UNBLEACHED KRAFT PULP PROPERTIES OF SOME OF THE BRAZILIAN AND U. S. PINES

by

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To my wife, Lorena

To my daughter, Alessandra

To my parents, Edmundo and Eugenia

FOREWORD

The experimental work was carried out between August 1972 and May 1973 at the Department of Paper Science and Engineering of the State University of New York College of Environmental Science and Forestry, in Syracuse, New York, United States of America (U.S.A.). Data are also included, which were obtained in Brazil between January and November, 1971 at the Escola Superior de Agricultura "Luiz de Queiroz"--Universidade de Sao Paulo, in whose pulp and paper laboratories the four Brazilian pulpwoods were studied, pulped and tested. The present work was made possible through the grant of an Agency for International Development scholarship to the author, covering the period from January 1972 to September 1973.

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INTRODUCTION

The natural resources of Parana pine (*Araucaria angustifolia*) in Brazil are being exhausted quickly. The heavy demand for this wood by the pulp and paper and lumber industries, and the difficulties encountered in regenerating these forests are the main reasons. Parana pine is a forest species that grows slowly and has special demands on soil and climate. Researches are being conducted with an aim toward replacing it by exotic species which can grow at a faster rate and on poorer lands. Among the long-fibered wood species, those from the genus *Pinus* have shown the most outstanding characteristics. *Pinus* species have been planted for economic purposes in Brazil for no more than 15 years. This represents, after *Eucalyptus* species, the most successful attempt in exotic tree introduction: the silvicultural and forest management practices pertaining to pine are simple and its nutritional demands are small.

At the moment, the problem of the exhaustion of natural forests of Parana pine is being solved by the planting of large areas with: *Pinus eliottii* and *Pinus taeda* in South Brazil, and *Pinus caribaea* var. *hondurensis* in Central Brazil. These species have found an excellent site for development and increases in volume vary from 15 to 35 stere cubic meters/ha/annum (1).

The man-made pine forests grow well in Brazil until reaching an age of 7 to 11 years, when trees begin to exhibit intense competition for mineral nutrients, water and light. At this time, a first thinning becomes necessary to guarantee better development of the remaining trees. The age of this thinning depends upon the spacing, climate, genetic quality of the seeds, silvicultural practices, and some factors inherent to each species, such as growth rate, natural pruning, and vigor.

The total volume of young wood that comes from this first thinning is very large and statistics show that it will increase greatly in the next few years. So, this kind of wood is potentially a large source of raw material to the Brazilian pulp and paper industry.

The present investigation is intended to study the wood and kraft pulps obtained from these young woods and from the woods of two of the American southern yellow pines which are comparable in many respects to the Brazilian pines: slash and loblolly pines. This study has the objective of obtaining information about these raw materials and making comparisons among the woods and with Parana pine mature wood. It was possible to make direct comparisons between the properties of all the woods studied because similar methods were used. However, since the procedures and instruments used in obtaining and testing the pulps from the Brazilian woods differed from those used for the American woods, no statistical comparisons for pulp properties relating all species were performed. Therefore, the results of the pulp investigation were statistically analyzed on the basis of two sets of data: one collected in Brazil and the other in the U.S.A. The conclusions which were reached in the pulp evaluation study were drawn with the splitting of the data taken into account.

REVIEW OF LITERATURE

1. The genus Pinus

The genus Pinus consists of over one hundred species (2) and many of these represent important sources of raw material for the wood products industries. Pines also comprise the principal softwood species pulped throughout the world, and their use is increasing rapidly. There are several good reasons why pines constitute such an important source of raw material for the industry (3): their wood has an unusual combination of desirable properties, the resources are easily renewable and substantial volumes of timber are available at the present time. In the U. S. A. the southern pines represent the principal timber species. It is estimated (4) that by the year 2000, more than 50 percent of the softwood used in this country will come from the South.

The spreading of the genus over the world is another feature to be considered. In the southern hemisphere there are only a few species that grow naturally. However, the

introduction of many species from the northern hemisphere has been extremely successful, especially in Latin America and Africa. Thus, geography does not constitute an impediment to the growth and economical importance of the genus.

1.1. Wood characteristics

A considerable amount of information pertinent to the wood characteristics of pines may be found in the literature. In recent years, very comprehensive reviews have appeared such as that by Koch (5), discussing the utilization of southern pines. Other sophisticated works deal with the ultrastructures of the wood [Cotè et al. (6)]; identification and quantitative analyses of chemical constituents [Hall and Gisvold (7,8), Posey and Robinson (9), Stanley (10), etc.]; and specific gravity [McMillin (11), Zobel (12), Zobel et al. (13), etc.].

1.1.1. Juvenile wood in pines

It has been recognized for a long time that the first wood which is formed in most wood plants is different from that which is formed later in the life of the tree.

This wood is commonly referred to as "core" or "juvenile" wood and the later-formed wood is known as "mature" or "adult" wood. There is no abrupt transition between juvenile and mature wood inside the tree. The transition is gradual and the characteristics change over the span of several years. Several studies (13,14,15) reported the formation of this immature wood for pine up to the age of 7 to 11 years: slash pine begins to form mature wood at an age 5 to 8 rings from the pith, whereas loblolly pine does so at the age of 7 to 11 years. The core of juvenile wood extends more or less cylindrically toward the top of the tree. Thus, the tops and branches of a tree are almost totally juvenile wood. Juvenile wood is not only a characteristic of fast-growing trees; its presence has also been reported in slow-growing trees (12).

Wood characteristics of juvenile and mature wood from the same tree differ considerably. Zobel (12) reported juvenile wood as having lower specific gravity, shorter fibers with a flat fibril angle and excessive compression wood. Kirk et al. (16) stated also that it has a high lignin and moisture contents and thin-walled cells.

Its lower specific gravity and recognized low tension and compressive strength properties have limited its use in many lumber applications. Juvenile wood represents a very significant proportion of the commercial logs in the South of the U. S. A. Amounts of juvenile wood in the merchantable volume of loblolly pines in South Carolina are reported by Zobel et al. (13) as follows:

Table 1. AMOUNT OF JUVENILE WOOD IN LOBLOLLY PINES (13)

Age Of Trees (Years)	Amount of Juvenile Wood	
	% of Dry Weight	% by Volume
15	76	85
25	50	55
40	15	19

Some properties of young wood as reported by various investigators are shown in Appendix A.

1.1.2. Mature wood

Fiber dimensions and chemical composition of pine woods are probably the most studied fields in wood science. However, because of the within-species and within-tree variability of the woods, many of the data are expressed

as wide ranges of values and it is difficult to find valid comparisons. Another source of variation is that each investigator has his own way of obtaining samples from a species population; and most of the time representative samples are difficult to obtain. Wood is also a material which is highly influenced by site and climatic conditions. In view of all these reasons, it is unwise to make general comparisons between the properties of woods which were studied by different investigators. Although good statistical comparisons are not available, several informative tables showing results found by various authors are in Appendix A.

1.2. Kraft pulping

1.2.1. Juvenile wood

In recent years, because of increasing wood shortages, more and more emphasis has been placed on the pulping of juvenile woods. A large source of this kind of wood is available at the present time from early thinnings in pine forests and it will be significantly larger in the future. This potential resource constitutes an attractive reason

for the interest of industries and research institutes. Today, the trend is to develop, through the use of tree breeding, pine trees with special qualities in juvenile wood that will supplement the hardwood furnished for the pulp industry (27).

Several studies on the pulping of southern pine juvenile wood have been reported by Zobel (17), Barefoot et al. (28), Einspahr et al. (29) and Kirk et al. (16). The last cited investigators summarized juvenile wood pulping results found in the literature as follows:

a) juvenile wood pulps contain more lignin than pulps prepared from mature wood under the same conditions;

b) juvenile wood pulps exhibit higher burst and tensile strength and apparent density, but lower tear strength;

c) pulp yields are low, making the use of juvenile wood more expensive;

d) pulps have low cellulose yields and high hemicellulose yields;

e) pulps from higher specific gravity juvenile wood exhibit higher tear strength but lower

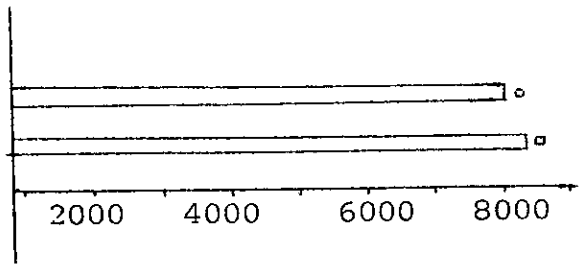
> burst and tensile strength and apparent density when compared to other juvenile wood pulps.

These authors also reported in their investigation a much higher tensile, burst strength and folding endurance for the juvenile wood when compared to pulps obtained from regular mill chips. This was attributed to higher fiber bonding at a given freeness as a result of the thinner-walled and more flexible fibers of the juvenile wood. Low opacity for juvenile wood pulp has been reported to be the result of a small unbonded area in the sheet (16).

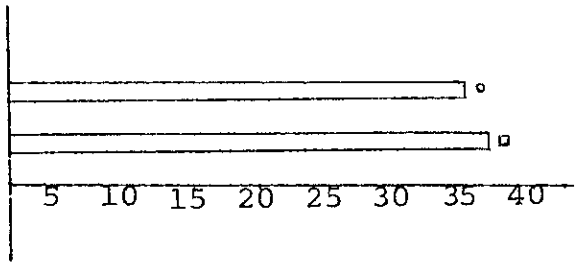
In Brazil, only a few studies have been published on this subject. Redko and Guimaraes (19) reported obtaining kraft and neutral sulfite pulps of high yield and quality from the wood of 8 year-old *Pinus elliottii*. High breaking length was considered the major characteristic of these pulps, and the low tear strength was attributed to the immaturity of the fibers. The utilization of this kind of wood for manufacturing linearboard and corrugating medium was suggested by the authors. Similar results were found by Zvinakevicius (30) when he studied the kraft pulping of

young trees of *Pinus elliottii* and *Pinus taeda*. The author considered the laboratory results for tear strength of these woods to be disappointing. Better results were reported when a mill trial was performed with just-harvested wood. A comparative diagram showing some of the strength properties of multi-wall sack paper which was manufactured by the mill during the trial is presented below. Two species of wood were utilized for this comparison. The following notation was used: o = paper obtained from *Pinus taeda* pulp, □ = paper obtained from *Araucaria angustifolia* pulp.

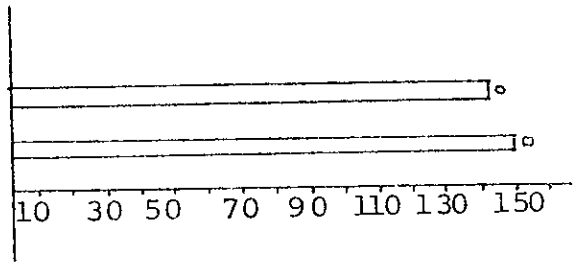
Breaking length (meters)



Burst factor



Tear factor



1.2.2. Mature wood

Because of the problems encountered in low pH pulping, pinewood is usually processed by alkaline methods, especially the kraft process. Kraft pinewood pulps represent the largest percentage of chemical pulps produced in the world. The literature is rich in papers dealing with this subject; however, only a few articles which are directly related to this investigation are discussed here.

In the U. S. A., since 1940, the southern part of the country has become the world's largest kraft pulp producer (31). Ten species of pines are commercially pulped in this area. Of these, loblolly pine ranks first and it is followed by shortleaf, longleaf and slash pines. The properties of the pulps produced in the southern kraft mills seem to be only slightly influenced by wood species (32). However, as the different species of pines grow in various climatic zones, the influence of species appears to be very strong (32). Lignin content of the pulp is one of the major sources of variation between the properties of these pulps (32,20).

Southern pines are well known to produce pulps with very high tear strength but low burst and tensile strength (33). These trends in strength properties are similar to those observed for the sulfite pulps of Araucaria angustifolia by Rys et al. (34).

In tropical and sub-tropical pulp-producing countries, attention has been given to the utilization of fast-growing pine species. The pulping of coniferous species growing in these areas has been the subject of investigations by the Tropical Products Institute in England. Two members of this institute, Palmer and Gibbs, have studied intensively the kraft pulping characteristics of Pinus caribaea from tropical areas of the world (35,36,37,38,39,40). Among their important findings, the authors concluded that Pinus caribaea is expected, under production conditions, to yield pulps somewhat weaker than commercial pulps such as Canadian and U. S. southern pine kraft pulps. Nevertheless, it could be used in the same way for the production of packaging grades of paper in an integrated plant.

Palmer and Tabb reported the results and conclusions of a long investigation in pulping characteristics of tropical conifers (41). The investigation showed that *Pinus caribaea*, in some cases, yielded pulps unsuitable for paper production if used alone, but because of their high tear strength, might be valuable as a component in pulp mixtures. Also, the tropical pines produced pulps with poorer bonding qualities than temperate species and so were weaker in burst and tensile strengths. Because of their usually inferior quality, the authors concluded that it was unwise to assume that the pulps obtained from these woods could be sold easily on the world markets.

More optimistic conclusions were drawn by Fairest (21) in the investigation of *Pinus caribaea* growing in Venezuela. The pulp obtained from mature wood was considered definitely better in quality when compared to the information found in the literature. However, the cooking of 5 year-old wood led to weak pulps. Burst, tensile and tear strengths were similar to the values reported for American and European pinewood pulps. Fairest concluded his work with a strong suggestion for the planting of this

species in Venezuela, as a new source of raw material for the kraft pulp industry.

2. The genus Araucaria

The genus Araucaria comprises less than 10 species confined to South America and to the Southwestern Pacific area. Araucaria angustifolia is the most important South American softwood. It is the only native softwood of commercial value in Brazil and it is still the major source of long-fibered raw material for the Brazilian pulp and paper industry.

2.1. Wood characteristics

Up to the present time the information on the Araucaria species is very limited. A few works (34,42,43) have appeared, in which the authors investigated the morphological, chemical and pulping properties of the species. Lack of precise information on the exact ages of the trees is another serious problem, since the species grow in virgin forests. Also, because of this, the wood is characterized by a lack of uniformity.

As major features, Araucaria is well known as having very long fibers, said to be the longest among the conifers (34), and high cellulose content. The fiber length often reaches 7 to 9 mm, with an average around 5 mm. The specific gravity runs from 0.400 to 0.585 (44).

Chemical analyses of Parana pine wood were performed by Rys et al. (34) and Redko and Guimaraes (19). The results obtained by them are shown in Appendix A.

2.2. Pulp properties

Although it has many desirable wood properties, known to be important in their effect on pulp properties, Parana pine pulp does not exhibit the high strength that might be expected (34). High tear factor is the principal feature of their pulps, but concomitantly, tensile and bursting strength are generally at a low level for softwoods.

MATERIALS USED AND EXPERIMENTAL PROCEDURES

WOOD

1. Source of the woods

Four different forest species were used in this investigation. The woods growing in Brazil were represented by the species *Araucaria angustifolia* (Bert) O. Kuntze, *Pinus elliottii* Engelmann var. *elliottii*, *Pinus taeda* L. and *Pinus caribaea* Morelet var. *hondurensis*, while those growing in the U. S. A. were represented by the species *Pinus elliottii* Engelmann var *elliottii* (slash pine) and *Pinus taeda* L. (loblolly pine).

To simplify the presentation of data, the scientific name will be kept for the Brazilian species and the common name for the American ones. Thus when the name slash pine is used, the author is referring to the species *Pinus elliottii* var. *elliottii* growing in the U. S. A., and so on.

The woods of *Pinus elliottii*, *Pinus taeda* and *Araucaria angustifolia* were obtained from Olinkraft Celulose e Papel Ltda. at Lages, Santa Catarina, Brazil. The wood of

Pinus caribaea came from Champion Papel e Celulose S. A. at Mogi-Guacu, Sao Paulo, Brazil. The woods of slash and loblolly pines were supplied through the courtesy of Union Camp Corporation at Savannah, Georgia, U. S. A. The age and type of forests from which the different woods were obtained are summarized below:

Table 2. CHARACTERISTICS OF THE SAMPLED FORESTS

Species	Type of Forest Stand	Spacing Between Trees	Age of the Stand at the Time of Harvesting
A. angustifolia	natural	random distributed	15 to 20 years (estimated)
P. elliottii	man-made	6.0×7.5 ft.	8 years
P. taeda	man-made	6.5×8.5 ft.	11 years
P. caribaea	man-made	6.5×6.5 ft.	8 years
Slash pine	man-made	9.0×10.0 ft.	18 years
Loblolly pine	man-made	6.0×8.0 ft.	16 years

2. Selection of the sample trees and preparation of the wood

2.1. Sampling of the Brazilian Pinus species

Since the natural variations among different trees and between trees of different stands are of great magnitude, the sampling of the pinewoods was carried out in accordance

with the following procedure:

- the sampled stand had the average growth rate for the species in the region,
- at the time of the thinning, five trees were randomly taken for each replication of each species. As the statistical analysis program is based on five replications for each species, 25 trees were sampled for each species,
- the trees selected were of good form with regard to straightness and absence of excess limbs.

These trees were cut into logs 6.5 ft. long from the ground to a minimum diameter of 3 inches. Tops and branches were discarded. The logs were then hand-debarked, identified and later chipped in an industrial knife chipper.

The chips obtained from each group of 5 trees were well mixed and a sample considered enough for the purpose of the work was taken. Then, the chips were air-dried to about 10% moisture content and screened to remove sawdust and knots. The acceptable chips comprising each replication were kept in poly-ethylene bags to prevent changes in moisture content and stored in a cold room. The moisture content of the chips was determined in replicate on

approximately 200 g samples dried at 105°C ± 3°C to constant weight.

2.2. Sampling of *Araucaria angustifolia*

The chips of *Araucaria angustifolia* were collected directly from the raw material that is normally used for the manufacture of unbleached kraft pulp by Olinkraft Celulose e Papel Ltda., located at Lages, Santa Catarina, Brazil. Five samples were obtained from the chip silos of that mill. The procedure of drying, screening and storing the materials was the same as that cited in item 2.1.

2.3. Sampling of slash and loblolly pines

These woods, supplied by Union Camp Corporation, were represented by 5 debarked logs approximately 6 feet long for each species. Each log was taken from an individual tree at a random height. The wood was chipped using a Carthage ten-knife chipper. After screening, the acceptable chips were air-dried and stored in poly-ethylene bags in a cold room. Five samples of chips were taken for each species, each one containing enough material for the purpose of the

experiment. The moisture content of the chips was determined in the same way as cited in item 2.1.

3. Distribution of chip size

The approximate distribution of chip size was found by using a William's chip classifier. The results of classification are presented in Tables 3 and 4.

Table 3. DISTRIBUTION OF CHIP SIZE OF THE BRAZILIAN WOODS

Species	Percentage of Chips Retained on Screen Size						
	1"	$\frac{3}{4}$"	$\frac{5}{8}$"	$\frac{1}{2}$"	$\frac{3}{8}$"	6 mesh	< 6 mesh
A. angustifolia	2.2	15.5	25.6	11.3	22.8	21.9	0.7
P. elliottii	11.0	32.9	25.1	11.2	10.7	8.8	0.3
P. taeda	10.2	26.9	27.1	9.5	15.3	10.9	0.1
P. caribaea	4.8	19.4	28.7	12.3	17.4	15.8	1.6

Table 4. DISTRIBUTION OF CHIP SIZE OF THE AMERICAN WOODS

Species	Percentage of Chips Retained on Screen Size					
	$1\frac{1}{8}$"	$\frac{7}{8}$"	$\frac{5}{8}$"	$\frac{3}{8}$"	$\frac{3}{16}$"	$<\frac{3}{16}$"
Slash pine	0.6	2.1	25.4	50.0	18.5	3.4
Loblolly pine	2.4	4.5	38.0	44.7	9.7	0.7

4. Wood properties

Physical and morphological tests and chemical analyses were performed in order to compare the wood characteristics of all species studied.

From each of the 30 plots (6 species, 5 replications/species) represented by chips stored in each of 30 poly-ethylene bags, a representative subsample was taken. For each of these subsamples, all of the tests which have been cited in this chapter were performed.

Statistical analyses were performed upon the recorded data, by application of the following tests:

- Cochran's test: test for equality of variances,
- F test: test for significance of differences between treatment effects,
- Tukey's test: test for comparisons between two means.

Also, the variability of the data was expressed by the coefficient of variation. All tests and analyses were randomly performed.

4.1. Wood fiber morphology

The relationship of the anatomical properties of wood fibers to the strengths of the corresponding pulps has been subject of considerable research during the last few decades. With this in mind, the following fiber characteristics were measured in this work:

- fiber length . . . . . FL
- fiber width . . . . . FW
- lumen diameter . . . . . LD
- cell wall thickness . . . . . CWT

In more recent years, more and more emphasis has been placed on sophisticated measurements, expressed as ratios between these fundamental dimensions. It was felt that the calculation of some of these ratios could aid in the explanation of pulp strength results, and also, could make it possible to better identify these woods. The following fiber dimension ratios considered important for papermaking purposes (28,45,46,47,48,49,50) were determined:

- felting coefficient (FC): ratio between fiber length and fiber width $FC = \frac{FL}{FW}$

- coefficient of flexibility (CF): ratio between lumen diameter and fiber width, expressed as percentage.

$$CF = \frac{LD}{FW} \times 100$$

- wall fraction (WF): ratio between cell wall thickness and fiber radii, expressed in percentage.

$$WF = \frac{CWT}{FW/2} \times 100$$

- fiber length/cell wall thickness ratio (L/C):

$$L/C = \frac{FL}{CWT}$$

- Runken index (RI): ratio between twice the cell wall thickness and the lumen diameter.

$$RI = \frac{2\ CWT}{LD}$$

- Mulsteph ratio (MR): ratio between the cell wall area and the cross fiber area.

$$MR = \frac{(FW)^2 - (LD)^2}{(FW)^2}$$

- Boiler number (BN): expressed by the following ratio (51):

$$BN = \frac{(FW)^2 - (LD)^2}{(FW)^2 + (LD)^2}$$

A representative amount of chips was randomly taken from each plot. The chips were split into small segments

and then macerated in a solution of 1 part of hydrogen peroxide, 5 parts of glacial acetic acid and 4 parts of distilled water. Glass vials containing the wood segments and the macerating solution were placed in an oven at $54^{o}C \pm 2^{o}C$ until the maceration was completed. Ten slides per sample were prepared by mounting the fibers in a glycerine gel (Kaiser's formula). Safranine stain was used; this gives a red color in reacting with the lignin present in the fibers. Fiber dimensions of 10 fibers per slide were determined by micro-projection. A total of 100 fibers were randomly measured for each sample.

4.2. Wood specific gravity

The specific gravity of unextracted wood chips was determined by the maximum moisture content method, suggested by Smith (52) and adapted by Foelkel and co-workers (53). Specific gravity of extractive-free wood was calculated by reducing the oven-dry weight of chips by the weight of the alcohol-benzene extractive content of the corresponding sample.

4.3. Chemical analyses of the woods

Chemical properties were determined from approximately 200 g samples of chips randomly selected. The chips were first ground in a Wiley mill. The sawdust obtained was screened and classified into three different fractions according to particle size:

- the fraction passing a 40-mesh screen,
- the fraction passing a 60-mesh screen,
- the fraction passing a 40-mesh screen and retained on a 60-mesh screen.

The wood meals were then conditioned to equilibrium moisture content in a room maintained at a constant 50% relative humidity and a temperature of 73°F, and finally they were individually stored in plastic bags. The oven-dry moisture content was carefully determined for each one of these samples. Chemical determinations were performed in duplicate and the average result was expressed as a percentage of the weight of oven-dry wood. The following chemical analyses were performed on the woods:

Table 5. CHEMICAL ANALYSES PERFORMED

Test	Method		
- Cold water solubility	TAPPI	Standard	T_{1m-59}
- Hot water solubility	TAPPI	Standard	T_{1m-59}
- 1% caustic soda solubility	TAPPI	Standard	T_{4m-59}
- Alcohol-benzene solubility	TAPPI	Standard	T_{6m-59}
- Ether solubility	TAPPI	Standard	T_{5m-59}
- Lignin content	ABCP	Standard	M 10/71
- Cross and Bevan cellulose content	ABCP	Standard	M 9/71
- Pentosan content	TAPPI	Standard	T_{19m-50}
- Ash content	ASTM	Standard	D 1102-56

TAPPI/Technical Association of the Pulp and Paper Industry
ABCP/ Associacao Brasileira de Celulose e Papel
ASTM/ American Society for Testing and Materials

PULPING

1. Process and cooking conditions

All woods were pulped by the kraft process to two different ranges of permanganate numbers: one between 16 - 18, to represent pulps prepared in the bleachable category, and the other between 25 - 30, to represent unbleachable grades. This means that two samples of each wood were pulped for a total of 60 cooks representing the scope of the investigation.

The following cooking conditions were found necessary in order to obtain the specified permanganate numbers:

Table 6. COOKING CONDITIONS

Cooking Variables	Pulping of the Brazilian Woods		Pulping of the American Woods	
	Bleachable Grade	Unbleachable Grade	Bleachable Grade	Unbleachable Grade
- Active alkali (based on oven-dry wood)	20%	19%	20%	19%
- Sulfidity	25%	25%	25%	25%
- Activity	88%	88%	88%	88%
- Maximum temperature	170°C	165°C	175°C	170°C
- Time to maximum temperature	2.0 hrs.	1.5 hrs.	2.0 hrs.	1.5 hrs.
- Total cooking time	3.5 hrs.	3.0 hrs.	3.5 hrs.	3.0 hrs.
- Liquor-to-wood ratio	4:1	4:1	4:1	4:1

Sodium carbonate was added to the cooking liquor to simulate mill conditions. The amount added was calculated taking the activity of the liquor equal to 88%.

$$\text{Activity (\%)} = \frac{NaOH + Na_2S}{NaOH + Na_2S + Na_2CO_3} \times 100$$

all chemicals expressed as Na_2O.

2. Liquor preparation

Solutions of technical grade NaOH, Na_2S and Na_2CO_3 were prepared at concentrations of approximately 100 grams per liter as Na_2O and were maintained in plastic carboys to be used as required. The solutions were periodically restandardized to avoid errors due to liquor degradation. The cooking liquor was prepared just before cooking, by adding the required amounts of the stock solutions and diluting with water to achieve the specified liquor-to-wood ratio. The water present in the wood was taken into account.

3. Cooking procedure

3.1. Cooking of the Brazilian woods

All of the 40 cooks performed in Brazil were done in a 20 liter stainless steel electrically-heated tumbling digester. The equivalent of 500 grams, on an oven-dry basis, was charged to the digester for each cook.

