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FINAL REPORT

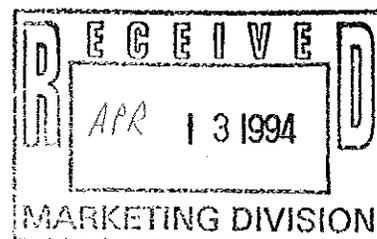
DETERMINATION OF CHANGES IN PROPERTIES OF KENAF AS A FUNCTION OF GROWING TIME

CO-OPERATIVE AGREEMENT BETWEEN FOREST PRODUCTS LABORATORY AND AGRECOL

By

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I. OVERVIEW OF PROJECT

Kenaf, *Hibiscus cannabinus* L. is a member of the Malvaceae, an annual dicotyledon which probably originated in East Central Africa [1]. Okra (*H. esculentus*) and roselle (*H. sadariffa*) are closely related species; cotton (*Gossypium* sp.) is also a member of this family. Kenaf is a fast-growing annual with woody stalks 6 to 12 feet tall and up to 1 to 2 inches in diameter. The stalks are mostly unbranched in dense plantings [2]. Willis lists 75 genera for the family and 300 species of *Hibiscus* [3].

The growing period of this plant is reported to be between 120-150 days. However, it is questionable whether this plant can be successfully grown in places like Wisconsin where the growing period is short.

If a full cycle growing season is not possible, there may be advantage in growing Kenaf for shorter period of time. It is known for other annual plants, that both chemical and physical properties change as function of the growing time. Annual plants have a lower lignin content early in the growing season and it is, therefore, economically feasible to harvest a young plant for pulp or textile fiber use even though the overall yield is low. It may also be possible to grow two annual crops per season.

The purpose of this study is to determine changes in chemical and physical properties of kenaf as a function of the growing time. The results of this research may lead to opportunity to grow annual groups for short period of times for specific applications.

Seeds of C-108, Tainung #1, and 45-9 were planted in Sun Prairie, Wisconsin. The flood of 1993 did not help the growing days in 1993. Seeds were washed away three times and the seeds planted in June 24, 1993 started to grow. Nitrogen, in the form of ammonium nitrate, was applied at the rate of 50 pounds per acre. Frost killed the plant late in September and the last sample was collected on September 16, thus the growing days in the southern Wisconsin was a short 84 days in 1993. Sampling was basically planned three days per week weather permitting. The first sample was collected on July 15 after 21 growing days and the length of stalk was about 20 cm. The final stalk height was about 1 to 1.2 m (A

study by Bagby et al. had about 150 growing days in Maryland. The height of the stalk was about 3 meters [4]).

II. PROCEDURE OF ANALYSIS

Procedure #1

Preparation of Extractive Free Plant Material

Scope and summary

Plant materials = Extractives + holocellulose + lignin + inorganics (ash)

This method describes a procedure for preparation of extractive free non-wood fiber for further analysis, such as holocellulose, hemicellulose, cellulose and lignin determination.

For the actual chemical analysis of extractives, it is suggested to scale up the volume of samples or combine the residues.

Mixture of toluene and ethanol is employed to remove extractives from the non-wood fibers. However, the choice of solvents is not limited to above mentioned.

Other solvents such as diethyl ether, methanol, acetone to 1% NaOH etc. could be applied according to the nature of extractives.

Apparatus

Buchner funnel

Extraction thimbles, ASTM 170 220 or Pyrex 33950-MEC E or -MC.

Extraction apparatus, extraction flask, 500 mL, Soxhlet extraction tube

Heating device, heating mantle

Boiling chips, glass beads, boilerezers or any inert granules for taming boiling action

Chemical Fume hood

Vacuum oven

Reagent and materials

Ethanol (ethyl alcohol), 200 proof ethanol, 95% ethanol by volume, or denatured with 5% methanol or isopropyl alcohol.

Toluene, reagent grade

Toluene-ethanol mixture, mix together one volume of ethanol and two volumes of toluene.

Procedures

Kenaf fibers and cores were hand separated while the samples were wet.

Cores were hammer milled using 3/16 screen.

Most of times, the samples are oven dried prior milling. However, wet sample could be milled while the sample is still frozen in order to prevent oxidation or other undesirable chemical reactions to occur.

Also, it is recommended to separate the sample into core and bast fibers.

Samples are ground to pass 40 mesh (0.40 mm) using a Wiley Mill [5].

2 to 3 grams of samples are placed into preweighed extraction thimbles, then dry in a vacuum oven at 105°C over night. The samples are cooled in a desiccator for one hour and weighed. Cover with aluminum foil with small holes to prevent any loss of specimen during the extraction. It is preferable to use fritted Disc glass extraction thimbles rather than extracted paper thimbles. Place 250 mL of toluene:ethanol mixture in 500 mL round bottom and several boiling chips to prevent bumping. The boiling temperature of this mixture is high and extraction flask and the soxhlet tube might need to be covered with a layer or two of aluminum foil. Carry out the extraction in a well ventilated chemical fume hood for 10 to 12 hours, keeping the liquid boiling so that siphoning from the extractor is no less than four times per hour. After the extraction, the solvents are drained from the thimbles and placed in a vacuum oven over night. Even though the boiling point of toluene is 110.7°C, vacuum oven temperature should not exceed 105 °C in order not to cause any degradation of the specimen. Take out the samples from the vacuum oven, place them in a desiccator, and weigh an hour later. Most of times, the extraction is complete at this stage. However, there is no guarantee if the extraction is complete. The extractability depends upon the matrix of sample and the nature of extractives. The second and the third extraction with different polarity of solvents are not unusual. Browning [6] calls for 4 hours of successive extraction with 95% alcohol. TAPPI Standard T 264 [7] and ASTM D 1105 [8] call for two successive extractions, 4 hours with ethanol followed with distilled water for 1 hour. Pettersen et al.[8] extracted pine sample with acetone/water, followed toluene/ethanol.

Note on use of benzene

ASTM 1105 and TAPPI T 264 om-88 both specify use of benzene.

OSHA Standard for occupational exposure to Benzene is 29CFR 1910.1028 which became effective as of 12/10/87. Benzene is no longer used due to the health hazard.

Procedure #2

Preparation of Holocellulose (chlorite holocellulose)

Scope

Holocellulose is defined as water-insoluble carbohydrate fraction of plant materials. (Holocellulose = hemicellulose + cellulose)

According to Browning [6], there are three ways of preparing holocellulose and their modified methods (1) Chlorination Method, (2) Modified Chlorination Methods, (3) Chlorine Dioxide and Chlorite Methods [10]. The Standard Purity of holocellulose is checked following lignin analysis.

Apparatus

Buchner funnel

250mL Erlenmeyer Flasks

25mL Erlenmeyer Flasks

Water bath

Filter paper

Chemical Fume hood

Reagent and materials

Acetic acid, reagent grade

sodium chlorite, NaClO₂

Procedure

Sample are prepared by Procedure #1

To 2.5 g of sample, add 80 mL of hot distilled water, 0.5 mL acetic acid, and 1 g of sodium chlorite in a 250 mL Erlenmeyer flask and an optional 25 ml Erlenmeyer flask is inverted in the neck of the reaction flask. The mixture is heated on a water bath at 70°C. After 30 minutes, 0.5 mL of acetic acid and 1 g of sodium chlorite are added. After each succeeding hour, fresh portions of 0.5 mL acetic acid and 1 g sodium chlorite are added with shaking. Samples are removed periodically, filtered,

washed with water, dried, and the amount of lignin remaining is determined by the 72 percent H₂SO₄ procedure. The delignification process degrades some of polysaccharides and the application of excess chloriting should be avoided. A small amount of lignin (less than 3%) will be removed after the 6 hours. Continued reaction will remove more lignin but hemicellulose will also be lost [11]. At the end of 6 hours reaction, the sample is cooled and the holocellulose is filtered on a filter paper using Buchner funnel until the yellow color (the color of holocellulose is white) and odor of chlorine dioxide is removed. If the weight of holocellulose content of the plant material is desired, the holocellulose is filtered on a tarred thimble, wash with acetone, oven dry at 105°C and the lignin content should be determined.

Procedure #3

Preparation of Lignin

Scope

Normal softwood and hardwood contains 26 to 32%, and 20 to 28% lignin [12], respectively. Non-wood plants lignin contents are generally less than 20%, except bamboo, jute etc. The FPL procedure is a modified version of TAPPI T222 om-88 Acid-insoluble lignin in wood and pulp [13] and ASTM D 1106 [14]. This procedure is called Klason lignin and also sulfuric acid lignin. It should be known that Klason lignin is not suitable for the study of lignin structures and some other lignins such as cellulolytic enzyme lignin, or milled wood lignin should be prepared [12] for the study of lignin structure.

Apparatus

Auto clave

Buchner funnel

100 ml centrifuge tube, Pyrex 8240

Desiccator

Glass rods

Water bath

60 ml syringe

Glass fiber Filter paper, Whatman Cat No. 1827-021, 934-AH

Glass Microfibre Filter, 2.1 cm

Reagent

Sulfuric acid, H₂SO₄ , 72% and 4% by volume

Fucose, 24.125 % in 4% H₂SO₄ [w/w] (internal standard for HPLC analysis of 5 sugars).

Procedure

Sample are prepared by Procedure #1

Dry the sample at 45°C in a vacuum oven over night.

Accurately weigh out approximately 200 mg of ground-vacuum dried, into a 100 ml centrifuge tube. To the sample in a 100 ml centrifuge tube add 1 ml of 72% (w/w) H₂SO₄ for each 100 mg of sample.

Stir and disperse the mixture thoroughly with glass rod twice, then incubate the tubes in water bath at 30°C for 60 min.

Add 56 ml of distilled water (use 60 ml syringe), this results in a 4% solution for the secondary hydrolysis.

Add 1 ml fucose internal standard, this procedure is required only if five sugars are to be analyzed by HPLC as a part of analysis.

Autoclave at 121°C, 15 psi, for 60 min. Remove the samples from the autoclave and filter off the lignin, keeping the solution hot. Filtering is done with glass fiber filters (filters were rinsed into crucibles, dried and tarred) in crucibles using suction. The residue is thoroughly washed with hot water

Dry at 105°C over night

Remove to desiccator, let it sit over an hour, weigh-five places.

Procedure #4

Nitrogen Content

Protein Determination by Kjeldahl Method [15]

Scope

0.8 to 1.5% of nitrogenous matter was reported in jute and Kenaf [16]. FPL study on kenaf showed that by separate Kjeldahl analysis, 32 % of nitrogen was found in Klason lignin and 68 % in hydrolysate of acid hydrolysis [17]. USDA, Dairy Forage Laboratory developed [18] acid-detergent lignin procedure where the detergent

removed the protein and other acid-soluble materials that would interfere with the lignin determination. Further study is desired in this area.

This Kjeldahl method was modified by Forest Products Laboratory [19] in 1967, and more modification was achieved in 1993 which will be used in determination of the amine and amide nitrogen content in non-wood fibers. The organic compound is digested with concentrated sulfuric acid, which converts combined nitrogen into ammonium sulfate. The solution is then made alkaline. The ammonia thus liberated is distilled, and its amount is determined by titration with standard acid. It is directly applicable to amines and amides but not to nitro, azo, and azoxy compounds. These latter compounds must be reduced (Zn-Hg amalgam and acid or salicylic acid, sodium thiosulfate and acid) before the Kjeldahl treatment). The protein content will then be obtained by multiplying the percent nitrogen in an aliquot of fiber by an empirical factor of 6.25.

Apparatus

Burette, 10, 25, or 50 mL

Desiccator

Erlenmeyer Flask, 250 mL

Micro Kjeldahl Digestion Apparatus

Micro Kjeldahl Digestion Rack, Labconco 7053-S10

Heating Element, Labconco 7053-S10

Kjeldahl Flasks, 30 mL, 100 mL, or 125 mL, Pyrex and Kimax

Micro Kjeldahl Distilling Apparatus, Thomas Scientific

Micro Kjeldahl Distilling Unit, 7052-J10

Distilling Unit, 7052-J20

Steam Generator, ASTM, 7052-J30

Immersion Heater, ASTM, 7052-J40

Note: See ASTM E 147 for detailed dimensions of the apparatus

Reagent

Boric acid, H_3BO_3

Copper sulfate, $CuSO_4 \cdot 5H_2O$

Hydrochloric acid, HCl, 0.01N

Mixed Indicator, place 200mg of bromocresol green and 40 mg of methyl red in 100 ml volumetric flask. Dissolve and fill up with 95% ethanol.

DL-Norvaline, 99%, Aldrich 85,162-0

Potassium sulfate, K_2SO_4

Sodium carbonate, $NaHCO_3$

Sodium hydroxide, $NaOH$

Sulfuric acid, H_2SO_4

Sodium thiosulfate, anhydrous, $Na_2S_2O_3$

Procedure

Sample Preparation

Sample are prepared by Procedure #1

Samples are placed in a in a vacuum oven at 45°C overnight, then place the sample in a desiccator prior to actual chemical analysis. A quality control sample of DL-Norvaline (%N=11.96%) and a blank sample should be carried out through this entire procedure.

Digestion

Weigh approximately 100 mg of sample to the nearest 0.1 mg into 30 ml Kjeldahl flask. Add 5 g of K_2SO_4 per gram of sample and 250 mg $CuSO_4 \cdot 5H_2O$ per gram of sample to each flask. Next, add 10 ml of conc. H_2SO_4 per gram of sample. Place specimens on low heat at first and cook until all black carbon has disappeared and the solution appears tint in color. Kenaf fiber requires about 2 hours for complete digestion, while 10 mg of DL-Norvaline should be fully digested within 1 hour.

Note: the weight of sample should be adjusted depends upon the nitrogen content followed by the size of Kjeldahl flask. More sulfuric acid may be needed and distilled water may be added to rinse the sample.

For nitro, azo or azoxy compounds:

1 ml 5% salicylic acid in H_2SO_4 and wait 30 min., add 100 mg $Na_2S_2O_3$ wait 10 -15 minutes and proceed with digestion.

