Mixtures of *Eucalyptus Grandis x Eucalyptus Urophylla* and *Pinus Taeda* Woodchip for the Production of Kraft Pulping Using the Lo-Solids Process

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ABSTRACT

This work investigates the effects of *Eucalyptus grandis x Eucalyptus urophylla* and *Pinus taeda* wood mixtures on the Lo-Solids® process, and the characteristics of the pulps produced. The wood chip mixtures had 10% to 50% proportions of *Pinus taeda*. The results of the analysis indicated a downwards trend in total and screened yield and the viscosity of the pulp, on the levels of hexenuronic acids, on solubility in NaOH 5%, on the number of fibers per gram, on drainability, and on the tensile strength and burst indices, with an increased proportion of *Pinus taeda* in the mixtures. On the other hand, upwards trends were observed in levels of total lignin in the pulp, in fiber length and width, in coarseness, in the tear index, and in the specific consumption of wood as the proportion of *Pinus taeda* increased in the mixtures. The addition of 10% *Pinus taeda* fiber to *Eucalyptus* could improve the quality of the pulp for tear index parameters, with increments of up to 23.9%. For this mixture level it was, furthermore, possible to get a pulp yield of close to 50%, so generating satisfactory dry solid/odt content and wood consumption.

INTRODUCTION

The main raw material sources for pulp and paper production in Brazil come from planted forests of the genera *Pinus* and *Eucalyptus*, with the main comparative advantages in Brazil being the development of eucalyptus-based short-fiber pulp and its success on the international market.

Eucalyptus grandis x *Eucalyptus urophylla* hybrids are prominent in Brazilian forestry for their rapid growth, with felling cycles of between six and seven years of age, and for their good performance in the production of pulp and paper. Technological advances in the forestry area and in the selection of superior populations have achieved a high wood production level of around 40 to 50 m^3/ha/year, allied to good wood quality, with pulp yields between 50% and 54% and wood density of around 0.500 to 0.520g/cm^3.

Pinus plantations in Brazil evidence volumetric growth of between 20 and 30 m^3/ha/year, and rotation is about 20 years, with plantations being thinning out at 8 and 14 years of age. Wood at 8 and 14 years of age is used for pulp and paper production and the wood from the final felling is used in sawmills and lamination. The bleachable pulp yield from *Pinus* is low - between 40% and 45%, and its wood density, depending on age, can vary from 0.300 to 0.400g/cm^3.

On comparing these two genera, or even within the same genus, we noted marked differences, amongst them the length of the fibers. The fibers from the genus *Eucalyptus* present a length of between 0.5m and 1.5 mm. *Pinus*, in turn, presents long fibers (measuring between 3mm and 6mm in length) and consequently produce papers with high physical-mechanical resistance which, besides providing the paper with specific characteristics, allow higher paper machine speed due to the greater resistance of wet and dry sheets, and easier drainage. Greater wet and dry sheet resistance and ease of drainage can mean greater efficiency in paper production and lower production costs.

Chen, Garceau and Kokta (1978) stated that there are few published studies on cooking mixtures of short and long fiber wood and they showed that the addition of *Populus tremuloides* woodchips to *Picea glauca* woodchips for kraft pulp production resulted in a rise in screened yield of between 2% to 4%, lower generation of rejects, little effect on alkali consumption, and better delignification.

Pulping processes have undergone many modifications to improve their efficiency, both in terms of yield and the properties of the pulp obtained. These modifications to the kraft process have been based on better energy and alkaline charge distribution, as well as the use of additives that act on the kinetics of delignification. The engineering modifications have resulted in process patents which are generically called modified cooking and, amongst them, are the Lo-Solids process (SILVA JR. and McDONOUGH, 2002).

According to Turner Jr. and Stromberg (1999) the Lo-solids process is based on the distribution of the alkaline charge throughout the process, essentially in order to minimize the concentration of dissolved wood solids in the main and residual delignification, at the same time as the conditions necessary for modified cooking are maintained.

This study verified the viability of kraft pulp production through the Lo-Solids process using *Eucalyptus grandis* x *Eucalyptus urophylla* and *Pinus taeda* wood in proportions of 10% to 50% of *Pinus taeda*, in order to verify the characteristics of the raw materials in the final product.

MATERIALS AND METHODS

A sample of a seven-year-old *Eucalyptus grandis* x *Eucalyptus urophylla* hybrid clone was used from the Votorantim Celulose e Papel commercial plantation in the State of São Paulo-Brazil, and also a sample of nine-year-old *Pinus taeda* from the Klabin commercial plantation in the region of Telêmaco Borba, Paraná-Brazil.

Ten trees were sampled for each genetic material. The felled trees were sectioned into 1-meter long logs at the following heights: base, 20%, 40%, 60%, 80% and 100% of the commercial height (up to 6 cm in diameter). These were mechanically chipped.

The methods used to determine wood samples characteristics are described in table 1.

Table 1 - Wood density and chemical composition methods

Analysis	Norms
Wood density	Maximum humidity level (FOELKEL, BRASIL, BARRICHELO, 1972)
Extractives content	TAPPI T204
Lignin content	TAPPI T222

Lo-solids cooking was done in duplicate, in an M&K – 609 model forced circulation digester, with two individual reactors. One reactor was used for pulping, and the other one was used to transfer the liquor. In each pulping 1,000 g of dry woodchips were used.

The proportions of woodchips varied from 10% to 50% of *Pinus taeda*, in a mixture with *Eucalyptus grandis* x *Eucalyptus urophylla*, as well as cooking of pure species.

The cooking conditions are shown in Tables 2 and 3.

Table 2 - Cooking conditions: liquor, alkali charge, sulfidity and factor H

Parameter	Condition
Liquor to wood ratio	3.5 : 1
Effective alkali (as NaOH)	Variable between 17.0% to 23.5%
Sulfidity level	30.0%
Factor H	Variable between 520 to 1500

Table 3 - PULPING TIME, TEMPERATURE AND ALKALI SPLIT

Phases	Time (min.)	Temperature Alkali (°C)	Alkali Distribution (%)
Pre-steaming	15	100	-
Impregnation	30	120	50
1st substitution	20	variable	30
Cooking	90	variable	-
2ª substitution	15	variable	20
Cooking	110	variable	-

The kappa number to be achieved in the brown stock varied proportionately to the components in the mixture between 18 ± 1 (100% *Eucalyptus grandis* x *Eucalyptus urophylla*) and 26 ± 1 (*Pinus taeda*). After each cooking the pulp obtained was washed, centrifuged, disaggregated, stored in polyethylene bags and refrigerated at 5ºC ± 2ºC. For each cooking the total yield, the screened yield, and the rejects content (0.2 mm gap) were determined. The pulp was analyzed according to the parameters described in table 2.4.

Table 4. Kappa number, viscosity, lignin content in the pulp, hexenuronic acids, solubility in NaOH 5% - S5, fiber dimensions, physical-mechanical and drainability tests methods

Analysis	Norms
Kappa number	TAPPPI T236
Viscosity	TAPPI T230
Lignin content in pulp	TAPPI T222
Hexenuronic acids	Chai et al. (2001).
Solubility in NaOH 5% - S5	SCAN C2:61
Fiber dimensions	Fiber Quality Analyzer (FQA) equipment
Drainability	SCAN-C 19:65.
Tensile strength and stretching	SCAN – P38:80
Tear index	SCAN – P 11:96
Burst index	SCAN – P 24:77

The data obtained in this study was statistically analyzed using regression analysis and adjustment of equations to the data observed.

RESULTS AND DISCUSSION

The wood density and chemical composition of the wood are presented in table 5.

Table 5 - Wood density and chemical composition of the wood

Treatment parameter	*Eucalyptus grandis* x *Eucalyptus urophylla*	*Pinus taeda*
Wood density (g/cm³)	0.505	0.332
Lignin content (%)	28.54	31.18
Extractives content (%)	2.50	2.37
Holocellulose content (%)	68.90	66.44

Table 6 presents the average results of the Lo-solids cooking, the dry solid/odt content generated and the specific consumption of the wood.

Table 6 - Results of Lo-solids cooking, tss/odt and wood consumption

% *Pinus taeda*	EA (%NaOH)	H Factor	K#	TY (%)	RC (%)	SY (%)	Visc	tss/ odt	WC (m^3/odt)
0	17.0	520	17.9	54.23	0.01	54.21	93.2	1.13	3.67
10	19.3	970	19.1	51.35	0.03	51.30	46.0	1.29	4.02
20	20.5	1150	19.0	49.65	0.01	49.64	36.0	1.39	4.30
30	21.0	1190	20.3	48.90	0.02	48.88	35.1	1.44	4.54
40	21.0	1340	21.0	47.99	0.02	47.97	30.1	1.48	4.80
50	21.3	1420	22.1	47.31	0.01	47.29	32.5	1.52	5.07
100	23.5	1500	25.6	43.04	0	43.04	26.4	1.82	7.00

Where: EA = Effective alkali, K# = kappa number, TY = total yield, RC = reject content, SY = screened yield, Visc = Viscosity, WC = wood consumption per ton of pulp. Sulfidity level = 30% for all treatments

Table 6 shows that distinct effective alkali charge (% as NaOH) and factor H were necessary to achieve the target kappa number in the study of 18 ± 1 for *Eucalyptus grandis* x *Eucalyptus urophylla* and 26 ± 1 for *Pinus taeda*.

Pinus taeda, owing to the nature of its lignin, besides the higher lignin content in its composition, and its anatomical characteristics, required an effective alkali charge of 23.5% and a factor H of 1500 to achieve the kappa number of 26 ± 1.

Eucalyptus grandis x *Eucalyptus urophylla* had a higher pulp yield than *Pinus taeda*. The yield is an extremely important characteristic in an industrial unit, as it has an effect on the generation of solids, on the specific consumption of wood, and consequently on the production costs.

Eucalyptus grandis x *Eucalyptus urophylla* presents a lower tss/odt when compared to *Pinus taeda*. This difference is due to the higher alkaline charge applied (higher inorganic level), and to the lower pulp yield observed for *Pinus taeda* (higher level of organic solids generated).

Due to the low wood density and pulp yield results, *Pinus taeda* presents a specific consumption of wood of 7.00 m^3/odt, whilst *Eucalyptus grandis* x *Eucalyptus urophylla* presents a significantly lower specific wood consumption per ton of pulp, of 3.67m^3/odt.

In table 6 it can be seen that the kappa number gradually increased as *Pinus taeda* was added to *Eucalyptus grandis* x *Eucalyptus urophylla*, resulting in kappa numbers between 19.1 and 22.1. This is due to the strategy adopted in the study to gradually increase the pulp kappa numbers, in order to preserve the pulp yield in the mixtures.

The alkaline charge increased considerably as *Pinus taeda* was added to the *Eucalyptus*, with the mixture with 10% *Pinus taeda* using 19.3% effective alkali, and the mixture with 50% *Pinus taeda* using 21.3%. Factor H, as in the case for effective alkali, increased considerably as *Pinus taeda* was added to the *Eucalyptus*, varying between 970 and 1420.

Table 7 is a summarized statistical analysis of the pulping results for the mixtures assessed in this study.

