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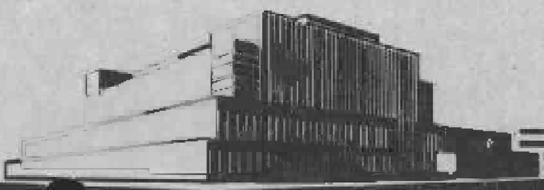

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

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

PULPS AND CORRUGATING PAPERBOARDS FROM CHESTNUT OAK[1]

By

E. L. KELLER, Chemist
and
J. S. MARTIN, Chemical Engineer

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

Summary

Pulps were made by the sulfate, sulfate semichemical, and neutral sulfite semichemical processes from chestnut oak (Quercus montana), a hardwood growing extensively in the eastern and southeastern States. The semichemical pulps produced in yields of 65 to 75 percent of the moisture-free wood on a weight basis had strength properties corresponding to those of woodpulps commonly used for corrugating paperboards. Paperboards made from these pulps compared favorably in strength properties with commercial hardwood semichemical corrugating board, and the corrugated material made, without liners, appeared to have satisfactory stiffness for containers. The sulfate pulp would probably be suitable for use in book and other printing papers to provide softness, bulk, and smoothness of surface.

Introduction

This report gives the results of experiments on the pulping of chestnut oak by the sulfate, sulfate semichemical, and neutral sulfite processes and on the production of corrugating boards from the semichemical pulps.

Chestnut oak is a ring-porous wood falling in the general class of white oaks. Its growth range extends from southern Maine through

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[1] This report was originally issued in 1949; sharing authorship at that time with the present authors were Chemical Engineer John N. McGovern and Chemist M. Heinig, both of whom have since left the Laboratory.

[2] Maintained at Madison 5, Wis., in cooperation with the University of Wisconsin.

central New York, northeastern Ohio, and southern Indiana; south to central Alabama; and northeastward in the Appalachians to the coast of New Jersey. It achieves its greatest growth in the Appalachian ranges between Pennsylvania and Georgia. On good growing sites, the tree grows to a height of 70 to 80 feet and a diameter of 20 to 30 inches. It associates with dry-soil species like black oak, chestnut, and pitch pine.

Chestnut oak is used largely for its bark in the production of tannin. A certain amount of the wood finds use as white oak lumber, a small amount is used in the soda pulp industry, and many bark-stripped trees are burned as fuel. Much of it, however, is not used at all. The experiments reported here were made to determine if chestnut oak wood can be made into a pulp satisfactory for corrugating board or other paper products and thus find utilization in pulp mills in the area of its growth.

The chestnut oak used in these experiments was obtained through the Southeastern Forest Experiment Station, Asheville, N.C., and was cut in the area of that Station.

Experimental Work

The Wood

The chestnut oak was received in the rough condition in the form of split sections of bolts approximately 15 inches in diameter. The wood was first tested for certain physical properties. The split sections, after the bark was removed with draw knives, were run through a chipper and reduced to nominal-sized 5/8-inch chips. The chips were screened on a vibrating screen to obtain material passing 1-1/4-inch openings and retained on a three-mesh screen. The acceptable chips were analyzed for chemical composition.

Sulfate Pulping

The sulfate digestions were made in duplicate in steam-jacketed, rotary, spherical autoclaves made of iron and with a capacity of 0.5 cubic foot. The independent variable in these experiments was the ratio of active chemical (sodium hydroxide plus sodium sulfide) to wood. This was varied by increasing the volume of a cooking liquor of constant chemical concentration to give three conditions affecting the degree of pulping. The pulps were screened through 0.012-inch openings of a slotted diaphragm screen, and yields of acceptable pulp and screening rejects were determined. The pulps were tested for permanganate number and for strength according to the standard TAPPI[3] beater test.

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[3] Technical Association of the Pulp and Paper Industry.

Sulfate Semichemical Pulping

Preliminary sulfate semichemical digestions were made in the autoclaves to establish conditions that were then used in single digestions in a steam-jacketed, tumbling digester made of steel and having a capacity of 14 cubic feet. The independent pulping variable was, as for the sulfate pulping, the ratio of chemical to wood. This was varied by changing the chemical concentration of the cooking liquor so as to obtain a wide difference in degree of pulping as measured by pulp yield. Yields of pulp from the autoclave digestions were determined by fiberizing the partially pulped chips in a small attrition mill, or by milling an aliquot sample taken from the digesters and washing out the soluble residues. The main portion of the partially digested chips from the larger scale cooks was fiberized in an attrition mill. The pulps were tested for strength by the standard beater test.

