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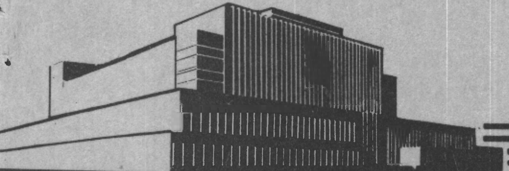

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

PULPING OF ASIAN AND AUSTRALASIAN WOOD AND PLANT FIBERS

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Summary

This report briefly discusses pulping and papermaking experiments by the U.S. Forest Products Laboratory on 14 broad-leaved and coniferous species of wood and 7 fibers and plants from Asian and Australasian countries made at times over the past 33 years. The experiments on some of the materials were fairly extensive, on others they were of relatively limited scope. Though varying in degree of quality, all were indicated to be technically suitable for making some kind of paper or other pulp product.

Introduction

The Forest Products Laboratory has been requested at various times to undertake pulp and paper investigations on woods and plants that were grown outside of the United States. This report discusses work done on materials received from five Asian and Australasian countries. Among the materials tested were the wood of 14 species of broad-leaved and coniferous trees and 7 kinds of fibers and plants. The experiments reported date from 1928, when tests were made on the production of newsprint paper from radiata pine, Corsican pine, tawa, and rimu for the New Zealand Forest Service.[2]

Following is a list of the species, arranged alphabetically by common name and country of origin:

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

[2] The experiments discussed in this report were financed by public and private organizations in the respective countries or their representatives in the United States.

Common name	Botanical name	Country
WOODS		
Eucalyptus	Eucalyptus gigantea	Tasmania
Gewa	Excoecaria agallocha	Pakistan
Ilang-ilang	Cananga odorata	Philippines
Kupang	Parkia javanica	.....Do.....
Lauan, red	Shorea negrosensis	.....Do.....
Lauan, white	Pentacme contorta	.....Do.....
Manggasinoro	Shorea philippinensis	.....Do.....
Pine, benguet	Pinus insularis	.....Do.....
Pine, Corsican	Pinus nigra var. calabarica	New Zealand
Pine, Monterey (insignis)(radiata)	Pinus radiata	.....Do.....
Poplar	Populus alba	.....Do.....
Rimu	Dacrydium cuppressinum	.....Do.....
Tangile	Shorea polysperma	Philippines
Tawa	Beilschmiedia tawa	New Zealand
PLANTS AND FIBERS		
Abaca	Musa textilis	Philippines
Bamboo	Schizostachyum lumampao	.....Do.....
Cornstalks	Zea mays	Israel
Ekra	Erianthus ravennae	Pakistan
Kenaf	Hibiscus cannabinis	Philippines
Khagra	Saccharum spontaneum	Pakistan
Nal	Phragmites karka	....Do...

Eucalyptus

A sample of Eucalyptus gigantea received for neutral sulfite semichemical pulping experiments contained 71.8 percent of holocellulose, 49.0 percent of alpha-cellulose, 22 percent of lignin, and 13.6 percent of pentosans.

The wood was impregnated with cooking liquor prior to digestions under conditions which retained 9 percent sodium sulfite (based on moisture-free wood) and 3.6 percent of sodium bicarbonate (expressed as carbonate) in the first cook, and 12.0 percent sodium sulfite and 7.8 percent sodium bicarbonate in the second cook. The first digestion was made in 2 hours and 5 minutes, of which 1 hour and 40 minutes were at the maximum temperature of 170° C. The yield of pulp was about 75 percent. The second cook was made similarly, except that the time at maximum temperature was 2 hours and 30 minutes. The yield of pulp from the second cook was about 71 percent.

The unbleached pulps were fairly strong in burst and tension, though not so strong as can be obtained by similar treatment from aspen (Populus tremuloides). Their resistance to tear was, however, better than that generally found for aspen.

The eucalyptus pulp made at the lower yield was bleached to 85 percent brightness with an increase in strength. In relation to bleached aspen pulp that was comparably prepared, the bleached eucalyptus was weaker in bursting and tensile strength, about equal in folding, and higher in tearing resistance.

The unbleached pulps were converted into linerboard. The board made from the lower yield pulp was comparable to commercial southern pine kraft linerboard in bursting strength. Both of the eucalyptus boards were a little better in tensile strength and compression resistance than the commercial linerboard, but both were lower in tearing resistance and folding endurance.

Gewa

The densities of two shipments of this wood were 24.2 and 26.1 pounds per cubic foot (weight moisture free and volume when green). A chemical analysis gave a lignin content of 19.9 percent; holocellulose, 80.1 percent; alpha-cellulose, 39.4 percent; and pentosans, 18.9 percent.

Typical data for the pulping of this wood by the groundwood, chemigroundwood, neutral sulfite semichemical, cold soda, and sulfate processes are given in table 1. The values are similar to those obtained from the wood of North American broad-leaved trees. The brightness level of the pulps was higher for green wood than for peeled wood that had been seasoned.

Newsprint with satisfactory strength was made with 80 percent gewa groundwood pulp and 20 percent of semibleached southern pine sulfate pulp. Satisfactory strong newsprint papers were also made from furnishes of 10 percent of the sulfate pulp, 60 percent of gewa groundwood pulp, and 30 percent of either chemigroundwood, neutral sulfite, or cold soda pulp made from the gewa.

Magazine coating base stock made with 50 percent of gewa groundwood pulp, 40 percent of either gewa chemigroundwood or gewa cold soda pulp, and 10 percent of bleached long-fibered kraft pulp (with 6 percent clay filler and 0.5 percent rosin size) had strength properties in the range of those obtained commercially from softwood pulps entirely. Clay-starch coating applied to the base paper stock increased the bursting and tensile strength appreciably, but decreased the tearing resistance.

A mill in East Pakistan is now producing newsprint paper by procedures developed in these experiments.

