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KRAFT PULP AND CHEMICAL PROPERTIES OF *CECROPIA PALMATA* WOOD

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The present study was aimed at evaluating the chemical properties and the kraft pulp produced for *Cecropia palmata* wood and comparing them with *Eucalyptus grandis* wood. Discs along the stem of 6-year-old trees were transformed into chips. Half of the chips were used for characterisation of wood chemical properties and the rest was cooked to produce kraft pulp. The properties of the pulp were determined and results showed that: (1) there was a decrease of 3.8% in the yield of *C. palmata* pulp compared with *E. grandis*; (2) specific volume of *C. palmata* wood pulp increased with increasing refining time but the time to reach the same Schopper-Riegler degree was shorter than *E. grandis* pulp; and (3) *C. palmata* had higher air resistance and tear index than *E. grandis*, while the opposite was observed for tensile index, burst index and stretch. *Cecropia palmata* wood had lower lignin content and higher total extractives and holocellulose contents than *E. grandis* wood.

Keywords: Imbaúba, pulp properties, pulp yield, fibre, chemical compounds

INTRODUCTION

Cecropia palmata (imbaúba) is a pioneer plant species native to Brazil and has high potential for ecological restoration projects in the Amazonian Forest (Antongiovanni & Metzger 2005, Zeller et al. 2013). This species presents fast-growing trees, high basal area and is one the most frequent species in secondary forests (Rodrigues et al. 2007). Its wood is used for making low-density particleboards, charcoal and paper.

In general, the heterogeneity of wood causes a great deal of inconvenience mainly to the furniture, wood and pulp and paper industries. Chemical, physical and anatomical variations in the wood change the yield and quality of the pulp and the paper (Forsström et al. 2005, Sansígolo & Ramos 2011, Santos et al. 2012, Severo et al. 2013). Variations in pulp properties of low and high density woods are due to fibre coarseness (Santos & Sansígolo 2007, Magaton et al. 2009). Longer fibre lengths and higher fines content of wood with high density positively influence the mechanical properties of pulp (Myers et al. 1996, Santos & Sansígolo 2007). Yield and tear index of pulp from mature wood of *Populus tremuloides* are higher than that of juvenile wood (Myers et al. 1996) but the opposite was observed in *Pinus contorta* (Hatton & Gee 1994).

Although various studies have been conducted on pulping of several softwood and hardwood, there is little knowledge on pulping of new potential species. Thus, the present study was aimed at evaluating the chemical properties and the kraft pulp produced from *C. palmata* wood and comparing it with those from *Eucalyptus grandis* wood.

MATERIALS AND METHODS

Collection of materials

This study utilised the wood of 10 trees from 6-year-old *C. palmata* from a naturally-grown forest located in Peixoto de Azevedo-Mato Grosso State (10° 21' S, 54° 19' W), Brazil, as well as 10 trees from 6-year-old *Eucalyptus grandis* from the reforested area managed by the Lwarcel Company located in Cabrália Paulista, São Paulo State (22° 27' S, 49° 20' W), Brazil. Trees were felled and 30-mm thick discs were sectioned in the stem with a chainsaw. The first disc was sectioned at the base and the others at 25, 50, 75 and 100% up to commercial height (diameter of 8 cm). Each disc was subdivided into 90° wedges. One wedge from each disc of each tree was used to determine the basic density (ratio between the oven-dry mass and saturated volume) (ABCP M14 1970), and the rest of the wedges were used for determination of chemical and anatomical properties and kraft pulping.

Chemical and anatomical properties of woods

Two wedges from each disc of each tree were manually turned into chips using a machete and hammer. Chips from discs of the same tree were grouped into composite samples, which represented each tree that was studied. A portion of the chips was processed into sawdust of between 40 and 60 mesh using a cutting mill. Total extractives content was determined by extraction sequences with ethanol/toluene 1/2 (v/v), ethanol and hot water (TAPPI T 12 wd-82 1999). The acid-insoluble Klason lignin (TAPPI T 13 wd-74 1999) and holocellulose contents (ASTM D-1104 1978) were determined in extractive-free wood.

