PULPING CHARACTERISTICS OF LAKE STATES AND NORTHEASTERN WOODS

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PULPING CHARACTERISTICS OF LAKE STATES AND NORTHEASTERN WOODS[1]

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Abstract

The pulpwood consumed in the Lake States and Northeast consists largely of softwood species, but hardwood (broad-leaved) species predominate in those regions. Though inferior in some respects to the softwoods as pulpwood, the little-used hardwoods can, with proper treatment, be used for pulp to a greater extent than they are at present.

High-quality, fine groundwood pulps prepared from the lower-density hardwoods, such as aspen and cottonwood, approach the quality of spruce pulps of this type, and large quantities are used in mixture with spruce. Coarse groundwood pulps from these species are used in insulating board, while fine grades are used in book and other papers. Groundwood pulps made from high-density species, such as oak and maple, are shorter fibered and have much lower strength than those made from spruce, pine, or low-density hardwoods. Some are suitable as filler pulps in printing and absorbent papers.

It is possible to replace softwood groundwood entirely or in part with hardwood chemigroundwood in newsprint, book, toweling, and other groundwood papers. Mixtures of hardwood chemigroundwood and hardwood groundwood can be made with properties comparable to those of softwood groundwood.

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No radical departure from conventional sulfite pulp procedures is necessary for the conversion of hardwoods. The strength of hardwood sulfite pulps ranges from 50 to 75 percent of that of spruce or fir sulfite pulps. Though lacking the opacity and softness of soda pulps, these hardwood pulps are sometimes used for similar purposes.

Hardwoods are well suited for semichemical pulping, and produce relatively strong pulps in high yield. Hardwood semichemical pulps are used in the Lake States for insulating and corrugating boards. The lighter-colored semichemical pulps may possibly replace softwood sulfites in some groundwood papers. Bleached semichemical pulps have especially high strength. They are suitable for glassine paper and, when mixed with suitable filler stocks, for other grades of white paper.

Aspen, birch, maple, and beech are customarily used for the production of soda pulp. Some of the other hardwood species, such as ash and the oaks, could also be used in a modified soda process.

The northern hardwoods have been used to some extent for sulfate pulping. Aspen mixed with jack pine has been used with certain advantages. Hardwood sulfate pulps, as a group, have greater strength than soda pulps, and in some instances may be used as a substitute for softwood sulfite. The sulfate process is well adapted to the pulping of hardwoods because the digestion and subsequent bleaching procedures can reduce inferior, dirty wood to usable pulp.

Introduction

Although the use of hardwoods for pulp in the Lake States and Northeast has increased considerably during recent years, the pulpwood consumed in these regions consists largely of softwood species, including white and black spruce, balsam fir, eastern hemlock, and jack pine. A great deal of softwood pulp and pulpwood is supplied by other regions and foreign sources. The wood resources in the Lake States and Northeast, on the other hand, are comprised to a large extent of hardwoods, including quaking aspen, yellow-poplar, birches, maples, oaks, American beech, and black cherry, and several less-used softwoods, including red spruce, tamarack, red pine, and eastern white pine.

In this report, the technology of the conversion of these hardwood species is reviewed, and some of the obstacles to an increase in their use are discussed.

Wood Characteristics and Preparation

Some of the little-used species are small, crooked, knotty, difficult to bark, and may be infected with rot. These species may also differ in other respects from the commonly used softwoods. For instance, most of them are fairly dense in comparison with the common pulpwoods, while aspen and cottonwood, though of lower density, have a high cellulose content. Both high density and high cellulose content favor high yields of pulp. A very important difference is that the hardwoods are shorter fibered than the softwoods. The length of hardwood fibers is generally about 1 millimeter while that of softwoods is about 3 millimeters.

The hardwoods differ chemically from softwoods. They have a higher content of pentosans and other hemicelluloses, frequently a lower lignin content, and often a higher cellulose content. Although there are no outstanding differences between hardwoods and softwoods in the amounts of chemical substances extracted by various organic and aqueous solvents, a characteristic difference in the composition of the extractives is that those obtained from hardwoods contain more gums and waxes, and those from softwoods contain oleoresins and terpenes.

Hardwoods have a shorter peeling season, and are generally more difficult to bark than softwoods. Drum barking has been fairly satisfactory, but with reduced output. Improvements in barking equipment and in chemical treatments that loosen the bark before trees are cut offer possibilities for reducing these difficulties.

Table 1 shows the density of some Eastern and Lake States woods, together with the amounts of certain chemical constituents they contain.

Groundwood Pulping

At the present time, jack, red, white, and pitch pine, eastern hemlock, and tamarack are used only in small amounts, if at all, for making groundwood pulp. In contrast to spruce and balsam, these woods may be high in resin content, dark in color, or knotty, or economic factors may have hindered their use. Eastern hemlock, for example, produces a somewhat shorter-fibered and darker-colored groundwood than spruce, but they are comparable in production rate, energy consumption, and yield per cord (65). With careful control of grinding conditions, groundwood of fairly good quality can be made from jack pine. The wood usually contains an appreciable amount of heartwood and is fairly knotty, characteristics that tend to darken the color of the pulp. Pitch trouble may develop on the paper machine if more than 15 percent of jack pine groundwood is used in a newsprint furnish (55).

Tamarack is a higher-density softwood, but it is like jack pine in groundwood pulping characteristics and probably could be used as a partial substitute for spruce groundwood (66).