For amine and amide compounds: skip the step above and start with 650 mg of K_2SO_4 , 16 mg of HgO , 1 ml of H_2SO_4 proceed with digestion.

Distillation

Rinsing the apparatus

Close the upper stopcock (sample stopcock), open the lower (vacuum) stopcock and pull distilled water from a large beaker submerge to the condenser tip by suction and close the lower stopcock. Open the upper stopcock and fill the still with distilled water. Repeat this process until approximately 1-2 liter of water has been

washed through the entire system. The lower drain spout is connected to an aspirator via a water trap and waste water is removed after the rinsing.

Distillation and Digested Samples

Add 5 ml of 4% Boric acid and 5 drops of the mixed indicator to a 250 ml Erlenmeyer flask. Dilute with 20 ml of distilled water (the solution should be green) and submerge the tip of the condenser in the solution.

Open the upper stopcock and quantitatively transfer the digested sample from the Kjeldahl flask to the still. Also rinse the filling cup to insure the complete transfer (Caution; when rinsing, the flask will become hot and sulfuric acid fumes may be emitted). Close the upper stopcock and fill the cup with 28 ml of 40% NaOH. If the filling cup cannot hold the full volume of NaOH, open the stopcock slightly and transfer the remaining NaOH to the cup. Close the stopcock immediately once the NaOH has completely drained. Replace the rubber stopper and plug in the heating coil.

Distill until the volume in the Erlenmeyer flask has doubled. The solution should be blue in color. Lower the flask and rinse the condenser tip. Remove the rubber stopper and turn off the heating coil. Allow the sample to cool.

Titrate the distillate from blue to a green endpoint with the standardized 0.01N HCl solution.

Calculate the percent of nitrogen in the sample as follow:

$$\%N = \frac{\text{ml HCl (sample - blank)} \times (\text{normality of HCl}) \times 14.0067 \times 100}{\text{Sample weight in mg}}$$

$$\% \text{ Protein} = 6.25 \times \%N$$

Procedure #5

Measurement of Fiber Length

Scope

The fiber length of non-wood origin could be longer than that of wood and special precaution must be taken not to overlook this aspect. The fiber length of Ramie

-longest reported to be 60 to 250 mm, average 120 mm followed by flax, 9 to 70 mm, average 35 mm. Rest of the lengths are about 3 to 10 mm [20].

Sample preparation [21]

A sample of 4 to 6 plants representative of an experimental plot is taken and these are subsampled in 10-cm segments at the base and at a point 1 m from the top of each plant. Divide the subsamples into bark+ bast fiber and core fractions and evaluate separately. The separated segments are quartered longitudinally. Then one quarter from each subsample is sliced length wise to increase surface area.

Maceration

There is no need to go through extraction procedure (experiment #1) unless apparent interference by extractive is noticed. Proceed with Procedure #2 Preparation of Holocellulose (chlorite holocellulose). It might be advisable to reduce the size of reaction bottle and sample (TAPPI T259 [22] calls for 170 x 20 mm test tubes at 60°C water bath). This laboratory found out that placing a stopper is a potential safety liability.

The bast portion of dicotyledons are easily macerated and do not require the lengthy treatment usually necessary for the woody portion or the whole stem of monocotyledons. Slow stirring with occasional pressing of clumps cells against the sides of the container with a smooth glass rod aid maceration of the more difficult materials.

The chemical maceration is stopped when the cellular bundles are fairly well separated (usually 2 to 6 hours) although some small clumps still remain. The chlorite liquor is filtered off through hardened filter paper in a Buchner funnel and the cellular material is thoroughly washed with hot water. During washing, it is best to avoid complete drying of the cellular material as this makes resuspension difficult. The slightly wet pad of cellular material is washed from the filter paper with distilled water into an Erlenmeyer flask. Then, visually examine if the fibers are completely separated. If not, the process should be repeated.

Another maceration technique is using equal parts of acetic acid and 100 vol. hydrogen peroxide at 50 °C for 17 hours followed by a further treatment at 100°C for 2 hours [23].

Preparation of slides

It is optional to make the slightly wet pad of cellular material into suspension of the wet fibers with 50 % glycerin in order to prevent dehydration. Otherwise distilled water can be used in place of 50% glycerin solution. Suspensions of the fibers are dyed with methylene blue (or Congo Red, the purpose of indicator is strictly to help visual examination of fiber concentration). One drop of 1% methylene blue is added to about 30 ml of suspension and microscope slides of cellular material are prepared from the well-shaken suspension by withdrawing a sample with an 8-mm i.d. glass tubing before the suspension settles. Drops placed on the microscope slide are air dried. The concentration of the fibrous suspension is adjusted by experience so that the cellular elements are not overly crowded on the slides.

Measurements

There are three ways of measuring the fiber length at the FPL.

(1) Kajaani Inc, Automation, Determination of FS-100

This procedure is one of the standards procedure in Pulp and Paper Industry. Suspension of fibers are prepared and fed to the machine and the Kajaani FS-100 measures between 4,000 to 7,000 fiber at a time. The report is divided into length weighted average, weight weighted average, numerical average, low limit value and percent low limit. Weight weighted average is considered to be the fiber length that can be easily co-related to our purpose. The drawback is that, in this procedure, the shape of the fibers that are measured are not selected. However, it is a good way of knowing the range of fiber length.

(2) Image Analysis

Fibers samples are mounted on slides, and the slides are projected on a screen from a microscope using a proper magnification. The primary function of image analyser at this laboratory was to recognize the pattern and the measurement of of fiber length was tried with limited success.

This method has a great potential if the programm could recognize the shape of fibers.

(3) Sigma Scan [24]

The approach of this method is basically same as the Image Analyzer except the program called digitizer physically measures the length of selected fibers of any shape. The entire measurement of fibers was conducted by this procedure.

The advantage is, an operator actually makes selection of fibers that represent the population. Usually fibers with tapered ends are selected in kenaf. It will be easy to identify which one should be selected. It takes about one second to measure two fibers.

Procedure #6

Preparation of Other Celluloses

Standard Test Method for Solubility of Cellulose in Sodium Hydroxide

Referenced Documents

TAPPI Standard T 429 Method for α -cellulose

Scope

Holocellulose is treated with sodium hydroxide and preparation of other celluloses such as a-cellulose, b-cellulose, g-cellulose, cellulose I, cellulose II, cellulose III, cellulose IV, cellulose X, hemicellulose (see ASTM D1695 for clear definitions of different celluloses) can be achieved by different treatments afterwards accordingly.

Sample Preparation, α -cellulose

The samples are extracted according to the Procedure #1, followed by the Procedure #2. After the procedure #2 (chlorite holocellulose), procedure #3 (Klason Lignin) is applied to check the lignin content. The degree of purity will depend upon the effective removal of lignin.

Reagents

Sodium hydroxide, NaOH, 17.5% (5.24N)

Procedure

Weigh about 300 mg of sample and add 20 mL of 17.5% NaOH, macerate until the fibers are uniformly wet and dispersed, wait for 10 minutes and 33 mL of water is added. Wait another 1 hour and the sample is filtered through 80-mesh screen fitted

into a Gooch crucible. If the actual α -cellulose content is required, entire T429 is performed.

III. Standard Terminology of Cellulose and Cellulose Derivatives ASTM D 1695-77 (Reapproved 1989)

Alpha-cellulose-(1) an imprecise and historic term (originally devised around 1900) that has been used to characterize cellulose purity. The currently preferred term is "R10" (2) When used, alpha cellulose is the portion of a cellulose pulp that remains insoluble after treatment with aqueous sodium hydroxide at 20°C. The term has meaning only if there is a precise statement of the initial sodium hydroxide concentration (usually about 18%), the subsequent dilution, and other conditions employed in its determination.

Beta-cellulose-(1) an imprecise and historic term (originally devised around 1900) that has been used to characterize cellulose purity. The currently preferred term is "S10-S18" (2) When used, beta-cellulose is the portion of a cellulose pulp which is dissolved in the alkaline solution of the alpha-cellulose test and is subsequently reprecipitated on neutralization of the alkaline solution. All condition must be specified exactly.

Cellulose-(1) the main solid constituent of woody plants; it occurs widely elsewhere in the vegetable kingdom, and to a small extent in the animal kingdom. (2) chemically, cellulose is b-1-4 glucan of high degree of polymerization. It is desirable to apply "cellulose" to this material only and to designate the predominantly cellulosic residue obtained by subjecting woody tissue to various pulping processes as "cellulosic residues," "cellulosic pulps," or the like.

Cellulose I- the crystalline modification of cellulose that normally occurs in nature.
Cellulose II-the crystalline modification of cellulose that is found in mercerized cellulose, in regenerated cellulose, and in cellulose produced by the hydrolysis of various cellulose derivatives.

Cellulose III-a crystalline modification of cellulose produced by treatment , under certain conditions, with ammonia or sometimes by amines. The method of removing the reagent determines the modification produced.

Cellulose IV-a crystalline modification of cellulose produced by heat treatment of cellulose II.

Cellulose X-a crystalline modification of cellulose produced by treatment of cellulose with strong hydrochloric acid or phosphoric acid.

Gamma-cellulose-(1) an imprecise and historic term (originally devised around 1900) that has been used to characterize cellulose purity. The currently preferred term is "S18" (2) When used, gamma-cellulose is the portion of a cellulosic material that remains dissolved after neutralization of the alkaline solution from the alpha-cellulose determination; all condition; all condition must be specified exactly.

Extractives-compounds occurring in plant materials, but not forming part of the structural elements, that are removed with neutral solvents such as ether, alcohol, and water.

Hemicellulose-any of a number of cell-wall polysaccharides that are removable by extraction with aqueous alkali and that may be hydrolyzed by boiling with dilute acids to give constituent monosaccharide units; any of the noncellulosic cell-wall polysaccharides.

Holocellulose-the total polysaccharide fraction of extractive-free wood. The method of isolation or determination should always be given.

Lignin- that part of plant material which is not saccharified by the action of 72% sulfuric acid or 42% hydrochloric acid, after the resins, waxes, and tannins have been removed.

IV. EXPERIMENT

Outline of the Experiment

Three varieties of kenaf, 45-9, C-108, and Tainung #1 were planted in two different plots at Agercol in Sun Prairie, Wisconsin. 50 pounds of ammonium nitrate per acre was applied. The flood of 1993 was a record high and the seeds were washed away three times and the seeds planted on June 24 finally started to grow. The samples were harvested three times per week weather permitting and stored in a refrigerator at Agercol and taken to the Forest Products Laboratory every two weeks. The samples were kept cool during the transit using dry ice.

The lengths and width of the stalks were measured and photos of every third samples were taken. The fibers were separated from the cores while wet and dried on a well ventilated wire screen rack in front of fume hood for . It was almost impossible to separate the barks from the basts.

The dried cores were shredded to 5 to 7 mm using a hammer mill and ground to pass 30 mesh Wiley Mill. The samples were macerated with Jeffries solution (10% HNO₃, 10% CrO₃) temperature ranging 50 to 70° C and between 30 minutes to 2 hours, filtered, mixed with 50% glycerin and mounted on slides.

It was noticed that Jeffries solution has tendency of damaging the fibers and later the maceration was done by sodium chlorite (Experiment #2).

Chemical Analysis

The bast fibers and cores were extracted according to procedure #1 after grinding to pass 30 mesh screen. Procedure #4 was applied to determine the nitrogen contents of cores and fibers and the values of Klason lignin were adjusted accordingly. Finally five sugars were analyzed by FPL HPLC procedure [9].

Measurements of fiber Length

The size of samples were kept between 5 to 7 mm in order to expedite the maceration process and not to cut the fibers into too small pieces. Later, it was concluded that it might have been better not to dry the fibers prior to measurement. Three different procedures were applied in measurement of the fiber length.

V. RESULTS

Growth: The first sample was taken on July 15 after 21 growing days (Figure #1). However, with stalk height of about 3 to 5 cm, it was impossible to separate the bast fibers from the core at this stage. The samples collected on August 11 after 48 growing days reached the stalk height of about 14 to 17 cm. It was then possible to separate the bast fibers from the cores. The first frost, on September 16 (84 growing days) killed the plants and harvesting was stopped. The height of stalks ranged from 103 to 118 cm (Figure #2, Table #1, Chart #1) and the width ranged from 1.2 to 1.6 cm (Table #2, Chart #2).

Fiber Length and width: Fiber length of bast fibers were measured at the end of 50, 60 and 84 days for three different varieties (Table # 3 and Chart # 3). The length reached to about 3.5 mm at the end of 84 growing days. The core fibers reached to about 0.8 mm at the end of 84 days (Table #4 and Chart #4).

Individual bast fibers are cylindrical and the fiber ends are sharp. Fibers can be easily damaged during the maceration and it is important to select undamaged fibers in measurement. An individual fiber has one continuous cavity and cell wall can be collapsed during the maceration. Figure #3 and #4 are the photographs of bast and core fibers. The length can vary a great deal and it is suggested to measure as many fibers as possible. About 60 to 70 measurements were made per a sample.

Lignin Content: It is noticeable that the core of the kenaf have a higher lignin content than the bast fibers. The lignin content increases as the plant grew. The lignin content of the bast fiber was about 11 % at the end of 84 growing days and core was about 16 % (Table #5, Chart #5 and #6). The types of these lignin need to be explored in the future. The term lignin in this report is Klason lignin without correction for the protein.

Protein Content: In procedure #3, it was assumed that since nitrogen or protein content in wood is fairly low, the value of Klason lignin is usually straight from the results of procedure #3. However, this procedure #3 needs a correction due to the significant protein content in the Klason lignin. The protein content in kenaf is between 4 to 14% of Klason lignin (Table #6, Chart #7). This much should be deducted from the Klason lignin. Only 38 % of protein is found in the Klason lignin and rest of 62 % is found in hydrolysate of acid hydrolysate. The total protein content in Kenaf found at this laboratory is between 1.1 to 2 % drybasis (Table #7, Chart #8). In general, protein content decreased as the plant grew. The Kjeldahl

process is time consuming and only 12 samples were analyzed (48 days and 70 days). There is a great need for an alternate, instrumental procedure of protein analysis. HPLC or Gas chromatographic procedure will be seriously considered at the FPL.