3.2. Cooking of the American woods

A 1.5 cu. ft. capacity digester with indirect heating and forced circulation was used to obtain the 20 required

cooks for the American woods. The equivalent of 3,000 grams, on an oven-dry basis, was charged to the digester for each cook.

4. Pulp processing

4.1. Washing

At the end of all cooks the digester was relieved to atmospheric pressure and the chips were dumped into a screen box which had a 100-mesh screen bottom. The chips were washed with warm water until the effluent attained a uniform low color.

4.2. Defibering

After washing, the chips from the cooks performed in Brazil (cooks number 1 to 40) were defibered in a laboratory disintegrator operating at 3000 r.p.m., over a period of 10 minutes. The chips from the cooks performed in the U. S. A. (cooks number 41 to 60) were defibered in a laboratory hydrapulper for 10 minutes.

4.3. Screening

The defibered materials from cooks 1 to 40 were screened through a 0.5 mm cut flat fiber classifier of the BH 6/12 Bretch and Holl model. Those from cooks 41 to 60 were screened on a laboratory vibrating flat screen with slits 0.01 inch wide. The screenings were collected and oven-dried at 105°C ± 3°C to constant weight.

4.4. Pressing or centrifuging

The screened pulps from cooks 1 to 40 (corresponding pulp numbers 1 to 40) were pressed by means of a wooden box press having a 100-mesh screen in the bottom.

Pulps from cooks 41 to 60 (corresponding pulp numbers 41 to 60) were centrifuged in a Sharples 20 Cyclone centrifuge for 15 minutes.

4.5. Crumbling and storing

The screened pulps (consistency *ca*. 30%) were shredded and stored in plastic bags in a cold room (temperature *ca*. 5°C).

4.6. Pulp yield and permanganate number determinations

The consistency was measured by oven-drying a representative sample of pulp to constant weight. Having ascertained the consistency and oven-dry weight of rejects, both total and screened yields and reject content were determined. Total yield, screened yield and reject content were expressed on two different bases: percent of oven-dry wood and percent of oven-dry extractive-free wood. The residual extractive content in the pulps was considered negligible for the second basis. Also, for the yield calculations, the weight of wood free from the alcohol-benzene extractives was used. The permanganate number (K Number) of the washed and screened pulp was determined according to TAPPI Standard $T_{214m-50}$.

PULP TESTING

Physical evaluation of all 60 pulps was carried out.

1. Beating

Beating of pulps 1 to 40 was performed in a Jokro-Muhle laboratory mill, according to the method

Merkblatt V/105 of the Verein der Zellstoff und Papier, Chemiker und Ingenieure (V.Z.P.C.I.). Pulps number 41 to 60 were processed in a Valley laboratory beater according to TAPPI Standard $T_{200ts-66}$. During the operation, samples were obtained at seven different beating times, including 0 time. These samples were used for freeness or slowness determinations and for making handsheets. The slowness of pulps 1 to 40 was determined as Schopper-Riegler degrees according to V.P.Z.C.I. method Merkblatt V/107. Using a conversion table (54), the Schopper-Riegler degrees were reexpressed approximately as equivalent freeness. The freeness of pulps 41 to 60 was determined according to TAPPI Standard $T_{227m-58}$.

2. Handsheet making

Seven handsheets were made for each of the samples taken during the beating operation. For sheet formation and drying a FS S/2 Rapid-Koethen apparatus was used for the pulps number 1 to 40. The method used was in accordance to V.Z.P.C.I. method Merkblatt V/108. The formation of handsheets for pulps number 41 to 60 was done in accordance to TAPPI Standard $T_{205m-58}$.

3. Physical testing of handsheets

Physical properties of all pulps were carried out according to TAPPI Standard $T_{220m-60}$. Data were recorded or calculated for the following pulp properties:

- beating time, expressed in minutes
- freeness, expressed in ml.
- basis weight, expressed in g/m^2
- tensile strength, expressed as breaking length, in meters.
- stretch, expressed as percentage of stretch
- bursting strength, expressed as burst factor
- internal tearing strength, expressed as tear factor
- thickness, expressed in microns
- apparent density, expressed in g/cc
- bulk, expressed in cc/g.

RESULTS AND DISCUSSION

1. Experimental design

Statistical analyses were performed to test the properties under investigation.

The application of statistical analysis to experimental data which are expressed in percentages has been the subject of many studies over a long period. One of the basic assumptions in the use of analysis of variance is that the errors of the several variables which comprise the experiment are independently and normally distributed with the same variance. Independence among the observations is necessary to assure unbiased inferences (55).

There are certain types of data which vary in such a way that the assumptions of independence and normality are not fulfilled. These data require special transformations for the application of analysis of variance. Sometimes, the analysis of variance of certain types of data which are expressed in percentages will be more soundly based when an angular, a square-root or a logarithmic transformation is used.

However, the generalization that all data expressed in percentages must be transformed is also not valid. Clark and Leonard (56) reported the following classification of types of percentages:

> "First, continuous data resulting from an experimental study may be expressed as percentages when each variate is divided by an arbitrary constant value, whereby each variate becomes a percentage of some standard or average. Clearly such a procedure merely transforms the unit of measurement. Percentages of this type should be treated statistically exactly as if the data were in their raw form. For example, yield data might be expressed in percentage of the check instead of actual yield in pounds. Second, continuous data are often expressed in percentages to show concentrations because a comparison of concentration is the principal objective of the study. This type of percentage is very common. Some examples are: seed purity given by weight of pure seed/ total weight of seed; leafiness given by leaf weight/ total plant weight; protein content given by weight of protein/ total weight; sugar content given by weight of sugar / weight of root. Such concentrations should not, as a rule, be subjected to any transformation to equalize the variance."

In this work, the data expressed in percentages fall in one of the two kinds of percentages cited above. Thus, no special transformation was applied to the data, which were analyzed in their raw form. Nevertheless, the assumption of equal variance for each of the treatments

was tested by Cochran's statistic. The non-significance of Cochran's ratio in all cases means that no significant difference was found between population variances and , as a consequence, these variances could be treated as being equal. The 5% level of significance was considered satisfactory for the purposes of this investigation.

The following notation appears in the course of presentation of the data, and the meaning is as follows:

s = statistically significant at the 5% level

ns = statistically not-significant at the 5% level

2. Wood characteristics

In this study, various characteristics of young wood of three species of pines were determined. Comparisons were drawn between the properties of these woods and those from other mature woods. The experimental data were statistically analyzed according to the following tests: Cochran's, F and Tukey's tests. The significance of the F ratio means that, with regard to the wood property under examination, at least one of the species has a value

significantly different from the overall population mean for that property, at the 5% level of significance.

Comparison between two treatment means is provided by Tukey's test. When the difference between two sample means exceeds the minimum significant difference (or critical difference), the treatments are different at the predetermined level of significance.

The results of the determination of wood characteristics are given in Tables B-1 to B-22, in Appendix B.

The only four properties found not to be statistically different in all six woods were: cold and hot water solubility, ether solubility and ash content. All other wood properties showed at least one significant difference between means.

The young thinned Brazilian pinewoods showed significantly shorter fibers, lower specific gravity, higher pentosan content and lower cellulose content, when compared to the *Araucaria angustifolia* wood.

Among the young Brazilian pinewoods, the fibers of *Pinus caribaea* turned out to be longer, wider and thicker;

its wood was denser, its alcohol-benzene solubility and cellulose content were lower and its pentosan and lignin content were higher. These properties are well correlated with pulp yield and strength, so that its behavior in producing pulps will probably be different from the other young pinewoods.

Among the Brazilian woods, that from Araucaria angustifolia showed longer and thicker-walled fibers, higher specific gravity and cellulose content and relatively low alcohol-benzene solubility and lignin content.

On the American side, the wood of slash pine had significantly longer and thicker-walled fibers, higher specific gravity, lower pentosan content and somewhat higher cellulose content, when compared to the wood of loblolly pine.

Further considerations on this subject are discussed in a later section along with the results of the evaluation of pulp properties.

3. Pulp properties

As was stated before, this work deals with the study of three species of Brazilian pines, two of American ones and *Araucaria angustifolia*, each pulped to two different intervals of permanganate number. As procedures and instruments used to pulp the wood and test the pulp strength in Brazil differed from those used in the U. S. A., each of the two collected sets of data for pulp properties are separately analyzed.

Permanganate numbers, pulp yields and reject content for all pulps are presented in Tables C-1 to C-14, in Appendix C.

The statistical analyses involve two distinct factorial experiments: one with 4 species and 2 intervals of permanganate number (comprising treatments 1 to 8) and the other with 2 species and two intervals of permanganate number (treatments 9 to 12). All treatments had 5 replications.

The results of the evaluation of all 60 pulps are presented in Appendix D.

3.1. Adjusting pulp properties to a constant handsheet density

The pulp properties studied in this work were compared at the same handsheet density. The pulp property data obtained from beating the pulps to seven different times were plotted against the corresponding sheet density values. The relationship between pulp strength properties and handsheet density was linear. Therefore, it was decided to apply linear regression equations to relate handsheet density to the pulp properties which were being studied. The regression analyses were made with a C.D.C. - 3200 computer with 32 K words of memory, using the BMDO-2R program.

The regression equations were of the form

$$Y = a + b \cdot X$$

where

Y : pulp property (e.g., breaking length, stretch, burst factor or tear factor)

a and b : regression coefficients

X : handsheet density in g/cc

The significance of the linear regression equations

obtained were tested by the F test at the 5% level. When the F ratio exceeded the 5% level of significance, the equation was considered to explain satisfactorily the relationship between the pulp property and handsheet density. As a non-significant regression line could not be effective in predicting the pulp property as a function of handsheet density, a graphical determination was made in those cases. The values which were graphically obtained are identified by an asterisk in the corresponding tables.

In most cases, the equations were shown to account for more than 95% of the variation in the data. This percentage is obtained by squaring the correlation coefficient R and multiplying by 100.

The majority of equations were obtained from 7 points, which gives 5 degrees of freedom (DF) for the residual. However, the tear factor of treatments 9 and 10 did not follow a linear relationship with handsheet density when the value for the unbeaten pulp was included. As the first time of sampling after 0 minutes always gave a density below 0.600 g/cc for these two treatments, 6 points were

used to fit the regression line. This gives 4 degrees of freedom for the residual in the analysis.

A handsheet density of 0.600 g/cc was selected as the basis for comparing the pulp properties. From the regression equations, estimated values at a constant handsheet density of 0.600 g/cc were obtained for breaking length, stretch, burst factor and tear factor.

Although beating time had shown an approximately linear relationship with handsheet density, the estimated values for 0.600 g/cc sheet density were generally higher than the experimental ones. Because of this, the beating time required to achieve a handsheet density of 0.600 g/cc was graphically estimated for all treatments.

The estimated values so obtained were used in the statistical analysis of the pulp properties. The results of the regression analyses which were developed are shown in Appendix E. Estimated pulp properties at a constant handsheet density of 0.600 g/cc for both bleachable and unbleachable grade pulps are presented in Tables F-1 to F-10, in Appendix F.

3.2. Establishment of relationships between wood and pulp properties

Although it was not within the scope of this investigation, further use of the available data was made by computing several correlation matrices. A C.D.C. - 3200 computer with 32 K words of memory was used for obtaining the correlation coefficients between wood and pulp properties.

For wood properties, three distinct sets of data were computerized:

- those obtained from the four Brazilian species (20 observations)
- those obtained from the two American species (10 observations)
- those obtained from all six species together (30 observations)

Thus, three matrices are provided in Appendix J, so the reader may perform his own analysis and reach his own conclusions.

The correlations between pulp properties and wood properties were calculated from 4 sets of data and 4 reduced correlation matrices (i.e., containing only the variables

of interest) are shown in Appendix J. The 4 sets of data which were separately analyzed were:

set a: relating bleachable grade pulp properties to wood properties for the 4 species of Brazilian woods (20 observations)

set b: relating bleachable grade pulp properties to wood properties for the 2 species of American woods (10 observations)

set c: relating unbleachable grade pulp properties to wood properties for the 4 species of Brazilian woods (20 observations)

set d: relating unbleachable grade pulp properties to wood properties for the 2 species of American woods (10 observations)

The pulp strength data which were used in calculating the correlation coefficients were those estimated at a constant handsheet density of 0.600 g/cc.

The notation, which appears below and also in Appendix J, was used in the presentation of the matrices:

Table 7. NOTATION USED IN THE PRESENTATION OF THE MATRICES

FL = unbroken fiber length

FW = fiber width

LD = lumen diameter

CWT = cell wall thickness

SG = unextracted specific gravity

ESG = extracted specific gravity

FC = felting coefficient of the fibers

CF = coefficient of flexibility of the fibers

WF = wall fraction of the fibers

L/C = fiber length/cell wall thickness ratio

RI = Runkel index

MR = Mulsteph ratio

BN = Boiler number

CWS = cold water solubility of the woods

HWS = hot water solubility of the woods

CSS = 1% caustic soda solubility of the woods

ABS = alcohol-benzene solubility of the woods

ES = ether solubility of the woods

PC = pentosans content of the woods

LC = lignin content of the woods

CBC = Cross and Bevan cellulose content of the woods

AC = ash content of the woods

PN = permanganate number of the pulps

TY = total pulp yield (oven-dry wood basis)

SY = screened pulp yield (oven-dry wood basis)

RC = rejects content (oven-dry wood basis)

Table 7--Continued

ETY = total pulp yield (oven-dry extractive-free wood basis)

ESY = screened pulp yield (oven-dry extractive-free wood basis)

ERC = reject content (oven-dry extractive-free wood basis)

BT = estimated beating time to achieve 0.600 g/cc sheet density

BL = estimated breaking length at a constant sheet density of 0.600 g/cc

S = estimated stretch at a constant sheet density of 0.600 g/cc

BF = estimated burst factor at a constant sheet density of 0.600 g/cc

TF = estimated tear factor at a constant sheet density of 0.600 g/cc

By consulting the matrices, the reader is able to find the relationship between each pair of properties which were studied. Thus, to answer the question as to how two different variables are related, the reader should choose the pertinent matrix and look for the position where the row that represents one particular variable intersects the column that represents the other. The value which is found

will indicate the correlation coefficient between these two properties, with a linear relationship assumed to hold between them. A negative number means a reverse relationship between the variables. To obtain the percentage of the variation of one variable which is accounted for by the other, the coefficient must be squared and multiplied by 100. Example: For the Brazilian woods (see Table J-2, in Appendix J), the unextracted specific gravity had a correlation coefficient of 0.50 with cell wall thickness. This means that there is a positive proportionality between these two variables and that the unextracted specific gravity is dependent to the extent of 25% upon the cell wall thickness of the wood fibers, in this particular situation. As correlation coefficients higher than 0.444 are significant at the 5% level, the influence of cell wall thickness on unextracted specific gravity was reported as statistically significant.

3.3. Statistical analyses of the pulp properties

Statistical analyses were performed separately on the data collected from Brazilian and American woods. The

influences of species and permanganate number on the pulp properties were tested in both cases. This simultaneous investigation was made possible by the use of factorial experiment designs. Factorial experiments also involve an important concept known as interactions. In this work, the relationship between species and permanganate number was studied. The presence of interaction between these two variables means that the species do have a different behavior in the two intervals of permanganate regarding the pulp property under examination.

3.3.1. Pulps obtained from the Brazilian woods

The experimental project followed a factorial design 4 × 2 for species and permanganate number.

Total and screened yields, beating time, breaking length, stretch, burst factor and tear factor were the pulp properties subjected to statistical analyses. Statistical analyses were not performed on the data obtained for reject content due to their excessive variation. However, a table displaying averages for species and intervals of permanganate number is provided in Appendix I.

The influence of each variable of the factorial experiment can be observed by the analysis of the tables provided in Appendix G.

3.3.2. Pulps obtained from the American woods

The experimental project followed a factorial design 2^2 for species and intervals of permanganate number. The same procedure as 3.3.1. was followed for these analyses.

The tables in Appendix H show the influence of the variables under consideration on the pulp properties.

The conclusions which were drawn in this work are not to be construed as generalized results for the investigated species under all pulping conditions or in all environments. They are valid specifically only for the materials which were studied in this research. Therefore, they may be considered rough estimates of the pulping characteristics of these species as grown in the areas from

which they were sampled. It should also be realized that if comparisons of pulp strength properties were made on the basis of another handsheet density, the conclusions could be altered to some extent.

4. Influence of species

4.1. Pulp yields

The two wood properties that have the greatest influence on pulp yield are specific gravity and cellulose content (57). There is evidence that pulps of higher yield are obtained from wood of higher specific gravity and cellulose content. Lignin content is also closely related to pulp yield. Extractives have only a minor effect on yield (57). Therefore, a higher extractive content is sometimes desirable to produce a substantial increase in the quantity of valuable by-products such as tall oil and turpentine.

4.1.1. Pulps obtained from the Brazilian woods

Araucaria angustifolia showed higher pulp yields either on oven-dry wood and extractive-free oven-dry wood bases. This outcome may be explained by the higher specific

gravity and cellulose content and the somewhat lower lignin content of its wood. Since it indirectly affects the specific gravity, the cell wall thickness of the fibers probably also contributed to these high yields. According to Byrd et al. (48), the Runkel index has a positive correlation with pulp yield. The significantly higher Runkel index for the fibers of Araucaria angustifolia may also explain its higher pulp yields.

When the yields of pulps obtained from the young thinned pinewoods were compared by Tukey's test, no significant differences were found among them. As a result, these differences are reported as due to experimental error. This is an important consideration if one has in mind that economics is the principal limitation in the use of this kind of wood. These woods do produce a pulp with lower yield than Araucaria angustifolia even excluding the effect of extractives, but they do not differ in yield among themselves.

4.1.2. Pulps obtained from the American woods

A very significant effect of species was observed in this case. Woods from slash pine always produced pulps with higher yields than those from loblolly pine. This also can be attributed to the higher specific gravity, cellulose content and Runkel index of the slash pine fibers.

4.2. Reject content

The wood properties reported as influencing strongly the reject content of the corresponding pulps are (49): chip moisture content (-)* and specific gravity (+). There is some indication that the coefficient of flexibility has also influence on reject content (49), but this evidence is not clear. It is assumed that this ratio would be a measure, perhaps, of the efficiency of liquor penetration into the chips. Extractive content has only a slight effect on reject content. (49).

4.2.1. Pulps obtained from the Brazilian woods

Araucaria angustifolia, *Pinus elliottii* and *Pinus taeda* gave pulps with approximately equal reject content.

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*The sign conventions are used in the following sense: (+) positive correlation; (-) negative correlation.

However, *Pinus caribaea* showed a high value for this property. The exact reason for this is not evident. The higher lignin content of its wood, perhaps reflecting a high percentage of compression wood is a possible explanation.

4.2.2. Pulps obtained from the American woods

The influence of species is also evident here. Loblolly pine was consistently reported to give pulps with higher reject content at the same permanganate number.

4.3. *Beating time*

This property is not easily explained in terms of wood characteristics. The properties commonly referred to as having influence on beating time are: moisture content of chips (+), specific gravity (-) and cell wall thickness (-) (49); fiber length (+), lumen diameter (+), compression wood content (+) and Runkel index (-) (58), and felting coefficient (-) (59).

4.3.1. Pulps obtained from the Brazilian woods

The influence of species was reported as significant on the basis of the analysis of variance. When the contrasts

between means were tested by Tukey's test, the pulp from *Araucaria angustifolia* and *Pinus caribaea* were shown to require longer beating time than the pulps from the other two species to achieve the specified handsheet density. *Pinus elliotti* and *Pinus taeda* gave pulps which were more easily beaten, so that they would require less power during the beating operation. The difficulty of beating *Araucaria angustifolia* pulps is a well known characteristic (30).

Based on the wood characteristics data, the proper explanation of these results is not clear. It is believed that the high compression wood possessed by the wood of *Araucaria angustifolia* is the principal reason for the long beating time. Fiber length is another property that could be responsible for this characteristic. *Pinus caribaea*, probably because of its high lumen diameter and lignin content and somewhat low Runkel index, showed the same property as *Araucaria angustifolia*.

4.3.2. Pulps obtained from the American woods

Slash pine pulps were shown to require significantly longer beating time than loblolly pine pulps. Here again,

the effects of each individual wood characteristic are not clear. One might assume that the higher Runkel index and fiber length would be the reason for this behavior. Otherwise, beating time seems to be affected by other wood characteristics in a more complex pattern.

4.4. Breaking length

Breaking length is one of the more important and frequently studied paper properties. Its relationship with wood characteristics has been largely investigated and major effects have been shown to be connected with the following variables: cell wall thickness (-), coefficient of flexibility (+), summerwood percentage (-) and specific gravity (-) (49); lumen diameter (+) and Runkel index (-) (48); fiber length/cell wall thickness ratio (+) (46); and Mulsteph ratio (-) (50).

4.4.1. Pulps obtained from the Brazilian woods

Among the pulps obtained from the Brazilian woods, *Pinus caribaea* was shown to produce pulps with significantly higher breaking length than the others. No statistically

significant differences were observed for the other three species. Regarding this property, Pinus elliottii and Pinus taeda showed very similar results and Araucaria angustifolia had the lower value. The comparatively high result for Pinus caribaea could be explained by its high lumen diameter, coefficient of flexibility and fiber length/ cell wall thickness ratio, and furthermore by its low Runkel index and Mulsteph ratio. The low result for the longer-fibered species Araucaria angustifolia may be a consequence of its thicker-walled fibers, high specific gravity and high Mulsteph ratio and Runkel index.

4.4.2. Pulps obtained from the American woods

The pulps obtained from the wood of slash pine showed significantly higher breaking length than those from loblolly pine. In this case, the results which were obtained could not be satisfactorily explained by the characteristics of the woods.

4.5. Stretch

Very little information is found in the literature about the causes of variation in stretch. It is a property

highly dependent on the handsheet making procedure, because fibers have the ability to shrink during drying. Bawagan (50) reported the influence of the following factors on stretch: fiber length (+), curling of fibers (+), micellar angle (+) and coefficient of flexibility (+).

4.5.1. Pulps obtained from the Brazilian woods

All four species were reported to be different one from another, as far as stretch was concerned. They were ranked as follows: *Pinus taeda*, *Pinus elliottii*, *Pinus caribaea* and *Araucaria angustifolia*. This reflects a negative effect from fiber length instead of a direct proportionality as claimed by Bawagan (50). Also, the coefficient of flexibility was of no help in explaining the results.

4.5.2. Pulps obtained from the American woods

Here also, the longer-fibered species gave pulps with lower stretch. Slash pine pulps were significantly poorer than those from loblolly pine when stretch was the property under investigation.

4.6. Burst factor

The following wood properties are considered to affect burst strength: cell wall thickness (-) and fiber length (+) (49); specific gravity (-) and summerwood content (+) (60); lumen diameter (+), Runkel index (-) and coefficient of flexibility (+) (58); and fiber length/cell wall thickness ratio (+) (46). The effect of fiber length is not consistent. Barefoot et al. (58) reported a negative correlation between burst strength and fiber length.

4.6.1. Pulps obtained from the Brazilian woods

Araucaria angustifolia gave pulps with significantly lower burst factor than each of the other three species studied, but no significant differences were found among the young pinewood pulps. The same trend was also found for breaking length, although statistically only *Pinus caribaea* had significantly higher tensile strength. This outcome agrees with the findings of Kirk et al. (16), who reported high burst and tensile strengths for juvenile wood pulps, as a consequence of the better fiber bonding achieved with the flexible young fibers. The low burst

strength found for the pulps of Araucaria angustifolia is probably an effect of its thick-walled fibers, high specific gravity, Runkel index and fiber length/cell wall thickness ratio and low coefficient of flexibility.

4.6.2. Pulps obtained from the American woods

Slash pine pulps were shown to be superior to those from loblolly pine in terms of burst strength. Similarly to the case with breaking length, the results for burst factor could not be satisfactorily explained in terms of wood characteristics.

4.7. Tear factor

The importance of this property to pulp evaluation studies has caused it to be a very highly investigated parameter. Several wood characteristics are considered to affect tear strength: specific gravity (+), percent of summerwood fibers (+), cell wall thickness (+), Runkel index (+) and fiber length (+) (58); and lumen diameter (-) (48). Fiber flexibility has also been shown to be desirable, particularly when combined with thick cell walls and long fibers (58).

4.7.1. Pulps obtained from the Brazilian woods

Araucaria angustifolia gave pulps with the highest tear factor, which can be easily explained by the above cited wood characteristics. *Pinus elliottii* showed the poorest pulps and *Pinus caribaea* and *Pinus taeda* did not differ on the basis of this property. The very low specific gravity of the wood of *Pinus elliottii*, reflecting its immature wood fibers, was probably the main reason for this low result.

4.7.2. Pulps obtained from the American woods

Although the contrast of means for tear factor between slash and loblolly pine pulps did not seem too great, it was shown to be significant at the 5% level. Loblolly pine produced pulps with higher tear factor than slash pine. The same species growing in Brazil (*Pinus taeda*) also gave pulps with relatively high tear factor--greater than that from *Pinus elliottii*. The finding of good tear strength for *Pinus taeda* pulps agrees with the results of a mill trial carried out by Svinakevicius (30) in Brazil.

5. Influence of permanganate number

The influence of the lignin present in pulps, expressed as lignin content or as some other measurement used for control purposes, is well known to affect the pulp properties. However, the relationship between each pulp property and the quantity of lignin is not well defined. Generally, it is accepted that the strength of the unbleached pulp decreases by increasing its lignin content (61,62). However, each kind of pulp has its own pattern of relationships between strength properties and lignin content, because of the many factors which are involved in the expression of this relationship. Some pulps show a slight increase in some strength properties with an increase in lignin content. Eventually, when the lignin contained in the pulp reaches a limiting point, the strength starts to drop rapidly (63). Pulp yields are the only properties concerning which most investigators tend to be in agreement. Total yield has a linear relationship either with Kappa number (64) or permanganate number (65,66). Screened yield increases up to a maximum and then starts

to drop because of the rapid increase in reject content of the pulps (66,67).

5.1. Pulps obtained from the Brazilian woods

Both total and screened yields exhibited a significant increase with an increasing permanganate number, either on the oven-dry wood basis or on the oven-dry extractive-free basis. As far as reject contents are concerned, it was also found that their values increased when the permanganate number rose.

The results of the pulping evaluation and statistcal analyses showed that, when comparisons were made at a constant handsheet density of 0.600 g/cc, the permanganate number had a positive influence on beating time, breaking length and burst factor and a negative influence on tear factor. Despite the variation in stretch, the analysis of variance did not show it to be significant.