The principal low-density hardwoods in the Lake States and Northeast are quaking aspen and eastern cottonwood. The groundwood pulps of both are suitable for fine grades of groundwood book and specialty papers, and particularly for use as a coarse grade in insulating board. The properties of an experimental newsprint paper containing aspen groundwood pulp are given in table 5. Experiments on quaking aspen at the U. S. Forest Products Laboratory indicate that a dull stone-surface condition is preferable for the production of pulp in the freeness range used for book paper. Higher pulp strength can be obtained on a dull stone, and, for a given quality, the production rate is higher and the energy consumption lower than on a sharper stone surface. To produce pulps of equal strength, aspen requires much more energy than does spruce. When aspen and spruce were ground under similar conditions, the aspen ground at a higher rate, consumed less energy per ton, had less strength, a greater average fiber length, and a higher freeness than the spruce. Data obtained in a Canadian newsprint mill showed aspen groundwood to be about 15 percent higher in freeness, and from one-half to two-thirds lower in various strength properties than spruce or balsam fir (55).

The higher density hardwoods include, of course, the birches, maples, and American beech. They produce much shorter fibered pulps that have lower strength than pulps from the lower density hardwoods. However, groundwood pulp produced from paper birch with relatively low energy consumption was shown experimentally to be suitable for use in a newsprint-type paper in proportions up to 30 percent of the total furnish. Fifty percent of this furnish was a paper birch neutral sulfite semichemical pulp, and the balance was a coniferous groundwood pulp (57). The properties of a similar experimental paper are given in table 5. On the other hand, the presence of only 4 percent of birch groundwood in a groundwood-sulfite news furnish lowered the bursting and tensile strength and the brightness of the sheet, and increased its bulk. This paper ran well on the printing presses, but was considered inferior to standard news furnish (27).

In another mill, studies were made of the effect of gradual increases in the birch groundwood content of papers of different weights and grades in a range from 5 to 20 percent of the groundwood furnish (59). Taking a number of factors into account, it appeared that the energy required per cord was no higher than that required for the softwood, and therefore a power saving per ton of pulp was obtained because of the higher yield per cord. Though pulp strength was lowered when more than 10 percent of the groundwood furnish consisted of birch, no particular difficulty in paper machine operation developed, and satisfactory printing papers were produced with up to 20 percent of birch in the groundwood furnish. Experimentally, paper birch groundwood has also been substituted for about half of the spruce groundwood in a groundwood-sulfite toweling paper (57). The absorbency was tripled without significantly lowering the dry strength. Although the distinct improvement in absorbency was offset by lower wet strength, it seems possible that this objection might be overcome by a suitable treatment to increase wet strength.

Table 2 shows typical groundwood pulping characteristics of some of the less commonly used woods in the Eastern and Lake States compiled from data obtained at the U. S. Forest Products Laboratory. These data exemplify the generally lower strength of hardwood groundwood pulps, compared to that of the more commonly used softwood pulps, and the lower strength of the pulps made from higher-density but shorter-fibered wood compared to that of pulps from woods of lower density.

A great deal of experimenting has been done on methods of steaming, boiling, and chemically treating wood before it is ground, in order to improve groundwood pulp quality. As yet, the practice has proved commercially practicable only in a few special cases. The most important commercial development along this line to date is a recently built mill capable of producing 400 tons of hardwood pulp per day. The pulp is to be used in the manufacture of newsprint (1). Though such treatments lower the yield of pulps slightly and sometimes cause higher energy consumption in grinding, the improved strength and fiber characteristics of the pulps broaden their fields of usefulness. In grinding experiments on steamed and boiled white spruce, balsam fir, aspen, paper birch, eastern hemlock, jack pine, white pine, and tamarack (66), the conifers yielded fairly strong, brownish-colored groundwood pulps suitable for the production of board and the cheaper grades of brown paper. Considerable energy per ton was required to produce satisfactory pulps, however. The aspen and paper birch groundwood pulps were also improved in strength by the steaming and boiling treatments, but they were not so discolored as the coniferous species, nor did they require an increase in energy consumption to obtain the improved pulp. Similar results are reported for yellow-poplar (30).

The chemical pretreatment of wood has received considerable attention (20, 22, 23). The term chemigroundwood recently has been given to the product obtained by grinding wood that has been impregnated with solutions of various chemicals and cooked at elevated temperatures (34). Generally, the object of chemical pretreatment is to obtain a lighter-colored pulp than is obtained by simple steaming and boiling. Most of the earlier work was concerned with the treatment of spruce with sodium sulfite and sodium carbonate. In one instance (43), the pulp obtained was not so light colored as desired, and the treated wood had to be ground at lower pressures with a lightly sharpened stone, thereby slowing groundwood production at the mill. In another instance (35), the cost of chemigroundwood production was higher than that of untreated wood, but since the use of the pulp allowed a reduction in the proportion of the sulfite pulp, a net saving in the cost of the newsprint paper was realized. The process should be practical if the cost of sulfite pulp is high. Jack pine also was treated with sodium sulfite and sodium carbonate (35). The chemigroundwood pulp was substituted satisfactorily for untreated spruce groundwood to the extent of 40 percent in newsprint furnish, although the brightness of the paper was slightly lowered. Experiments on the chemical pretreatment of a number of northern hardwoods have been reported (29, 34, 57). Hardwood chemigroundwood pulps have been found, experimentally, to be suitable for use as a substitute for part of the softwood groundwood in newsprint, book, and toweling papers. It also can be mixed with hardwood groundwood to give mixtures comparable in properties to softwood groundwood pulp.