Sugar Content: The polymeric carbohydrate contents of bast fibers and cores of three varieties harvested on 48, 60, 70 and 84 growing days are tabulated in Table#8.

There is a trend that glucan and xylan increased as the plant grew and the rest of sugars decreased. Charts #9 to #14 are the comparisons of changes of sugars for three different varieties.

Ash Content: Ash content was checked only on the 84 days old samples due to lack of samples. On the average bast fibers had more ash than the cores (Table #9, Chart #15). C-108 showed higher ash content than rest of the two. X-ray scan revealed the C-108 contained trace of magnesium, aluminum, silicon, phosphorous, sulfur, potassium, calcium, iron and copper. It appears that potassium and calcium are the predominant (Figure #5, #6).

Extractive Content: Extractive content of bast fibers and cores were conducted. Bast fibers: C-108 had over 3%, 45-9 about 2%, and Tainung about 1.6%. Cores; 45-9 had the highest extractive content of 13 %, C-108 about 11% and Tainung lowest 5 to 9 % (Table #10, Chart #16). The difference between 60 growing days and 84 growing days was more significant in cores. These values are consistent and the color of extracting solvent might be used to distinguish three varieties of kenaf. The color of C-108 extracted solvent was turbid yellow, Tainung was clear yellow-green, and 45-9 was turbid brown. It would be a good idea to pursue the chemical breakdown of these extractives.

IV. CONCLUSIONS

Results to date indicate that both fiber length and width as growing time increases. All of these results will be preliminary because a full growing season was not completed. This experiment will be repeated the summer of 1994 when a complete growing season is possible.

502 C-108

7/15/93

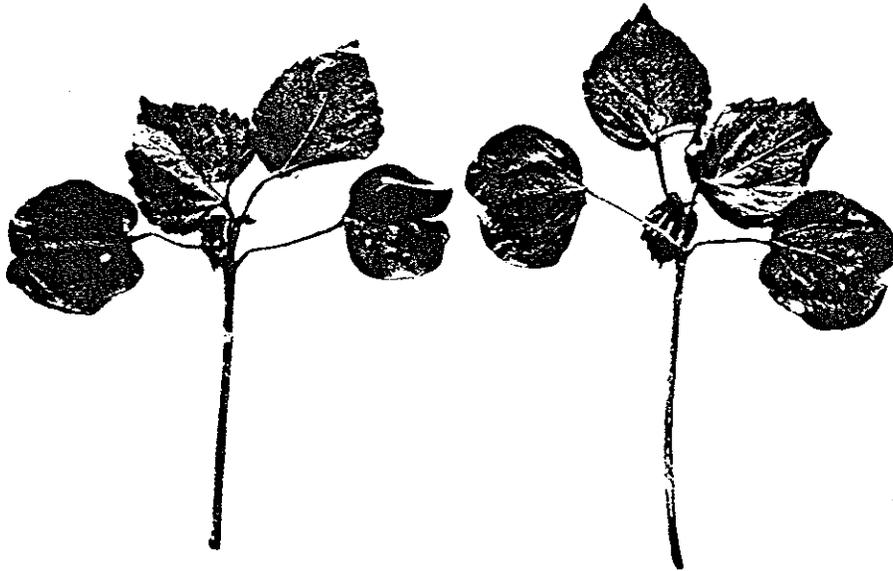
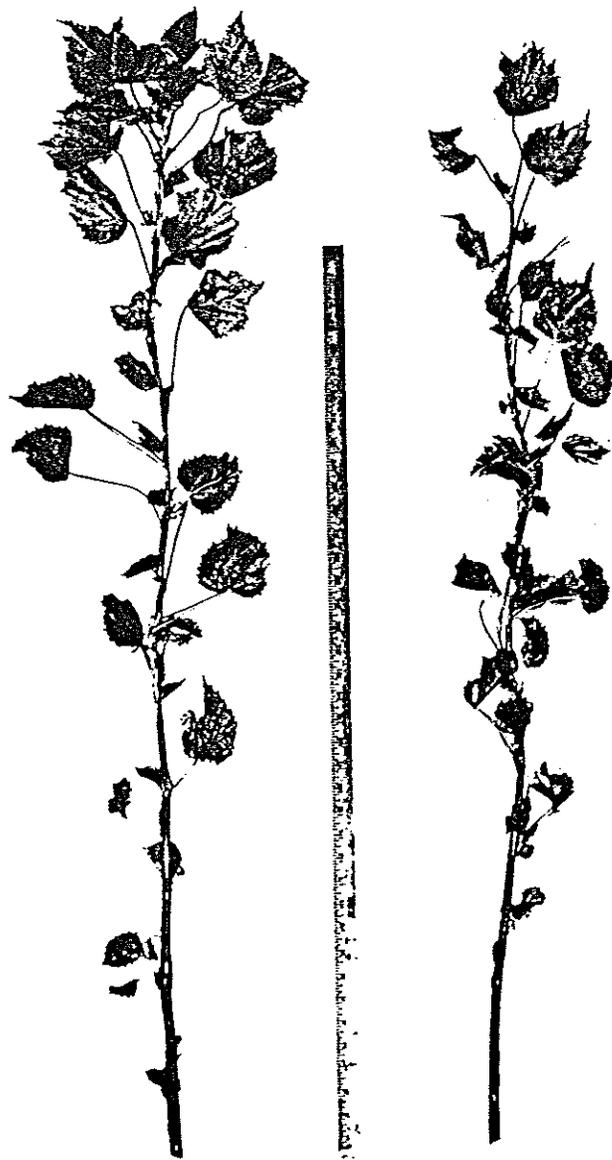


Figure #1
21 days old C-108



512 C-108 N-108

Figure #2
84 days old C-108

Table #1 Height of Kenaf Stalks, cm

		45-9			C-108			Tainung #1		
date	growing days	length	sd	numbers sampled	length	sd	numbers sampled	length	sd	numbers sampled
7/15/93	21	3.02	1.03	10	4.90	0.97	10	5.14	1.08	10
7/15/93	21	3.79	1.23	8	4.10	0.87	9	4.37	1.23	10
7/19/93	25	7.10	1.09	10	8.16	0.70	10	9.02	2.11	10
7/19/93	25	6.70	1.08	10	8.19	1.24	10	7.76	2.24	3
7/22/93	28	8.84	0.88	5	8.34	1.00	5	9.93	1.02	4
7/22/93	28	8.40	1.67	5	8.78	1.04	5	9.46	2.37	5
7/26/93	32	11.52	1.35	5	13.34	2.13	5	11.52	1.55	5
7/26/93	32	11.57	2.29	3	13.83	0.24	4	13.10	0.26	5
7/28/93	34	12.30	1.63	5	15.66	3.20	5	20.88	3.41	5
7/28/93	34	14.50	1.87	5	16.40	2.02	5	16.32	1.17	5
7/30/93	36	12.54	4.50	5	16.86	1.76	5	19.38	2.79	5
7/30/93	36	18.26	2.12	5	18.36	2.98	5	19.54	2.26	5
8/2/93	39	20.46	2.27	5	23.40	2.53	5	26.46	3.53	5
8/2/93	39	21.30	4.56	5	24.08	2.12	5	22.46	0.38	5
8/4/93	41	25.24	2.78	5	26.24	2.40	5	30.36	2.13	5
8/4/93	41	26.42	3.26	5	28.60	2.50	5	27.50	2.57	4
8/6/93	43	23.30	3.21	5	26.72	2.58	5	26.94	3.81	3
8/6/93	43	27.54	3.35	5	27.92	3.76	5	29.28	1.92	4
8/10/93	47	31.06	3.41	5	34.00	2.94	5	36.30	4.74	4
8/10/93	47	34.52	2.54	5	31.30	2.82	4	31.86	2.98	3
8/11/93	48	37.00	2.65	3	33.62	2.02	5	35.48	1.10	3
8/11/93	48	37.13	0.71	3	35.38	3.52	4	37.57	0.12	3
8/13/93	50	38.55	0.76	4	43.48	0.21	4	40.70	2.04	3
8/13/93	50	41.00	1.22	4	42.00	1.58	4	43.83	0.56	3
8/19/93	56	53.80	1.39	3	53.67	2.73	3	56.23	2.97	3
8/19/93	56	57.17	1.76	3	55.71	2.61	3	55.40	2.12	3
8/23/93	60	68.17	3.61	3	68.70	1.91	3	70.70	5.14	3
8/23/93	60	68.37	3.78	3	71.60	4.40	3	70.60	2.07	3
8/25/93	62	79.37	0.78	3	83.50	2.18	3	84.33	2.57	3
8/25/93	62	83.43	2.10	3	79.93	4.52	3	81.00	4.11	3
9/2/93	70	82.63	4.55	3	92.30	6.20	3	83.27	13.50	3
9/2/93	70	97.73	4.25	3	114.60	6.66	3	106.77	8.67	3
9/6/93	74	87.50	9.05	2	88.55	14.07	2	93.80	6.24	3
9/6/93	74	101.80	6.93	2	102.80	14.99	2	114.35	4.03	2
9/9/93	77	98.90	6.22	2	109.45	5.30	2	108.40	22.63	2
9/9/93	77	111.10	7.78	2	121.85	8.41	2	120.60	7.64	2
9/16/93	84	106.75	5.73	2	111.00	1.41	2	118.50	14.14	2
9/16/93	84	109.65	0.35	2	121.20	12.73	2	103.50	2.12	2