Table 7 - Statistical analysis of pulping parameters, tss/odt, and wood consumption

Parameter	ANOVA	Adjusted model	A	b	R^2 (%)
Effective alkali (%NaOH)	Significant	$Y = a + b\sqrt{x}$	17,2533	0,625486	95,84

Factor H	Significant	$Y = a + b\sqrt{x}$	543,614	125,563	98,99
kappa number	Significant	$Y = 1/(a + bx)$	0,05558	-0,00020	95,73
Total yield (%)	Significant	$Y = a + b\sqrt{x}$	54,2711	-0,98902	99,12
Reject content (%)	Not significant	-	-	-	-
Screened yield (%)	Significant	$Y = a + b\sqrt{x}$	54,2459	-0,98842	99,08
Viscosity Cp	Significant	$Y = a + b\sqrt{x}$	1353,63	-55,8436	89,90
tss/odt	Significant	$Y = a + b\sqrt{x}$	1,12599	0,056742	99,13
Wood consumption (m^3/odt)	Significant	$Y = a + bx$	3,7169	0,027357	99,52

Where: y = parameter to be estimated and x = % of raw material in the mixture

Figure 1 shows the screened yield results obtained in the study.

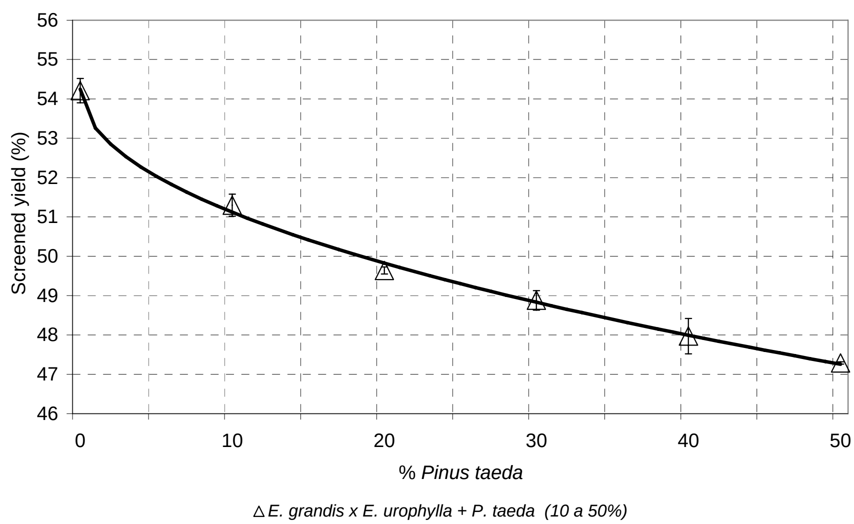

Figure 1 - Screened yield

Figure 1 shows a marked fall in the screened yield as *Pinus taeda* is added to *Eucalyptus grandis* x *Eucalyptus urophylla*. For the mixture with 90% *Eucalyptus grandis* x *Eucalyptus urophylla* with 10% *Pinus taeda*, the screened yield obtained was 51.3%, whilst in the mixture with 50% *Eucalyptus grandis* x *Eucalyptus urophylla* with 50% *Pinus taeda* the screened yield was 47.29%.

Based on the yield results observed, it can be stated that despite the losses seen for the yield in pulp, it is possible to get acceptable yields for the *Pinus taeda* mixture in small proportions with eucalyptus species.

Table 6 shows a rise in tss/odt values as *Pinus taeda* is added to *Eucalyptus grandis* x *Eucalyptus urophylla*. This rise is due to the higher alkaline charge applied (higher inorganic content), and to the lower pulp yield (higher solid content generated by the breaking down of the wood) observed in the mixtures.

Increased wood consumption is observed as *Pinus taeda* is added to *Eucalyptus grandis* x *Eucalyptus urophylla*, achieving values of up to 5.07m³/odt for the mixtures.

According to the results obtained in this study, the addition of *Eucalyptus* to *Pinus* in pulp production units that use 100% *Pinus* as raw material could be advantageous. The alkali charge and factor H used for pulping the 50% *Pinus taeda* mixture with 50% *Eucalyptus* were lower when compared to the cooking of *Pinus taeda*. The yield gains are significant, leaping from a screened yield of 43.04% when cooking *Pinus taeda*, to a yield of 47.2% when adding 50% *Eucalyptus*. Finally, the gains are strengthened by the reduced consumption of wood, which falls from 7.0m^3/odt using 100% *Pinus taeda* to 5.07 m^3/odt on using 50% eucalyptus.

Table 8 shows the results obtained in this study for total lignin content, hexenuronic acids content and solubility in NaOH 5% (S5) in the pulps.

Table 8 - Lignin content, hexenuronic acid content and S5%

% *Pinus taeda*	Lignin content (%)	Hexenuronic acids (μmol/g)	S5 (%)
0	3.47	50.41	11.47
10	2.56	56.06	11.27
20	3.02	51.25	10.27
30	2.70	39.57	9.55
40	3.78	40.97	9.43
50	3.93	43.49	9.16
100	3.59	30.35	7.95

Eucalyptus grandis x *Eucalyptus urophylla* pulp present a total lignin content of 3.47%, near that found in the pulp obtained from *Pinus taeda,* 3.59%. However, to achieve such levels of delignification distinct values of effective alkali and factor H were needed. This is evidence of the qualitative difference between lignins from eucalyptus and pinus, as for *Pinus taeda* more chemical and thermal energy was needed for the individualization of the fibers, for a higher kappa number.

As regards the hexenuronic acid content, pulp from *Pinus taeda*, with 30.35μmol/g of hexenuronic acids in its composition, presents approximately 40% fewer hexenuronic acids when compared to the pulp from *Eucalyptus grandis* x *Eucalyptus urophylla*.

The hemicelluloses are important chemical compounds in the final pulp. Their presence, within certain limits, increases the ease of fiber refining and they also improve the physical properties of the paper. Table 3.4 shows that pulp from *Eucalyptus grandis* x *Eucalyptus urophylla* presents a higher content of hemicelluloses, expressed by the S5 level, at 11.47%.

Table 9 shows a summary of the statistical analysis of the chemical characteristics of the pulps assessed in this study.

Table 9 - Statistical analysis for lignin content, hexenuronic acid content and S5%.

Parameter	ANOVA	Adjusted model	A	b	R^2
Lignin content (%)	Significant	$Y = a + bx$	2.8381	0.01614	22.62
Hexenuronic acid (μmol/g)	Significant	$Y = a + bx$	53.626	-0.2565	50.56
S5 (%)	Significant	$Y = 1/(a + bx)$	0.0868	0.00048	90.44

Table 9 shows that the total lignin values increase as *Pinus taeda* is added to the *Eucalyptus*. The increase in the lignin content in the pulp from the mixtures of *Eucalyptus* and *Pinus taeda* can be explained in part by the strategy used in the study, to progressively increase the kappa number as the proportion of *Pinus taeda* increases in the mixtures. As *Pinus taeda* is added to *Eucalyptus*, hexenuronic acid content decreases. This was expected as a result of the values obtained for this parameter in assessing the pure species.

For S5, as *Pinus taeda* is added to *Eucalyptus grandis* x *Eucalyptus urophylla*, a fall is noted in the values of this parameter. This is again explained by the value obtained in the pure materials.

Foelkel and Barrichelo (1975) say the assessment of wood for pulp production must bear in mind the amount and arrangement of constituent woody tissue, as well as considering the fiber length and thickness of the cellular wall. Knowledge of the anatomical characteristics of the fibrous elements of the pulps makes it possible to predict their paper properties.

Table 10 presents the values obtained for the characteristics of the pulps fibers.

Table 10 - Fiber dimension results

% *Pinus taeda*	Length (mm)	Width (μm)	Fines content (%)	Coarseness (mg/m)	# of fibers /g
0	0.832	18.15	2.32	0.062	23.80
10	0.866	17.30	2.35	0.063	23.23
20	0.918	17.73	2.16	0.064	22.17
30	0.974	17.58	2.36	0.072	19.73
40	1.044	18.55	2.37	0.074	18.60
50	1.137	19.08	2.39	0.083	16.06
100	1.975	32.00	2.90	0.148	6.29

Table 10 shows that the fiber dimensions (length and width) for *Eucalyptus grandis x Eucalyptus urophylla* are smaller than those for *Pinus taeda*.

Fiber coarseness, defined as the mass per unit of length, is an essential property that affects the structural properties of the paper (density, smoothness, porosity), resistance and optical properties. The flexibility of the fiber and its capacity to form inter-fiber connections fall when the coarseness increases (HORTAL, 1988). This is influenced by the width of the fiber’s cell wall and increases as the length of the fiber increases. On assessing the coarseness of the pulps produced, values are found of 0.062, and 0.148mg/m, respectively, for the pulps produced from *Eucalyptus grandis x Eucalyptus urophylla* and *Pinus taeda*.

The number of fibers per unit of mass is an important characteristic for short fibers; it impacts the formation of the paper, the surface smoothness, the dispersal of light/opacity and the distribution of the size of the pores. The properties that depend on the degree of connection between the fibers, such as apparent density and resistance to tensile strength and bursting, are generally of greater indices in pulps with more fibers per gram. This proves that this characteristic provides more contact points, increasing the number of connections (SANTOS, 2002).

A large variation is observed for the number of fibers per gram between the pulps assessed. The pulp produced from *Pinus taeda* presents the lowest value for this parameter, 6.29×10^6 fibers/g, due to the larger fiber dimensions of this species. The pulp produced from *Eucalyptus grandis x Eucalyptus urophylla* presented a value of 23.8×10^6 fibers/g.

Table 11 presents a summary of the statistical analysis for characteristics of the pulp fibers from the mixtures assessed in this study.

Table 11 - Statistical analysis of fiber dimensions

Parameter	ANOVA	Adjusted model	a	b	R^2 (%)
Length (mm)	Significant	$Y = 1/(a + bx)$	1.2139	-0,0064753	98.37
Width (µm)	Significant	$Y = a + bx$	17.475	0.0235	42.49
Fine content (%)	Not significant	-	-	-	-
Coarseness (mg/m)	Significant	$Y = 1/(a + bx)$	16.574	-0,0823864	88.97
Fibers x 10^6/g	Significant	$Y = a + bx$	24.535	-0.157429	93.10

Where: y = parameter to be estimated and x = % of raw material in the mixture

As shown in table 10, for the mixtures of *Eucalyptus* and *Pinus taeda*, the fiber length and width values increase as *Pinus* is added to the mixture.

Figure 2 shows the behavior observed for the mixtures with regard to coarseness.