Density, Chemical Composition, and Fiber Length

These hardwoods ranged in density from a low value of 17.3 pounds per cubic foot (moisture-free weight, green volume) for ilang-ilang to 27.2 pounds per cubic foot for manggasinoro (table 2). Thus, they were all lower than the average for hardwoods used in the United States for pulping. The average for the four Philippine mahoganies (manggasinoro, red lauan, white lauan, and tangile), which could possibly be used together in the form of woods or sawmill wastes, was 25 pounds per cubic foot.

The Philippine hardwoods considered together were distinguished from the average for a number of U.S. hardwoods by being relatively high in lignin, low in holocellulose, high in alpha-cellulose, and low in pentosans (table 2). Ilang-ilang differed from the four other woods by containing more pentosans and less lignin.

The average and range of the lengths of the fibers in these woods are given in table 3. They are typical of hardwoods in general. The longest fibers were found in manggasinoro and the shortest in ilang-ilang.

Sulfate Pulping

Ilang-ilang and white lauan were pulped individually, and the others in mixtures, by the sulfate process. One mixture consisted of equal volumes of white lauan, red lauan, tangile, and mangassinoro. The other mixture consisted of equal volumes of white lauan, red lauan, and tangile. Using conditions which had been found satisfactory for many hardwoods previously tested at the Forest Products Laboratory, it was found that these woods were not appreciably different in pulping characteristics among themselves. Table 4 gives the averages of tests made with 20 percent total chemical.

The similarity of the results for the two mixtures indicated that manggasinoro was not much different than the others in pulping characteristics. It would be expected, therefore, that random mixtures of these four woods would give similar results. The permanganate numbers were within the range desired for bleachable pulps.

Compared at the same sheet density, the pulp from the mixture of three woods was lower in strength than that made from the mixture of four woods. It would therefore appear that a high proportion of manggasinoro in the mixture would be desirable.

The sulfate pulps were readily bleached by conventional single-stage and multistage bleaching methods and produced clean, white pulps with from 5 to 7 percent of chlorine. The bleached pulps were weaker than the unbleached pulps, especially in folding endurance.

Semichemical Pulping

On the basis of delignification and yield, the white lauan appeared to respond most satisfactorily, the ilang-ilang next most satisfactory and the others somewhat less satisfactorily to neutral sulfite semichemical pulping. There was no difficulty in pulping a mixture of the red and white lauans, tangile, and manggasinoro. The pulps had high lignin and low pentosan contents which are characteristic of these components in the woods themselves. For a given lignin removal, the Philippine woods required more sodium sulfite and a longer time than has been experienced with most North American hardwoods. Pulped under similar conditions, the yields of pulp were higher and they contained more lignin than North American hardwood pulps. Except for the ilang-ilang pulp, the strength of the neutral sulfite semichemical pulps was low in comparison with those made from North American hardwoods. In a single-stage procedure, the pulps required an excessive amount of bleaching chemical to produce pulps with a satisfactory brightness.

A sulfate semichemical digestion using 10 percent total chemical was made on the mixture of four woods. The yield of about 74 percent was in the range of yields obtained from North American hardwoods pulped under similar conditions. The strength of the pulp was low and comparable with that made in the same yield by the neutral sulfite semichemical process.

Groundwood Pulping of Ilang-Ilang

Groundwood pulp made from ilang-ilang with a relatively dull stone surface and energy consumption of about 85 horsepower-days per ton of wood ground (moisture-free basis) was about half as strong as that of the average North American softwood groundwood made for newsprint manufacture. Although by screen classification it was somewhat higher in average fiber length than groundwood made from the lower density North American hardwoods, in strength it was about like that made from the higher density hardwoods--birch, ash, and sweetgum. The ilang-ilang groundwood was dark colored and had to be bleached before use in making newsprint paper.

Papers and Boards from the Philippine Hardwood Pulps

Linerboards made entirely from the mixed hardwood sulfate pulp met test liner specifications, but were lower in tearing resistance and folding endurance than the highest quality boards made in the United States from southern pine. Improvements in tearing and folding were obtained by adding moderate amounts of long-fibered pulps made from abaca and kenaf fibers (mentioned later).

Kraft wrapping paper made entirely from the mixed hardwood sulfate pulp was servicable but below the best standards, especially in folding endurance. A great improvement in quality was obtained when abaca sulfate pulp was substituted for 20 percent of the hardwood pulp. This paper had practically the same strength as standard softwood kraft wrapper.

Newsprint papers made from 40 to 50 percent of the Philippine hardwood bleached sulfate pulp and the remainder of ilang-ilang bleached groundwood pulp had adequate strength and were satisfactory in other respects, except for being less opaque than desirable.

White papers including bond, printing, tissue, and towel grades made from the bleached sulfate pulps were clean, bright, well formed, and appeared to be of servicable quality, although they were generally not high in strength for the representative kinds.

Corrugating board made with neutral sulfite semichemical pulp produced from ilang-ilang had the high flat-crush resistance after corrugating necessary for the best quality in this product, but it was low in tearing resistance and folding endurance, which might give trouble in the scoring of the board in the manufacture of containers. Comparison of corrugating boards made with the sulfate semichemical pulp and a sulfate pulp that was completely digested indicated that a satisfactory pulp for making board with good flat-crush resistance and also strength possibly could be obtained if made at yields of 65 to 70 percent.