5.2. Pulps obtained from the American woods

The effect of permanganate number was found to be positive as it applied to pulp yields, reject content,

beating time, stretch and burst factor. A negative effect was reported for tear factor. The non-significant effect for breaking length was accounted for by a complete reversal interaction between species and K Number. At the same time, the breaking length increased with permanganate number for the pulps from loblolly pine, and decreased for the pulps made from slash pine.

6. Interactions between species and K Number

Interactions may be described as differential responses. The significance of the mean square for interaction in the analysis of variance would indicate whether or not the species behaved in a similar manner at each interval or K Number. If the effect of interaction is reported as significant, two kinds of differential responses might provide an explanation: complete reversal interaction--in this case, the results for the property under investigation increase for one species from the lower to the higher interval of K Number and decrease for another; change-in-rate interaction--in this case, the rate of increase (or decrease) in a particular property due to K Number is greater for one species

than for another.

6.1. Pulps obtained from the Brazilian woods

Significant effects of interaction were found for total yield (percent of oven-dry wood), beating time and breaking length. Tables C-3 and C-4 (Appendix C), F-1 and F-2, and F-3 and F-4 (Appendix F), indicate the differential behavior of the species in each interval of permanganate number. It can be seen that the species are ranked differently for each grade of pulp.

Removal of the effect of wood extractives on total pulp yield reduced the mean square for interaction and eliminated the differential behavior of the species.

6.2. Pulps obtained from the American woods

Significant effects of interaction were found for screened yield (percent of oven-dry wood), breaking length and burst factor. Likewise, by expressing screened yield on an extractive-free wood basis the differential response of the species was eliminated.

SUMMARY AND CONCLUSIONS

The purpose of this work was to compare wood characteristics and properties of the pulps obtained from several wood species, four of them growing in Brazil and two in the U. S. A. The four Brazilian pulpwoods, namely *Araucaria angustifolia*, *Pinus elliottii* var. *elliottii*, *Pinus taeda* and *Pinus caribaea* var. *hondurensis* , were sampled, analyzed, pulped and tested in that country. The two American pulpwoods, *Pinus elliottii* var. *elliottii* (slash pine) and *Pinus taeda* (loblolly pine) were studied in the U. S. A. Fiber measurements, chemical analyses and specific gravity determinations were performed on all samples. The three species of the genus *Pinus* from Brazil were young thinned woods and had a large juvenile wood component.

The woods were pulped by the kraft process to two different intervals of permanganate number: 16 to 18 and 25 to 30. The objective was to compare pulps of equivalent lignin contents in each interval.

The young Brazilian pinewoods were characterized by short fibers, low specific gravity and cellulose content, and high pentosan content. *Araucaria angustifolia* turned out to have long and thick-walled fibers, high specific gravity and cellulose content, and somewhat low alcohol-benzene solubility and lignin content. The wood of the American slash pine had longer and thicker-walled fibers, higher specific gravity and lower pentosan content when compared to the wood of loblolly pine.

The pulps obtained from *Araucaria angustifolia* showed high tear strength but low burst and tensile strength. However, the young Brazilian pinewoods produced pulps with relatively high tensile and burst strength. Tear strength was low for *Pinus elliottii* and *Pinus caribaea* but high for *Pinus taeda*. *Pinus caribaea* pulps had high breaking length and burst factor and required a longer beating time to achieve a given handsheet density. The same trend regarding beating time was observed for *Araucaria angustifolia* pulps. Shorter-fibered species produced pulps with higher percentage stretch.

The main objection to the use of the pulps obtained from the young thinned Brazilian woods was the low pulp yield. This important feature leads to an economic problem in using these woods for manufacturing some grades of paper. However, this work demonstrates that kraft pulps from these woods have acceptable strength properties. If wood shortages become more severe, they may be used.

The two American southern pine species which were studied gave very strong pulps, but low yields. Comparing the two species, slash pine pulps had higher yields, breaking lengths and burst factors, while loblolly pine pulps showed higher tear strength and stretch and were more easily refined.

The effect of K Number on pulp properties and interaction between species and K Number were also successfully isolated and analyzed. For all species, pulp yields, beating time and burst factor increased significantly as a consequence of the increase in the K Number in the ranges which were studied, but the tear factor decreased. Among the Brazilian raw materials, significant effects of interaction between species and K Number were found for total

yield (percent of oven-dry wood), beating time and breaking length. For the American woods, these effects were reported for screened yield (percent of oven-dry wood), breaking length and burst factor.

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APPENDIX A

PROPERTIES OF THE WOODS STUDIED AS REPORTED BY VARIOUS INVESTIGATORS

Table A-1 COMPARISON OF WOOD PROPERTIES OF YOUNG TREES, TOPWOOD AND MATURE WOOD OF LOBLOLLY PINE, ACCORDING TO ZOBEL (17)

Wood Property	11-Year-Old Trees	Mature Trees (topwood only)	Mature Trees (merchantable wood, juvenile wood excluded)
Specific gravity	0.42	0.41	0.48
Tracheid length (mm.)	2.98	3.59	4.28
Cell wall thickness (μ)	3.88	6.72	8.04
Cell diameter (μ)	50.01	45.91	48.86

Table A-2. SPECIFIC GRAVITY AND EXTRACTIVE CONTENT FOR JUVENILE AND MATURE WOOD OF LOBLOLLY PINE, ACCORDING TO GILMORE AND PEARSON (18)

Height of Tree Above Ground Where Sample Was Taken (ft.)	Average Specific Gravity				Extractives (%)	
	J	M	J	M	J	M
5	.490	.551	.434	.540	12.8	2.0
15	.437	.463	.417	.462	4.6	2.2
25	.526	.500	.462	.486	13.8	2.7

J = juvenile wood

M = mature wood

Table A-3. CHEMICAL ANALYSES OF THE WOOD OF 8-YEAR-OLD *Pinus elliottii* GROWING IN BRAZIL, ACCORDING TO REDKO AND GUIMARAES (19)

Constituent	Just-harvested Wood (%)	6-Month Stored Chips (%)
Cross & Bevan Cellulose content	55.5	58.1
Lignin content	26.6	28.5
Pentosan content	7.1	8.3
Ash content	0.3	-
Solubility in		
1% NaOH	16.9	11.4
Cold water	1.8	1.2
Hot water	3.8	3.4
Alcohol-benzene	6.7	2.6

Table A-4. PROPERTIES OF SOUTHERN PINE PULPWOOD ACCORDING TO KLEPPE (20)

Properties	Range	Most Frequent Range
Specific gravity	0.38-0.75	0.42-0.55
Lignin content (%)	24-30	26-29
Extractive content (%)	2-10	2.5 - 4.5
Fiber length (mm)	2.0 - 5.5	2.5 - 4.5

Table A-5. PROPERTIES OF THE TROPICAL WOOD OF *Pinus caribaea* FROM VENEZUELA, ACCORDING TO FAIREST (21)

Properties	Age of the Wood			
	5 Years	10 Years	14 Years	17 Years
Fiber length (mm)	2.54	3.12	3.69	4.12
Fiber width (μ)	38.1	48.2	49.3	37.4
Lumen diameter (μ)	25.5	37.2	34.2	25.4
Cell wall thickness (μ)	6.3	5.5	7.5	7.5
Cellulose content (%)	48.5	49.0	51.2	51.9
Extractive content (%)	3.11	2.84	2.95	2.50
Ash content (%)	0.28	0.46	0.34	0.31

Table A-6. CHEMICAL COMPOSITION OF THE WOOD OF LOBLOLLY PINE

Properties	Authors		
	Curran and Bray (22)	Curran and Bray (23)	Uprichard (24)
	(%)	(%)	(%)
Solubility in			
- Hot water	3.3	3.4	-
- 1% NaOH	14.7	14.8	-
- Alcohol-benzene	-	2.7	-
- Ether	1.3	-	-
Cellulose content (%)	60.4	60.1	-
Lignin content (%)	30.2	32.0	29.5
Pentosans (%)	12.1	12.3	10.8
Alpha-cellulose (%)	44.7	-	50.2

Table A-7. CHEMICAL COMPOSITION OF THE WOOD OF SLASH PINE

Properties	Authors	
	McGovern *et al.* (25) (%)	Young (26) (%)
Holocellulose content	62.8	-
Alpha-cellulose	48.5	-
Lignin content	27.6	26.1
Pentosan content	8.4	13.2
Solubility in		
- alcohol-benzene	2.6	3.9
- ether	2.4	2.8
- 1% NaOH	12.7	-
- hot water	2.7	5.0
Ash content	0.3	-

Table A-8. CHEMICAL COMPOSITION OF PARANA PINE WOOD

Properties	Authors		
	Rys *et al.* (34)		Redko and Guimaraes (19)
	Sapwood (%)	Heartwood (%)	(%)
Solubility in			
- water	1.2	0.8	2.5
- ether	1.8	0.4	-
- alcohol-benzene	2.6	2.1	0.9
- 1% NaOH	10.2	11.6	10.6
Ash content	0.4	1.4	0.3
Lignin content	29.1	31.7	28.5
Pentosan content	4.8	4.2	6.1
Cross & Bevan cellulose content	65.5	62.5	58.3

APPENDIX B

CHARACTERISTICS OF THE PULPWOODS

Table B-1. UNBROKEN FIBER LENGTH OF THE PULPWOODS (mm.)

Species	replication 1	2	3	4	5	Mean	Confidence Interval (95%)
A. angustifolia	5.68	5.37	4.79	4.90	5.03	5.15	± 0.45
P. elliottii	3.12	2.68	3.45	3.19	3.26	3.14	± 0.35
P. taeda	2.81	2.72	2.69	2.97	2.70	2.78	± 0.15
P. caribaea	3.79	3.66	3.54	3.68	3.37	3.61	± 0.20
"Slash pine"	3.40	3.65	3.49	3.27	3.48	3.46	± 0.17
"Loblolly pine"	2.92	2.79	2.88	2.92	2.84	2.87	± 0.07

Cochran's ratio: 0.4800^{ns}

F ratio: 82.4^{s}

Minimum significant difference (Tukey's test): 0.42

Coefficient of variation: 6.1%

Table B-2. FIBER WIDTH OF THE PULPWOODS (μ)

Species	replication 1	2	3	4	5	Mean	Confidence Interval (95%)
A. angustifolia	53.80	45.20	45.45	45.40	45.70	47.11	± 4.64
P. elliottii	48.05	44.35	46.80	44.85	42.50	45.31	± 2.68
P. taeda	44.65	41.95	42.65	44.65	45.15	43.81	± 1.75
P. caribaea	56.25	52.32	55.07	55.00	50.35	53.80	± 2.98
"Slash pine"	49.49	49.33	46.04	51.92	46.74	48.70	± 2.93
"Loblolly pine"	45.53	43.76	44.39	45.25	49.88	46.16	± 3.13

Cochran's ratio: 0.3647^{ns}

F ratio: 9.9^{s}

Minimum significant difference (Tukey's test): 4.91

Coefficient of variation: 5.3%

Table B-3. LUMEN DIAMETER OF THE PULPWOOD FIBERS (μ)

Species	replication 1	2	3	4	5	Mean	Confidence Interval (95%)
A. angustifolia	37.65	31.29	34.95	33.30	33.90	34.22	± 2.90
P. elliottii	37.00	34.95	36.00	36.65	30.80	34.88	± 2.97
P. taeda	35.45	33.55	33.60	34.50	34.30	34.28	± 0.96
P. caribaea	45.25	42.32	45.57	45.35	39.50	43.60	± 3.29
"Slash pine"	34.27	36.00	32.39	40.00	32.18	34.96	± 3.98
"Loblolly pine"	35.37	35.30	36.31	32.47	39.92	35.87	± 3.32

Cochran's ratio: 0.2840^{ns}

F ratio: 10.8^{s}

Minimum significant difference (Tukey's test): 4.81

Coefficient of variation: 6.8%

Table B-4. CELL WALL THICKNESS OF THE PULPWOOD FIBERS (μ)

Species	replication 1	2	3	4	5	Mean	Confidence Interval (95%)
A. angustifolia	8.07	6.95	5.25	6.05	5.90	6.44	± 1.35
P. elliottii	5.52	4.70	5.40	5.60	5.85	5.41	± 0.53
P. taeda	4.60	4.20	4.52	5.07	5.42	4.96	± 0.60
P. caribaea	5.50	5.00	4.75	4.82	5.41	5.10	± 0.42
"Slash pine"	7.61	6.66	6.82	5.96	7.29	6.87	± 0.78
"Loblolly pine"	6.08	4.23	4.04	6.39	4.98	5.14	± 1.32

Cochran's ratio: 0.3667^{ns}

F ratio: 6.6^{s}

Minimum significant difference (Tukey's test): 1.43

Coefficient of variation: 13.0%

Table B-5. UNEXTRACTED SPECIFIC GRAVITY OF THE PULPWOODS

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	0.405	0.423	0.405	0.440	0.429	0.420	± 0.019
P. elliottii	0.307	0.324	0.322	0.309	0.320	0.316	± 0.009
P. taeda	0.350	0.352	0.344	0.352	0.338	0.347	± 0.007
P. caribaea	0.343	0.349	0.361	0.342	0.370	0.353	± 0.015
"Slash pine"	0.490	0.478	0.478	0.490	0.495	0.482	± 0.009
"Loblolly pine"	0.421	0.417	0.419	0.421	0.416	0.419	± 0.004

Cochran's ratio: 0.4528^{ns}

F ratio: 213.3^{s}

Minimum significant difference (Tukey's test): 0.019

Coefficient of variation: 2.5%

Table B-6. EXTRACTED SPECIFIC GRAVITY OF THE PULPWOODS

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	0.393	0.415	0.396	0.428	0.423	0.411	± 0.020
P. elliottii	0.300	0.313	0.311	0.300	0.312	0.307	± 0.008
P. taeda	0.341	0.345	0.337	0.343	0.333	0.340	± 0.006
P. caribaea	0.338	0.343	0.357	0.336	0.360	0.347	± 0.014
"Slash pine"	0.457	0.461	0.455	0.475	0.469	0.463	± 0.010
"Loblolly pine"	0.400	0.402	0.402	0.397	0.392	0.399	± 0.005

Cochran's ratio: 0.4735^{ns}

F ratio: 184.7^{s}

Minimum significant difference (Tukey's test): 0.018

Coefficient of variation: 2.5%

Table B-7. FELTING COEFFICIENT OF THE PULPWOOD FIBERS

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	106	119	105	108	110	109	± 7
P. elliottii	65	60	74	71	77	69	± 8
P. taeda	63	65	63	66	60	63	± 3
P. caribaea	67	70	64	67	67	67	± 3
"Slash pine"	69	74	76	63	74	71	± 6
"Loblolly pine"	61	64	65	64	57	62	± 4

Cochran's ratio: 0.3730^{ns}

F ratio: 75.7^{s}

Minimum significant difference (Tukey's test): 9

Coefficient of variation: 6.2%

Table B-8. COEFFICIENT OF FLEXIBILITY OF THE PULPWOOD FIBERS (%)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	70	69	77	73	74	73	± 4
P. elliottii	77	79	77	79	72	77	± 4
P. taeda	79	80	79	77	76	78	± 2
P. caribaea	80	81	83	82	78	81	± 2
"Slash pine"	69	73	70	77	69	72	± 4
"Loblolly pine"	74	81	82	72	80	78	± 6

Cochran's ratio: 0.3550^{ns}

F ratio: 6.6^{s}

Minimum significant difference (Tukey's test): 6

Coefficient of variation: 4.0%

Table B-9. WALL FRACTION OF THE PULPWOOD FIBERS (%)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	30	31	23	27	26	27	± 4
P. elliottii	23	21	23	25	27	24	± 3
P. taeda	21	20	21	23	24	22	± 2
P. caribaea	20	19	17	18	21	19	± 2
"Slash pine"	31	27	30	23	31	28	± 4
"Loblolly pine"	26	19	18	28	20	22	± 6

Cochran's ratio: 0.3833^{ns}

F ratio: 7.3^{s}

Minimum significant difference (Tukey's test): 6

Coefficient of variation: 12.4%

Table B-10. LENGTH/CELL WALL THICKNESS RATIO OF THE PULPWOOD FIBERS

Species	replication					Mean	Confidence Interval(95%)
	1	2	3	4	5		
A. angustifolia	704	772	912	810	852	810	± 98
P. elliottii	565	570	639	569	557	580	± 41
P. taeda	611	648	595	586	498	588	± 69
P. caribaea	689	732	745	763	623	710	± 69
"Slash pine"	447	548	512	549	477	507	± 55
"Loblolly pine"	480	659	713	457	570	576	± 137

Cochran's ratio: 0.4415^{ns}

F ratio: 13.2^{s}

Minimum significant difference (Tukey's test): 133

Coefficient of variation: 10.8%

Table B-11. RUNKEL INDEX OF THE PULPWOOD FIBERS

Species	replication 1	2	3	4	5	Mean	Confidence Interval (95%)
A. angustifolia	0.429	0.444	0.300	0.363	0.348	0.376	± 0.074
P. elliottii	0.298	0.268	0.300	0.314	0.379	0.310	± 0.051
P. taeda	0.259	0.250	0.269	0.293	0.316	0.289	± 0.033
P. caribaea	0.243	0.236	0.208	0.213	0.274	0.234	± 0.033
"Slash pine"	0.444	0.370	0.421	0.298	0.453	0.397	± 0.080
"Loblolly pine"	0.344	0.240	0.222	0.394	0.250	0.290	± 0.093

Cochran's ratio: 0.3429^{ns}

F ratio: 7.0^{s}

Minimum significant difference (Tukey's test): 0.102

Coefficient of variation: 16.6%

Table B-12. MULSTEPH RATIO OF THE PULPWOOD FIBERS.

Species	replication 1	2	3	4	5	Mean	Confidence Interval (95%)
A. angustifolia	0.510	0.521	0.409	0.462	0.450	0.470	± 0.057
P. elliottii	0.407	0.406	0.408	0.368	0.475	0.413	± 0.048
P. taeda	0.370	0.360	0.379	0.403	0.423	0.387	± 0.032
P. caribaea	0.353	0.346	0.315	0.320	0.384	0.344	± 0.034
"Slash pine"	0.520	0.467	0.505	0.406	0.526	0.485	± 0.063
"Loblolly pine"	0.396	0.349	0.331	0.485	0.359	0.384	± 0.076

Cochran's ratio: 0.3339^{ns}

F ratio: 7.9^{s}

Minimum significant difference (Tukey's test): 0.085

Coefficient of variation: 10.5%

Table B-13. BOILER NUMBER OF THE PULPWOOD FIBERS.

Species	replication 1	2	3	4	5	Mean	Confidence Interval (95%)
A. angustifolia	0.342	0.352	0.257	0.300	0.290	0.308	±0.048
P. elliottii	0.256	0.234	0.256	0.226	0.311	0.257	±0.041
P. taeda	0.227	0.220	0.234	0.252	0.268	0.240	±0.024
P. caribaea	0.214	0.209	0.187	0.190	0.238	0.208	±0.026
"Slash pine"	0.352	0.305	0.338	0.256	0.357	0.322	±0.052
"Loblolly pine"	0.247	0.212	0.198	0.320	0.219	0.239	±0.060

Cochran's ratio: 0.3122^{ns}

F ratio: 7.7^{s}

Minimum significant difference (Tukey's test): 0.069

Coefficient of variation: 13.5%

Table B-14. COLD WATER SOLUBILITY OF THE PULPWOODS (%)

Species	replication 1	2	3	4	5	Mean	Confidence Interval (95%)
A. angustifolia	2.0	0.9	1.2	2.0	0.9	1.4	±0.7
P. elliottii	1.1	1.3	1.4	1.1	2.4	1.5	±0.7
P. taeda	2.3	1.6	1.3	2.1	1.6	1.8	±0.5
P. caribaea	0.8	1.6	0.7	1.9	1.4	1.3	±0.6
"Slash pine"	0.9	1.7	1.3	1.1	1.5	1.3	±0.4
"Loblolly pine"	1.8	1.0	1.6	1.0	2.1	1.5	±0.6

Cochran's ratio: 0.2279^{ns}

F ratio: 0.7^{ns}

Minimum significant difference (Tukey's test): 0.9

Coefficient of variation: 34.4%

Table B-15. HOT WATER SOLUBILITY OF THE PULPWOODS (%)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	3.5	1.4	1.9	2.1	1.3	2.0	±1.1
P. elliottii	1.8	3.2	2.4	1.2	3.0	2.3	±1.0
P. taeda	3.8	1.8	2.4	2.6	2.8	2.7	±0.9
P. caribaea	2.8	3.0	2.6	3.0	3.2	2.9	±0.3
"Slash pine"	1.2	3.0	1.5	1.4	1.9	1.8	±0.9
"Loblolly pine"	3.0	1.3	1.7	1.5	3.0	2.1	±1.0

Cochran's ratio: 0.2384^{ns}

F ratio: 1.6^{ns}

Minimum significant difference (Tukey's test): 1.4

Coefficient of variation: 32.1%

Table B-16. ONE PERCENT CAUSTIC SODA SOLUBILITY OF THE PULPWOODS (%)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	7.2	8.3	7.0	7.3	6.6	7.3	±0.8
P. elliottii	6.0	8.1	8.4	6.4	6.5	7.1	±1.4
P. taeda	7.4	7.9	7.9	9.2	7.7	8.0	±0.9
P. caribaea	9.8	9.9	14.0	8.6	12.9	11.0	±2.8
"Slash pine"	9.4	11.7	8.1	8.7	11.4	9.9	±2.0
"Loblolly pine"	11.4	10.4	10.1	9.6	12.4	10.8	±1.4

Cochran's ratio: 0.4703^{ns}

F ratio: 8.4^{s}

Minimum significant difference (Tukey's test): 2.7

Coefficient of variation: 15.2%

Table B-17. ALCOHOL-BENZENE SOLUBILITY OF THE PULPWOODS (%)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	3.0	1.8	2.2	2.7	1.5	2.2	±0.8
P. elliottii	2.4	3.5	3.3	2.8	2.6	2.9	±0.6
P. taeda	2.6	1.9	2.0	2.6	1.4	2.1	±0.6
P. caribaea	1.4	1.7	1.1	1.9	2.6	1.7	±0.7
"Slash pine"	6.4	3.5	4.8	3.0	5.3	4.6	±1.7
"Loblolly pine"	5.0	3.6	4.1	5.6	5.8	4.8	±1.2

Cochran's ratio: 0.4748^{ns}

F ratio: 13.3^{s}

Minimum significant difference (Tukey's test): 1.6

Coefficient of variation: 26.2%

Table B-18. ETHER SOLUBILITY OF THE PULPWOODS (%)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	2.5	0.9	1.4	2.5	1.0	1.7	±1.0
P. elliottii	1.1	3.1	2.5	1.5	2.3	2.1	±1.0
P. taeda	1.1	0.7	0.9	2.0	0.9	1.1	±0.6
P. caribaea	0.7	1.3	0.9	1.7	2.4	1.4	±0.8
"Slash pine"	2.5	1.8	2.0	2.3	1.9	2.1	±0.4
"Loblolly pine"	2.4	1.6	2.9	2.8	2.2	2.4	±0.6

Cochran's ratio: 0.2733^{ns}

F ratio: 1.8^{ns}

Minimum significant difference (Tukey's test): 1.6

Coefficient of variation: 44.8%

Table B-19. PENTOSAN CONTENT OF THE PULPWOODS (%)

Species	replication 1	2	3	4	5	Mean	Confidence Interval (95%)
A. angustifolia	7.2	7.3	7.6	7.6	7.4	7.2	±0.7
P. elliottii	7.8	9.9	9.7	9.7	8.8	9.2	±1.1
P. taeda	10.8	10.3	10.4	10.7	9.9	10.4	±0.4
P. caribaea	9.1	9.4	8.8	9.2	8.2	8.9	±0.6
"Slash pine"	11.4	10.8	11.5	10.9	11.7	11.3	±0.5
"Loblolly pine"	12.0	12.6	13.0	12.3	12.5	12.5	±0.5

Cochran's ratio: 0.4560^{ns}

F ratio: 61.3^{s}

Minimum significant difference (Tukey's test): 1.0

Coefficient of variation: 5.4%

Table B-20. LIGNIN CONTENT OF THE PULPWOODS (%)

Species	replication 1	2	3	4	5	Mean	Confidence Interval (95%)
A. angustifolia	28.0	30.4	30.0	28.9	29.4	29.3	±1.2
P. elliottii	28.2	30.2	30.1	30.5	29.8	29.8	±1.1
P. taeda	27.5	28.8	29.9	28.8	28.9	28.8	±1.0
P. caribaea	29.8	31.4	31.4	30.7	30.6	30.8	±0.8
"Slash pine"	27.0	27.8	26.6	27.5	27.0	27.2	±0.6
"Loblolly pine"	27.5	27.9	28.1	28.6	27.2	27.9	±0.7

Cochran's ratio: 0.2618^{ns}

F ratio: 15.0^{s}

Minimum significant difference (Tukey's test): 1.5

Coefficient of variation: 2.6%

Table B-21. CROSS AND BEVAN CELLULOSE CONTENT OF THE PULPWOODS (%)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	53.3	53.4	53.5	51.9	55.0	53.4	± 1.4
P. elliottii	50.4	48.4	50.2	49.8	46.9	49.1	± 1.8
P. taeda	51.6	45.9	49.2	47.3	49.8	48.8	± 2.7
P. caribaea	44.8	47.4	44.6	46.4	48.2	46.3	± 1.9
"Slash pine"	48.5	48.1	49.0	47.9	49.0	48.5	± 0.6
"Loblolly pine"	43.5	43.0	47.6	46.3	47.0	45.5	± 2.6

Cochran's ratio: 0.3184^{ns}

F ratio: 15.0^{s}

Minimum significant difference (Tukey's test): 3.1

Coefficient of variation: 3.3%

Table B-22. ASH CONTENT OF THE PULPWOODS (%)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	0.3	0.3	0.4	0.4	0.2	0.3	± 0.1
P. elliottii	0.6	0.2	0.4	0.3	0.2	0.3	± 0.2
P. taeda	0.6	0.3	0.4	0.6	0.2	0.4	± 0.1
P. caribaea	0.4	0.3	0.2	0.1	0.3	0.3	± 0.1
"Slash pine"	0.3	0.6	0.5	0.4	0.3	0.4	± 0.2
"Loblolly pine"	0.3	0.3	0.4	0.4	0.6	0.4	± 0.1

