THOROUGH CHARACTERIZATION OF TROPICAL PINE SPECIES FOR KRAFT PULP PRODUCTION

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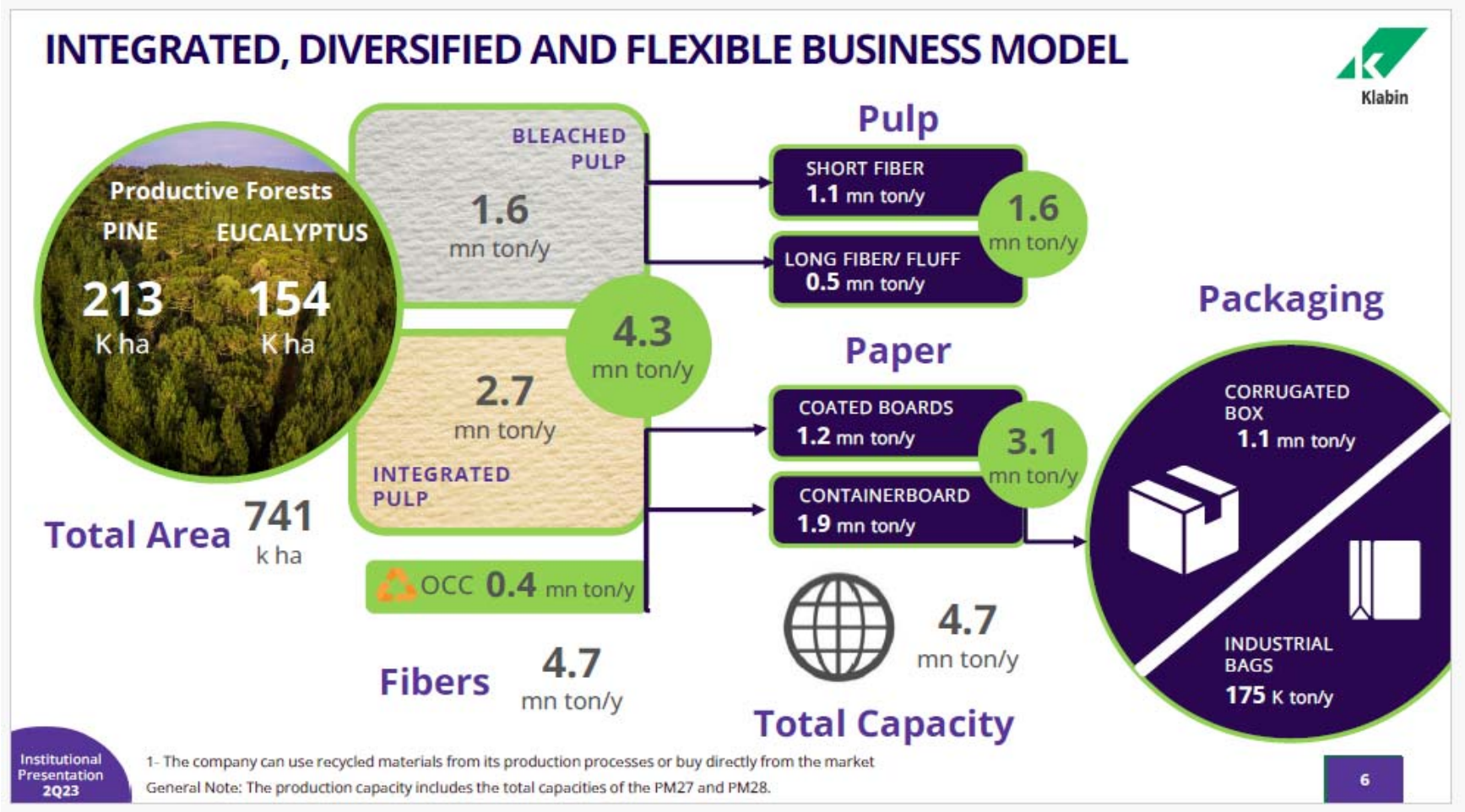

Source: 2Q23 Institutional Presentation (ri.klabin.com.br)

CELLULOSE PRODUCTION

- Brazil is the second largest pulp producer in the world, reaching 22.5 million tons of production in 2021.
- The total area of planted trees in 2021 was 9.93 million hectares, being only 19.4 % of *Pinus* species.
- Pine wood (softwood) is the main raw material for the long fiber kraft pulp production in Brazil.

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Long Fiber Cellulose
(softwood)

CORONAVIRUS PANDEMIC

The growth in delivery and e-commerce, led to an increase of 3.9 % in packaging paper demand in 2021.

PLANTATION

Among the most planted species of *Pinus* in Brazil, the one that stands out is *Pinus taeda*, cultivated mainly in southern region.

OTHER SPECIES (ex.: tropical)

There are other species of *Pinus*, such as the tropical ones, with great potential for use.

Pinus maximinoi	*Pinus caribaea* var. *hondurensis*	*Pinus caribaea* var. *caribaea*
It has shown a remarkable difference in growth and wood quality for pulp production.	Originally from Central America.	Good development and adaptation in other regions.

OBJECTIVE

THE AIM OF THIS STUDY IS TO EVALUATE THE WOOD QUALITY OF 4 GENETIC MATERIALS OF PINUS GENDER, SIMULATING THE PULPING (KAPPA 30) AND BLEACHING PROCESSES (BRIGHTNESS 90% ISO), AT 13 YEARS OLD.

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Pinus taeda	13,3 years old
Pinus maximinoi	13,4 years old
Pinus caribaea* var. *hondurensis	12,8 years old
Pinus caribaea* var. *caribaea	13,3 years old