Morphologic analysis of fibres from *C. palmata,* as well as *E. grandis* was performed using fibre quality analyser. The analyser measured the dimensions of 20,000 fibres and gave the average values (fibre length, fibre width, fibre coarseness and fibre population, i.e. fibres per mass unit) that represented the compound samples.

Kraft pulping of wood

Kraft pulping of *C. palmata* and *E. grandis* wood was performed using a digester. The following kraft cooking conditions were used: active alkali as Na_2O of 16% oven-dry wood, 0.05% anthraquinone, 25% sulfidity, maximum cooking temperature of 170 °C, time up to target a maximum temperature of 90 min, cooking time at maximum temperature of 30 min, and liquor-to-wood ratio of 3.8 L kg^{-1}. Subsequently, the pulps were washed, screened and processed using fibre sorter equipped with a 0.2-mm slot screen.

Refining and physic-mechanical properties of kraft pulp

Samples of each kraft pulp were beaten in a mill at 4500, 6750, 9000, 11,250 and 13,500 revolutions min^{-1}. The refining degree was determined using Schopper-Riegler method (SCAN M3:65 1980). Handsheets, each weighing 60 g m^{-2}, were made in a Rapid-Köthen sheet former for the physico-mechanical tests, and placed in a climatic chamber adjusted to 23 ± 2 °C and 50 ± 2% relative humidity, according to the standards presented in TAPPI T 402 om-93 (1999). The following physico-mechanical properties were evaluated: specific volume (TAPPI T 220 sp-96 1999), tensile properties (TAPPI T 494 om-96 1999), burst index (TAPPI T 403 om-97 1999), tear index (TAPPI T 414 om-98 1999), and air resistance (TAPPI T 460 om-96 1999). The relationship between each physico-mechanical property and the Schopper-Riegler degree (°SR) was evaluated using linear and polynomial regression by taking into account the observed tendency of data.

RESULTS AND DISCUSSION

Chemical and anatomical properties of wood

Table 1 shows that the total extractives, lignin and holocellulose contents of *C. palmata* wood are 4.05, 20.81 and 76.51% respectively, and these respective compounds in *E. grandis* wood are 2.68, 24.03, and 73.29%. Morphologic analyses of fibres of *C. palmata* and *E. grandis* wood are tabulated in Table 2. Average fibre lengths of the two species were 1.289 and 0.832 mm and fibre widths were 26.37 and 18.53 mm. Fibre coarseness of both species were 23.55 and 13.23 mg 100 m^{-1}respectively, while fibre population values in the pulp were 5.7 and 12.1 mil fibre g^{-1} respectively. These results are similar to those of hardwood (Fengel & Wegener 1989), some eucalypts (e.g. Severo et al. 2013) and *C. palmata* (Paula 2003). The values of *C. palmata* wood are similar to values of other common species used in pulping industries, so this Amazonian species has potential to the proposed use.

Kraft pulping of woods

Total and screened pulp yield values of *C. palmata* wood were smaller (up to 3.8%) than that of *E. grandis* wood (Table 3). The reject rate based on wood and pulp used of both species were not significantly different.

Low basic density and holocellulose content and high lignin and total extractives contents

Table 1 Chemical properties of *Cecropia palmata* and *Eucalyptus grandis* wood

Property	N	*E. grandis*		*C. palmata*		Reduction or (increase) %
		CV	Mean	CV	Mean	
Total extractives content, %	10	22.69	2.68	12.85	4.05	(51.1)*
Klason lignin content, %	10	5.34	24.03	4.91	20.81	13.4*
Holoceluloses content, %	10	2.16	73.29	2.33	76.51	(4.4)*

N = repeat number of trees, CV = coefficient of variation, * = significant difference by F test at probability 95%

Table 2 Morphologic analysis of fibres and basic density of *Cecropia palmata* and *Eucalyptus grandis* wood

Property	N	*E. grandis*		*C. palmata*		Reduction or (increase) %
		CV	Mean	CV	Mean	
Fiber length (mm)	10	n.d.	0.832	n.d.	1.289	(54.9)
Fiber width (mm)	10	n.d.	18.53	n.d.	26.37	(42.3)
Fiber coarseness (mg 100 m^{-1})	10	n.d.	13.23	n.d.	23.55	(78.0)
Fiber population (millions of fibers g^{-1})	10	n.d.	12.1	n.d.	5.7	52.9
Fines fraction (%)	10	n.d.	1.27	n.d.	3.70	(191.3)
Basic density (g cm^{-3})	10	6.09	0.455	14.31	0.389	14.5*