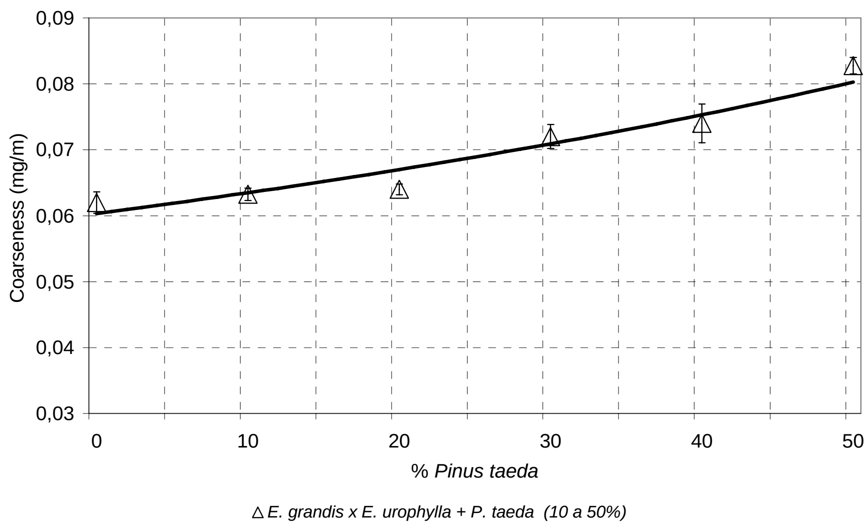

Figure 2 - Coarseness

Figure 2 shows that as *Pinus taeda* is added to *Eucalyptus*, coarseness increases. This result was expected, as wider and longer and therefore heavier fibers are added to the short *Eucalyptus* fibers.

Figure 3 presents the behavior of the mixtures regarding the number of fibers per gram.

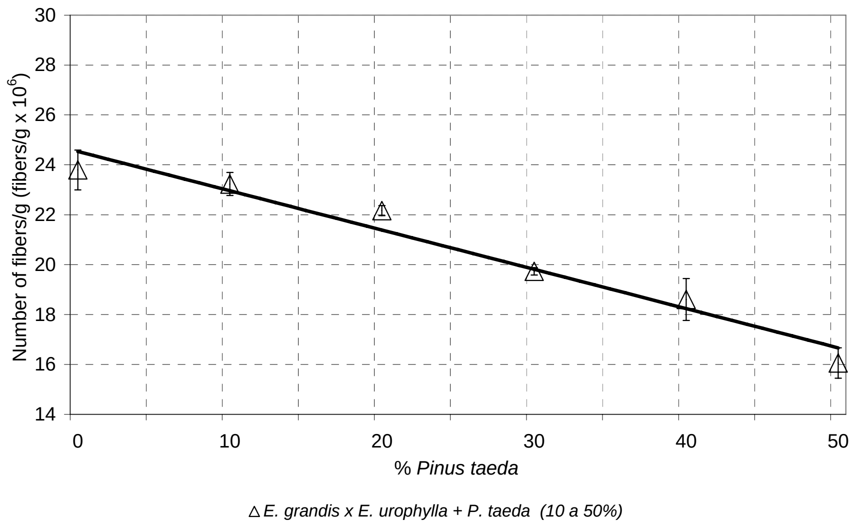

Figure 3 – Number of fibers per gram

It is noted that as the *Pinus* is added to the *Eucalyptus grandis* x *Eucalyptus urophylla*, the number of fibers per gram tends to fall. This can be explained by remembering the difference in the parameter in question verified in the pure materials.

Table 12 presents the results obtained for drainability and physical tests on the unrefined pulps.

Table 12 - Physical-mechanical tests and drainability results for unrefined pulps

% *Pinus taeda*	Drainability (°SR)	Tensile strength (N.m/g)	Stretching (%)	Burst index (kPa.m^2/g)	Tear index (mN.m^2/g)
0	23.8	64.4	1.5	2.8	7.0
10	22.8	55.9	1.5	2.3	7.3
20	19.2	48.8	1.4	1.8	7.7
30	20.5	50.7	1.5	2.0	9.0
40	19.0	51.7	1.6	2.2	9.9
50	19.2	50.4	1.7	2.3	11.5
100	14.8	53.1	2.7	3.6	13.9

The hemicelluloses are hydrophilic, amorphous and promote the water absorption capacity of the fibers, whilst the greater number of fibers per gram favors a greater number of inter-fiber connections and consequently there is a rise in the ^{o}SR. *Eucalyptus grandis* x *Eucalyptus urophylla* presents a solubility in NaOH 5% (S5) of 11.47%, and 23.8 x 10^6 fibers per gram, factors that may contribute to the observed drainability value.

Pulp from *Pinus taeda* stands out as regards the tear index, with 13.9mN.m^2/g. The greater resistance to tearing observed for the pulp from *Pinus taeda* was expected due to the greater length of this material's fiber compared with other material assessed in this study.

The greater stretching observed in the pulp from *Pinus taeda* can be explained by the greater length of the fiber, which favors resistance to stretching as a result of its greater individual resistance.

Table 13 presents a summary of the statistical analysis of the results for drainability and physical tests of the mixtures assessed in this study.

Table 13 - Statistical analysis of physical-mechanical tests and drainability results

Parameter	ANOVA	Adjusted model	a	b	R^2 (%)
Drainability (°SR)	Significant	$Y = a + b\sqrt{x}$	23.8965	-0,7122	50.37
Stretching (%)	Not significant	-	-	-	-
Tear index (mNm^2/g)	Significant	$Y = 1/(a + bx)$	0.148122	-0,0011	88.55
Tensile strength (Nm/g)	Significant	$Y = a + b\sqrt{x}$	62.5322	-2.0125	74.90
Burst index ($kPam^2/g$)	Not significant	-	-	-	-

Where: y = parameter to be estimated and x = % of raw material in the mixture

The behavior observed for the drainability parameter is in accord with the values obtained in the pure materials, where the pulp from *Eucalyptus grandis* x *Eucalyptus urophylla* presented drainability of 23.8°SR and that for *Pinus taeda* of 14.8°SR and also with the behavior verified in the mixtures of the species, in which a reduction was observed of the values for solubility in NaOH 5% (S5) and in the number of fibers per gram, with a greater proportion of *Pinus taeda* in the mixtures, causing a smaller number of inter-fiber connections and lower capacity for water absorption and flexibility in the fibers.

Tear index results are shown in figure 4.

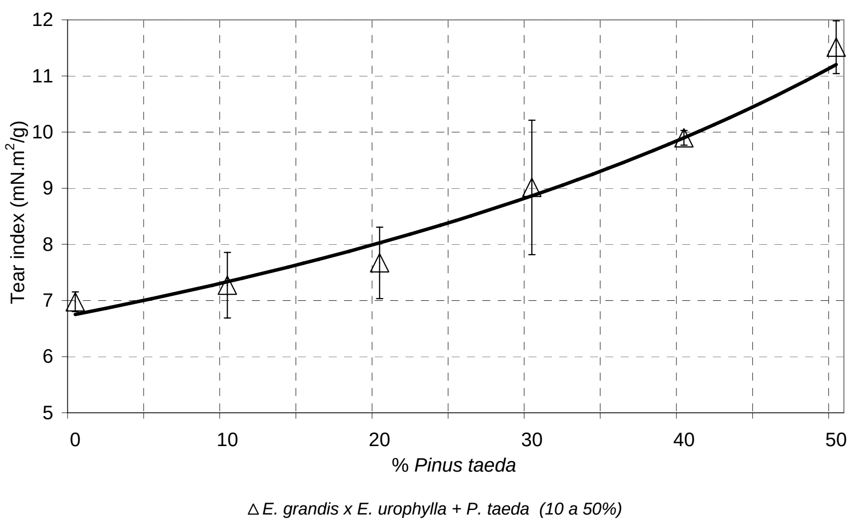

Figure 4 – Tear index

Adding 10% and 20% of *Pinus taeda* to *Eucalyptus grandis* x *Eucalyptus urophylla* resulted in average increases of 4.2% and 10% respectively in resistance to tearing.

A fall is observed in the tensile strength in the mixtures of *Eucalyptus* and *Pinus taeda*, with an increase in the proportion of *Pinus taeda* in the treatments. It should be remembered that the mixtures of *Eucalyptus* and *Pinus taeda* show a drop in solubility in NaOH 5% (S5) values and in the number of fibers per gram as the proportion of *Pinus taeda* is increased in the mixtures. As a result, it can be supposed that the number of inter-fiber connections was reduced, and consequently the pulps resistances suffered a decline.

The increased proportion of *Pinus taeda* causes a moderate decrease in the burst index, but not very significant in industrial terms. Once again, reference is made to the number of fibers per gram and solubility in NaOH 5% (S5), which decrease for the mixtures with the addition of *Pinus taeda*. These factors may explain the decrease in resistance to bursting with the addition of *Pinus taeda* to *Eucalyptus*.

CONCLUSIONS

Based on the results the following can be concluded:

A 10% addition of *Pinus taeda* fiber to *Eucalyptus* can improve the quality of pulp for the tear index (increases of up to 8.4%) and drainability parameters. These characteristics can lead to faster operating speeds in a paper machine and higher productivity. For this level of mixture, it is also possible to get a pulp yield close to 50% and thus satisfactory solid generation and wood consumption levels.

The fall in pulp yield observed with the addition of *Pinus taeda* to *Eucalyptus* in proportions over 10% can make the process unviable, as the reduction in the pulp yield will cause greater wood consumption and a reduction in the production capacity of an industrial unit.

The mixture of *Pinus taeda* with *Eucalyptus* is favorable for industrial units that work with 100% *Pinus*, as the substitution of *Pinus* woodchips for *Eucalyptus* woodchips is advantageous through gains in yield in pulp, reduced wood consumption, productivity gains in the industrial unit, and savings in raw material (wood and alkali), amongst others.

Manufacturing units that want to produce a differentiated kind of pulp with a high resistance to tearing, to get higher productivity from paper machines, or even to produce special, low-gram papers, must consider the addition of small proportions of *Pinus* to *Eucalyptus*.

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Advantages and disadvantages of the Lo-Solids kraft pulp production process based on *Eucalyptus grandis x Eucalyptus urophylla* and loblolly pine wood chip mixtures

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INTRODUCTION

- The main raw material sources for pulp and paper production in Brazil – Pine and *Eucalyptus*

- The main comparative advantage in Brazil - development of eucalyptus-based short-fiber pulp and its success on the international market

INTRODUCTION

- *Eucalyptus grandis* x *Eucalyptus urophylla*

- Loblolly pine *(P. taeda)*

INTRODUCTION

- Marked differences - length of the fibers
- *Eucalyptus* - length of fibres between 0.5mm and 1.5 mm
- Loblolly pine presents long fibers - measuring between 3mm and 6mm in length

- Papers with high physical-mechanical resistance

- Higher paper machine speed due to the greater resistance of wet and dry sheets and easier drainage

Greater efficiency in paper production and lower production costs

INTRODUCTION

- Differentiated qualities of the wood impact the pulp production process and the characteristics of the final product

quality of the wood

process conditions

INTRODUCTION

- Pulping processes - modifications to improve efficiency - yield and the properties of the pulp obtained
  - Based on better energy and alkaline charge distribution
  - Use of additives that act on the kinetics of delignification

↓

modified cooking - Lo-Solids process

INTRODUCTION

- Lo-solids process is founded on the:

  - Distribution of the alkaline charge throughout the process in order to minimize the concentration of dissolved wood solids in the main and residual delignification

  - Conditions necessary for modified cooking are maintained → More flexibility

OBJECTIVE

- Verify the viability of kraft pulp production through the Lo-Solids process using:

  - *Eucalyptus grandis* x *Eucalyptus urophylla* and loblolly pine

  - In proportions of 10% to 50% of loblolly pine , in order to check the characteristics of the raw materials in the final product

Literature

- Addition of *Populus tremuloides* to *Picea glauca* wood chips for kraft pulp production resulted in:

  - A rise in screened yield of between 2% to 4%
  - Lower generation of rejects
  - Little effect on alkali consumption
  - Better delignification

Chen, R.; Garceau, J.J.; Kokta, B.V. Hardwood mixed with softwood in kraft pulping. Tappi, Atlanta, v. 61, n. 7, p. 35-38, 1978

Literature

- Conventional cooking based on mixtures of eastern white pine and *Eucalyptus urophylla* in proportions of 33%, 66% and 100% eastern white pine

  - Results:

1. As the level of pine wood increased in the mixture, the screened yield fell markedly
2. An increase in the proportion of pine wood chips led to an increase in the kappa number
3. For physical-mechanical properties - significant effect on the refining process = greater energy consumption being required

Oliveira, R.C.; Foelkel, C.E.B.; Gomide, J.L. Misturas de madeiras de *Pinus strobus* var. *chiapensis* e *Eucalyptus urophylla* na polpação Kraft. O Papel, São Paulo, v. 42, n. 1, p.67-78, jan. 1981

MATERIALS AND METHODS

Materials

- Seven-year-old *Eucalyptus grandis* x *Eucalyptus urophylla* hybrid clone from Votorantim Celulose e Papel commercial plantation - State of São Paulo – Brazil

- Nine-year-old loblolly pine from the Klabin commercial plantation in the region of Telêmaco Borba, Paraná – Brazil

MATERIALS AND METHODS

Methods

Analysis	Norms
Wood density	Maximum humidity level (FOELKEL, BRASIL, BARRICHELO, 1972)
Extractives content	TAPPI T204
Lignin content	TAPPI T222

MATERIALS AND METHODS

Methods

- Lo-solids cooking - duplicate, in an M&K – 609 model forced circulation digester
- 1,000 g of dry wood chips
- Pure species and 10% to 50% of loblolly pine , in a mixture with *Eucalyptus* hybrid
- Target kappa number:

  - 18 ± 1 -100% *Eucalyptus*

  - 26 ± 1 loblolly pine

  - Mixtures - varied proportionately to the components in the mixture

MATERIALS AND METHODS

Methods

Parameter	Condition
Liquor to wood ratio	3.5 : 1
Effective alkali (as NaOH)	Variable between 17.0% to 23.5%
Sulfidity level	30.0%
H Factor	Variable between 520 to 1500

- Total yield
- Screened yield
- Level of rejects

MATERIALS AND METHODS

Methods

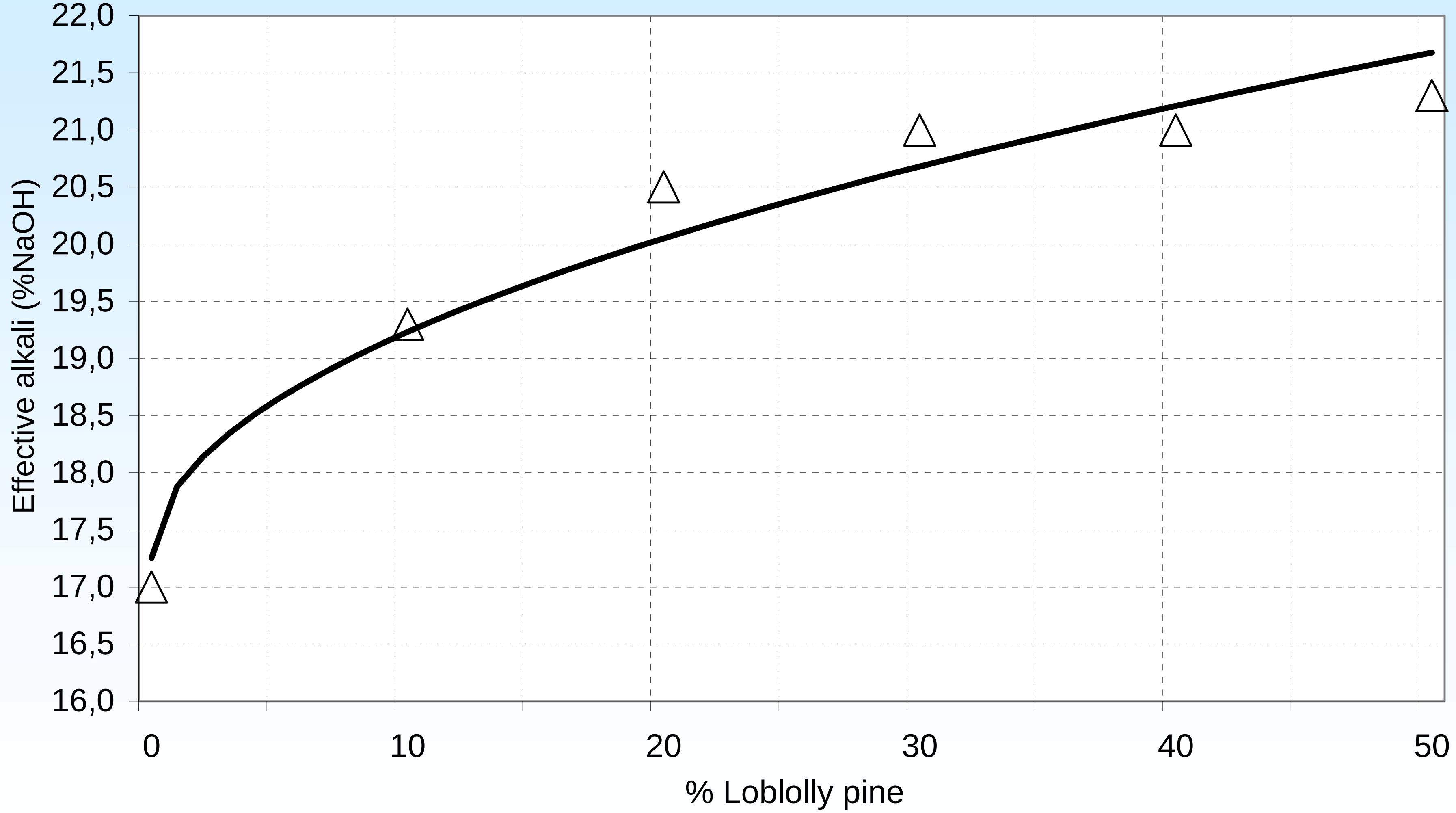
Analysis	Norms
Kappa number	TAPPPI T236
Viscosity	TAPPI T230
Hexenuronic acids	Chai et al. (2001)
Solubility in NaOH 5% - S5	SCAN C2:61
Fiber dimensions	Fiber Quality Analyzer (FQA) equipment
Drainability	SCAN-C 19:65.
Tensile strength and stretching	SCAN – P38:80
Tear index	SCAN – P 11:96
Burst index	SCAN – P 24:77

RESULTS AND DISCUSSION

Wood density and chemical composition of wood

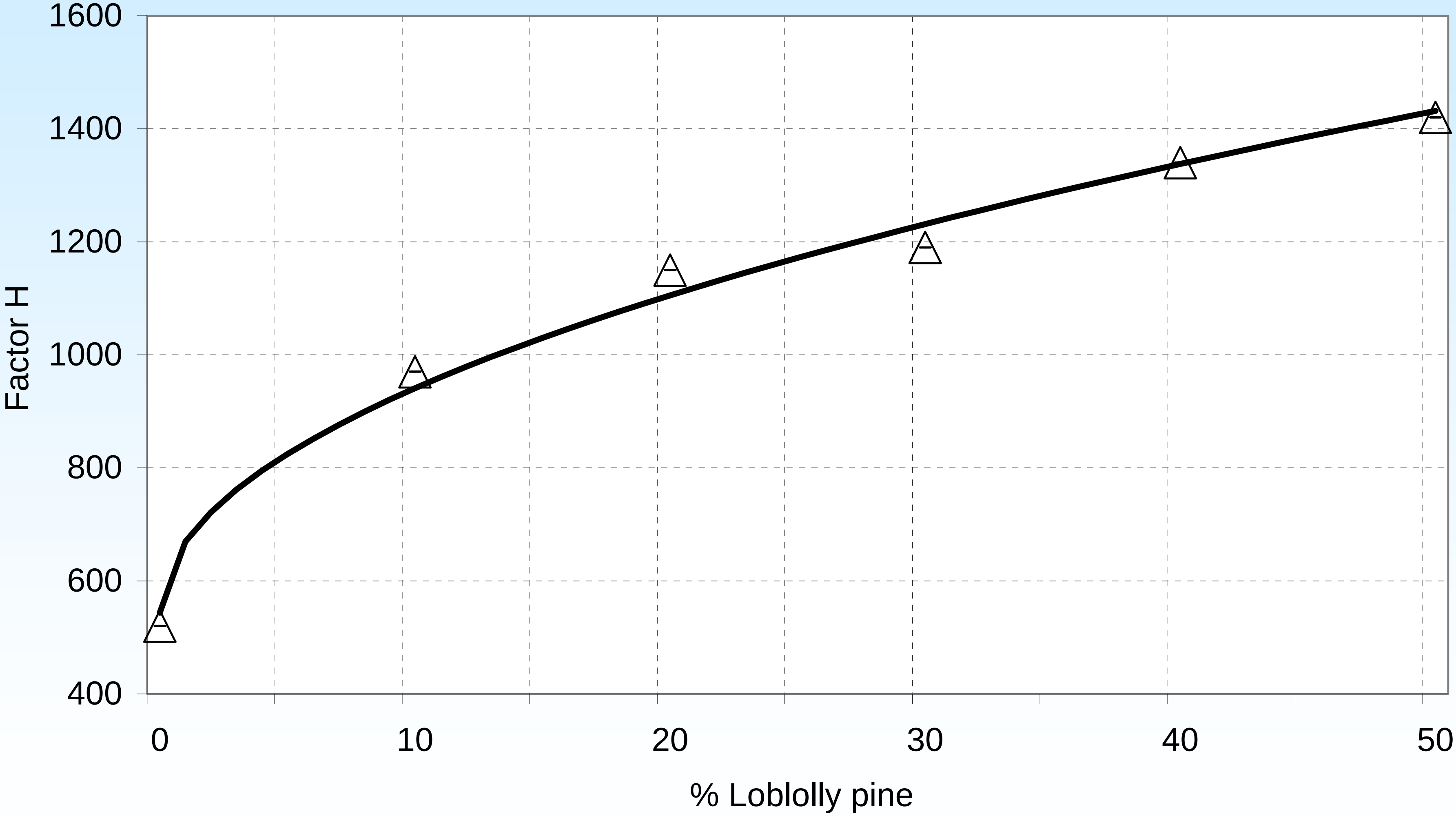
Parameter	*Eucalyptus grandis* x *Eucalyptus urophylla*	Loblolly pine
Wood density (g/cm^3)	0.505	0.332
Lignin content (%)	28.54	31.18
Extractives content (%)	2.50	2.37
Holocellulose content (%)	68.90	66.44