The usefulness of groundwood pulp can be increased by bleaching or brightening treatments. Though carried on to a limited extent for many years, the practice was not especially attractive, because of cost and the lack of permanent effects. The need for brighter groundwood pulp of more permanent color for book and other papers containing groundwood aroused a new interest in bleaching. The art of bleaching has advanced considerably during the past 10 years, and now the added costs are not so important. The earlier practice of using reducing agents, such as solutions of sulfurous acid or bisulfites, has largely been replaced by the use of zinc hydrosulfite (4, 48). Oxidizing agents, which give more permanent results than reducing agents, are also generally employed now. Among these, the most consideration has been given to the hypochlorites (sodium and calcium) (7, 17, 31) and sodium peroxide (5, 45, 46, 47, 48). In addition to being brighter, papers containing bleached groundwood pulp tend to be slightly higher in strength and have better formation, cleanliness, absorbency, and printing properties than those containing the unbleached pulp.

Sulfite Pulping

The spruces (black, red, and white), balsam fir, and, to some extent, eastern hemlock have been the species highly favored for sulfite pulp in the Eastern and Lake States. The little-used species associated with these preferred conifers are the pines (jack, red, and white), tamarack, and numerous deciduous species, including paper and yellow birch, hard and soft maple, beech, yellow-poplar, and the oaks. The little-used species owe their disfavor to certain difficulties in harvesting, handling, and barking, to unsuccessful application of standard pulping methods in some cases, and, most importantly, to certain deficiencies in pulp quality.

The pulping of a great number of species by the sulfite process was explored by Wells and Rue (71). The poplars, birches, and maples were reported to be reduced readily, jack and white pines to be reduced fairly readily but unevenly, and certain oaks to be reduced with difficulty. There also have been several reviews of the sulfite pulping of little-used species (44, 55, 56). The difficulties encountered in pulping certain specific species of wood have been discussed recently (38). The general pulping characteristics of many Eastern and Lake States woods are given in table 3.

Although no radical changes in sulfite pulping procedures are required for pulping the little-used species, compared to spruce, certain differences can be noted. For instance, compared to the amount of spruce chips charged to a digester, the amount of aspen chips is somewhat less, the amount of pine chips is about the same, and the amount of chips of dense hardwoods like birch, maple, and beech is considerably more. This difference in charge is due mainly to wood density. The weight of birch chips may be 50 percent higher than the weight of spruce chips under the same charging conditions. The extra weight of dense hardwood chips is usually compensated for by charging to a lower level in the digester, because it is generally difficult to increase the acid concentration by the needed amount.

The penetrability of sulfite cooking acid into various species appears to be about the same. Spruce, birch, and aspen have almost the same values for percent of saturation with sulfite acid at 110° C. (25) and for penetration time (table 4). However, the dense hardwoods, because of their low void volume, can absorb roughly only one-half the volume of acid that spruce does. Thus insufficient chemical may be present for cooking, and the rest of the chemical, the base in particular, must reach the wood by diffusion after the pulping temperature is reached (74). If this deficiency is not corrected, high screenings and decreased pulp strength may result (50).

The little-used species may also differ from spruce in rate of pulping. Aspen requires a shorter cooking time because of its faster pulping rate and lower initial lignin content (25). The cooking temperature may be reduced as much as 10° C. in comparison with spruce for the same cooking time. Good practice in aspen cooking includes chip packing, forced circulation, use of preheated acid, and indirect cooking. A typical schedule would include 3 hours to a temperature of 135° C. (at a pressure of 90 pounds per square inch), and a total cooking time of 8 hours. With a cooking liquor containing 6 percent total and 1.1 to 1.2 percent combined sulfur dioxide, the permanganate number would be about 9 (24). On the other hand, birch chips require longer cooking, higher temperature, or stronger acid than aspen for complete pulping (25). An increase in the cooking temperature of a few degrees over that used for spruce may be necessary when cooking birch for the same length of time. Because of the low void volume of dense hardwoods, adequate time should be allowed for raising the temperature to the maximum while the cooking liquor diffuses into the chips so that uniformly pulped chips without burned centers will be produced (39, 55). The pulping of the dense hardwoods is improved considerably by the substitution of sodium for calcium as the cooking liquor base (50).

Black cherry is resistant to sulfite pulping, and is commonly set aside for special treatment. The resistance is believed to be due to a chemical constituent rather than to physical structure (3). Chestnut is resistant because of the presence of a catechin-type tannin (38). Sulfite pulping of beech wood has been commercially practiced for the production of nitrating pulp (37).

The sapwood and heartwood of all species pulp somewhat differently by the sulfite process (50), but the pines are outstanding in this respect. Pine sapwood is readily pulped, whereas the heartwood is more or less refractory, depending on species and other little-known factors. The heartwood of tamarack may also be refractory. The refractoriness of pine heartwood is apparently due to the presence of certain inhibiting agents that prevent the complete sulfonation of the lignin (38, 73). Improved pulping can be obtained by increasing the sulfur dioxide concentration as much as the acid system will permit and using lower temperatures and a longer cooking time or a slower rate of rise to the usual maximum temperature. Also, pine heartwood is more successfully pulped by magnesium- than calcium-base sulfite liquors (8, 62, 74). The varying success obtained in the commercial sulfite pulping of jack pine is undoubtedly due mainly to differences in heartwood content. Young, fast-growth jack pine (74) and red pine (63), presumably low in heartwood, are readily pulped by the sulfite process to give a pulp of good quality. Growth factors affect the quality of sulfite pulps from jack pine in an appreciable manner (15) -- more so, perhaps, than those made of spruce.

The currently increasing application of ammonium-base liquors in sulfite cooking in pulp mills should promote the use of the little-used wood species (28). Such woods as jack pine, maple, and beech would be pulped more rapidly and completely due to the improved penetration of ammonium-base liquor and the greater solubility of the reaction products. It has been claimed that a mixture of beech, birch, and maple can be cooked in about 7 hours (18). The cooking of a similar mixture in 5 or 6 hours by a 2-stage process is also described in the literature (67).

