high-yield product requiring disintegration and further refinement was obtained. These high-yield pulps were satisfactorily fiberized and refined either in a Bauer mill or in a beater and made into board suitable for corrugating. The sulfate semichemical pulps were higher in strength than those made from the same species with caustic soda alone. The sulfate semichemical pulp made from the less-dense hardwoods had considerably higher strength properties than that made from the Southern yellow pine. The nine-point corrugating boards made on the Laboratory Fourdrinier machine had satisfactory strength properties, comparing favorably with commercial pine ground wood, chestnut chip, and straw corrugating boards.

Introduction

With the present pulpwood shortage, the pulp and paper industry is now confronted with the problem of producing sufficient quantities of new pulp to meet the exigencies of a wartime economy. A more effective utilization of the present wood supply through the application of high-yield

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pulping methods, especially to high density species, should materially help in alleviating this situation. Semichemical pulping methods, which result in high yields of pulp and therefore in an increased utilization of the hardwoods, or broad leaf species, offer possibilities in this direction. There is a limit, of course, to the degree of rawness to which a pulp can be made for the satisfactory production of certain grades of papers. Nevertheless, for the manufacture of paperboards, such as corrugating board, it is possible to use these high-yield pulps, especially those made from the hardwoods, which are well adapted to semichemical pulping methods.

Even though hardwoods present more wood-cutting, barking, and handling problems than the softwoods, or conifers, there are several reasons why they should be given more serious consideration for use in pulping at this time than they have received in the past. Hardwoods are plentiful in the forests east of the Rocky Mountains where they dominate much of the forested area and create silvicultural as well as forest management problems. In addition, many of the hardwoods are high in density and therefore result in high yields of pulp per unit of volume and per unit of digester space.

The Forest Products Laboratory has, for a number of years, done considerable detailed work to demonstrate the possibility of pulping hardwoods by the several modifications of the semichemical process as well as by other processes. Heretofore, much of the experimental work on the semichemical process has involved the use of either acid or neutral sulfite cooking liquors. In fact, with the exception of blackjack oak, all the species discussed here were pulped with both of these types of cooking liquors[2], and, in addition, equal portions of these hardwoods with Southern yellow pine were pulped by the sulfate process for the production of liner boards.[3]

The present article is concerned with additional experiments with the semichemical process using the more strongly alkaline liquors of the sulfate and soda processes.

Description of the Wood

The several species employed in this investigation were: black willow (Salix nigra), southern cottonwood (Populus deltoides virginiana), American elm (Ulmus americana), sugarberry (Celtis laevigata), green ash (Fraxinus pennsylvanica lanceolata), bitter pecan (Hicoria texana), blackjack oak (Quercus marilandica), and one of the Southern yellow pines. With the exception of the blackjack oak, which came from Sharp County, Arkansas, the hardwood species were logged in Phillips County, Arkansas. This region of the Delta supports almost pure stands of bottom-land hardwoods. The yellow pine was obtained in the vicinity of Bogalusa, Louisiana. Physical properties and chemical analyses of these species are recorded in table 1.

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[2]McGovern and Chidester, U. S. Forest Products Laboratory Report No. R1292.

[3]Martin, J. S., Southern Pulp and Paper Jour. 6 (7), 13 (Dec. 1943).

All the samples were classed as young growth wood and, with the exception of the blackjack oak, were of comparatively rapidly grown stock. Outstanding in these respects were the samples of black willow, and cottonwood, which, although twice the age, were comparable in growth rate to the Southern yellow pine. The green ash, sugarberry, and pine contained no heartwood. As shown in table 1, the diameter of some of the logs was somewhat larger than those commonly used for pulpwood.

Two of the species, black willow and southern cottonwood, represent diffuse-porous woods; the others, with the possible exception of bitter pecan, a borderline case, represent ring porous woods. The Southern yellow pine, on the other hand, is nonporous. Since, among the physical properties of these samples, the greatest variation occurred in the density of the woods (23.5 pounds per cubic foot for black willow and 39.6 pounds for blackjack oak), the species are arranged in table 1 in the ascending order of their density to facilitate comparison.