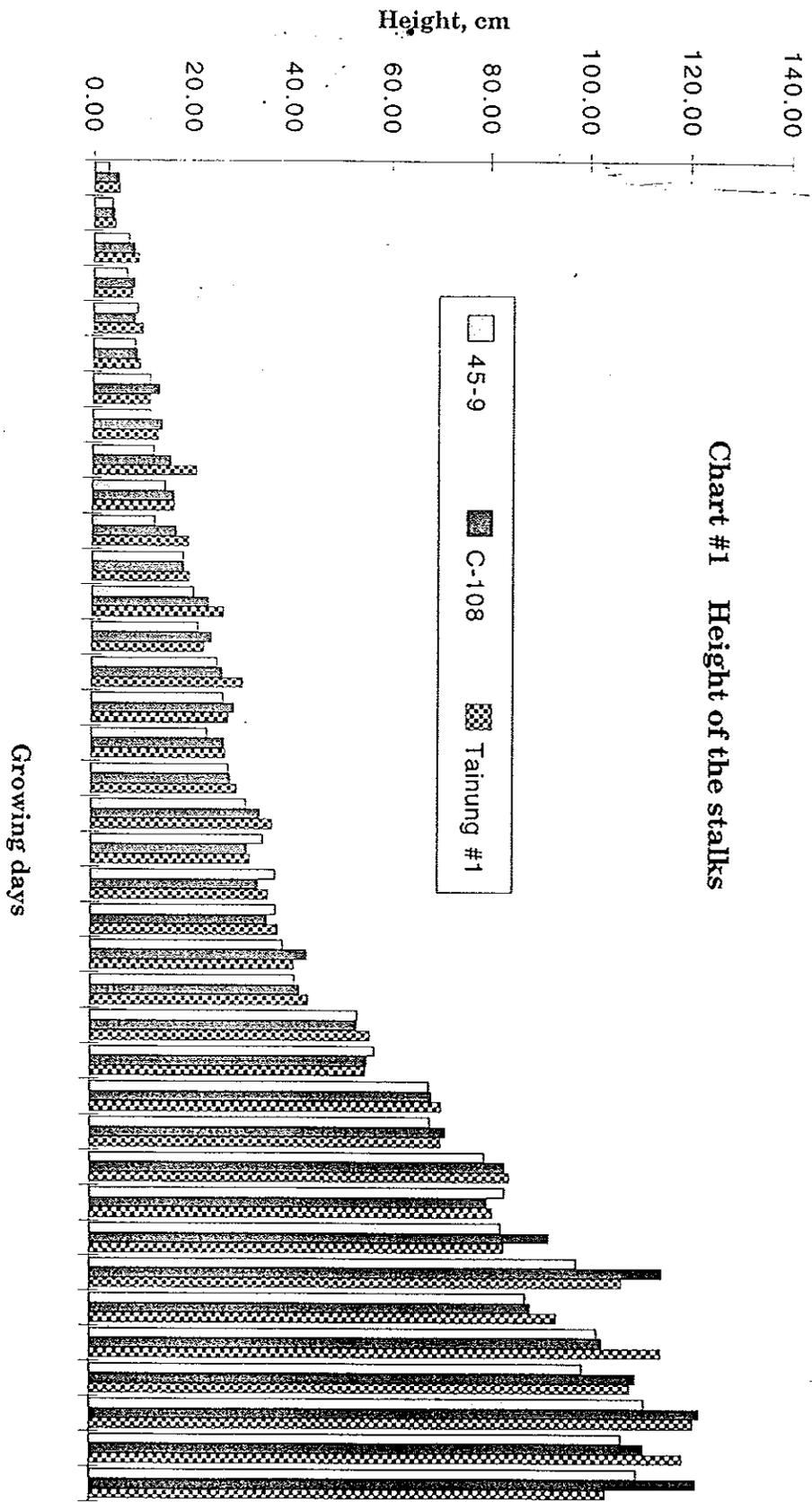


Table #2 Width of Kenaf Stalks, cm										
		45-9			C-108			Tainung #1		
date	growing days	width	sd	numbers sampled	width	sd	numbers sampled	width	sd	numbers sampled
7/15/93	21	0.18	0.05	10	0.21	0.04	10	0.19	0.05	10
7/15/93	21	0.18	0.04	9	0.17	0.04	9	0.18	0.04	10
7/19/93	25	0.23	0.05	10	0.25	0.03	10	0.26	0.04	10
7/19/93	25	0.24	0.04	10	0.20	0.00	10	0.20	0.00	10
7/22/93	28	0.22	0.04	5	0.24	0.05	5	0.29	0.02	4
7/22/93	28	0.25	0.05	5	0.26	0.04	5	0.23	0.04	5
7/26/93	32	0.30	0.00	5	0.30	0.00	5	0.30	0.00	5
7/26/93	32	0.30	0.00	3	0.30	0.00	4	0.30	0.00	5
7/28/93	34	0.30	0.00	5	0.32	0.05	5	0.44	0.05	5
7/28/93	34	0.40	0.00	5	0.40	0.00	5	0.32	0.04	5
7/30/93	36	0.40	0.07	5	0.36	0.10	5	0.38	0.04	5
7/30/93	36	0.44	0.05	5	0.42	0.06	5	0.40	0.00	5
8/2/93	39	0.46	0.05	5	0.58	0.05	5	0.56	0.05	5
8/2/93	39	0.50	0.10	5	0.58	0.00	5	0.52	0.04	5
8/4/93	41	0.64	0.05	5	0.54	0.06	5	0.66	0.05	5
8/4/93	41	0.60	0.10	5	0.60	0.12	5	0.62	0.11	4
8/6/93	43	0.60	0.12	5	0.62	0.10	5	0.54	0.11	3
8/6/93	43	0.66	0.11	5	0.62	0.05	5	0.58	0.04	4
8/10/93	47	0.66	0.15	5	0.66	0.05	5	0.70	0.12	4
8/10/93	47	0.72	0.19	5	0.60	0.08	4	0.64	0.05	3
8/11/93	48	0.48	0.10	3	0.54	0.11	5	0.60	0.07	3
8/11/93	48	0.65	0.00	3	0.60	0.08	4	0.63	0.03	3
8/13/93	50	0.69	0.06	4	0.78	0.09	4	0.59	0.07	3
8/13/93	50	0.73	0.18	4	0.71	0.05	4	0.70	0.04	3
8/19/93	56	0.83	0.15	3	0.73	0.03	3	0.82	0.13	3
8/19/93	56	0.97	0.16	3	0.83	0.15	3	0.73	0.15	3
8/23/93	60	0.93	0.08	3	0.93	0.08	3	1.20	0.20	3
8/23/93	60	0.93	0.15	3	1.03	0.16	3	0.97	0.03	3
8/25/93	62	1.00	0.10	3	0.75	0.05	3	0.93	0.08	3
8/25/93	62	1.13	0.06	3	0.85	0.18	3	0.80	0.17	3
9/2/93	70	1.23	0.12	3	1.20	0.17	3	1.03	0.06	3
9/2/93	70	1.37	0.32	3	1.23	0.12	3	1.20	0.20	3
9/6/93	74	1.45	0.07	2	1.35	0.35	2	1.07	0.06	3
9/6/93	74	1.15	0.07	2	1.20	0.00	2	1.15	0.07	2
9/9/93	77	1.45	0.35	2	1.55	0.07	2	1.30	0.42	2
9/9/93	77	1.35	0.21	2	1.35	0.21	2	1.40	0.00	2
9/16/93	84	1.60	0.14	2	1.35	0.07	2	1.65	0.07	2
9/16/93	84	1.45	0.21	2	1.45	0.21	2	1.25	0.07	2

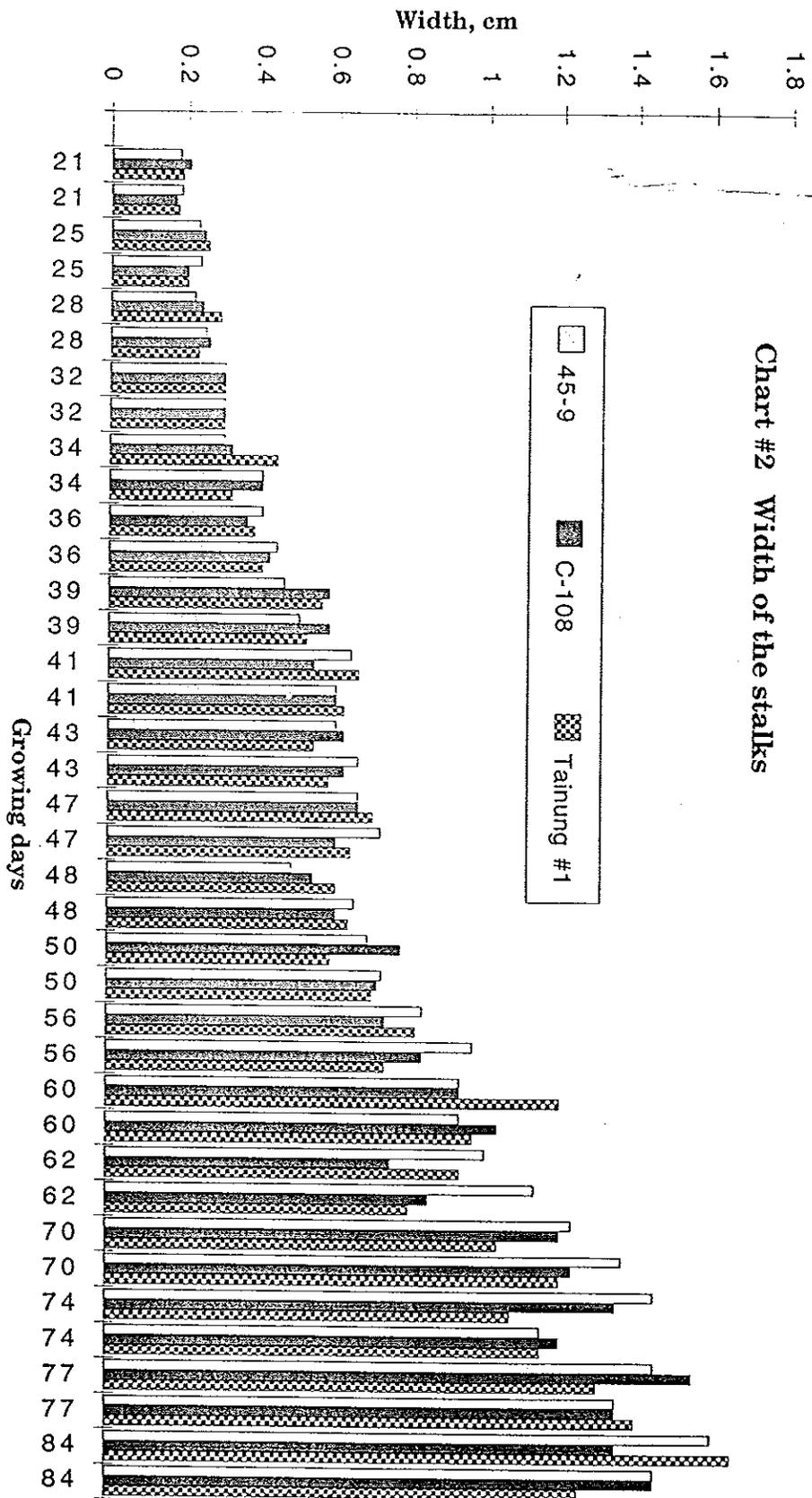


Chart #2 Width of the stalks

Table #3 Fiber length of Bast Fibers, mm

(C= C-108, T=Tainung #1, 4= 45-9)

50 days			60 days			77 days			84 days										
C	T	4	C	T	4	C	T	4	C	T	4								
2005	2241	2387	2471	2201	1988	2403	2860	3045	2439	2774	2837	2838	2158	3143	2808	3096	3148	3559	4706
2322	2402	2697	2307	2118	2109	3344	3528	3016	2756	2622	3176	3078	2396	3077	3004	3361	2408	3546	2832
2100	2216	2420	2039	2082	2377	2272	2867	2501	2942	2467	3832	2842	2704	3157	3064	2837	2874	3308	2884
2653	2545	2179	2370	2113	2461	2521	2136	2606	2647	2567	2731	2718	3112	2975	3327	2753	3565	3023	3383
2501	2628	2502	2126	2107	2032	2899	2469	2833	3096	2583	3171	3115	3038	2851	2909	3098	4263	3092	3318
2250	2418	2367	2082	2305	2178	2282	2419	2688	2632	2712	3643	3442	3131	3389	2784	2615	4027	2828	2723
2391	2859	2020	2113	2343	2052	2292	2643	2923	2640	3249	3710	2714	3119	2896	3174	2605	2863	2525	3110
2503	2637	2200	1945	2173	1971	2616	2768	2569	3152	2803	2919	2632	2704	3266	2774	3334	2884	2960	2863
2774	2016	2024	1896	1952	2133	2901	2722	3052	3252	2778	2778	2869	3111	3641	3325	2750	3560	2953	3535
2148	2159	2018	2541	2713	2324	2376	2563	2544	2527	2630	2841	2575	3006	2896	2999	3134	3313	3431	2739
2276	2110	2124	1991	2166	2656	2900	2880	2622	2469	2657	2464	2815	3000	2964	2625	2949	3321	3336	3850
2269	2225	2215	2592	2594	2019	2632	2574	2703	3033	2750	2667	3144	3361	2559	3346	3108	2803	3177	2695
2371	2460	2144	2165	2511	2349	2873	2600	2448	2885	2172	2795	2909	3127	3085	3149	3049	3707	2807	2860
2200	2424	2023	2212	2345	1948	2859	2773	2336	2395	2857	3058	3466	3140	3035	3190	2848	3740	2920	2838
2154	2149	2108	2030	2193	1909	2854	2369	2845	2600	2981	2574	2887	3237	2876	2712	2690	3696	3211	2648
2193	2256	2111	2438	2212	1948	2501	2820	2768	3041	2495	2769	2724	2902	2982	3013	2903	3828	3493	2942
3042	2087	1943	2270	2231	2490	2647	2670	2925	2968	2784	2906	2855	3365	3017	3062	3256	2798	2973	2684
2043	2513	2242	2191	2217	2167	2743	2456	3381	2638	2649	2779	2628	2938	2933	2974	2726	3476	3167	3338
2404	2121	2085	1899	2299	2050	3076	2746	2971	2762	2981	2749	3045	2788	3357	3055	2820	3568	2765	3126
2421	2440	2380	2552	2227	1916	2594	2448	2959	2919	2850	3085	3190	3283	2996	3003	2720	3200	3850	3394
2483	2186	2263	1999	2409	2049	2908	2922	3258	2992	3065	2836	3375	2572	2783	3280	3009	3594	2623	3071
2429	2333	2016	2194	2110	2032	2369	2465	3187	3168	2703	2590	3150	3319	2870	2962	2728	3383	3350	2875
2033	2421	1980	2366	2241	2297	2486	3402	2783		2632	2976	2772	2958	3007	3329	2756	3348	2996	2707
2092		1977	1927	2077	2382	2344	2657	3460		3075	2742	3560	2904	3257	3067	3595	3390	3446	2618
2399		2517	2301	2078	1953	2354	2450	3063		2579	2556		2756	2883	2824	3182	3260	2994	2701
2313		2033	2010	2443	2381	2632		2867		2923	2805		3023	2995	3065	2912	3417	2503	2782
2437		2078	2046	2115	1895	2733		3378		2665	3145		3186	3148	2972	3208	3317	3760	3184
2279		2351	2291	2176	2293	3181		3008		2742	2429		2672		2948	2463	3484	3654	3057
2354		2142	1918	2126	2018	2469		3172		2857	2620		2876		3097	3066		3030	3347
2063		1958	1864	1973	2177	2755		2661		2925	2658		3235		2701	3048		2922	3305
2567		1969		2216		3309		2972		3054	2878		3052		3285				
2010		1960		2330		2744		2939		2449	2848		2958		3059				
2135		2197		2142		2594		2785		2168	2803		3067		2892				
2343		2022		2114		2369		2666		2436	2685		3267		3098				
2131		1861		2055		2524		2530		2736	2975		3279		3497				
2191		2072		2023		2343		2747		2708	3009		3086		3247				
2312		1985		1989		3014		3269		2484	3032		3452		2481				
2154		1840		2243		2706		2257			2971		3316		3473				
2312		2043		1956		2657		2498			3128		2962		3213				
2628		2494		2011		2612		2805			3348		3295		3181				
2321	2158	2178	2675	2839	2718	2935	3028	3008	3366	3140	371								