It is generally recommended that all species be pulped separately. This may be difficult in many mills because the various species cannot be handled separately. However, considerable success has been achieved in cooking pine and hardwoods in mixture with spruce. The greatest objection to the cooking of mixtures is the difficulty in controlling the composition of the mixture. Aspen, for example, cooks satisfactorily in all proportions with spruce or balsam (55). Aspen, birch, and maple have been found experimentally to pulp satisfactorily in 50-50 mixtures with spruce (39). The general practice appears to be to use 10 to 30 percent of aspen mixed with spruce, with the best balance at the higher value. Birch and hemlock can be cooked together in any proportion with success, because the pulping characteristics of these species and the quality of the pulp obtained from them are very similar.

A point in favor of the dense hardwoods is their high yield per cord, as shown in table 3. Paper birch and maple may yield over 30 percent more pulp than does spruce. The amount of pulp obtained from a cord of aspen is approximately the same as that obtained from a cord of spruce because, although the aspen is less dense, it has a higher percentage yield.

Hardwood sulfite pulps are generally used in the bleached condition because they are too dirty and shivey for applications normally requiring unbleached pulp. Pine sulfite pulps, however, can be used unbleached. Bleaching of pine and hardwood pulps that have been properly cooked for bleaching is apparently no more difficult than the bleaching of spruce pulps. Although well-cooked pulps can be bleached in a single stage, 2- and 3-stage systems are common. More stages may be found where very high brightness is required, or where the pulp is intended for chemical conversion (61). Recent developments include the use of sodium peroxide for medium brightness and chlorine dioxide for high brightness (6). Oaks, maples, and elms give darker unbleached pulps than birch or aspen, and the pulps are more difficult to bleach because of the inherent coloring matter (38). Although seasoning the wood is the best way to reduce the wax or pitch content of aspen and paper birch sulfite pulps, considerable work has been done on methods of removing these constituents during bleaching. A caustic stage favors pitch reduction in aspen pulp (41), but has not proved beneficial for wax reduction in paper birch pulps. Mechanical removal of resinous fines, the use of detergents, and the proper selection of the bleaching reagents and their order of application have been suggested as means of removing the troublesome wax or pitch from hardwood sulfite pulps (49).

Small amounts of hardwood sulfite pulp are purified for use in special paper products and for chemical conversion. For most of these uses the pentosan content of the hardwood sulfite pulps must be lowered. Special procedures may be necessary (49).

The relative strength of some hardwood sulfite pulps is compared with that of spruce sulfite pulps in table 3. The ratings are for unbleached pulps, but the order would not be expected to change if the pulps were bleached. Birch sulfite pulp approaches the softwood sulfite pulps in strength, having 75 percent of the bursting strength and 90 percent of the tearing strength of spruce sulfite pulp. It is considered to be nearly the equal of hemlock sulfite pulp. Birch sulfite pulps can be used in place of softwood sulfite pulps for all but the strongest papers. The unsolved problem created by the excessive wax in paper birch pulp has apparently hindered its use.

Although aspen sulfite pulp is the weakest of the common hardwood sulfite pulps, (it has only 50 percent of the bursting strength and 60 percent of the tearing strength of spruce sulfite pulp) small amounts have been used in newsprint, mimeograph, and tissue papers, in addition to the usual uses in writing and book papers. Up to 85 percent of bleached poplar has been used in a toweling furnish, and 75 percent in a tissue furnish (24). The strength of bleached aspen approaches that of bleached hemlock (24). Yellow birch, maple, and beech fall between paper birch and aspen sulfite pulps in strength. Beech is practically as strong as aspen.

The outstanding characteristic of the hardwood sulfite pulps is their ability to impart good formation and finish to papers, which accounts for their most important uses in printing and writing papers (44). A secondary characteristic is their potential suitability as a base material for viscose rayon (51). Although the sulfite and soda pulps have been used interchangeably, the hardwood sulfite pulps apparently are not so soft and opaque as the soda pulps, especially aspen soda pulp (25, 44, 71). The hardwood sulfite pulps have been used advantageously in combination with coarse long-fibered pulps to improve the fineness of certain papers that depend on strength for their use (58).

The procedures used for processing softwood sulfite pulps are not entirely suitable for the hardwood pulps (42).

Hardwood sulfite pulps have found some small use as a so-called alpha fiber in paper making (52, 58). Purified hardwood pulps are deficient in tearing strength and folding endurance, but are very soft, absorbent, bright, and clean. These qualities are utilized in absorbent tissue paper.

Purified hardwood sulfite pulps have also been used in the viscose industry. Although the hardwood pulps are short fibered, they form sheets strong enough to be processed (51). The hardwood pulps can also be processed advantageously in combination with softwood pulps.

Undercooked or non-uniformly cooked jack pine sulfite pulps contain red or brown shives. These shives cannot be removed by screening, and therefore prohibit the use of the pulps where cleanliness is important (8). White pine sulfite pulps are inferior to first-grade spruce or balsam sulfite pulps because of the excessive pitch and low tearing strength of the pine pulp (62). Young red pine sulfite pulp compares favorably with high-grade newsprint sulfite pulp, whereas pulp from the mature wood has too much pitch to be usable (63).

Sodium Sulfite Process

Sodium sulfite pulping is of interest in the utilization of hardwoods because bleachable pulps of rather remarkable strength properties have been made by this process. For example, yellow birch has been pulped experimentally with a sodium sulfite liquor buffered with sodium sulfate to produce a pulp with a bursting strength near that of softwood sulfate pulp (16). Also, hard maple and yellow birch sodium sulfite pulps have been developed that have tearing strength equal to that of softwood pulps. Although hardwood sodium sulfite pulps have been produced commercially to a limited extent, this method of pulping has been hindered by the lack of a satisfactory method of recovering the soda in the spent liquor. Much research and process development is now being done on this recovery.