Neutral Sulfite Semichemical Pulping

The neutral sulfite semichemical digestions were made in duplicate in a steam-jacketed, tumbling digester lined with stainless steel and with a capacity of 13 cubic feet. The independent pulping variable was again the ratio of total chemical (sodium sulfite plus sodium bicarbonate) to wood to give semichemical pulps in a wide range of yields. The digestions consisted of four steps as follows: (1) The chips were steamed at atmospheric pressure for 0.5 hour; (2) the chips were impregnated for 1 hour at 120° C. with cooking liquor; (3) the liquor not absorbed during the impregnation period was removed from the digester; and (4) the impregnated chips were cooked at 170° C. for varying times depending on the chemical-wood ratio. The partially digested chips were fiberized, the pulp yields determined, and the pulps tested for strength.

Corrugating Board

The semichemical pulps were made into corrugating board on an experimental Fourdrinier paper machine with a 12-inch web width. The corrugating boards were tested for strength, and samples about 24 inches long were corrugated on a small commercial corrugator.

Discussion of Tests

Analysis of Wood

The density of 36.2 pounds per cubic foot found for the chestnut oak (table 1) agrees with previous values for the species. This value is slightly below the average of southern oaks. The wood had a high volume of dark-colored heartwood, which gave it an overall dark color.

The chestnut oak sample had a chemical composition (table 2) that is typical of that for several white oaks determined previously at the Forest Products Laboratory. This sample had a lignin content in the upper range of hardwoods and the lower range of softwoods in general, a low holocellulose content, and a pentosan content high in the usual hardwood range. The high solubilities in hot water and caustic soda solutions indicated the presence of water-soluble materials like the tannins and of alkali-soluble hemicellulose material of low molecular weight. The wood of chestnut oak has been reported[4] to have a tannin content of 3.3 percent and the bark 10.8 percent. The minimum economic value for commercial extraction of tannin from the wood is about 5 percent.

Sulfate Pulping

Varying the chemical-wood ratio from 17.5 to 22.5 percent resulted in yields of acceptable sulfate pulp ranging from 41.7 to 44.8 percent of the weight of the moisture-free wood (table 3). The screenings decreased from 5.1 to 0.6 percent, and the permanganate number decreased from 22.8 to 18.0. The total active chemical of 20 percent, which is a normal amount for the pulping of many softwood and hardwood species, was found to be optimum for the production of pulp with satisfactorily low screenings. The permanganate number of the pulp made with 20 percent chemical was also satisfactorily low. Increasing the chemical ratio to 22.5 percent had no advantage in appreciably increasing the yield or decreasing the permanganate number. The yield of 44.3 percent obtained under the optimum conditions was fairly high for a sulfate pulp from oak and compared favorably with that from some softwoods cooked similarly. Because of the high density of chestnut oak, high yields could be expected per unit volume of wood and per unit digester volume.

The pulps differed only slightly in strength with variation in yield within the range of the experiments (table 4). There was a trend toward decreased bursting strength at the freeness level of 600 cubic centimeters with decreasing yield. Otherwise, the pulp strength did not vary with the change in yield. These observations were not changed by adjusting the strength for the slight differences in density of the test sheets.

Because of their low strength, the chestnut oak sulfate pulps would find their best use in blends with long-fibered pulps. If cooked properly for bleaching, they could possibly be utilized as bleached filler stock in certain white papers where much strength is not essential.

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[4] Forman, Loren V., and Niemeyer, Donald D. Paper Industry 29 (4): 586-588 (July 1947).

Sulfate Semichemical Pulping

The sulfate semichemical pulps were produced in a wide yield range of 56.6 to 73.5 percent (table 3). The decrease in yield with increasing chemical consumption was closely linear within this range. For a given percentage yield, the chemical consumed in producing the chestnut oak semichemical pulps was about the same as for softwoods, but less than for many hardwoods. Stated otherwise, the percentage yields of chestnut oak sulfate semichemical pulps were lower for a given chemical consumption than those from many hardwoods. This difference is due, in the case of the chestnut oak as compared to other hardwoods, to its high content of material soluble in hot water and caustic soda (table 2).

Though varying in pulp yield, the sulfate semichemical pulps differed only slightly in strength properties (table 4). When the strength comparisons were made on the basis of pulps beaten to equal freeness values, there was found to be a small increase in all the strength properties and in the density of the test sheets with decrease in yield. These semichemical pulps were somewhat low in strength, especially in folding endurance. The strength of the pulps made in yields of 56.6 and 64.6 percent was, however, in the range needed for pulps used for corrugating board.