Kupang

The sample of kupang had a density of 25.5 pounds per cubic foot (moisture-free weight, green volume). The small amount of wood available permitted only one groundwood pulping experiment of short duration being made. The sandstone pulpstone used had a fairly well-conditioned grinding surface. The wood, containing 47 percent moisture (based on wet wood), was ground at a 35-pound-per-square-inch pressure of wood against the stone surface with an energy consumption of 47 horsepower-days per ton of wood ground (moisture-free basis). As is common with woods ground at low energy consumption, the strength of the pulp was low. Aspen (Populus tremuloides)--a hardwood with about the same density as kupang--was ground on about the same stone surface at the same pressure and close to the same energy consumption. For comparison, the strength and brightness of the two pulps are listed as follows:

Property	Kupang	Aspen
Bursting strength.....pts. per lb. per rm.:	0.04	0.12
Tearing resistance......g. per lb. per rm.:	.24	.40
Breaking length.........................m.:	686	788
Brightness........................ percent:	60.4	57.2

Aspen groundwood pulp produced with higher energy consumption is higher in strength than that shown above. Such pulp is used in North America in the furnish of printing papers. It could be expected that kupang would respond similarly.

The kupang groundwood made in this experiment was mixed with bleached bamboo sulfate pulp (to be discussed later) and made into a good grade of tablet paper.

Benguet Pine

The density and chemical analysis of benguet pine are given in table 1, and fiber length measurements in table 2. The values are typical of pines used for pulping in North America.

The wood was pulped by the sulfate process to 50 percent yield for kraft-type pulp and to 46 percent for a bleachable grade. The permanganate numbers were 24 and 15 respectively, which were noted to be slightly lower than usually obtained under similar cooking conditions from southern pine. The pulps had strengths typical of the best quality of softwood sulfate pulps.

Corsican Pine

Two samples of New Zealand grown Corsican pine received had densities of 27 and 23 pounds per cubic foot; lignin contents of 27 and 28 percent; alpha-cellulose, 49 and 41 percent; and pentosans, 8 and 13 percent respectively.

Groundwood pulp made from this wood was not quite so strong as that made with comparable energy consumption from white spruce, but it was a little stronger than that made from southern pine. The brightness of the pulp was comparable to that of spruce groundwood pulp.

A yield of 46 percent of screened pulp was obtained by cooking Corsican pine by the sulfate process, using 14.3 percent of caustic soda (based on wood) and 5.7 percent of sodium sulfide at a concentration of 80 grams per liter of total chemical. The schedule was 1-1/2 hours to the maximum temperature of 170° C. and 2 hours at the maximum temperature. A waterleaf sheet of this pulp weighing 125 pounds per ream (25 by 40 inches, 500 sheets) tested 0.65 point per pound per ream in bursting strength, 2.92 grams per pound per ream in tearing resistance, 5,270 meters breaking length, and 1,748 double folds.

Monterey Pine

(Also Insignis Pine or Radiata Pine)

The density of the sample of Pinus radiata received was 25 pounds per cubic foot, and the average fiber length was 2.61 millimeters. The wood contained 29.6 percent lignin, 42.9 percent alpha-cellulose, and 14.1 percent pentosans. It was pulped by the groundwood and sulfate processes.

Groundwood pulp produced at about 55 horsepower-days per ton was comparable with spruce groundwood pulp in screen classification and strength. The bursting strength of the pulp was 0.29 point per pound per ream (25 by 40 inches, 500 sheets); tearing resistance, 0.85 grams per pound per ream; and breaking length, 2,432 meters. The pine pulp was 6 to 9 percentage points lower in brightness than a spruce groundwood pulp and had a distinct orange hue.

A bleachable sulfate pulp was made by using 22.5 percent of caustic soda (based on wood) and 7.5 percent of sodium sulfide at a concentration of total chemical of 70 grams per liter. The cooking time was 4-1/4 hours, of which 2-3/4 hours were at the maximum temperature of 170° C. The yield of unbleached screened pulp was 42 percent.

Newsprint paper was made with a furnish of 25 percent of the bleached sulfate pulp and 75 percent of the groundwood pulp that was comparable to the average commercial newsprint in strength, whiteness, and opacity. The bleached sulfate pulp was also made into satisfactory quality book and writing papers.

Since the second World War, radiata pine has been extensively used for kraft papers and newsprint in Chile and New Zealand. Plantations in Australia are also beginning to yield pulpwood.

Poplar

A sample of New Zealand grown Populus alba had a density of 25.7 pounds per cubic foot (moisture-free weight, green volume), which is comparable to that of the Populus species (P. tremuloides and P. deltoides) grown in the United States. It was also comparable to these species in being low in lignin and pentosan contents and high in cellulose and extractive contents.

The wood was pulped by the soda, soda-sulfur, and sulfate processes, using a total cooking time of 6 hours, of which 4-1/2 hours were at the maximum temperature of 170° C. and a ratio of liquor to wood of 4:1.

By the soda process, cooking with 25 percent of sodium hydroxide (based on moisture-free wood) gave a yield of 47.5 percent of screened pulp and no screenings. The pulp was easily bleached and had strength properties indicating it could be used for the manufacture of book and other papers in which soda pulp is commonly used.

The addition of 2 percent of elemental sulfur (based on wood) to the soda liquor increased the yield to 50.2 percent of screened pulp and caused a moderate increase in strength properties. There was a small increase in bleach requirement.

Sulfate pulp was made by using total chemical (sodium hydroxide plus sodium sulfide) in amounts of 25 and 30 percent (based on moisture-free wood) and a sulfidity (based on active alkali) of 34 percent in each case. The yield of screened pulp obtained by cooking with 25 percent total chemical was about 52 percent. Compared with the soda process cook using the same amount of chemical, there was an increase in all strength properties as well as bleach requirement. Cooking with 30 percent total chemical gave a yield of 47.7

percent, practically the same as that obtained in the soda cook with 25 percent of caustic soda. The bursting strength and folding endurance were higher however. The sulfate pulps were suitable for making papers in which other hardwood sulfate pulps are used.

Rimu

The sample of rimu, a softwood species, had a density of 32 pounds per cubic foot and average fiber length of 3.14 millimeters. The lignin content was 32.0 percent; alpha-cellulose, 43.2 percent; and pentosans, 12.8 percent. In chemical composition, it was therefore similar to the jack pine of North America. The rimu was pulped by the sulfite and sulfate processes.