Semichemical Pulping

The idea of softening wood chips with chemicals and then fiberizing the softened chips mechanically dates from the early days of wood pulping. Semichemical pulping, as it is now called, is of especial interest in the utilization of hardwoods, because the resulting pulps have relatively high strength for their short fiber length (36).

All the common pulping reagents can be used for semichemical pulping. The acid pulps are weaker than the neutral or alkaline pulps, which are of approximately equal strength. The alkaline pulps are dark colored, and the acid and neutral pulps are light colored, depending mainly on the brightness of the wood. At a given yield level, the greatest amount of lignin is removed in acid pulping and the least in alkaline semichemical pulping.

The initial commercial application of neutral sulfite semichemical pulping was in the South nearly 30 years ago, when extracted chestnut chips were used to make corrugating board (54). The procedure can be applied to a variety of hardwoods to produce pulps suitable for use in bleached papers as well as in corrugating board.

Sulfate semichemical pulps are also being made commercially from southern hardwoods for corrugating board and wrapping paper.

Hardwood neutral sulfite semichemical pulps are light colored when made from light-colored woods. The pulps are relatively strong, but tend to be hard (tinny) and slow on the paper machine, depending on the fiberizing action. Aspen and birch semichemical pulps are particularly bright and strong. They are used as a partial substitute for chemical pulps in a number of paper products, including newsprint and other groundwood-sulfite papers (9, 10, 19) in addition to their customary uses for corrugating board and coarse wrapping paper. Newsprint papers have been made successfully at the Forest Products Laboratory from furnishes containing 20 to 60 percent of birch or aspen neutral sulfite semichemical pulp, together with varying percentages of spruce, jack pine, aspen, and birch groundwood pulp (40, 57). The properties of two such experimental newsprint papers are given in table 5. Hardwood neutral sulfite semichemical pulp is being used successfully in newsprint in Canada, and groundwood book paper containing semichemical pulp is made in the United States (36, 64). A satisfactory tissue of No. 2 grade has been made from yellow birch semichemical and aspen groundwood pulps and a small percentage of softwood pulp (table 6).

A fully bleached hardwood pulp of exceptional strength and high yield can be made by applying conventional chlorine-hypochlorite bleaching to a neutral-sulfite semichemical pulp (60). The semichemical pulping removes one-third to one-half of the lignin, under relatively mild, neutral conditions, and converts the wood chips into a fibrous form suitable for the removal of the residual lignin by the action of chlorine and hypochlorite. As a result of the secondary removal of lignin, the strength of the unbleached semichemical pulp is increased considerably, and a pulp of desired brightness is obtained. This strength increase for aspen is shown in table 8. Because of its high cellulose and low lignin content and its ease of pulping, aspen is especially suited for the semichemical process. Yields of bleached aspen pulp of 58 percent have been obtained, and the beater-test strength characteristics have been at least the equivalent of certain bleached softwood sulfite pulps. Birch semichemical pulps have similarly high strength. The strength of aspen and birch pulps made by several processes is compared to the strength of spruce unbleached-sulfite pulp in table 8. Bleached semichemical pulps are used in book and magazine papers, glassine and greaseproof papers, food wrappers, and specialty boards (36, 64). They may be used where hardwood pulp of higher strength than can be obtained by the other processes is desired.

Peroxide bleaching has also been applied experimentally to neutral-sulfite semichemical pulps to produce a considerable increase in pulp brightness and a slight increase in strength (32).

The cold soda process being developed at the U. S. Forest Products Laboratory (13, 14) for producing semichemical pulp consists of steeping chips at room temperature in a relatively strong solution of caustic soda for about 2 hours. The treated chips are then fiberized in an attrition mill. The experimental work in progress indicates that the process can be made continuous. The yield is about 90 percent of the weight of the wood used. Aspen cold soda pulp contained more fibers of intermediate length and less fines than aspen and spruce groundwood pulps of equal freeness. It was also stronger than the groundwood pulps, and the test sheet had a higher density. The experiments show that it may be possible to blend this pulp with hardwood groundwoods to produce mixtures approaching the properties of softwood groundwoods. Cold soda pulp responds readily to bleaching treatments. Hardwood cold soda pulps have been used experimentally for making corrugating board and up to 40 percent of the furnish for newsprint and book papers.

A coarse semichemical pulp for insulating products and saturating felts can be made by subjecting wood chips to a light treatment with steam, sodium sulfite, or sodium hydroxide, then fiberizing the chips in an Asplund defiberator (53). Pine and a wide variety of northern and southern hardwoods are being processed successfully in this way. For certain products, it is not necessary to remove the bark from the wood before pulping. Aspen, birch, and a few of the oaks are some of the northern hardwoods that can be used to meet increasing requirements for this type of pulp.

Soda Process

Soda pulps, characterized by their opacity, bulk, softness and absorbency, are customarily made from hardwoods such as aspen, birch, maple, oak, and beech. Aspen is used alone or in mixtures with other available hardwoods.

The strength properties of experimental soda pulps made from quaking aspen, yellow birch, and American beech are given in table 7 as a percentage of those of spruce sulfate pulp. On this basis, the bursting strength was 42 percent for aspen, 52 percent for birch, and 38 percent for beech pulps. The corresponding tearing strength values were 61, 93, and 52 percent, respectively. Relative folding endurance and tensile strength values also indicated that the birch pulps are the strongest of the three, and that beech pulps are the weakest. Aspen and maple, respectively, fall between birch and beech soda pulps when listed in order of decreasing strength (68). Some investigators believe that maple is to be preferred to aspen pulp from the standpoint of yield and pulp properties (55).