In addition to the variation in the density of the woods, the data in table 1 show that some of the species differed considerably in chemical composition. This is particularly noticeable in their cellulose content, which, in general, varied indirectly with their density from 54 percent for green ash to 63 percent for cottonwood. Sugarberry and green ash were low in alpha-cellulose, whereas the others, especially the lighter woods, had fairly high alpha-cellulose contents. Except for the low lignin content of sugarberry, this constituent increased as the density of the wood increased. The pentosan contents were high in all the hardwoods in comparison to that of the pine, especially that of sugarberry. Sugarberry and green ash were higher than the other species in materials soluble in hot water and in 1 percent caustic soda solution. The ether solubility of all the hardwoods was low, while their caustic soda and hot water solubilities were high in comparison with the pine.

Description of Experiments

Usually in the operation of other modifications of the semichemical process such as that employing neutral sodium sulfite cooking liquors, the chips are merely impregnated with the cooking liquor, and excess liquor not absorbed and retained by them is returned to tanks for fortification and re-use. In these experiments, however, where soda and sulfate liquor were used, the chips were charged with a definite volume of cooking liquor, all of which was allowed to remain in contact with the chips for the duration of the cooking period, just as in the commercial operation of these processes.

The sulfidity of the cooking liquors for all the sulfate digestions was 33.9 percent, which corresponds to a 2 to 1 ratio of caustic soda and sodium sulfide, respectively. The initial concentration of the chemicals in the cooking liquor (including moisture in the wood) was 25 grams per liter except for digestions of American elm (digestion No. 2556) and blackjack oak (digestion No. 2517), where the concentrations were 30 and 40 grams per liter, respectively. The total weight of the chemicals (calculated as caustic soda and sodium sulfide for the sulfate cooks and as caustic soda for the soda cooks) charged per 100 pounds of moisture free wood was 10 pounds; thus the sodium oxide content was 7.82 and 7.75 pounds, respectively, for the sulfate and the soda digestions. By using these low concentrations and a low chemical-wood ratio, high-yield pulps of the semichemical type were obtained.

The digestions were made in a tumbling-type digester with a capacity of 14 cubic feet, which was heated indirectly by a surrounding steam jacket. The customary 5/8-inch chips, which had been prepared in a 48-inch diameter chipper, were used. A linear temperature-increase schedule was employed to raise the temperature of the digester from about 30° C. to the maximum cooking temperature of 170° C. in 1-3/4 hours, where it was held for a period of 1-1/2 hours.

After cooking for the prescribed time, the chips were dumped from the digester and washed. With the exception of the blackjack oak, they were then fiberized in a Bauer mill prior to conversion to nine-point corrugating board on the Laboratory Fourdrinier machine. The cooked blackjack oak chips were fiberized and processed in a beater to illustrate the possibilities of using this type of equipment as well.

The chemical composition of the fiberized pulps and their physical properties are recorded in table 2.

Discussion of Results

The data showing the cooking conditions and the results of the pulping experiments are recorded in table 2; the strength properties of the nine-point corrugating boards made from the pulps are recorded in table 3.

As would be expected in cooking under the conditions chosen, the chemicals were almost completely consumed in each digestion, and high pulp yields were obtained from all the woods tested. Although, as previously shown, the species differed considerably in their chemical composition, the yields of pulp obtained by either the sulfate or the soda semichemical processes fell within a narrow range (73 to 78 percent). The lowest yield (73 percent) was obtained from American elm (cook 2556). Although this wood was cooked with a liquor slightly more concentrated than that used for most of the other species, its somewhat lower yield cannot be attributed to this fact, for the blackjack oak with a lower cellulose content and higher lignin and extractives contents, gave a yield of 75.7 percent even though it was cooked at a still higher concentration.

