Potential for multiple use of *Pinus caribaea* var. *hondurensis* wood with emphasis on pulp production

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Abstract

Total tree utilization and multiple use of wood are alternatives to increase both silvicultural and industrial yields. Planted forests with *Pinus* spp. are an important source of raw material for sawmills, veneer plants, and pulp and paper mills. The use of tropical pines, especially *Pinus caribaea*, has been changing the geographical distribution of forests planted with *Pinus* spp. Sawmills and plywood mills that use *Pinus* spp. wood as raw material show approximately 25 and 13.6 percent waste for slab and peeler core, respectively. The materials investigated in this research were: wood from 8-year-old trees, slabs, peeler core, and the upper part (called top) of 23-year-old trees. These materials were characterized in terms of basic density, chemical composition, tracheid dimensions, kraft pulping efficiency, and pulp resistance. The wood from peeler core and 8-year-old trees are juvenile wood, while slab and top are mature woods. Consequently, peeler core and 8-year-old woods showed a lower basic density, higher extractives and lignin contents, and also thinner walled tracheids when compared to slabs and top woods; in terms of pulping, slabs and top woods had higher yields when compared to the pulp from peeler core and 8-year-old trees. Findings showed that all four raw materials investigated in the study had about the same pattern for almost every pulp property analyzed.

The growing world demand for wood and wood products, especially pulp, and the need to conserve natural resources and the environment constitute a challenge to forestry: to simultaneously increase industrial production (lumber, boards, pulp) and reduce environmental impacts.

Considerable research efforts have been carried out in order to increase both silvicultural and industrial yields and two possible alternatives to achieve this are total tree utilization and multiple use of wood.

In Brazil, planted forests with *Pinus* spp. and *Eucalyptus* spp. are the main source of raw material for veneer mills and also for sawmills and pulp and paper mills. The introduction of tropical pine species in Brazil, especially *Pinus caribaea*, and the technological and silvicultural wood characteristics of *Pinus* spp. have been changing the geographical distribution of planted forests with this genus. Planting areas, originally restricted to the South of Brazil, have now spread to the Southeast and West as well as to the North and Northeast regions.

In 1999, the Brazilian conifer roundwood consumption destined for the production of sawn timber and plywood was approximately 15.1 million m^3 and 3.96 million m^3, respectively. The genus *Pinus* spp. is responsible for almost all the conifer industrial wood in Brazil (Brazilian Society of Silviculture and Brazilian Forestry 1990).

Sawmills and plywood mills that use *Pinus* spp. wood as raw material have slab and peeler core wastes of about 25 and 13.6 percent, respectively (Aguiar 1984, Assini et al. 1984).

Considering roundwood volumes and percentage of residues associated with the production of sawn timber and plywood in Brazil, a volume of approxi-

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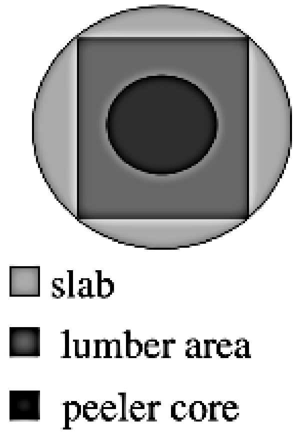

Figure 1. — Sampling design.

mately 4.3 million m^3 of wood from *Pinus* spp. is discarded annually, which presents problems to the wood industry due to the volume of waste produced. Considering an 8-year-old *Pinus* spp. forest, the volume of wood residue produced would correspond to a forest area of approximately 22,000 hectares. This area, if used for pulp production, would result in almost 800,000 tons of unbleached long fiber pulp. There is a great volume of raw material being discarded or simply burnt as firewood. The use of these residues could contribute to increasing pulp production, reduce costs, and conserve natural resources.

The present research evaluated the technological characteristics of sawmill and plywood residues of *Pinus caribaea* var. *hondurensis* used as raw materials for pulp production.

Methods

Sample preparation

Samples used in this study were originated from *P. caribaea* var. *hondurensis* commercial forests at Agudos County, São Paulo State, Brazil (22 degrees 20 min. S and 48 degrees 51 min. W). The trees were 8 years old and 23 years old, and each age group had five trees harvested. Trees were selected based on a forest inventory in which harvested trees were individuals that exhibited the average diameter for the forest.