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ORIGIN OF THE SAMPLES

TELÊMACO BORBA - PR

Pinus taeda

Pinus maximinoi

JAGUARIAÍVA - PR

Pinus caribaea var. *hondurensis*

VENTANIA - PR

Pinus caribaea var. *caribaea*

TELÊMACO BORBA - PR

JAGUARIAÍVA - PR

VENTANIA - PR

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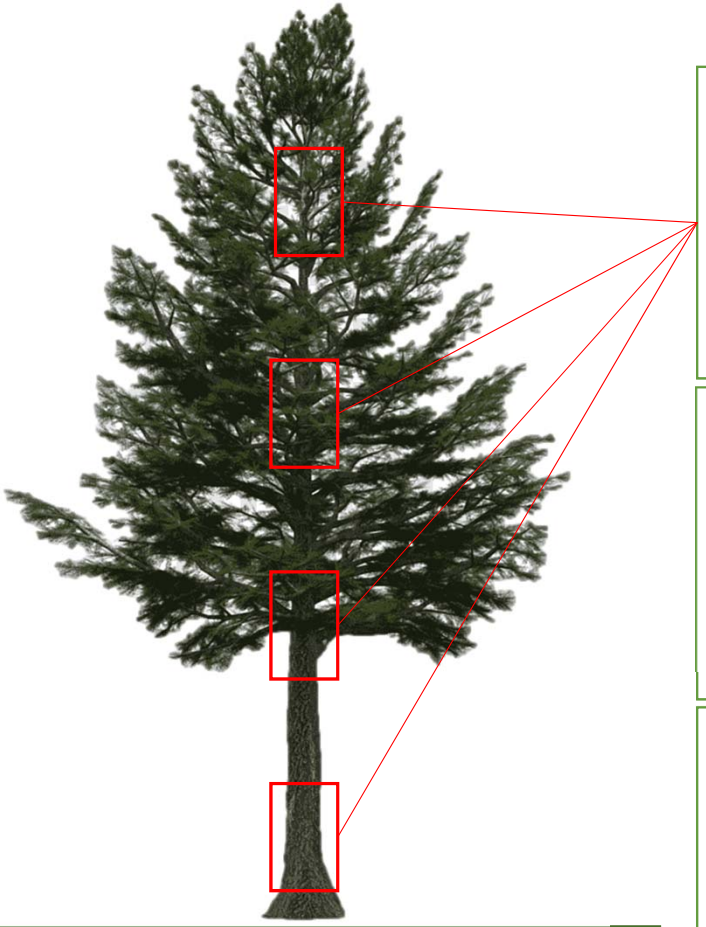


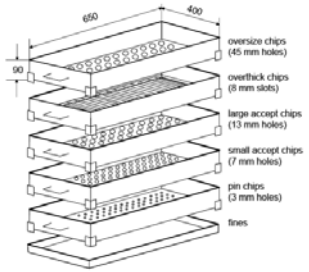
WOOD SAMPLES

LOG SAMPLES

Base, 33, 66 and 100 % of commercial height.

CHIP SAMPLES

The logs were processed into chips.



CLASSIFICATION

The chips were classified according to the SCAN-CM 40:1 standard procedure.

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Experimental (Wood Characterization)

- Basic Density (SCAN CM-46:92)
- Extractives Content (TAPPI T 204 cm-17)
- Insoluble Lignin Content (TAPPI T 222 om-97)
- Soluble Lignin Content (TAPPI UM 250)
- Ash Content (TAPPI T 211 om-16)
- Carbohydrate Content (TAPPI T 249 cm-09)

Experimental
(Pulping Process)

Pulping Stage	Time to temperature, min	Time at temperature, min	Temperature, C°
Pre-steaming	10	20	100
Impregnation	15	45	138
Pulping	20	124	166.2

- ❑ Active Alkali
- ❑ Screened Yield
- ❑ Rejects Content
- ❑ Pulp Viscosity (TAPPI T 230 om-13)

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Parameters	Bleaching Stages				
	O/O	D_0	(EOP)	D_1	P
Consistency, %	10/10	11	11	11	11
Time, min	30/60	15	100	93	90
Temperature, °C	90/100	80	84	72	80
Pression, kPa	1000/500	-	200	-	-
Bleaching Reagents					
NaOH, kg/a.d. ton	35.0/0	-	11.5	-	2.3 - 4.0
O_2, kg/a.d. ton	25.0/0	-	3.5	-	-
$MgSO_4$, kg/a.d.ton	3.33/0	-	-	-	-

NaOH = sodium hydroxide; O_2 = oxygen; $MgSO_4$ = magnesium sulfate.

Bleaching

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Experimental
(Bleached Pulp)

- Morphology (TAPPI T 271 om-12 and ISO 16065-N)
- Carbohydrate Content (TAPPI T 249 cm-09)
- Pulp viscosity (TAPPI T 230 om-13)
- Pulp Brightness (TAPPI T 527 om-13)

Oxygen Delignification Process

$$Efficiency = \left(\frac{kappa\ number\ decrease}{initial\ kappa\ number}\right) * 100$$

$$Selectivity = \frac{kappa\ number\ decrease}{viscosity\ decrease, cm^3/g}$$

Bleaching Process

$$Efficiency = \frac{kappa\ number\ decrease}{initial\ kappa\ number}$$

$$Selectivity = \frac{kappa\ number\ decrease}{Total\ Active\ Chlorine}$$

$$Total\ Active\ Chlorine\ (TAC) = (ClO2\ x\ 2.63) + (H2O2\ x\ 2.09)$$

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(Physical-mechanical properties)

- ❑ Tensile Index (TAPPI T 494 om-13)
- ❑ Burst Index (TAPPI T 403 om-15)
- ❑ Tear Index (TAPPI T 414 om-12)
- ❑ Bulk (TAPPI T 411 om-15)

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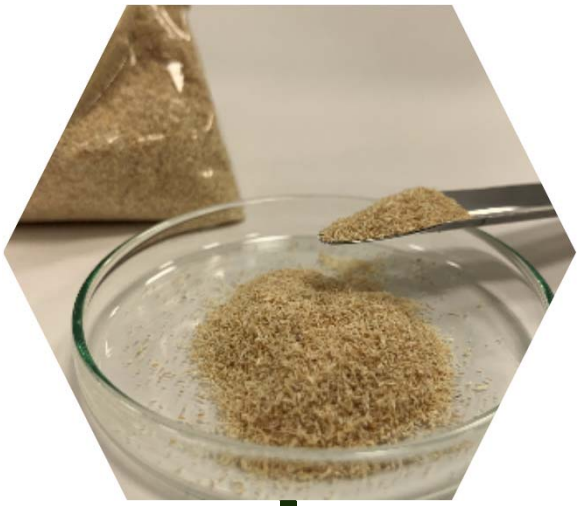
RESULTS



