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MASTER'S THESIS

Variation of Wood Basic Density, Pulp Yield and Other Wood Properties for Four Eucalyptus Clones in Stora Enso Guangxi (China) Plantation

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Variation of Wood Basic Density, Pulp Yield and Other Wood Properties for Four Eucalyptus Clones in Stora Enso Guangxi (China) Plantation.

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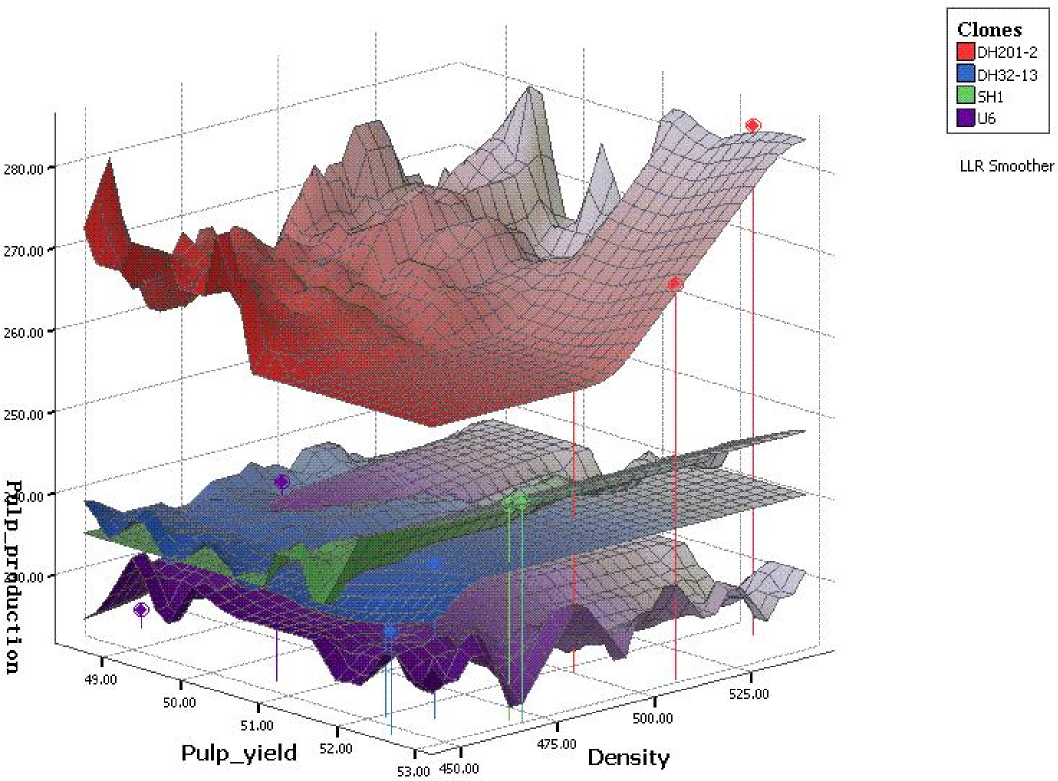

Abstract

Stora Enso Guangxi is developing eucalyptus plantations in southern Guangxi for a future pulp and paper industry. The genetic compositions vary between the eucalyptus clones and it is likely that their wood properties and pulp yield are also very different.
The project is to assess and analyze the variation of Wood Basic Density, Pulp Yield and Pulp Production between selected eucalyptus clones in Stora Enso Guangxi plantation. These work and data as preparative and indicator in chemical pulping.

Four eucalyptus clones in Stora Enso Guangxi plantations have been selected for research. 3 trees from each clone were felled, in all 12 trees from 4 clones. The 12 trees were in the same age, in the same fertilization and in the same plantation. The variation of the 3 trees within each clone would be small.

The studied 4 clones are DH201-2 (grandis x camaldulensis), DH32-13 (urophylla x grandis), U6 (urophylla x tereticornis), SH1 (urophylla x ecerta).

The clone DH201-2 is showing the highest wood basic density of the 4 clones, and there is significant difference with the other 3 clones.
There are indications of clone DH32-13 is showing the lowest mean density.

The bark volume of clone U6 is higher than clone SH1; the differences between them are significant.
There are indications of clone U6 is showing the highest bark volume percentage and clone SH1 is showing the lowest bark volume percentage.

There are indications of clone U6 is showing the lowest total pulp yield at Kappa 18 of the 4 clones.

Clones DH201-2 is showing the highest value in pulp production. Clones U6 is showing the lowest value in pulp production.

In this project, the clones DH201-2 is showing the highest value in the pulping of the 4 clones, clones U6 is showing the lowest value in pulp production of the 4 clones, although just one project cannot fully determine the entire value of the 4 clones.

It is a suggestion that the eucalyptus plantations in southern Guangxi for a future pulp/ paper industry, should based on clone DH201-2, and avoid clone U6.

Preface

This master thesis is a full report for my thesis work, the thesis work carried through in Guangxi China, from January 2006 to July 2006.

The thesis work was financial supported by Stora Enso Guangxi (China), was carried out and assisted by staffs in R&D Department of Stora Enso Guangxi (China), personnel in Light Industry Division of Institute of Light Industry & Food Engineering in Guangxi University (China).

The field work was carried out in eucalyptus plantation of Stora Enso Guangxi; wood basic density measurement was carried out in eucalyptus nursery of Stora Enso Guangxi. These works were carried out together with staffs in R&D Department of Stora Enso Guangxi.

Pulping and assessments was carried out in Institute of Light Industry & Food Engineering. These works were carried out together with students and personnel in Light Industry Division in Institute of Light Industry & Food Engineering in Guangxi University.

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Yu Chen,
August 2006.

List of contents

1. Introduction

1.1. Background.

For the last thirty years, the eucalypts plantations have experienced an important development in the sub-tropical and tropical zones. Successful genetic improvement amplified by vegetative propagation and more recently by promising biotechnology, has added to the natural qualities of the tree: fast growing, excellent fiber, and relatively high wood density. This has favored eucalyptus as one of the best tree species for ligni-culture.

The high productivity and short rotation, along with uniformity clonal plantations and improvement of wood quality, attracted private investments, especially fro the pulp and paper industry that continues to invest in R&D to reduce the agronomic, pathological and ecological risks of this crop. Eucalyptus has also started to attract financial groups who have joined multinational pulp and paper companies in the investment of its plantations development.

In the last decade of China, the eucalypt wood production has been increasing year by year, reaching 5 millions m^3 annually in the recent years. The processing and utilization industry of logs and byproducts have also been developing with the extensions. Eucalypt wood chips mills were built near harbors of Zhanjiang, Yangjiang, Haikou, Beihai and Fangcheng. To explore the downsteam products, many pulp and artificial board mills are or are being build by state-own or private companies, such as Hepu, Liujiang and Fengfang pulp mills in Guangxi, and Jiangmen and Zhujiang pulp mills in Guangdong. (Run-Peng Wei, Daping Xu. 2003)

Stora Enso started investing in Guangxi in 2002 with the aim of establishing 120 000 ha of industrial hardwood plantations to provide fibre for integrated pulp, paper and board production in southern Guangxi. Stora Enso have started the application process for an integrated forest industry project in Guangxi, including annual production capacity of about 1,000,000 tonnes of chemical and chemi-thermomechanical pulp, and about 1,000,000 tonnes of paper and board. (Stora Enso Guangxi. 2005)

Stora Enso Guangxi is developing eucalyptus plantations in southern Guangxi for a future pulp/ paper industry. There is a wide range of genetically different material available for establishing such plantations. Presently most of planting is carried out using eucalyptus clones which have been developed by various agencies in southern China. The genetic compositions (parent species) vary between these clones and it is likely that their wood properties and pulp yield are also very different. (Risto Vuokko. 2006)

1.2. Mission & vision.

Investigate and analyse the variation between selected eucalyptus clones by trees characteristics assessments in Stora Enso Guangxi plantations. These work and data as preparative and indicator in chemical pulping.

1) Assessments and analysis the variation of wood basic density and bark percentage between 4 selected eucalyptus clones in Stora Enso Guangxi plantation.

2) Assessments and analysis the variation of pulp yield between 4 selected eucalyptus clones in Stora Enso Guangxi plantation.

3) Analysis pulp production of 4 selected eucalyptus clones，and the relationships of pulp production, wood basic density and pulp yield.

Table 2.2-1. The 4 selected eucalyptus clones for assessments and analysis.

Clone No.	Hybrid ways	Source
DH201-2	grandis x camaldulensis	Dongmen, China
DH32-13	urophylla x grandis	Dongmen, China
U6	urophylla x tereticornis	Zhanjiang, China
SH1	urophylla x ecerta	Leizhou, China

2. Theory

2.1. Wood preparation in pulping.

1) Debarking.
Debarking because bark has very little useful fiber and contains dirt that reduces the overall pulp quality, logs are usually debarked before being used for pulp manufacturing.
Prior to removal, the bark is softened by one of various techniques, including: spraying the logs with water, soaking the logs in ponds, or steaming the logs in special chambers.

2) Chipping.
After the logs have been debarked, they must be reduced in size so that cooking chemicals can easily penetrate the wood fiber to separate lignin and carbohydrates from the cellulose.
This is achieved by feeding the logs into chippers, which use powerful high-speed rotating knives to reduce the wood to a uniform size.

3) Screening.
After passing through the chipper, the wood contains fines, slivers, and oversized chips. Wood chips are therefore passed over vibratory screens to remove oversized chips and fines.
Oversized chips remain on the upper screen and are recycled to a chipper, slicer or crusher. Fines drop into a collection hopper below the screens and are usually used, along with bark, as boiler fuel. (Office of Industrial Technologies, U.S. Department of Energy. 1995)

2.2. Chemical pulping.

Chemical pulps are typically manufactured into products that have high-quality standards or require special properties. Chemical pulping degrades wood by dissolving the lignin bonds holding the cellulose fibers together.
Generally, this process involves the cooking/digesting of wood chips in aqueous chemical solutions at elevated temperatures and pressures. There are two major types of chemical pulping currently used:
1) Kraft (soda or sulfate) pulping,
2) Sulfite pulping.
These processes differ primarily in the chemicals used for digesting. The specialty paper products rayon, viscose, acetate, and cellophane are made from dissolving pulp, a variant of standard kraft or sulfite chemical pulping processes.

2.2.1. Kraft (sulfate) pulping.
The success of the Kraft (sulfate) pulping processes and its widespread adoption are due to several factors.
First, because the kraft cooking chemicals are selective in their attack on wood constituents, the

pulps produced are notably stronger than those from other processes (Kraft is German for "strength"). The kraft process is also flexible, in so far as it is amenable to many different types of raw materials (i.e., hard or soft woods) and can tolerate contaminants frequently found in wood (e.g., resins). Lignin removal rates are high in the kraft process (up to 90 percent) allowing high levels of bleaching without pulp degradation. Finally, the chemicals used in kraft pulping are readily recovered within the process, making it very economical and reducing potential environmental releases.

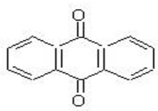
The kraft process uses a sodium-based alkaline pulping solution consisting of sodium sulfide (Na_2S) and sodium hydroxide (NaOH) in 10 percent solution. This white liquor is mixed with the wood chips in a digester. The output products are separated wood pulp and a liquid that contains the dissolved lignin solids in a solution of reacted and un-reacted pulping chemicals (black liquor). The black liquor undergoes a chemical recovery process to regenerate white liquor for the first pulping step. Overall, the kraft process converts approximately 50 percent of input furnish into pulp.

The kraft process evolved from the soda process. The soda process uses an alkaline liquor of only sodium hydroxide (NaOH). The kraft process has virtually replaced the soda process due to the economic benefits of chemical recovery and improved reaction rates.

2.2.2. Sulfite pulping.
In sulfite pulping processes only non-resinous species are generally pulped. The sulfite pulping process relies on acid solutions of sulfurous acid (H_2SO_3) and bi-sulfite ion (HSO_3-) to degrade the lignin bonds between wood fibers.

Sulfite pulps have less color than kraft pulps and can be bleached more easily, but are not as strong. The efficiency and effectiveness of the sulfite process is also dependent on the type of wood furnish and the absence of bark. For these reasons, the use of sulfite pulping has declined in comparison to kraft pulping over time.
(EPA Office of Compliance Sector Notebook Project.2002)

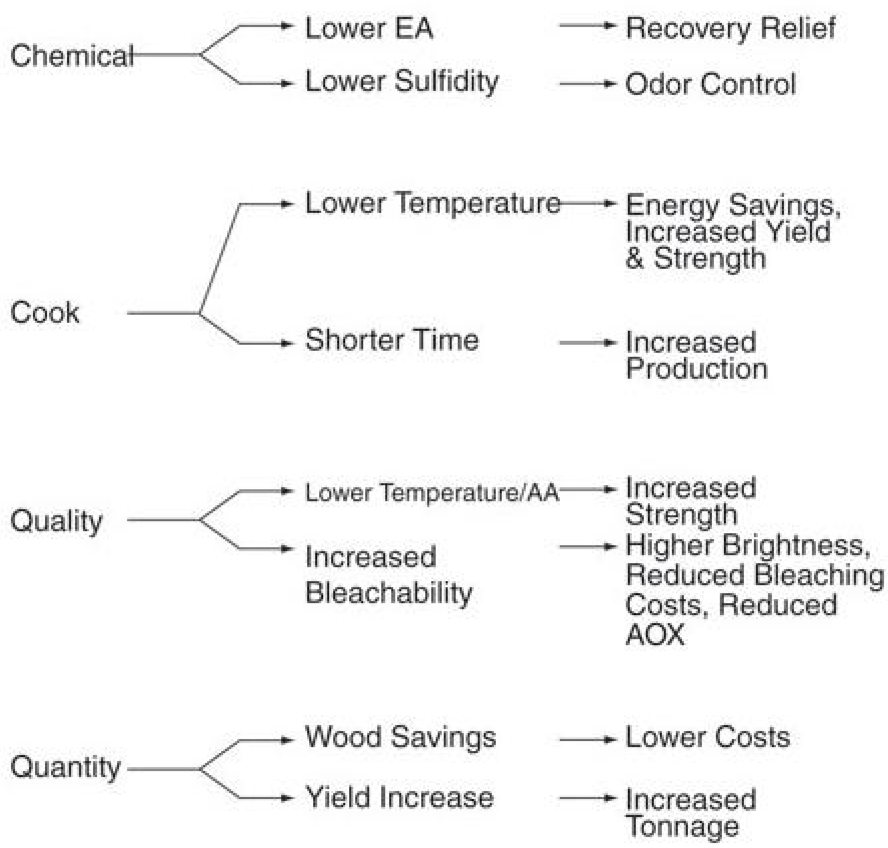
2.2.3. Catalyst Anthraquinone (AQ).