The 23-year-old trees were converted to 2.4-m-long logs. Logs with diameter greater than 15 cm were considered possible raw materials for sawmill and plywood production. The upper part of the trees whose diameters were between 15 cm and 6 cm (denominated top) were considered a type of residue. A 1-inch-thick disc was obtained from each log and each disc had the slab (sawmill residue) and peeler core (plywood mill residue) areas determined, as illustrated in **Figure 1**.

The 8-year-old *Pinus caribaea* var. *hondurensis* trees were used as controls. From each tree, a 1-inch-thick disc was sampled at 0, 25, 50, 75, and 100 percent of the commercial height (top diameter of 6 cm). Materials were separated by tree and each tree was considerated one replication. The following nomenclature was used:

8-year-old = wood obtained from 8-year-old trees;

slabs = material that corresponds to sawmill residues obtained from 23-year-old trees;

peeler core = material that corresponds to plywood residues obtained from 23-year-old trees;

top = material that corresponds to the upper part (diameter between 15 cm and 6 cm) of 23-year-old trees.

The materials mentioned above were manually chipped using a knife and a hammer; chips greater than 4 mm and less than 3 mm thick were later selected using a caliper.

According to the experimental design, each material is considered a treatment and each tree a repetition, that is, there are 4 treatments and 5 repetitions, totaling 20 samples.

Wood characterization

The following parameters were determined for each material:

- basic density: following procedures described by TAPPI Methods T-258 om-94 (TAPPI 1998);

- tracheid dimensions: small chip fragments were obtained using a blade (50 g). The chips were then treated with nitric-acetic water solution (1:5:2) at boiling temperature for 1 hour and washed with water. The objective was to individualize the tracheids. After being washed, tracheids were treated with safranine 1 percent. Ten laminaes were prepared and for each laminae 10 tracheids were measured for length, width, wall thickness, and lumen diameter. Tracheid dimensions were measured using an optical microscope and a micrometric scale. For each sample (total of 20), 100 tracheids were measured for each of the dimensions just mentioned. The obtained averages for each sample were considered for statistical analysis.

- chemical composition: the total extractives, and lignin and holocellulose contents, were measured for each sample following the procedures described by TAPPI Methods T-222 om-98 and T-264 cm-97 (TAPPI 1998).

Kraft pulping

A rotary laboratory digester was used for kraft pulping and the following cooking conditions were considered for all samples:

- chip weight (ovendried equivalent): 80 g;
- active alkali (% as Na_2O): 22;
- sulfidity (%): 25;
- maximum temperature (°C): 170;
- time to maximum temperature: 90 minutes;
- time at maximum temperature: 60 minutes;
- liquor-to-wood ratio: 5:1.

After cooking, pulps were washed and screened using a 0.05-mm slot screen. Pulps were then centrifuged to remove water and stored in plastic bags in a cold room for further analysis. The following parameters were considered:

- total yield: ratio between ovendried pulp weight and ovendried wood weight;

- screened yield: ratio between ovendried screened pulp weight and ovendried wood weight;

- rejects content: ratio between ovendried rejects weight and ovendried wood weight;

- kappa number: the degree of delignification of pulp or the amount of residual lignin in the pulp (TAPPI Methods T-236 cm-85) (TAPPI 1998); kappa number is the volume (in mL) of 0.1 N potassium permanganate solution consumed by one gram of moisture-free pulp as specified by the TAPPI Methods just mentioned; results were corrected to 50 percent consumption of the permanganate added.

Table 1. — Basic density[a]

Material	Basic density Average	Standard deviation
	-------------(g/cm³)------------	
8-year-old	0.399 A	0.0215
Slabs	0.624 D	0.0294
Peeler core	0.449 B	0.0185
Top	0.505 C	0.0201

[a]Values with the same capital letter are not statistically different (Tukey Test at 0.05 significance level).

Pulp properties

After yield, rejects content, and kappa number analyses, pulps from the five repetitions of each material were mixed forming a composed sample. The four resultant samples were then submitted to bleaching using a sequence CEDD, where C, E, and D denote bleaching stages of chlorine (Cl_2), alkaline extraction, and chlorine dioxide (ClO_2), respectively.