WOOD

PULP

PAPER

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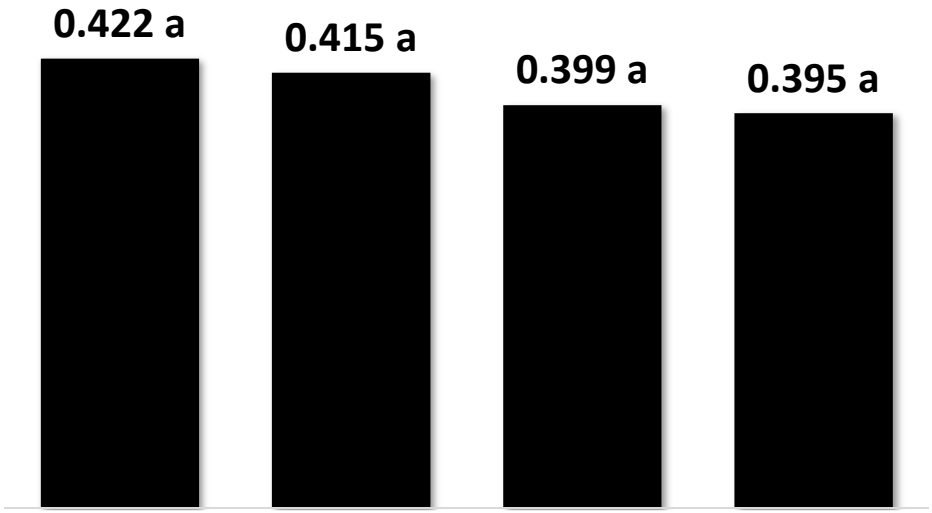
Basic Density



- *Pinus maximinoi* – 0.399 g/cm³ (14 years old).
- *Pinus caribaea* var. *hondurensis* – 0.431 g/cm³ (18 years old).
- *Pinus caribaea* var. *caribaea* – 0.339 g/cm³ (6,5 years old) and 0.374 g/cm³ (17 years old).

The basic density influences the performance of pulping process, concerning the digester productivity and kraft pulp quality. Among many reasons, it can be considered as one of the main parameters to evaluate the wood quality.

Fiber dimensions are important indicators of wood's potential for pulp and paper manufacturing.

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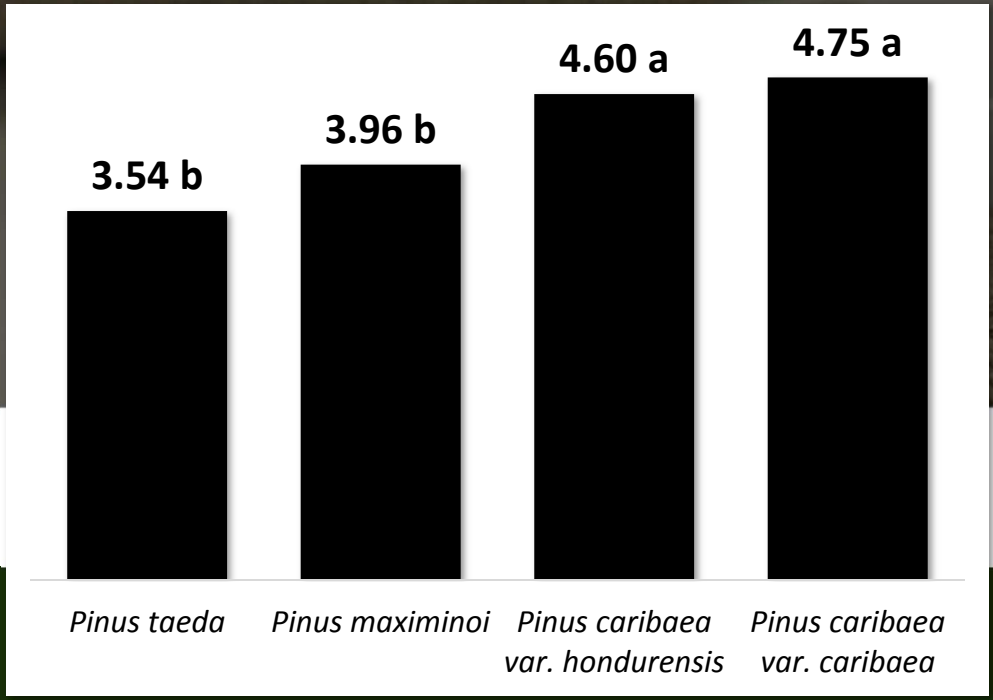
Extractives Content



- *Pinus maximinoi* – 3.5% and 4.5%.
- *Pinus caribaea* var. *hondurensis* – 4.71% and 7.39%.

For pulping, wood with lower extractives and lignin content is preferred as this greatly reduces the cost of chemicals used for its removal.

High extractives levels can cause “pitch”, incrustations in industrial equipment, in addition to being deposited in the cellulosic pulp and consume more alkali in the pulping process.

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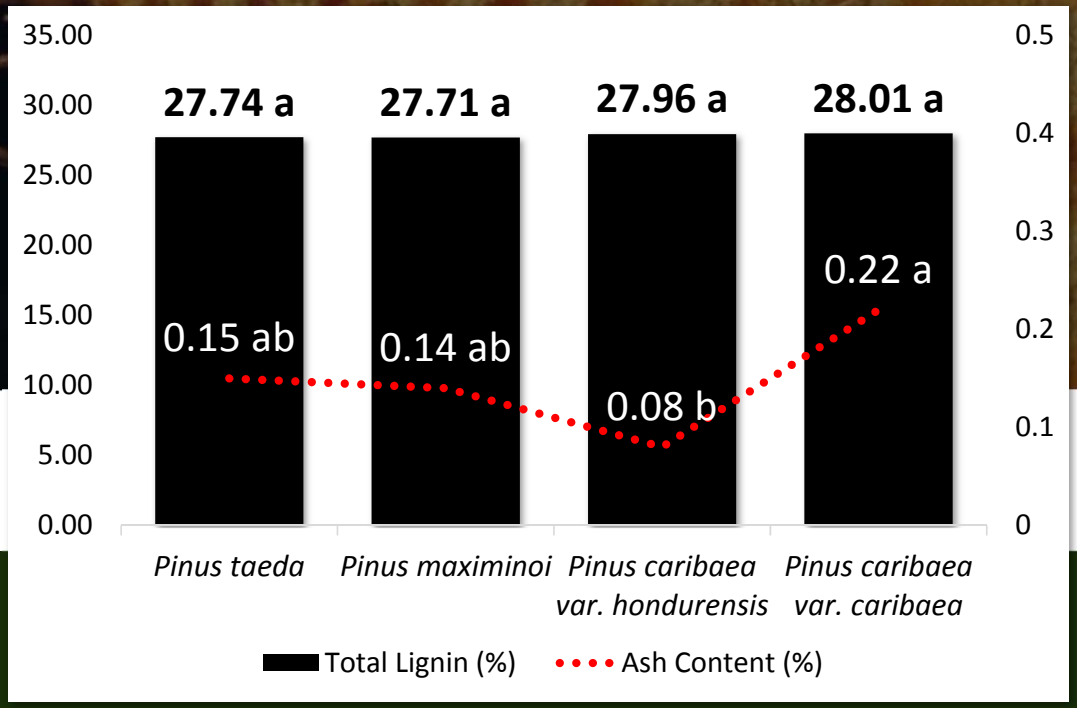
Lignin and Ash Content



- The lignin and ash contents are in agreement with the expected values for conifers (28 % to 30 % for lignin and 0.1 % to 1.0 % for ash).