Effective alkali



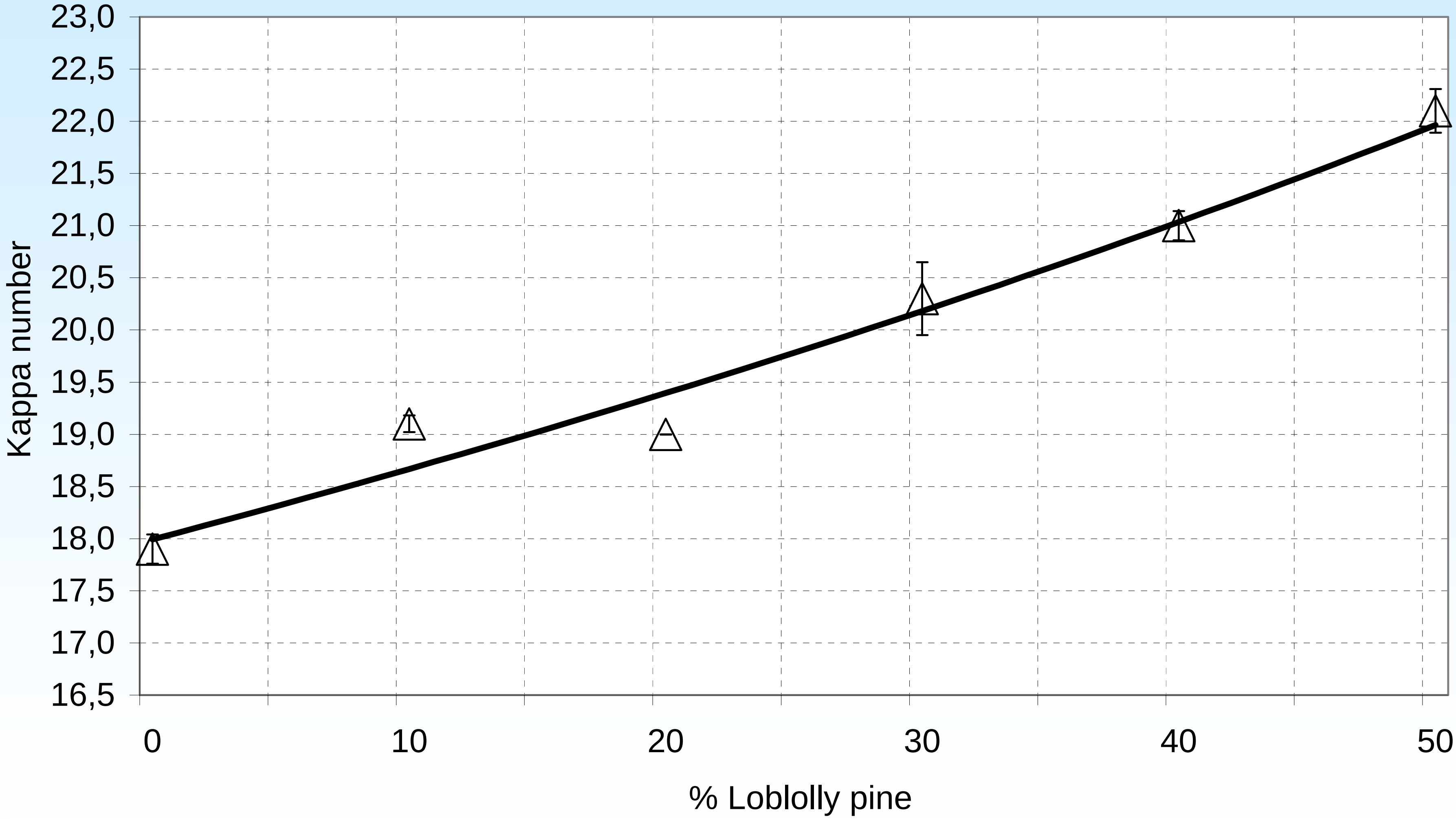
△ *E. grandis x E. urophylla + P. taeda (10 a 50%)*

H Factor



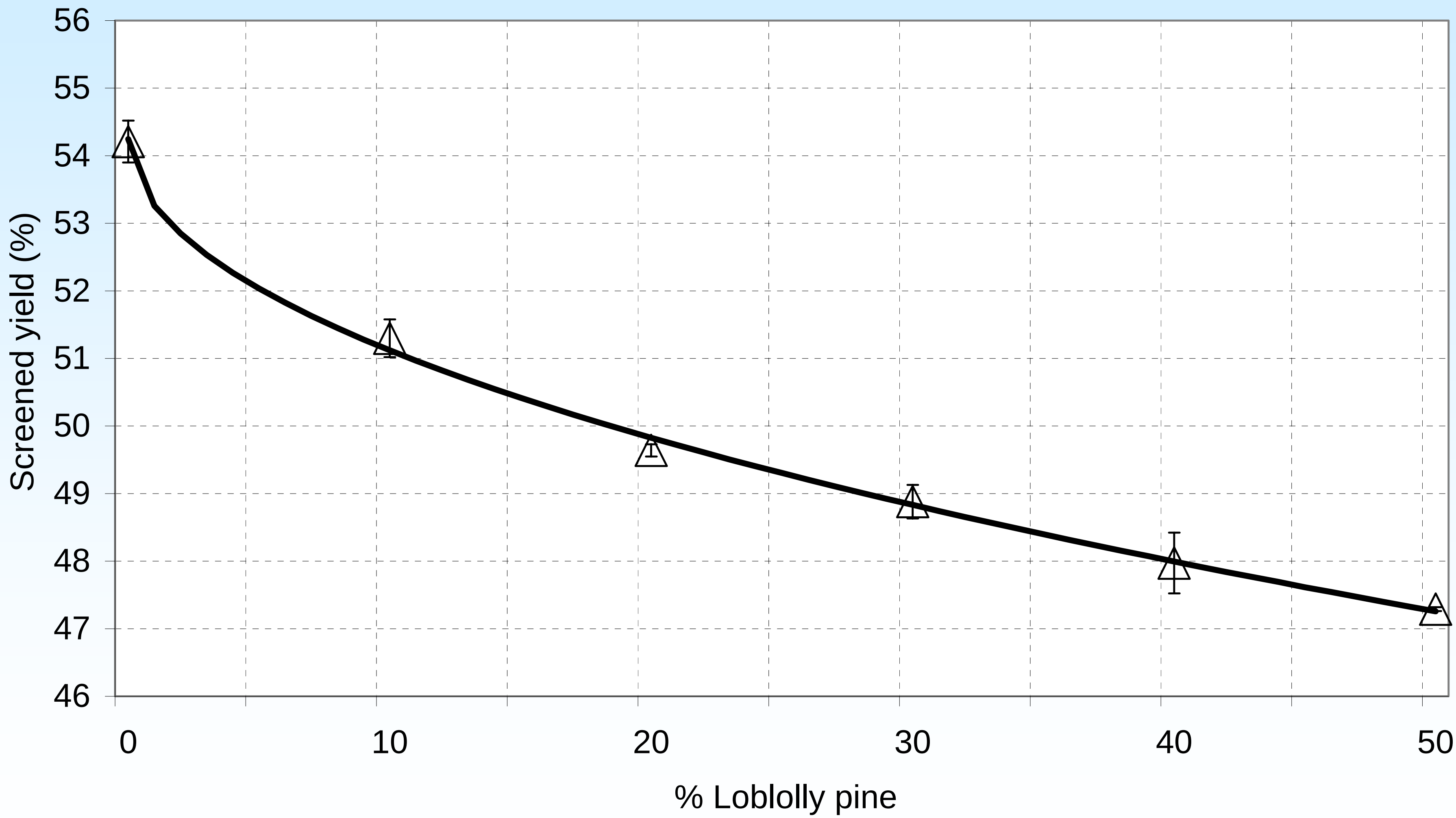
△ *E. grandis x E. urophylla + P. taeda (10 a 50%)*

Kappa number



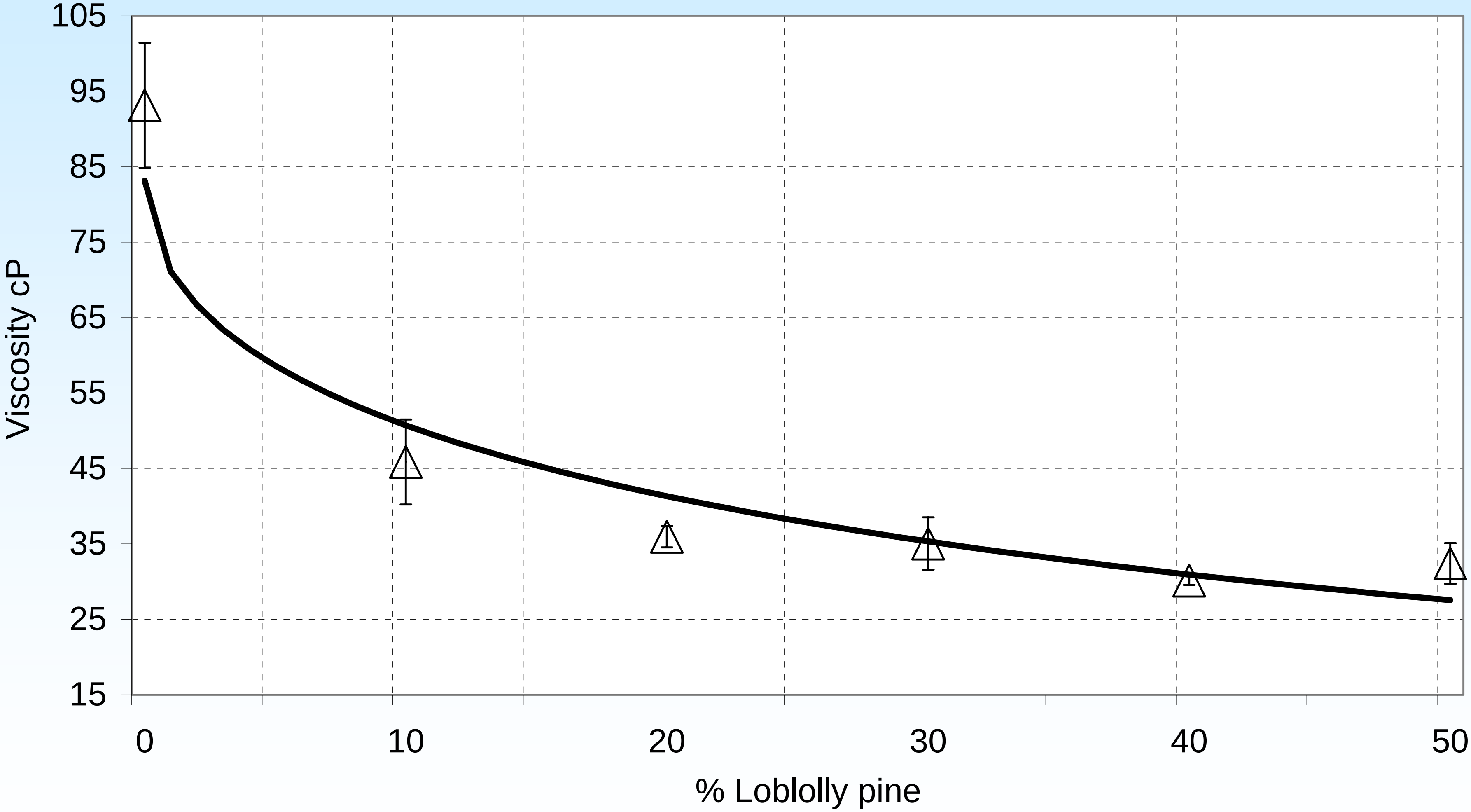
△ *E. grandis x E. urophylla + P. taeda* (10 a 50%)