After bleaching, pulps were refined in a PFI mill at refining levels of 20, 30, 40 and 55° Schopper-Riegler (SR), according to methodology described by TAPPI Methods T248 (TAPPI 1998). Refined pulps were transformed into handsheets, so that pulp properties could be evaluated according to TAPPI Methods T205 sp-95 and T220 sp-96.

Statistical analysis

The results for basic density, chemical analysis, fiber dimensions, and pulping were analyzed using the analysis of variance (ANOVA); when a statistical difference was detected, the Tukey test was used.

Results and discussion

Although specific gravity is a gross measurement reflecting the sum of numerous variables within successive individual growth rings, it has been investigated more than any other wood property. This is due to the fact that specific gravity strongly affects lumber strength and yield and also the quality of the corresponding kraft pulp (Koch 1972).

Table 1 shows basic density results for materials evaluated in this research. Basic density is one of the most important characteristic to evaluate wood as a raw material for pulping because it is closely related to several pulping process parameters, such as yield, rejects content, and alkali consumption, among others.

An important basic density aspect should be considered about *Pinus* spp. wood – its growth rings are formed by earlywood and latewood. The proportion of earlywood and latewood is related to cambium activity and strongly affects basic density and other wood properties.

Table 1 results show a statistical difference for basic density of the materials investigated in this research. This difference is mainly due to the position of the materials in the tree, that is, a difference in their physiological age. **Table 1** also shows a difference between slab and top densities, probably because the *Pinus* spp. wood density profile shows a decrease with height (Koch 1972). The basic densities of the peeler core and the top woods are somewhat similar; considering the growth pattern of trees, both peeler core and top are woods produced during similar growth periods in terms of physiological aspects. Additionally, both peeler core and top woods are typically juvenile wood.

The value range for top wood basic density can be placed between basic density values found for 8-year-old woods (juvenile woods) and slab woods. These results suggest that despite the fact that top wood is formed during the late stage of tree growth, the wood does not show a juvenile characteristic; this fact may be related to its more mature vascular cambium.

The variation of wood properties in conifers is usually greater within a tree than among the averages between trees (Barrichelo 1979). Basic density in *Pinus* species usually increases from the center of the disc (pith) to the bark. However, this increment is not uniform due to different types of wood that compose the growth rings.

The ratio between juvenile wood and mature wood should also be considered during the analysis of wood technological properties. Juvenile wood has a lower basic density, larger microfibril angle, shorter tracheids, smaller amount of latewood, thin-walled cells, higher lignin content, and lower cellulose content.

When compared to hardwoods, conifers have a more uniform and less complex wood structure, in which tracheids are the main structural element.

The main objective of wood anatomy focused on wood technology is to establish relationships between the structural characteristics of the wood and its use. Fiber dimensions are important pulp property parameters and determine, for example, the suitability of the pulp to produce specific grades of paper.

The most important fiber dimensions are length, width or diameter, lumen diameter, and wall thickness. Some relationships can be obtained using these dimensions to establish correlations with pulp properties. The following fiber dimension relationships are important: felting index (ratio between fiber length and width), flexibility coefficient (ratio between lumen diameter and fiber width, in percent), wall fraction (ratio between twice the wall thickness and fiber width, in percent), and Runkel index (ratio between twice the fiber wall thickness and lumen diameter) (Foelkel 1973).

Tracheid length is an important wood strength characteristic, especially in the production of kraft pulp from pines (Koch 1972).

Table 2 shows that 8-year-old and peeler core tracheids, in general, have smaller dimensions when compared to slabs and top wood tracheids, which is not surprising because juvenile wood is generally characterized by tracheids of smaller dimensions (Barrichelo 1979).

The difference between juvenile wood and adult wood is also related to the dimensions of anatomic elements. Adult wood, for example, is formed by tracheids that have their length constant. In 30-year-old *Pinus taeda* trees, this stabilization can be observed between the 11th and 13th growth ring.

Much of the tracheid length variation associated with tree diameter and height results from differences between juvenile wood (or core wood), found in the first 4 to 10 rings from the pith, and mature wood (or outer wood) (Koch 1972).