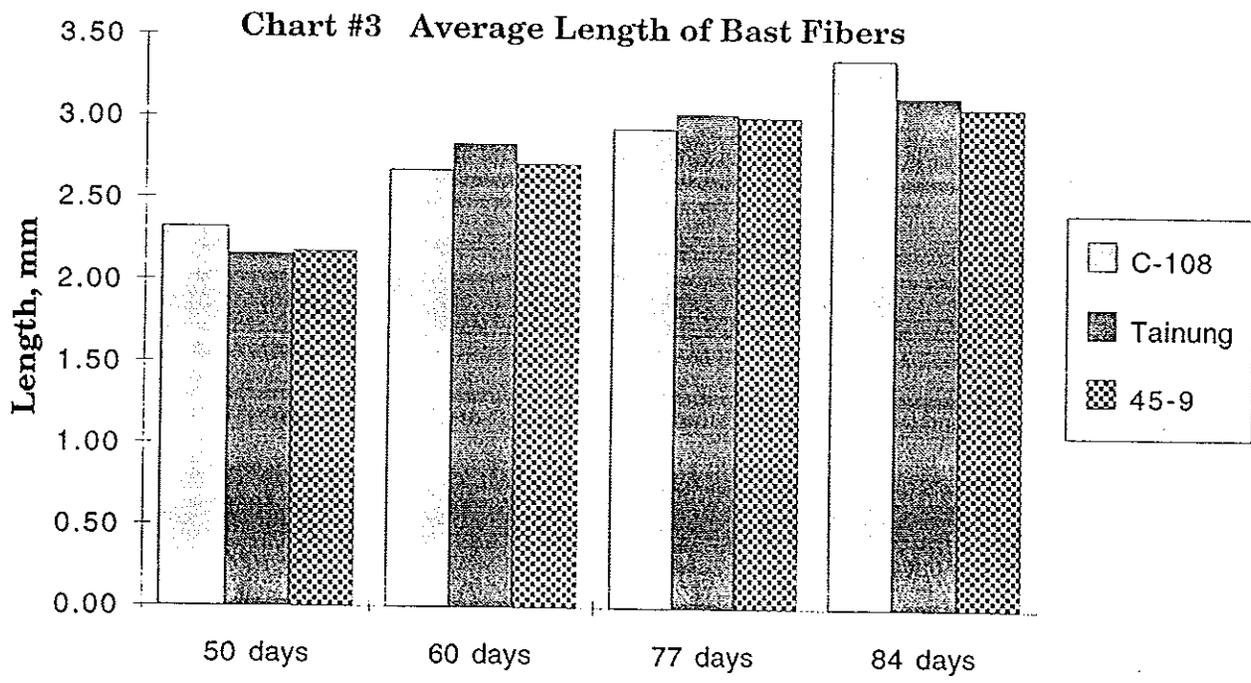


Table #4 Fiber Length of Core Fibers, micrometer

Table #4 Fiber Length of Core Fibers, micrometer																
11-Aug					9-Sep					16-Sep						
C-108	Tainung		45-9		C-108	T	45-9		C-108	Tainung	45-9					
511	845	614	592	982	702	768	702	672	777	794	746	856	717	669	1811	
391	717	777	614	741	689	677	949	760	941	954	807	1053	771	852	778	
693	773	755	675	819	680	558	659	638	1177	810	945	923	697	921	737	
834	772	728	805	936	412	653	989	772	816	733	852	689	893	553	1047	
736	701	770	660	823	713	789	940	834	749	541	713	976	977	768	793	
613	736	947	664	756	687	643	644	906	1014	841	752	919	681	605	1818	
582		772	772	956	484	634	824	633	616	654	782	770	898	635	603	
642		926	673	741	607	736	755	685	562	803	856	861	780	659	604	
505		672	618	1108	835	692	902	564	511	1038	785	781	909	602	705	
969		743	719	932	653	853	456	808	527	1018	980	848	669	753	1063	
684		946	540	760	759	727	616	650	727	956	787	642	727	687	673	
912		657	676	669	511	680	645	713	560	575	761	700	822	537	965	
603		947	694	788	494	713	534	722	685	829	613	841	522	822	744	
870		806	825	540	348	830	634	751	467	738	543	948	567	574	948	
639		840	890	824	583	631	654	737	541	729	713	860	690	984	926	
690		866	827	684	507	636	906	700	633	860	778	824	1119	489	812	
571		635	657	899	633	568	656	693	1039		1151		948	605	774	
890		838	755	781		742		550	713		601		793		641	
663		834	883	592		654		897	874		546		1202		742	
633		750		714		542		669	574		666		837		716	
406		613		895		600		779	524		775		924		875	
520		578		812		622		806	593		465		606		689	
493		686		629		713		678	876		687		736		568	
628		838		780		603		726	872		1015		731		624	
629		706		724		778		640	631		826		982		1125	
817		807		637		815		575	714		990		676		595	
766		761		1174		641		507	743		925		907		771	
792		637		764		707		484	605		1021		1108		699	
799		689		673		683		608	603		746		745		772	
890		978		868		493		671	665		635		725		478	
937		864		652		682		861	927		894		820		570	
722		816		703		719		559	747		693		1000		481	
784		761		675		873		1040	586		754		885			
804		668		577		922		637	510		1105		936			
699		716		965		434		643	683		666		756			
827		511		704		561		1162	543		709		544			
691		651		643		697		673	662		799		940			
626		788		557		729		834	759		765		674			
785		617		483		833		824	711		728		1721			
569		749		556		675		707	690		808		876			
685		754		594		576		747	669		799		659			
698		588		656		887		536	821		771		612			
739		806		507		696		624	602		835		852			
703	741			709		702		713			730		801		789	817

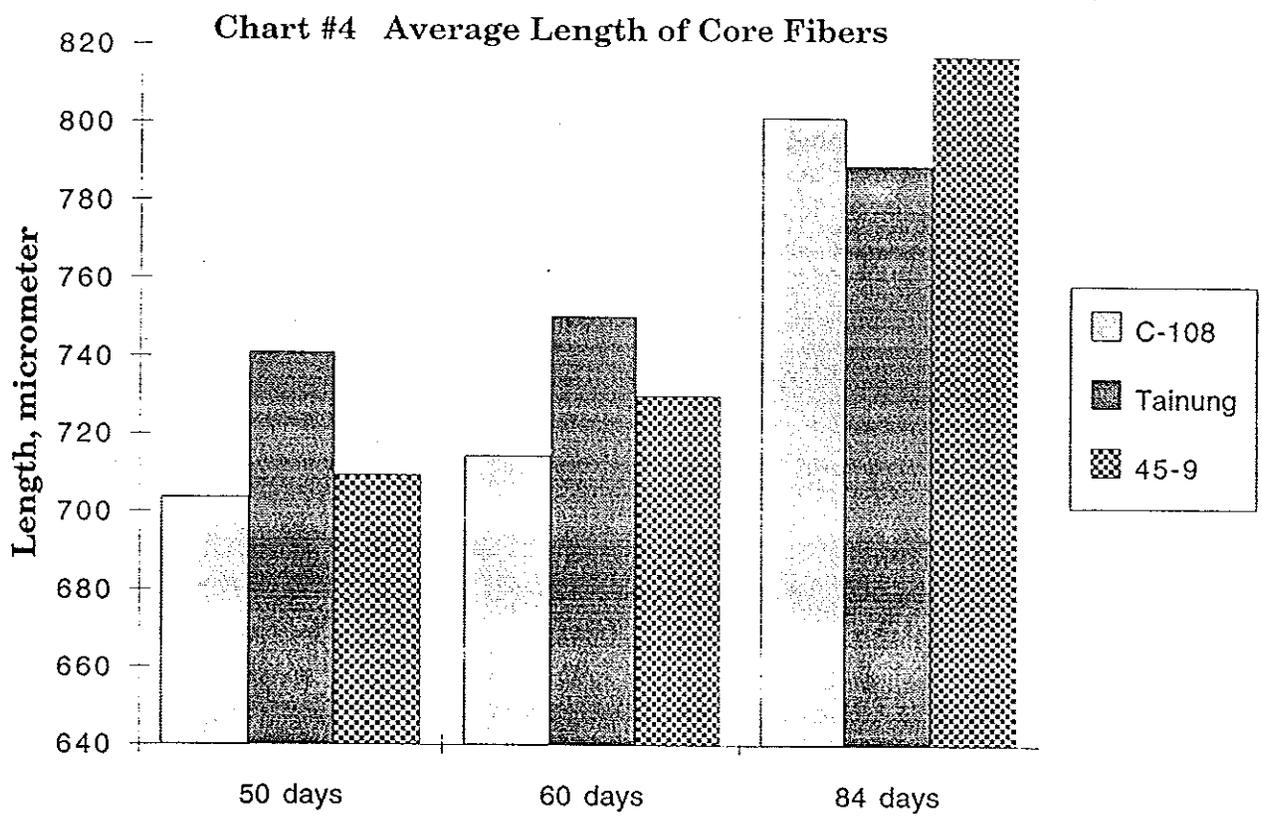
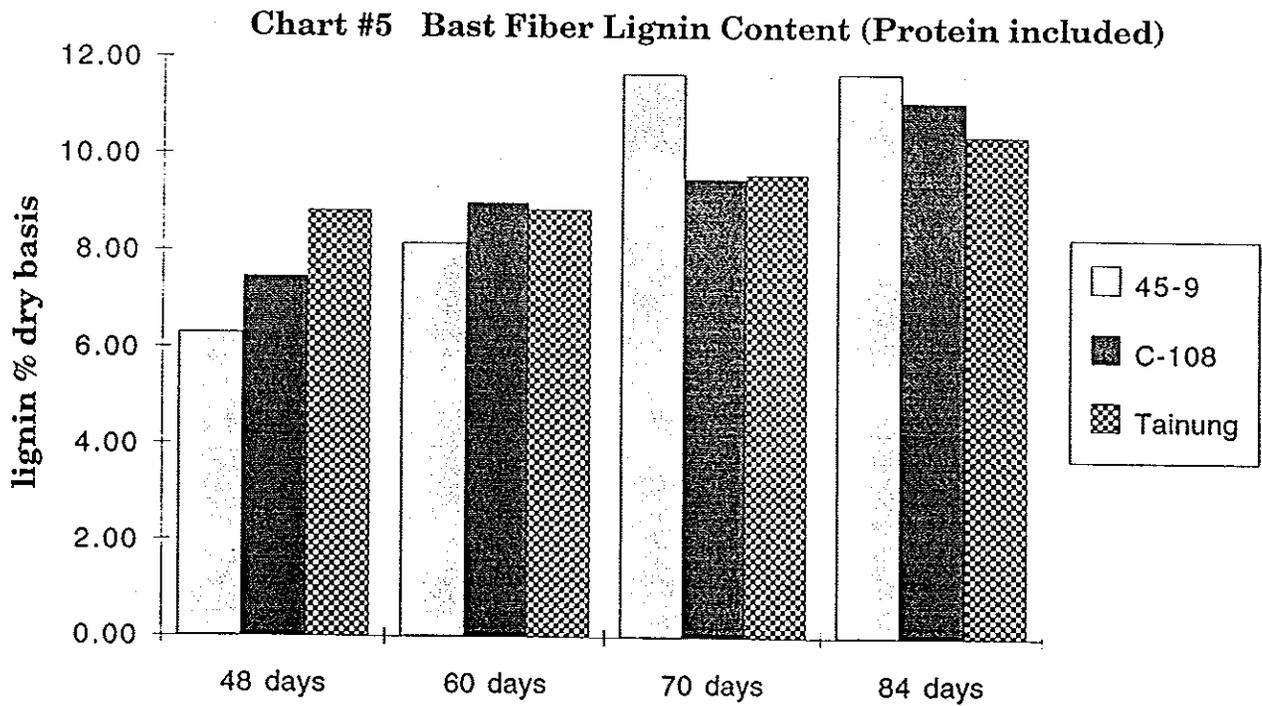


Table #5						
Lignin Content of Bast Fiber as a Function of Growth						
(Protein Content included), % dry basis						
	Bast Fiber			Core		
	45-9	C-108	Tainung	45-9	C-108	Tainung
48 days	6.31	7.46	8.83	10.09	12.80	13.50
60 days	8.16	8.99	8.86	13.73	15.76	16.05
70 days	11.67	9.51	9.60	16.24	16.72	16.84
84 days	11.69	11.10	10.40	15.62	17.47	15.33



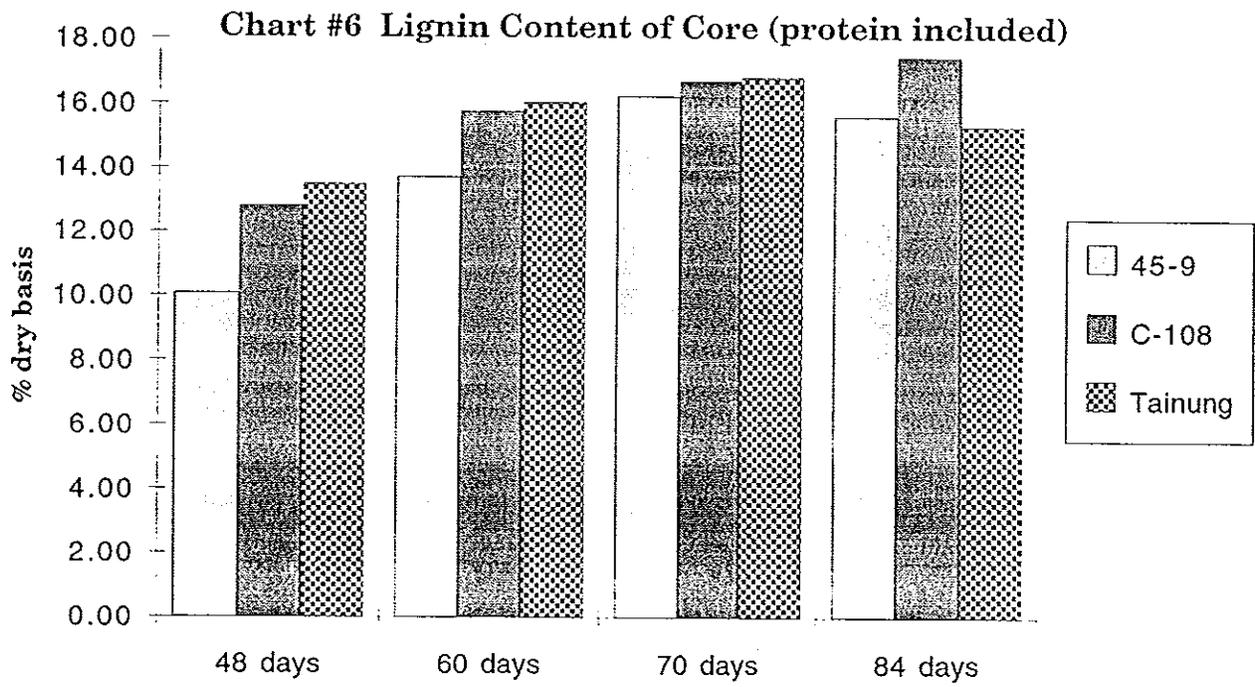
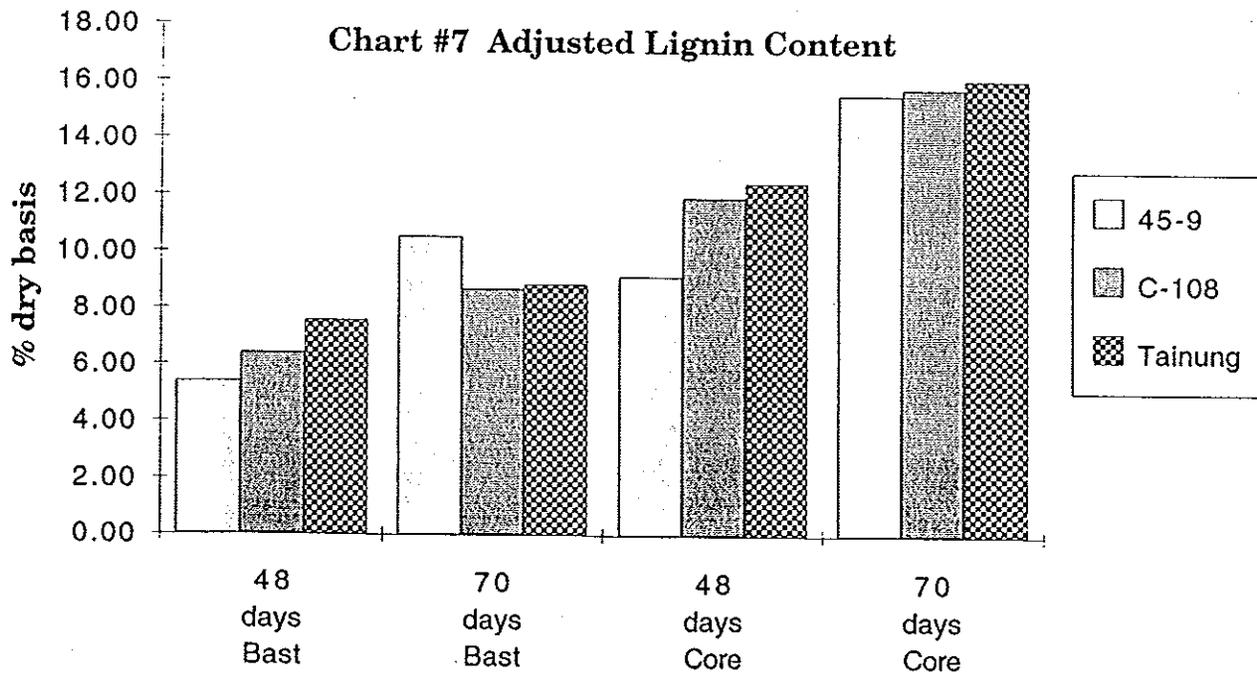