Anthraquinone (AQ), chemical structure is  , formula is $C_{14}H_8O_2$, mole weight is 208.22.

AQ is used in paper industry as a catalyst to increase the pulp production yield and to improve the fiber strength through reduction reaction of cellulose to carboxylic acid.

Anthraquinone (AQ) acts as a catalyst for the delignification reaction. AQ also stabilizes carbohydrates during cooking against the "peeling" reaction, which is the systematic removal of sugar end units from cellulose and hemicelluloses. Thus, mills can increase pulp yield through the incorporation of AQ. (Greer Carol, Duggirala Prasad, Duffy Brian. 2004) Chart 2.2-1 shows additional benefits of using AQ.

Chart 2.2-1 Benefits of using anthraquinone (AQ) in pulping.



2.3. Pulp processing.

After pulp production, pulp processing removes impurities, such as uncooked chips, and recycles any residual cooking liquor via the washing process. Pulps are processed in a wide variety of ways, depending on the method that generated them (e.g., chemical, semi-chemical). Some pulp processing steps that remove pulp impurities include screening, de-fibering, and de-knotting. Pulp may also be thickened by removing a portion of the water. At additional cost, pulp may be blended to ensure product uniformity. If pulp is to be stored for long periods of time, drying steps are necessary to prevent fungal or bacterial growth.

1) Pulp screening.
Removes remaining oversized particles such as bark fragments, oversized chips, and uncooked chips. In open screen rooms, wastewater from the screening process goes to wastewater treatment prior to discharge. In closed loop screen rooms, wastewater from the process is reused in other pulping operations and ultimately enters the mill's chemical recovery system.

2) Centrifugal cleaning.

Centrifugal cleaning is used after screening to remove relatively dense contaminants such as sand and dirt. Rejects from the screening process are either re-pulped or disposed of as solid waste.
(EPA Office of Compliance Sector Notebook Project.2002)

2.4. Calculations in kraft pulping.

The active chemical reagents in kraft pulping are sodium hydroxide (NaOH) and sulfureted hydrogen (Na_2S).
Using equated sodium oxide (Na_2O) as benchmark represents all sodium compound (sometimes also using equated NaOH as benchmark, but should have annotation). In laboratory normally use g/L as unit express concentration of chemical reagents.

1) Total alkali.
NaOH+ Na_2S+ Na_2CO_3+ Na_2SO_3+ $Na_2S_2O_3$, not including NaCl, express with g/L Na_2O.

2) Total titratable alkali.
Total alkali in alkali liquor, NaOH+ Na_2S+ Na_2CO_3+ Na_2SO_3 (not similar with total alkali) in kraft pulping, express with g/L Na_2O.

3) Active alkali.
NaOH+ Na_2S, express with g/L Na_2O.

4) Effective alkali.
NaOH+ ½ Na_2S, express with g/L Na_2O.

5) Activity degree.
Active alkali (equated Na_2O) divide total titratable alkali (equated Na_2O), express with percent (%).

6) Causticizing efficiency.
NaOH (equated Na_2O) divide sum of NaOH+ Na_2CO_3 (equated Na_2O) in white liquor.

7) Causticity.
NaOH divide active alkali NaOH+ Na_2S, express with g/L Na_2O.

8) Sulphidity.
In white liquor, Na_2S divide active alkali NaOH+ Na_2S, express with g/L Na_2O.
In green liquor, Na_2S divide total alkali, express with g/L Na_2O.

9) Percent reduction.
In green liquor, Na_2S divide sum of Na_2S+ Na_2SO_4+ other caustic soda (NaOH) and sulphur compound, express with percent (%).

10) Not-reductive sodium sulfate (Na_2SO_4).
Na_2SO_4 in white liquor and green liquor, express with g/L Na_2SO_4.

11) Consumption of chemical reagents supply.
For keep constant sodium content in cooking, produce one ton of air-dry pulp adding fresh sodium sulfate (Na_2SO_4), express with kg Na_2SO_4.

12) Loss of chemical reagents.
Total loss: fresh chemical reagents divide total chemical reagents, express with percent (%).

13) Alkali charge and calculation.
Alkali charge is mass of active alkali in cooking divide mass of absolute-dry raw material, express with percent (%).

14) Consumption of alkali.
Actually consumption of alkali in cooking, mass of active alkali divide mass of absolute-dry raw material, express with percent (%).

15) Liquor to wood ratio.
In digester, mass of absolute-dry raw material (in kg or t) divide volume of cooking liquor (in L or m^3).

16) Pulp yield.
Coarse pulp yield is mass of absolute-dry total coarse pulp divide absolute-dry raw material, express with percent (%).
Screened pulp yield is mass of absolute-dry screened pulp divide absolute-dry raw material, express with percent (%).
(Shu lai Xie, Yu huai Zhang. 2005. In Chinese)

2.5. Statistics and analysis using SPSS 13.0.

1) Descriptive statistics.
Descriptive statistics calculates the number of cases, mean, standard deviation, standard error of the mean, minimum, maximum, and 95%-confidence intervals for each dependent variable for each group.

Fixed and random effects in descriptive statistics.
Fixed and random effects display the standard deviation, standard error, and 95%-confidence interval for the fixed-effects model, and the standard error, 95%-confidence interval, and estimate of between-components variance for the random-effects model.

2) One-way ANOVA (analysis of variance).
The One-Way ANOVA procedure produces a one-way analysis of variance for a quantitative

dependent variable by a single factor (independent) variable. Analysis of variance is used to test the hypothesis that several means are equal. This technique is an extension of the two-sample t test.

In addition to One-Way ANOVA procedure determining that differences exist among the means, know which means differ. There are two types of tests for comparing means: a priori contrasts and post hoc tests. Contrasts are tests set up before running the experiment, and post hoc tests are run after the experiment has been conducted, can also test for trends across categories.

Homogeneity of variance test in One-way ANOVA (analysis of variance).
Homogeneity of variance test calculates the Levene statistic to test for the equality of group variances. This test is not dependent on the assumption of normality.

3) One-way ANOVA (analysis of variance) post hoc tests.
Once have determined that differences exist among the means, post hoc range tests and pairwise multiple comparisons can determine which means differ. Range tests identify homogeneous subsets of means that are not different from each other. Pairwise multiple comparisons test the difference between each pair of means, and yield a matrix where asterisks indicate significantly different group means at an alpha level of 0.05.

Student-Newman-Keuls in ANOVA (analysis of variance) post hoc tests.
Makes all pairwise comparisons between means using the Studentized range distribution. With equal sample sizes, it also compares pairs of means within homogeneous subsets, using a stepwise procedure. Means are ordered from highest to lowest, and extreme differences are tested first.

4) Boxplot.
Boxplot sometimes called a box-and-whiskers plot, shows the median, quartiles, and outlier and extreme values for a scale variable. It can be split into categories and clusters.

Outliers, extremes, and the median line can be displayed for each box. Outliers are between 1.5 box lengths and 3 box lengths from the end of the box. Extremes are more than 3 box lengths from the end of the box.

The box length is the inter-quartile range.
Outliers are cases with values between 1.5 and 3 box lengths from the upper or lower edge of the box.
Extreme cases are cases with values more than 3 box lengths from the upper or lower edge of the box.

5) Scatter plots.
Scatter plots highlight the relationship between two or three quantitative variables by plotting the actual values along three axes. It shows relationships, such as a curvilinear pattern, that descriptive statistics do not reveal, and they can uncover bivariate outliers.

Selected smoother (local linear regression) and specify the kernel Uniform, and used same bandwidth for all smoothers. The same bandwidth can be useful for subgroups or panels.
Spikes are lines drawn from cloud symbols to surface. Spikes can help to read values from the axis or compare distances using line length.
(SPSS Inc.)

3. Materials and Methods

The field work was carried out in eucalyptus plantation of Stora Enso Guangxi; wood basic density measurement was carried out in eucalyptus nursery of Stora Enso Guangxi. These works were carried out together with staffs in R&D Department of Stora Enso Guangxi.

Pulping and assessments was carried out in Institute of Light Industry & Food Engineering. These works were carried out together with students and personnel in Light Industry Division in Institute of Light Industry & Food Engineering in Guangxi University.

3.1. Field work.

Four eucalyptus clones in Stora Enso Guangxi plantations have been selected for research.
3 trees from each clone were felled, in all 12 trees from 4 clones.
The 12 trees were in the same age, the same fertilization and the same plantation. The variation of the 3 trees within each clone would be small.
These trees were planted in 2002 in Hepu clone trial of Stora Enso Guangxi plantations.
The selected trees were suitable time of life, upright trunk for a tree. We selected a bigger tree, a medium tree and a smaller tree in each clone make the selecting trees more representative.

Table 3.1-1. The 4 selected eucalyptus clones.

Clone No.	Hybrid ways	Source
DH201-2	grandis x camaldulensis	Dongmen, China
DH32-13	urophylla x grandis	Dongmen, China
U6	urophylla x tereticornis	Zhanjiang, China
SH1	urophylla x ecerta	Leizhou, China

Field work processes.
1) Select the tree.
3 trees from each clone was felled, the 3 tree in the same age, the same fertilization and the same plant plot. The variation of the 3 trees within each clone should be small. Normally for the 3 trees in each clone, select a bigger tree, a middling tree and a smaller tree, make the selected trees representative.

2) Measure and mark 1.3 meter (breast height) of the selected tree.

3) Measure the DBH (Diameter of Breast Height) of the selected tree.

4) Take a core sample.

5) Fell the tree.

6) Measure length of the selected tree.

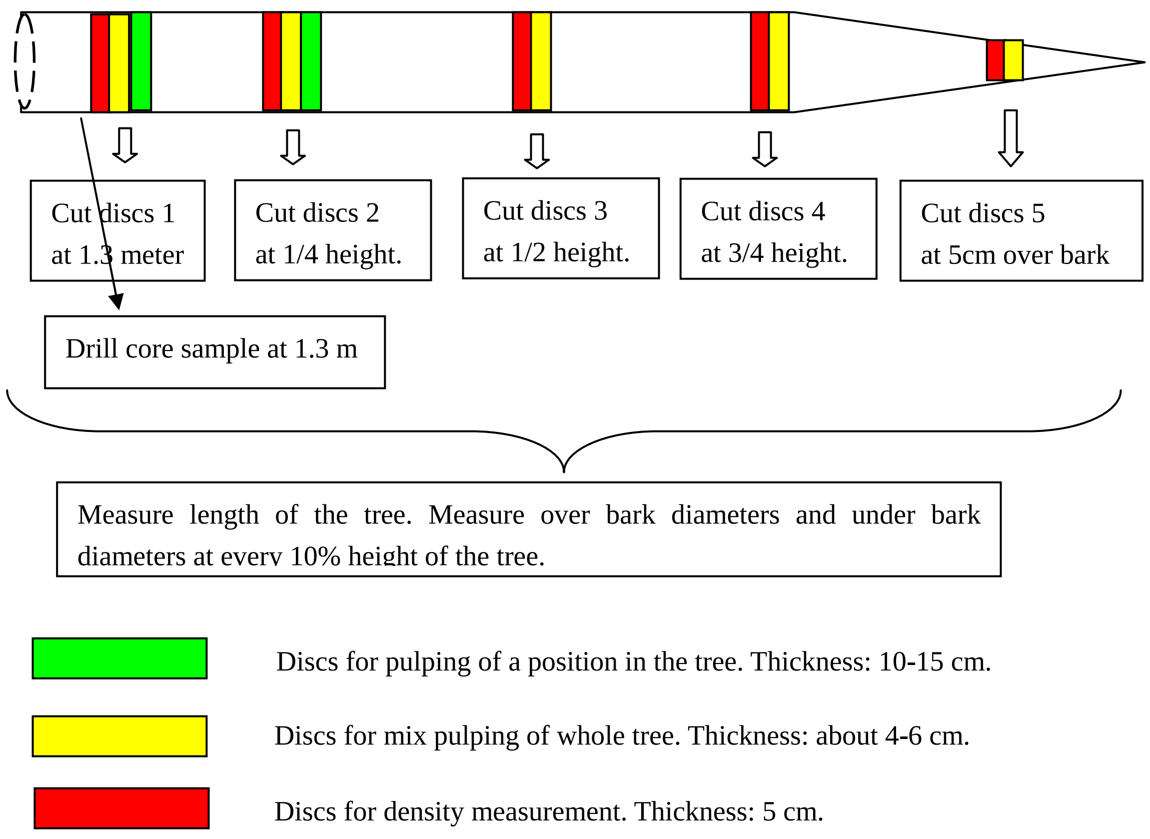
7) Mark positions of discs from the selected tree. The discs from breast height (at 1.3 meter), 1/4, 2/4, 3/4, top (at 5 cm over bark) of a tree. Methods see Chart 3.1-2.
Measure and mark each 10% from the selected tree.