Cochran's ratio: 0.2857^{ns}

F ratio: 1.1^{ns}

Minimum significant difference (Tukey's test): 0.3

Coefficient of variation: 34.2%

APPENDIX C

PERMANGANATE NUMBERS AND PULP YIELDS

Table C-1. BLEACHABLE GRADE PULPS: PERMANGANATE NUMBER

Species	replication 1	2	3	4	5	Mean	Confidence Interval (95%)
A. angustifolia	16.6	17.5	16.4	16.9	16.4	16.8	± 0.6
P. elliottii	17.4	16.3	16.0	18.0	16.7	16.9	± 1.0
P. taeda	17.7	18.0	17.7	16.9	16.0	17.3	± 1.0
P. caribaea	16.1	17.5	18.0	17.8	17.9	17.5	± 1.0
"Slash pine"	17.2	17.7	16.8	17.0	17.9	17.3	± 0.6
"Loblolly pine"	16.8	16.2	18.0	17.5	17.2	17.1	± 0.9

Table C-2. UNBLEACHABLE GRADE PULPS: PERMANGANATE NUMBER

Species	replication 1	2	3	4	5	Mean	Confidence Interval (95%)
A. angustifolia	28.5	28.4	28.2	26.0	28.8	28.0	± 1.4
P. elliottii	27.2	29.9	27.5	27.0	26.2	27.6	± 1.7
P. taeda	25.2	25.1	28.7	27.6	27.4	26.8	± 2.0
P. caribaea	25.6	27.3	29.0	29.8	29.4	28.2	± 2.2
"Slash pine"	27.4	29.7	29.9	27.4	27.9	28.5	± 1.5
"Loblolly pine"	27.0	30.0	27.8	27.7	28.4	28.2	± 1.4

Table C-3. BLEACHABLE GRADE PULPS:
TOTAL YIELD (PERCENT OF OVEN-DRY WOOD)

Species	replication 1	2	3	4	5	Mean	Confidence Interval (95%)
A. angustifolia	49.2	54.2	52.2	48.2	51.5	51.1	± 3.0
P. elliottii	46.8	41.2	44.8	47.6	42.6	44.6	± 3.3
P. taeda	45.0	50.8	48.0	49.2	44.8	47.6	± 3.2
P. caribaea	45.2	41.7	45.4	42.8	47.4	44.5	± 2.8
"Slash pine"	44.0	44.0	43.7	43.5	44.6	44.0	± 0.5
"Loblolly pine"	43.4	41.9	41.9	41.1	41.7	42.0	± 1.0

Table C-4. UNBLEACHABLE GRADE PULPS:
TOTAL YIELD (PERCENT OF OVEN-DRY WOOD)

Species	replication 1	2	3	4	5	Mean	Confidence Interval(95%)
A. angustifolia	51.3	53.6	52.8	50.0	55.2	52.6	± 2.5
P. elliottii	48.4	51.0	51.7	49.4	48.9	49.9	± 1.7
P. taeda	50.2	48.9	46.8	50.0	51.2	49.4	± 2.0
P. caribaea	54.2	51.1	50.4	50.5	46.9	50.6	± 3.2
"Slash pine"	46.3	47.8	47.3	47.4	47.4	47.2	± 0.7
"Loblolly pine"	44.0	44.5	45.7	45.0	43.8	44.6	± 1.0

Table C-5. BLEACHABLE GRADE PULPS:
SCREENED YIELD (PERCENT OF OVEN-DRY WOOD)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	49.0	54.0	51.8	47.8	51.2	50.8	± 3.0
P. elliottii	46.3	41.1	44.5	47.2	42.5	44.3	± 3.1
P. taeda	44.7	50.2	47.8	48.6	44.5	47.2	± 3.1
P. caribaea	44.3	40.7	43.9	40.7	45.0	42.9	± 2.6
"Slash pine"	43.9	43.8	43.5	43.1	44.5	43.8	± 0.6
"Loblolly pine"	42.8	41.6	41.7	40.6	41.3	41.6	± 1.0

Table C-6. UNBLEACHABLE GRADE PULPS:
SCREENED YIELD (PERCENT OF OVEN-DRY WOOD)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	50.8	53.1	52.2	49.6	54.7	52.1	± 2.5
P. elliottii	48.0	50.1	51.1	48.6	48.2	49.2	± 1.7
P. taeda	49.7	48.2	46.1	49.4	50.5	48.8	± 2.1
P. caribaea	53.4	49.7	46.7	48.8	44.5	48.6	± 4.1
"Slash pine"	45.8	47.4	46.8	46.9	47.0	46.8	± 0.7
"Loblolly pine"	42.9	42.7	44.5	43.6	43.0	43.3	± 0.9

Table C-7. BLEACHABLE GRADE PULPS:
REJECT CONTENT (PERCENT OF OVEN-DRY WOOD)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	0.2	0.2	0.4	0.4	0.3	0.3	± 0.1
P. elliottii	0.5	0.1	0.3	0.4	0.1	0.3	± 0.2
P. taeda	0.3	0.6	0.2	0.6	0.3	0.4	± 0.2
P. caribaea	0.9	1.0	1.5	2.1	2.4	1.6	± 0.8
"Slash pine"	0.1	0.2	0.2	0.4	0.1	0.2	± 0.1
"Loblolly pine"	0.6	0.3	0.2	0.5	0.4	0.4	± 0.2

Table C-8. UNBLEACHABLE GRADE PULPS:
REJECT CONTENT (PERCENT OF OVEN-DRY WOOD)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	0.5	0.5	0.6	0.4	0.5	0.5	± 0.1
P. elliottii	0.4	0.9	0.6	0.8	0.7	0.7	± 0.2
P. taeda	0.5	0.7	0.7	0.6	0.7	0.6	± 0.1
P. caribaea	0.8	1.4	3.7	1.7	2.4	2.0	± 1.4
"Slash pine"	0.5	0.4	0.5	0.5	0.4	0.5	± 0.1
"Loblolly pine"	1.1	1.8	1.2	1.4	0.8	1.3	± 0.5

Table C-9. BLEACHABLE GRADE PULPS:
TOTAL YIELD (PERCENT OF OVEN-DRY EXTRACTIVE-FREE WOOD)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	50.7	55.2	53.4	49.5	52.3	52.2	±2.7
P. elliottii	47.9	42.7	46.3	49.0	43.7	45.9	±3.3
P. taeda	46.2	51.8	49.0	50.5	45.4	48.6	±3.3
P. caribaea	45.8	42.4	45.9	43.6	48.7	45.3	±3.0
"Slash pine"	47.0	45.6	45.9	45.0	47.1	46.1	±1.1
"Loblolly pine"	45.7	43.5	43.7	43.5	44.3	44.1	±1.1

Table C-10. UNBLEACHABLE GRADE PULPS:
TOTAL YIELD (PERCENT OF OVEN-DRY EXTRACTIVE-FREE WOOD)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	52.9	54.6	54.0	51.4	56.0	53.8	± 2.2
P. elliottii	49.6	52.8	53.5	50.8	50.2	51.4	± 2.1
P. taeda	51.5	49.8	47.7	51.3	51.9	50.4	± 2.1
P. caribaea	55.0	52.0	51.0	51.5	48.1	51.5	± 3.1
"Slash pine"	49.5	49.5	49.7	48.9	50.0	49.5	± 0.5
"Loblolly pine"	46.3	46.2	47.6	47.7	46.5	46.9	± 0.9

Table C-11. BLEACHABLE GRADE PULPS:
SCREENED YIELD (PERCENT OF OVEN-DRY EXTRACTIVE-FREE WOOD

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	50.5	55.0	53.0	49.1	52.0	51.9	± 2.8
P. elliottii	47.4	42.6	46.0	48.6	43.6	45.6	± 3.1
P. taeda	45.9	51.2	48.8	49.9	45.1	48.2	± 3.2
P. caribaea	44.9	41.4	44.4	41.5	46.2	43.7	± 2.6
"Slash pine"	46.9	45.4	45.7	44.4	47.0	45.9	± 1.4
"Loblolly pine"	45.0	43.2	43.5	43.0	43.8	43.7	± 1.0

Table C-12. UNBLEACHABLE GRADE PULPS:
SCREENED YIELD (PERCENT OF OVEN-DRY EXTRACTIVE-FREE WOOD)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	52.4	54.1	53.4	51.0	55.5	53.3	± 2.1
P. elliottii	49.2	51.9	52.8	50.0	49.5	50.7	± 2.0
P. taeda	51.0	49.1	47.0	50.7	51.2	49.8	± 2.2
P. caribaea	54.2	50.6	47.2	49.7	45.7	49.5	± 4.1
"Slash pine"	48.9	49.1	49.2	48.3	49.6	49.0	± 0.6
"Loblolly pine"	45.2	44.3	46.4	46.2	45.6	45.5	± 1.0

Table C-13. BLEACHABLE GRADE PULPS: REJECT CONTENT (PERCENT OF OVEN-DRY EXTRACTIVE-FREE WOOD)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	0.2	0.2	0.4	0.4	0.3	0.3	± 0.1
P. elliottii	0.5	0.1	0.3	0.4	0.1	0.3	± 0.2
P. taeda	0.3	0.6	0.2	0.6	0.3	0.4	± 0.2
P. caribaea	0.9	1.0	1.5	2.1	2.5	1.6	± 0.9
"Slash pine"	0.1	0.2	0.2	0.6	0.1	0.2	± 0.2
"Loblolly pine"	0.7	0.3	0.2	0.5	0.5	0.4	± 0.2

Table C-14. UNBLEACHABLE GRADE PULPS: REJECT CONTENT (PERCENT OF OVEN-DRY EXTRACTIVE-FREE WOOD)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	0.5	0.5	0.6	0.4	0.5	0.5	± 0.1
P. elliottii	0.4	0.9	0.7	0.8	0.7	0.7	± 0.2
P. taeda	0.5	0.7	0.7	0.6	0.7	0.6	± 0.1
P. caribaea	0.8	1.4	3.8	1.8	2.4	2.0	± 1.4
"Slash pine"	0.6	0.4	0.5	0.6	0.4	0.5	± 0.1
"Loblolly pine"	1.1	1.9	1.2	1.5	0.9	1.3	± 0.5

APPENDIX D

PHYSICAL PROPERTIES OF THE PULPS

To simplify the presentation of data, the different treatments were codified as shown in Table D-1.

Table D-1. CODIFICATION OF THE TREATMENTS

Species	Permanganate Number Interval	Number of Treatment
A. angustifolia	16-18	1
A. angustifolia	25-30	2
P. elliottii	16-18	3
P. elliottii	25-30	4
P. taeda	16-18	5
P. taeda	25-30	6
P. caribaea	16-18	7
P. caribaea	25-30	8
Slash pine	16-18	9
Slash pine	25-30	10
Loblolly pine	16-18	11
Loblolly pine	25-30	12

Treatment: 1
Replication: 1

- beating time	0	15	25	40	50	55	60
- freeness	755	705	686	560	392	305	205
- basis weight	60.0	60.7	59.5	58.1	59.3	58.6	58.6
- breaking length	2635	4558	5031	6545	6920	7258	7199
- stretch	0.50	0.80	0.95	1.15	1.15	1.20	1.40
- burst factor	11.5	33.8	43.2	42.5	43.0	47.3	48.0
- tear factor	268	171	161	120	108	105	100
- thickness	151	102	97	88	86	83	83
- density	.397	.595	.613	.661	.692	.703	.703
- bulk	2.52	1.68	1.63	1.51	1.44	1.42	1.42

Treatment: 1
Replication: 2

- beating time	0	15	25	40	50	55	60
- freeness	749	710	678	508	400	292	154
- basis weight	60.7	61.1	60.9	57.7	57.8	57.6	57.2
- breaking length	2989	5128	5914	6708	7397	7502	7822
- stretch	0.25	0.85	1.10	1.45	1.50	1.45	1.55
- burst factor	13.5	36.0	37.8	44.9	46.0	46.4	47.4
- tear factor	308	188	167	125	111	109	98
- thickness	150	109	98	88	86	84	80
- density	.404	.560	.621	.659	.670	.687	.711
- bulk	2.47	1.78	1.61	1.52	1.49	1.46	1.41

Treatment: 1
Replication: 3

- beating time	0	15	25	40	50	55	60
- freeness	715	701	675	520	404	262	168
- basis weight	63.4	60.9	60.7	61.4	60.9	60.5	61.0
- breaking length	3016	5725	6832	7044	7924	7746	8386
- stretch	0.35	1.05	1.00	1.80	1.90	1.80	1.95
- burst factor	16.2	42.4	45.3	50.8	54.5	52.7	59.8
- tear factor	294	234	178	135	108	108	107
- thickness	154	114	100	93	86	88	85
- density	.412	.534	.607	.660	.707	.690	.718
- bulk	2.43	1.87	1.65	1.52	1.41	1.45	1.39

Treatment: 1
Replication: 4

- beating time	0	15	25	40	50	55	60
- freeness	751	712	689	528	390	296	189
- basis weight	62.7	61.6	59.6	60.8	59.6	60.2	60.7
- breaking length	3041	5487	5843	6716	6941	7377	7769
- stretch	0.35	1.05	1.25	1.55	1.50	1.80	1.80
- burst factor	17.7	40.7	43.6	44.0	43.8	44.4	49.7
- tear factor	310	195	181	119	108	105	110
- thickness	147	113	98	90	86	84	86
- density	.426	.545	.608	.678	.695	.709	.715
- bulk	2.34	1.83	1.63	1.48	1.44	1.41	1.40

Treatment: 1
Replication: 5

- beating time	0	15	25	40	50	55	60
- freeness	748	707	649	575	425	318	204
- basis weight	62.8	61.0	61.0	61.2	60.9	61.6	58.2
- breaking length	2752	4940	5612	6549	6699	6449	7244
- stretch	0.35	0.85	1.00	1.65	1.80	1.70	1.85
- burst factor	13.5	32.8	39.5	47.4	47.0	45.0	48.5
- tear factor	298	233	157	138	137	131	113
- thickness	159	115	101	95	93	93	85
- density	.395	.530	.604	.644	.654	.660	.686
- bulk	2.53	1.89	1.66	1.55	1.53	1.51	1.46

Treatment: 2
Replication: 1

- beating time	0	15	25	40	50	55	60
- freeness	752	708	682	512	397	289	192
- basis weight	61.4	59.6	60.4	58.6	57.1	58.4	58.0
- breaking length	2498	4702	4776	5660	6653	6182	7696
- stretch	0.25	0.60	0.95	1.35	1.40	1.35	1.60
- burst factor	10.3	27.3	34.5	37.6	38.7	40.4	47.1
- tear factor	242	181	157	110	104	100	95
- thickness	165	114	104	99	93	89	84
- density	.372	.523	.581	.594	.633	.658	.691
- bulk	2.69	1.91	1.72	1.68	1.58	1.52	1.45

Treatment: 2
Replication: 2

- beating time	0	15	25	40	50	55	60
- freeness	745	702	679	526	376	258	122
- basis weight	60.8	60.4	60.9	56.7	58.5	58.3	57.6
- breaking length	2586	4382	4663	7029	7345	7660	7931
- stretch	0.20	0.40	1.15	1.60	1.55	1.55	1.65
- burst factor	11.5	27.6	40.9	51.3	53.1	56.6	59.7
- tear factor	249	191	168	115	103	103	98
- thickness	157	115	110	88	86	86	79
- density	.387	.525	.554	.644	.680	.678	.729
- bulk	2.58	1.90	1.80	1.55	1.47	1.48	1.37

Treatment: 2
Replication: 3

- beating time	0	15	25	40	50	60	70
- freeness	764	725	697	600	446	244	158
- basis weight	62.5	60.9	60.5	60.6	59.4	60.9	61.3
- breaking length	2635	4335	4507	7093	7382	7682	8041
- stretch	0.20	0.80	1.00	1.45	1.80	1.75	1.85
- burst factor	11.4	28.7	40.8	51.5	53.8	57.0	59.7
- tear factor	271	181	170	120	123	116	109
- thickness	169	117	111	95	91	88	86
- density	.370	.520	.545	.638	.651	.695	.714
- bulk	2.70	1.92	1.83	1.56	1.54	1.44	1.40

Treatment: 2
Replication: 4

- beating time	0	15	25	40	50	60	65
- freeness	740	703	679	576	400	260	193
- basis weight	63.5	61.1	60.4	61.1	61.6	64.8	60.0
- breaking length	2634	4934	5052	6322	7115	7651	8262
- stretch	0.20	0.90	1.15	2.00	1.95	2.00	2.00
- burst factor	12.4	33.7	42.5	46.2	54.6	60.0	60.7
- tear factor	279	227	159	114	106	103	95
- thickness	158	118	102	94	92	92	86
- density	.402	.518	.592	.652	.669	.704	.701
- bulk	2.49	1.93	1.69	1.53	1.50	1.42	1.43

PHYSICAL PROPERTIES OF THE PULPS

Treatment: 2
Replication: 5

- beating time	0	15	25	40	50	55	60
- freeness	752	724	691	620	508	312	175
- basis weight	61.4	60.6	61.1	59.0	59.2	57.8	59.8
- breaking length	2465	4675	4959	6043	6716	7075	7062
- stretch	0.30	0.65	0.95	1.40	1.45	1.70	1.75
- burst factor	9.9	34.1	37.3	40.8	44.6	45.0	46.8
- tear factor	269	248	185	128	110	101	103
- thickness	166	119	113	94	89	87	87
- density	.370	.509	.541	.629	.665	.667	.685
- bulk	2.70	1.96	1.85	1.59	1.50	1.50	1.46

Treatment: 3
Replication: 1

- beating time	0	20	40	60	70	80	90
- freeness	702	692	573	449	375	247	161
- basis weight	60.3	63.2	61.8	60.0	59.5	58.6	59.0
- breaking length	3318	6329	7174	7647	7757	7747	7993
- stretch	1.80	2.75	2.80	3.00	3.05	2.60	2.75
- burst factor	27.2	51.9	50.4	54.5	50.3	57.0	60.9
- tear factor	183	120	118	83	87	80	82
- thickness	150	103	89	83	83	79	78
- density	.402	.614	.694	.719	.718	.737	.758
- bulk	2.49	1.63	1.44	1.39	1.39	1.36	1.32

Treatment: 3
Replication: 2

- beating time	0	20	40	60	70	80	90
- freeness	712	684	547	461	372	229	204
- basis weight	61.7	62.9	61.5	61.3	61.2	59.0	61.3
- breaking length	3264	6454	6526	6892	7211	7932	7735
- stretch	1.95	2.60	2.70	2.70	2.75	2.65	2.60
- burst factor	25.9	50.4	50.2	46.3	49.2	49.7	48.4
- tear factor	203	126	108	94	88	84	87
- thickness	148	103	90	86	84	80	82
- density	.416	.611	.683	.711	.725	.740	.751
- bulk	2.40	1.64	1.46	1.41	1.38	1.35	1.33

Treatment: 3
Replication: 3

- beating time	0	20	40	60	70	80	90
- freeness	708	690	553	425	367	257	168
- basis weight	64.0	63.1	62.7	61.2	62.0	60.9	61.8
- breaking length	3312	6170	6688	7949	7801	7349	7938
- stretch	2.25	2.65	2.80	3.15	2.75	2.45	2.45
- burst factor	26.2	47.4	54.9	59.3	52.3	58.4	58.1
- tear factor	187	121	111	91	89	87	90
- thickness	154	103	91	85	86	83	84
- density	.416	.613	.689	.718	.720	.737	.738
- bulk	2.40	1.63	1.45	1.39	1.39	1.36	1.36

Treatment: 3
Replication: 4

- beating time	0	20	40	60	70	80	90
- freeness	712	645	528	479	396	257	202
- basis weight	61.0	63.3	62.6	61.7	61.0	60.5	60.8
- breaking length	3681	6340	6624	7926	7085	7636	7850
- stretch	2.00	2.80	2.80	2.95	2.50	2.40	2.40
- burst factor	28.8	51.0	53.0	59.4	53.5	59.1	50.2
- tear factor	177	114	102	97	92	93	83
- thickness	151	103	91	86	85	81	84
- density	.405	.614	.688	.721	.714	.743	.723
- bulk	2.47	1.63	1.45	1.39	1.40	1.35	1.38

Treatment: 3
Replication: 5

- beating time	0	20	40	60	70	80	90
- freeness	709	684	547	457	341	259	153
- basis weight	62.4	63.0	62.4	61.3	60.9	59.2	60.0
- breaking length	3662	6444	6816	7776	7675	7740	7909
- stretch	2.20	2.80	2.95	2.75	2.55	2.40	2.70
- burst factor	27.5	51.7	56.6	55.8	55.5	54.1	58.5
- tear factor	172	125	108	90	83	77	74
- thickness	150	106	92	86	84	79	80
- density	.417	.594	.678	.716	.727	.749	.754
- bulk	2.40	1.68	1.47	1.40	1.38	1.34	1.33

Treatment: 4
Replication: 1

- beating time	0	20	40	60	75	90	105
- freeness	708	675	621	512	377	300	131
- basis weight	62.3	61.4	59.0	58.9	58.8	57.7	57.0
- breaking length	2878	5972	7887	7957	7799	8231	8304
- stretch	1.40	2.35	2.70	3.20	3.00	2.80	2.85
- burst factor	19.4	48.7	60.5	60.4	63.8	58.6	58.6
- tear factor	174	109	87	86	83	87	76
- thickness	160	104	85	84	81	80	75
- density	.388	.590	.694	.703	.722	.718	.764
- bulk	2.58	1.69	1.44	1.42	1.38	1.39	1.31

Treatment: 4
Replication: 2

- beating time	0	20	40	60	75	90	105
- freeness	732	701	654	552	412	291	161
- basis weight	61.9	62.0	61.3	58.2	58.6	58.3	57.5
- breaking length	3071	6086	7091	7551	8050	8548	7926
- stretch	1.40	2.75	2.80	2.70	3.00	3.05	2.95
- burst factor	20.7	43.9	57.9	63.4	59.1	66.1	57.2
- tear factor	192	116	98	96	96	93	79
- thickness	160	105	93	83	85	81	77
- density	.388	.590	.659	.698	.692	.721	.751
- bulk	2.59	1.69	1.52	1.43	1.44	1.39	1.33

Treatment: 4
Replication: 3

- beating time	0	20	40	60	70	80	90
- freeness	705	675	580	415	301	202	129
- basis weight	58.0	61.8	61.2	57.1	57.6	57.6	58.0
- breaking length	2816	5933	7582	8069	8558	8633	8776
- stretch	1.50	2.80	2.95	2.75	2.45	2.75	2.60
- burst factor	21.2	47.6	58.3	56.2	55.2	58.4	57.4
- tear factor	158	115	95	87	81	83	87
- thickness	153	103	88	80	79	77	78
- density	.378	.600	.695	.717	.733	.749	.745
- bulk	2.64	1.67	1.44	1.39	1.36	1.34	1.34

Treatment: 4
Replication: 4

- beating time	0	20	40	60	70	80	90
- freeness	712	686	591	471	325	229	177
- basis weight	61.3	62.0	59.2	57.9	57.2	56.4	56.8
- breaking length	2739	5935	7342	7756	7884	7791	8643
- stretch	1.20	3.20	3.05	2.65	2.75	2.85	2.95
- burst factor	18.1	43.9	56.1	57.1	58.3	56.7	58.8
- tear factor	166	115	111	94	83	84	81
- thickness	159	106	90	82	79	77	77
- density	.386	.585	.656	.703	.727	.732	.733
- bulk	2.59	1.71	1.52	1.42	1.38	1.37	1.36

Treatment: 4
Replication: 5

- beating time	0	20	40	60	70	80	90
- freeness	712	675	608	500	374	216	150
- basis weight	61.3	61.6	61.3	59.1	58.8	58.5	58.3
- breaking length	2849	5996	7058	7246	7710	7852	8256
- stretch	1.50	2.95	2.85	3.05	2.85	2.85	2.75
- burst factor	20.4	50.5	56.3	58.4	56.0	58.7	58.5
- tear factor	169	115	92	83	87	85	83
- thickness	159	104	89	84	81	78	77
- density	.386	.592	.689	.708	.726	.750	.757
- bulk	2.56	1.69	1.45	1.41	1.38	1.33	1.32

Treatment: 5
Replication: 1

- beating time	0	20	40	60	70	80	90
- freeness	708	684	572	497	375	229	131
- basis weight	60.6	62.6	61.0	59.2	59.2	58.1	57.6
- breaking length	3355	5601	6852	7960	7432	7433	7840
- stretch	2.55	3.40	3.80	3.25	3.05	3.05	2.80
- burst factor	27.6	54.3	55.6	56.7	58.1	55.7	59.3
- tear factor	194	150	115	105	102	100	96
- thickness	155	104	90	86	86	83	79
- density	.391	.602	.678	.690	.692	.704	.729
- bulk	2.56	1.66	1.47	1.45	1.44	1.42	1.37

Treatment: 5
Replication: 2

- beating time	0	20	40	60	70	80	90
- freeness	732	685	547	471	312	246	102
- basis weight	62.6	61.6	60.3	60.2	59.4	60.0	60.2
- breaking length	3470	5519	6490	7373	7401	7244	7642
- stretch	2.35	2.80	2.90	2.85	3.05	2.85	2.90
- burst factor	27.6	49.4	50.7	53.1	55.1	54.3	57.9
- tear factor	182	148	115	107	104	99	97
- thickness	158	104	90	87	85	83	78
- density	.396	.592	.670	.692	.698	.719	.772
- bulk	2.52	1.69	1.49	1.44	1.43	1.39	1.29

Treatment: 5
Replication: 3

- beating time	0	20	40	60	90	97.5	105
- freeness	732	677	616	563	330	281	160
- basis weight	63.9	60.7	60.7	61.6	61.0	61.4	60.4
- breaking length	3602	5458	6019	7749	7909	8077	8487
- stretch	3.10	3.40	3.80	4.00	3.65	3.75	3.65
- burst factor	29.0	49.4	56.3	54.4	58.2	57.3	59.3
- tear factor	271	153	119	114	109	105	100
- thickness	156	106	90	85	82	82	78
- density	.409	.573	.674	.723	.746	.742	.772
- bulk	2.44	1.74	1.48	1.38	1.34	1.33	1.29

Treatment: 5
Replication: 4

- beating time	0	20	40	60	75	90	105
- freeness	729	691	574	461	370	212	97
- basis weight	61.5	62.3	60.2	60.0	58.5	59.5	59.0
- breaking length	3470	5136	6190	6891	7459	7702	7917
- stretch	1.85	3.15	3.00	2.75	2.80	2.70	2.80
- burst factor	25.4	49.9	50.6	53.7	56.9	57.6	51.3
- tear factor	236	156	122	124	110	96	84
- thickness	154	106	88	82	80	78	71
- density	.399	.588	.684	.728	.730	.760	.827
- bulk	2.51	1.70	1.46	1.37	1.37	1.32	1.21