Table #6			
Protein Content			
% dry basis of Klason Lignin			
		Bast	Core
48 days	45-9	14.38	9.25
48 days	C-108	14.06	6.81
48 days	Tainung	14.25	7.69
70 days	45-9	9.56	4.19
70 days	C-108	8.56	5.63
70 days	Tainung	7.63	4.38

Table # 7 Protein Content and Adjusted Lignin Content, % dry basis							
		Bast Fiber			Core		
		45-9	C-108	Tainung	45-9	C-108	Tainung
48 day	protein	1.48	1.71	2.05	1.52	1.42	1.69
	adjusted lignin	5.40	6.41	7.57	9.16	11.93	12.46
70 day	protein	1.84	1.33	1.20	1.11	1.54	1.20
	adjusted lignin	10.54	8.70	8.87	15.56	15.78	16.10



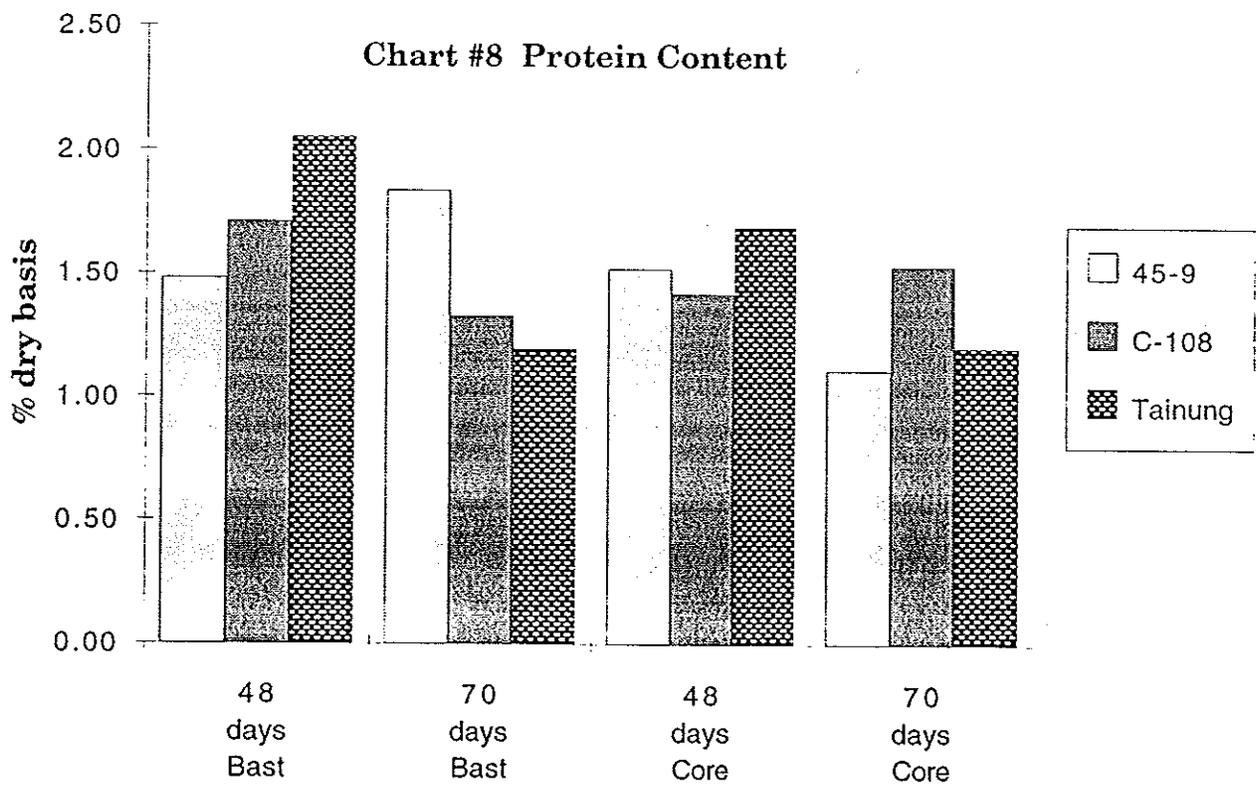


Table # 8 Polysaccharides content (% of anhydro sugar on oven-dry basis)									
	days	Arabinan	Rhamnan	Galactan	Glucan	Xylan	Mannan	Other	
Core	48 days / 45-9	3.16	0.69	2.59	32.81	6.26	1.59	0.25	
	60 days / 45-9	2.54	0.66	1.81	36.91	7.78	1.02	0.22	
	70 days / 45-9	2.44	0.56	1.80	37.99	6.97	1.20	0.47	
	70 days / 45-9	2.46	0.68	1.67	36.30	7.49	1.18	0.23	
	48 days / C-108	3.04	0.71	2.21	34.91	7.26	1.07	0.25	
	60 days / C-108	2.58	0.70	1.98	38.38	7.94	1.19	0.24	
	70 days / C-108	2.18	0.54	1.58	39.47	7.47	1.03	0.40	
	84 days / C-108	2.49	0.71	1.85	38.13	7.94	1.15	0.31	
	48 days / Tainung	3.31	0.69	2.10	35.39	7.61	1.12	0.20	
	60 days / Tainung	2.92	0.68	2.05	37.42	7.60	1.17	0.25	
	70 days / Tainung	2.49	0.62	1.84	39.38	7.76	0.97	0.32	
	84 days / Tainung	2.41	0.64	1.76	38.89	7.99	1.09	0.26	
	Bast	48 days / 45-9	3.16	0.69	2.59	32.81	6.26	1.59	0.25
		60 days / 45-9	2.54	0.66	1.81	36.91	7.78	1.02	0.22
70 days / 45-9		2.44	0.56	1.80	37.99	6.97	1.20	0.47	
70 days / 45-9		2.46	0.68	1.67	36.30	7.49	1.18	0.23	
48 days / C-108		3.04	0.71	2.21	34.91	7.26	1.07	0.25	
60 days / C-108		2.58	0.70	1.98	38.38	7.94	1.19	0.24	
70 days / C-108		2.18	0.54	1.58	39.47	7.47	1.03	0.40	
84 days / C-108		2.49	0.71	1.85	38.13	7.94	1.15	0.31	
48 days / Tainung		3.31	0.69	2.10	35.39	7.61	1.12	0.20	
60 days / Tainung		2.92	0.68	2.05	37.42	7.60	1.17	0.25	
70 days / Tainung		2.49	0.62	1.84	39.38	7.76	0.97	0.32	
84 days / Tainung		2.41	0.64	1.76	38.89	7.99	1.09	0.26	