8) Record diameters of each 10% from the selected tree, including over bark diameter and under bark diameter.

9) Cut discs from the selected tree.
The discs from breast height (at 1.3 meter), 1/4, 2/4, 3/4, top (at 5 cm over bark) of a tree.

10) Label the discs.
Discs 1 (consist of 3 discs) at breast height, i.e. 1.3 meter height of a tree .
Discs 2 (consist of 3 discs) at 1/4 height of a tree.
Discs 3 (consist of 2 discs) at 2/4 height of a tree.
Discs 4 (consist of 2 discs) at 3/4 Height of a tree.
Disc5 (consist of 3 discs) at 5 cm over bark of a tree.

Chart 3.1-2. Samples from a tree.



3.2. Wood basic density measurement.

3.2.1. Principle of wood basic density measurement.
This method describes the measurement of basic density (dry weight per maximum fresh volume) of pulpwood samples which are taken as disks. Method allows also assessment of bark percentage, both based on volume and weight.

Basic density: The oven-dry mass of a wood sample dived by its green volume (kg/ m^3).
Green volume: The solid volume of a wood sample when it is in equilibrium with surrounding water.

3.2.2. Instruments and materials.
1) Electronic Balance, capacity 3000 g, sensitivity 0.1 g.
2) Container.
3) Drying oven.
4) Water (Aqua).
5) Iron stand and supports.
8) Needle.

3.2.3. Procedures of measurement.
1) Soak the samples completely in water for at least 1 day but not more than 3 days. If bark volume percentage will be assessed, samples are soaked with barks remaining on the wood. If the sample disk is to large for the container, it must carefully split into sectors. Each sector will then be analyzed separately, and the results are combined during final calculations.

2) Remove the samples from the water and remove the excess water by wiping them carefully with towel.

3) Fill the water container to the mark with water at 20 ℃ (max 25 ℃) and place it on the balance. Adjust the support so that the water level is at the mark of the support. Tare the balance reading to zero.

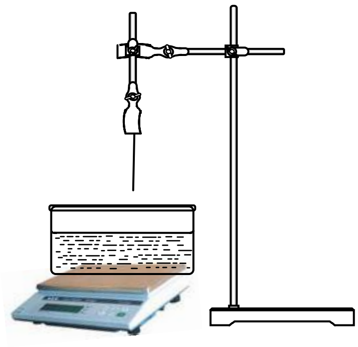
4) Fix the sample to the needle of the support. Immerse the sample completely in the water of the container. Rotate the sample to ensure that al the air adhering to the word disk is removed. Adjust the support so that the water level is at the mark and check that the sample is under water and doesn’t touch the container walls.
Record the balance reading = volume of the samples (1 g = 1 cm^3).
Remove the sample from the container.

6) Remove the bark from the wood carefully, and repeat the volume assessment for the wood sample.

7) Dry the bark and wood samples in separate paper bags (dry weight of the bags measured in advance) in the drying oven for 2-4 days at 105 ℃.

8) Measure the dry weights of the wood and bark samples (including the bag weight), record readings on the form. Record the weight of each bag on the form (g).

Chart 3.2-1. Instruments for wood basic density measurement.



3.2.4. Calculations.

The dry weights of the wood and bark samples are received by subtracting the weights of the bags from the respective total weights.

Results will be calculated with Excel program. If the sample has been dived into sub-samples, the records will be first combined.

The calculations include:

1) Wood basic density (kg/ m^3): The mass of the dried wood sample divided by it's fresh volume (obtained by reading the balance),

Wood basic density (kg/ m^3) = $\frac{\text{the mass of the dried wood sample}}{\text{fresh volume}}$

2) Bark density (kg/ m^3): Bark dry weight divided by the product of total sample volume minus wood volume,

Bark density (kg/ m^3) = $\frac{\text{bark dry weight}}{\text{total sample volume - wood volume}}$

3) Bark percentage (volume), %: 100 * the product of total sample volume minus wood volume divided by total sample volume,

4) Bark percentage (volume) (%) = $\frac{\text{total sample volume - wood volume}}{\text{total sample volume}} * 100$

5) Bark percentage (dry weight), %: 100 * bark dry weight divided by the product of bark dry weight plus wood dry weight,

Bark percentage (dry weight) (%) = $\frac{\text{bark dry weight}}{\text{bark dry weight} + \text{wood dry weight}}$ *100

Reporting: Dry weight results are expressed as kg/ m^3 with no decimals. Bark percentages are expressed with one decimal. A copy will be taken for R&D manager in Stora Enso.
(Stora Enso Guangxi, 2006)

3.3. Preparing raw material samples for pulping.

Raw material samples for laboratory assessments in miniature would be representative. Whatever wood or non-wood samples, for selection of raw material, pay attention to representative of the selection area and selection parts.

The qualified wood chips are: length 15-20 mm, thickness3-5 mm, width no more than 20 mm generally, the rate of qualified wood chips demand above 85%. The samples would be non-rotten, non-degenerative and no high moisture content of the wood samples.

After selection of raw material, on occasion, the raw material need further processing in laboratory, for example need to further select and air-dry the high moisture content of green wood.

Put the selected samples into sample bottles or plastic bags, for airproof and EMC (Equilibrate Moisture Content). Label source, species, pre-treatment, storage date and selection date.
(Shu lang Shi, Fu wang He. 2006. In Chinese)

3.4. Moisture content assessment.

Moisture content assessments for cooking samples are basis of accurate cooking conditions and calculation, would select the EMC wood samples.
Normally, Moisture content assessments for cooking samples using oven-drying.

3.4.1. Principle of assessments.
Raw material samples be oven-dry in 105±2 ℃ condition until gain constant mass. Moisture Content of raw material is the ratio of the oven-dry mass to green samples mass, expression in percent style.

3.4.2. Instruments and materials.
1) Controllable drying oven, temperature be controlled in 105±2 ℃ condition.
2) Electronic balance, sensitivity 0.0001 g.
3) Weighing bottle.

4) Desiccator, in which silica gel should maintain blue.

3.4.3. Assessments procedures.

Weigh up 1- 2 g samples accurately, precision is 0.0001 g. Put it into a clean and dry weighing bottle, put them into drying oven, in 105±2 ℃ conditions for more than 6 hours, till dry the samples to constant mass. Then put the weighing bottle into the desiccator, cooling in the air for 0.5 hours then weigh in.

3.4.4. Calculations.

Moisture Content x (%) use this formula,

$$x = \frac{m - m1}{m} * 100\%$$

In which, m: mass of samples before the oven-drying, m1: mass of samples after the oven-drying.

Do above such assessment twice and get average for report, calculation result would be double-digit. Error between such two assessments should be less than 0.2%.

3.4.5. Notes.

1) In the meantime of multi-samples assessments, the weighing bottles would be number beforehand.

2) When putting the samples into the drying oven, lids of the weighing bottles must be open, and oven-dry them with the lids. When the oven-drying complete, cover the weighing bottles with lid in the drying oven, take them to the desiccator for air-cooling.

3) Temperature of oven-dry samples is the key of Moisture content assessments, thereby the temperature of oven-drying would be controlled precisely in stated range.
(China National Standard. In Chinese)

3.5. Digester facilities and cooking preparation.

3.5.1. Laboratory digester facilities.

1) There are 4 small cooking pots within digester; each volume of pot is 1 L, using heating medium glycerin.

Such digester is suitable for cooking experimentation of similar cooking curve and dissimilar solutions; it is also suitable for study of cooking processes.

Due to oil bath digester producing oil gas and pollute environment, sometimes using air bath digester instead of oil bath digester, working environment would be cleanly, but variation in temperature will be large

2) Centrifuge.

3.5.2. Develop cooking solutions.
According to aims and requirements of assessments, develop cooking solutions and specific cooking condition.

Combine with cooking condition and information of papermaking, base on material species, product characteristics, quality requirements and practical condition, we develop cooking solutions.

The content of cooking solutions:
1) Fix on cooking methods.

2) Develop suitable cooking condition (such as cooking chemical demand, liquor to wood ratio, duration of cooking, maximum temperature, duration of heat preservation, etc).

3) Develop suitable cooking curve, i.e. curve of cooking temperature (Y-coordinate) and cooking time (X-coordinate).

4) Then according cooking condition, calculate raw material, chemical demand and water supply.

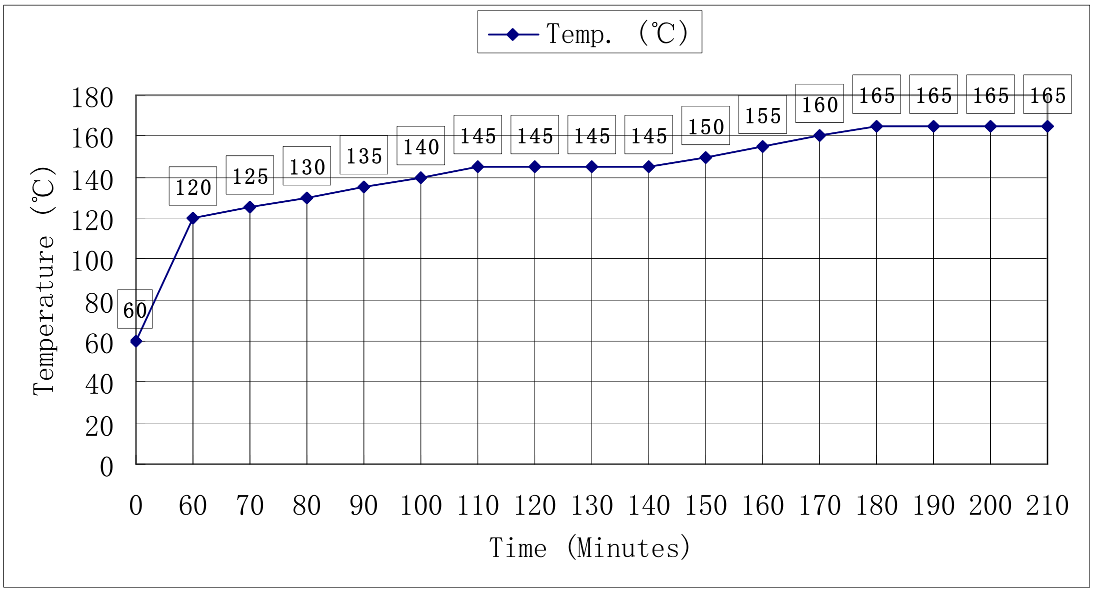
Table 3.5-1. Develop cooking conditions.

Cooking conditions:	
Sulfidity (%):	25
Alkali Content (%):	15.4 or 15.7 or 16 or 16.3
AQ Content (%):	0 or 0.5
Liquor to wood ratio :	4:1
Maximum Temperature (℃):	165
Duration of cooking (Minutes):	210

Table 3.5-2. Develop cooking schedule and temperature.

Time (Minutes)	Temp. (℃)
0	60
60	120
70	125
80	130
90	135
100	140
110	145
120	145
130	145
140	145
150	150
160	155
170	160
180	165
190	165
200	165
210	165

Table 3.5-3 Develop temperature curve.



5) Notes.
Each sample did another replicate analysis.

The sulfidity 25%, liquor to wood ratio 4:1, maximum temperature 165 ℃, duration of cooking 210 min., cooking temperature curve would be keeping the same for the total cooking. However in some cooking adding catalyst anthraquinone (AQ) 0.05%, some cooking without anthraquinone (AQ). Alkali charge was adjusted from 15.4 to 16.3 for control the Kappa number in around 18.

The Kappa number of pulp in pulp yield less than 70% have linear relationship with lignin content, the Kappa number equal to lignin content divide 0.15.

In order to assess the pulp yield correctly, we used the target Kappa 18 for cooking, tried to control the Kappa Number in 18 ±1 for the whole cooking.

Then we used this transform to pulp yield at Kappa 18 approximately.
Pulp yield (at Kappa 18) = Pulp yield (at different Kappa Number) + (18- (different Kappa Number))* 0.15

Pulp production (didn't consider bark) (kg/m^3) = (Pulp yield (%)* 0.01)* Wood basic density (kg/m^3)* Green volume (m^3)

Pulp production (with bark volume) (kg/m^3) = (Pulp yield (%)* 0.01)* Wood basic density (kg/m^3)* (1- Bark volume percentage (%)* 0.01)* Green volume (m^3)

3.5.3. Preparing for cooking.
1) Moisture Content assessment for raw material, calculate mass of air-dry material, weight and preparing.

2) Titrate concentration of cooking liquor, according cooking condition and absolute-dry material calculate chemical demand and water supply, liquor. Note: spare some distilled water for wash containers.

3.5.4. Cooking and digester facilities operation.

1) Check the cooking digester whether it is clean, whether all hardware in good condition.

2) Encase the prepared material into cooking digester, add the cooking liquor (Note: the cooking liquor should touch the material equably).