LIGNIN CONTENT

One of the main objectives of the pulping process is to remove the lignin present in the wood.

ASH CONTENT

Inorganic portion of wood, resulting from the complete combustion of the material.

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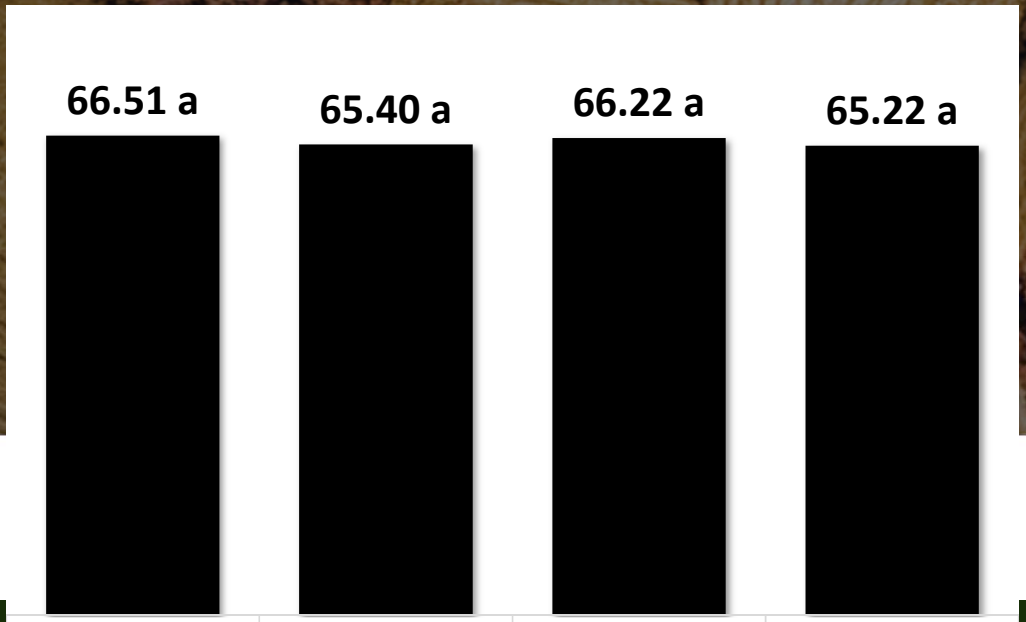
Holocellulose Content

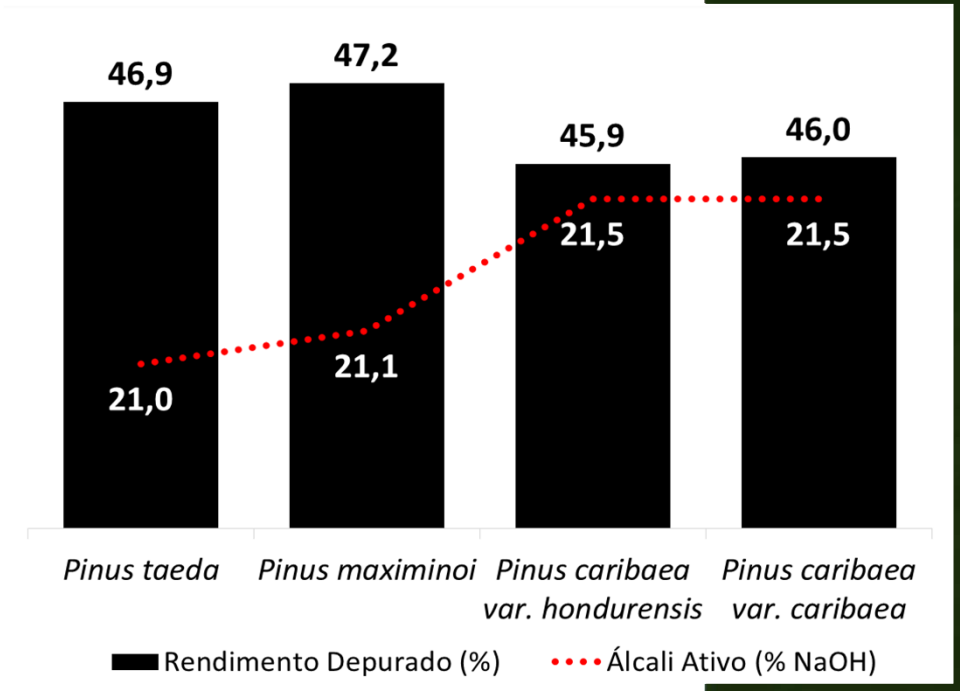


- *Pinus maximinoi* – 64.5 % and 67.7 %.
- *Pinus caribaea* var. *hondurensis* – 70.03 %.

Total carbohydrate content present in wood.

It positively correlates with the yield of the pulping process, **when under the same conditions**.

Pulping Process



Pinus taeda and *Pinus maximinoi* presented the highest yields, besides the higher basic density, the cooking process for these two species consumed less active alkali.

Similar screened yields were found for *Pinus taeda* and *Pinus maximinoi* with 14 years old, 47.4% and 47.5%, respectively.

Oxygen Delignification

Species	Efficiency, Δk/kf	Selectivity, Δk/Δv
PTA	54,5	0,083
PMA	53,9	0,089
PHO	57,1	0,088
PCA	57,3	0,068

PTA: *Pinus taeda*; PMA: *Pinus maximinoi*; PHO: *Pinus caribaea* var. *hondurensis*; PCA: *Pinus caribaea* var. *caribaea*.

The oxygen delignification process can be evaluated through its efficiency and selectivity, which are determining factors in the performance analysis of this stage.

Pinus maximinoi presented the highest selectivity, where oxygen attacked the lignin more than carbohydrates, preserving viscosity, however, this species showed the lowest efficiency.

Another highlight is the low selectivity of *Pinus caribaea* var. *caribaea*, approximately 30.9 % smaller when compared to *Pinus maximinoi*.