The sulfite pulps made from rimu were too dark to be used unbleached in the making of newsprint. A pulp with satisfactory bleachability was made by cooking with a liquor containing 5.63 percent total sulfur dioxide and 1.34 percent combined sulfur dioxide, using a volume of 50 gallons per 100 pounds of moisture-free wood. The cooking time was 10 hours, of which 1 hour was at the maximum temperature of 148° C. The yield was 48 percent of screened pulp.

The sulfite pulp, either bleached or unbleached, appeared to be suitable for use in glassine, wrapping paper, and specialties. A newsprint paper containing 15 percent of bleached rimu sulfite pulp and the balance tawa sulfite pulp and tawa groundwood pulp will be discussed in connection with tests on tawa.

Rimu was cooked by the sulfate process with 14.3 percent of caustic soda (based on moisture-free wood) and 5.7 percent of sodium sulfide with a total chemical concentration of 80 grams per liter. A schedule of 2 hours to 180° C. and 1 hour at a maximum temperature gave a yield of screened pulp of about 44 percent. A waterleaf sheet of this pulp weighing 112 pounds per ream (25 by 40 inches, 500 sheets) tested 0.96 point per pound per ream in bursting strength, 2.34 grams per pound per ream in tearing resistance, 6,488 meters breaking length, and 3,243 double folds. These values are fairly comparable to those of unbeaten Southern pine kraft pulp. A kraft semichemical pulp was made from rimu under conditions such that, after blowback, 8.5 percent of caustic soda (based on wood) and 2.8 percent of sodium hydroxide remained in the digester. The cooking schedule was 30 minutes to 160° C. and 75 minutes at that maximum temperature. The yield of pulp was 66 percent. A waterleaf sheet of the pulp weighing 119 pounds per ream (25 by 40 inches, 500 sheets) tested 0.93 point per pound per ream in bursting strength, 6,679 meters breaking length, and 1,261 double folds.

Tawa

The hardwood tawa, received for the experiments, had a density of about 32 pounds per cubic foot and contained 28.5 percent lignin, 42.4 percent alpha-cellulose, and 19.2 percent pentosans. The fiber length was relatively short, ranging from 1.10 to 0.63 millimeter, with an average of 0.88 millimeter. The wood was pulped by the groundwood, sulfite, soda, and neutral sulfite semichemical processes.

As the density and fiber length would indicate, the tawa groundwood pulp was very fine fibered and suitable principally for use as a filler. The energy consumption was about 65 horsepower-days per ton. Ten percent of a commercial sulfite pulp was added to the tawa groundwood pulp in order to run a waterleaf sheet on the experimental paper machine. The bursting strength of this sheet was 0.14 point per pound per ream (25 by 40 inches, 500 sheets) and the tearing resistance was 0.30 gram per pound per ream.

Tawa was pulped by the sulfite process with liquor containing 6.00 percent of total sulfur dioxide and 1.35 percent of combined sulfur dioxide, using 50 gallons of liquor per 100 pounds of wood and a cooking schedule of 9 hours to a maximum temperature of 148° C. The yield was 49 percent screened pulp. As often occurs in sulfite pulp made from hardwoods, the tawa pulp contained shives and had a dirty appearance. Some shives were eliminated by beating.

A newsprint paper made with 35 percent of tawa groundwood pulp, 50 percent tawa sulfite pulp, and 15 percent of insignis pine sulfite pulp had a bursting strength of 0.25 point per pound per ream (25 by 40 inches, 500 sheets), a tearing resistance of 0.58 gram per pound per ream, and a tensile strength of 10.4 pounds per inch width. These properties are in the lower part of the range for North American newsprint papers.

In a series of neutral sulfite semichemical pulping experiments on tawa, the best results were obtained by impregnating it with a solution of sodium sulfite and sodium bicarbonate under conditions that gave, after blowback, 9.8 percent of sodium sulfite (based on wood) and 3.1 percent of sodium bicarbonate (in terms of sodium carbonate) in the cooking liquor. The total cooking time was about 3 hours, of which 2.5 hours were at a maximum temperature of 170° C. The pulp, after processing in a rod mill, tested 0.69 point per pound per ream (25 by 40 inches, 500 sheets) in bursting strength, 0.69 gram per pound per ream in tearing resistance, and 6,105 meters breaking length. The pulp was fairly "specky."

Experiments on making newsprint paper with this pulp were not very satisfactory, probably because of the attempt to use excessively high proportions in the furnish. Though not tested for the purpose, the semichemical pulp was thought to have possibilities for use in paperboards.

A bleachable soda pulp was produced from tawa by cooking it with 22 percent of caustic soda for 5-1/2 hours, of which 4 hours were at the maximum temperature of 170° C. The yield was about 40 percent of screened pulp. The pulp was typical of soda pulp made from hardwoods in strength and appeared to have the bulk desired in this kind of pulp as used in making book paper.

Abaca

The abaca consisted of the hurds and the commercial fiber in the form of new Manila hemp rope. A sample of abaca fiber prepared by stripping plantation waste was also supplied. The tests on the rope fiber were made to give an indication of what might be expected from the original decorticated abaca fiber.

The lengths of whole fibers in pulps made from the hurds and rope fiber are given in table 3. The average lengths of the fibers in these pulps were equivalent to those of many of the softwoods.

The hurds and rope were reduced to clippings of approximately 1/2 to 1 inch in length before sulfate pulping. The rope material was digested with 12 percent total chemical, 9.37 percent active alkali, and 20 percent sulfidity, based on active alkali, using a total time of 3 hours, of which 1-1/2 hours were at the maximum temperature of 150° C. The yield of pulp was about 78 percent, and there were no screenings. The permanganate number of the pulp was 4.0. The hurds were cooked similarly, except the time at maximum temperature was 2 hours. The yield of screened pulp was about 48 percent and the permanganate number about 11. The strength properties of the rope fiber pulp, especially the tearing resistance, were comparable to those of the highest grade of softwood sulfate pulp, while the pulp made from the hurds had strength equivalent to that of Philippine hardwood mixture pulps.