3) Complete filling the material, cover cooking pots (make sure airproof circles of cooking pots are intact), bolt the lids of cooking pots symmetrically. Then close gas gates of cooking pots.

4) Start-up, cooking pots would be turning, check whether there is leak gas. After make sure the cooking pots turn without mistake, start heat up.

5) Record the time of heat up and beginning temperature, then record time and temperature for every 10-15 min.

6) When cooking completed, turn off the power supply, make sure the lids of cooking pots upward when stop turning. Connect the gas gates of cooking pots with rubber tube, release gas of cooking pots carefully. Then unbolt the lids of cooking pots symmetrically, uncover cooking pots.

7) Release pulp and residual liquor inside the cooking pots. Take sufficient back liquor into clean and dry reagent bottles, for assessments and analysis of residual liquor. Displace total pulp inside the pot and sticky in the lids to a container.

8) Clean cooking pots, using water above 50 ℃. Then wipe all parts of cooking pots.

3.5.5. Disposal the pulp.

1) Displace the pulp to plastic nets scrubbers, wash using water.

2) After the wash, put the plastic nets into bags, using centrifuge dry the pulp (till no any more centrifugal water come out).

3) Take out the bags of pulp, twist up and mix. Weigh the moist pulp, then put the pulp into airproof glass jars or airproof plastic bags, label them. After the EMC (Equilibrate Moisture Content), measure moisture content of pulp and calculate total pulp yield. The rest of pulp store in a refrigerator, spare for further assessments and analysis.

3.5.6. Screen pulp.

Due to small quantity of laboratory cooking experiments, raw material easily mix with cooking liquor, material heat up equably, so compare with pulp from pulp mills, the pulp from laboratory cooking is more homogeneous.

However due to plant fibre of different parts of wood, different quality of raw material, some non-fibre impurity and affect of cooking conditions, there will be some coarse pulp, which is haven't been decomposed or non-fibre impurity. Ought to screen and clean the pulp.

Chart 3.5-4 Pulp screener machine.

3.6. Screen pulp and determine rate of coarse pulp.

3.6.1. Principles of determination.
Use apertures of screen out big-size coarse pulp.

3.6.2. Facilities of determination.
Screen pulp machine, 0.30 – 0.35 apertures of screen for chemical pulp, net bags.

3.6.3. Procedure of determination.
Clean the apertures of screen, start up water supply, keep a certain water level, add the pulp, make the concentration reach around 0.2%- 0.3%, start up blender and pulsator, put pulp pipe down, then pulp could via the pipe through the screen down to the bags.
After screening the pulp, collect pulp residue, weight it and calculate the moisture content, then calculate the rate of coarse pulp. If quantity of coarse pulp is small, could oven-dry whole coarse pulp and then calculate the rate of coarse pulp.

3.6.4. Rate of coarse pulp y (%) using this formula,

$$y = \frac{m4}{m3} * 100\%$$

In which, m3: mass of absolute dry pulp (g), m4: mass of absolute dry coarse pulp (g).

3.7. Determination of Kappa number.

Determination of permanganate number and Kappa number.
Permanganate number and Kappa number in the pulp represent content of lignin and other

reductant residual in the pulp after cooking, indirect represent scale of delignify, so they could estimate effect of cooking and bleach ability of pulp, and they could be basis of bleach conditions.

Permanganate number and Kappa number in the pulp is decided by reagents consumption of quantificational absolute-dry pulp. The determination principle of permanganate number and Kappa number are the same, but condition and computing methods of permanganate number and Kappa number are not the same, the two computing methods could be converse. Permanganate number is applicable to chemical pulp, Kappa number is applicable to extensive pulp, not only to chemical pulp, but also to semi-chemical pulp under 60% pulp yield.

Standard China national determination of Kappa number (GB/ T1546-1989) could be used in diversified unbleached chemical pulp and semi-chemical pulp fewer than 60% pulp yield. For low lignin content or small testing pulp, could use micro determination of Kappa number (like TAPPI method).
(Shu lang Shi, Fu wang He. 2006. In Chinese)

Determination of Kappa number.
Method also according to TAPPI Useful Method U M246.
3.7.1. Principle of determination.
Scattered pulp reacts with quantificational potassium permanganate ($KMnO_4$) in certain conditions. The chosen pulp is: When chemical reaction ending, around 50% potassium permanganate haven't been consumed. Add potassium iodide (KI) and end chemical reaction , use sodium hydrosulfite ($Na_2S_2O_3$) standard solution titrate free iodine (I_2). Then use the gained data converse to 50% quantity of potassium permanganate.

The chemical reaction is:
$2KMnO_4 + 8H_2SO_4 + 10KI = 2MnO_4 + 6KSO_4 + 5I_2 + 8H_2O$.
$2Na_2S_2O_3 + I_2 = Na_2S_4O_6 + 2NaI$.

3.7.2. Instruments and reagents.
1) Electric blender, rotational speed is (500±100) r/ min.
2) Scatter machine for pulp, minitype.
3) Constant temperature water bath.
4) Stopwatch.
5) Potassium permanganate ($KMnO_4$) standard solution, c= (0.02± 0.001) mol/L ($KMnO_4$). Contain 3.161 g $KMnO_4$ per liter liquor.
6) Sodium hydrosulfite ($Na_2S_2O_3$) standard solution, c= (0.02± 0.0005) mol/L ($Na_2S_2O_3$). Contain 24.82 g $Na_2S_2O_3 . 5H_2O$ per liter liquor.
7) Potassium iodide (KI) solution, c= 1 mol/L (KI). Weight 166 g Potassium iodide (KI) and dissolve it in distilled water, transfer it to 1000 mL volumetric flask, use distilled water dilute it to 1000 mL.
8) Sulphuric acid (H_2SO_4) solution, c= 2 mol/ L (H_2SO_4). Measure sulphuric acid (H_2SO_4) (relative density is 1.84) 112 mL, slow infuse 800 mL distilled water; cooling and then use distilled water dilute it to 1000 mL.

9) Distilled water.
10) 5 g/L starch solution. Weight 0.5 g soluble starch, dissolve it in 100 mL distilled water, boiling and then cooling.
11) 5 mL or 10 mL titration droppers.
12) Transfer pipettes.
13) Beakers, containers, measuring cylinders, volumetric flasks, measuring flasks and other vessels.

3.7.3. Procedure of determination.

1) Estimate moisture content of pulp and estimated Kappa number, take some pulp samples and weight it, then put the pulp into minitype scatter machine.

2) Use measuring cylinder measure 400 mL distilled water, infuse 200- 240 mL distilled water into scatter machine.

3) Start up scatter machine scatter the pulp to scattered pulp completely and no any more concentrated pulp.

4) Put the scattered pulp into beaker, use some of distilled water wash the whole pulp in scatter machine to the beaker.

5) Place the beaker on the electric blender, start up electric blender in around 25 ℃ circumstance, make sure mix the pulp equably. If the room temperature and water temperature outside the standard temperature 20- 30 ℃, then place the beaker in 25 ℃ constant temperature water bath and use electric blender.

6) Use transfer pipette transfer 50 mL 0.02 mol/L potassium permanganate ($KMnO_4$) standard solution and 50 mL 2 mol/L sulphuric acid (H_2SO_4) solution to a big beaker, add the mixed liquor with the scattered pulp, at the same time start up stopwatch. Use the rest distilled water wash the mixed liquor; make sure whole mixed liquor to the big beaker.

7) Duration of reaction is exact 10 minutes; record the temperature inside the big beaker at reaction time 5 minutes.

8) When 10 min reaction time ending, add 10 mL 1mol/L potassium iodide (KI) solution immediately, and use 0.2 mol/L sodium hydrosulfite ($Na_2S_2O_3$) standard solution titrate extracted the iodine (I_2) immediately, till the liquor appears light purple-yellow colour, add 2-3 starch solution, continue sodium hydrosulfite ($Na_2S_2O_3$) standard solution titrate the liquor until the blue colour disappear.

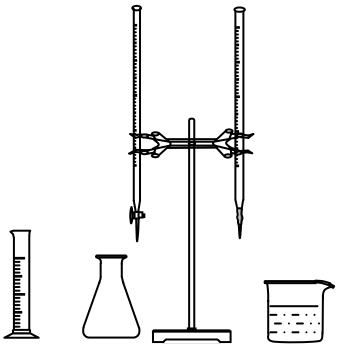
9) Do another parallel determination, take arithmetic mean.

10) Test for blanks according to the same procedure of determinations.

Table 3.7-1. Kappa number determination conditions.

Items	Determination of Kappa number
Volume of 0.02 mol/L $KMnO_4$ standard solution.(mL)	50
Volume of 2 mol/L H_2SO_4 solution. (mL)	50
Volume of distilled water.(mL)	400
Volume of total liquor.(mL)	500
Volume of 1 mol/L KI.(mL)	10
Concentration of $Na_2S_2O_3$ standard solution.(mol/L)	0.1-0.2
The maximum mass of absolute-dry pulp.(g)	5

Chart 3.7-2. Instruments for Kappa number determination.



3.7.4. Notes.

1) The quantity of reagents, duration of reaction, temperature of reaction and scatteration of pulp will affect the determination, so every step should according to the requirements.

2) Due to I^{-1} in acidic condition could easily be oxidized to I_2 by O_2, so slow stir the liquor after adding KI, prevent I^{-1} be oxidized, and titrate immediately sodium hydrosulfite ($Na_2S_2O_3$) standard solution.

3) Due to the volatilization of I_2 is alterable, so the duration of adding KI and titration should be shorten.

3.7.5. Calculations.

Calculate Kappa number (K) use this formula,

$$K = \frac{(V2 - V1) * c}{0.1} * \frac{f}{m} * [(25 - t) * 0.013 + 1].$$

In which, V1: consumption of sodium hydrosulfite ($Na_2S_2O_3$) standard solution in the titration, mL.

V2: consumption of sodium hydrosulfite ($Na_2S_2O_3$) standard solution in the test for blanks, mL.

c: concentration of sodium hydrosulfite ($Na_2S_2O_3$) standard solution, mol/L.

m: mass of absolute-dry pulp, g.

K: Kappa number.
t: temperature of reaction, should be in the range 20 – 30 ℃ and close to 25 ℃ had best,-Could choose temperature at 5 min reaction, hypothetically this temperature is average temperature of the whole reaction. ℃.
f: correction factor for conversion 50% consumption of potassium permanganate ($KMnO_4$). The correction factor see the table.
The correction factor base on research of determination, it is calculated by this formula:
$\log f$ = 0.00093*(V2-50).

Table 3.7-3. Table of the correction factor f in Kappa number calculations.

Consumption $KMnO_4$ standard solution.(%)	Table of the correction factor f f									
(V2-V1)/V2*100	0	1	2	3	4	5	6	7	8	9
10	0.911	0.913	0.915	0.918	0.920	0.923	0.925	0.927	0.929	0.930
20	0.934	0.936	0.938	0.941	0.943	0.945	0.947	0.949	0.952	0.954
30	0.958	0.960	0.962	0.964	0.966	0.968	0.970	0.973	0.975	0.977
40	0.979	0.981	0.983	0.985	0.987	0.989	0.991	0.994	0.996	0.998
50	1.000	1.002	1.004	1.006	1.009	1.011	1.013	1.015	1.017	1.019
60	1.022	1.024	1.026	1.028	1.030	1.033	1.035	1.037	1.039	1.042
70	1.044									

(China National Standard. In Chinese)

3.8. Determination of residual alkali in black liquor.

3.8.1. Principle of determination.
The residual alkali in black liquor in kraft pulping is NaOH+ 1/2 Na_2S. Use barium chloride ($BaCl_2$) precipitate lignin, sodium carbonate (Na_2CO_3) and sodium sulfite (Na_2SO_3), then titrate the supernatant liquor and calculate it.

3.8.2. Instruments and reagents.
1) Volumetric flasks, capacity 500 mL.
2) Barium chloride ($BaCl_2$) solution, 100 g/L.
3) Sodium chloride (NaCl) standard solution, 0.1 mol/L.
4) Phenolphthalein indicator.
5) Distilled water.
6) Transfer pipettes.
7) Titration droppers.
8) Sulphuric acid (H_2SO_4).

3.8.3. Procedure of determination.
50- 70 mL 100 g/L barium chloride ($BaCl_2$) solution in a 500 mL volumetric flask, add distilled water around 150 mL. Then transfer 50 mL black liquor to the volumetric flask using transfer pipettes. Then add distilled water to scale of the volumetric flask, shake it up and place it.

Imbibe some drops of supernatant liquor, use sulphuric acid (H_2SO_4) check whether the barium chloride ($BaCl_2$) was excessive. If there is not chemical precipitation barium sulfate ($BaSO_4$), indicate the barium chloride ($BaCl_2$) was insufficient, then should do the determination again.

Filtrate some supernatant liquor using dry filter paper. Then take 40 mL filtrate, phenolphthalein as indicator, 0.1 mol/L sodium chloride (NaCl) standard solution titrate the filtrate till the red colour disappear.

3.8.4. Calculations.
Residual alkali (NaOH) in black liquor (g/L),

Residual alkali (NaOH) $= \dfrac{V * c * 0.040}{50 * \dfrac{50}{500}} * 1000$ (g/L).

In which, V: consumption of sodium chloride (NaCl) standard solution in the titration, mL.
c: concentration of sodium chloride (NaCl) standard solution, mol/L.
0.040: mass of sodium hydroxide (NaOH) correspond to 1 m mol sodium chloride (NaCl) standard solution.