Chart # 9 Change of Sugars in C-108 Core

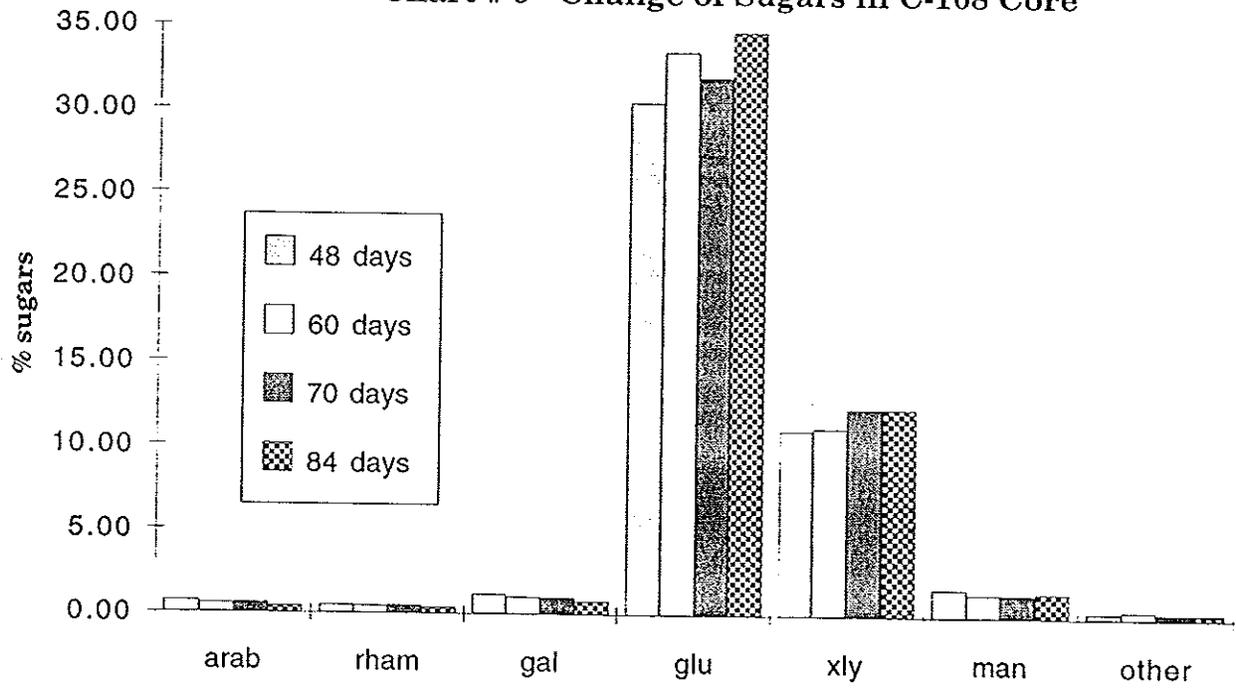


Chart #10 Change of Sugars in 45-9 Core

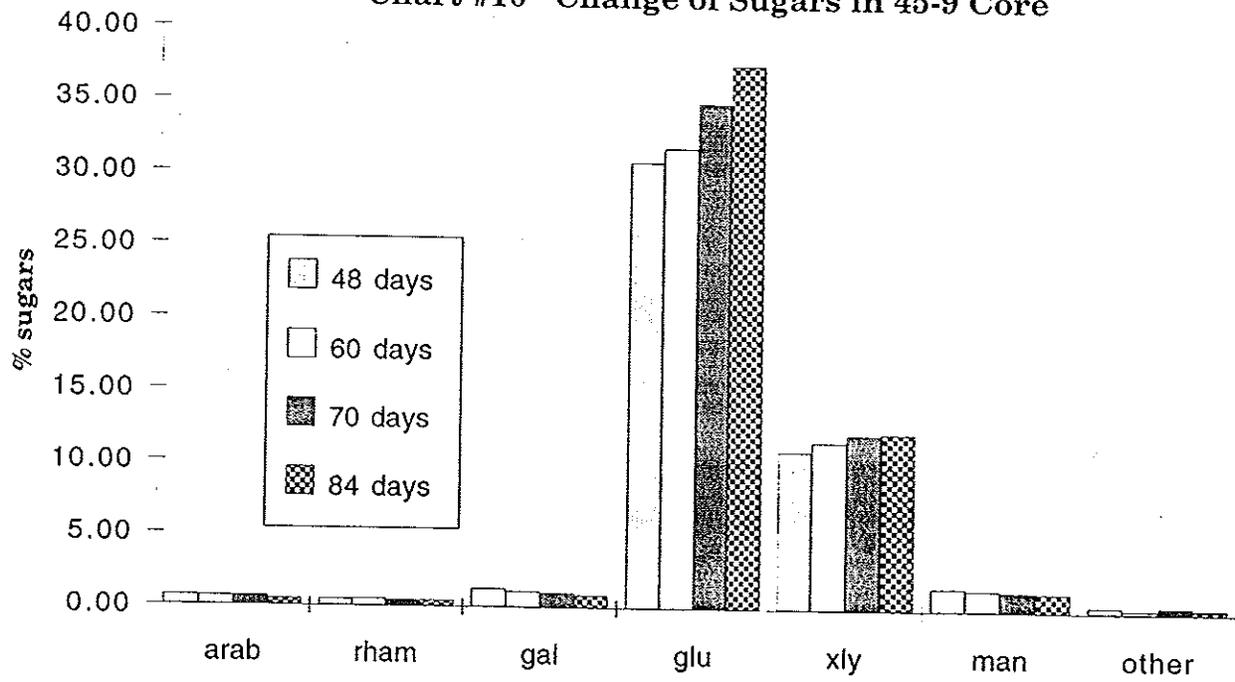


Chart #11 Change of Sugars in Tainung #1 Core

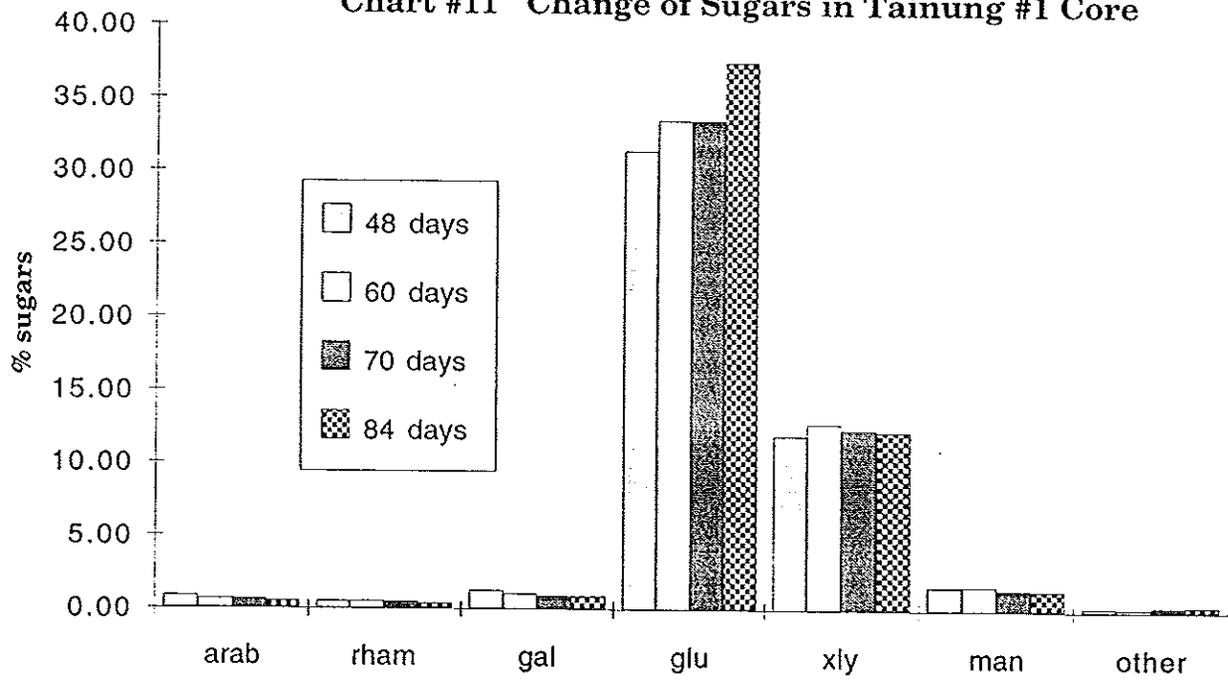


Chart #12 Change of Sugars in C-108 Bast Fiber

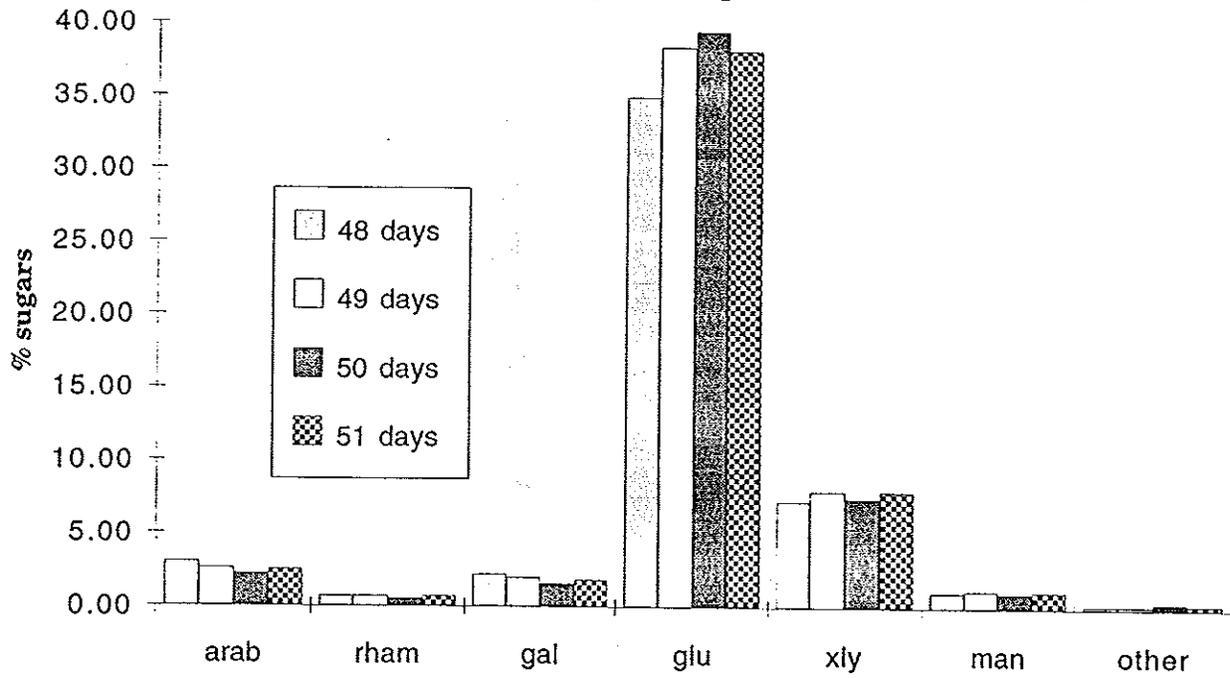


Chart #13 Change of sugars in 45-9 Bast Fiber

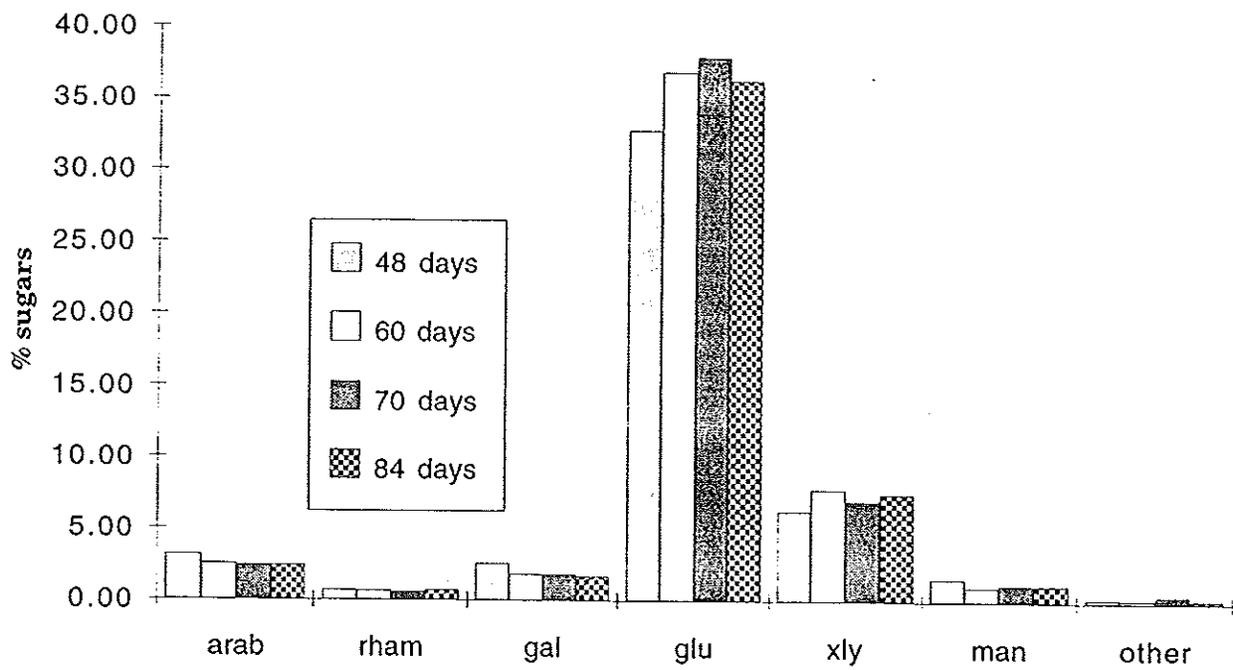


Chart # 14 Change of Sugars in Tainung Bast Fibers

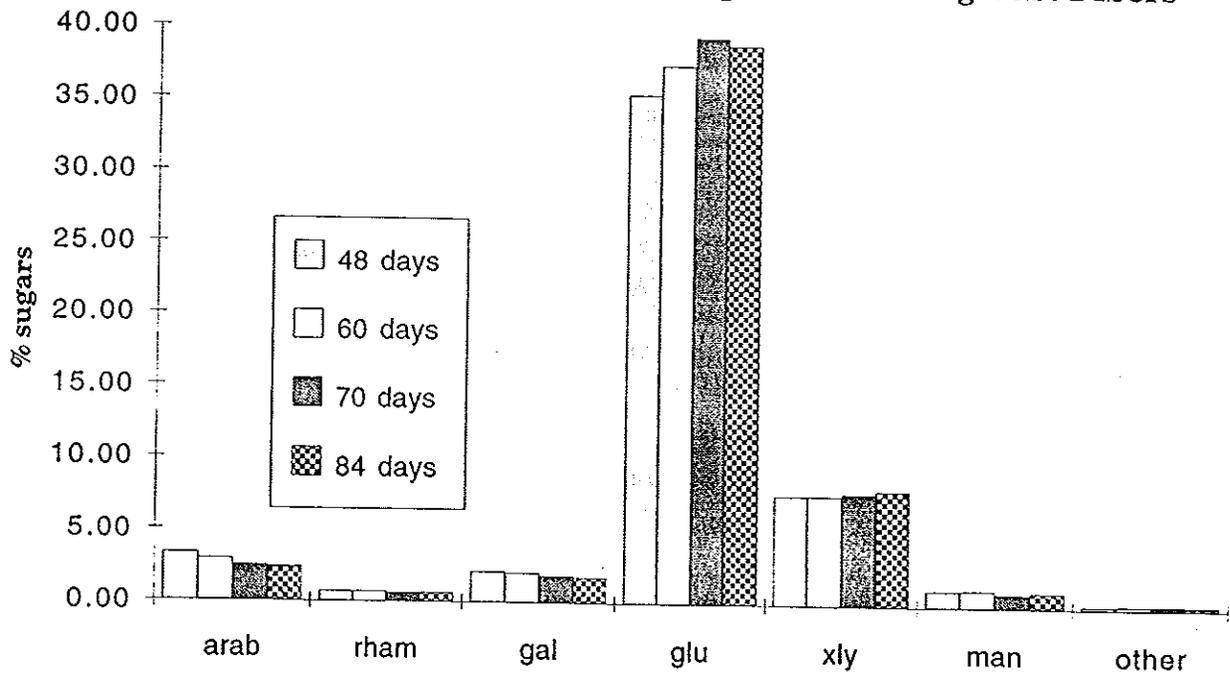


Table #9		
Ash Content of 84 days old Kenaf		
	Bast	Core
45-9	5.35	4.65
C-108	6.10	6.25
Tainung #1	5.90	5.60
Average	5.78	5.50