N = repeat number of trees, CV = coefficient of variation, n.d. = not determined because composite samples by 20,000 fibres were measured, * = significant difference by F test at probability 95%

Table 3 Kraft pulping of *Cecropia palmata and Eucalyptus grandis* wood

Property	N	*E. grandis*		*C. palmata*		Reduction or (increase) %
		CV	Mean	CV	Mean	
Total pulp yield, % oven-dry wood	10	3.52	52.26	4.46	50.28	3.8*
Screened pulp yield, % oven-dry wood	10	3.12	51.70	3.85	49.89	3.5*
Reject rate, % oven-dry wood	10	66.28	0.56	181.11	0.39	30.4^{NS}
Reject rate, % oven-dry pulp	10	63.28	1.07	176.40	0.75	29.9^{NS}
Wood consumption, m^3/t oven-dry pulp	10	7.03	4.27	15.39	5.26	23.2*
Kappa number	10	12.27	19.1	26.86	18.2	4.7^{NS}

N = repeat number of trees, CV = coefficient of variation, * = significant difference by F test at probability 95%, ^{NS} = non-significant difference

reduce wood pulping yield and increase the rejects produced during pulping (Magaton et al. 2009, Sansígolo & Ramos 2011, Santos et al. 2012). Thus, as seen in Table 1, the higher total extractives content of *C. palmata* compared with *E. grandis* wood can explain its lower pulp yield and reject rate obtained during pulping process. In addition, the lignin structure (syringyl/guaiacyl ratio), the higher total extractives content and the lower basic density of wood have been considered as the main causes of this variability (Santos et al. 2012). Thus the structure of lignin from *C. palmata* should be studied in future studies.

Physico-mechanical properties of the kraft pulps

The physico-mechanical properties of the kraft pulps from *C. palmata* and *E. grandis* wood are shown in Figures 1 and 2 in the form of the Schopper-Riegler degree. Kraft pulp from *C. palmata* wood required shorter refining revolution and, consequently, shorter refining time compared with pulp from *E. grandis* to reach the same Schopper-Riegler degree. This effect may be explained by the difference in basic density between *C. palmata* (0.389 g cm^{-3}) and *E. grandis* wood (0.455 g cm^{-3}). Similar results were shown by Hatton and Gee (1994) and Santos and Sansígolo (2007).

Kraft pulp from *E. grandis* wood produced sheets with lower specific volume than pulp from *C. palmata* wood at the highest refining levels (Figure 1b). Similar results were reported by Hatton and Gee (1994), Forsström et al. (2005) and Santos and Sansígolo (2007) for pulps of *Pinus contorta*, *Picea* sp. and *E. urophylla* × *grandis* respectively. This effect on sheets specific