Bleaching Process

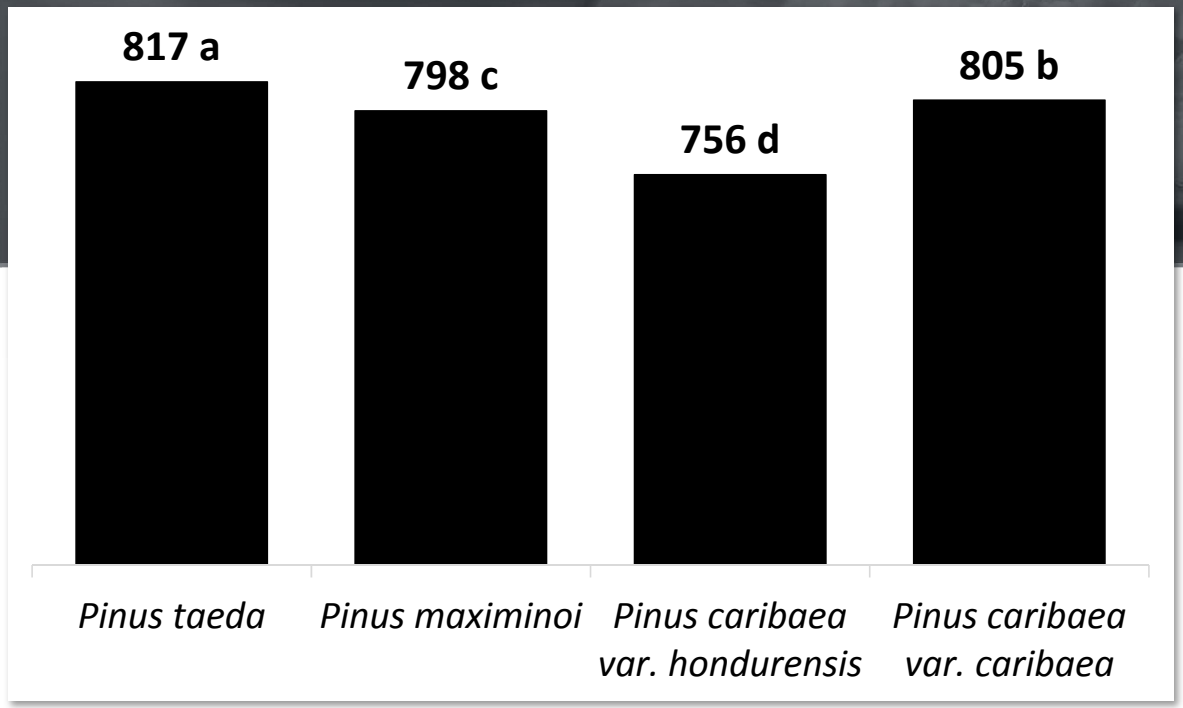
Parameter	PTA	PMA	PHO	PCA
ClO_2, kg/a.d. ton	27.0	28.0	26.0	26.0
H_2O_2, kg/a.d. ton	6.5	7.0	6.5	6.5
Total Active Chlorine (TAC), %	84.6	88.3	82.0	82.0
Efficiency, Δk/kf	33.5	26.2	30.8	24.2
Selectivity, Δk/TAC	0.158	0.148	0.150	0.148

PTA: *Pinus taeda*; PMA: *Pinus maximinoi*; PHO: *Pinus caribaea* var. *hondurensis*; PCA: *Pinus caribaea* var. *caribaea*.

Consumptions of 20.78 kg/a.d.ton for ClO_2 and 10.7 kg/a.d.ton for H_2O_2 were observed in another study, for *Pinus taeda* and *Pinus maximinoi*.

Total active chlorine consumption was lower for *Pinus caribaea* var. *hondurensis* and *Pinus caribaea* var. *caribaea*, however, the greater efficiency and selectivity of the bleaching process were observed for *Pinus taeda.*

Viscosity
Bleached Pulp



The viscosity of a pulp gives an indication of the cellulose degradation (decrease in cellulose molecular weight) resulting from the pulping and/or bleaching process.

The highest value was observed for *Pinus taeda.*

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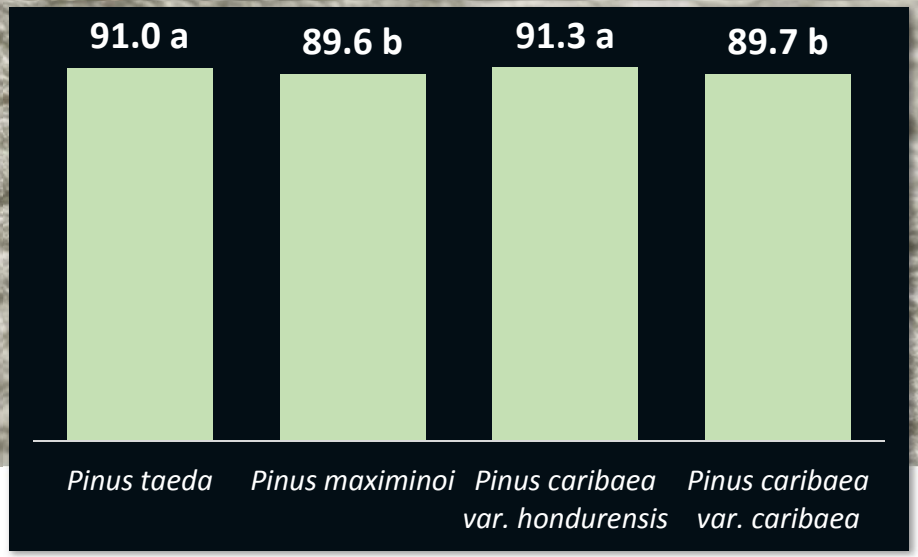

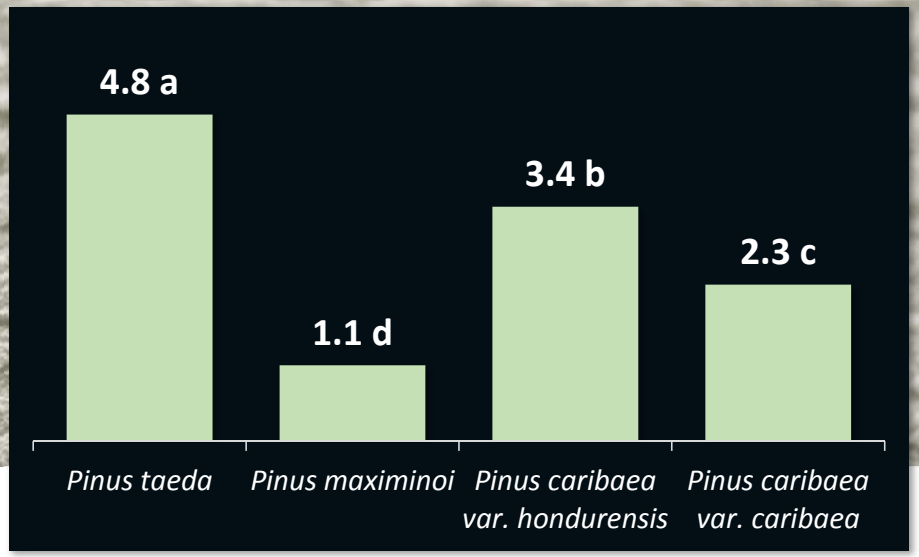

BRIGHTNESS (% ISO)

The results were very similar, all above the brightness practiced in the industry for bleached softwood pulp (89 % ISO).