3.8.5. Notes.
1) In the operation, first adding barium chloride ($BaCl_2$) solution and black liquor and then adding distilled water, it is better, in favor of chemical precipitation, and taking the supernatant liquor is easier.

2) If the black liquor is too dense (solidification of black liquor more than 20%), should weight the black liquor samples. When calculate residual alkali, should consider the density of black liquor, use this formula,

Residual alkali (NaOH) $= \dfrac{V * c * 0.040}{m * \dfrac{50}{500}} * d * 1000$ (g/L).

In which, V: consumption of sodium chloride (NaCl) standard solution in the titration, mL.
c: concentration of sodium chloride (NaCl) standard solution, mol/L.
0.040: mass of sodium hydroxide (NaOH) correspond to 1 m mol sodium chloride (NaCl) standard solution.
m: The mass of black liquor samples, g.
d: The density of black liquor samples, g/cm^3.

3) The distilled water in the determination should be fresh boiling, without carbon dioxide (CO_2) and cooling. In order to prevent sodium carbonate (Na_2CO_3) affect the assessments.
(Shu lang Shi, Fu wang He. 2006. In Chinese)

4. Results

More summary of data results was put in Part Appendix.

4.1. Results for wood basic density measurement and other wood characteristics analysis.

Descriptive statistics.

Introduction: Table 4.1-1. Descriptive statistic of all data from the wood basic density assessments. The purpose is to find out the variation of wood basic density between 4 eucalyptus clones, to find out which clone is showing the highest wood basic density of the 4 clones, etc. For comparing the 4 clones, mainly by comparing the mean, standard deviation, 95% confidence interval for mean, with lower bound and upper bound of the 4 eucalyptus clones. And minimum, maximum and numbers is giving more additional information.

In Table 4.1-1. each clone represents total 5 discs from a whole tree. The 5 discs from breast height (at 1.3 meter), 1/4, 2/4, 3/4, top (at 5 cm over bark) of a tree.

Fixed and random effects displays the standard deviation, standard error, and 95% confidence interval for the fixed-effects model, and the standard error, 95% confidence interval, and estimate of between-components variance for the random-effects model.
Confidence interval for mean is a range of values, based on the sample mean, that, with a designated likelihood, include the population mean.

Clone DH201-2 is showing the highest wood basic density of the 4 clones, the 95% Confidence Interval for mean lower bound is 503.80, upper bound is 530.51, and this is significant higher than the other clones.
Clone DH32-13, 95% Confidence Interval for mean lower bound is 443.94, upper bound is 461.45, and it is the lowest wood basic density of the 4 clones.

Table 4.1-1. Descriptive statistics of wood basic density for the 4 clones. Number of cases, mean, standard deviation, standard error, 95% confidence interval for mean, minimum, maximum and between- component variance were given.
Original data see Appendix Table 7-1.

					95% Confidence Interval for Mean				
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum	Between-Component Variance
U6	15	470.16	19.18	4.95	459.54	480.78	440.72	498.95	
DH201-2	15	517.15	24.12	6.23	503.80	530.51	479.92	562.53	

SH1		15	479.15	22.11	5.71	466.90	491.40	451.78	532.50	
DH32-13		15	452.70	15.81	4.08	443.94	461.45	421.54	482.31	
Total		60	479.79	31.08	4.01	471.76	487.82	421.54	562.53	
Model	Fixed Effects		20.54	2.65	474.48	485.10				
	Random Effects			13.61	436.47	523.11				712.94

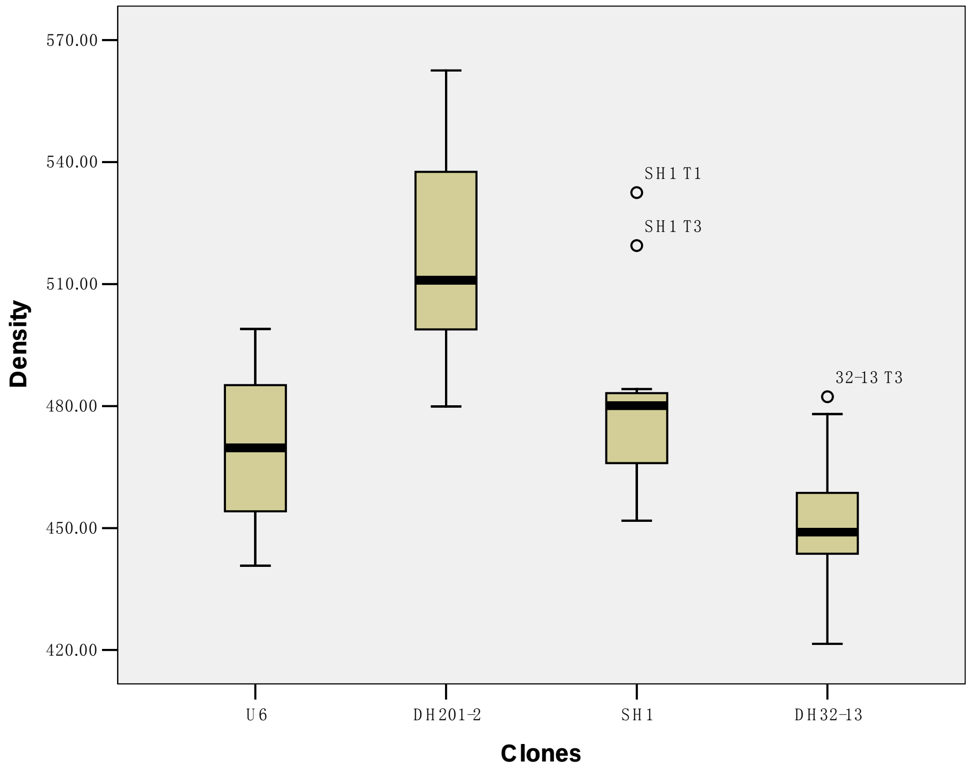
Boxplot of wood basic density for the 4 clones.

Introduction: Chart 4.1-2. are showing boxplots from the wood basic density assessments. The purpose is to show the variation of wood basic density between the 4 eucalyptus clones, to show which clone is showing the highest of wood basic density of the 4 clones, etc. For comparing the 4 clones, mainly by comparing the median, quartiles, outliers and extremes.

The box length is the inter-quartile range.
Outliers are cases with values between 1.5 and 3 box lengths from the upper or lower edge of the box.
Extreme cases are cases with values more than 3 box lengths from the upper or lower edge of the box.

Chart 4.1-2. shows that there is big variation between the 4 clones.
Clone DH201-2 is showing the highest median wood basic density of the 4 clones, and significant different to the other 3 clones.
The wood basic density of SH1 and U6 can not be statistically separated, and they are medium wood basic density.
Clone DH32-13 is showing the lowest wood basic density for median value of the 4 clones, and it is a little lower than SH1 and U6, but the differences between them are not large enough to be statistically significant.
Clone SH1 and DH32-13 are showing some outliers, but none of them can be proven to be false. The outliers influence on means and median of clones and is making the differences between DH32-13 and SH1 look bigger than it might be.

Chart 4.1-2. Boxplot of wood basic density for the 4 clones. Outliers, extremes, quartiles and the median line have been displayed for each box.
Original data see Appendix Table 7-1.



ANOVA (analysis of variance) for wood basic density.

Introduction: ANOVA (analysis of variance) using computer statistic the variation of wood basic density between 4 eucalyptus clones, post hoc range tests and pairwise multiple comparisons determine which clone is different from the others by separating different sub-groups.

The One-Way ANOVA procedure produces a one-way analysis of variance for a quantitative dependent variable by a single factor (independent) variable. Analysis of variance is used to test the hypothesis that several means are equal. This technique is an extension of the two-sample t test.

In analysis of variance, the F value = 26.339, P value = 0.000 < 0.001, means that the clones have statistically high significant effect on density, the density of the 4 clones were dissimilar.

Post hoc multiple comparisons for wood basic density.

Student-Newman-Keuls in ANOVA (analysis of variance) post hoc tests. Makes all pairwise comparisons between means using the Studentized range distribution. With equal sample sizes, it also compares pairs of means within homogeneous subsets, using a stepwise procedure. Means are ordered from highest to lowest, and extreme differences are tested first.

Table 4.1-3. show that the 4 clones can be apart in 3 sub-groups. Clone DH201-2 is in one sub-group and it is showing the highest wood basic density. Clone SH1 and U6 are forming one sub-group, and they are homogeneous. Clone DH32-13 is in one sub-group and it is showing the lowest wood basic density. Sub-group DH201-2 is showing significantly higher wood basic density than sub-group SH1 and U6, and these two sub-groups are both higher than sub-group DH32-13.

Table 4.1-3. Post hoc multiple comparisons of wood basic density. Means density of the 4 clones were given. Use Student-Newman-Keuls for post hoc multiple comparisons.
Homogeneous Subsets: Wood basic density
Original data see Appendix Table 7-1.

Student-Newman-Keuls a

Clones4	N	Subset for alpha = .05		
		1	2	3
DH32-13	15	452.6961		
U6	15		470.1606	
SH1	15		479.1489	
DH201-2	15			517.1534
Sig.			0.236	

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 15.000.

4.2. Results for bark volume percentage analysis.

Descriptive statistics.

Introduction: Table 4.2-1 Descriptive statistic of all data from the bark volume percentage assessments. The purpose is to find out the variation of bark percentage between the 4 eucalyptus clones, to find out which clone is showing the lowest in bark percentage of the 4 clones, etc. For comparing the 4 clones, mainly by comparing the mean, standard deviation, 95% confidence interval for mean with lower bound and upper bound of the 4 eucalyptus clones. And minimum, maximum and numbers give more additional information.

Table 4.2-1. Each clone represents total 5 discs from a whole tree. The 5 discs from breast height (at 1.3 meter), 1/4, 2/4, 3/4, top (at 5 cm over bark) of a tree.

Fixed and random effects displays the standard deviation, standard error, and 95% confidence interval for the fixed-effects model, and the standard error, 95% confidence interval, and estimate of between-components variance for the random-effects model.
Confidence interval for mean is a range of values, based on the sample mean, that, with a designated likelihood, include the population mean.

In Table 4.2-1. There is a significant difference between the bark volume percentage of clone U6 and SH1; SH1 is much lower bark volume percentage than U6.
Clone U6, 95% Confidence Interval for mean lower bound was 17.07%, upper bound is 20.01%,

and it is the highest bark volume percentage of the 4 clones. Clone SH1, 95% Confidence Interval for mean lower bound is 12.79%, upper bound is 15.17%, and it is the lowest bark volume percentage of the 4 clones.

Table 4.2-1. Descriptive statistics of bark volume percentage for the 4 clones. Number of cases, mean, standard deviation, standard error, 95% confidence interval for mean, minimum, maximum and between- component variance were given.
Original data see Appendix Table 7-1.

						95% Confidence Interval for Mean				
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum	Between-Component Variance
U6		15	18.54	2.65	0.69	17.07	20.01	14.82	23.10	
DH201-2		14	15.93	2.72	0.73	14.36	17.50	11.40	19.65	
SH1		15	13.98	2.15	0.56	12.79	15.17	11.85	17.86	
DH32-13		15	16.55	2.56	0.66	15.13	17.97	12.72	20.38	
Total		59	16.25	2.96	0.39	15.48	17.03	11.40	23.10	
Model	Fixed Effects		2.53	0.33	15.60	16.91				
	Random Effects			0.95	13.24	19.27				3.15

Boxplot of bark volume percentage for the 4 clones.

Introduction: Chart 4.2-2. are showing boxplots from the bark volume percentage assessments. The purpose is to show the variation of bark percentage between 4 eucalyptus clones, to show which clone is showing the lowest bark percentage of the 4 clones, etc. For comparing the 4 clones, mainly by comparing the median, quartiles, outliers and extremes.

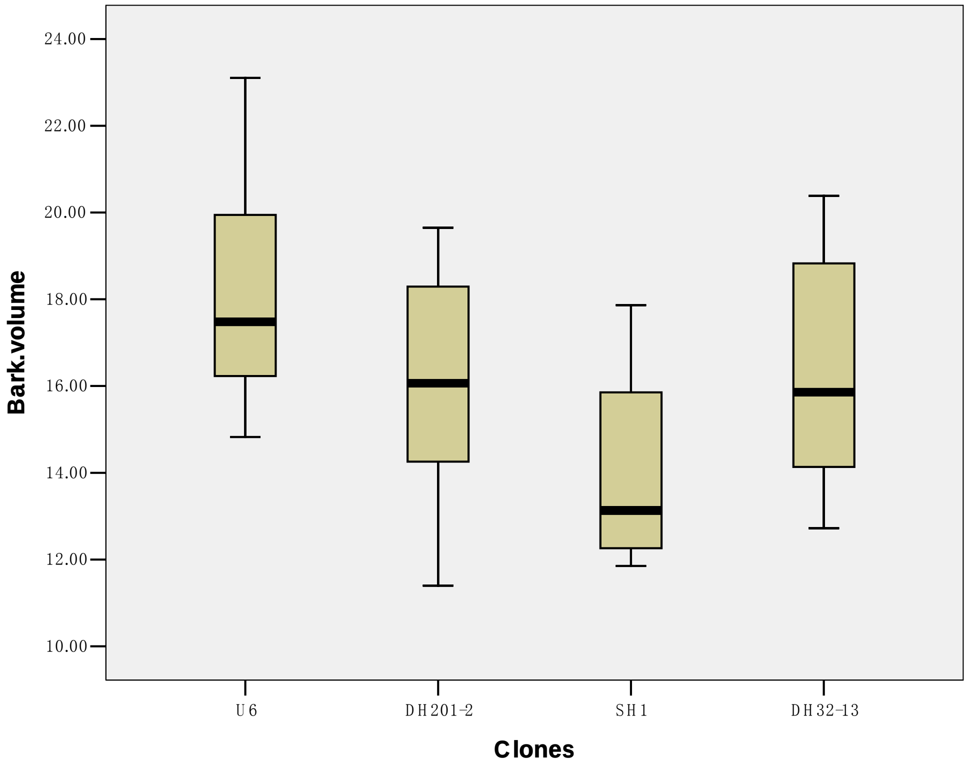
The box length is the inter-quartile range.
Outliers are cases with values between 1.5 and 3 box lengths from the upper or lower edge of the box.
Extreme cases are cases with values more than 3 box lengths from the upper or lower edge of the box.