Table 2 results show that, like basic density results, slab and top woods have

Table 2. — Tracheid dimensions and relations.[a]

Material	L	W	LD	T	FI	FC	RI	WF
	(mm)	---------	-μm-	---------		(%)		(%)
8-year-old	3.81 A	53.4 A	36.6	8.4 A	71	69	0.46	31
Slabs	4.48 B	54.9 A	34.7	10.1 B	82	63	0.58	37
Peeler core	3.46 C	54.5 A	39.3	7.6 C	63	72	0.39	28
Top	4.43 D	48.3 B	29.2	9.6 D	92	60	0.66	40

[a]Values with the same capital letter are not statistically different (Tukey Test at 0.05 significance level); L = tracheid length; W = width; LD = lumen diameter; T = fiber wall thickness; FI = felting index; FC = flexibility coefficient; RI = Runkel index; WF = wall fraction.

Table 3. — Chemical composition.[a]

Material	Total extractives	Lignin	Holocelullose
	-------------------	-(%)-	-------------------
8-year-old	7.63 A	26.44 A	65.93 A
Slabs	6.54 B	26.63 A	66.83 B
Peeler core	7.56 A	27.22 B	65.22 A
Top	5.29 C	26.83 A	67.88 C

[a]Values with the same capital letter are not statistically different (Tukey Test at 0.05 significance level).

Table 4. — Total yield, screened yield, rejects, content, and kappa number.[a]

Material	Total yield	Rejects	Screened yield	Kappa number	Screened yield/ kappa number
	--------------	-(%)-	--------------		
8-year-old	48.4 A	0.5 C	48.0 A	55.9 B	0.86
Slabs	52.2 B	0.2 AB	52.0 B	57.1 B	0.91
Peeler core	46.0 C	0.7 BC	45.3 C	59.7 C	0.76
Top	50.2 D	0.1 A	50.1 D	51.8 A	0.97

[a]Values with the same capital letter are not statistically different (Tukey Test at 0.05 significance level).

Table 5. — Pulp properties: slabs, PFI mill.

Parameter	Drainability (°SR)				
	11	20	30	40	55
Revolutions (× 1,000)	0	0.475	0.630	0.730	0.865
Bulk (cm^3/g)	3.3	1.85	1.67	1.65	1.61
Air resistance (sec./100 cm^3)	ND[a]	2.1	3.9	6.4	17.9
Klemm capillarity (mm/10 min.)	142	52	41	34	27
Tensile index (Nm/g)	14.9	72.5	85.6	87.5	87.3
Stretch (%)	1.1	3.8	4.1	4.2	4.0
Burst index ($kPa \cdot m^2/g$)	0.7	6.8	7	7.1	7.2
Tear index ($mN \cdot m^2/g$)	22.0	29.8	29.0	27.0	23.6

[a]ND = not determined.

tracheids with similar dimensions, different from 8-year-old trees and peeler core tracheid dimensions.

Transversal dimensions of tracheids are related to basic density; consequenty, thick-walled tracheids contribute to an increase in the basic density of the wood. Analysis of **Table 1** and **Table 2** results show that slab and top woods show a higher wall fraction because they have higher basic density.

Since chemical composition is extremely important for woods used as pulping raw material, the wood should have low lignin and extractives contents. **Table 3** shows that the chemical composition of the tested materials is similar; however, it should be highlighted that 8-year-old and peeler core woods show a tendency to higher total extractives and lignin contents. These results are typical of juvenile woods and negatively affect the pulping process in terms of delignification and yield.

The efficiency of the kraft pulping process is affected by all technological characteristics of the wood. Eight-year-old woods should be considered standard in Brazil for pulping.

Analyzing **Table 4**, it is possible to verify that the top and slab woods had higher yields and lower kappa numbers when compared to peeler core and 8-year-old chips. These differences in yield and kappa number are related to the higher holocelullose content and lower lignin and extractives contents observed in slab and top woods when compared to other more juvenile materials.

The higher slab and top woods yield is very interesting from an economic point of view because pulp production costs can be reduced by diminishing the amount of chemicals required and energy and wood consumed. These essential points should be taken into account when considering the availability of slab and top woods as a good raw material source.

Even though the performance of fibrous raw material during pulping is an important step in evaluating the wood quality for pulp production, pulp properties should also be considered. **Tables 5, 6, 7,** and **8** show the results of pulp properties analyzed in this study.

An important step in paper production is refining or beating. Refining causes the fiber surface to become frayed as the internal layers of fiber walls separate and the fiber absorbs a great amount of water. This process make fibers swell and become more flexible and conformable. Refining is one of the most important operations during the paper production process because at this stage pulp properties need to meet specific paper grading requirements (Busnardo and Cabeda 1991).