BRIGHTNESS REVERSION (% ISO)

The highest value found for *Pinus taeda* may be correlated with the highest xylan content present in this pulp.

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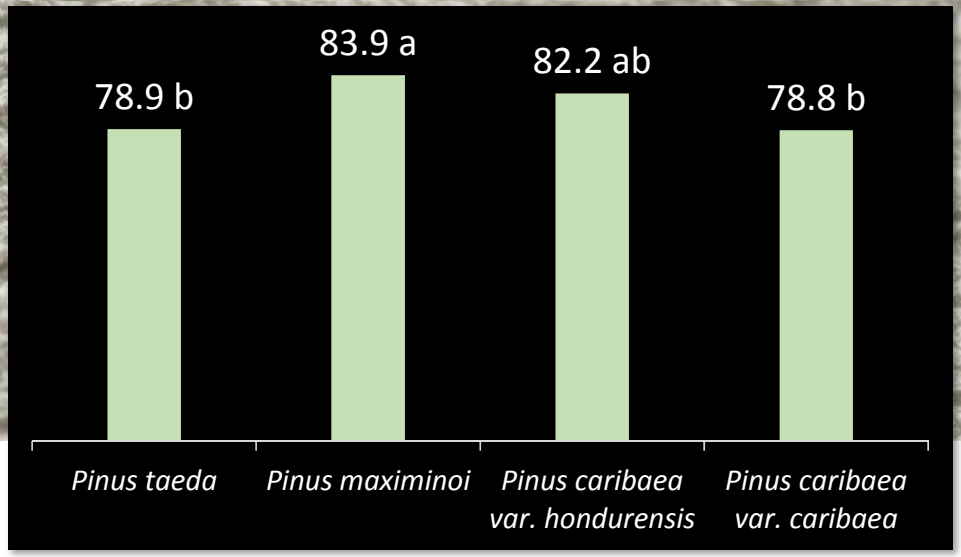
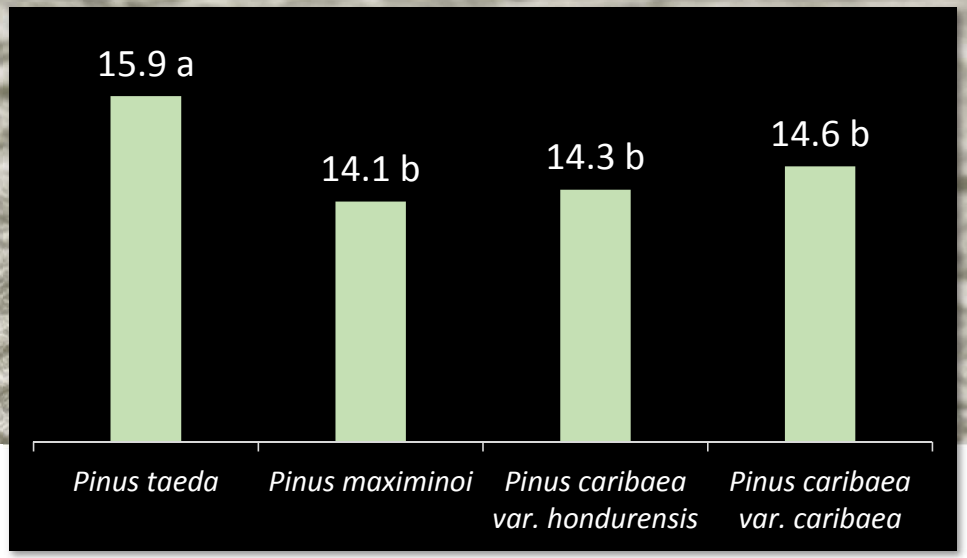
Morphology
Bleached Pulp

Parameter	PTA	PMA	PHO	PCA
***Coarseness*, mg/m**	0.269 d	0.333 c	0.382 a	0.358 b
Tracheid length, mm	2.385 d	2.859 c	3.090 b	3.199 a
Tracheid width, µm	25.17 d	28.63 c	29.33 b	30.20 a

PTA: *Pinus taeda*; PMA: *Pinus maximinoi*; PHO: *Pinus caribaea* var. *hondurensis*; PCA: *Pinus caribaea* var. *caribaea.*

Tracheid morphological parameters varied between species and contrary to what was expected, woods with higher densities did not result in tracheids with greater morphological properties.





GLUCOSE (%)

Pinus maximinoi showed the greatest value for glucose.

Pinus taeda the highest value for hemicelluloses, especially xylans content.

HEMICELLULOSES (%)

Hemicelluloses are important components in the performance of physical-mechanical tests, as they help in the refining stage.

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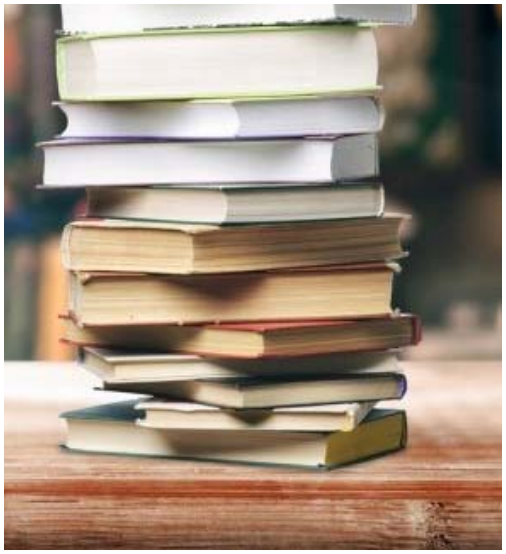