In this case there are no any outliers or extreme value.

Chart 4.2-2. shows that there is big variation between the 4 clones.
Clone U6 is showing the highest bark volume percentage of the 4 clones, it is a little higher than DH32-13 and DH201-2, but the differences between them are not large enough to be statistically significant.
The bark volume percentage of DH32-13 and DH201-2 can not be statistically separated, there are showing medium bark volume percentage.
SH1 is showing the lowest bark volume percentage of the 4 clones, it is a little lower than DH32-13 and DH201-2, but the differences between them are not large enough to be statistically

significant.
There is significant difference between clone U6 and SH1; SH1 is much lower bark volume percentage than U6.

Chart 4.2-2. Boxplot of bark volume percentage for the 4 clones. Outliers, extremes, quartiles and the median line have been displayed for each box.
Original data see Appendix Table 7-1.



ANOVA (analysis of variance) for bark volume percentage.

Introduction: ANOVA (analysis of variance) using computer statistic the variation of bark volume percentage between 4 eucalyptus clones, post hoc range tests and pairwise multiple comparisons determine which clone is different from the others by separating different sub-groups.

The One-Way ANOVA procedure produces a one-way analysis of variance for a quantitative dependent variable by a single factor (independent) variable. Analysis of variance is used to test the hypothesis that several means are equal. This technique is an extension of the two-sample t test.

In the analysis of variance, the F value = 8.286, P value = 0.000 < 0.001, means that the clones statistically high significant effecting on bark volume percentage, bark volume percentage of the 4 clones are dissimilar.

Post hoc multiple comparisons for bark volume percentage.

Student-Newman-Keuls in ANOVA (analysis of variance) post hoc tests. Makes all pairwise comparisons between means using the Studentized range distribution. With equal sample sizes, it also compares pairs of means within homogeneous subsets, using a stepwise procedure. Means are ordered from highest to lowest, and extreme differences are tested first.

Table 4.2-3. The tests show that the 4 clones can be apart to 3 sub-groups. Clone U6 is in one sub-group and it is showing the highest bark volume percentage of the 4 clones. Clone SH1 and DH32-13 are forming one sub-group. Clone SH1 is in one sub-group and it is the lowest bark volume percentage. Sub-group U6 is higher bark volume percentage than sub-group DH32-13 and DH201-2, and the two sub-groups are both higher than sub-group SH1.

Table 4.2-3. Post hoc multiple comparisons of bark volume percentage. Means bark volume percentage of the 4 clones were given. Use Student-Newman-Keuls for post hoc multiple comparisons.
Original data see Appendix Table 7-1.
Homogeneous Subsets: Bark volume percentage
Student-Newman-Keuls a,b

Clones4	N	Subset for alpha = .05		
		1	2	3
SH1	15	13.9780		
DH201-2	14		15.9288	
DH32-13	15		16.5528	
U6	15			18.5361
Sig.			0.505	

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 14.737.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

4.3. Results for pulp assessments.

Cooking process conditions.

Introduction: To show different cooking conditions (mainly AQ Content and Alkali Content) of all these pulp assessments. The results will be different from different cooking conditions and different pulp assessments.

The sulfidity 25%, liquor to wood ratio 4:1, maximum temperature 165 ℃, duration of cooking 210 min., cooking temperature curve would be keeping the same for the total cooking. However in some cooking adding catalyst anthraquinone (AQ) 0.05%, some cooking without using anthraquinone (AQ). Alkali charge was adjusted from 15.4 to 16.3 for control the Kappa number in around 18.

The Kappa number of pulp in pulp yield less than 70% have linear relationship with lignin content, the Kappa number equal to lignin content divide 0.15.

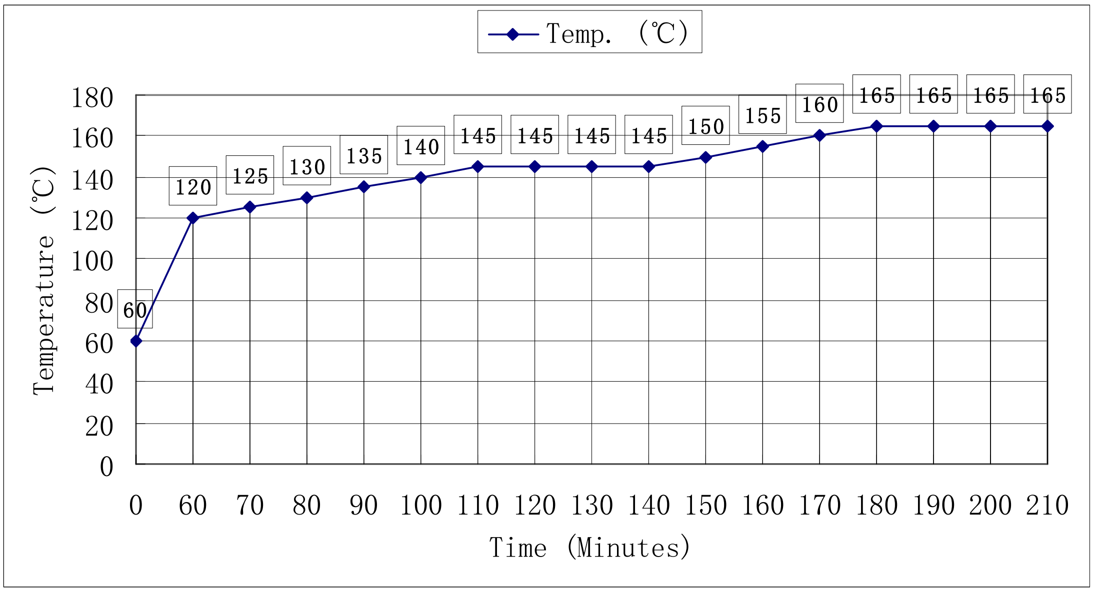
In order to assess the pulp yield correctly, we used the target Kappa 18 for cooking, tried to control the Kappa Number in 18 ±1 for the whole cooking.

Then using this transform to pulp yield at Kappa 18 approximately.
Pulp yield (at Kappa 18) = Pulp yield (at different Kappa number) + (18- (different Kappa number))* 0.15

Table 4.3-1. Cooking conditions.

Cooking conditions:	
Sulfidity (%):	25
Alkali Content (%):	15.4 or 15.7 or 16 or 16.3
AQ Content (%):	0
Liquor to wood ratio :	4:1
Maximum Temperature (℃):	165
Duration of cooking (Minutes):	210

Table 4.3-2. Cooking temperature curve.



Descriptive statistics.

Introduction: Table 4.3-4. Descriptive statistic of all data in total pulp yield at Kappa 18 from the pulp yield assessments and Kappa number assessments. The purpose is to find out the variation of total pulp yield at Kappa 18 between the 4 eucalyptus clones, to find out which clone is showing the highest in total pulp yield at Kappa 18 of the 4 clones, etc. For comparing the 4 clones, mainly by comparing the mean, standard deviation, 95% confidence interval for mean with lower bound and upper bound of the 4 eucalyptus clones. And minimum, maximum and numbers give more additional information.

In Table 4.3-4. Each Clone represents total 5 discs from a whole tree. The 5 discs from breast height (at 1.3 meter), 1/4, 2/4, 3/4, top (at 5 cm over bark) of a tree. And mix the 5 discs as for mix pulping of whole tree.

Fixed and random effects displays the standard deviation, standard error, and 95% confidence interval for the fixed-effects model, and the standard error, 95% confidence interval, and estimate of between-components variance for the random-effects model.
Confidence interval for mean is a range of values, based on the sample mean, that, with a designated likelihood, include the population mean.

Table 4.3-4. The means and 95% Confidence Interval for mean of total pulp yield of the 4 clons can not be statistically separated, the differences between them are not large enough to be statistically significant.
There are indications of the mean of DH201-2 and DH32-13 and SH1 is higher total pulp yield than U6, the U6 is showing the lowest pulp yield. And the mean of DH32-13 and DH201-2 are a little higher than and SH1.

Table 4.3-4. Descriptive statistics of total pulp yield at Kappa 18 for the 4 clones. Data from total cooking without using anthraquinone (AQ). Number of cases, mean, standard deviation, standard error, 95% confidence interval for mean, minimum, maximum and between- component variance were given.
Original data see Appendix Table 7-2. Total pulp yield at K18 (%) column.

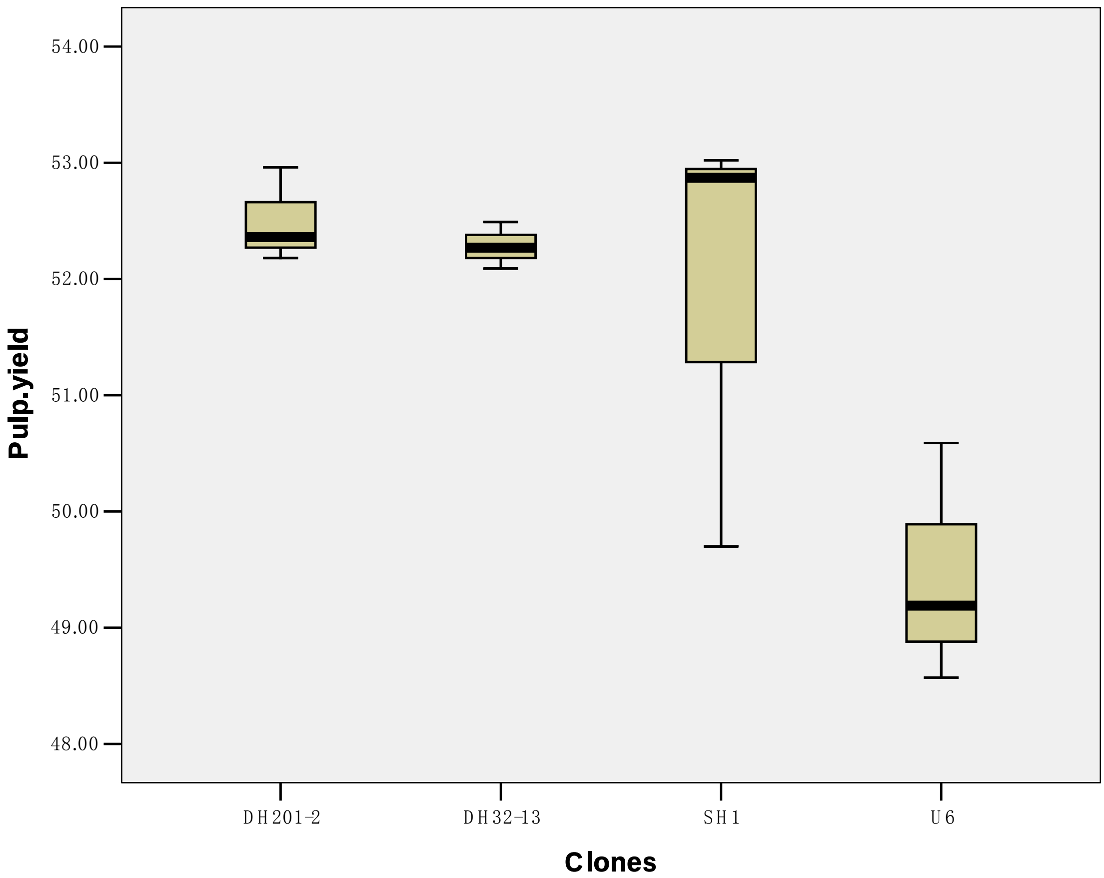
						95% Confidence Interval for Mean				
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum	Between-Component Variance
DH32-13		3	52.28	0.20	0.12	51.79	52.78	52.09	52.49	
DH201-2		3	52.50	0.41	0.24	51.49	53.51	52.18	52.96	
SH1		3	51.86	1.88	1.08	47.21	56.52	49.70	53.02	
U6		3	49.45	1.03	0.60	46.88	52.02	48.57	50.59	
Total		12	51.52	1.58	0.46	50.52	52.53	48.57	53.02	
Model	Fixed Effects			1.09	0.32	50.80	52.25			
	Random Effects				0.70	49.28	53.76			1.58

Boxplot of total pulp yield at Kappa 18 for the 4 clones.

Introduction: Chart 4.3-4. are showing boxplot of total pulp yield at Kappa 18 from the pulp yield assessments and Kappa number assessments. The purpose is to show the variation of total pulp yield at Kappa 18 between the 4 eucalyptus clones, to show which clone is showing the highest for total pulp yield at Kappa 18, etc. For comparing the 4 clones, mainly by comparing the median, quartiles, outliers and extremes.

Chart 4.3-4. Clone U6 is showing the lowest total pulp yield of the 4 clones, but it can not well separated with other clones.
The total pulp yield of clones SH1, DH32-13 and SH1 can not be statistically separated, the differences between them are not large enough to be statistically significant.