Table 7 shows that aspen and birch give higher unbleached soda pulp yields on a weight basis than does beech. On a cord basis, however, the density of the wood is taken into consideration, and aspen gives the lowest pulp yield.

Several mills now use a small amount of elemental sulfur in the cooking liquor. Sulfur has a favorable influence on delignification, screenings reduction, yield, bleach requirement, and strength properties of the pulps (11, 12, 69).

There is a possibility that some of the little-used species, especially those considered difficult to pulp, such as ash and the oaks, might produce more desirable pulps by other modified pulping procedures. For instance, an injection method gave a pulp lighter in color and higher in strength than a straight soda pulp from the same hardwood species (70). Another procedure uses low concentrations of alkali in cooking and a special bleaching technique to obtain a high yield of bleached pulp and improved strength properties (21).

Best results are obtained by cooking hardwood species separately (26), but if separation is not feasible, the mixture should be kept as nearly constant as possible.

Sulfate Process

In the Lake States and Northeast, sulfate pulp is made chiefly from jack pine, but small quantities of hemlock, spruce, tamarack, and hardwoods are used.

Softwoods, of course, are readily reduced by the sulfate process, and give good yields of very strong pulp. The hardwoods are generally easier to pulp, and produce larger yields of fiber.

Most of the more abundant species of both softwoods and hardwoods have been pulped by the sulfate process, either commercially or experimentally (33, 71). However, certain details should be pointed out in connection with hardwood sulfate pulping. The differences in physical characteristics and chemical composition between the various species of hardwoods, and the consequent differences in rate of reduction in the digester, require adjustments in the wood-chemical relationship. This is especially important when trying to reduce a mixture of species uniformly. For high-density hardwoods, an additional allowance should be made for the greater digester charge resulting from increased packing of chips. Because of their higher density, proportionally higher production of pulp can be expected per digester charge without an increase in chemical consumption per ton of pulp. Research at the U. S. Forest Products Laboratory has shown that the strongest and most easily bleached pulps are obtained from hardwoods by using the lowest concentration of chemical possible for the chemical-wood ratio requirements.

The disadvantages of aspen sulfate pulp, as compared with jack pine sulfate pulp, are that it does not take dye so well, and it contains more dirt, although not enough to be objectionable in paper of darker shades (72). Mixtures of up to 25 percent of aspen with jack pine are satisfactorily pulped with about the same temperature schedule as used for jack pine alone, and with approximately 10 percent less chemical. The qualities gained by the use of aspen with jack pine are better formation, a closed sheet and, because less refining is required, improved tear resistance.

Oak is satisfactorily pulped in mixture with other woods by the sulfate process for use in white papers in a few eastern and southern mills. Promising results from experiments on the sulfate pulping of oak in a Wisconsin mill have been reported (2). The oak used in the tests had been chemically debarked. Experiments at the U. S. Forest Products Laboratory indicate that the yield of sulfate pulp obtained from northern red oak is about 45 percent. The tearing strength of the pulp is about equal to that of aspen, but it is appreciably lower in bursting strength and folding endurance.

The relative strength properties of experimental unbleached sulfate (kraft type) pulps from several species are given in table 7, as a percentage of those of spruce sulfate pulp. The pulps made from balsam fir, eastern hemlock, and jack pine are weaker than spruce sulfate pulp, but they have higher strength values than any of the hardwood pulps. The hardwood sulfate pulps, as a group, have higher strength than the hardwood soda pulps. Although comparatively low in tearing strength, paper birch sulfate pulp seems to have the best overall strength properties in the hardwood group, while the American beech pulp definitely has the lowest strength. The yields given in table 7 for hardwood sulfate pulps are higher than those obtained for the soda pulps, and in some instances are higher than yields of softwood sulfate pulps.

Birch and maple sulfate pulps are lower in strength than spruce sulfite pulp, but are softer, bulkier, more opaque, and, because of their short fiber, cause a closer formation in a sheet of paper (56).

Wood of lower quality than that used for sulfite or groundwood pulps probably can be used for making sulfate pulp of acceptable quality (33). Unpeeled aspen can be pulped with very little more chemical than is required for peeled aspen (72).

Certain hardwoods, especially those with a high tannin content, cause undue corrosion in pulp mill equipment. This factor has been an obstacle to their utilization.

Strength of Aspen and Birch Pulps

As mentioned above, the strength of aspen and birch pulps made by various processes is shown in table 8, as a percentage of that of spruce sulfite pulp. These data are from beater-strength tests on experimental pulps. Bleached aspen semichemical pulp produced in a yield of 58 percent had the highest strength values. The values were slightly higher than those for the spruce sulfite used for comparison. The strength of the unbleached and bleached sulfate pulps from both aspen and birch is relatively high. The aspen and birch bleached sulfate and the unbleached birch sulfite pulps approach the softwood sulfite pulps in strength. The aspen soda and sulfite pulps are lower in strength than the others.

Conclusions

Definite possibilities exist for the increased utilization of available Lake States and Northeastern woods, especially the predominant hardwoods, by all the known pulping processes. With the sulfate and soda processes lower-quality wood can be used than with the others. The bleached hardwood sulfate pulps, in addition, approach the softwood sulfite pulps in strength and usefulness, and the weaker soda pulps are noted for their qualities in bulk, opacity, and absorbency. The hardwood sulfite pulps, with the exception of birch, tend to be low in strength, but they can be used in many papers where formation and finish are more important than strength. Strong bleached semichemical hardwood pulps can be made in extra-high yields. The usefulness of groundwood pulp made from the lower-density hardwoods is demonstrated by fairly extensive commercial utilization. The manufacture of hardwood chemigroundwood pulp is in the initial commercial stages. Results of experiments are encouraging for the use of high-yield pulps made from hardwoods by the cold soda process for corrugating board and printing papers. The advantages of using species available locally undoubtedly justifies full consideration of their qualifications.