Prior to bleaching, a small quantity of gritty black particles was removed from the abaca hurds pulp by riffling. A single stage bleach with 5.7 percent chlorine consumption as calcium hypochlorite gave a brightness of 68 percent.

These pulps (unbleached) were used to provide long fiber in paperboard, kraft wrapping, and newsprint paper furnishes composed largely of Philippine hardwood sulfate pulps, as mentioned previously. Linerboards containing from 10 to 25 percent of the abaca pulps were made with proportionate improvement in strength, particularly folding endurance. As mentioned, the use of 20 percent of the abaca rope pulp with 80 percent of hardwood pulp in wrapping paper raised the strength to that of a softwood kraft wrapping. It appeared that although substantial amounts of hurd pulp might be used in newsprint paper furnishes along with the Philippine hardwood pulps to obtain improvement in paper strength, such substitution would tend to lower opacity.

The plantation waste fiber was cut to 1-inch length and cooked by the sulfate process with 20 percent total chemical; active alkali, 15.6 percent; sulfidity based on active alkali, 25.5 percent; and liquor-to-fiber ratio, 6:1 using a total time of 3-1/4 hours, of which 2 hours were at a maximum temperature of 160° C. The yield of screened pulp was about 56 percent, and the permanganate number of the pulp was 6.8. The pulp was bleached with about 2.5 percent total chlorine in a three-stage--chlorination, alkaline extraction, and hypochlorite oxidation--process to a brightness of 84 percent.

The bleached plantation waste pulp was processed, heavily loaded with calcium carbonate filler, and converted into cigarette paper. The properties of cigarette paper as determined on three commercial samples were used for comparison. One of the commercial samples was comparable in weight to the best of the experimental papers; the other two commercial papers were of the same weight and lighter than this experimental paper. The experimental papers were higher in tensile strength than any of the three commercial samples. The best experimental paper was higher in opacity than the lighter commercial samples but lower in opacity than the heavier one. The porosity of this paper was equal to that of the heavier and one of the lighter commercial samples and higher than that of the other lighter paper.

An airmail bond paper was made from the bleached plantation waste pulp with about 7 percent of clay filler, and was comparable to commercial papers of the same type.

Bamboo

Cooking conditions for producing clean sulfate pulp for bleaching from the bamboo were established by two- and one-stage methods similar to those used in India. The pulping data are given in table 5.

Good yields of pulp, about 46 percent, were obtained by both methods. The permanganate numbers of about 10 indicated their bleaching qualities were fully as good as those of sulfate pulps made from bamboo in India and from the best North American hardwoods. The strength of the bamboo pulp was developed quickly by beating. The tearing resistance was comparable to that of sulfate pulps from southern pine and second-growth Douglas-fir. Other strength properties were similar to those obtainable from hardwood sulfate pulps of good quality.

The bamboo pulps were easily bleached by a three-stage process consisting of chlorination, alkaline extraction, and hypochlorite treatments. The total chlorine requirement for a brightness of 80 to 83 percent was 3.5 to 4.0 percent, which is about one-half the amount usually required for bleaching softwood sulfate pulps. The shrinkage of the pulp due to bleaching was very low (less than 5 percent) which indicated that a yield of about 44 percent of bleached pulp could be expected with either two- or one-stage pulping.

The retention of strength after bleaching was high and somewhat better for pulp cooked with the two-stage process. From 90 to 100 percent of the bursting and tensile strength and 75 to 100 percent of the tearing resistance was retained. However, folding endurance decreased 20 to 40 percent, as can be expected in bleaching pulps with low permanganate numbers.

Specialty bag or wrapping papers similar in bursting strength and tearing resistance to experimental papers made at the Forest Products Laboratory from commercial southern pine sulfate pulp were made entirely from bamboo pulp produced by the single-stage sulfate process.

Paper machine furnishes consisting entirely of bleached bamboo pulp prepared by the two-stage process (plus normal amounts of filler and size) were used in producing (1) 20-pound bond paper having qualities for a No. 1 bond, (2) airmail bond having good bursting strength and formation, (3) lithographic paper having characteristics of good-quality printing paper, and (4) offset printing paper having sheet characteristics comparable to good-quality offset paper made from woodpulp.

A pencil tablet paper was also made from a fiber furnish consisting of 70 percent of the bleached bamboo pulp and 30 percent of unbleached kupang groundwood, as mentioned previously. The paper had good bursting and tearing strengths, and its porosity and castor oil penetration were satisfactory. The brightness was better than usual for this grade of paper.

Cornstalks

The cornstalks consisted of one portion designated "Hybrid-Irrigated" and another portion designated "Yellowdent-Unirrigated." The material contained husks and leaves as well as the stalks. Since cornstalks are similar to sugarcane bagasse, with which, in papermaking, the removal of pith has been found desirable, the material received was depithed.[3] Depithing the cornstalks was somewhat more difficult than the depithing of bagasse, which was attributed mostly to the fact that the cornstalks had not received the crushing treatment that is given to sugarcane. The procedure followed consisted of (1) chopping the material into short lengths, (2) washing the chopped material in a hydrapulper, (3) coarse milling with a double-rotating disk mill, and (4) washing out the pith in a hydrapulper. By this procedure, the "Hybrid" and "Yellowdent" cornstalks (including husks and leaves) were respectively reduced to 54 and 51 percent of depithed material, 17 and 23 percent pith, and 29 and 26 percent water solubles, fines, and dirt.