Drainability is measured by the ability of water to drain away from a pulp slurry until it forms a pad. This is a common test used by papermakers to determine the degree of refining that the fibers have been subjected to. The more intense the refining, the greater will be the drainability value measured by the Schopper-Riegler (SR) scale.

Table 6. — Pulp properties: peeler core, PFI mill.

Parameter	Drainability (°SR)				
	14	20	30	40	55
Revolutions (× 1,000)	0	0.45	0.64	0.78	1.30
Bulk (cm^3/g)	3.24	1.86	1.63	1.49	1.34
Air resistance (sec./100cm^3)	ND[a]	0.84	14	23	36.1
Klemm capillarity (mm/10 min.)	84	20	16.5	15	12
Tensile index (Nm/g)	35.9	101	105	106.5	107.6
Stretch (%)	2.3	3.4	3.8	4	4.4
Burst index (kPa·m^2/g)	2.9	6.5	7.6	8.1	8.2
Tear index (mN·m^2/g)	22.3	13.8	12	10.5	10.3

[a]ND = not determined.

Table 7. — Pulp properties: top wood, PFI mill.

Parameter	Drainability (°SR)				
	11	20	30	40	55
Revolutions (× 1,000)	0	0.52	0.7	0.82	1.4
Bulk (cm^3/g)	3.05	1.66	1.62	1.61	1.6
Air resistance (sec./100cm^3)	ND[a]	1	2.8	15	60
Klemm capillarity (mm/10 min.)	71	29	20	16	12
Tensile index (Nm/g)	23	87.5	95	100	89.5
Stretch (%)	1.7	4.1	4.3	4.5	4.7
Burst index (kPa·m^2/g)	1	7.3	8.1	9.8	8.6
Tear index (mN·m^2/g)	27.8	27	27.5	27.5	26

[a]ND = not determined.

Table 8. — Pulp properties: 8-year-old , PFI mill.

Parameter	Drainability (°SR)				
	13	20	30	40	55
Revolutions (× 1,000)	0	0.52	0.69	0.9	1.17
Bulk (cm^3/g)	2.47	1.61	1.51	1.47	1.46
Air resistance (sec./100cm^3)	0.5	6.5	17	36	80.5
Klemm capillarity (mm/10 min.)	122	37	23	17	16
Tensile index (Nm/g)	33.8	98	105	106	105
Stretch (%)	2.1	3.6	4	4.3	4.5
Burst index (kPa·m^2/g)	2.2	7.6	8.2	8.2	8.1
Tear index (mN·m^2/g)	28.1	18.5	16	15.5	18.5

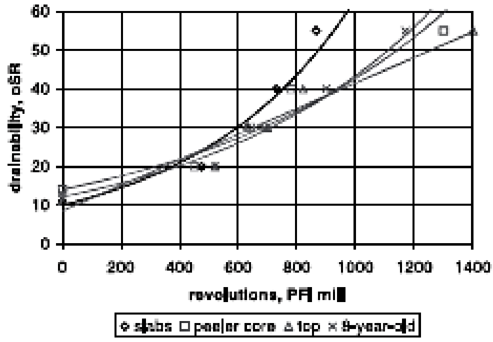

Figure 2. — Pulp drainability.

Figure 2 shows that pulp from slabs has a different performance during refining when compared to other pulps. Over the drainability level of 30° SR, pulp from slabs "reaches" drainability faster than other pulps. Pulp from slabs requires a lower amount of energy to reach a targeted refining level when compared to pulps originated from other materials. This represents a significant advantage because the refining operation is highly energy intensive. The three other materials analyzed showed almost the same pattern during refining.

Pulp properties are related to fiber dimensions; for example, kraft pulps from earlywood generally produce much denser papers with higher bursting and tensile strengths than papers made from latewood. These differences in properties have been attributed to latewood thick-walled tracheids (Koch 1972).

Figure 3 shows that the analyzed pulps are similar in terms of bulk. However, differences are observed when pulps are unrefined or slightly refined; high resistance papers require higher refining levels.