Pulp Properties

The freeness values of the pulps after Bauer milling and before processing in the test beater were low in comparison with ordinary kraft pulps from the same species. This probably indicates that in addition to fiberization some fibrillation and cutting of the fibers has occurred. Both the hardwood pulps and the pine pulps required only short periods of additional processing in the test beater to lower their freeness to 550 cc. (Schopper-Riegler). The density values of the sheeted Bauer-milled pulps, with the exception of black willow and cottonwood, were about equal to values obtained from well-cooked sulfate pulps but, in contrast to such pulps, showed little increase in sheet density on continued beating in the test beater. There appeared to be a trend indicating an increase in pulp sheet density with a decrease in the density of the wood. In general, there was a trend toward an increase in the strength properties of the hardwood pulps as the density of the wood decreased.

The sulfate semichemical pulps were higher in strength than those made from the same species with caustic soda alone. Most of the hardwood pulps, especially those from the less dense species, were considerably stronger than that from the longer-fibered Southern yellow pine, which must be cooked to much lower yields before the inherent strength in its fibers is realized.

Chemical Analysis of Pulps

Like the strength properties, the cellulose and alpha-cellulose contents of both the sulfate and soda hardwood semichemical pulps increased with a decrease in density of the wood and were considerably higher than those of the pine pulps. The reverse was true regarding their lignin content. There appeared to be no special trend regarding the pentosan contents of the pulps, but, as expected, all the hardwood pulps contained much more of this type of material than the Southern yellow pine pulps.

Properties of the Nine-point Corrugating Boards

The data in table 3 compare the strength properties of the nine-point experimental boards made on the Laboratory Fourdrinier machine with those of several commercial boards of the same type.

In general, the strength properties of the boards varied considerably among the several species and also as to the pulping process employed. The sulfate semichemical boards were considerably stronger in all respects than those made entirely with caustic soda liquors. The trend in bursting and tensile strengths and the densities of the corrugating boards, like those of the corresponding pulps, showed an increase as the density of the woods decreased. Of special interest, is the fact that the hardwood semichemical boards were superior in bursting and tensile strengths to those made from Southern yellow pine by the same method. In their tearing resistance the black willow and American elm corrugating boards were outstanding among the boards made from the several hardwoods and were even slightly superior to that made from the long-fibered Southern yellow pine.

The experimental hardwood semichemical boards were at least equal to and in most cases superior to the various types of commercial boards in all strength properties with the exception of bursting and tearing strength of the pine kraft board. Noteworthy is the fact that the tensile strength of several of the hardwood boards far exceeded that of the commercial pine kraft corrugating material.

One of the most noticeable characteristics of the hardwood sulfate semichemical boards is their high degree of stiffness, a property which is desirable in the fabrication of wound tubes and laminated solid fiberboards as well as in corrugating containers.

The sulfate semichemical blackjack oak nine-point board was run over the Laboratory corrugating machine and fabricated into corrugated box boards by gluing either to a 16-point kraft liner or to a blackjack oak liner made from the same kind of pulp. In view of the good quality of the semichemical blackjack oak board and its performance on the corrugating machine it was indicated that corrugated container boards made from this material would be satisfactory in every respect. Since the blackjack oak board was one of the weaker nine-point boards, the suitability of the other hardwood boards is indicated.

Conclusions

The experimental data indicate that hardwood soda and sulfate semichemical pulps of high yield (75 percent) are technically satisfactory for the production of nine-point corrugating boards and also indicate the possibilities for their use in other products.

Table 1.--Physical and chemical characteristics of seven selected southern (Arkansas) hardwoods and southern (Louisiana) yellow pine (Average values)