Neutral Sulfite Semichemical Pulping

The neutral sulfite semichemical pulps were also produced in a wide yield range, 65.1 to 82.5 percent (table 5). The chemical requirements for pulping and the pulping time increased normally with decrease in pulp yield. It is calculated that, for the production of 1 ton of air-dry pulp made in a yield of 75 percent, 55 pounds of sulfur and 275 pounds of sodium carbonate would be needed. Compared on an equal yield basis, the chemical requirements for the chestnut oak semichemical pulps were slightly higher than those found in previous experiments at the Forest Products Laboratory for two other white oaks, overcup oak and post oak. The requirements were less, however, than those for other hardwoods, such as cottonwood, yellow-poplar, tupelo, or any of the northern hardwoods. As with the several oaks tested previously, the chestnut oak was pulped to a given yield in a shorter time than other common deciduous species when using the same digestion conditions.

In general the chestnut oak gave weak neutral sulfite semichemical pulps (table 4). The highest yield pulp fell in the range of weak groundwood and insulating-board pulps. The pulp made in the medium yield was stronger than the one in highest yield, as expected, but it was in the bottom range of pulps used for material like corrugating board. The lowest yield pulp of the three was strongest in all properties.

It had roughly twice the bursting and tensile strength of the highest yield pulp and fell in the range of strong pulps for corrugating board or materials with like strength requirements. The density of the test sheets made from the three pulps also increased with decreasing yield.

Although the chestnut oak neutral sulfite semichemical pulps made in the present experiments were relatively weak, they were slightly stronger than pulps made in the same yields from overcup oak, post oak, and blackjack oak. On the other hand, compared on the basis of equal yields with semichemical pulps from hardwoods like southern cottonwood or tupelo, the chestnut oak pulps showed roughly one-half the bursting and tensile strength, two-thirds of the tearing strength, and a small fraction of the folding endurance.

The relatively dark color of chestnut oak neutral sulfite semichemical pulp (table 6) is caused by the dark color of the heartwood. Light-colored woods like cottonwood give light-colored semichemical pulps.

The chemical analysis of the pulps (table 2) showed that they have somewhat higher lignin content at a given pulp yield than for aspen or birch, for example. The relatively high lignin content indicates that the production of bleached semichemical pulps with economical yields and chlorine consumption would not be promising. The chestnut oak pulps also showed relatively high pentosan content in comparison with other species. The pentosans showed a slight tendency to increase with increasing yields. The lignin contents decreased and the holocellulose and alpha content increased with decreasing yield, as would be expected.

The relative weakness, the dark color, and the high lignin content of the chestnut oak neutral sulfite semichemical pulp might limit the usefulness of this material. It will be shown below that some of the pulps had strength properties satisfactory for corrugating board.

Properties of Corrugating Boards

The corrugating boards made from the sulfate semichemical pulps did not show any significant variation in strength with respect to pulp yield (table 6). This is in general agreement with the observations regarding the pulp strength. All of the sulfate semichemical boards approached or equaled the commercial corrugating boards in strength, except for low tearing strength in comparison with the stronger of the two commercial boards (table 6). The three experimental boards corrugated well, and the products had well-defined corrugations and, without liners, appeared to be satisfactorily stiff.

The neutral sulfite semichemical corrugating boards, like the pulps from which they were made, increased in strength with decrease in pulp yield (table 6). The board made from the pulp of highest yield was considerably weaker than commercial semichemical board (table 6) and probably would not be satisfactory for the product. It was soft and brash and had low compression resistance. The boards made from the pulps of medium and low yield did not differ greatly in strength; in fact, the difference was less than might be expected from the differences in pulp strength and headbox freeness. Both of these experimental boards equaled or closely approached the commercial corrugating boards in bursting and tensile strength and compression resistance, but were somewhat lower in tearing strength than the stronger of the two commercial boards and lower in folding endurance than both of them. The corrugated board made without liners from the highest yield pulp was quite soft and appeared unsatisfactory. The corrugated board made from the pulps of medium and low yield had well-defined corrugations and appeared to have a satisfactory stiffness.