Air permeability, or air resistance, is defined as the resistance that paper presents to the flux of air generated by a difference in pressure. It is a structure-related property that depends on number, size, shape, and distribution of pores in a paper sheet. Air permeability may also provide an indication of how the paper will respond to penetration by other fluids. It indicates the impregnating properties of saturating papers and how much penetration will occur when a paper sheet is coated. Air permeability has a direct importance to the final use and performance of many papers; bag papers, cement sacks, absorbent tissues and toweling, and filter papers all require high air permeability. On the other hand, grease-proof and insulation papers must have a very low air permeability. **Figure 4** shows air resistance results for pulps analyzed in this study.

Figure 4 findings show that as refining increases pulps tend to show different air resistance results. Pulp originated from 8-year-old tree woods will produce pulp with higher air resistance. As mentioned before, this is an important characteristic for papers that will be submitted to a coating process. Pulp produced from slabs shows lower levels of air resistance when drainability is considered a parameter of refining intensity. Pulp

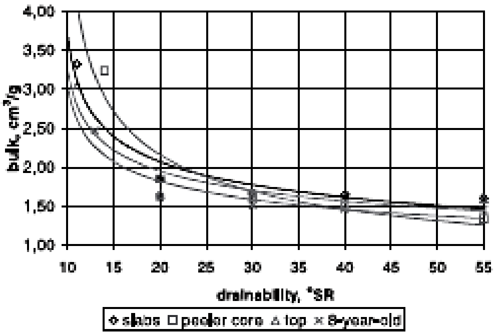

Figure 3.— Bulk.

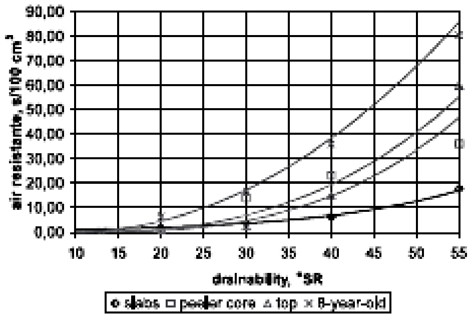

Figure 4. — Air resistance.

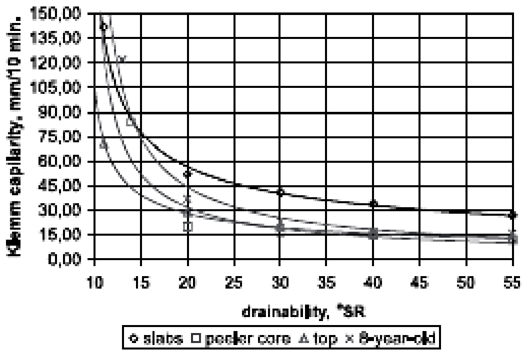

Figure 5. — Klemm capillarity.

produced from slabs is suitable for producing sack papers and tissues when considering only air resistance.

Pulp air resistance is related to the ability of the fiber to collapse during the paper production, and fiber collapsibility is linked to fiber wall thickness. Results presented in **Table 2** show that fibers from slab and top woods have a higher wall fraction. This fact may explain the lower air resistance observed in these pulps.

Klemm capillarity is another important parameter in evaluating pulp suitability for tissue paper production. The aspects already mentioned for air resistance are also important for Klemm capillarity analysis, but other aspects such as residual lignin and carbohydrate contents should also be considered. Due to its hydrophobic characteristics, residual lignin has a negative impact on fiber ability to absorb water; hydrophilic carbohydrates on the other hand have a positive impact on fiber ability to absorb water.

Pulp produced from slabs showed a distinct Klemm capillarity pattern when compared to other pulps. This fact is possibly related to tracheid traversal dimensions, as already mentioned for air resistance. Considering that all pulps had almost the same level of residual lignin (expressed as kappa number), pulp chemical composition does not impact the observed difference significantly.

Tensile strength is a direct indication of the durability and potential final use performance for several papers such as wrappings, bags, gummed tapes, cable wrappings, twisting papers, and printing papers. In general, any paper that undergoes a conversion operation needs to have a minimum tensile strength, since the paper will be subjected to tensile stresses while being pulled during the process, such as printing papers (Scott and Abbott 1995).

There are several ways to increase the tensile strength of paper. For example, it is possible to increase beating or refining, increase wet pressing, add an adhesive, increase long fiber furnish content, among several others (Scott and Abbott 1995). **Figure 6** shows that slab and top wood pulps have a lower tensile resistance and this may be related to the fact that those pulps have thick-walled fibers and consequently a lower collapsibility.