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Table 1.--Density and chemical composition of some Eastern and Lake States species[1]

Species	Density (moisture-free weight and green volume)	Holocellulose: Total	Holocellulose: Alpha	Cross and Bevan cellulose: Total	Cross and Bevan cellulose: Alpha	Lignin	Total pentosans	Solubility in: Ether	Solubility in: 1 percent caustic soda	Solubility in: Hot water	Ash
	Lb. per cu. ft.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Hardwoods											
Quaking aspen (Populus tremuloides)	22	82	51	64	48	17	23	1.0	19	3	0.3
American beech (Fagus grandifolia)	34	78	...	61	47	23	20	.8	21	2	.2
Paper birch (Betula papyrifera)	34	...	...	60	41	25	26	1.5	19	4	...
Yellow birch (B. lutea)	34	...	...	61	...	...	25	.6	20	4	.5
Eastern cottonwood (Populus deltoides)	23	...	...	63	46	24	19	.3	15	2	...
Sugar maple (Acer saccharophorum)	35	76	...	57	42	23	21	.3	20	3	.2
Silver maple (A. saccharinum)	32	83	...	61	47	21	18	.7	15	2	.2
Yellow-poplar (Liriodendrum tulipifera)	25	...	...	62	45	20	19	.2	17	2	...
Black cherry (Prunus serotina)	30	85	...	60	45	21	20	.9	18	4	.1
White oak (Quercus alba)	37	...	...	51	...	32	22	.7	23	5	.4
Softwoods											
Balsam fir (Abies balsamea)	21	70	44	58	42	29	11	1	11	4	.5
Eastern hemlock (Tsuga canadensis)	24	68	48	56	43	32	10	.7	13	4	.4
Jack pine (Pinus banksiana)	24	72	49	58	41	27	13	2	13	4	...
Eastern white pine (P. strobus)	21	...	...	60	44	28	11	5	16	5	...
Red pine (P. resinosa)	27	...	...	54	...	24	11	5	...	...	...
Black spruce (Picea mariana)	24	...	...	61	44	27	11	1	11	3	.3
Red spruce (P. rubra)	24	73	48	60	43	27	12	1.5	...	...	.2
White spruce (P. glauca)	24	73	49	61	44	27	11	1.5	12	3	.3
Tamarack (Larix laricina)	31	...	...	...	...	...	...	...	...	...	...

[1] Typical values obtained at Forest Products Laboratory; wide variations may occur within single species.

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Table 2.--Typical groundwood pulping characteristics of some less commonly used Eastern and Lake States species
Compiled from data obtained at the U. S. Forest Products Laboratory

Species	Density of wood[1]	Stone surface condition	Pressure of wood on stone	Energy consumed per ton dry wood	Freeness (S.R.)	Screen analysis: Retained on 24 mesh	Screen analysis: Passing 150 mesh	Screen analysis: Fiber length index	Bursting[2] per pound per ream	Tearing[2] per pound per ream	Tensile[2]	Whiteness (Ives parts blue)	Brightness (Hunter)[3]
	Lb. per cu. ft.		Lb. per sq. in.	Hp.-days	Cc.	Percent	Percent		Points	Grams	Lb. per sq. in.	Percent	Percent
Lower-density Species													
Quaking aspen	22	Fairly dull	25	77	435	1.7	40.1	0.097	0.22	0.52	1,122		59
Eastern cottonwood	23	do	30	68	430	1.3	48.9	.084	.19	.45	1,090	64	
Yellow-poplar	25	do	20	83	433	.7	46.1	.089	.15	.45	870		63
Eastern hemlock	24	do	25	80					[4].27		[4]2,600		
2/3 Eastern hemlock 1/3 Jack pine	24 24	Moderately dull	21	83					[4].26		[4]1,970		
2/3 Eastern hemlock 1/3 White spruce	24 24	do	21	69					[4].30		[4]2,580	[4]53	
Jack pine	24	do	32	76	340	14.3	49.1	.087	.24	.80	1,470	65	
Black willow	24	Fairly dull	30	67	325	1.5	54.0	.079	.22	.50	1,230	44	
Higher-density Species													
Green ash	34	Fairly dull	30	62	317	0	74.8	.063	.13	.28	716	72	
White ash	34	do	30	51	483	0	62.8	.071	.09	.35	1,018		62
Paper birch	34	do	30	67	475	.1	62.4	.069	.08	.25	528	67	
American elm	30	do	30	78	252	.1	72.8	.065	.16	.42	940	52	
Sugar maple	32	do	35	75	355	.1	59.7	.072	.13	.34	910		48
Tamarack	31	Moderately dull	32	74					[5].33		[5]2,490	[5]57	
1/2 Tamarack 1/2 White spruce	31 24	Moderately sharp	16	79					[5].32		[5]2,340	[5]61	
Commonly Used Species for Comparison													
Western hemlock	25	Moderately dull	22	50	322	4.3	54.5	.080	.22	.62	1,410	54	
Southern yellow pine[6]	29	Fairly dull	32	79	300	7.0	55.8	.080	.25	.59	1,178	66	
White spruce	24	Sharp	20	52	404	12.7	34.6	.108	.25	.71	1,420	66	
Average of 29 commercial groundwoods				65	350	17.0	35.0	.109	.19	.59	945	59	

[1]Oven-dry weight -- green volume. Typical values; wide variations may occur within species.
[2]Ream size, 25 x 40 - 500. Unless otherwise noted, tests were made on sheets containing groundwood pulp only.
[3]Calibrated in accordance with TAPPI Method T-217 Sm-42.
[4]Twenty-five percent of sulfite pulp and 2 percent of clay added.
[5]Twenty-five percent of sulfite pulp added.
[6]Typical for four major species, loblolly, slash, longleaf, and shortleaf, less than 35 years of age and growth rate less than 10 rings per inch.