Comparison of Sulfate and Neutral Sulfite Processes for Semichemical Pulping of Chestnut Oak

Compared on the basis of equal pulp yields, the sulfate and neutral sulfite semichemical processes gave pulps and corrugating boards having approximately the same strength properties. The neutral sulfite pulping gave pulps considerably lighter in color than the sulfate pulping. Under mill operating conditions, the chemical consumption for producing pulps in yields of 75 percent would be approximately the same, about 7 percent sodium oxide on the basis of the moisture-free wood. In yields of 65 percent, however, the chemical consumption on an equivalent sodium oxide basis for the neutral sulfite pulps would be about 12 percent, and that for sulfate pulping about 9 percent, of the moisture-free wood. The time at the cooking temperature of 170° C. was less for pulping to a yield of 75 percent with the sulfate process than the neutral sulfite process (tables 3 and 5). Considerably less time was needed for the sulfate than the neutral sulfite process to obtain pulps in a yield of 65 percent. The sulfate pulp strengths varied but little with pulp yield, whereas the neutral sulfite pulp strengths increased with decreasing yield.

Conclusions

Like other hardwood pulps, chestnut oak sulfate pulps are relatively low in strength and are likely to be most suitable for blending with longer fibered pulps in the production of soft, bulky types of paper.

Chestnut oak semichemical pulps produced in yields of 65 to 75 percent by the sulfate and neutral sulfite processes can be made into corrugating boards that compare favorably with commercial hardwood semichemical corrugating boards.

Table 1.--Growth and physical characteristics of chestnut oak

Average age[1]............................years:	147.4
Average growth rate............rings per inch:	20.9
Heartwood by volume..................percent:	73.9
Decay volume..........................percent:	3.9
Specific gravity[2]...........................:	0.58
Density[2]................pounds per cubic foot:	36.2

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[1] Rings counted on sectors of split wood. The value is probably lower than the actual age of the logs.

[2] Based on moisture-free weight and volume when green.

Table 2.--Chemical analyses of wood and neutral sulfite semichemical pulps from chestnut oak

Material	Shipment or digestion No.	Pulp yield	Lignin	Holocellulose	Alpha-cellulose	Total pentosans	Solubility in--			
							Alcohol-benzene	Ether	1 percent NaOH	Hot water
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Chips	2741	....	24.3	68.4	46.8	19.2	4.7	0.6	21.1	7.2
Pulps	5423-26	82.5	20.0	80.5	53.8	20.8	....	....	....	2.0
	5422-25	74.8	14.0	82.1	59.6	21.7	....	....	....	2.5
	5424-27	65.1	10.0	83.0	65.3	21.8	....	....	....	2.9

Table 3.--Digestion conditions and yields of sulfate and sulfate semichemical pulps from chestnut oak

Digestion No.	Cooking conditions						Pulp yield[1]			Bleach test data	
	Chemicals[2]					Black liquor density at 15° C.	Screened	Screenings	Total	Brightness[3]	Permanganate number
	Charged				Consumed						
	Initial concentration (calculated as Na_2O)	NaOH plus Na_2S per 100 pounds of moisture-free wood									
		Weight of chemical	Calculated as Na_2O	Volume of chemical							
	G. per l.	Lb.	Lb.	Gal.	Percent	°B.	Lb.	Lb.	Lb.	Percent	
Sulfate semichemical:											
2967	19.5	10.0	7.8	48.0	93.4	5.8	....	....	73.5	....	....
2030X, 2031X	19.5	10.0	7.8	48.0	100.0	6.1	....	....	69.6	....	....
2968	24.4	12.5	9.8	48.0	95.8	7.6	....	....	64.6	....	....
2969	29.3	15.0	11.7	48.0	95.3	8.9	....	....	56.6	....	....
Sulfate:											
2036X, 2038X	39.1	17.5	13.7	42.0	94.9	11.3	41.7	5.1	46.8	37.3	22.8
2027X, 2028X	39.1	20.0	15.6	48.0	90.0	11.0	44.3	.9	45.3	56.0	18.1
2029X, 2033X	39.1	22.5	17.6	54.0	90.7	10.7	44.8	.6	45.4	....	18.0

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[1] Moisture-free pulp per 100 pounds of moisture-free wood.

[2] All cooks made at 30 percent sulfidity, 170° C. maximum temperature, 1.5-hour temperature rise period, and 1.5 hours at maximum temperature except for cook 2967 in which the time at 170° C. was 0.

[3] Pulp bleached with 8.75 percent chlorine.