Wood	Physical properties						Chemical analyses							
Species	Shipment	Diameter	Age	Growth rate	Density[1]	Heartwood	Cellulose	Alpha cellulose	Lignin	Total pentosans	Solubility in Alcohol-benzene	Solubility in Ether	Solubility in 1 percent NaOH	Solubility in Hot water
	No.	Inches	Years	Rings per inch	Pounds	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Southern yellow pine	1554	7.2	13	3.8	29.3	......	59.4	43.8	27.8	11.5	2.2	1.2	9.5	1.9
Black willow (Salix nigra)	1549	15.5	28	3.7	23.5	36.9	61.6	46.6	21.9	18.8	2.2	.3	17.4	3.6
Southern cottonwood (Populus deltoides virginiana)	1548	13.0	27	4.1	23.7	43.4	63.2	46.5	23.6	19.0	1.8	.4	15.4	2.0
American elm (Ulmus americana)	1550	13.7	56	8.2	29.3	21.6	58.3	46.9	24.3	18.1	2.6	.4	16.7	3.6
Sugarberry (Celtis laevigata)	1545	9.9	47	9.5	30.5	None	54.4	40.2	20.8	21.6	3.1	.3	22.7	6.4
Green ash (Fraxinus pennsylvanica lanceolata)	1546	10.2	46	9.2	32.4	None	53.7	41.0	25.3	16.5	5.5	.5	18.4	6.8
Bitter pecan (Hicoria texana)	1547	22.7	88	7.9	36.6	30.9	55.8	44.4	25.1	19.2	3.6	.5	16.4	4.6
Blackjack oak (Quercus marilandica)	1508	5.6	48	17.1	39.6	45.8	56.6	43.9	26.3	20.1	3.5	.6	15.0	4.7

[1] Moisture-free weight per cubic foot green volume.

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Table 2.--Results of pulping selected southern hardwoods and southern yellow pine by the sulfate and soda semichemical processes