Chart 4.3-4. Boxplot of total pulp yield at Kappa 18 for the 4 clones. Data from total cooking without using Anthraquinone (AQ).Tthe median line have been displayed for each box.
Original data see Appendix Table 7-2. Total pulp yield at K18 (%) column.



4.4. Results for pulp production and the interaction of pulp production, density and pulp yield.

Introduction: Table 4.4-1. Statistics of means pulp production using means wood basic density, means pulp yield at Kappa number 18 and means bark volume percentage. For comparing the 4 clones, by comparing the means pulp production (didn't consider bark) and means pulp production (with bark volume). The purpose is to find out which clone is showing the highest pulp production.

In Table 4.4-1.the means were given. Each Clone represents total 5 discs from a whole tree. The 5 discs from Breast Height (at 1.3 meter), 1/4, 2/4, 3/4, top (at 5 cm over bark diameter) of a tree. And mix the 5 discs for mix pulping of whole tree.

It including means wood basic density, means total pulp yield and means bark volume percentage, calculate the pulp production (didn't consider bark) and pulp production (with bark volume). These means from all data could be seen further in Appendix, Table 7-4. Data from field work and wood basic density measurements. And Table 7-7. Data from cooking without using AQ and cooking adding 0.05% AQ assessments.

Pulp production (didn't consider bark) (kg/m^3) = (Pulp yield (%)* 0.01)* Wood basic density (kg/m^3)

Pulp production (with bark volume) (kg/m^3) = (Pulp yield (%)* 0.01)* Wood basic density (kg/m^3)* (1- Bark volume percentage (%)* 0.01)

Clone DH201-2 is showing the highest pulp production (didn't consider bark) and pulp production (with bark volume) of the 4 clones. U6 is showing the lowest pulp production (didn't consider bark) and pulp production (with bark volume).

Table 4.4-1. Statistics of bark volume percentage, bark weight percentage, wood basic density, total pulp yield at Kappa 18, pulp production (didn't consider bark), pulp production (with bark volume). Data and results from total cooking without using anthraquinone (AQ).
Original data see Appendix Table 7-4, Table 7-5 and Table 7-6.

Clones &position	Bark volume (%)	Wood basic density (kg/m^3)	Total pulp yield at K18 (%)	Pulp production (kg/m^3)	Pulp production with bark Vol. (kg/m^3)
U6	17.76	467.11	49.35	230.52	189.58
DH201-2	14.61	517.59	52.53	271.89	232.17
SH1	13.09	470.51	52.41	246.59	214.32
DH32-13	15.74	452.84	52.27	236.70	199.44

The interaction and relationship of pulp production, density and pulp yield.

Introduction: By scatter plots, the relationship between three quantitative variables pulp production, density and pulp yield can be highlighting by plotting the actual values along three axes.

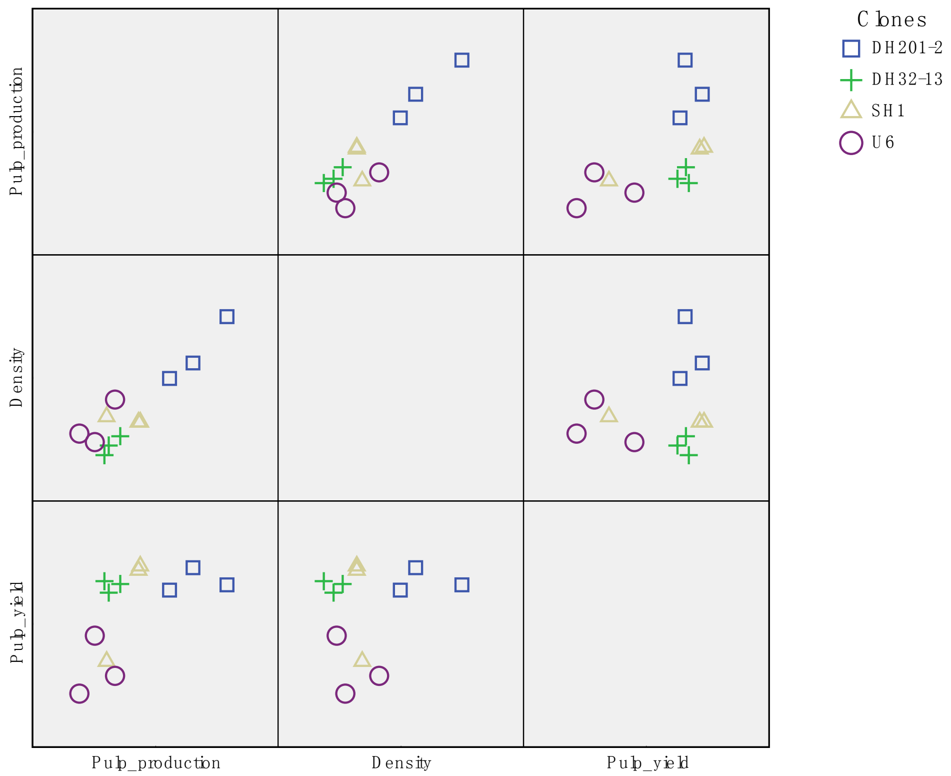
Chart 4.4-2. shows the relationship between wood basic density, pulp yield and pulp production (didn't consider bark).

Clones showing high density is showing high pulp production and vice versa.

DH201-2 is showing the highest density and pulp yield, and it is showing the highest pulp production.
U6 is showing the lowest pulp yield, and it is showing the lowest pulp production.

High wood basic density clones are showing high pulp production, even it seems to be linear relationship. It is also likely to the 4 clones cooking in the same conditions, and in this case the variation of pulp yield is not too high, making wood basic density became the most influencing factor to pulp production.
DH201-2 is showing the highest wood basic density and pulp yield, and it is showing the highest pulp production. U6 is showing the lowest pulp yield, and it is showing lowest pulp production.

Chart 4.4-2. Scatter plot matrix for density, pulp yield and pulp production (didn't consider bark). Data from total cooking without using anthraquinone (AQ). Data were average.



5. Discussion and Conclusion

1) In the wood basic density assessments and analysis, clone DH201-2 is showing the highest wood basic density of the 4 clones, it is significant different to the other 3 clones, its mean and median values are well separated from the other 3 clones.
In the wood basic density assessments and analysis, there are not significant differences shown between the 3 clones SH1, U6 and DH32-13.
There are indications of clone DH32-13 is showing the lowest density. Clone DH32-13 is showing the lowest mean value and medium value of the 3 clones, and in the ANOVA (analysis of variance) the clone DH32-13 is separated from SH1 and U6, and in one sub-group which is lowest density.

In the bark volume assessments and analysis, the bark volume of clone U6 is significant higher than clone SH1.
There are not significant differences shown between the bark volume percentage of the 3 clones SH1, DH201-2 and DH32-13.
There are indications of clone U6 is showing the highest bark volume percentage, in the ANOVA clone U6 is separated from the other 3 clones, in one sub-group which is highest bark volume percentage.
There are indications of clone SH1 is showing the lowest bark volume percentage, in the ANOVA clone SH1 is separated from the other 3 clones, in one sub-group which is lowest bark volume percentage.

In the pulping and Kappa number assessments and analysis, clone U6 is showing the lowest total pulp yield at Kappa 18 of the 4 clones, but it can not well separated with other clones.
There are not significant differences shown between the 3 clones SH1, DH201-2 and DH32-13. The means pulp yield of the 3 clones can not be statistically separated.
There are indications of the mean of DH201-2 and DH32-13 and SH1 is higher total pulp yield than U6, and the mean of DH32-13 and DH201-2 are a little higher than and SH1.

2) In this project, the clones DH201-2 is showing the highest value in the pulping of the 4 clones, it is 271.89 kg/m^3 (without bark) or 232.17 kg/m^3 (with bark).
The clone U6 is showing the lowest value in pulp production of the 4 clones, it is 230.52 kg/m^3 (without bark) or 189.58 kg/m^3 (with bark).
However just one project cannot fully determine the entire value of the 4 clones.

It is a suggestion that the eucalyptus plantations in southern Guangxi for a future pulp/ paper industry, should based on clone DH201-2, and avoid clone U6.

3) In the wood basic density analysis, there is an outlier which is showing high density value influencing the 95% Confidence Interval. This outlier is not proving false, but if the outlier is false then clone DH32-13 could be proving significant lower than the other 2 clones SH1 and U6.

In the wood basic density assessments and analysis, the clones SH1 and DH32-13 are showing a few outliers, these made the means values of DH32-13 and SH1 seems bigger. SH1 Tree1 and SH1 Tree3 are showing variation with others trees in clone SH1. The reasons could be the tree size influencing and nature environment influencing.

For every 3 trees from each clone, we select a bigger size tree, a middling size tree and a smaller size tree, make the selected trees more representative, but this way could make the 3 trees from each clone showing bigger variation.

Although we tried to select the 3 trees from each clone are all in the same age, the same fertilization and the same plant plot, but it do not insure the 3 trees in the same nature environment; this could make the 3 trees from each clone showing variation.

6. References

Peng Wei, Daping Xu, 2003. Eucalyptus Plantations. World Scientific Publishing Co. Pte. Ltd. ISBN 981-238-557-6.

Stora Enso. Stora Enso strengthens its presence in Guangxi. 2005.

Stora Enso Guangxi. 2006. Work Instructions for Basic Density Measurement.

Office of Industrial Technologies, U.S. Department of Energy. 1995. Materials Needs and Opportunities in the Pulp and Paper Industry.

EPA Office of Compliance Sector Notebook Project. 2002. Profile of the Pulp and Paper Industry, 2nd Edition.

Greer Carol, Duggirala Prasad, Duffy Brian. 2004. Digester Additives Maximize Pulping Efficiency, Reduce Bleaching Demand.

Shu lai Xie, Yu huai Zhang. 2005. (In Chinese) Principle and Engineering for Pulping, 2nd Edition. China Light Industry Press. ISBN 7-5019-0846-X / TS.0554.

Shu lang Shi, Fu wang He. 2006. (In Chinese) Pulping and Papermaking Assessments and Analysis. China Light Industry Press. ISBN 7-5019-3920-9/ TS.2332.

China National Standard, GB/ T 741-1989. (In Chinese) Pulps- Determination of moisture content.

China National Standard, GB/ T 1546-1989. (In Chinese) Pulps- Determination of Kappa number.

SPSS Inc. SPSS 13.0 instruction.

Appendix

More summary of data results was put in this part.

Table 7-1. Data from field work and wood basic density measurements.

Statistics of bark volume percentage, bark weight percentage, wood basic density, bark basic density and average bark thickness.

Clone and clone tree represents total 5 discs from a whole tree.
The 5 discs from breast height (at 1.3 meter), 1/4, 2/4, 3/4, top (at 5 cm over bark) of a tree.

Clones & Tree No.	Disc No.	Wood basic density (kg/m3)	Bark volume (%)	Bark weight (%)
U6 Tree1	1	440.72	17.48	9.55
U6 Tree1	2	455.52	15.76	8.97
U6 Tree1	3	469.71	15.87	9.29
U6 Tree1	4	486.7	17.35	13.43
U6 Tree1	5	486.7	17.35	13.43
U6 Tree2	1	478.66	16.12	8.99
U6 Tree2	2	483.62	14.82	8.56
U6 Tree2	3	498.95	16.35	8.82
U6 Tree2	4	480.48	21.52	12.73
U6 Tree2	5	498.89	23.1	15.09
U6 Tree3	1	450.57	19.77	11.22
U6 Tree3	2	460.78	19.88	11.79
U6 Tree3	3	464.68	19.82	11.5
U6 Tree3	4	443.7	22.83	15.65
U6 Tree3	5	452.72	20.02	12.87
201-2 Tree1	1	489.72	14.43	9.14
201-2 Tree1	2	496.01	12.51	7.44
201-2 Tree1	3	524.53	16.4	9.3
201-2 Tree1	4	479.92	19.17	12.24
201-2 Tree1	5	510.93	17.61	9.82
201-2 Tree2	1	535.36	14.26	8.81
201-2 Tree2	2	539.86	12.67	7.63
201-2 Tree2	3	562.53	15.72	9.15
201-2 Tree2	4	548.34	19.65	13.14
201-2 Tree2	5	540.57	19.23	12.9

201-2 Tree3	1	504.49	14.4	8.29
201-2 Tree3	2	522.97	11.4	6.28
201-2 Tree3	3	500.99	.	.
201-2 Tree3	4	496.76	18.29	11.24
201-2 Tree3	5	504.31	17.26	10.98
SH1 Tree1	1	452.93	13.12	7.38
SH1 Tree1	2	481.27	13.16	7.34
SH1 Tree1	3	481.31	13.56	7.86
SH1 Tree1	4	532.5	17.86	10.32
SH1 Tree1	5	482.31	16.78	10.31
SH1 Tree2	1	458.57	12.47	6.99
SH1 Tree2	2	470.91	12	6.3
SH1 Tree2	3	484.05	12.05	6.47
SH1 Tree2	4	462.96	16.68	10.31
SH1 Tree2	5	475.88	15.03	8.64
SH1 Tree3	1	451.78	12.67	7.18
SH1 Tree3	2	468.97	12	6.38
SH1 Tree3	3	480.11	11.85	6.44
SH1 Tree3	4	519.48	17.29	9.91
SH1 Tree3	5	484.19	13.13	7.72
32-13 Tree1	1	452.35	15.55	9.23
32-13 Tree1	2	455.64	14	8.7
32-13 Tree1	3	443.18	14.27	9.12
32-13 Tree1	4	448.95	17.46	13.71
32-13 Tree1	5	472.26	18.4	13.61
32-13 Tree2	1	441.41	15.86	9.02
32-13 Tree2	2	449	12.72	7.71
32-13 Tree2	3	439.67	13.8	10.79
32-13 Tree2	4	478.02	20.38	16.02
32-13 Tree2	5	461.62	19	15.1
32-13 Tree3	1	482.31	18.66	10.54
32-13 Tree3	2	454.45	13.73	8
32-13 Tree3	3	421.54	15.38	10.01
32-13 Tree3	4	445.84	19.57	14.71
32-13 Tree3	5	444.21	19.49	14.57

Table 7-2. Data from cooking (without using anthraquinone (AQ)) and assessments.