PHYSICAL-MECHANICAL PROPERTIES

TROPICAL PINES

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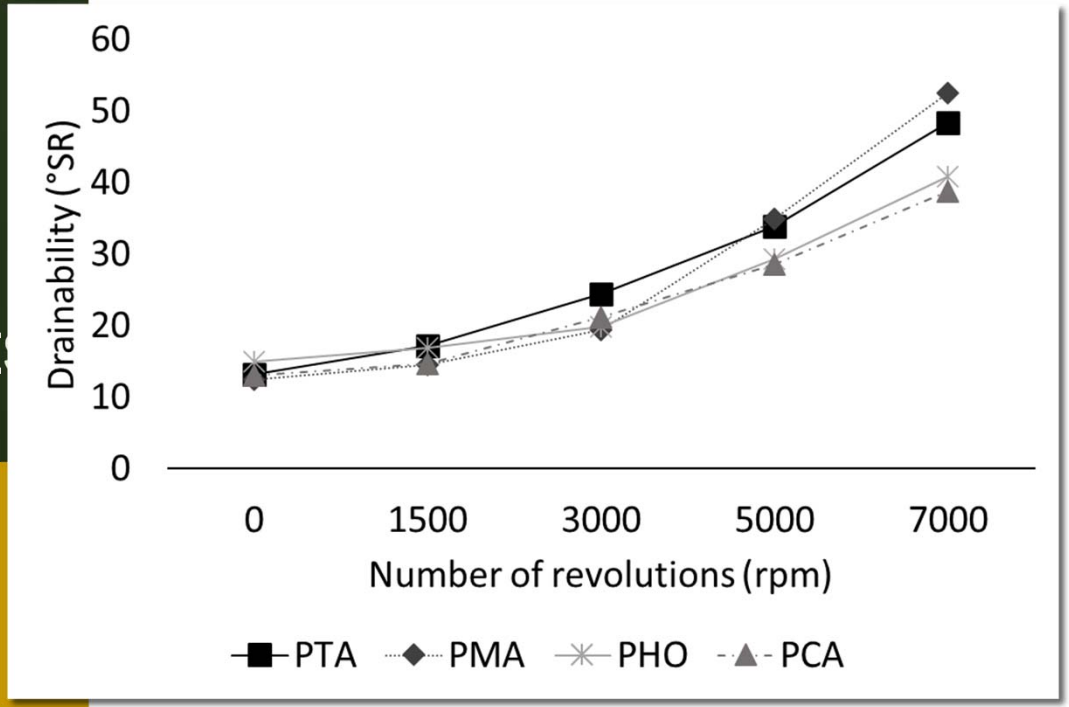
TROPICAL

PINES

Physical-mechanical tests

The four species had similar refining behaviors, however, *Pinus taeda* and *Pinus maximinoi* showed a slightly trend to refine faster and better than the others in final revolutions.



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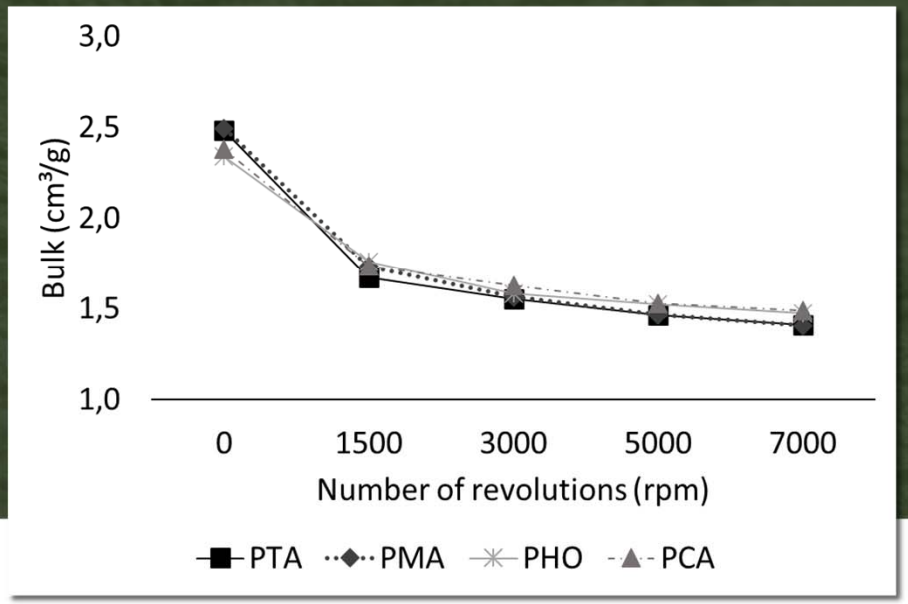

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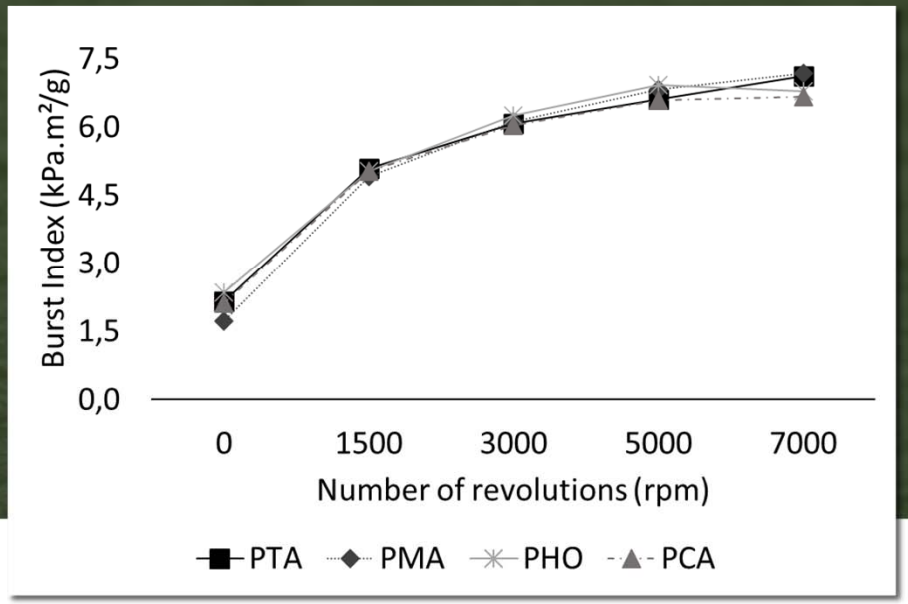

PTA: *Pinus taeda*; PMA: *Pinus maximinoi*; PHO: *Pinus caribaea* var. *hondurensis*; PCA: *Pinus caribaea* var. *caribaea*.

Physical-mechanical tests

The four species showed similar behavior for bulk and burst index properties.