After a series of small-scale tests with the depithed "Hybrid" material, larger scale cooks to prepare pulp for papermaking were made with a mixture of equal parts of the two depithed materials. The cooking schedule for making bleaching-type pulps was 30 minutes to a maximum temperature of 175° C. and 15 minutes at 175° C. For making soda semichemical pulp above 60 percent in yield that was not to be bleached, the same schedule was used except, when maximum temperature was reached, the steam was turned off during the final 15 minutes. The ratio of liquor to fiber was 7 to 1 for pulp to be bleached and 6 to 1 for those that were not to be bleached.

Soda pulp for bleaching was made with 14 percent sodium hydroxide. The yield of screened pulp was 45 percent and screening rejects 4.6 percent. The permanganate number of this pulp was 8.5. The unbleached cornstalk pulp contained dark specks and fiber bundles and so was cleaned in centrifugal cleaners before bleaching. The cleaned pulp was estimated to be 42 percent of the depithed cornstalks and 23 percent of the original cornstalks. The pulp was bleached by a three-stage process consisting of chlorination, caustic soda extraction, and hypochlorite with 5.0 to 5.5 percent chlorine to 83 to 85 percent brightness. The shrinkage during bleaching was about 15 percent. From this, it was estimated the yield of bleached soda pulp was about 19 percent (moisture-free basis) of the original cornstalks. The loss in bursting, tearing, and tensile strengths on bleaching was about 10 percent, but the loss in folding endurance was about 50 percent. The

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[3] This work was done by the Northern Utilization Research and Development Division, Agricultural Research Service, U.S. Department of Agriculture, Peoria, Ill.

strength of the bleached cornstalk pulp was better than that of a bleached straw pulp made commercially by the caustic soda-chlorine process and about equal to that of medium-quality hardwood sulfate pulps.

Good-quality book and bond papers were made from furnishes comprising 30 and 50 percent respectively of the bleached cornstalk soda pulp.

Linerboard and wrapping paper were made from a furnish of 40 percent unbleached cornstalk soda pulp and 60 percent northern pine sulfate pulp. The linerboard had high bursting strength and stiffness. The wrapping paper had good formation, surface texture, and bursting strength, but it did not quite meet Federal Specifications for grade B kraft wrapping paper.

A newsprint paper comparable in strength and brightness to conventional newsprint paper was made from 30 percent of the unbleached cornstalk soda pulp and 70 percent commercial groundwood pulp, thus substituting the cornstalk pulp for all the long-fibered chemical pulp and part of the groundwood of a normal newsprint furnish. The opacity of the experimental paper was slightly lower than that of standard newsprint.

A corrugating board of good stiffness and adequate strength was made from a cornstalk soda semichemical pulp of 65 percent yield (based on moisture-free depithed material) that had been made with 6 percent sodium hydroxide. Another soda semichemical pulp of 61 percent yield was made from the depithed cornstalks by the mechano-chemical process.[3] Corrugating board made from this pulp was somewhat higher in strength, except tearing resistance, than the board made with the pulp produced in the rotary digester. It was also higher in stiffness and flat-crush resistance than commercial aspen neutral sulfite semichemical board.

In addition to the work on depithed cornstalk, an experiment was made on the whole material. For this, the stalks were shredded in a hammermill to a maximum length of about 1 inch, then cooked in the same manner as for making the bleachable grade depithed cornstalk pulp. Screening rejects and permanganate number of the whole stalk pulp were about the same as those of the depithed stalk pulp, and the yield of screened pulp was about 33 percent--about 12 percentage points less. It was estimated that centrifugal cleaning would reduce the yield to about 30 percent. Based on original stalks, however, the yield from the whole stalks at this stage was 7 percentage points higher than was obtained from the depithed stalks. The tearing resistance of the whole stalk pulp was lower than that of the depithed stalk pulp, but the other strength properties were a little higher.

Ekra, Khagra, and Nal

The grasses, ekra, khagra, and nal, which grow in other Asian countries as well as Pakistan, were found, by chemical analysis, to be nearly alike in content of lignin, alpha-cellulose, and pentosans, having an average of about 20, 51, and 24 percent respectively of these constituents. Ekra and khagra were about alike in content of extractable substances, but nal contained from 2 to 3 times more alcohol-benzene and hot-water-soluble materials than the others.

They were pulped separately and in various mixtures with one or another by the sulfate process. Pulps made from a mixture of equal parts by weight of the three grasses were converted into wrapping paper and several kinds of white paper.

It was established that each grass or any mixture of them could be satisfactorily pulped using a liquor containing 17.6 percent of active alkali and sulfidity based on active alkali of 25.5 percent, a ratio of liquor to grass of 4 to 1, and a total cooking time of 1-3/4 hours, of which 1 hour was at the maximum temperature of 170° C. Individually, the yield of pulp from nal was about 2.5 percent (that is, percentage points) lower, and from khagra, about 1 percent lower than that from ekra. The yield of pulp from the 1:1:1 mixture was about 45 percent.

The ekra and khagra pulps were, in general, about equal in strength, and the nal pulp was about 15 percent lower than these pulps in strength. The pulp made from the mixture had slightly better strength properties than the average of the three grasses digested separately. The strength values were in the lower part of the range of values reported for American hardwoods.

The grass pulp was bleached in a three-stage--chlorination, alkaline extraction, and hypochlorite--process to a brightness of 75 percent (for use in making the newsprint paper and cover stock) and 82 percent (for use in the book, offset, and bond papers). The strength of bleached pulp was 85 percent of that of the unbleached pulp, except for the tearing resistance, which was not lowered. The strength properties of the bleached pulp were in the range of American bleached hardwood sulfate pulps.

A wrapping paper with properties close to those of paper made from southern pine kraft pulp was made from a furnish of 50 percent of the grass unbleached pulp and 50 percent of a commercial long-fibered kraft pulp.