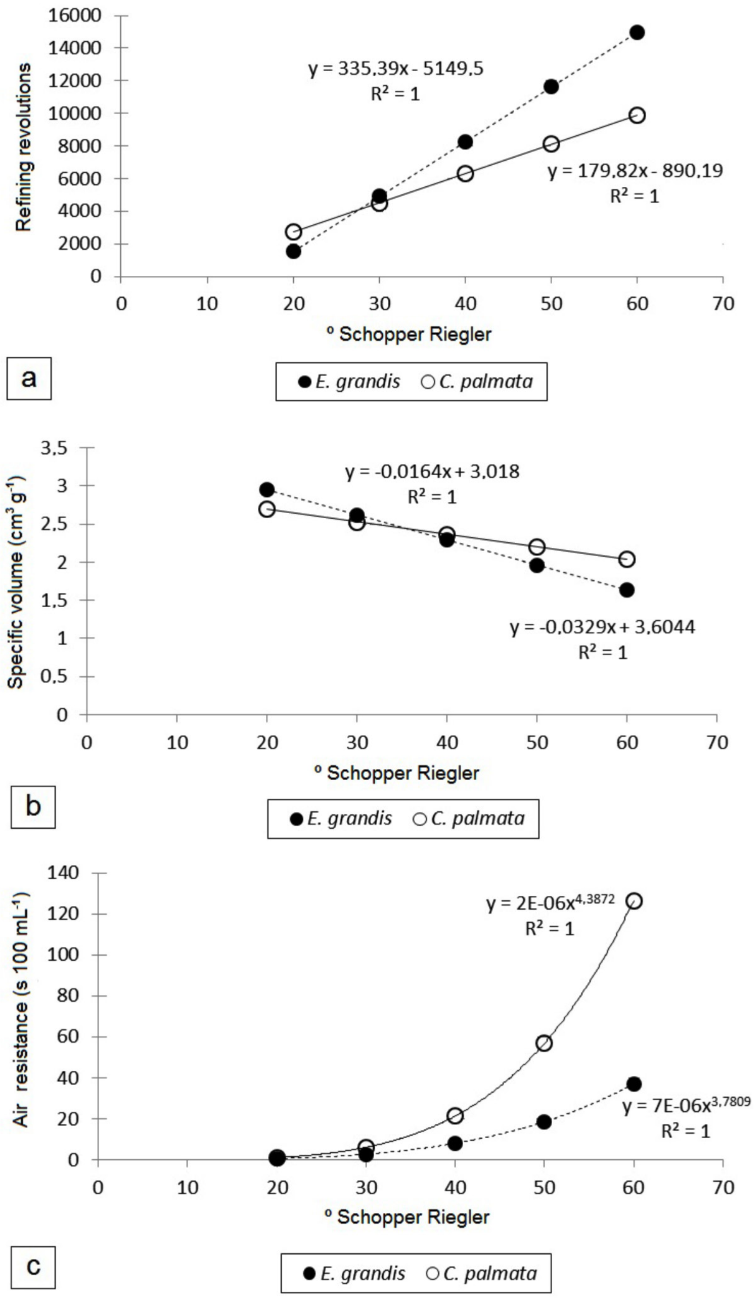

Figure 1 Physical properties and air resistance of kraft pulp from *Cecropia palmata* and *Eucalyptus grandis*