Screened yield



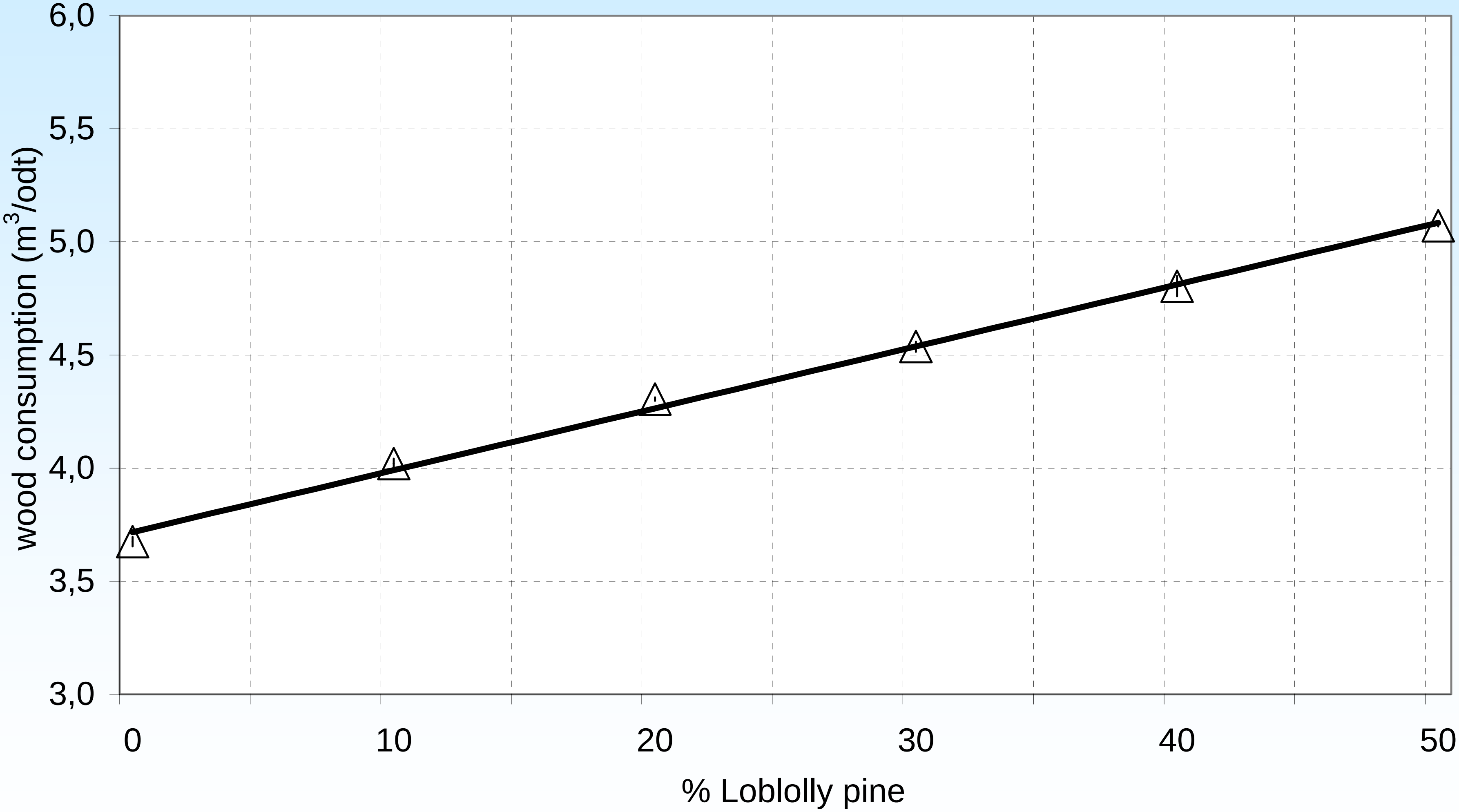
△ *E. grandis x E. urophylla + P. taeda* (10 a 50%)

Viscosity



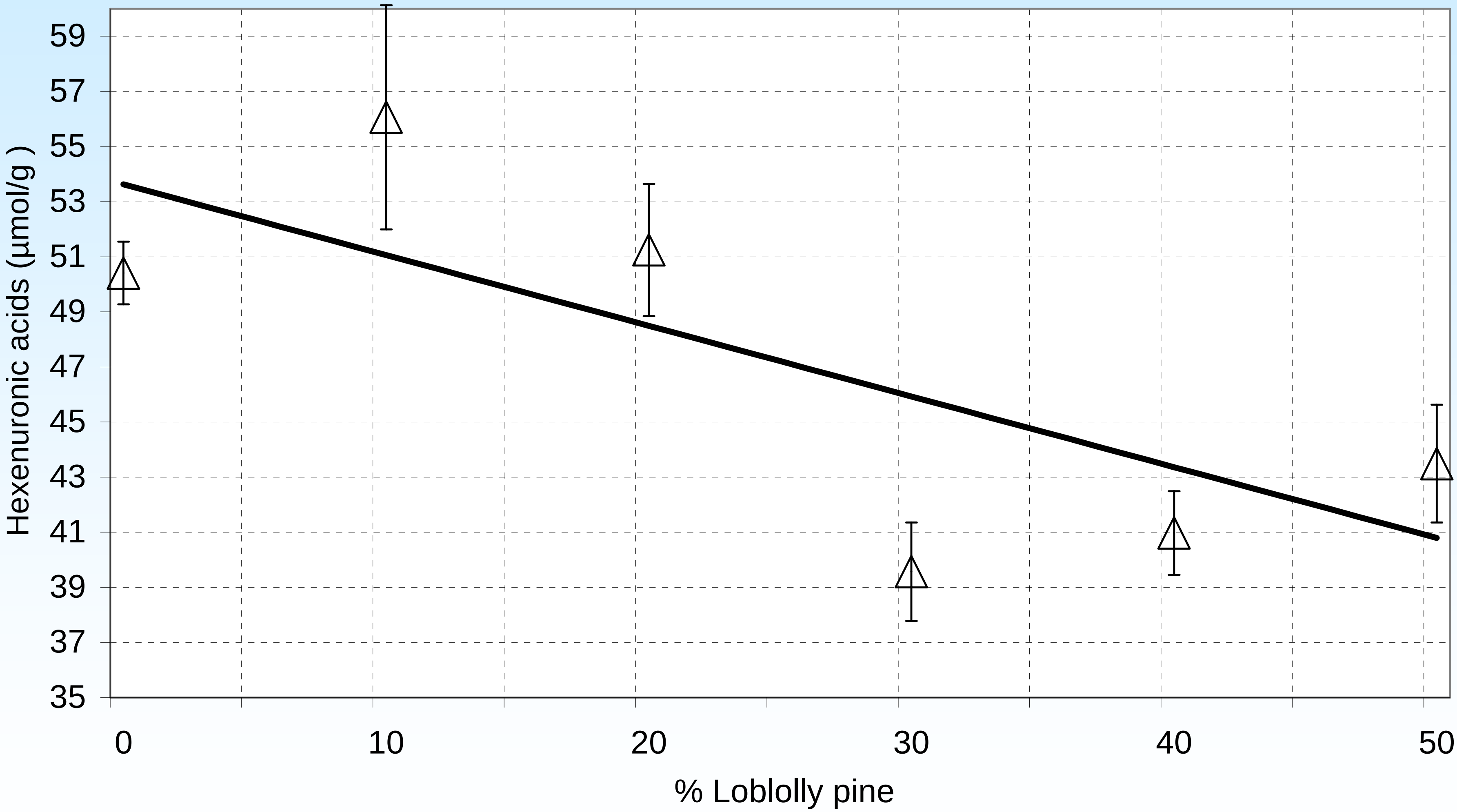
△ *E. grandis x E. urophylla + P. taeda* (10 a 50%)

Wood consumption



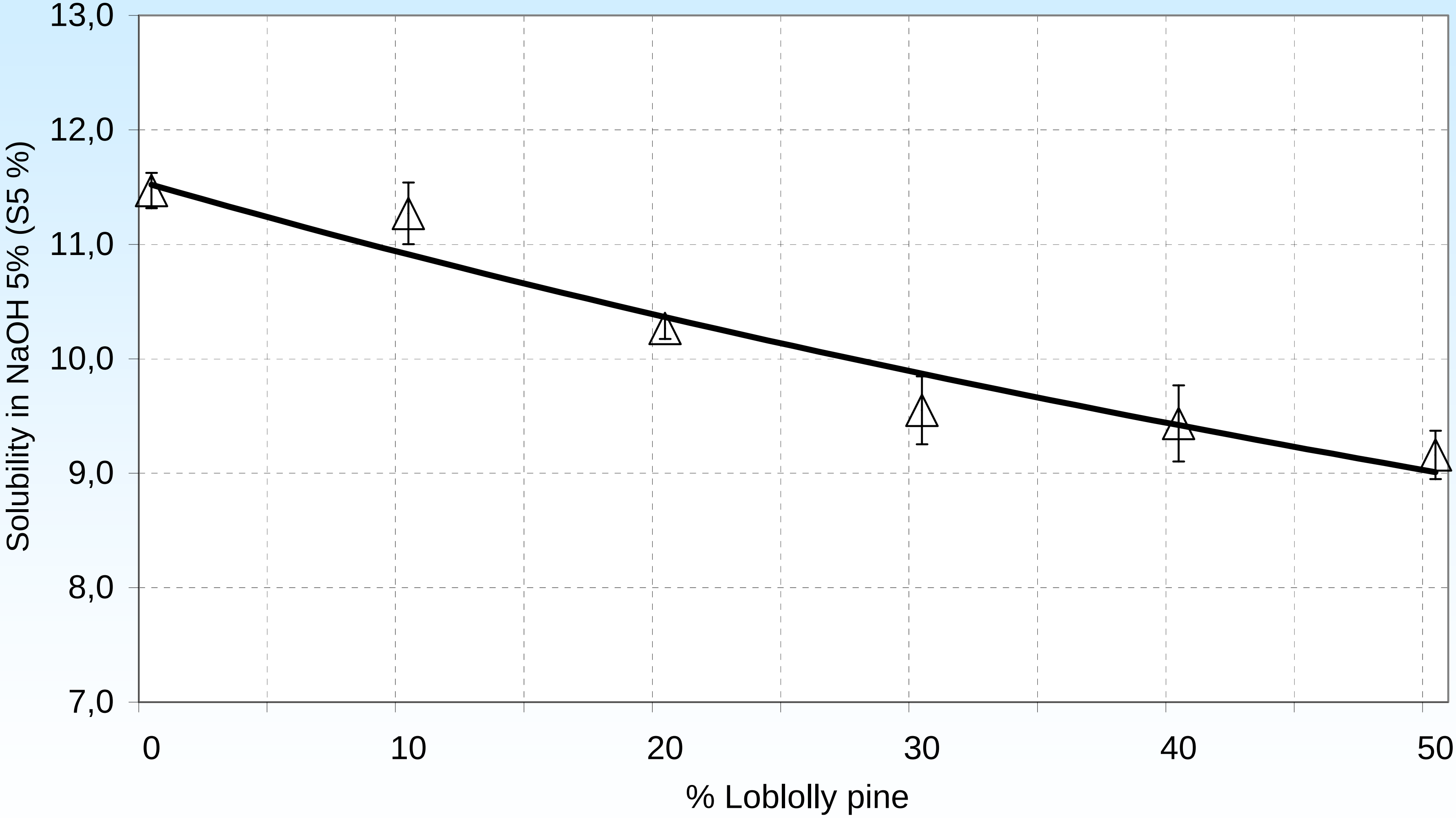
△ *E. grandis x E. urophylla + P. taeda (10 a 50%)*