A typical newsprint paper was made with a furnish of 25 percent of the grass bleached pulp and 75 percent of a commercial groundwood pulp. It had good tearing resistance, but was a little lower in bursting and tensile strength than the average commercial newsprint.

Cover-stock paper was made from a furnish of 70 percent grass bleached pulp and 30 percent bleached southern pine kraft pulp that had good brightness, oil penetration, and porosity values, all desirable properties in printing paper. A satisfactory strong and well-formed magazine-book coating base was made from 65 percent of the grass bleached pulp and 35 percent of a commercial groundwood pulp. A well-formed, good-appearing offset paper was made from 100 percent grass bleached pulp. This paper was filled with clay and titanium dioxide and surface coated with starch.

A 20-pound bond paper made entirely from the grass bleached pulp was also filled with clay and titanium dioxide and surface coated with starch. This paper was satisfactory in appearance and formation, but did not quite meet the requirement of a No. 1 bond in bursting strength. It was indicated that more suitable processing of the pulp would overcome this deficiency. A lightweight paper, similar to airmail bond, was made from the same furnish with an additional amount of clay, which had the good formation, and good surface characteristics, and the strength required for this kind of paper.

Kenaf

The kenaf consisted of samples of the whole stalks, the depithed stem, and the decorticated fiber in the form of tow. The chemical analysis of these materials is given in table 1. The stems were typical of a woody plant material, being farily well lignified but also having a high content of material soluble in sodium hydroxide, which is characteristic of pith and parenchyma tissue. Removal of the pith reduced the alkali-soluble matter but did not affect the other chemical components appreciably. Removal of most of the highly lignified parts (as well as reduction in the amount of pith) in the decorticating operation gave a tow with low lignin and high holocellulose and alpha-cellulose contents. The measurements of the lengths of whole fibers in pulps made from the three materials are given in table 2.

The whole stalks and the depithed material were digested with a total chemical of 30 percent; active alkali, 23.4 percent; and sulfidity based on active alkali, 30 percent, using a total time of 4 hours, of which 2-1/2 hours were at the maximum temperature of 170° C. Though these conditions were severe, the pulping action on the woody parts of the stems was not as complete as desired. The yields of screened pulps were only about 39 and 42 percent respectively, and the screenings were high--about 2 percent. Removal of the pith did not improve the pulping.

Better pulping was obtained with the kenaf tow. It was satisfactorily cooked with 25 percent of total chemical, 19.5 percent active alkali, and 30 percent sulfidity, using 3-1/2 hours total cooking time, of which 2 hours were at the maximum temperature of 170° C. The yield of pulp was 55 percent, and there were no screenings. The permanganate number was 7.8.

In strength, the kenaf pulps were somewhat lower than the pulps made from the mixture of Philippine hardwoods previously discussed. A linerboard was made with 20 percent of kenaf tow pulp in the furnish with a Philippine hardwood (mixture) pulp, as previously mentioned. Compared to a linerboard made without kenaf pulp, the bursting strength was unchanged, but a small increase in tearing resistance and an appreciable increase in folding endurance were obtained.

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Table 1.--Test results on pulps made from gewa (*Excoecaria agallocha*)[1]

Process	Digestion or grinder run No.	Freeness (Canadian Standard)	Ream weight (25 by 40 inches, 500 sheets)	Thickness	Density	Bursting strength	Tearing resistance	Breaking length	Brightness: Unbleached	Brightness: After bleaching[2]
		Ml.	Lb.	Mils	G. per cc.	Pts. per lb. per rm.	G. per lb. per rm.	M.	Percent	Percent
Groundwood[3]	1027	170	120	18	0.37	0.14	0.45	1,660	62	72
Chemigroundwood[4]	1037	335	127	12	.61	.77	1.13	6,520	58	71
Neutral sulfite semichemical[5]	5576N	610	57	6	.53	.29	.88	3,440	50	70
Cold soda[6]	4132	610	54	6	.47	.20	.77	2,710	48	71
Sulfate[7] [8]	3120X-3124X	250	....	......	.78	1.05	.90	9,050	28	[9]83

[1]Unbeaten except as noted.

[2]Single stage except as noted.

[3]Energy consumed, 78 horsepower-days per ton of wood (moisture-free basis).

[4]Pretreatment conditions were: Vacuum phase, 0.5 hour; time at 150° C., 5 hours; pressure, 200 pounds per square inch; liquor composition, ratio of sodium sulfite to sodium bicarbonate 6:1 (as sodium carbonate); total chemical concentration, 1.92 pounds per gallon; total chemical consumed, 19.2 percent of moisture-free wood. Energy consumed in grinding, 30 horsepower-days per ton of wood (moisture-free basis).

[5]Cooking conditions were: Volume of liquor, 45 gallons per 100 pounds of wood (moisture-free basis); sodium sulfite, 12.0 percent and sodium bicarbonate, 6.5 percent, based on moisture-free wood; total chemical concentration, 49.6 grams per liter; chips presteamed 1/2 hour; 2-1/2 hours to 170° C.; 3/4 hour at 170° C.; pulp yield, 79 percent of wood (moisture-free basis). Disk mill fiberizing energy, 22 horsepower-days per ton of moisture-free wood.

[6]Steeping conditions were: Caustic soda solution, 37.5 grams per liter; time, 1 hour; pressure, 11 atmospheres; temperature, 24° C.; sodium hydroxide consumed during steeping, 4.3 percent based on moisture-free wood; pulp yield, 85 percent of moisture-free wood. Fiberizing energy in disk mill, 27 horsepower-days per ton of moisture-free pulp.

[7]Cooking conditions were: Caustic soda plus sodium sulfide, 17.5 percent of wood (moisture-free basis); sulfidity, 30 percent (based on active alkali); liquor-to-wood ratio, 4:1; schedule, 1-1/2 hours to 170° C., and 1-1/2 hours at 170° C.; yield screened pulp, 52 percent of moisture-free wood; permanganate number of pulp, 16.