Statistics of screened pulp yield, total pulp yield, screened pulp yield at Kappa 18, total pulp yield at Kappa 18 and average residual alkali.

Disc 1 at breast height, i.e. 1.3 meter height of a tree.
Disc 2 at 1/4 height of tree.
Clone and clone tree (without mark discs) represents total 5 discs from a whole tree.
The 5 discs from breast height (at 1.3 meter), 1/4, 2/4, 3/4, top (at 5 cm over bark) of a tree.
And mix the 5 discs for mix pulping of whole tree.

Label	Alkali Content (%)	Average Kappa Number	Screened pulp yield (%)	Total pulp yield (%)	Screened pulp yield at K18 (%)	Total pulp yield at K18 (%)	Average Residual alkali (g/L)
DH32-13 Tree1	16.30	18.18	52.25	52.28	52.23	52.25	12.93
DH32-13 Tree1	16.30	18.00	52.83	52.98	52.83	52.98	12.36
DH32-13 Tree1	16.30	19.86	51.26	51.31	50.98	51.03	9.20
(Average Tree1)					52.01	52.09	
DH32-13 Tree2	16.30	19.95	52.56	52.64	52.27	52.34	12.41
DH32-13 Tree2	16.00	21.02	52.97	53.10	52.51	52.64	11.39
(Average Tree2)					52.39	52.49	
DH32-13 Tree3	15.70	21.66	52.81	52.94	52.26	52.39	8.84
Average DH32-13			52.45	52.54	52.18	52.27	
DH201-2 Tree1	15.70	19.22	52.23	52.36	52.04	52.18	10.40
DH201-2 Tree2	15.70	20.64	52.78	52.89	52.38	52.49	9.41
DH201-2 Tree2	15.70	20.00	52.68	52.73	52.38	52.43	10.27
DH201-2 Tree2	15.70	17.97	51.99	52.15	52.00	52.16	10.79
(Average Tree2)					52.25	52.36	
DH201-2 Tree3	15.70	17.74	52.44	52.59	52.48	52.63	14.07
DH201-2 Tree3	15.70	18.45	53.16	53.35	53.09	53.29	11.31
(Average Tree3)					52.78	52.96	
Average DH201-2			52.54	52.68	52.39	52.53	
SH1 Tree1	15.70	21.62	49.37	50.24	48.83	49.70	9.97
SH1 Tree2	16.30	17.64	52.18	52.30	52.24	52.36	12.43
SH1 Tree2	16.30	16.27	53.82	53.85	54.08	54.11	5.19
SH1 Tree2	16.30	19.21	52.66	52.77	52.48	52.58	12.39
(Average Tree2)					52.93	53.02	
SH1 Tree3	16.30	19.48	54.13	54.16	53.91	53.94	12.93
SH1 Tree3	16.00	19.91	51.97	52.09	51.68	51.81	11.96
(Average Tree3)					52.79	52.87	
Average SH1			52.36	52.57	52.20	52.41	
U6 Tree1	15.70	22.44	48.65	49.23	47.99	48.57	6.91
U6 Tree2	16.30	25.07	50.13	50.19	49.07	49.13	9.94
U6 Tree2	16.30	23.20	49.68	49.79	48.90	49.01	9.69
U6 Tree2	16.30	21.66	49.83	49.99	49.28	49.44	12.13

(Average Tree2)					49.08	49.19	
U6 T3	16.00	21.56	50.92	51.13	50.39	50.59	10.84
Average U6			49.84	50.07	49.12	49.35	

Table 7-3. Data from cooking (adding 0.05% anthraquinone (AQ)) and assessments.

Statistics of screened pulp yield, total pulp yield, screened pulp yield at Kappa 18, total pulp yield at Kappa 18 and average residual alkali.

Disc 2 at 1/4 height of tree.
Clone and clone tree (without mark discs) represents total 5 discs from a whole tree.
The 5 discs from breast height (at 1.3 meter), 1/4, 2/4, 3/4, top (at 5 cm over bark) of a tree.
And mix the 5 discs for mix pulping of whole tree.

Label	AQ content (%)	Alkali Content (%)	Average Kappa Number	Screened pulp yield (%)	Total pulp yield (%)	Screened pulp yield at K18 (%)	Total pulp yield at K18 (%)	Average Residual alkali(g/L)
DH32-13 Tree3 Disc2	0.05	15.40	20.96	52.45	53.05	52.01	52.61	11.77
DH32-13 Tree3 Disc2	0.05	15.40	20.99	52.16	52.43	51.71	51.99	12.31
Average DH32-13 Disc2				52.31	52.74	51.86	52.30	
(Standard deviation)				0.21	0.44	0.21	0.44	
DH201-2 Tree1 Disc2	0.05	15.40	17.98	54.40	54.51	54.40	54.51	13.23
DH201-2 Tree1 Disc2	0.05	15.40	17.01	53.23	53.28	53.38	53.43	13.58
Average DH201-2 Disc2				53.81	53.90	53.89	53.97	
(Standard deviation)				0.83	0.87	0.72	0.76	
DH32-13 Tree3	0.05	15.40	22.68	52.44	52.56	51.74	51.85	8.76
DH32-13 Tree3	0.05	15.70	22.52	52.87	53.10	52.19	52.42	6.90
DH32-13 Tree2	0.05	15.70	21.04	51.98	52.21	51.53	51.76	9.24
Average DH32-13				52.43	52.62	51.82	52.01	
(Standard deviation)				0.44	0.45	0.34	0.36	
DH201-2 Tree1	0.05	15.40	19.41	52.08	52.44	51.87	52.22	10.96
DH201-2 Tree1	0.05	15.40	19.27	53.25	53.53	53.06	53.34	10.30
DH201-2 Tree1	0.05	15.70	16.38	51.27	52.28	51.52	52.52	9.95
DH201-2 Tree3	0.05	15.70	15.99	52.63	53.06	52.93	53.36	11.28
DH201-2 Tree3	0.05	15.40	18.64	52.16	52.74	52.06	52.64	8.10
Average DH201-2				52.28	52.81	52.29	52.82	
(Standard deviation)				0.73	0.50	0.68	0.51	
SH1 Tree1	0.05	15.40	22.65	49.87	50.04	49.18	49.34	9.42
SH1 Tree1	0.05	15.70	20.08	51.60	51.75	51.29	51.44	9.50
SH1 Tree3	0.05	15.70	19.41	51.03	51.54	50.82	51.33	9.29
Average SH1				50.84	51.11	50.43	50.71	
(Standard deviation)				0.88	0.94	1.11	1.18	

U6 Tree1	0.05	15.40	23.82	48.90	49.24	48.02	48.37	9.52
U6 Tree1	0.05	15.70	21.34	50.33	50.74	49.83	50.24	8.89
U6 Tree3	0.05	15.70	22.41	49.44	49.76	48.78	49.09	8.30
Average U6				49.55	49.91	48.88	49.23	
(Standard deviation)				0.72	0.76	0.91	0.94	

Table 7-4. Data from cooking without using AQ and cooking adding 0.05% AQ assessments.

Statistics of screened pulp yield, total pulp yield, screened pulp yield at Kappa 18, total pulp yield at Kappa 18.

Disc 1 at breast height, i.e. 1.3 meter height of a tree.
Disc 2 at 1/4 height of tree.
Clone and clone tree (without mark discs) represents total 5 discs from a whole tree.
The 5 discs from breast height (at 1.3 meter), 1/4, 2/4, 3/4, top (at 5 cm over bark) of a tree.
And mix the 5 discs for mix pulping of whole tree.

Clones& position	AQ content (%)	Screened pulp yield (%)	Total pulp yield (%)	Screened pulp yield at K18 (%)	Total pulp yield at K18 (%)
DH32-13	0.00	52.45	52.54	52.18	52.27
(Standard deviation)		0.63	0.67	0.63	0.66
DH201-2	0.00	52.54	52.68	52.39	52.53
(Standard deviation)		0.42	0.42	0.39	0.41
SH1	0.00	52.36	52.57	52.20	52.41
(Standard deviation)		1.70	1.41	1.91	1.61
U6	0.00	49.84	50.07	49.12	49.35
(Standard deviation)		0.82	0.69	0.86	0.76
DH32-13 Disc1	0.00	51.34	51.43	50.98	51.06
(Standard deviation)		1.34	1.35	1.47	1.49
DH32-13 Disc2	0.00	53.19	53.32	53.09	53.22
(Standard deviation)		0.48	0.50	0.48	0.45
DH201-2 Disc1	0.00	52.04	52.17	52.01	52.14
(Standard deviation)		0.56	0.58	0.57	0.59
DH201-2 Disc2	0.00	52.99	53.11	52.98	53.15
(Standard deviation)		0.78	0.81	0.86	0.88

Clones& position	AQ content (%)	Screened pulp yield (%)	Total pulp yield (%)	Screened pulp yield at K18 (%)	Total pulp yield at K18 (%)
DH32-13	0.05	52.43	52.62	51.82	52.01
(Standard deviation)		0.44	0.45	0.34	0.36

DH201-2	0.05	52.28	52.81	52.29	52.82
(Standard deviation)		0.73	0.50	0.68	0.51
SH1	0.05	50.84	51.11	50.43	50.71
(Standard deviation)		0.88	0.94	1.11	1.18
U6	0.05	49.55	49.91	48.88	49.23
(Standard deviation)		0.72	0.76	0.91	0.94
DH32-13 Disc2	0.05	52.31	52.74	51.86	52.30
(Standard deviation)		0.21	0.44	0.21	0.44
DH201-2 Disc2	0.05	53.81	53.90	53.89	53.97
(Standard deviation)		0.83	0.87	0.72	0.76

Table 7-5. Data from cooking (without using anthraquinone (AQ)) and assessments.

Statistics of bark volume percentage, bark weight percentage, wood basic density, total pulp yield at Kappa 18, pulp production (didn't consider bark), pulp production (with bark volume).

Clone and clone tree represents total 5 discs from a whole tree.
The 5 discs from breast height (at 1.3 meter), 1/4, 2/4, 3/4, top (at 5 cm over bark) of a tree.
And mix the 5 discs for mix pulping of whole tree.

Clones & Tree No.	Wood basic density (kg/m^3)	Screened pulp yield at K18 (%)	Total pulp yield at K18 (%)	Pulp production (kg/m^3)
U6 Tree1	461.20	47.99	48.57	224.01
U6 Tree2	484.91	49.08	49.19	238.53
U6 Tree3	455.23	50.39	50.59	230.30
DH201-2 Tree1	499.66	52.04	52.18	260.72
DH201-2 Tree2	542.72	52.25	52.36	284.17
DH201-2 Tree3	510.39	52.78	52.96	270.30
SH1 Tree1	473.05	48.83	49.7	235.10
SH1 Tree2	469.25	52.93	53.02	248.80
SH1 Tree3	469.25	52.79	52.87	248.09
DH32-13 Tree1	452.96	52.01	52.09	235.95
DH32-13 Tree2	446.18	52.39	52.49	234.20
DH32-13 Tree3	459.37	52.26	52.39	240.66

Table 7-6. Data from cooking (without using anthraquinone (AQ)) and assessments.

Statistics of bark volume percentage, bark weight percentage, wood basic density, total pulp yield at Kappa 18, pulp production (didn't consider bark), pulp production (with bark volume).

Disc 1 at breast height, i.e. 1.3 meter height of a tree.
Disc 2 at 1/4 height of tree.
Clone and clone tree (without mark discs) represents total 5 discs from a whole tree.

The 5 discs from breast height (at 1.3 meter), 1/4, 2/4, 3/4, top (at 5 cm over bark) of a tree. And mix the 5 discs for mix pulping of whole tree.

Clones &position	Bark volume (%)	Bark weight (%)	Wood basic density (kg/m^3)	Total pulp yield at K18 (%)	Pulp production (kg/m^3)	Pulp production with bark Vol. (kg/m^3)
U6	17.76	10.57	467.11	49.35	230.52	189.58
DH201-2	14.61	8.74	517.59	52.53	271.89	232.17
SH1	13.09	7.34	470.51	52.41	246.59	214.32
DH32-13	15.74	9.93	452.84	52.27	236.70	199.44
U6 Disc1	18.18	10.25	320.47			
DH201-2 Disc1	14.36	8.75	509.86	52.14	265.84	227.67
SH1 Disc1	12.75	7.18	454.43			
DH32-13 Disc1	16.69	9.59	458.69	51.06	234.21	195.12
U6 Disc2	16.82	9.77	313.2			
DH201-2 Disc2	12.19	7.12	519.61	53.15	276.17	242.51
SH1 Disc2	12.39	6.67	473.72			
DH32-13 Disc2	13.48	8.14	453.03	53.22	241.10	208.60