Table 4.--Properties of chestnut oak sulfate and semichemical pulps

Digestion No.	Pulping process	Pulp yield	Freeness[1] (Canadian Standard)	Bursting strength[1]	Tearing strength[1]	Breaking length[1]	Folding endurance[1]	Density[1]
		Percent	Cc.	Pts. per lb. per ream[2]	G. per lb. per ream[2]	M.	Double folds	G. per cc.
2029-33	Sulfate	[3]44.8	600	0.30	0.60	2,100	3	0.48
			450	.45	.90	4,200	12	.60
2027-8	.......do........	[3]44.3	600	.26	.60	2,200	3	.50
			450	.46	.87	4,100	30	.62
2036-8	.......do........	[3]41.7	600	.23	.60	2,900	4	.47
			450	.46	.88	4,400	10	.57
2969	Sulfate semichemical	56.6	600	.20	.68	2,300	3	.43
			450	.37	.95	3,600	9	.51
2968	.......do........	64.6	600	.19	.62	2,100	2	.42
			450	.32	.92	3,100	7	.48
2030-1	.......do........	69.6	600	.17	.58	800	1	.37
			450	.27	.97	1,800	3	.44
2967	.......do........	73.5	600	.15	.58	1,800	1	.37
			450	.24	.73	2,600	2	.43
5424-7	Neutral sulfite semichemical	65.1	600	.20	.52	1,900	2	.44
			450	.34	.72	3,100	5	.54
5422-5	.......do........	74.8	600	.13	.52	1,400	2	.40
			450	.24	.65	2,450	3	.48
5423-6	.......do........	82.8	600	.09	.42	750	0	.34
			450	.15	.52	1,450	0	.40

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[1] Interpolated data from freeness vs. strength and density curves.

[2] Five hundred 25- by 40-inch sheets, the standard ream.

[3] Yield of screened pulp.

Table 5.--Digestion conditions and yields of neutral sulfite semichemical pulps from chesnut oak[1]

Digestion No.	Impregnation liquor[2]		Chemicals absorbed[3]		Digestion time at 170° C.	Na_2SO_3 in spent liquor	Pulp yield
	Na_2SO_3	$NaHCO_3$	Na_2SO_3	$NaHCO_3$			
	G. per l.	G. per l.	Percent	Percent	Hr.	G. per l.	Percent
5424-27	141.6	50.6	17.8	8.2	4.25	12.1	65.1
5422-25	89.9	24.4	9.1	6.0	1.0	9.7	74.8
5423-26	43.7	24.0	4.9	5.4	[4].12	12.6	82.8

[1] Averages of results from duplicate digestions.

[2] Impregnation time, 1 hour at 120° C.

[3] Based on weight of moisture-free wood.

[4] Digestion temperature, 160° C.

Table 6.--Properties of experimental chestnut oak and commercial semichemical corrugating boards

Machine run No.	Semichemical pulping process	Pulp yield	Headbox freeness[1]	Properties of corrugating board										
				Weight	Caliper	Density	Strength				Stretch	Folding endurance	Compression endurance	Brightness
							Bursting		Tearing	Tensile				
							Mullen	Unit						
		Percent	Cc.	Lb. per 1,000 sq. ft.	0.001 in.	G. per cc.	Pts.	Pts. per lb. per ream[2]	G. per lb. per ream[2]	Lb. per in. width	Percent	Double folds	Lb.	Percent
							CHESTNUT OAK							
3036	Sulfate	56.6	450	26.4	9.0	0.55	31.4	0.34	0.90	28.5	2.0	....	11.7	....
3035	...do....	64.6	380	26.4	9.1	.56	32.3	.35	1.02	28.9	2.0	....	12.0	....
3034	...do....	73.5	360	26.4	9.3	.56	32.6	.35	.82	27.6	2.0	....	12.5	....
3039	Neutral sulfite	65.1	320	26.0	9.2	.54	35.4	.39	1.06	33.4	1.9	8	12.3	22
3037	...do....	74.8	390	25.9	9.6	.52	30.3	.34	.99	29.4	1.5	6	12.0	22
3038	...do....	82.8	435	25.8	10.0	.50	16.5	.19	.57	14.9	1.4	0	6.2	22
							COMMERCIAL HARDWOOD BOARDS							
[3]2786	Neutral sulfite	....	....	27.6	8.5	.63	28.0	.29	.81	24.8	1.6	15	12.9	....
[3]2785	...do....	....	....	26.6	9.8	.52	32.0	.34	1.33	33.7	1.9	36	12.9	....

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[1] Canadian Standard.

[2] Five hundred 25- by 40-inch sheets, the standard ream.

[3] Shipment No.

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