Treatment: 5
Replication: 5

- beating time	0	20	40	45	60	75	90
- freeness	751	707	671	550	369	173	79
- basis weight	59.4	61.7	60.6	57.2	58.0	57.2	59.2
- breaking length	3355	5370	6094	7051	6980	7757	7969
- stretch	1.75	2.60	3.05	2.80	2.80	2.85	2.65
- burst factor	24.2	34.6	44.8	42.2	44.7	46.2	49.1
- tear factor	185	164	118	102	99	87	60
- thickness	147	106	91	84	81	77	69
- density	.403	.582	.666	.685	.716	.741	.865
- bulk	2.48	1.72	1.50	1.46	1.40	1.35	1.16

Treatment: 6
Replication: 1

- beating time	0	20	40	60	75	90	105
- freeness	708	684	647	576	425	308	135
- basis weight	61.3	61.0	60.2	59.6	59.1	58.5	57.6
- breaking length	3250	5858	7265	8377	8315	8863	8949
- stretch	2.65	3.70	4.05	3.85	3.90	3.95	3.25
- burst factor	27.1	52.6	59.8	62.8	63.0	66.7	66.1
- tear factor	225	147	141	120	122	115	100
- thickness	164	101	95	86	85	82	78
- density	.373	.604	.634	.690	.693	.714	.735
- bulk	2.68	1.66	1.58	1.45	1.44	1.40	1.36

Treatment: 6
Replication: 2

- beating time	0	20	40	60	75	90	105
- freeness	710	684	609	523	375	297	131
- basis weight	60.4	61.2	59.6	60.6	60.0	58.2	57.1
- breaking length	3201	6220	6208	8097	8119	7953	8432
- stretch	1.95	3.15	3.60	2.95	2.90	2.90	2.95
- burst factor	25.7	51.5	57.6	60.9	60.0	58.2	67.1
- tear factor	222	140	130	112	112	117	96
- thickness	155	100	97	84	81	80	75
- density	.390	.612	.614	.721	.728	.737	.789
- bulk	2.56	1.63	1.63	1.39	1.37	1.36	1.27

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Treatment: 6
Replication: 3

- beating time	0	20	40	60	75	90	105
- freeness	711	690	627	575	412	290	184
- basis weight	62.1	60.8	60.2	60.8	59.5	60.7	59.8
- breaking length	2920	6239	6556	8019	8403	8632	8904
- stretch	2.75	4.05	4.00	4.15	4.05	3.90	3.85
- burst factor	26.2	56.6	55.8	62.4	65.2	66.6	68.2
- tear factor	235	185	124	127	117	106	112
- thickness	168	104	98	89	87	86	84
- density	.370	.585	.614	.685	.687	.709	.713
- bulk	2.70	1.71	1.63	1.46	1.46	1.41	1.40

Treatment: 6
Replication: 4

- beating time	0	20	40	60	70	80	90
- freeness	715	664	595	507	375	275	200
- basis weight	59.6	60.5	60.5	57.9	58.4	58.1	57.1
- breaking length	2931	6016	6578	7545	7389	7940	8056
- stretch	2.15	3.20	3.65	3.50	3.00	3.00	3.15
- burst factor	21.0	50.6	53.7	55.8	48.2	58.2	61.1
- tear factor	191	173	127	98	106	86	92
- thickness	158	101	99	84	86	82	81
- density	.376	.599	.611	.686	.676	.710	.708
- bulk	2.66	1.67	1.64	1.46	1.48	1.41	1.41

Treatment: 6
Replication: 5

- beating time	0	20	40	60	70	80	90
- freeness	712	677	591	470	375	298	196
- basis weight	61.8	60.5	60.1	62.0	60.8	59.8	59.8
- breaking length	2673	5983	6689	6812	7759	7452	7833
- stretch	1.30	3.20	3.80	3.15	3.10	2.85	3.15
- burst factor	17.0	51.2	57.4	55.3	54.4	58.3	59.2
- tear factor	182	143	142	112	106	95	95
- thickness	168	101	98	90	88	85	85
- density	.369	.599	.613	.687	.690	.704	.707
- bulk	2.71	1.67	1.63	1.46	1.45	1.42	1.41

Treatment: 7
Replication: 1

- beating time	0	20	40	60	70	80	90
- freeness	751	712	650	498	400	325	180
- basis weight	61.5	61.9	61.5	59.9	59.7	57.7	57.4
- breaking length	4042	6634	6981	8558	9050	9324	9177
- stretch	1.35	2.00	1.95	2.00	2.05	1.95	1.90
- burst factor	26.8	53.6	56.7	61.1	60.8	63.8	62.4
- tear factor	253	140	129	101	104	96	87
- thickness	135	104	92	81	80	77	75
- density	.456	.595	.668	.729	.743	.753	.769
- bulk	2.19	1.68	1.50	1.37	1.35	1.33	1.30

Treatment: 7
Replication: 2

- beating time	0	20	40	60	70	80	90
- freeness	732	695	591	497	368	225	161
- basis weight	63.6	61.1	62.0	61.7	61.0	60.1	60.2
- breaking length	4446	6426	6763	7977	8586	8662	8634
- stretch	1.45	1.90	2.05	2.10	2.10	2.10	1.90
- burst factor	32.7	55.2	54.8	56.6	53.3	57.9	59.2
- tear factor	177	151	123	95	99	90	82
- thickness	136	105	94	82	79	78	76
- density	.468	.582	.660	.749	.774	.773	.791
- bulk	2.14	1.72	1.51	1.34	1.29	1.29	1.26

Treatment: 7
Replication: 3

- beating time	0	20	40	60	70	80	90
- freeness	761	712	687	570	437	370	135
- basis weight	61.8	61.9	61.9	58.2	58.8	59.3	57.9
- breaking length	3429	6063	6699	7887	8135	8562	8699
- stretch	1.35	1.90	2.15	2.10	2.35	2.20	2.00
- burst factor	19.1	45.4	50.8	50.5	51.0	52.1	54.6
- tear factor	238	167	117	122	116	119	109
- thickness	153	107	95	86	89	83	79
- density	.405	.578	.652	.651	.687	.711	.737
- bulk	2.47	1.73	1.53	1.54	1.47	1.41	1.36

Treatment: 7
Replication: 4

- beating time	0	20	40	60	70	80	90
- freeness	758	717	672	491	374	259	169
- basis weight	61.6	60.9	61.1	60.0	59.2	59.1	59.2
- breaking length	3725	5627	6639	7782	8035	7830	8021
- stretch	1.35	1.80	1.90	1.80	2.00	1.95	2.00
- burst factor	21.1	43.2	49.2	52.0	52.0	50.9	53.6
- tear factor	192	173	118	108	109	98	106
- thickness	155	107	93	87	85	82	80
- density	.397	.569	.657	.691	.696	.723	.740
- bulk	2.52	1.76	1.52	1.45	1.44	1.38	1.35

Treatment: 7
Replication: 5

- beating time	0	20	40	60	75	90	105
- freeness	750	721	664	581	384	230	170
- basis weight	61.8	60.9	61.8	60.5	61.0	59.3	59.1
- breaking length	3377	5254	7163	7846	7565	8173	8655
- stretch	1.20	2.00	2.00	2.15	1.90	2.00	1.90
- burst factor	20.2	44.0	48.8	47.8	45.9	55.0	58.9
- tear factor	213	179	124	111	96	96	89
- thickness	149	106	93	85	85	83	79
- density	.415	.574	.664	.708	.716	.718	.752
- bulk	2.40	1.74	1.51	1.41	1.39	1.39	1.33

Treatment: 8
Replication: 1

- beating time	0	15	25	45	60	75	90
- freeness	730	702	690	575	385	281	131
- basis weight	58.7	60.8	60.0	57.3	60.1	57.8	57.2
- breaking length	3284	6217	6222	7862	8558	9090	9187
- stretch	1.10	1.90	2.00	1.85	2.15	2.50	2.20
- burst factor	20.8	54.1	56.8	68.7	69.6	74.3	65.8
- tear factor	230	168	144	99	90	87	81
- thickness	142	106	102	84	85	81	76
- density	.413	.574	.588	.679	.710	.713	.752
- bulk	2.42	1.74	1.70	1.47	1.41	1.40	1.33

Treatment: 8
Replication: 2

- beating time	0	15	25	45	60	75	90
- freeness	751	712	674	575	390	251	90
- basis weight	63.1	60.3	58.4	60.8	61.5	61.2	60.0
- breaking length	3140	5760	6724	8229	8279	8711	8803
- stretch	1.45	1.85	2.20	2.55	2.40	2.25	2.30
- burst factor	25.7	54.7	56.8	64.8	63.9	68.7	62.5
- tear factor	166	160	141	80	80	75	76
- thickness	152	104	101	88	85	83	76
- density	.415	.580	.578	.689	.720	.737	.789
- bulk	2.41	1.77	1.73	1.45	1.39	1.36	1.27

Treatment: 8
Replication: 3

- beating time	0	15	25	60	75	90	105
- freeness	750	724	670	500	412	297	161
- basis weight	62.8	60.9	61.0	59.4	60.3	59.7	58.4
- breaking length	2855	5988	6503	7901	8631	9061	9178
- stretch	1.00	1.80	2.10	2.35	2.30	2.70	2.15
- burst factor	14.6	51.0	53.5	55.0	59.8	57.0	62.5
- tear factor	211	165	154	118	109	114	102
- thickness	166	106	104	88	87	84	80
- density	.378	.574	.586	.676	.692	.707	.726
- bulk	2.65	1.74	1.71	1.48	1.44	1.41	1.38

Treatment: 8
Replication: 4

- beating time	0	15	25	60	70	80	90
- freeness	754	723	691	512	400	304	212
- basis weight	63.6	60.8	60.2	60.0	59.7	58.8	59.2
- breaking length	2945	6162	6567	8436	7653	8206	8353
- stretch	1.00	1.80	2.25	2.25	2.20	2.15	2.25
- burst factor	17.8	53.0	55.6	62.7	65.8	61.9	62.8
- tear factor	218	161	155	106	96	92	88
- thickness	161	106	103	88	87	86	82
- density	.395	.574	.584	.678	.684	.687	.724
- bulk	2.52	1.74	1.71	1.48	1.46	1.45	1.38

Treatment: 8
Replication: 5

- beating time	0	15	25	60	70	80	90
- freeness	757	716	642	472	364	292	202
- basis weight	62.5	60.8	59.2	61.2	58.5	58.3	59.2
- breaking length	2911	5789	6847	7759	8228	8740	8981
- stretch	0.75	2.10	2.20	2.00	2.30	2.40	2.45
- burst factor	12.3	53.3	54.5	60.9	58.3	64.4	60.6
- tear factor	201	175	143	100	96	95	96
- thickness	160	105	103	91	87	84	84
- density	.391	.579	.575	.670	.674	.691	.708
- bulk	2.56	1.73	1.74	1.49	1.48	1.45	1.41

Treatment: 9
Replication: 1

- beating time	0	15	30	35	40	45	50
- freeness	734	682	491	412	307	232	148
- basis weight	63.0	61.9	60.9	62.0	61.7	62.4	60.1
- breaking length	2776	7454	9469	11098	10834	10303	10408
- stretch	0.94	1.84	2.20	2.34	2.56	2.64	2.76
- burst factor	16.4	50.8	75.7	79.0	85.6	85.7	83.4
- tear factor	180	226	174	168	149	147	133
- thickness	217	132	110	107	103	100	96
- density	.290	.467	.554	.581	.601	.623	.629
- bulk	3.45	2.14	1.80	1.72	1.66	1.60	1.59

Treatment: 9
Replication: 2

- beating time	0	15	30	35	40	45	50
- freeness	725	676	512	423	330	251	164
- basis weight	61.0	62.8	61.6	60.5	61.5	62.7	62.6
- breaking length	3041	7176	9349	10057	10770	10872	10463
- stretch	1.00	2.12	2.26	2.40	2.58	2.55	2.48
- burst factor	15.4	59.8	74.4	81.6	78.7	78.0	78.6
- tear factor	150	209	171	163	149	143	125
- thickness	221	133	109	103	99	100	97
- density	.276	.472	.567	.585	.620	.627	.645
- bulk	3.62	2.12	1.76	1.71	1.61	1.59	1.55

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Treatment: 9
Replication: 3

- beating time	0	15	30	35	40	45	50
- freeness	726	672	460	370	272	220	165
- basis weight	62.9	61.1	60.2	61.2	62.2	60.4	62.1
- breaking length	2652	7705	9489	10205	10161	10429	9761
- stretch	0.98	2.02	2.42	2.70	2.74	2.52	2.68
- burst factor	14.9	61.8	81.4	84.7	85.1	88.2	84.4
- tear factor	185	200	155	139	149	139	140
- thickness	210	122	102	100	100	97	97
- density	.299	.499	.588	.615	.619	.621	.641
- bulk	3.34	2.00	1.70	1.63	1.62	1.61	1.56

Treatment: 9
Replication: 4

- beating time	0	15	30	35	40	45	50
- freeness	729	676	489	410	305	208	138
- basis weight	62.6	61.6	60.5	59.8	59.7	59.9	61.0
- breaking length	2493	6948	9146	9701	10330	10683	11515
- stretch	0.84	1.85	2.22	2.37	1.82	2.30	2.54
- burst factor	11.1	60.5	75.0	73.7	82.8	77.0	79.9
- tear factor	189	227	170	170	156	149	140
- thickness	219	129	109	104	98	96	94
- density	.286	.476	.553	.572	.608	.622	.647
- bulk	3.50	2.10	1.81	1.75	1.64	1.61	1.54

Treatment: 9
Replication: 5

- beating time	0	15	30	35	40	45	50
- freeness	751	683	543	467	373	270	201
- basis weight	58.9	62.8	61.8	61.8	60.7	63.3	62.2
- breaking length	2671	6356	8587	8608	9611	9394	10772
- stretch	1.04	2.14	2.76	2.66	2.80	2.88	3.02
- burst factor	12.2	53.3	71.0	83.0	74.6	80.4	81.0
- tear factor	170	215	174	145	133	123	132
- thickness	208	126	109	105	100	99	95
- density	.283	.499	.565	.589	.608	.639	.652
- bulk	3.53	2.00	1.77	1.70	1.64	1.56	1.53

Treatment: 10
Replication: 1

- beating time	0	15	30	40	45	50	55
- freeness	730	687	560	362	285	217	158
- basis weight	62.5	61.8	60.8	59.8	62.3	61.2	60.9
- breaking length	2496	5853	8184	9491	9545	9647	9448
- stretch	1.12	1.86	2.34	2.80	2.64	2.83	3.08
- burst factor	15.3	54.4	72.0	78.4	78.8	83.5	79.6
- tear factor	188	237	176	148	139	132	123
- thickness	240	145	114	101	102	95	94
- density	.260	.427	.534	.590	.611	.643	.646
- bulk	3.85	2.34	1.87	1.69	1.64	1.56	1.55

Treatment: 10
Replication: 2

- beating time	0	15	30	40	45	50	55
- freeness	737	715	623	498	362	296	220
- basis weight	59.0	61.0	61.8	62.0	60.5	62.3	61.5
- breaking length	2282	5836	7939	8107	8837	8753	8702
- stretch	0.82	1.70	2.35	2.44	2.46	2.60	2.98
- burst factor	11.0	41.5	58.5	67.4	73.9	75.2	73.8
- tear factor	143	233	174	148	128	132	123
- thickness	258	153	124	114	104	103	97
- density	.229	.399	.498	.543	.581	.605	.633
- bulk	4.37	2.50	2.01	1.84	1.72	1.65	1.58

Treatment: 10
Replication: 3

- beating time	0	15	30	40	45	50	55
- freeness	724	713	624	495	392	296	230
- basis weight	62.6	62.1	60.5	62.5	63.4	62.9	59.9
- breaking length	2465	5921	7959	9131	9001	9496	10078
- stretch	1.02	1.92	2.48	2.64	2.60	2.64	2.86
- burst factor	15.7	45.5	62.7	70.4	71.6	74.6	78.6
- tear factor	147	252	184	159	150	134	134
- thickness	236	144	116	111	106	102	94
- density	.265	.430	.520	.563	.598	.617	.639
- bulk	3.77	2.32	1.92	1.78	1.67	1.62	1.56

Treatment: 10
Replication: 4

- beating time	0	15	30	40	45	50	55
- freeness	744	696	593	454	358	260	190
- basis weight	60.4	61.4	62.1	62.7	63.7	60.5	62.5
- breaking length	3168	6891	7463	8756	8854	8888	9153
- stretch	1.16	2.00	2.06	2.86	2.88	3.00	3.16
- burst factor	19.0	52.0	68.5	81.8	81.0	78.5	68.2
- tear factor	196	229	168	148	139	132	122
- thickness	211	136	114	108	109	101	102
- density	.286	.451	.542	.580	.584	.597	.613
- bulk	3.50	2.22	1.84	1.72	1.71	1.68	1.63

Treatment: 10
Replication: 5

- beating time	0	15	30	40	45	50	55
- freeness	725	700	613	468	360	270	201
- basis weight	61.6	61.0	59.4	59.5	59.7	61.4	62.6
- breaking length	2209	5213	8576	9753	10280	8899	9304
- stretch	0.74	1.66	2.15	2.26	2.22	2.42	2.48
- burst factor	11.8	43.1	64.6	68.4	74.5	74.6	73.7
- tear factor	152	287	183	159	146	126	119
- thickness	242	145	114	105	101	100	98
- density	.255	.420	.522	.564	.589	.611	.635
- bulk	3.92	2.38	1.92	1.77	1.70	1.64	1.57

Treatment: 11
Replication: 1

- beating time	0	15	25	30	35	40	45
- freeness	724	664	539	468	387	301	229
- basis weight	61.5	61.4	61.3	60.6	59.1	60.2	61.2
- breaking length	3873	8401	9917	9487	9944	10462	10758
- stretch	1.70	2.94	2.94	3.00	3.02	3.18	2.92
- burst factor	25.9	64.5	78.2	81.5	81.2	87.2	83.9
- tear factor	228	152	134	130	128	115	116
- thickness	177	105	95	91	87	85	86
- density	.348	.585	.644	.669	.681	.706	.713
- bulk	2.87	1.71	1.55	1.49	1.47	1.42	1.40

Treatment: 11
Replication: 2

- beating time	0	15	25	30	35	40	45
- freeness	706	649	535	453	378	299	212
- basis weight	62.3	60.3	60.0	62.8	61.4	60.4	59.9
- breaking length	3924	8106	9416	10058	10208	10361	10169
- stretch	1.96	3.02	3.14	3.16	3.04	3.28	2.92
- burst factor	28.2	65.7	74.0	76.0	73.4	82.4	74.3
- tear factor	230	153	136	143	134	120	108
- thickness	170	104	94	95	90	87	83
- density	.367	.578	.640	.661	.682	.692	.718
- bulk	2.72	1.73	1.56	1.51	1.47	1.44	1.39

Treatment: 11
Replication: 3

- beating time	0	15	25	30	35	40	45
- freeness	716	651	557	492	408	323	259
- basis weight	63.1	62.6	61.7	61.5	60.8	62.2	61.9
- breaking length	3429	7594	9055	9402	9420	9648	10015
- stretch	1.80	3.12	3.54	3.20	3.28	3.06	2.92
- burst factor	24.5	65.3	69.4	79.4	79.6	82.9	84.3
- tear factor	228	161	138	127	120	125	112
- thickness	178	108	96	91	90	89	86
- density	.355	.578	.641	.675	.678	.702	.722
- bulk	2.82	1.73	1.56	1.48	1.47	1.42	1.38

Treatment: 11
Replication: 4

- beating time	0	15	25	30	35	40	45
- freeness	720	645	559	483	424	336	257
- basis weight	62.6	60.7	59.3	58.8	59.8	60.3	60.7
- breaking length	3966	8908	9489	10359	9776	10659	11294
- stretch	1.82	2.88	2.88	3.16	2.70	2.88	2.88
- burst factor	29.4	66.9	79.4	77.9	81.4	77.5	75.7
- tear factor	252	156	143	133	134	134	116
- thickness	168	102	94	90	88	87	85
- density	.373	.597	.629	.655	.677	.694	.717
- bulk	2.68	1.68	1.59	1.53	1.48	1.44	1.39

Treatment: 11
Replication: 5

- beating time	0	15	25	30	35	40	45
- freeness	706	634	536	449	377	291	220
- basis weight	59.8	58.4	60.2	61.6	61.6	60.0	60.2
- breaking length	2307	7360	8307	9102	9532	9437	10280
- stretch	1.84	2.86	2.84	3.42	3.08	3.20	3.20
- burst factor	25.4	61.0	68.8	73.1	75.6	80.4	77.5
- tear factor	219	172	148	142	138	130	117
- thickness	170	105	95	92	90	86	84
- density	.351	.554	.636	.673	.683	.696	.713
- bulk	2.85	1.80	1.57	1.48	1.46	1.44	1.40

Treatment: 12
Replication: 1

- beating time	0	15	30	40	45	50	55
- freeness	709	670	552	438	363	281	218
- basis weight	61.3	59.3	59.1	58.3	60.2	59.3	60.4
- breaking length	3904	7421	8956	10250	10059	10270	9940
- stretch	1.92	3.20	3.58	3.56	3.14	3.40	3.05
- burst factor	26.6	67.9	72.3	81.8	83.3	82.0	80.2
- tear factor	237	190	156	138	134	122	114
- thickness	192	116	96	88	88	84	84
- density	.319	.510	.618	.666	.686	.702	.722
- bulk	3.13	1.96	1.62	1.50	1.46	1.42	1.38

Treatment: 12
Replication: 2

- beating time	0	15	30	40	45	50	55
- freeness	715	685	609	492	432	350	279
- basis weight	62.2	62.2	61.8	60.0	59.4	59.8	60.3
- breaking length	4086	7683	9002	10428	9847	9404	10760
- stretch	1.94	2.48	2.84	3.28	2.94	2.59	3.06
- burst factor	25.2	57.9	78.5	83.1	86.4	83.1	82.9
- tear factor	253	189	151	149	132	126	115
- thickness	216	125	105	93	90	90	87
- density	.288	.498	.591	.644	.661	.665	.695
- bulk	3.47	2.01	1.69	1.55	1.51	1.50	1.44

Treatment: 12
Replication: 3

- beating time	0	15	30	40	45	50	55
- freeness	716	693	596	507	460	385	307
- basis weight	62.6	60.7	62.5	61.2	60.7	62.8	63.0
- breaking length	3674	7622	8768	10610	10390	10801	10751
- stretch	1.82	2.84	3.14	3.16	3.06	3.10	3.18
- burst factor	25.7	65.6	75.6	78.3	78.5	82.6	86.1
- tear factor	207	186	150	137	134	126	116
- thickness	235	126	107	97	94	95	94
- density	.266	.482	.584	.631	.646	.661	.670
- bulk	3.76	2.07	1.71	1.58	1.55	1.51	1.49

Treatment: 12
Replication: 4

- beating time	0	15	30	40	45	50	55
- freeness	704	676	598	488	430	358	300
- basis weight	62.2	62.7	62.7	63.4	61.2	61.6	63.5
- breaking length	3706	7347	9123	9464	9673	10498	10540
- stretch	2.10	3.06	3.40	3.26	3.38	3.50	3.38
- burst factor	23.8	62.2	82.1	82.5	80.9	83.5	82.1
- tear factor	202	182	146	136	137	128	120
- thickness	223	125	105	99	94	92	92
- density	.279	.501	.597	.640	.651	.670	.690
- bulk	3.58	2.00	1.68	1.56	1.54	1.49	1.45

Treatment: 12
Replication: 5

- beating time	0	15	30	40	45	50	55
- freeness	712	686	604	514	451	362	297
- basis weight	63.6	63.7	62.0	62.0	61.7	62.6	62.8
- breaking length	3899	7870	9656	10333	10553	10377	9897
- stretch	2.14	2.78	2.94	3.12	3.20	2.95	2.88
- burst factor	31.8	59.6	81.7	84.8	87.9	84.0	88.7
- tear factor	246	185	145	137	134	126	120
- thickness	216	126	105	101	98	96	94
- density	.294	.505	.590	.615	.632	.649	.668
- bulk	3.40	1.98	1.69	1.63	1.58	1.54	1.50

APPENDIX E

PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 1								
Replication: 1								
- breaking length	-3859.2	15389.6	491.35	.966	.933	5	69.6^{s}	5375
- stretch	- 0.587	2.580	0.1113	.940	.884	5	38.1^{s}	0.96
- burst factor	- 32.80	114.33	3.15	.974	.949	5	93.6^{s}	35.8
- tear factor	490.2	- 549.5	6.38	-.995	.991	5	525.7^{s}	160
Treatment: 1								
Replication: 2								
- breaking length	-3660.0	16020.5	275.10	.989	.978	5	227.0^{s}	5952
- stretch	- 1.582	4.459	0.0811	.988	.976	5	202.5^{s}	1.09
- burst factor	- 30.38	112.39	2.20	.986	.972	5	175.1^{s}	37.0
- tear factor	586.6	- 695.8	8.69	-.994	.988	5	428.6^{s}	169
Treatment: 1								
Replication: 3								
- breaking length	-3349.6	16201.5	327.16	.987	.973	5	182.7^{s}	6371
- stretch	- 1.873	5.306	0.1791	.964	.929	5	65.4^{s}	1.31
- burst factor	- 30.99	124.45	3.96	.968	.936	5	73.5^{s}	43.7
- tear factor	570.9	- 654.6	9.05	-.994	.987	5	389.2^{s}	173

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 1								
Replication: 4								
- breaking length	-2972.2	14620.5	312.33	.984	.968	5	151.5^{s}	5800
- stretch	- 1.601	4.687	0.0950	.985	.971	5	168.2^{s}	1.21
- burst factor	- 14.05	87.35	4.99	.899	.809	5	21.1^{s}	38.4
- tear factor	594.5	- 693.2	12.90	-.988	.976	5	199.7^{s}	179
Treatment: 1								
Replication: 5								
- breaking length	-3071.8	14796.9	198.87	.993	.986	5	346.7^{s}	5806
- stretch	- 1.911	5.410	0.1669	.951	.904	5	47.3^{s}	1.33
- burst factor	- 33.60	121.96	1.86	.991	.982	5	268.7^{s}	39.6
- tear factor	563.0	- 655.2	9.56	-.992	.983	5	294.1^{s}	170
Treatment: 2								
Replication: 1								
- breaking length	-3318.9	15152.8	491.12	.963	.928	5	64.6^{s}	5773
- stretch	1.480	4.407	0.1644	.952	.907	5	48.8^{s}	1.16
- burst factor	30.76	111.35	1.53	.993	.986	5	358.7^{s}	36.0
- tear factor	430.8	- 500.2	15.45	-.967	.934	5	71.2^{s}	131