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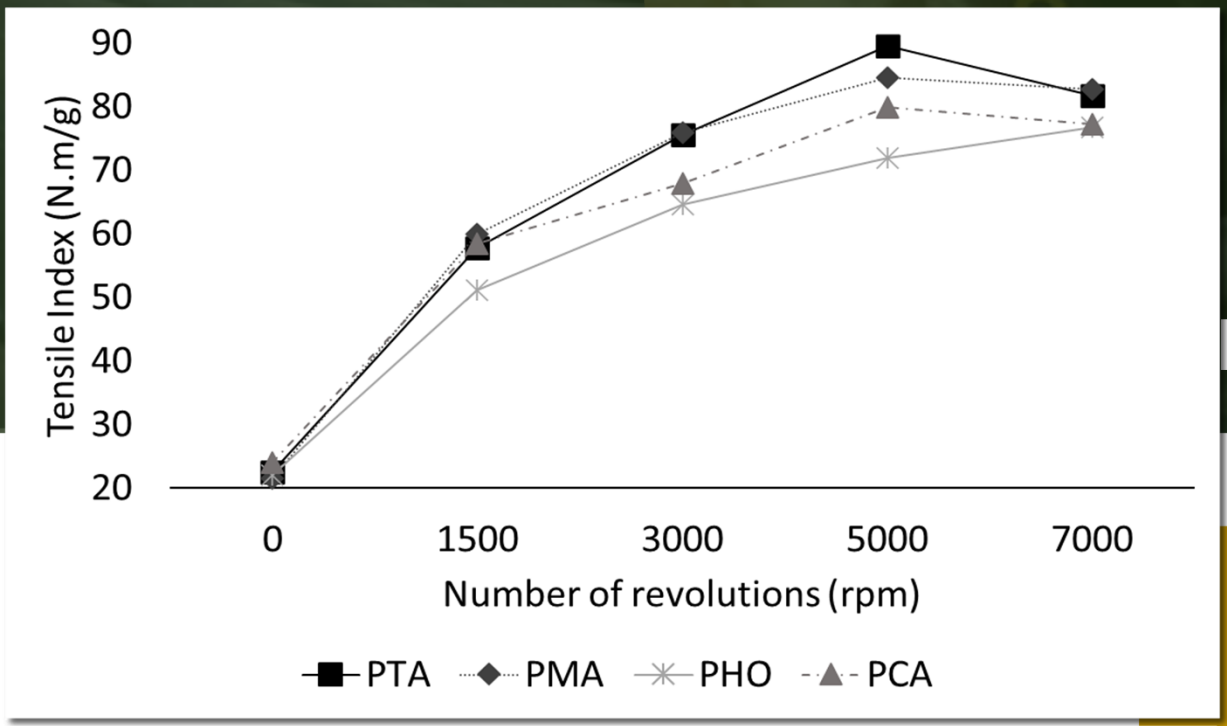
Physical-mechanical tests



PTA: *Pinus taeda*; PMA: *Pinus maximinoi*; PHO: *Pinus caribaea* var. *hondurensis*; PCA: *Pinus caribaea* var. *caribaea*.

Slightly low values were observed for *Pinus caribaea* var. *hondurensis* and *Pinus caribaea* var. *caribaea* for tensile index.

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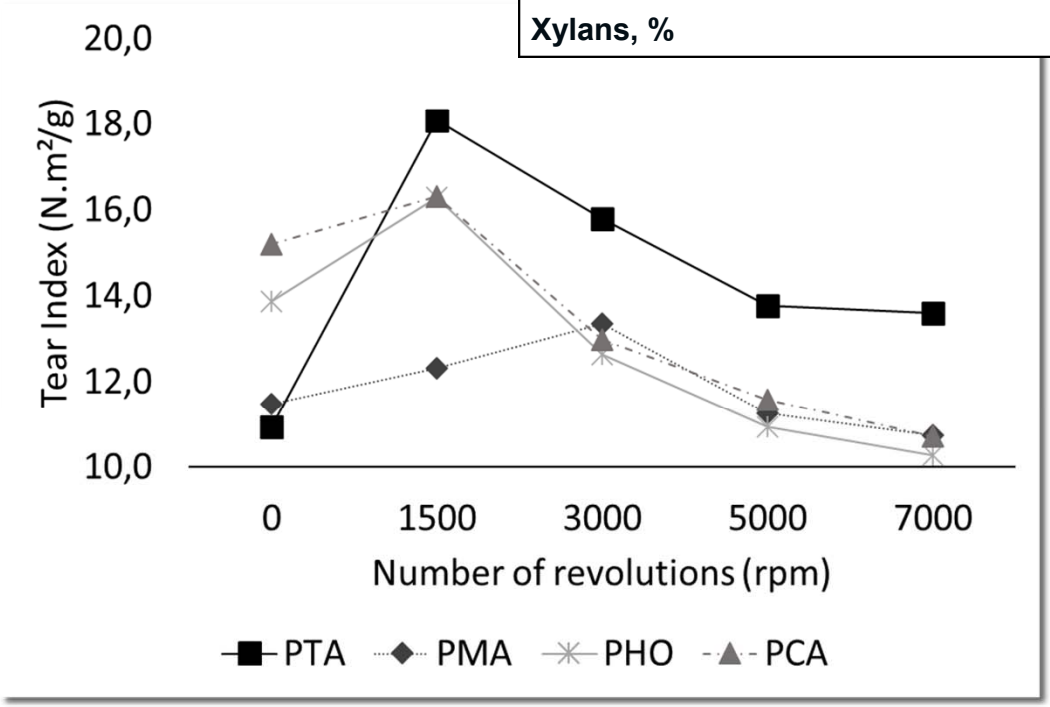
Parameter	PTA	PMA	PHO	PCA
Total Arab, Xil, Man, Gala e Glic, %	15.9	14.1	15.3	14.7
Xylans, %	8.5	6.7	7.7	7.5



PTA: *Pinus taeda*; PMA: *Pinus maximinoi*; PHO: *Pinus caribaea* var. *hondurensis*; PCA: *Pinus caribaea* var. *caribaea*.

There was no significant difference in the tracheids wall thickness, however, *Pinus taeda* presented higher hemicelluloses contents, mainly xylans, which contribute to the refining process and may have positively influenced the development of this mechanical property.

Physical-mechanical tests

CONCLUSIONS

- Technological characteristics of *Pinus taeda* and *Pinus maximinoi* wood are very similar, resulting in good performances in pulping process with higher yields and also in the development of physical-mechanical properties of bleached kraft pulp.

- *Pinus caribaea* var. *hondurensis* and *Pinus caribaea* var. *caribaea* showed slightly lower results when compared to *Pinus taeda*.

- *Pinus maximinoi* showed the highest selectivity in the oxygen delignification process and *Pinus taeda* in the bleaching process.

- All four species of *Pinus* presented morphological and technological characteristics very suitable for production of bleached kraft pulp.

THANK YOU!

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