Digestion Number	Wood: Species Name	Wood: Shipment (Number)	Wood: Moisture content (Per cent)	Weight: Moist (Pounds)	Weight: Moisture-free (Pounds)	Cooking[1] and yield data: Chemicals charged: Concentration: NaOH (Grams per liter)	Concentration: Na_2S (Grams per liter)	Concentration: Total (Grams per liter)	Concentration: Total Na_2O (Grams per liter)	Concentration: Total effective alkali as NaOH (Grams per liter)	Per 100 pounds moisture-free wood: NaOH (Pounds)	Per 100 pounds: Na_2S (Pounds)	Per 100 pounds: Total (Pounds)	Per 100 pounds: Total Na_2O (Pounds)	Per 100 pounds: Total effective alkali as NaOH (Pounds)	Chemicals consumed: Ratio of combined to total alkali (Per cent)	Chemicals consumed: On moisture-free wood (Per cent)	Chemicals consumed: Total effective alkali as NaOH (Per cent)	Black liquor density at 15° C. (°B.)	Total yield of moisture-free pulp (Per cent)	Interpolated test-beater strength data on unbleached pulp (Tests made at 72° F. and 65 percent relative humidity) (Ream size 25 x 40 - 500): Freeness (Schopper-Riegler) (cc.)	Time of treatment (Minutes)	Bursting strength (Points per pound per ream)	Tearing resistance (Grams per pound per ream)	Tensile strength (Pounds per square inch)	Density (Grams per cc.)	Color of unbleached pulp Ives readings: Red (Parts)	Green (Parts)	Blue (Parts)	Chemical analysis: Cellulose: Total (Per cent)	Cellulose: Alpha (Per cent)	Lignin (Per cent)	Total pentosans (Per cent)	Chlorine number (Roe) (Per cent)	Ash (Per cent)
	Series I. Sulfate semichemical process																																		
2557	Black willow	1549	16.7	132.1	110.0	16.67	8.33	25.0	19.54	20.94	6.67	3.33	10.00	7.82	8.38	99.0	9.9	8.3	5.6	77.5	710 700 550	0 2 24	0.67 .68 .84	1.2 1.2 1.1	4397 4600 6700	0.61 .61 .70	25	17	14	79.0	65.4	16.8	14.0	19.2	1.4
2560	Southern cottonwood	1548	39.3	173.0	105.0	16.67	8.33	25.0	19.54	20.94	6.67	3.33	10.00	7.82	8.38	99.0	9.9	8.3	5.9	74.7	485	0	.66	1.0	5310	.60	26	18	15	77.1	62.2	19.2	15.2	18.6	2.0
2556	American elm	1550	34.2	197.6	130.0	20.00	10.00	30.0	23.45	25.13	6.67	3.33	10.00	7.82	8.38	98.4	9.8	8.2	6.1	73.0	705 700 550	0 1 27	.47 .48 .65	1.3 1.3 1.1	2659 2700 4300	.49 .49 .60	24	15	12	75.8	63.6	21.3	13.0	22.4	1.7
2558	Sugarberry	1545	15.0	152.9	130.0	16.67	8.33	25.0	19.54	20.94	6.67	3.33	10.00	7.82	8.38	99.0	9.9	8.3	5.8	74.3	720 700 550	0 6 22	.44 .47 .58	.8 .8 .8	2700 2800 3400	.48 .49 .55	29	19	15	72.3	57.4	23.3	15.3	24.3	1.6
2561	Green ash	1546	17.2	169.1	140.0	16.67	8.33	25.0	19.54	20.94	6.67	3.33	10.00	7.82	8.38	99.0	9.9	8.3	5.9	75.3	735 700 550	0 8 24	.31 .38 .44	.7 .7 .7	1790 2500 3200	.42 .46 .51	27	17	14	70.0	56.6	24.7	14.6	26.5	1.7
2562	Bitter pecan	1547	35.9	249.6	160.0	16.67	8.33	25.0	19.54	20.94	6.67	3.33	10.00	7.82	8.38	98.1	9.8	8.2	5.9	73.5	700 550	0 21	.42 .56	.9 .9	2740 3700	.48 .57	25	15	12	75.5	62.3	21.6	17.7	21.4	1.9
2517	Blackjack oak	1508	25.6	201.7	150.0	26.67	13.34	40.0	31.25	33.50	6.67	3.33	10.00	7.82	8.38	......	......	......	9.4	75.7	795 700 550	40 50 68	.17 .20 .24	.6 .5 .6	945 1300 1800	.36 .39 .43	18	12	9	69.8	56.8	23.2	18.7	......	......
2559	Southern yellow pine	1554	32.1	206.2	140.0	16.67	8.33	25.0	19.54	20.94	6.67	3.33	10.00	7.82	8.38	97.1	9.7	8.1	5.7	76.1	820 700 550	0 8 20	.31 .36 .35	1.2 1.2 .9	1237 1700 2400	.36 .42 .48	22	13	10	67.3	53.9	27.4	10.2	27.3	1.8
	Series II. Soda semichemical process																																		
2566	Black willow	1549	27.0	137.0	100.0	25.00	......	25.0	19.4	25.00	10.00	......	10.00	7.75	10.00	96.8	9.9	9.9	5.7	76.0	565 550	0 1	.42 .44	.6 .6	2670 2900	.54 .54	36	25	21	73.7	58.6	21.4	14.4	23.6	1.2
2565	Sugarberry	1545	16.4	155.5	130.0	25.00	......	25.0	19.4	25.00	10.00	......	10.00	7.75	10.00	98.4	9.8	9.8	5.6	78.4	790 700 550	0 15 32	.21 .25 .34	.5 .6 .6	526 1400 1900	.36 .38 .45	37	25	19	66.6	53.6	27.5	15.3	25.1	1.1
2564	Southern yellow pine	1554	33.2	187.1	125.0	25.00	......	25.0	19.4	25.00	10.00	......	10.00	7.75	10.00	97.2	9.7	9.7	5.4	74.7	760 700 550	0 3 11	.23 .22 .22	1.0 .8 .6	1069 1100 1200	.33 .35 .39	35	21	15	64.2	51.6	31.2	10.0	40.4	1.5

[1]All digestions were made in a 14-cubic foot, steam-jacketed tumbling digester heated indirectly with steam. The cooking conditions other than those given were as follows:

Temperature increase period	1-3/4 hours
Duration at maximum temperature	1-1/2 hours except digestion 2556 which was cooked for 1 hour at maximum temperature
Maximum digestion temperature	170° C.
Volume of cooking liquor (including moisture in chips) per 100 pounds of moisture-free wood	48 gallons except digestions 2556 and 2517 which were 40 gallons and 30 gallons, respectively.
Sulfidity of sulfate digestions	33.9 percent

[2]Pulps were in the form of softened chips and were therefore not screenable.