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Table 3.--Sulfite pulp yields, pulping characteristics, and pulp properties of some Eastern and Lake States woods

Species	Yield of screened pulp		Relative bursting strength[2]	Relative tearing strength[2]
	Moisture-free wood basis	Per cord[1]		
	Percent	Pounds	Percent	Percent
Black and white spruce	48	920	100	100
Balsam fir	47	790	90	100
Jack pine	45	865	75	100
Paper birch	46	1,250	75	90
Yellow birch	45	1,195	65	70
Maple	45	1,255	65	70
Beech	44	1,195	55	60
Aspen	52	915	50	60

[1]Based on an 85 cubic foot cord: logs 4 feet long with bark on, in stacks 4 feet high, 8 feet long. Six percent allowed for barking, chipping, and fiber loss. Values may vary widely within species.

[2]In the Schopper-Riegler freeness range of 550-600 cc.

Table 4.--Minimum times for penetration of sulfite acid[1] at 110° C. into innermost portion of chips from different species

Species[2]	Time required for penetration
	Hours
White spruce	3.00
Paper birch	3.25
Aspen	3.00

[1]Acid concentration -- 6.25 percent total sulfur dioxide with 1.25 percent combined sulfur dioxide.

[2]Chips prepared by sawing and planing to 1/8 inch thick, 5/8 inch in grain direction, and 1 inch long.

Table 5.--Comparison of properties of experimental newsprint containing hardwood pulps with commercial newsprint

Properties	Experimental newsprint[1] A	Experimental newsprint[1] B	Commercial newsprint[2]
Ream weight (25x40-500)....lb.	39	38	38
Thickness....mils	3.5	2.2	3.3
Density....	.62	.96	.64
Bursting strength.....pts. per lb. per ream	.25	.25	.25
Tearing strength.......gm. per lb. per ream	.57	.52	.54
Tensile strength..........lb. per in. width	9.9	....	8.4
Stretch....percent	2.25	....	1.00
Castor oil penetration....seconds	74	66	50
Gloss....percent	30.2	....	42
Porosity....seconds	55	48	52
Opacity....percent	91	90	92
Brightness....percent	53	56	58

[1] Sheet A contained 35 percent of paper birch semichemical, 20 percent of paper birch groundwood and 45 percent of jack pine groundwood pulp. Sheet B contained 25 percent of aspen semichemical, 37.5 percent of aspen groundwood and 37.5 percent of spruce groundwood pulp.

[2] Average of 56 commercial newsprint papers.

Table 6.--Properties of creped tissue from softwood and hardwood pulps

Properties	Experimental furnish[1]	Commercial furnish[2]
Ream weight (25x40-500)....lb.	15.2	12.2
Thickness....mils	2.36	2.65
Bursting strength......pts. per lb. per ream	.67	.80
Tearing strength........gm. per lb. per ream	.71	.78
Tensile strength..........lb. per sq. inch	561	294
Absorbency..........0.01 cc. per sec.	30	28
Head-box freeness (Schopper-Riegler)....cc.	365	415

[1] 50 percent of yellow birch semichemical, 40 percent of aspen groundwood and 10 percent of commercial softwood sulfite pulp.

[2] 50 percent of softwood sulfite and 50 percent of softwood groundwood pulp.

Table 7.--Yield and strength of experimental unbleached sulfate and soda pulps

Species	Wood: Density (moisture-free weight and green volume)	Wood: Moisture-free wood per cord (85 cubic feet)	Pulp: Yield of screened pulp, moisture-free, per 100 pounds moisture-free wood	Strength values relative to spruce sulfate as 100 percent[1]: Bursting strength	Tearing strength	Folding endurance	Tensile strength
	Lb. per cu. ft.	Pounds	Pounds	Percent	Percent	Percent	Percent
Sulfate (kraft type) pulps							
Spruce	24	2,040	50	100	100	100	100
Balsam fir	21	1,790	50	96	91	106	105
Eastern hemlock	24	2,040	45	96	113	......	94
Jack pine	24	2,040	48	90	92	94	96
Quaking aspen	22	1,870	54	65	65	30	87
Hybrid poplar	23	1,960	55	64	88	......	73
Paper birch	34	2,890	50	77	62	41	86
Yellow birch	34	2,890	53	66	79	33	72
American beech	34	2,890	49	53	69	9	51
Soda pulps							
Quaking aspen	22	1,870	46	42	61	6	53
Yellow birch	34	2,890	47	52	93	13	59
American beech	34	2,890	37	38	52	3	41

[1] In the Schopper-Riegler freeness range of 550 to 600 cc.

Table 8.--Comparison of strength properties of aspen and birch pulps made by various processes

Pulp	Strengths[1] relative to unbleached spruce sulfite pulp as 100 percent			
	Aspen		Birch	
	Bursting strength	Tearing strength	Bursting strength	Tearing strength
	Percent	Percent	Percent	Percent
Bleached semichemical	110	105	...	...
Unbleached sulfate	90	75	110	90
Unbleached semichemical	80	85	75	70
Bleached sulfate	80	90	85	90
Unbleached soda	65	75	...	...
Bleached soda	50	60	...	...
Unbleached sulfite	50	60	75	90

[1] In the Schopper-Riegler freeness range of 550-600 cc.