[8]Data interpolated from beater test curve of unbleached pulp.

[9]Multistage bleach.

Table 2.--Density and chemical composition of Philippine and United States woods and kenaf

Material	Density (moisture-free weight and green volume)	Chemical composition								
		Lignin	Holo-cellulose	Alpha-cellulose	Total pentosans	Solubility in--				Ash
						Alcohol-benzene	Ether	1 percent sodium hydroxide	Hot water	
	Lb. per cu. ft.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
PHILIPPINE HARDWOODS										
Ilang-ilang	17.7	28.8	70.8	48.3	12.6	1.0	0.3	11.4	1.5	0.8
White lauan	23.0	30.7	66.6	50.5	8.9	2.6	1.0	11.2	1.8	....
Red lauan	23.5	34.2	61.9	50.0	7.4	1.8	.6	13.9	3.0	....
Tangile	26.5	36.6	60.8	45.3	7.8	1.8	.6	13.5	2.2	....
Manggasinoro	27.2	34.0	63.7	51.5	7.5	1.0	.3	11.4	1.5	....
Average	23.6	32.9	64.8	51.1	8.8	1.6	.6	12.3	2.0	....
UNITED STATES HARDWOODS										
Average of 18 pulpwoods	[1]30	22	75	47	19	2.8	.6	14	3.5	.5
PHILIPPINE SOFTWOOD										
Benguet pine	28.7	27.5	72.9	50.5	6.6	1.3	.7	10.4	1.4	.3
KENAF										
Whole stalk	....	17.5	70.3	45.1	15.9	5.7	.9	31.3	11.2	4.0
Depithed stems	....	19.8	69.5	46.3	15.5	4.4	.4	27.6	9.4	4.4
Decorticated fiber	....	12.0	77.0	56.6	14.3	1.9	.8	23.1	4.6	2.8

[1] Range of 23 to 41 pounds per cubic foot.

Table 3.--Lengths of whole fibers in woods and plant fibers from the Philippines

Source of fibers	Cook No.	Length of fibers			Standard deviation	Coefficient of variation
		Average	Maximum	Minimum		
		Mm.	Mm.	Mm.	Mm.	Percent
		MACERATED WOODS				
Ilang-ilang	....	0.99	1.42	0.53	0.174	17.6
Tangile	....	1.32	2.04	.60	.238	18.0
White lauan	....	1.70	2.41	.93	.281	16.5
Red lauan	....	1.73	2.45	.93	.309	17.9
Manggasinoro	....	1.87	2.49	1.03	.263	14.1
		SULFATE PULPS				
Ilang-ilang	4032	1.19	1.83	.46	.296	24.9
White lauan	4034	1.70	2.65	.99	.283	16.6
Abaca fibers[1]	2672	3.82	8.37	1.09	1.507	39.5
Abaca hurds	4039	2.86	7.81	.66	1.397	48.8
Kenaf, whole stalks	2585	2.21	6.97	.53	1.411	63.8
Kenaf, depithed stems	2590	2.07	7.14	.45	1.444	69.8
Kenaf, decorticated fiber	2593-4	2.74	7.60	.98	1.145	41.8
Benguet pine	2649	3.70	6.75	.86	1.612	43.6

[1] Pulp from commercial Manila hemp rope.

Table 4.--Pulp yields obtained with Philippine woods[1]

Woods	Chemicals consumed	Pulp yield		Permanganate number
		Screened	Screenings	
	Percent	Percent	Percent	
Ilang-ilang	90.9	48.8	0.5	18.5
White lauan	92.1	51.1	.2	18.3
Mixture, 4 woods	92.5	45.7	.2	17.1
Mixture, 3 woods	93.5	47.1	.2	16.7

[1] Total chemical 20 percent, sulfidity 30 percent. Liquor-to-wood ratio, 4 to 1; schedule, 1-1/2 hours to 170° C., 1-1/2 hours at 170° C.

Table 5.--Sulfate pulping of bamboo (Schizostachyun lumpampoo)

Item	Two-stage process[1] First stage	Two-stage process[1] Second stage	One stage process
Chemicals charged:[2]			
Active alkali[3] ... percent	5.0	14.0	18.7
Sulfidity (based on active alkali) ... percent	25.0	25.0	25.0
Liquor-to-bamboo ratio ...	5.0:1	3.5:1	3.8:1
Cooking schedule:			
Maximum temperature ... °C.	115	162	162
Time to maximum temperature ... hr.	0.75	0.75	1.25
Time at maximum temperature ... hr.	2.00	.75	2.00
Time to reduce temperature from maximum to 140° C ... hr.	.25	.25	....
Time at 140° C ... hr.	1.50	1.50	....
Total cooking time ... hr.	2.75	3.25	3.25
Yield of screened pulp[2] [4] ... percent	46.2		45.8
Properties of unbleached pulp[5]			
Permanganate number ...	9.8		10.9
Bursting strength ... pts. per lb. per rm.[6]	0.90		0.98
Tearing resistance ... g. per lb. per rm.[6]	1.79		1.99
Double folds (MIT) ...	570		560
Breaking length ... m.	6,800		7,500
Sheet density ... g. per cc.	.70		.69
Brightness of bleached pulp[7] ... percent	78.4		80.1

[1] Between stages, spent liquor was drained and chips were washed twice with hot water.

[2] Based on moisture-free wood.

[3] Sodium hydroxide plus sodium sulfide expressed as sodium oxide.

[4] Screenings were less than 1 percent.

[5] Physical properties interpolated from TAPPI Standard beater test curves at 250-milliliter (Canadian Standard) freeness.

[6] Ream size of 500 sheets, each 25 by 40 inches.

[7] Conventional three-stage--chlorination, alkaline extraction, and hypochlorite--process. Total chlorine consumption about 3 percent, based on moisture-free unbleached pulp.

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