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	Regression Coefficients b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 2								
Replication: 2								
- breaking length	-4271.9	16955.1	341.66	.988	.977	5	212.5^{s}	5901
- stretch	- 1.740	4.809	0.2198	.944	.892	5	41.3^{s}	1.14
- burst factor	- 44.42	145.05	3.26	.986	.972	5	170.9^{s}	42.6
- tear factor	435.1	- 478.7	7.78	-.992	.985	5	326.7^{s}	148
Treatment: 2								
Replication: 3								
- breaking length	-4076.2	16987.3	466.23	.979	.959	5	116.5^{s}	6116
- stretch	- 1.722	5.057	0.1220	.984	.968	5	150.7^{s}	1.31
- burst factor	- 41.90	144.26	2.99	.988	.976	5	202.9^{s}	44.7
- tear factor	434.6	- 472.3	11.50	-.984	.967	5	148.0^{s}	151
Treatment: 2								
Replication: 4								
- breaking length	-4238.9	16904.7	515.92	.970	.941	5	79.7^{s}	5904
- stretch	- 2.379	6.336	0.1615	.979	.958	5	114.3^{s}	1.42
- burst factor	- 47.80	152.13	2.81	.989	.978	5	217.6^{s}	43.5
- tear factor	541.6	- 639.0	11.27	-.990	.979	5	238.8^{s}	158

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 2								
Replication: 5								
- breaking length	-2880.3	14549.3	171.30	.996	.991	5	569.0^{s}	5849
- stretch	- 1.555	4.694	0.1312	.976	.953	5	100.9^{s}	1.26
- burst factor	- 25.33	107.14	3.73	.964	.929	5	65.0^{s}	39.0
- tear factor	510.0	- 596.7	21.60	-.961	.923	5	60.2^{s}	152
Treatment: 3								
Replication: 1								
- breaking length	-1977.6	13314.9	129.76	.997	.995	5	970.2^{s}	6011
- stretch	0.743	2.919	0.2277	.867	.752	5	15.2^{s}	2.49
- burst factor	- 5.04	83.47	3.71	.950	.903	5	46.5^{s}	45.0
- tear factor	301.5	- 292.5	10.12	-.969	.939	5	77.0^{s}	126
Treatment: 3								
Replication: 2								
- breaking length	-1984.7	12919.3	364.10	.977	.955	5	105.7^{s}	5767
- stretch	1.141	2.149	0.1192	.919	.845	5	27.3^{s}	2.43
- burst factor	2.10	65.86	4.61	.880	.774	5	17.1^{s}	41.6
- tear factor	349.5	- 357.3	4.03	-.996	.992	5	658.9^{s}	135

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 3								
Replication: 3								
- breaking length	-2470.7	13928.3	361.27	.980	.960	5	121.2^{s}	5886
- stretch	1.783	1.300	0.2772	.514	.264	5	1.8^{ns}	2.68^{*}
- burst factor	- 14.10	98.31	2.48	.981	.962	5	128.2^{s}	44.9
- tear factor	313.5	- 306.3	5.01	-.992	.984	5	304.4^{s}	130
Treatment: 3								
Replication: 4								
- breaking length	-1208.1	12065.7	362.95	.975	.949	5	94.4^{s}	6031
- stretch	1.505	1.587	0.2998	.582	.339	5	2.6^{ns}	2.75^{*}
- burst factor	- 3.11	81.77	3.70	.945	.893	5	41.8^{s}	45.9
- tear factor	280.9	- 262.2	6.15	-.984	.969	5	155.4^{s}	124
Treatment: 3								
Replication: 5								
- breaking length	-1308.4	12336.7	273.95	.986	.973	5	178.6^{s}	6094
- stretch	1.970	0.983	0.2486	.465	.216	5	1.4^{ns}	2.77^{*}
- burst factor	- 3.57	83.00	4.13	.936	.877	5	35.5^{s}	46.2
- tear factor	294.0	- 286.7	4.60	-.993	.986	5	341.7^{s}	122

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 4								
Replication: 1								
- breaking length	-2979.3	15261.6	278.87	.992	.984	5	298.5^{s}	6178
- stretch	- 0.248	4.374	0.2124	.946	.894	5	42.3^{s}	2.38
- burst factor	- 23.17	116.22	4.27	.968	.936	5	73.7^{s}	46.6
- tear factor	271.5	- 261.8	4.98	-.991	.982	5	275.5^{s}	114
Treatment: 4								
Replication: 2								
- breaking length	-2632.9	14837.3	395.92	.981	.962	5	128.2^{s}	6269
- stretch	- 0.148	4.376	0.2102	.942	.888	5	39.6^{s}	2.48
- burst factor	- 25.86	122.09	4.96	.958	.917	5	55.2^{s}	47.4
- tear factor	304.0	- 301.9	6.77	-.986	.973	5	181.3^{s}	123
Treatment: 4								
Replication: 3								
- breaking length	-3398.6	16061.8	212.86	.996	.992	5	615.3^{s}	6238
- stretch	0.582	2.973	0.3041	.821	.674	5	10.3^{s}	2.37
- burst factor	- 14.49	98.71	2.80	.982	.964	5	134.0^{s}	44.7
- tear factor	236.2	- 205.2	3.07	-.995	.989	5	483.5^{s}	113

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	Regression Coefficients b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 4								
Replication: 4								
- breaking length	-3216.0	15612.9	321.82	.989	.978	5	226.4^{s}	6152
- stretch	- 0.014	4.146	0.4582	.782	.612	5	7.9^{s}	2.47
- burst factor	- 24.99	115.87	2.90	.984	.968	5	153.5^{s}	44.5
- tear factor	257.4	- 236.1	4.82	-.989	.979	5	231.1^{s}	116
Treatment: 4								
Replication: 5								
- breaking length	-2477.3	13955.8	161.29	.997	.994	5	783.7^{s}	5896
- stretch	0.415	3.449	0.2995	.857	.735	5	13.9^{s}	2.48
- burst factor	- 15.90	102.02	3.74	.969	.939	5	78.0^{s}	45.3
- tear factor	257.9	- 236.9	4.81	-.990	.981	5	253.8^{s}	116
Treatment: 5								
Replication: 1								
- breaking length	-2182.9	13765.9	398.84	.975	.951	5	97.8^{s}	6077
- stretch	2.137	1.546	0.3995	.444	.198	5	1.2^{ns}	3.47^{*}
- burst factor	- 6.54	92.09	2.90	.971	.943	5	82.8^{s}	48.7
- tear factor	317.3	- 302.9	7.99	-.979	.959	5	117.9^{s}	136

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	Regression Coefficients b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 5								
Replication: 2								
- breaking length	-1280.7	11919.7	312.56	.982	.964	5	133.8^{s}	5871
- stretch	1.783	1.589	0.1060	.897	.805	5	20.7^{s}	2.74
- burst factor	- 2.24	80.14	2.36	.977	.955	5	105.8^{s}	45.8
- tear factor	284.0	- 250.3	7.28	-.978	.956	5	108.8^{s}	134
Treatment: 5								
Replication: 3								
- breaking length	-2123.7	13400.9	454.30	.973	.946	5	88.2^{s}	5917
- stretch	2.361	1.901	0.1720	.844	.712	5	12.4^{s}	3.50
- burst factor	- 0.30	78.90	3.13	.963	.928	5	64.5^{s}	47.0
- tear factor	439.1	- 453.2	16.74	-.968	.937	5	74.3^{s}	167
Treatment: 5								
Replication: 4								
- breaking length	-1142.1	11187.4	337.47	.982	.963	5	131.8^{s}	5570
- stretch	1.476	1.848	0.3535	.629	.396	5	3.3^{ns}	3.14^{*}
- burst factor	3.20	68.49	5.66	.882	.778	5	17.5^{s}	44.3
- tear factor	373.3	- 357.3	8.02	-.990	.979	5	238.0^{s}	159

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	Regression Coefficients b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 5								
Replication: 5								
- breaking length	- 818.9	10800.4	443.19	.968	.937	5	73.8^{s}	5661
- stretch	1.218	2.142	0.3121	.734	.539	5	5.8^{ns}	2.72^{*}
- burst factor	2.47	57.64	2.54	.963	.928	5	64.1^{s}	37.0
- tear factor	312.4	- 294.5	12.22	-.967	.935	5	72.2^{s}	136
Treatment: 6								
Replication: 1								
- breaking length	-3138.4	16395.6	454.75	.980	.960	5	119.9^{s}	6699
- stretch	1.769	2.918	0.3804	.721	.520	5	5.4^{ns}	3.75^{*}
- burst factor	- 14.08	111.78	1.74	.994	.987	5	381.8^{s}	52.9
- tear factor	349.2	- 331.9	3.20	-.997	.995	5	989.6^{s}	150
Treatment: 6								
Replication: 2								
- breaking length	-2194.5	13851.3	225.85	.994	.989	5	406.6^{s}	6116
- stretch	1.566	2.055	0.4476	.560	.313	5	2.3^{ns}	3.35^{*}
- burst factor	- 8.96	96.66	4.04	.962	.925	5	61.9^{s}	49.0
- tear factor	332.6	- 304.8	9.41	-.979	.958	5	113.3^{s}	150

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	Regression Coefficients b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 6								
Replication: 3								
- breaking length	-3619.9	17192.9	266.20	.993	.987	5	371.1^{s}	6696
- stretch	1.684	3.429	0.2657	.865	.748	5	14.8^{s}	3.74
- burst factor	- 16.35	118.14	2.09	.991	.983	5	283.8^{s}	54.5
- tear factor	377.2	- 374.6	16.49	-.950	.902	5	45.9^{s}	152
Treatment: 6								
Replication: 4								
- breaking length	-2813.4	15150.9	144.17	.997	.995	5	919.9^{s}	6277
- stretch	1.287	2.895	0.3795	.707	.499	5	5.0^{ns}	3.52^{*}
- burst factor	- 17.83	108.43	4.53	.951	.905	5	47.7^{s}	47.2
- tear factor	322.2	- 316.7	20.04	-.898	.806	5	20.8^{s}	132
Treatment: 6								
Replication: 5								
- breaking length	-2658.8	14605.8	363.35	.983	.966	5	141.2^{s}	6105
- stretch	- 0.180	4.992	0.5368	.776	.602	5	7.6^{s}	2.81
- burst factor	- 23.56	118.50	4.86	.955	.912	5	52.0^{s}	47.5
- tear factor	283.1	- 253.3	10.82	-.952	.905	5	47.9^{s}	131

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	Regression Coefficients b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 7								
Replication: 1								
- breaking length	-3663.3	16848.9	344.40	.987	.974	5	183.9^{s}	6446
- stretch	0.734	1.710	0.1574	.803	.645	5	9.1^{s}	1.76
- burst factor	- 18.41	109.07	4.22	.955	.911	5	51.4^{s}	47.0
- tear factor	460.8	- 491.3	15.49	-.969	.939	5	77.3^{s}	166
Treatment: 7								
Replication: 2								
- breaking length	-1403.1	12782.1	256.44	.989	.978	5	221.9^{s}	6266
- stretch	0.853	1.590	0.1458	.825	.680	5	10.6^{s}	1.81
- burst factor	10.77	61.34	5.64	.824	.678	5	10.6^{s}	47.6
- tear factor	314.4	- 288.5	4.89	-.992	.984	5	310.0^{s}	141
Treatment: 7								
Replication: 3								
- breaking length	-3276.2	16378.0	409.65	.980	.960	5	120.7^{s}	6551
- stretch	0.393	2.555	0.1638	.887	.786	5	18.4^{s}	1.93
- burst factor	- 20.55	105.71	3.45	.967	.934	5	70.9^{s}	42.9
- tear factor	398.3	- 407.1	11.32	-.975	.951	5	97.6^{s}	154

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 7								
Replication: 4								
- breaking length	-1672.6	13272.3	338.60	.982	.964	5	133.7^{s}	6291
- stretch	0.691	1.780	0.0818	.944	.892	5	41.2^{s}	1.76
- burst factor	- 13.59	93.25	2.66	.977	.955	5	106.9^{s}	42.4
- tear factor	317.8	- 295.2	12.45	-.953	.907	5-	48.9^{s}	141
Treatment: 7								
Replication: 5								
- breaking length	-3359.5	15735.6	294.08	.990	.979	5	240.3^{s}	6082
- stretch	0.489	2.139	0.1976	.814	.663	5	9.8^{s}	1.77
- burst factor	- 18.27	98.63	4.72	.938	.880	5	36.7^{s}	40.9
- tear factor	386.3	- 394.9	10.82	-.978	.957	5	111.9^{s}	149
Treatment: 8								
Replication: 1								
- breaking length	-4193.6	18012.1	241.17	.995	.989	5	460.3^{s}	6614
- stretch	- 0.131	3.299	0.2208	.887	.787	5	18.4^{s}	1.84
- burst factor	- 34.10	146.49	6.37	.947	.897	5	43.6^{s}	53.8
- tear factor	424.8	- 468.4	8.09	-.991	.982	5	276.6^{s}	144

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 8								
Replication: 2								
- breaking length	-3085.3	15803.7	491.96	.976	.953	5	101.5^s	6397
- stretch	0.544	2.483	0.2148	.851	.724	5	13.1^s	2.03
- burst factor	- 9.32	102.56	6.71	.906	.821	5	22.9^s	52.2
- tear factor	306.8	- 303.8	18.38	-.918	.843	5	26.9^s	124
Treatment: 8								
Replication: 3								
- breaking length	-4300.7	18488.6	256.09	.995	.990	5	463.6^s	6792
- stretch	- 0.492	4.112	0.2225	.927	.859	5	30.4^s	1.98
- burst factor	- 28.40	127.27	5.48	.952	.906	5	48.0^s	48.0
- tear factor	338.0	- 321.1	7.06	-.987	.974	5	184.0^s	145
Treatment: 8								
Replication: 4								
- breaking length	-3655.9	17085.8	354.48	.986	.972	5	178.4^s	6596
- stretch	- 0.335	3.756	0.2028	.917	.840	5	26.3^s	1.92
- burst factor	- 33.04	141.20	5.25	.958	.918	5	55.6^s	51.7
- tear factor	393.2	- 424.6	9.22	-.985	.970	5	162.6^s	138

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	Regression Coefficients b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 8								
Replication: 5								
- breaking length	-4533.4	18887.4	412.81	.984	.969	5	154.8^{s}	6799
- stretch	- 0.943	4.852	0.2523	.919	.845	5	27.3^{s}	1.97
- burst factor	- 41.96	153.46	6.15	.950	.902	5	46.1^{s}	50.1
- tear factor	357.4	- 372.2	16.86	-.937	.878	5	36.0^{s}	134
Treatment: 9								
Replication: 1								
- breaking length	-3873.2	23886.4	705.27	.976	.953	5	101.0^{s}	10459
- stretch	- 0.580	5.164	0.0683	.995	.990	5	503.3^{s}	2.52
- burst factor	- 45.10	211.56	3.38	.993	.986	5	344.1^{s}	81.8
- tear factor	478.2	- 541.9	5.26	-.990	.980	4	191.8^{s}	153
Treatment: 9								
Replication: 2								
- breaking length	-2937.0	21700.3	337.00	.994	.988	5	423.0^{s}	10083
- stretch	- 0.048	4.146	0.1272	.978	.956	5	108.5^{s}	2.44
- burst factor	- 29.36	177.21	5.82	.975	.950	5	94.7^{s}	77.0
- tear factor	426.1	- 454.1	5.23	-.987	.974	4	148.2	154

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 9								
Replication: 3								
- breaking length	-3922.5	22632.5	441.62	.989	.979	5	234.3^{s}	9657
- stretch	- 0.546	5.122	0.0908	.991	.983	5	283.9^{s}	2.53
- burst factor	- 48.07	215.60	3.27	.994	.987	5	388.6^{s}	81.3
- tear factor	423.3	- 451.6	8.71	-.975	.951	4	78.4^{s}	152
Treatment: 9								
Replication: 4								
- breaking length	-4678.5	24858.0	149.30	.999	.998	5	2566.0^{s}	10236
- stretch	- 0.268	4.202	0.2579	.912	.831	5	24.6^{s}	2.25
- burst factor	- 39.93	196.48	6.44	.972	.945	5	86.3^{s}	78.0
- tear factor	455.1	- 494.2	7.44	-.977	.954	4	82.3^{s}	159
Treatment: 9								
Replication: 5								
- breaking length	-3484.3	20962.0	507.32	.985	.971	5	166.1^{s}	9093
- stretch	- 0.469	5.367	0.1012	.991	.982	5	273.6^{s}	2.75
- burst factor	- 42.18	195.77	5.32	.982	.964	5	131.9^{s}	75.3
- tear factor	509.9	- 601.8	11.08	-.959	.919	4	45.6^{s}	148

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 10								
Replication: 1								
- breaking length	-2257.0	18987.7	417.16	.990	.980	5	248.4^{s}	9136
- stretch	- 0.147	4.769	0.1170	.988	.976	5	199.4^{s}	2.71
- burst factor	- 23.50	168.82	5.14	.981	.963	5	129.2^{s}	77.8
- tear factor	448.9	- 503.8	4.82	-.995	.990	4	380.2^{s}	147
Treatment: 10								
Replication: 2								
- breaking length	-1060.0	16592.9	550.94	.978	.956	5	109.5^{s}	8896
- stretch	- 0.287	4.979	0.1264	.987	.974	5	187.2^{s}	2.70
- burst factor	- 25.18	165.58	3.29	.992	.984	5	304.5^{s}	74.2
- tear factor	418.9	- 481.9	9.62	-.979	.958	4	90.7^{s}	130
Treatment: 10								
Replication: 3								
- breaking length	-2769.8	20220.2	310.07	.994	.989	5	444.9^{s}	9362
- stretch	- 0.163	4.763	0.1233	.984	.969	5	156.2^{s}	2.69
- burst factor	- 27.33	168.06	2.32	.995	.991	5	548.4^{s}	73.5
- tear factor	491.0	- 574.2	8.95	-.984	.968	4	121.0^{s}	146

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	Regression Coefficients b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 10								
Replication: 4								
- breaking length	-1770.3	17948.3	359.7	.988	.976	5	204.7^{s}	8999
- stretch	- 0.631	5.895	0.2529	.948	.899	5	44.7^{s}	2.91
- burst factor	- 31.78	183.81	6.96	.959	.919	5	56.9^{s}	78.5
- tear factor	526.1	- 658.9	2.41	-.998	.997	4	1291.3^{s}	131
Treatment: 10								
Replication: 5								
- breaking length	-3032.3	20984.5	932.00	.957	.916	5	54.8^{s}	9558
- stretch	- 0.327	4.510	0.0977	.989	.979	5	230.4^{s}	2.38
- burst factor	- 30.09	172.79	3.75	.989	.979	5	229.8^{s}	73.6
- tear factor	608.6	- 787.7	10.46	-.988	.977	4	170.6^{s}	136
Treatment: 11								
Replication: 1								
- breaking length	-3588.1	20100.2	337.28	.992	.983	5	292.5^{s}	8472
- stretch	0.300	4.022	0.1805	.944	.891	5	40.9^{s}	2.71
- burst factor	- 42.23	182.35	2.40	.995	.990	5	475.8^{s}	67.2
- tear factor	352.7	- 334.9	3.31	-.997	.994	5	844.9^{s}	152

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 11								
Replication: 2								
- breaking length	-3008.1	19202.2	335.95	.991	.983	5	282.5^{s}	8513
- stretch	0.880	3.310	0.2158	.896	.803	5	20.3^{s}	2.87
- burst factor	- 22.59	145.72	5.07	.967	.935	5	71.4^{s}	64.8
- tear factor	348.4	- 326.2	7.44	-.985	.971	5	166.2^{s}	153
Treatment: 11								
Replication: 3								
- breaking length	-2951.1	18207.4	194.94	.997	.994	5	836.8^{s}	7973
- stretch	0.731	3.632	0.3487	.832	.676	5	10.4^{s}	2.91
- burst factor	- 33.29	165.12	2.27	.995	.990	5	509.4^{s}	65.8
- tear factor	340.4	- 315.4	4.21	-.995	.991	5	539.1^{s}	151
Treatment: 11								
Replication: 4								
- breaking length	-3711.9	20827.8	353.26	.991	.982	5	281.5^{s}	8785
- stretch	0.739	3.231	0.2269	.876	.767	5	16.4^{s}	2.68
- burst factor	- 23.85	150.89	6.05	.954	.909	5	50.3^{s}	66.7
- tear factor	393.0	- 387.6	6.81	-.991	.981	5	261.8^{s}	160

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	Regression Coefficients b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 11								
Replication: 5								
- breaking length	-4859.6	20980.5	340.89	.993	.987	5	371.2^{s}	7729
- stretch	0.553	3.847	0.1777	.950	.902	5	45.9^{s}	2.86
- burst factor	- 24.66	147.33	2.68	.992	.983	5	296.7^{s}	63.7
- tear factor	313.8	- 262.6	5.50	-.989	.978	5	223.1^{s}	156
Treatment: 12								
Replication: 1								
- breaking length	-1009.2	16070.2	409.91	.987	.974	5	191.1^{s}	8633
- stretch	1.234	3.128	0.3790	.793	.629	5	8.5^{s}	3.11
- burst factor	- 10.94	135.13	6.07	.962	.925	5	61.6^{s}	70.1
- tear factor	337.7	- 301.5	5.33	-.994	.988	5	397.4^{s}	157
Treatment: 12								
Replication: 2								
- breaking length	- 327.3	15710.4	456.38	.983	.967	5	145.9^{s}	9099
- stretch	1.182	2.685	0.2391	.870	.756	5	15.5^{s}	2.79
- burst factor	- 17.82	153.85	4.04	.986	.973	5	178.2^{s}	74.5
- tear factor	350.0	- 330.3	6.57	-.992	.984	5	311.2^{s}	152

STATISTICAL VALUES OBTAINED FROM REGRESSION EQUATIONS TESTED FOR USE IN CALCULATING SOME PULP PROPERTIES AS FUNCTION OF HANDSHEET DENSITY (Y = a + b X)

	Regression Coefficients a	b	Standard Error of Estimate	R	R^2	DF	F	Pulp Properties Estimated at .600 g/cc Sheet Density
Treatment: 12								
Replication: 3								
- breaking length	-1086.0	17821.8	330.91	.993	.987	5	370.6^{s}	9607
- stretch	1.089	3.218	0.1523	.959	.919	5	57.0^{s}	3.02
- burst factor	- 8.32	139.77	3.88	.985	.971	5	165.4^{s}	75.5
- tear factor	274.4	- 219.5	10.40	-.959	.919	5	56.9^{s}	143
Treatment: 12								
Replication: 4								
- breaking length	- 954.3	16641.3	204.94	.997	.994	5	829.6^{s}	9030
- stretch	1.292	3.237	0.1379	.966	.933	5	69.3^{s}	3.23
- burst factor	- 15.10	149.66	4.90	.979	.959	5	117.3^{s}	74.7
- tear factor	265.8	- 200.9	9.07	-.962	.925	5	61.8^{s}	145
Treatment: 12								
Replication: 5								
- breaking length	-1243.2	18033.8	513.03	.981	.962	5	126.4^{s}	9577
- stretch	1.494	2.417	0.1582	.909	.827	5	23.9^{s}	2.94
- burst factor	- 15.99	159.48	3.77	.987	.974	5	183.5^{s}	79.7
- tear factor	349.6	- 342.6	4.28	-.996	.992	5	654.8^{s}	144

APPENDIX F

ESTIMATED PULP PROPERTIES AT A CONSTANT HANDSHEET DENSITY OF 0.600 g/cc

Table F-1. BLEACHABLE GRADE PULPS:
ESTIMATED BEATING TIME TO ACHIEVE .600 g/cc
SHEET DENSITY (MINUTES)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	19	22	24	23	24	22	± 3
P. elliottii	19	19	19	19	21	19	± 1
P. taeda	20	22	25	22	24	23	± 2
P. caribaea	21	24	26	27	26	25	± 3
"Slash pine"	40	37	32	39	37	37	± 4
"Loblolly pine"	20	20	20	16	18	19	± 2

Table F-2. UNBLEACHABLE GRADE PULPS:
ESTIMATED BEATING TIME TO ACHIEVE .600 g/cc
SHEET DENSITY (MINUTES)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	41	33	34	27	35	34	± 6
P. elliottii	22	23	20	24	23	22	± 2
P. taeda	20	19	31	20	20	22	± 6
P. caribaea	27	28	28	28	34	29	± 4
"Slash pine"	42	40	44	48	48	44	± 4
"Loblolly pine"	27	32	33	30	34	31	± 3

Table F-3. BLEACHABLE GRADE PULPS:
ESTIMATED BREAKING LENGTH AT A CONSTANT SHEET DENSITY OF .600 g/cc (METERS)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	5375	5952	6371	5800	5806	5861	± 443
P. elliottii	6011	5767	5886	6031	6094	5958	± 162
P. taeda	6077	5871	5917	5570	5661	5819	± 252
P. caribaea	6446	6266	6551	6291	6082	6327	± 223
"Slash pine"	10459	10083	9657	10236	9093	9906	± 670
"Loblolly pine"	8472	8513	7973	8785	7729	8294	± 534

Table F-4. UNBLEACHABLE GRADE PULPS:
ESTIMATED BREAKING LENGTH AT A CONSTANT SHEET DENSITY OF .600 g/cc (METERS)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	5773	5901	6116	5904	5849	5909	± 158
P. elliottii	6178	6269	6238	6152	5896	6147	± 183
P. taeda	6699	6116	6696	6277	6105	6379	± 371
P. caribaea	6614	6397	6792	6596	6799	6640	± 206
"Slash pine"	9136	8896	9362	8999	9558	9190	± 334
"Loblolly pine"	8633	9099	9607	9030	9577	9189	± 507

Table F-5. BLEACHABLE GRADE PULPS: ESTIMATED STRETCH AT A CONSTANT SHEET DENSITY OF .600 g/cc (%)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	0.96	1.09	1.31	1.21	1.33	1.18	±0.19
P. elliottii	2.49	2.43	2.68	2.75	2.77	2.62	±0.19
P. taeda	3.47	2.74	3.50	3.14	2.72	3.11	±0.47
P. caribaea	1.76	1.81	1.93	1.76	1.77	1.81	±0.18
"Slash pine"	2.52	2.44	2.53	2.25	2.75	2.50	±0.22
"Loblolly pine"	2.71	2.87	2.91	2.68	2.86	2.81	±0.13