Hexenuronic acids



△ *E. grandis x E. urophylla + P. taeda (10 a 50%)*

Solubility in NaOH 5% (S5%)



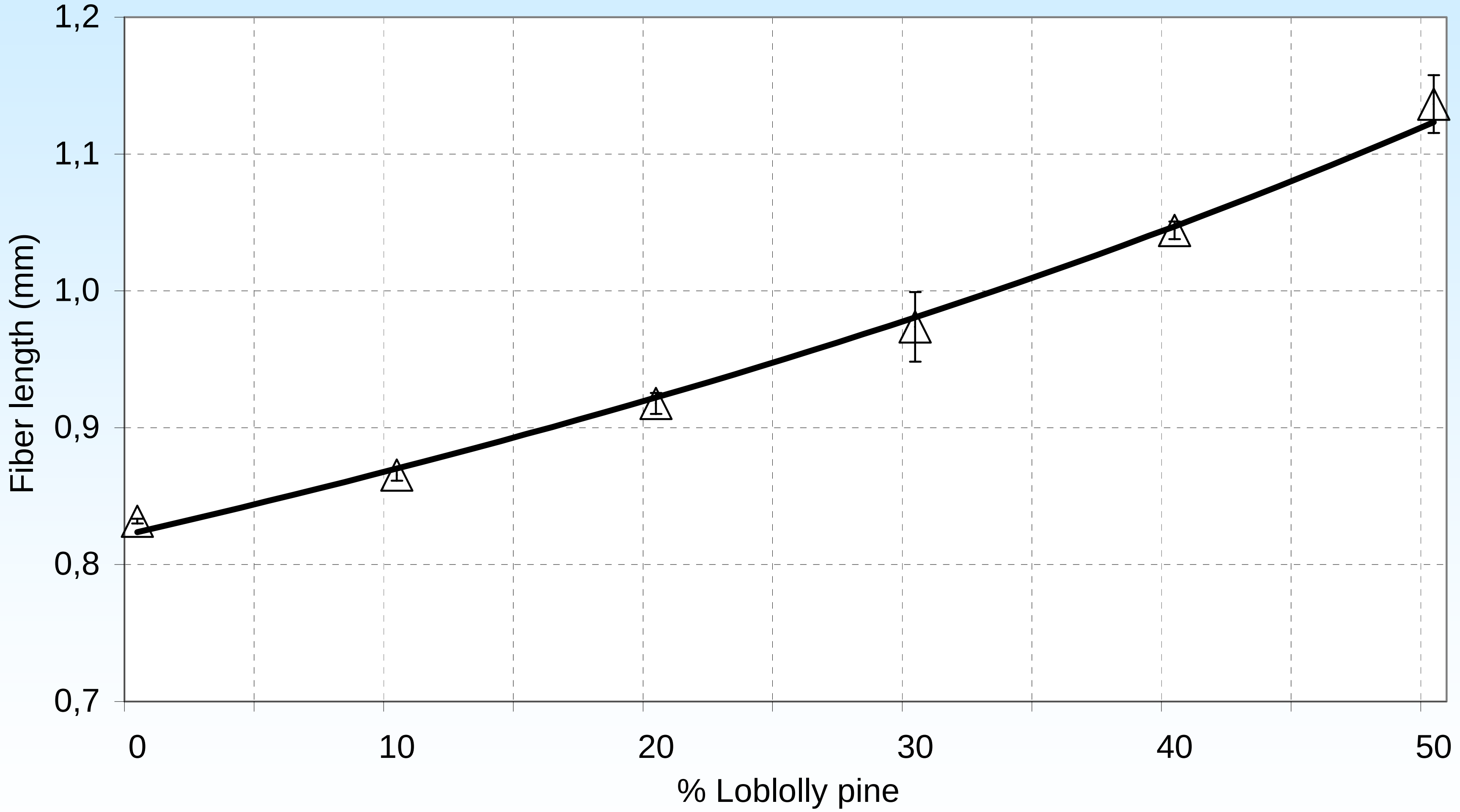
△ *E. grandis x E. urophylla + P. taeda (10 a 50%)*

- The assessment of wood for pulp production must bear in mind:

- The amount and arrangement of constituent woody tissue
- The fiber length and thickness of the cellular wall

- Knowledge of the anatomical characteristics makes it possible to predict paper properties

Fiber length



△ *E. grandis x E. urophylla + P. taeda (10 a 50%)*

Coarseness

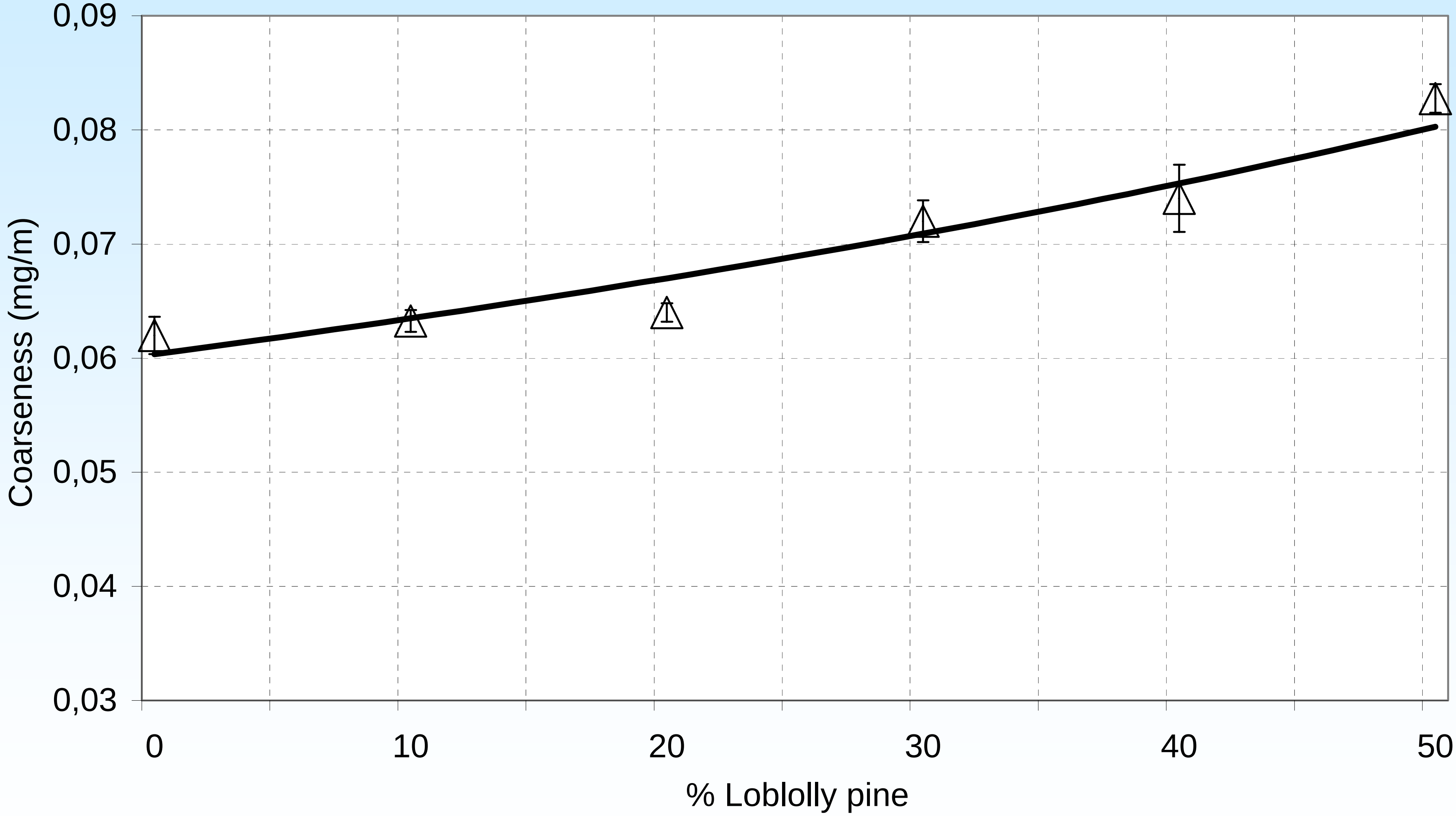
- Defined as the mass per unit of length, affects:

  - The structural properties of the paper (density, smoothness, porosity)

  - Resistance

  - Optical properties
- The flexibility of the fiber and its capacity to form inter-fiber connections fall when the coarseness increases
- It is influenced by the width of the fiber's cell wall and increases as the length of the fiber increases.

Coarseness



△ *E. grandis x E. urophylla + P. taeda (10 a 50%)*

Number of fibers/g

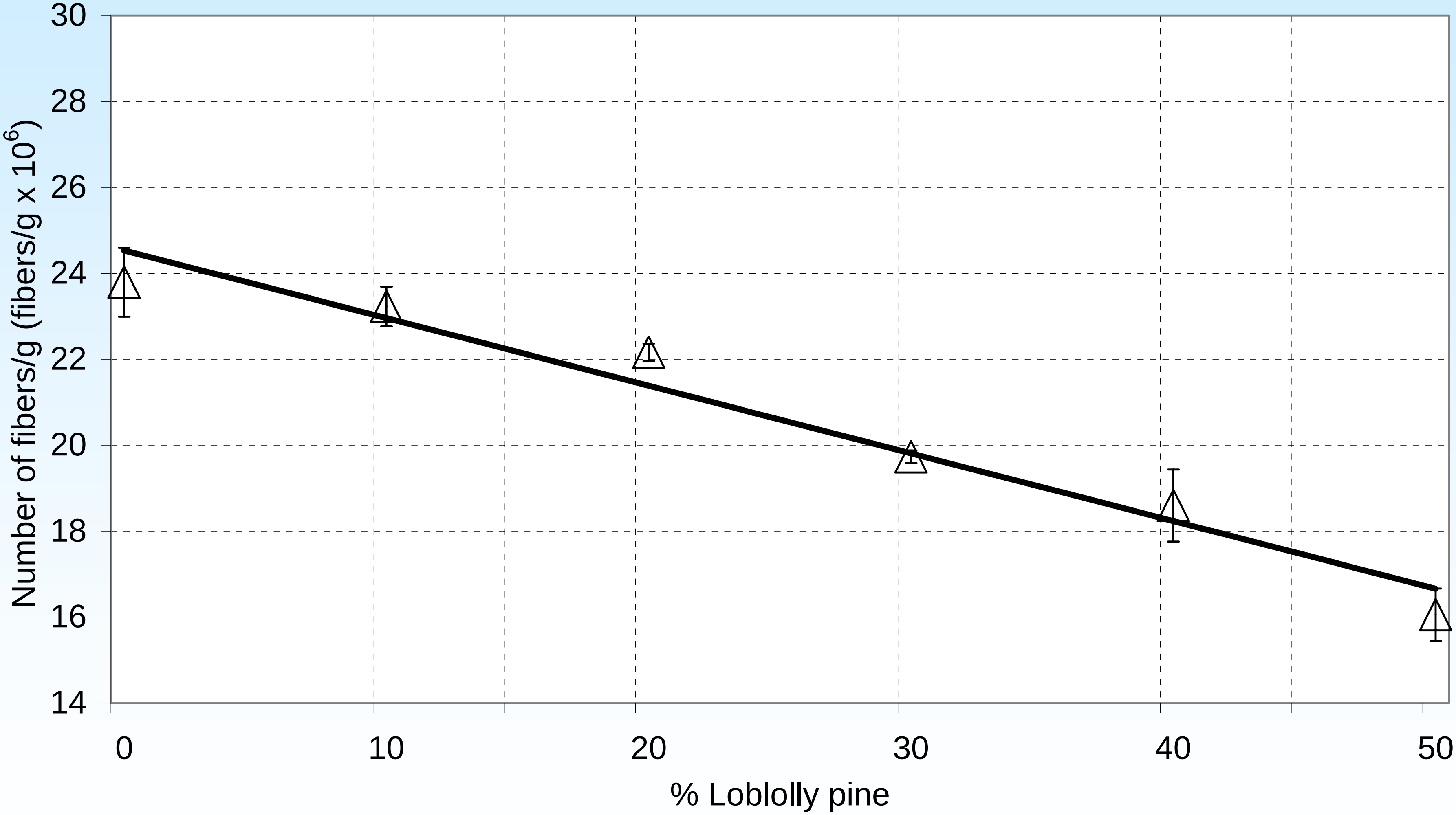
- The number of fibers impacts:

  - The sheet formation
  - The surface smoothness
  - The light scattering / opacity
  - The distribution of the size of the pores

- Properties that depend on the degree of connection between the fibers (apparent density, tensile strength and bursting), are generally of greater indices in pulps with more fibers per gram

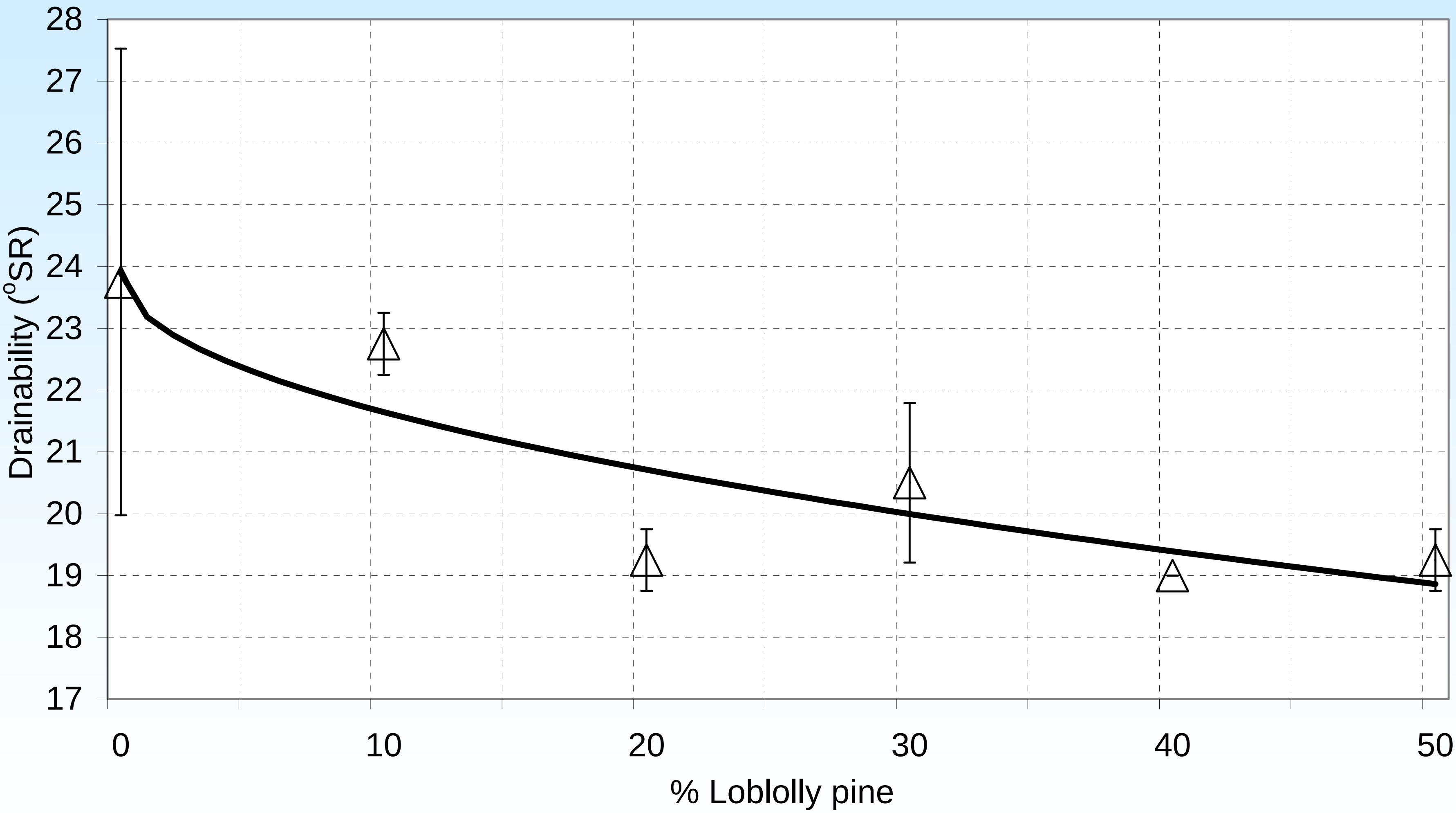
- This proves that this characteristic provides more contact points, increasing the number of connections

Number of fibers/g



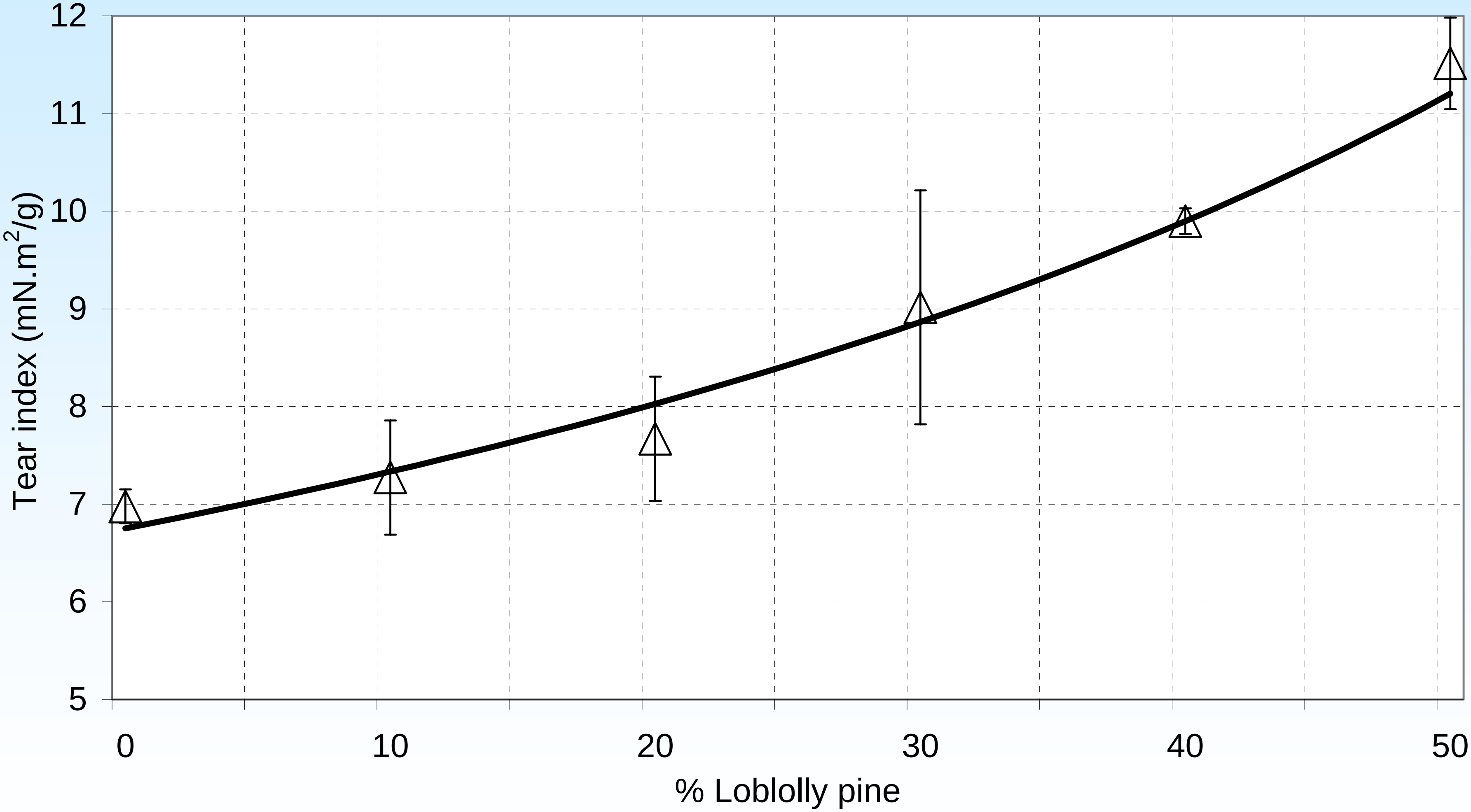
△ *E. grandis x E. urophylla + P. taeda (10 a 50%)*

Drainability



△ *E. grandis x E. urophylla + P. taeda (10 a 50%)*

Tear index



△ *E. grandis x E. urophylla + P. taeda (10 a 50%)*

CONCLUSIONS

Based on the results obtained, the following can be concluded:

- Better results can be achieved by optimization in the Lo-Solids pulping process - loblolly pine and mixtures

CONCLUSIONS

- A 10% addition of loblolly pine fiber to *Eucalyptus* can:

- Improve tear index and drainability

These characteristics allow faster operating speeds in a paper machine, which leads to greater productivity

- For this level of mixture, it is also possible to get a pulp yield close to 50% and satisfactory wood consumption levels

CONCLUSIONS

- The fall in pulp yield observed with the addition of loblolly pine to *Eucalyptus* in proportions over 10% can make the process unviable

Reduction in the pulp yield will cause greater wood consumption and a reduction in the production capacity of an industrial unit

CONCLUSIONS

- The mixture of loblolly pine with *Eucalyptus* is favorable for industrial units that work with 100% Pine
- The substitution of Pine wood chips for *Eucalyptus* is advantageous –

1. Gains in yield in pulp
2. Reduced wood consumption
3. Productivity gains in the industrial unit
4. Savings in raw material (wood and alkali)

CONCLUSIONS

- Manufacturing units that want to produce a differentiated kind of pulp with a high resistance to tearing, to get higher productivity from paper machines, or even to produce special, low-gram papers, must consider the addition of small proportions of Pine to *Eucalyptus*.

Thank you!