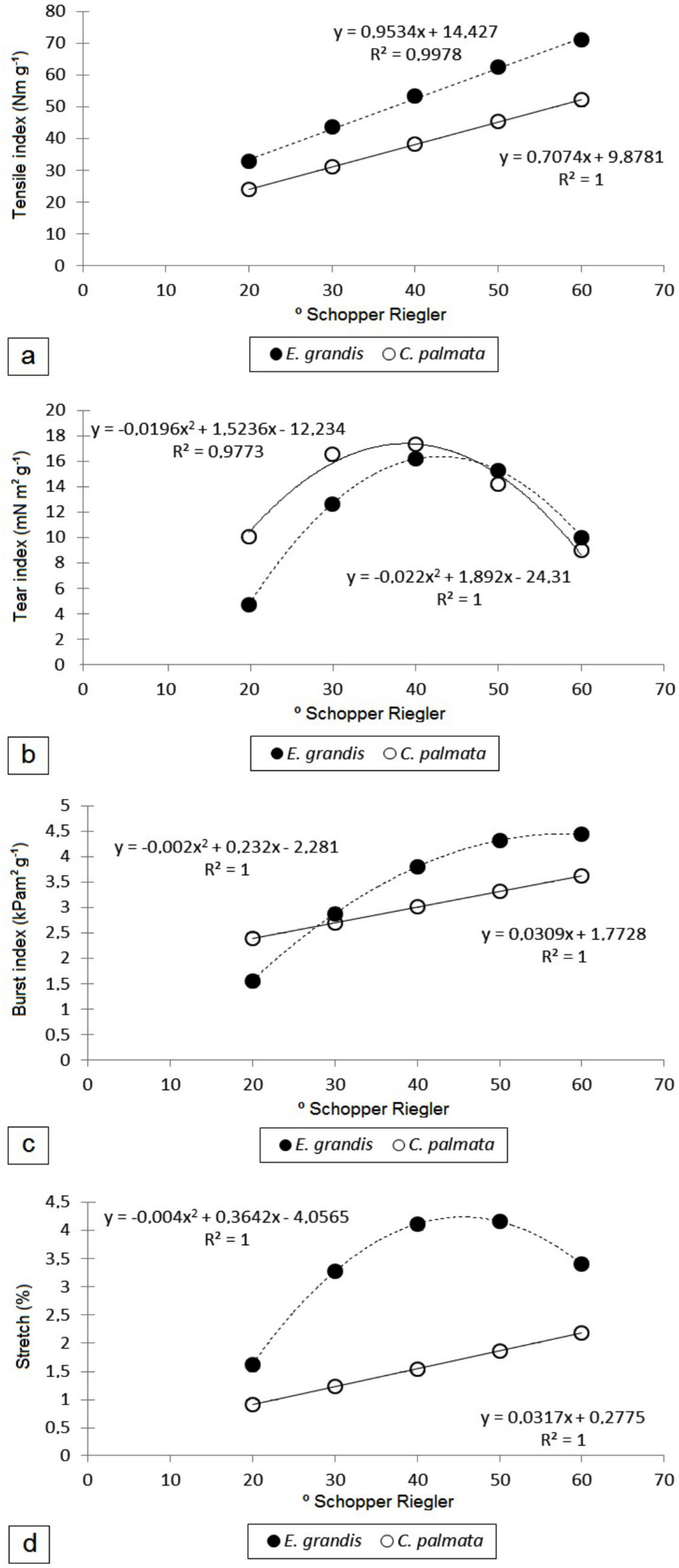

Figure 2 Mechanical properties of kraft pulp from *Cecropia palmata* and *Eucalyptus grandis*

volume may be explained by the difference in coarseness (see Table 2) between *C. palmata* (23.55 mg 100 m^{-1}) and *Eucalyptus* wood (13.25 mg 100 m^{-1}). Wood fibres with low coarseness produce pulp with high consolidation among the fibres (Forsström et al. 2005).

Refined pulp of *C. palmata* had similar air resistance as *E. grandis* pulp until 30 Schopper-Riegler degree but increased thereafter (Figure 1c). Longer and wider fibres in *C. palmata* wood pulp with an increase in the Schopper-Riegler degree can be associated with higher fines fractions produced at the higher levels of refining (Santos & Sansígolo 2007). Low levels of refining and good air resistance of *E. grandis* wood pulp are due to strong interfibre bonding. This bonding is due to the lower coarseness of these fibres (Hatton & Gee 1994, Forsström et al. 2005). In this present study, fines fraction of *C. palmata* was 3.70%, while in *E. grandis* it was 1.27% (Table 2). The fines fraction, also called fines content, is an important property for pulping of wood species. The higher the fines content the lower the pulping yield.

Kraft pulp from *C. palmata* had lower tensile index, tear index and stretch compared with *E. grandis* for all levels of the Schopper-Riegler degree (Figure 2). This shows that the higher the basic density, the higher the mechanical resistance of kraft pulps. (Hatton & Gee 1994, Forsström et al. 2005, Myers et al. 1996, Santos & Sansígolo 2007). *Eulalyptus grandis* pulp had lower tear index than *C. palmata* wood at the smallest Schopper-Riegler degree. However, at 40 Schopper-Riegler degree the pulps showed opposite behaviour showing that high levels of refining produce high fines fraction. Although lower fibre coarseness of wood improved interfibre bonding (Hatton & Gee 1994, Forsström et al. 2005), increased refining level produced higher fines fractions in *E. grandis* wood, and the tear index values of this pulp were similar to those presented by the *C. palmata* wood pulp. In general, the pulps that produced paper with higher tensile strength (Figure 2a) also produced stiffer sheets. However, interfibre bonding, chemical properties and refining time can change this relationship.

CONCLUSIONS

Cecropia palmata wood had lower lignin content and higher total extractives and holocellulose contents than *E. grandis* wood. Through kraft pulping of *C. palmata*, it was concluded that: (1) there was a decrease of 3.8% in the total pulp yields compared with *E. grandis* wood; (2) this wood pulp had higher specific volume with increasing refining time and required a shorter refining time than the pulping of *E. grandis* wood to reach the same Schopper-Riegler degree; and (3) this wood pulp had higher air resistance and tear index than *E. grandis*, while the opposite was observed for pulp tensile index, burst index and stretch.

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