Table F-6. UNBLEACHABLE GRADE PULPS: ESTIMATED STRETCH AT A CONSTANT SHEET DENSITY OF .600 g/cc (%)

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	1.16	1.14	1.31	1.42	1.26	1.26	± 0.14
P. elliottii	2.38	2.48	2.37	2.47	2.48	2.44	± 0.07
P. taeda	3.75	3.35	3.74	3.52	2.81	3.43	± 0.48
P. caribaea	1.84	2.03	1.98	1.92	1.97	1.95	± 0.09
"Slash pine"	2.71	2.70	2.69	2.91	2.38	2.68	± 0.23
"Loblolly pine"	3.11	2.79	3.02	3.23	2.94	3.02	± 0.21

Table F-7. BLEACHABLE GRADE PULPS:
ESTIMATED BURST FACTOR AT A CONSTANT SHEET DENSITY OF .600 g/cc

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	35.8	37.0	43.7	38.4	39.6	38.9	±3.8
P. elliottii	45.0	41.6	44.9	45.9	46.2	44.7	±2.3
P. taeda	48.7	45.8	47.0	44.3	37.0	44.6	±5.6
P. caribaea	47.0	47.6	42.9	42.4	40.9	44.2	±3.7
"Slash pine"	81.8	77.0	81.3	78.0	75.3	78.7	±3.5
"Loblolly pine"	67.2	64.8	65.8	66.7	63.7	65.6	±1.8

Table F-8. UNBLEACHABLE GRADE PULPS:
ESTIMATED BURST FACTOR AT A CONSTANT SHEET DENSITY OF .600 g/cc

Species	replication					Mean	Confidence Interval(95%)
	1	2	3	4	5		
A. angustifolia	36.0	42.6	44.7	43.5	39.0	41.2	± 4.4
P. elliottii	46.6	47.4	44.7	44.5	45.3	45.7	± 1.6
P. taeda	52.9	49.0	54.5	47.2	47.5	50.2	± 4.1
P. caribaea	53.8	52.2	48.0	51.7	50.1	51.2	± 2.7
"Slash pine"	77.8	74.2	73.5	78.5	73.6	75.5	± 3.0
"Loblolly pine"	70.1	74.5	75.5	74.7	79.7	74.9	± 4.2

Table F-9. BLEACHABLE GRADE PULPS:
ESTIMATED TEAR FACTOR AT A CONSTANT SHEET DENSITY OF .600 g/cc

Species	replication					Mean	Confidence Interval (95%)
	1	2	3	4	5		
A. angustifolia	160	169	173	179	170	170	± 9
P. elliottii	126	135	130	124	122	127	± 6
P. taeda	136	134	167	159	136	146	± 19
P. caribaea	166	141	154	141	149	150	± 13
"Slash pine"	153	154	152	159	148	153	± 5
"Loblolly pine"	152	153	151	160	156	154	± 5

Table F-10. UNBLEACHABLE GRADE PULPS:
ESTIMATED TEAR FACTOR AT A CONSTANT SHEET DENSITY OF .600 g/cc

Species	replication					Mean	Confidence Interval(95%)
	1	2	3	4	5		
A. angustifolia	131	148	151	158	152	148	± 13
P. elliottii	114	123	113	116	116	116	± 5
P. taeda	150	150	152	132	131	143	± 13
P. caribaea	144	124	145	138	134	137	± 11
"Slash pine"	147	130	146	131	136	138	± 10
"Loblolly pine"	157	152	143	145	144	148	± 8

APPENDIX G

STATISTICAL ANALYSES OF THE PULP PROPERTIES BRAZILIAN WOODS

Total Yield (percent of oven-dry wood)

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	3	43.952	8.64^{s}
- K Number	1	126.406	24.84^{s}
- Species × K Number	3	17.117	3.36^{s}
- (Treatment)	(7)	44.231	8.69^{s}
- Error	32	5.088	
- Total	39		

Cochran's ratio: 0.1808^{ns}

Coefficient of variation: 4.62%

2. Minimum significant difference to be used for comparing the influence of species according to Tukey's test

Minimum significant difference: 2.73

(5% level of significance)

3. Significance of the contrasts between means tested by the Tukey's test

Species	Mean	A. angustifolia	Pinus eliottii	Pinus taeda	Pinus caribaea
A. angustifolia	51.82	-	4.58^{s}	3.33^{s}	4.26^{s}
P. elliottii	47.24		-	1.25^{ns}	0.32^{ns}
P. taeda	48.49			-	0.93^{ns}
P. caribaea	47.56				

s = statistically significant at 5% level

Screened Yield (percent of oven-dry wood)

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	3	60.687	11.37^{s}
- K Number	1	114.244	21.40^{s}
- Species × K Number	3	12.478	2.34^{ns}
- (Treatment)	(7)	47.677	8.93^{s}
- Error	32	5.338	
- Total	39		

Cochran's ratio: 0.2617^{ns}

Coefficient of variation: 4.81%

2. Minimum significant difference to be used for comparing the influence of species according to Tukey's test

Minimum significant difference: 2.80

(5% level of significance)

3. Significance of the contrasts between means tested by the Tukey's test

Species	Mean	A. angustifolia	Pinus eliottii	Pinus taeda	Pinus caribaea
A. angustifolia	51.42	-	4.66^{s}	3.45^{s}	5.65^{s}
P. elliottii	46.76		-	1.21^{ns}	0.99^{ns}
P. taeda	47.97			-	2.20^{ns}
P. caribaea	45.77				-

s = statistically significant at 5% level

STATISTICAL ANALYSIS OF THE PULP PROPERTIES

Total Yield (percent of oven-dry extractive-free wood)

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	3	45.247	8.94^{s}
- K Number	1	142.884	28.22^{s}
- Species × K Number	3	14.574	2.88^{ns}
- (Treatment)	(7)	46.050	9.14^{s}
- Error	32	5.063	
- Total	39		

Cochran's ratio: 0.1852^{ns}

Coefficient of variation: 4.51%

2. Minimum significant difference to be used for comparing the influence of species according to Tukey's test.

Minimum significant difference: 2.72

(5% level of significance)

3. Significance of the contrasts between means tested by the Tukey's test

Species	Mean	A. angustifolia	Pinus eliottii	Pinus taeda	Pinus caribaea
A. angustifolia	53.00	-	4.35^{s}	3.49^{s}	4.60^{s}
P. elliottii	48.65		-	0.86^{ns}	0.25^{ns}
P. taeda	49.51			-	1.11^{ns}
P. caribaea	48.40				-

s = statistically significant at 5% level

STATISTICAL ANALYSIS OF THE PULP PROPERTIES

Screened Yield (percent of oven-dry extractive-free wood)

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	3	64.983	12.33^{s}
- K Number	1	128.842	24.44^{s}
- Species × K Number	3	9.982	1.89^{ns}
- (Treatment)	(7)	50.534	9.58^{s}
- Error	32	5.272	
- Total	39		

Cochran's ratio: 0.2550^{ns}

Coefficient of variation: 4.68%

2. Minimum significant difference to be used for comparing the influence of species according to Tukey's test

Minimum significant difference: 2.78

(5% level of significance)

3. Significance of the contrasts between means tested by the Tukey's test

Species	Mean	A. angustifolia	Pinus eliottii	Pinus taeda	Pinus caribaea
A. angustifolia	52.60	-	4.44^{s}	3.61^{s}	6.02^{s}
P. elliottii	48.16		-	0.83^{ns}	1.58^{ns}
P. taeda	48.99			-	2.41^{ns}
P. caribaea	46.58				-

s = statistically significant at 5% level

STATISTICAL ANALYSIS OF THE PULP PROPERTIES ESTIMATED AT A CONSTANT SHEET DENSITY OF 0.600 g/cc

Beating Time

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	3	124.092	13.17^{s}
- K Number	1	153.375	16.28^{s}
- Species × K Number	3	83.508	8.86^{s}
- (Treatment)	(7)	110.882	11.77^{s}
- Error	32	9.420	
- Total	39		

Cochran's ratio: 0.3382^{ns}

Coefficient of variation: 12.49%

2. Minimum significant difference to be used for comparing the influence of species according to Tukey's test.

Minimum significant difference: 3.7

(5% level of significance)

3. Significance of the contrasts between means tested by the Tukey's test

Species	Mean	A. angustifolia	Pinus eliottii	Pinus taeda	Pinus caribaea
A. angustifolia	28.2	-	7.3^{s}	5.9^{s}	1.30^{ns}
P. elliottii	20.9		-	1.4^{ns}	6.00^{s}
P. taeda	22.3			-	4.60^{s}
P. caribaea	26.9				-

s = statistically significant at 5% level

STATISTICAL ANALYSIS OF THE PULP PROPERTIES ESTIMATED AT A CONSTANT SHEET DENSITY OF 0.600 g/cc

Breaking Length

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	3	640278.5	13.71^{s}
- K Number	1	767844.1	16.44^{s}
- Species × K Number	3	353286.9	7.56^{s}
- (Treatment)	(7)	434566.6	9.30^{s}
- Error	32	46706.4	
- Total	39		

Cochran's ratio: 0.3421^{ns}

Coefficient of variation: 3.53%

2. Minimum significant difference to be used for comparing the influence of species according to Tukey's test

Minimum significant difference: 261.7

(5% level of significance)

3. Significance of the contrasts between means tested by the Tukey's test

Species	Mean	A. angustifolia	Pinus eliottii	Pinus taeda	Pinus caribaea
A. angustifolia	5884.7	-	167.5^{ns}	214.2^{ns}	598.7^{s}
P. elliottii	6052.2		-	46.7^{ns}	431.2^{s}
P. taeda	6098.9			-	384.5^{s}
P. caribaea	6483.4				-

s = statistically significant at 5% level

STATISTICAL ANALYSIS OF THE PULP PROPERTIES ESTIMATED AT A CONSTANT SHEET DENSITY OF 0.600 g/cc

Stretch

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	3	7.755	168.59^{s}
- K Number	1	0.077	1.68^{ns}
- Species × K Number	3	0.111	2.41^{ns}
- (Treatment)	(7)	3.382	75.53^{s}
- Error	32	0.046	
- Total	39		

Cochran's ratio: 0.3902^{ns}

Coefficient of variation: 9.62%

2. Minimum significant difference to be used for comparing the influence of species according to Tukey's test

Minimum significant difference: 0.260

(5% level of significance)

3. Significance of the contrasts between means tested by the Tukey's test

Species	Mean	A. angus-tifolia	Pinus eliottii	Pinus taeda	Pinus caribaea
A. angustifolia	1.219	-	1.311^{s}	2.055^{s}	0.658^{s}
P. elliottii	2.530		-	0.744^{s}	0.653^{s}
P. taeda	3.274			-	1.397^{s}
P. caribaea	1.877				-

s = statistically significant at 5% level

STATISTICAL ANALYSIS OF THE PULP PROPERTIES ESTIMATED AT A CONSTANT SHEET DENSITY OF 0.600 g/cc

Burst Factor

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	3	125.039	13.89^{s}
- K Number	1	149.390	16.59^{s}
- Species × K Number	3	22.789	2.53^{ns}
- (Treatment)	(7)	84.697	9.41^{s}
- Error	32	9.004	
- Total	39		

Cochran's ratio: 0.2841^{ns}

Coefficient of variation: 6.66%

2. Minimum significant difference to be used for comparing the influence of species according to Tukey's test

Minimum significant difference: 3.63

(5% level of significance)

3. Significance of the contrasts between means tested by the Tukey's test

Species	Mean	A. angustifolia	Pinus eliottii	Pinus taeda	Pinus caribaea
A. angustifolia	40.03	-	5.18^{s}	7.36^{s}	7.63^{s}
P. elliottii	45.21		-	2.18^{ns}	2.45^{ns}
P. taeda	47.39			-	0.27^{ns}
P. caribaea	47.66				-

s = statistically significant at 5% level

STATISTICAL ANALYSIS OF THE PULP PROPERTIES ESTIMATED AT A CONSTANT SHEET DENSITY OF 0.600 g/cc

Tear Factor

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	3	2352.82	25.99^{s}
- K Number	1	1847.18	20.40^{s}
- Species × K Number	3	50.64	0.56^{ns}
- (Treatment)	(7)	1293.94	14.29^{s}
- Error	32	90.54	
- Total	39		

Cochran's ratio: 0.3290^{ns}

Coefficient of variation: 6.68%

2. Minimum significant difference to be used for comparing the influence of species according to Tukey's test.

Minimum significant difference: 11.5

(5% level of significance)

3. Significance of the contrasts between means tested by the Tukey's test

Species	Mean	A. angus-tifolia	Pinus eliottii	Pinus taeda	Pinus caribaea
A. angustifolia	159.1	-	37.2^{s}	14.4^{s}	15.5^{s}
P. elliottii	121.9		-	22.8^{s}	21.7^{s}
P. taeda	144.7			-	1.1^{ns}
P. caribaea	143.6				-

s = statistically significant at 5% level

INFLUENCE OF THE PERMANGANATE NUMBER (K NUMBER) AS EXPRESSED BY THE DIFFERENCE BETWEEN THE OVERALL MEANS FOR BOTH INTERVALS WHICH WERE STUDIED. The influence was tested by the F test (see corresponding analysis of variance table).

Total Yield (percent of oven-dry wood)

K Number	Mean	between 16-18	between 25-30
between 16-18	46.93	-	3.69
between 25-30	50.62		-

F ratio = 24.84^{s}

s = statistically significant at 5% level

Screened Yield (percent of oven-dry wood)

K Number	Mean	between 16-18	between 25-30
between 16-18	46.29	-	3.38
between 25-30	49.67		-

F ratio = 21.40^{s}

s = statistically significant at 5% level

Total Yield (percent of oven-dry extractive-free wood)

K Number	Mean	between 16-18	between 25-30
between 16-18	48.00	-	3.78
between 25-30	51.78		-

F ratio = 28.22^{s}

s = statistically significant at 5% level

INFLUENCE OF THE PERMANGANATE NUMBER (K NUMBER) AS EXPRESSED BY THE DIFFERENCE BETWEEN THE OVERALL MEANS FOR BOTH INTERVALS WHICH WERE STUDIED. The influence was tested by the F test (see corresponding analysis of variance table).

Screened Yield (percent of oven-dry extractive-free wood)

K Number	Mean	between 16-18	between 25-30
between 16-18	47.36	-	3.45
between 25-30	50.81		-

F ratio = 24.44^{s}

s = statistically significant at 5% level

Beating Time

K Number	Mean	between 16-18	between 25-30
between 16-18	22.3	-	4.5
between 25-30	26.8		-

F ratio = 16.28^{s}

s = statistically significant at 5% level

Breaking Length

K Number	Mean	between 16-18	between 25-30
between 16-18	5991.2	-	277.2
between 25-30	6268.4		-

F ratio = 16.44^{s}

s = statistically significant at 5% level

INFLUENCE OF THE PERMANGANATE NUMBER (K NUMBER) AS EXPRESSED BY THE DIFFERENCE BETWEEN THE OVERALL MEANS FOR BOTH INTERVALS WHICH WERE STUDIED. The influence was tested by the F test (see corresponding analysis of variance table).

Stretch

K Number	Mean	between 16-18	between 25-30
between 16-18	2.181	-	0.088
between 25-30	2.269		-

F ratio = 1.68^{ns}

s = statistically significant at 5% level

Burst Factor

K Number	Mean	between 16-18	between 25-30
between 16-18	43.08	-	3.98
between 25-30	47.06		-

F ratio = 16.59^{s}

s = statistically significant at 5% level

Tear Factor

K Number	Mean	between 16-18	between 25-30
between 16-18	148.6	-	12.5
between 25-30	136.1		-

F ratio = 20.40^{s}

s = statistically significant at 5% level

APPENDIX H

STATISTICAL ANALYSES OF THE PULP PROPERTIES AMERICAN WOODS

STATISTICAL ANALYSIS OF THE PULP PROPERTIES

Total Yield (percent of oven-dry wood)

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	1	26.450	58.78^{s}
- K Number	1	43.218	96.04^{s}
- Species × K Number	1	0.582	1.29^{ns}
- (Treatment)	(3)	23.417	52.04^{s}
- Error	16	0.450	
- Total	19		

Cochran's ratio: 0.3997^{ns}

Coefficient of variation: 1.51%

2. Influence of the species as expressed by the difference between the overall means for both species which were studied. The influence was tested by the F test (see analysis of variance table).

Species	Mean	Slash pine	Loblolly pine
- Slash pine	45.60	-	2.30
- Loblolly pine	43.30		-

F ratio = 58.78^{s}

3. Influence of the permanganate number (K Number) as expressed by the difference between the overall means for both intervals which were studied. The influence was tested by the F test (see analysis of variance table).

K Number	Mean	between 16-18	between 25-30
- between 16-18	42.98	-	2.94
- between 25-30	45.92		-

F ratio = 96.04^{s}

STATISTICAL ANALYSIS OF THE PULP PROPERTIES

Screened Yield (percent of oven-dry wood)

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	1	39.200	87.69^{s}
- K Number	1	28.322	63.36^{s}
- Species × K Number	1	2.048	4.58^{s}
- (Treatment)	(3)	23.190	51.88^{s}
- Error	16	0.447	
- Total	19		

Cochran's ratio: 0.3551^{ns}

Coefficient of variation: 1.52%

2. Influence of the species as expressed by the difference between the overall means for both species which were studied. The influence was tested by the F test (see analysis of variance table).

Species	Mean	Slash pine	Loblolly pine
- Slash pine	45.27	-	2.80
- Loblolly pine	42.47		-

F ratio = 87.69^{s}

3. Influence of the permanganate number (K Number) as expressed by the difference between the overall means for both intervals which were studied. The influence was tested by the F test (see analysis of variance table).

K Number	Mean	between 16-18	between 25-30
- between 16-18	42.68	-	2.38
- between 25-30	45.06		-

F ratio = 63.36^{s}

STATISTICAL ANALYSIS OF THE PULP PROPERTIES

Total Yield (percent of oven-dry extractive-free wood)

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	1	26.912	45.00^{s}
- K Number	1	46.818	78.29^{s}
- Species × K Number	1	0.578	0.97^{ns}
- (Treatment)	(3)	24.769	41.42^{s}
- Error	16	0.598	
- Total	19		

Cochran's ratio: 0.3963^{ns}

Coefficient of variation: 1.66%

2. Influence of the species as expressed by the difference between the overall means for both species which were studied. The influence was tested by the F test (see analysis of variance table).

Species	Mean	Slash pine	Loblolly pine
- Slash pine	47.82	-	2.32
- Loblolly pine	45.50		-

F ratio = 45.00^{s}

3. Influence of the permanganate number (K Number) as expressed by the difference between the overall means for both intervals which were studied. The influence was tested by the F test (see analysis of variance table).

K Number	Mean	between 16-18	between 25-30
- between 16-18	45.13	-	3.06
- between 25-30	48.19		-

F ratio = 78.29^{s}

STATISTICAL ANALYSIS OF THE PULP PROPERTIES

Screened Yield (percent of oven-dry extractive-free wood)

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	1	40.004	58.31^{s}
- K Number	1	31.000	45.19^{s}
- Species × K Number	1	2.153	3.14^{ns}
- (Treatment)	(3)	24.386	35.55^{s}
- Error	16	0.686	
- Total	19		

Cochran's ratio: 0.4327^{ns}

Coefficient of variation: 1.80%

2. Influence of the species as expressed by the difference between the overall means for both species which were studied. The influence was tested by the F test (see analysis of variance table).

Species	Mean	Slash pine	Loblolly pine
- Slash pine	47.45	-	2.83
- Loblolly pine	44.62		-

F ratio = 58.31^{s}

3. Influence of the permanganate number (K Number) as expressed by the difference between the overall means for both intervals which were studied. The influence was tested by the F test (see analysis of variance table).

K Number	Mean	between 16-18	between 25-30
- between 16-18	44.79	-	2.49
- between 25-30	47.28		-

F ratio = 45.19^{s}

STATISTICAL ANALYSIS OF THE PULP PROPERTIES ESTIMATED AT A CONSTANT SHEET DENSITY OF 0.600 g/cc

Beating Time

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	1	1232.45	148.49^{s}
- K Number	1	490.05	59.04^{s}
- Species × K Number	1	31.25	3.76^{ns}
- (Treatment)	(3)	584.58	70.43^{s}
- Error	16	8.30	
- Total	19		

Cochran's ratio: 0.3855^{ns}

Coefficient of variation: 8.77%

2. Influence of the species as expressed by the difference between the overall means for both species which were studied. The influence was tested by the F test (see analysis of variance table).

Species	Mean	Slash pine	Loblolly pine
- Slash pine	40.7	-	15.7
- Loblolly pine	25.0		-

F ratio = 148.49^{s}

3. Influence of the permanganate number (K Number) as expressed by the difference between the overall means for both intervals which were studied. The influence was tested by the F test (see analysis of variance table).

K Number	Mean	between 16-18	between 25-30
- between 16-18	27.9	-	9.9
- between 25-30	37.8		-

F ratio = 59.04^{s}

STATISTICAL ANALYSIS OF THE PULP PROPERTIES ESTIMATED AT A CONSTANT SHEET DENSITY OF 0.600 g/cc

Breaking Length

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	1	3248986.05	18.11^{s}
- K Number	1	40230.45	0.22^{ns}
- Species × K Number	1	3240930.05	18.06^{s}
- (Treatment)	(3)	2176715.52	12.13^{s}
- Error	16	179414.00	
- Total	19		

Cochran's ratio: 0.2588^{ns}

Coefficient of variation: 4.63%

2. Influence of the species as expressed by the difference between the overall means for both species which were studied. The influence was tested by the F test (see analysis of variance table).

Species	Mean	Slash pine	Loblolly pine
- Slash pine	9547.9	-	806.1
- Loblolly pine	8741.8		-

F ratio = 18.11^{s}

3. Influence of the permanganate number (K Number) as expressed by the difference between the overall means for both intervals which were studied. The influence was tested by the F test (see analysis of variance table).

K Number	Mean	between 16-18	between 25-30
- between 16-18	9100.0	-	89.7
- between 25-30	9189.7		-

F ratio = 0.22^{ns}

STATISTICAL ANALYSIS OF THE PULP PROPERTIES ESTIMATED AT A CONSTANT SHEET DENSITY OF 0.600 g/cc

Stretch

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	1	0.5249	19.58^{s}
- K Number	1	0.1921	7.17^{s}
- Species × K Number	1	0.0012	0.04^{ns}
- (Treatment)	(3)	0.2394	8.93^{s}
- Error	16	0.0268	
- Total	19		

Cochran's ratio: 0.3367^{ns}

Coefficient of variation: 5.95%

2. Influence of the species as expressed by the difference between the overall means for both species which were studied. The influence was tested by the F test (see analysis of variance table).

Species	Mean	Slash pine	Loblolly pine
- Slash pine	2.588	-	0.324
- Loblolly pine	2.912		-

F ratio = 19.58^{s}

3. Influence of the permanganate number (K Number) as expressed by the difference between the overall means for both intervals which were studied. The influence was tested by the F test (see analysis of variance table).

K Number	Mean	between 16-18	between 25-30
- between 16-18	2.652	-	0.196
- between 25-30	2.848		-

F ratio = 7.17^{s}

STATISTICAL ANALYSIS OF THE PULP PROPERTIES ESTIMATED AT A CONSTANT SHEET DENSITY OF 0.600 g/cc

Burst Factor

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	1	223.244	34.05^{s}
- K Number	1	46.512	6.79^{s}
- Species × K Number	1	202.822	29.61^{s}
- (Treatment)	(3)	157.526	22.99^{s}
- Error	16	6.849	
- Total	19		

Cochran's ratio: 0.4256^{ns}

Coefficient of variation: 3.55%

2. Influence of the species as expressed by the difference between the overall means for both species which were studied. The influence was tested by the F test (see analysis of variance table).

Species	Mean	Slash pine	Loblolly pine
- Slash pine	77.10	-	6.83
- Loblolly pine	70.27		-

F ratio = 34.05^{s}

3. Influence of the permanganate number (K Number) as expressed by the difference between the overall means for both intervals which were studied. The influence was tested by the F test (see analysis of variance table).

K Number	Mean	between 16-18	between 25-30
- between 16-18	72.16	-	3.05
- between 25-30	75.21		-

F ratio = 6.79^{s}

STATISTICAL ANALYSIS OF THE PULP PROPERTIES ESTIMATED AT A CONSTANT SHEET DENSITY OF 0.600 g/cc

Tear Factor

1. Analysis of variance table

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
- Species	1	162.45	4.95^{s}
- K Number	1	572.45	17.45^{s}
- Species × K Number	1	101.25	3.09^{ns}
- (Treatment)	(3)	278.72	8.50^{s}
- Error	16	32.80	
- Total	19		

Cochran's ratio: 0.4992^{ns}

Coefficient of variation: 3.86%

2. Influence of the species as expressed by the difference between the overall means for both species which were studied. The influence was tested by the F test (see analysis of variance table).

Species	Mean	Slash pine	Loblolly pine
- Slash pine	145.6	-	5.7
- Loblolly pine	151.3		-

F ratio = 4.95^{s}

3. Influence of the permanganate number (K Number) as expressed by the difference between the overall means for both intervals which were studied. The influence was tested by the F test (see analysis of variance table).

K Number	Mean	between 16-18	between 25-30
- between 16-18	153.8	-	10.7
- between 25-30	143.1		-

F ratio = 17.45^{s}

APPENDIX I

ANALYSES OF THE PULP PROPERTIES

REJECT CONTENT

ANALYSIS OF THE PULP PROPERTIES

Reject Content (percent of oven-dry wood) for the pulps obtained from the Brazilian woods.

1. Influence of species as expressed by pairwise comparisons between the overall means for the species under investigation.

Species	Mean	A. angus-tifolia	Pinus eliottii	Pinus taeda	Pinus caribaea
A. angustifolia	0.40	-	0.08	0.12	1.39
P. elliottii	0.48		-	0.04	1.31
P. taeda	0.52			-	1.27
P. caribaea	1.79				-

2. Influence of the permanganate number (K Number) as expressed by the difference between the overall means for both intervals which were studied.

K Number	Mean	between 16-18	between 25-30
between 16-18	0.64	-	0.32
between 25-30	0.96		-

ANALYSIS OF THE PULP PROPERTIES

Reject Content (percent of oven-dry extractive-free wood) for the pulps obtained from the Brazilian woods.