Chart # 15 Ash Content of 84 Days Old Kenaf

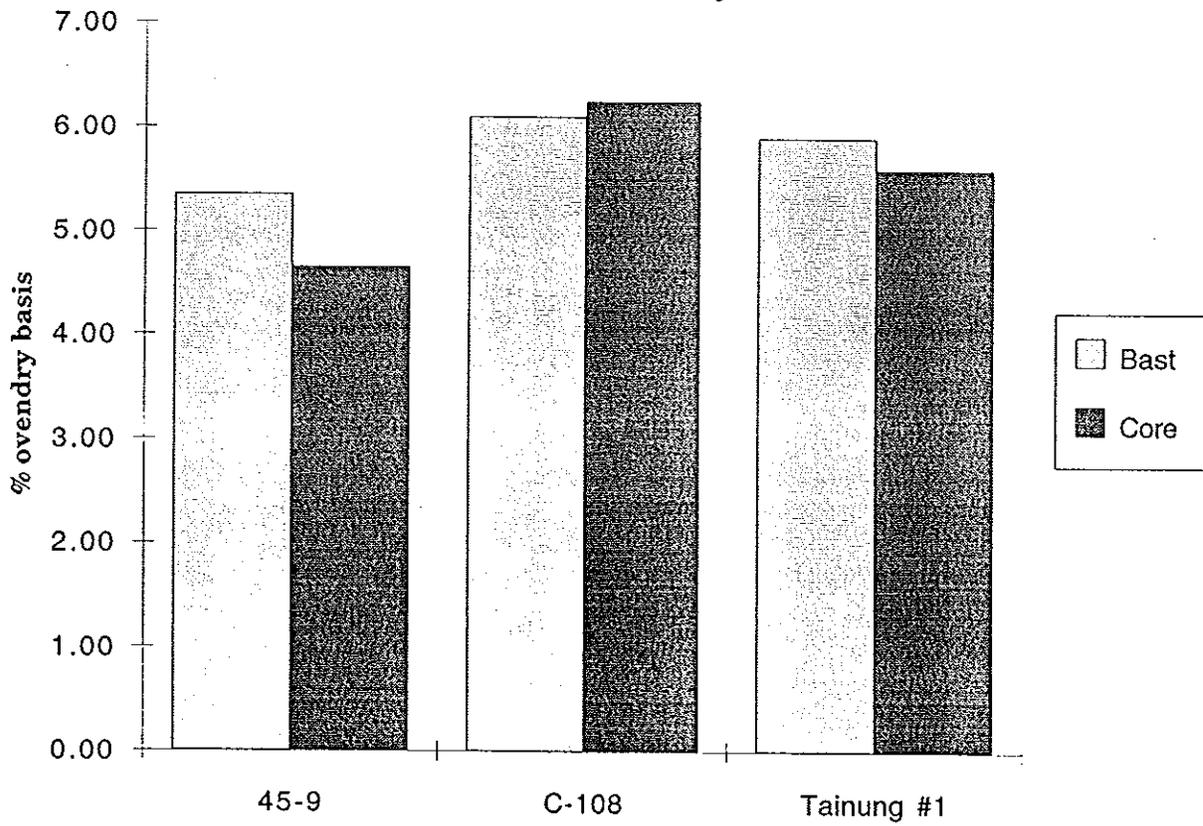
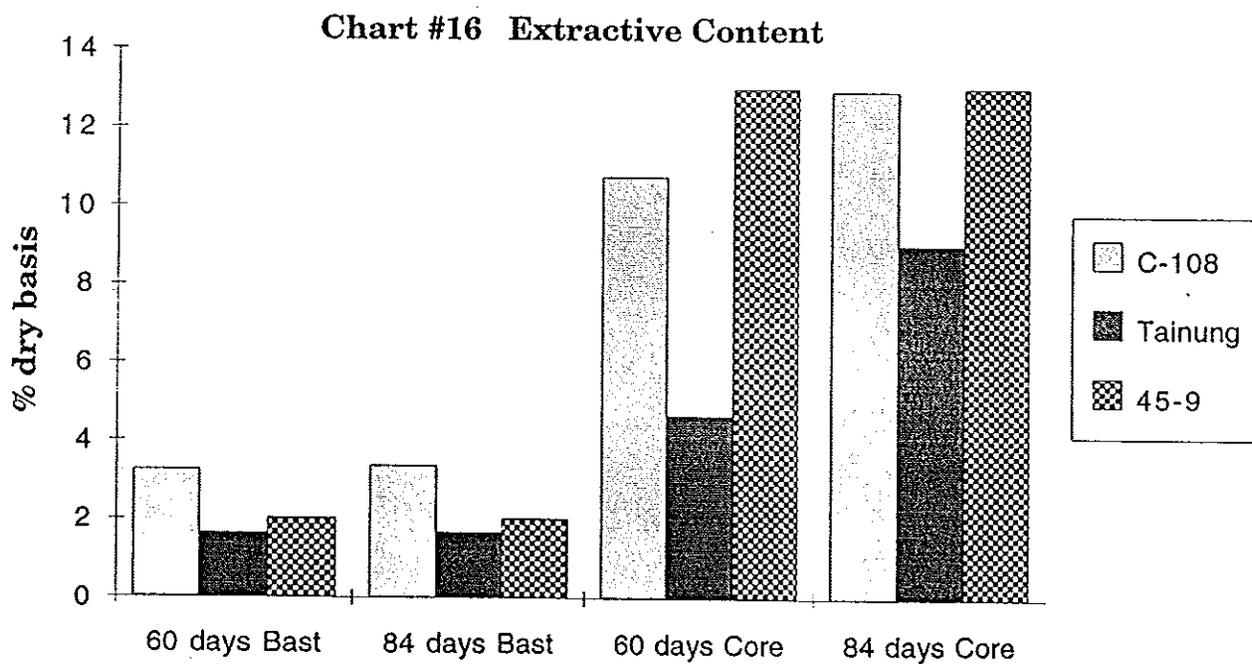


Table #10						
Extractive Content						
	Bast Fibers			Cores		
	C-108	Tainung	45-9	C-108	Tainung	45-9
60 days	3.25	1.63	2.02	10.75	4.67	13.03
84 days	3.36	1.66	2.03	12.96	9.04	13.06



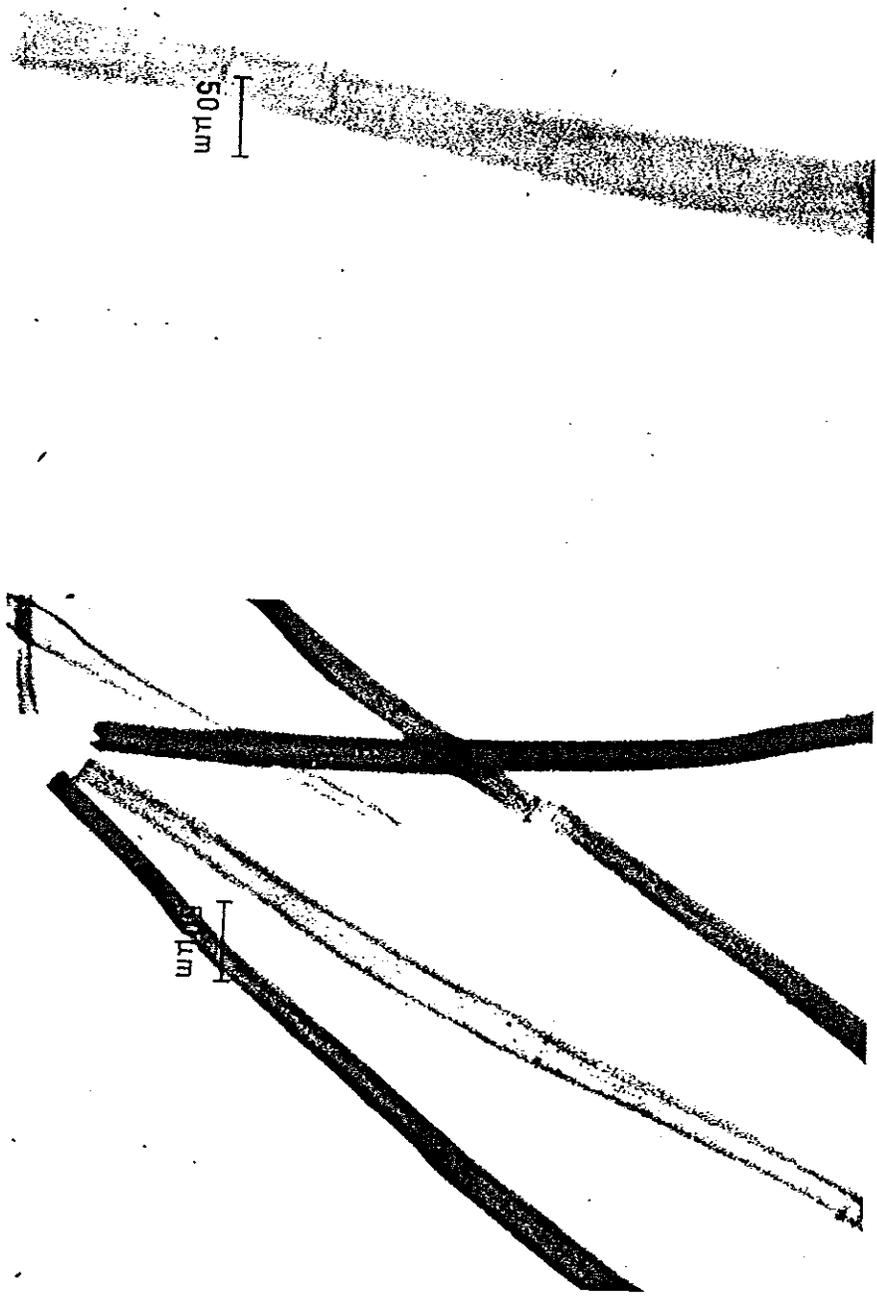


Figure #3 Bast Fibers

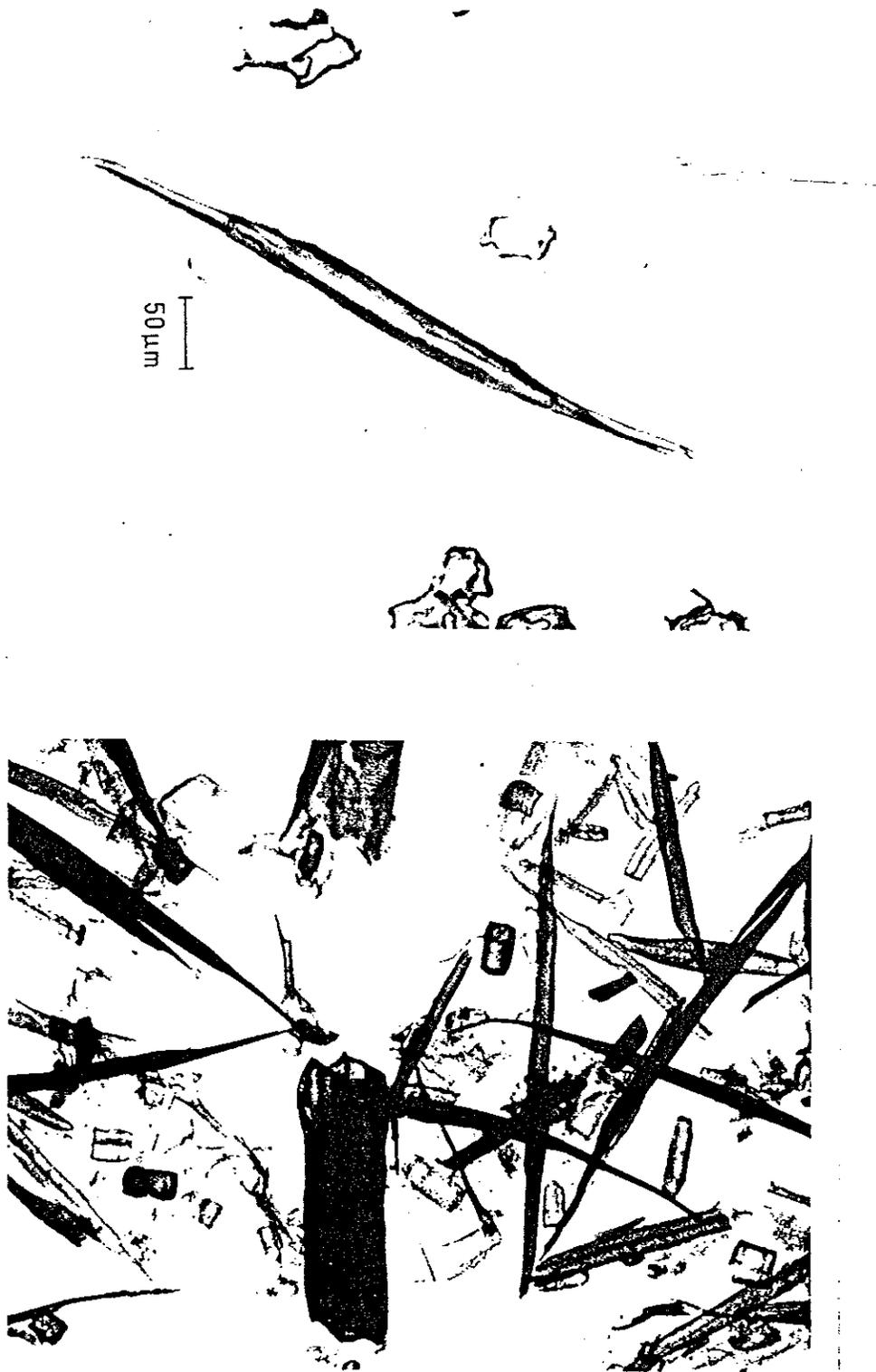


Figure #4 Core Fibers

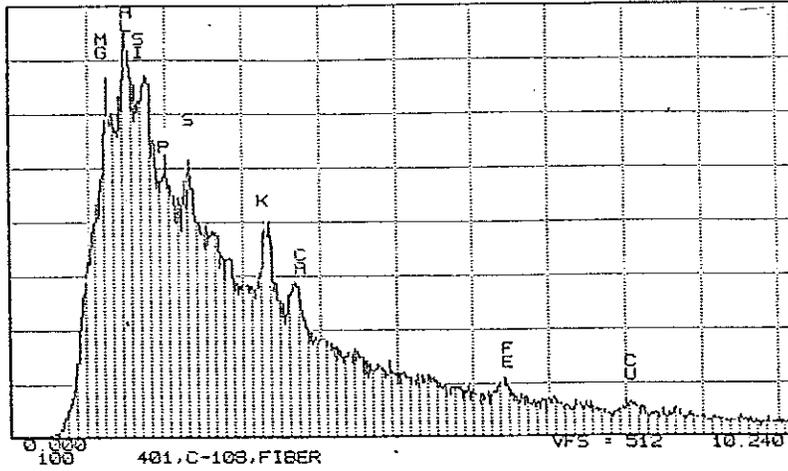


Figure #5
X-Ray Scan of 84 Days Old C-108 Bast Fiber

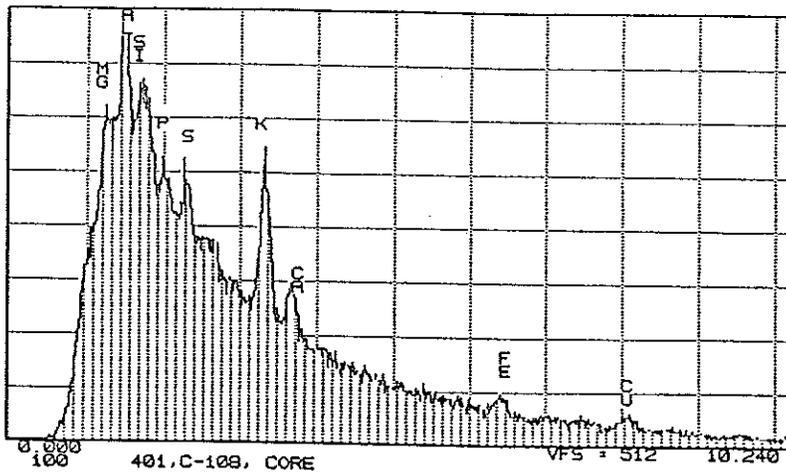


Figure #6
X-Ray Scan of 84 Days Old C-108 Core

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