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Table 3.--Properties of corrugating boards from southern hardwood and southern yellow pine sulfate and soda semichemical pulps, and commercial boards

Designation: Machine run or test	Designation: Digestion	Species or kind of board	Bauer mill[1] data: Run	Bauer mill[1] data: Freeness (Schopper Riegler)	Physical properties of machine-made papers[2] (Tests made at 75° F. and 50 percent relative humidity): Weight per ream 25x40-500	Weight per 1000 sq.ft.	Thickness	Density	Bursting strength	Tearing resistance	Folding endurance	Tensile strength	Porosity	Stretch	Gloss	Ash content
Number	Number		Number	cc.	Pounds	Pounds	Mils	Grams per cc.	Points per pound per ream	Grams per pound per ream	Double folds	Pounds per square inch	Seconds	Percent	Percent	Percent
						Series I. Sulfate semichemical pulps										
1765	2557	Black willow	22	710	145.7	42.0	9.5	0.85	0.59	1.14	979	6395	173.8	6.70	49.1	1.8
1784	2560	Southern cottonwood	29	485	136.7	39.4	9.0	.84	.64	.95	41	7035	471.4	7.30	53.0	2.9
1764	2556	American elm	21	705	117.5	33.8	9.4	.69	.38	1.13	231	3766	14.4	5.05	39.7	1.6
1783	2558	Sugarberry	27	720	97.6	28.1	8.4	.64	.44	.89	80	4127	16.2	5.05	37.5	2.1
1788	2561	Green ash	30	735	111.0	32.0	9.9	.63	.31	.66	10	3330	16.5	4.45	38.8	1.6
1789	2562	Bitter pecan	31	700	123.0	35.4	10.0	.67	.48	.92	42	4243	27.3	5.85	40.1	2.4
1613	2517	Blackjack oak	(3)	770	95.5	27.5	9.5	.55	.32	.70	....	2575	....	4.00	....	....
1787	2559	Southern yellow pine	28	820	95.2	27.4	10.0	.52	.32	1.06	55	2649	10.6	4.95	43.5	2.1
						Series II. Soda semichemical pulps										
1816	2566	Black willow	37	565	125.4	36.1	9.8	.70	.40	.94	16	5050	308.0	3.55	43.0	1.6
1815	2565	Sugarberry	33	790	85.8	24.7	9.5	.51	.19	.66	3	2490	4.0	2.25	30.0	1.8
1814	2564	Southern yellow pine	36	760	88.2	24.5	10.9	.45	.16	.83	4	1336	4.5	2.25	33.5	1.7
						Commercial Corrugating boards										
T-6767	....	Pine kraft	......	....	90.1	25.9	9.6	.52	.73	2.80	....	3988	7.0	5.50	34.2	....
T-6769	....	Pine groundwood	......	....	106.5	30.7	10.5	.56	.31	.74	....	2987	114.0	2.90	37.5	....
T-6768	....	Chestnut chip	......	....	111.2	32.0	10.9	.56	.23	.72	....	2440	20.0	2.40	50.0	....
T-6078	....	Straw	......	....	120.3	34.6	10.6	.63	.17	.64	....	1950	....	1.60	....	....

[1] Bauer mill treated pulp was given an additional light jordan treatment for machine runs 1788 and 1789.

[2] 0.5 percent rosin size was added to each run and the final pH was adjusted to 4.5 - 5.0 with alum before running over the paper machine.

[3] Processed in a 40-pound beater and jordaned, beater runs 1209 and 1210.

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5.15 C
5.22 C
5.22 H
5.22 M
5.22 McG
5.22
5.22 S
5.22 S
5.22 S
5.12
5.20