1. Influence of species as expressed by pairwise comparisons between the overall means for the species under investigation.

Species	Mean	A. angus-tifolia	Pinus eliottii	Pinus taeda	Pinus caribaea
A. angustifolia	0.40	-	0.09	0.12	1.42
P. elliottii	0.49		-	0.03	1.33
P. taeda	0.52			-	1.30
P. caribaea	1.82				-

2. Influence of the permanganate number (K Number) as expressed by the difference between the overall means for both intervals which were studied.

K Number	Mean	between 16-18	between 25-30
between 16-18	0.64	-	0.33
between 25-30	0.97		-

ANALYSIS OF THE PULP PROPERTIES

Reject Content (percent of oven-dry wood) for the pulps obtained from the American woods.

1. Influence of the species as expressed by the difference between the overall means for both species which were studied.

Species	Mean	Slash pine	Loblolly pine
Slash pine	0.33	-	0.50
Loblolly pine	0.83		-

2. Influence of the permanganate number (K Number) as expressed by the difference between the overall means for both intervals which were studied.

K Number	Mean	between 16-18	between 25-30
between 16-18	0.30	-	0.56
between 25-30	0.86		-

ANALYSIS OF THE PULP PROPERTIES

Reject Content (percent of oven-dry extractive-free wood) for the pulps obtained from the American woods.

1. Influence of the species as expressed by the difference between the overall means for both species which were studied.

Species	Mean	Slash pine	Loblolly pine
Slash pine	0.37	-	0.51
Loblolly pine	0.88		-

2. Influence of the permanganate number (K Number) as expressed by the difference between the overall means for both intervals which were studied.

K Number	Mean	between 16-18	between 25-30
between 16-18	0.34	-	0.47
between 25-30	0.91		-

APPENDIX J

CORRELATION MATRICES

TABLE J-1

NOTATION USED IN THE PRESENTATION OF THE MATRICES

FL = unbroken fiber length

FW = fiber width

LD = lumen diameter

CWT= cell wall thickness

SG = unextracted specific gravity

ESG= extracted specific gravity

FC = felting coefficient of the fibers

CF = coefficient of flexibility of the fibers

WF = wall fraction of the fibers

L/C= fiber length/cell wall thickness ratio

RI = Runkel index

MR = Mulsteph ratio

BN = Boiler number

CWS= cold water solubility of the woods

HWS= hot water solubility of the woods

CSS= 1% caustic soda solubility of the woods

ABS= alcohol-benzene solubility of the woods

ES = ether solubility of the woods

PC = pentosans content of the woods

LC = lignin content of the woods

CBC= Cross and Bevan cellulose content of the woods

AC = ash content of the woods

PN = permanganate number of the pulps

IY = total pulp yield (oven-dry wood basis)

SY = screened pulp yield (oven-dry wood basis)

TABLE J-1--Continued

RC = rejects content (oven-dry wood basis)

ETY= total pulp yield (oven-dry extractive-free wood basis)

ESY= screened pulp yield (oven-dry extractive-free wood basis)

ERC= reject content (oven-dry extractive-free wood basis)

BT = estimated beating time to achieve 0.600 g/cc sheet density

BL = estimated breaking length at a constant sheet density of 0.600 g/cc

S = estimated stretch at a constant sheet density of 0.600 g/cc

BF = estimated burst factor at a constant sheet density of 0.600 g/cc

TF = estimated tear factor at a constant sheet density of 0.600 g/cc

Table J-2 . CORRELATION COEFFICIENTS BETWEEN THE PROPERTIES OF THE BRAZILIAN WOODS *

	FL	FW	LD	CWT	SG	ESG	FC	CF	WF	L/C	RI
FL	1.00	.28	-.03	.79	.83	.83	.94	-.63	.62	.78	.64
FW		1.00	.92	.19	.04	.05	-.06	.31	-.34	.30	-.31
LD			1.00	-.19	-.19	-.16	-.36	.65	-.66	.19	-.65
CWT				1.00	.50	.48	.73	-.84	.85	.22	.86
SG					1.00	.99	.86	-.53	.48	.78	.49
ESG						1.00	.84	-.51	.45	.79	.47
FC							1.00	-.76	.76	.72	.76
CF								1.00	-.97	-.12	-.98
WF									1.00	.09	.99
L/C										1.00	.11
RI											1.00

* All correlation coefficients above 0.44 and below - 0.44 are significant at the 5% level.

Table J-2 . CONTINUED *

	MR	BN	CWS	HWS	CSS	ABS	ES	PC	LC	CBC	AC
FL	.60	.64	-.14	-.25	-.12	-.08	.08	-.86	-.01	.62	-.15
FW	-.35	-.31	-.24	.35	.56	-.33	-.05	-.24	.33	-.33	-.22
LD	-.68	-.66	-.28	.35	.64	-.38	-.15	.06	.43	-.55	-.19
CWT	.81	.84	.04	-.08	-.25	.18	.26	-.74	-.21	.56	-.08
SG	.51	.54	-.06	-.23	.01	-.20	-.01	-.67	-.10	.60	-.08
ESG	.48	.51	-.09	-.24	.03	-.25	-.06	-.67	-.08	.58	-.10
FC	.74	.76	-.09	-.42	-.31	.01	.09	-.82	-.08	.75	-.09
CF	-.99	-1.00	-.21	.19	.47	-.26	-.27	.63	.38	-.68	-.03
WF	.95	.96	.15	-.31	-.54	.29	.23	-.60	-.36	.71	.03
L/C	.10	.13	-.26	-.30	.08	-.31	-.12	-.61	.24	.37	-.17
RI	.97	.98	.15	-.26	-.49	.27	.25	-.63	-.33	.69	-.01
MR	1.00	.99	.19	-.17	-.48	.31	.32	-.61	-.38	.69	.01
BN		1.00	.19	-.19	-.46	.25	.26	-.64	-.38	.68	.02
CWS			1.00	.55	-.28	.43	.44	.31	-.46	-.02	.16
HWS				1.00	.33	.22	.37	.35	-.13	-.32	-.01
CSS					1.00	-.33	-.03	.08	.56	-.56	-.19
ABS						1.00	.83	.11	-.26	.24	.26
ES							1.00	-.06	.01	.08	-.01
PC								1.00	-.07	-.55	.19
LC									1.00	-.39	-.57
CBC										1.00	.17
AC											1.00

* All correlation coefficients above 0.44 and below - 0.44 are significant at the 5% level.

Table J-3 . CORRELATION COEFFICIENTS BETWEEN THE PROPERTIES OF THE AMERICAN WOODS *

	FL	FW	LD	CWT	SG	ESG	FC	CF	WF	L/C	RI
FL	1.00	.46	-.30	.78	.92	.91	.85	-.72	.72	-.45	.72
FW		1.00	.59	.38	.57	.56	-.05	-.16	.16	-.30	.13
LD			1.00	-.50	-.18	-.12	-.65	.68	-.68	.43	-.71
CWT				1.00	.76	.68	.61	-.97	.97	-.90	.96
SG					1.00	.99	.71	-.67	.67	-.46	.68
ESG						1.00	.71	-.59	.59	-.36	.59
FC							1.00	-.67	.67	-.25	.69
CF								1.00	-1.00	.88	-.99
WF									1.00	-.88	.99
L/C										1.00	-.86
RI											1.00

* All correlation coefficients above 0.63 and below - 0.63 are significant at the 5% level.

Table J-3 . CONTINUED *

	MR	BN	CWS	HWS	CSS	ABS	ES	PC	LC	CBC	AC
FL	.77	.76	-.12	-.03	-.20	-.06	-.36	-.85	-.52	.74	.20
FW	.19	.19	.10	.18	.02	-.03	-.07	-.69	-.36	.50	.40
LD	-.68	-.68	.38	.33	.25	.38	.03	-.02	.06	-.11	.38
CWT	.95	.95	-.24	-.05	-.19	.42	-.08	-.73	-.48	.54	-.08
SG	.72	.73	-.30	-.25	-.34	-.06	.29	-.85	-.59	.73	-.02
ESG	.64	.64	-.29	-.24	-.35	.21	.34	-.87	-.53	.70	.01
FC	.73	.73	-.23	-.22	-.29	-.06	-.37	-.52	-.39	.60	.05
CF	-.97	-.97	.28	.11	.23	-.47	.07	.60	.44	-.47	.15
WF	.97	.97	-.28	-.11	-.23	.47	-.07	-.60	-.44	.47	-.15
L/C	-.81	-.80	.19	-.04	.10	-.59	-.06	.53	.33	-.24	.15
RI	.98	.98	-.30	-.15	-.23	.48	-.07	-.57	-.42	.49	-.17
MR	1.00	1.00	-.36	-.22	-.28	.43	-.11	-.60	-.40	.58	-.08
BN		1.00	-.36	-.23	-.28	.44	-.11	-.59	-.41	.59	-.10
CWS			1.00	.90	.75	.05	-.06	.18	-.14	-.01	.53
HWS				1.00	.81	.03	-.15	-.04	-.02	-.16	.51
CSS					1.00	.14	-.24	.23	.11	-.27	.22
ABS						1.00	.34	.22	-.29	.16	-.13
ES							1.00	.34	.39	.10	-.14
PC								1.00	.40	-.48	-.18
LC									1.00	-.45	-.05
CBC										1.00	.36
AC											1.00

* All correlation coefficients above 0.63 and below - 0.63 are significant at the 5% level.

Table J-4 . CORRELATION COEFFICIENTS BETWEEN THE PROPERTIES OF ALL WOODS STUDIED *

	FL	FW	LD	CWT	SG	ESG	FC	CF	WF	L/C	RI
FL	1.00	.29	-.01	.54	.27	.32	.94	-.44	.44	.66	.44
FW		1.00	.86	.21	.07	.08	-.05	.18	-.19	.18	-.18
LD			1.00	-.29	-.24	-.22	-.31	.64	-.64	.28	-.64
CWT				1.00	.57	.56	.48	-.91	.91	-.27	.92
SG					1.00	.99	.26	-.56	.53	-.14	.55
ESG						1.00	.31	-.54	.52	-.07	.54
FC							1.00	-.51	.51	.64	.51
CF								1.00	-.98	.30	-.99
WF									1.00	-.32	.99
L/C										1.00	-.32
RI											1.00

* All correlation coefficients above 0.36 and below - 0.36 are significant at the 5% level.

Table J-4 . CONTINUED *

	MR	BN	CWS	HWS	CSS	ABS	ES	PC	LC	CBC	AC
FL	.44	.46	-.10	-.09	-.24	-.27	-.09	-.74	.19	.66	-.17
FW	-.20	-.17	-.17	.30	.40	-.14	-.06	-.21	.18	-.16	-.10
LD	-.66	-.64	-.13	.37	.43	-.32	-.18	-.09	.37	-.37	-.11
CWT	.88	.89	-.08	-.16	-.07	.39	.25	-.20	-.37	.36	-.01
SG	.54	.56	-.14	-.40	.31	.57	.30	.31	-.64	.08	.16
ESG	.53	.55	-.16	-.40	.29	.50	.25	.25	-.60	.11	.14
FC	.52	.53	-.07	-.22	-.39	-.25	-.09	-.70	.15	.74	-.14
CF	-.98	-.99	-.02	.23	.20	-.42	-.26	.14	.44	-.42	-.04
WF	.96	.97	-.01	-.30	-.25	.42	.24	-.14	-.42	.44	.04
L/C	-.28	-.28	-.09	-.01	-.18	-.62	-.32	-.62	.53	.40	-.22
RI	.98	.98	-.02	-.29	-.21	.44	.26	-.12	-.42	.42	.01
MR	1.00	.99	-.01	-.25	-.24	.40	.27	-.16	-.40	.47	.04
BN		1.00	-.02	-.27	-.22	.40	.24	-.16	-.42	.46	.05
CWS			1.00	.63	-.99	.08	.27	.11	-.21	.02	.22
HWS				1.00	.22	-.20	.07	-.11	.18	-.11	.04
CSS					1.00	.30	.15	.41	-.05	-.59	.34
ABS						1.00	.67	.68	-.70	-.22	.27
ES							1.00	.34	-.29	-.10	.02
PC								1.00	-.58	-.61	.27
LC									1.00	.04	-.50
CBC										1.00	.09
AC											1.00

* All correlation coefficients above 0.36 and below - 0.36 are significant at the 5% level.

Table J-5 . BRAZILIAN RAW MATERIALS CORRELATION COEFFICIENTS BETWEEN WOOD AND BLEACHABLE GRADE PULP PROPERTIES*

	PN	TY	SY	RC	ETY	ESY	ERC	BT	BL	S	BF	TF
FL	-.22	.54	.53	-.01	.54	.53	-.10	.05	-.09	-.88	-.60	.65
FW	.05	-.29	-.38	.64	-.32	-.41	.63	.26	.43	-.50	-.09	.15
LD	.20	-.43	-.53	.73	-.46	-.56	.72	.36	.60	-.24	.18	.01
CWT	-.31	.37	.40	-.26	.39	.41	-.26	-.30	-.42	-.63	-.67	.30
SG	-.10	.66	.64	-.05	.65	.62	-.05	.31	-.17	-.73	-.62	.83
ESG	-.09	.66	.63	-.03	.64	.62	-.04	.34	-.14	-.73	-.61	.84
FC	-.24	.67	.69	-.31	.67	.69	-.30	-.02	-.21	-.75	-.58	.63
CF	.38	-.48	-.55	.53	-.50	-.57	.52	.32	.58	.38	.62	-.28
WF	-.32	.51	.58	-.58	.54	.61	-.57	-.41	-.59	-.35	-.58	.23
L/C	-.04	.45	.40	.16	.43	.38	.15	.40	.32	-.77	-.26	.70
RI	-.31	.50	.57	-.56	.52	.59	-.55	-.37	-.57	-.38	-.61	.24
MR	-.43	.45	.52	-.58	.48	.55	-.57	-.36	-.62	-.37	-.63	.27
BN	-.38	.49	.56	-.55	.51	.58	-.54	-.32	-.59	-.39	-.63	.29
CWS	-.01	-.28	-.25	-.11	-.25	-.22	-.11	-.12	-.39	.29	.07	-.24
HWS	-.10	-.64	-.65	.25	-.63	-.64	.26	.02	-.01	.18	.10	-.19
CSS	.31	-.19	-.30	.73	-.22	-.33	.74	.53	.48	-.13	.01	.15
ABS	-.17	-.16	-.10	-.29	-.07	-.02	-.28	-.63	-.47	.19	.01	-.31
ES	-.29	-.31	-.30	-.01	-.24	-.23	-.01	-.28	-.39	-.11	-.26	-.13
PC	.12	-.49	-.47	-.01	-.49	-.46	-.01	-.07	-.02	.86	.62	-.47
LC	.22	-.24	-.31	.48	-.26	-.33	.47	.48	.59	-.23	.10	.01
CBC	-.28	.57	.62	-.50	.59	.64	-.49	-.22	-.44	-.36	-.48	.36
AC	.02	.22	.26	-.26	.25	.28	-.26	-.41	-.12	.36	.39	.08
PN	1.00	.09	.01	.47	.08	-.01	.47	.32	.31	.17	.28	-.16
TY		1.00	.99	-.22	.99	.98	-.21	.05	-.24	-.34	-.36	.59
SY			1.00	-.38	.99	1.00	.37	-.06	-.32	-.29	-.35	.56
RC				1.00	-.24	-.40	1.00	.65	.50	-.22	.03	-.01
ETY					1.00	.99	-.23	.01	-.28	-.33	-.36	.57
ESY						1.00	-.39	-.11	-.35	-.27	-.35	.54
ERC							1.00	.65	.49	-.22	.03	-.01
BT								1.00	.40	-.22	-.14	.40
BL									1.00	-.01	.50	-.02
S										1.00	.63	-.56
BF											1.00	-.40
TF												1.00

* All correlation coefficients above 0.44 and below - 0.44 are significant at the 5% level.

Table J-6 . AMERICAN RAW MATERIALS CORRELATION COEFFICIENTS BETWEEN WOOD AND BLEACHABLE GRADE PULP PROPERTIES*

	PN	TY	SY	RC	ETY	ESY	ERC	BT	BL	S	BF	TF
FL	.30	.85	.87	-.62	.77	.80	-.54	.90	.82	-.69	.91	-.25
FW	.11	.39	.38	-.08	.38	.33	.13	.62	.55	-.69	.50	.39
LD	-.12	-.22	-.24	.31	-.32	-.38	.49	-.06	-.15	-.13	-.25	.41
CWT	.19	.72	.70	-.29	.83	.81	-.27	.68	.72	-.59	.78	-.08
SG	.20	.86	.88	-.61	.80	.81	-.47	.98	.87	-.74	.94	-.19
ESG	.18	.85	.87	-.58	.73	.74	-.43	.98	.87	-.77	.92	-.16
FC	.27	.68	.72	-.73	.60	.67	-.76	.65	.59	-.35	.74	-.48
CF	-.18	-.66	-.65	.29	-.78	-.78	.32	-.57	-.63	.46	-.71	.17
WF	.18	.66	.65	-.29	.78	.78	-.32	.57	.63	-.46	.71	-.17
L/C	-.03	-.45	-.40	-.11	-.64	.58	-.09	-.36	-.48	.45	-.48	-.13
RI	.21	.64	.63	-.33	.77	.78	-.37	.57	.61	-.43	.70	-.20
MR	.24	.61	.62	-.41	.72	.74	-.44	.61	.67	-.48	.74	-.12
BN	.24	.61	.62	-.43	.73	.75	-.46	.62	.66	-.46	.74	-.14
CWS	.30	-.07	-.03	.20	.01	-.03	.22	-.28	-.53	.34	-.38	-.26
HWS	.18	-.06	.01	.35	.06	.01	.34	-.21	-.33	.14	-.31	-.08
CSS	.25	-.06	-.07	.14	-.01	-.03	.11	-.28	-.50	.48	-.52	-.24
ABS	.16	-.04	-.03	-.05	.33	.33	-.13	-.14	-.14	.30	-.05	.11
ES	.42	-.40	-.40	.28	-.24	-.26	.25	-.32	-.20	.10	-.20	.30
PC	-.02	-.77	-.74	.22	-.65	-.62	.09	-.86	-.90	.92	-.84	-.13
LC	.19	-.68	-.69	.43	-.76	-.75	.30	-.56	-.33	.24	-.60	.47
CBC	.62	.48	.54	-.66	.51	.56	-.56	.67	.50	-.43	.70	-.11
AC	.21	-.14	-.13	0	-.18	-.18	.03	-.03	-.03	.16	.02	.31
PN	1.00	.12	.16	-.36	.16	.20	-.37	.16	-.02	.06	.07	-.17
TY		1.00	.99	-.50	.93	.92	-.38	.87	.69	-.56	.81	-.50
SY			1.00	-.59	.93	.93	-.48	.89	.70	-.53	.82	-.54
RC				1.00	-.48	-.59	.96	-.62	-.40	.06	-.56	.57
ETY					1.00	.99	-.40	.78	.60	-.42	.76	-.51
ESY						1.00	-.52	.79	.61	-.38	.78	-.56
ERC							1.00	-.46	-.30	-.09	-.45	.60
BT								1.00	.88	-.75	.92	-.20
BL									1.00	-.90	.92	.12
S										1.00	-.79	-.39
BF											1.00	-.13
TF												1.00

* All correlation coefficients above 0.63 and below - 0.63 are significant at the 5% level.

Table J-7 . BRAZILIAN RAW MATERIALS
CORRELATION COEFFICIENTS BETWEEN WOOD AND UNBLEACHABLE GRADE PULP PROPERTIES *

	PN	TY	SY	RC	ETY	ESY	ERC	BT	BL	S	BF	TF
FL	.18	.59	.56	-.15	.60	.56	-.15	.77	-.53	-.87	-.69	.34
FW	.27	.23	.02	.56	.20	-.02	.57	.39	.39	-.47	.13	-.04
LD	.22	.09	-.14	.68	.04	-.19	.68	.15	.63	-.20	.42	-.03
CWT	.10	.35	.40	-.30	.39	.43	-.30	.59	-.65	-.67	-.77	-.10
SG	.13	.44	.42	-.09	.43	.40	-.10	.67	-.38	-.62	-.50	.71
ESG	.13	.46	.43	.07	.43	.40	-.08	.67	-.37	-.62	-.48	.73
FC	.09	.54	.58	-.34	.56	.59	-.34	.65	-.68	-.75	-.74	.38
CF	.04	-.25	-.40	.55	-.30	-.44	.55	-.36	.79	.42	.75	-.02
WF	-.07	.26	.42	-.59	.31	.46	-.59	.34	-.83	-.41	-.79	-.03
L/C	.19	.57	.46	.10	.54	.43	.10	.62	-.17	-.71	-.30	.60
RI	-.03	.24	.39	-.54	.30	.43	-.54	.38	-.82	-.44	-.79	-.03
MR	.01	.26	.41	-.56	.32	.46	-.57	.35	-.81	-.41	-.76	-.01
BN	-.02	.26	.40	-.54	.31	.44	-.54	.38	-.80	-.43	-.76	.02
CWS	-.32	-.36	-.22	-.28	-.30	-.17	-.28	-.26	-.16	.35	.02	-.11
HWS	.05	-.22	-.28	.25	-.20	-.25	.25	-.04	.43	.24	.36	-.14
CSS	.32	-.13	-.40	.88	-.18	-.44	.87	.13	.68	-.53	.38	.13
ABS	.03	-.30	-.15	-.36	-.15	-.01	-.35	-.14	-.22	.12	-.28	-.47
ES	.29	-.20	-.16	-.05	-.06	-.04	-.04	.05	-.21	-.16	-.33	-.42
PC	-.27	-.39	-.35	.03	-.39	-.34	.04	-.71	.49	.89	.64	-.17
LC	.49	.06	-.16	.64	.02	-.19	.64	.20	.34	-.30	.23	-.13
CBC	.12	.36	.50	-.55	.41	.53	-.56	.44	-.58	-.40	-.66	.21
AC	-.46	-.18	-.03	-.41	-.14	.01	-.41	-.28	.12	.39	.16	.03
PN	1.00	.03	-.11	.43	.04	-.11	.43	.52	.15	-.34	-.17	-.07
TY		1.00	.95	-.22	.99	.92	-.21	.26	-.36	-.57	-.38	.23
SY			1.00	-.52	.96	.99	-.51	.18	-.52	-.47	-.43	.19
RC				1.00	-.28	-.57	1.00	.15	.63	-.10	.30	.03
ETY					1.00	.95	-.27	.25	-.41	-.58	-.44	.16
ESY						1.00	-.56	.16	-.56	-.46	-.47	.13
ERC							1.00	.14	.63	-.10	.29	.02
BT								1.00	-.14	-.70	-.40	.34
BL									1.00	.41	.83	.11
S										1.00	.59	-.10
BF											1.00	.10
TF												1.00

* All correlation coefficients above 0.44 and below - 0.44 are significant at the 5% level.

Table J-8 . AMERICAN RAW MATERIALS CORRELATION COEFFICIENTS BETWEEN WOOD AND UNBLEACHABLE GRADE PULP PROPERTIES*

	PN	TY	SY	RC	ETY	ESY	ERC	BT	BL	S	BF	TF
FL	.21	.90	.94	-.86	.93	.95	-.86	.80	-.04	-.71	-.06	-.61
FW	-.21	.38	.49	-.72	.40	.48	-.66	.57	-.07	-.19	.65	-.62
LD	-.15	-.21	-.16	-.05	-.37	-.29	-.09	-.03	-.01	.28	.62	-.26
CWT	-.17	.56	.62	-.70	.76	.77	-.69	.55	-.23	-.45	-.15	-.24
SG	.01	.89	.93	-.85	.93	.94	-.84	.93	.01	-.73	.12	-.61
ESG	.07	.92	.95	-.82	.90	.91	-.81	.94	-.02	-.71	.10	-.67
FC	.43	.82	.79	-.54	.84	.80	-.58	.61	.11	-.72	-.33	-.38
CF	.11	-.51	-.55	.58	-.72	-.71	.58	-.45	.19	.43	.30	.11
WF	-.11	.51	.55	-.58	.72	.71	-.58	.45	-.19	-.43	-.30	-.11
L/C	.35	-.18	-.26	.45	-.42	-.44	.43	-.24	.36	.12	.17	-.02
RI	-.10	.52	.56	-.56	.73	.72	-.57	.46	-.14	-.46	-.29	-.13
MR	-.01	.60	.63	-.59	.80	.78	-.59	.55	-.06	-.50	-.16	-.25
BN	-.01	.60	.63	-.59	.81	.78	-.59	.56	-.04	-.52	-.16	-.25
CWS	-.01	-.03	-.16	-.19	-.28	-.16	-.23	-.24	.21	.05	-.09	-.04
HWS	-.01	-.26	-.16	-.18	-.28	-.16	-.21	-.32	-.19	.12	-.21	-.03
CSS	-.02	-.39	-.32	.05	-.38	-.30	.03	-.35	.46	-.06	-.08	0
ABS	-.36	-.33	-.24	-.10	.02	.04	-.08	-.15	.24	.01	.09	.42
ES	-.72	-.25	-.24	.16	-.14	-.15	.16	-.33	.06	.67	.15	.16
PC	-.06	-.76	-.80	.78	-.72	-.76	.76	-.70	.42	.43	-.04	.59
LC	-.11	-.33	-.43	.68	-.46	-.53	.68	-.61	-.27	.66	-.08	.01
CBC	-.02	.77	.82	-.82	.87	.89	-.82	.78	.50	-.51	.38	-.68
AC	.45	.14	.20	-.33	.09	.16	-.33	.06	.20	.05	.33	-.44
PN	1.00	.20	.14	.08	.08	.04	.06	.09	.13	-.38	-.10	-.08
TY		1.00	.98	-.73	.93	.92	-.74	.86	.08	-.64	.02	-.76
SY			1.00	-.84	.95	.96	-.85	.89	.10	-.66	.07	-.77
RC				1.00	-.81	-.89	1.00	-.80	-.14	.58	-.21	.63
ETY					1.00	.99	-.81	.86	.17	-.67	.06	-.64
ESY						1.00	-.89	.87	.17	-.68	.08	-.66
ERC							1.00	-.78	-.14	.59	-.14	.61
BT								1.00	.28	-.76	.31	-.70
BL									1.00	-.35	.42	-.19
S										1.00	-.01	.39
BF											1.00	-.39
TF												1.00

* All correlation coefficients above 0.63 and below - 0.63 are significant at the 5% level.

VITA

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	State University of New York College of Environmental Science and Forestry, Syracuse, New York, U.S.A.	1972-1973	M. S.