The most important pulp property is often considered to be the maximum tensile resistance, but the deformation the paper undergoes while being stressed is also fundamental. Pulp stretching ability is proportional to the energy that pulps are able to absorb up to the breaking point, especially significant for papers used for sacks. **Figure 7** shows that all raw materials considered in this study had the same stretch pattern.

Tearing strength is particularly important when testing papers and paperboards that will be subjected to tearing forces during their final transformation, that is, during their end-use conversion. Bags, wrapping papers, tissue papers, books, magazines, newsprint pa-

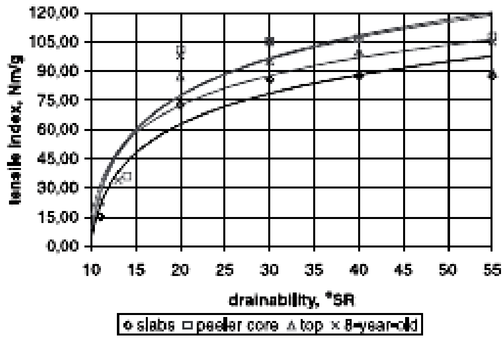

Figure 6. — Tensile index.

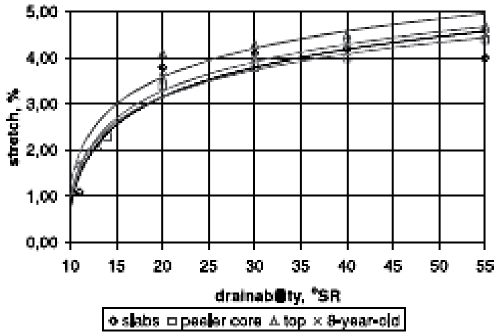

Figure 7. — Stretch.

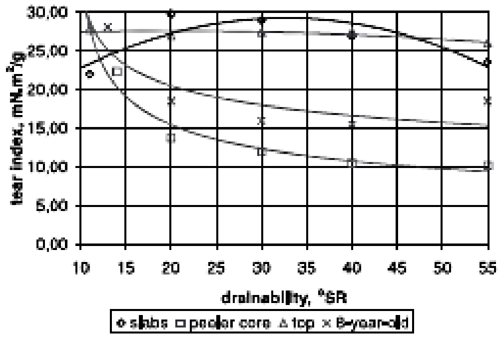

Figure 8. — Tear index.

pers, paperboard for bottle packs, and similar products are important types of paper where tearing resistance is essential (Scott and Abbott 1995).

Figure 8 results indicate that pulps from slab and top woods show similar tear resistance patterns. These results, on the other hand, are completely distinct from those observed for pulps of peeler core and 8-year-old samples.

Tear resistance is related to intrinsic fiber resistance; in general, thick-walled fibers lead to higher tear resistance. **Table 2** shows that slab and top wood fibers have thicker walls when compared to pulps from peeler core and 8-year-old samples, which, therefore, explains the higher values obtained for tear index.

Conclusions

The four materials analyzed, that is slabs, top, peeler core, and 8-year-old *Pinus caribaea* var. *hondurensis* wood samples grown in Brazil, can be classified into two groups based on their technological characteristics and physiological age. The wood from peeler core and 8-year-old trees are essentially juvenile woods, while slabs and tops are mature woods. The consequences of these differences are:

- Peeler core and 8-year-old woods show lower basic density and higher extractives and lignin contents as well as thinner-walled tracheids when compared to slab and top woods.
- Slab and top woods had higher pulping yields when compared to peeler core and 8-year-old tree pulps.

Results obtained showed that all investigated raw materials had almost the same pattern during refining for pulp physical-mechanical properties, with the exception of tear resistance; pulps generated from slab and top woods showed much better tear resistance.

In Brazil, 8-year-old tree woods would be considered as the standard for comparison. Since slab and top woods had higher yields and pulp properties than the 8-year-old wood, they can be considered a suitable raw material for kraft pulping. On the other hand, peeler core wood should be used for energy production because its higher lignin content results in lower pulp yields.

Slab and top woods represent a technical and economical raw material alternative that could be effectively used in sawmills and veneer mills.

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