STUDIES ON PULPING AND BLEACHING CHARACTERISTICS OF SACCHARUM SPONTANEUM LINN

A DISSERTATION

submitted in partial fulfilment of the requirements for the award of the degree

of

MASTER OF ENGINEERING

in

PULP AND PAPER TECHNOLOGY

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled "STUDY ON PULPING AND BLEACHING CHARACTERISTICS OF SACCHARUM SPONTANEUM LINN" in the partial fulfillment for the award of degree of Master of Engineering in Pulp and Paper Technology submitted at Institute of Paper Technology (University of Roorkee), Saharanpur, is an authentic record of my own work carried out during the period from September 1995 to March 1996 under the supervision of Dr. J. S. Upadhayay, Reader and Dr. C. H. Tyagi, Reader, Institute of Paper technology (University of Roorkee), Saharanpur

The matter embodied in this thesis has not been submitted by me for the award of any other degree.

(YASHVEER SINGH)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

The present study was under taken to check the suitability of "SACCHARUM SPONTANEUM LINN" for conversion into pulp and paper product since this material is available abundantly in nature as weed throughout the year. The results of proximate chemical analysis of S. spontaneum Linn indicated that it is a bulky material having comparatively lower extractive content, lower lignin content and higher total carbohydrate fraction. The alkali requirement is low (11-13%) in comparison to pulping of wood. The unbleached pulp showed good results towards oxygen pre-bleaching, thereby reducing the kappa number by 62%. The pulp showed further good response towards multi-stage bleaching sequences to give pulp with a high brightness ceiling. The pulp also showed good response during bleaching since the structure of fiber is comparatively open with respect to wood fiber.

The results of present investigations indicated that the S. spontaneum Linn is one of the potential non wood fibrous raw material for conversion into paper and pulp product. As the fiber length is comparatively low, so it is advisable to use it with long fibered raw material/pulp to run on high speed machines.

CONTENTS

1. INTRODUCTION

Pulp and paper industry has been considered as a vital and core industry and its per capita consumption has been used as index of a country's development, therefore per capita consumption of paper can be taken as a growth in areas related to industrial, cultural and educational development, but it is rather disappointing that per capita consumption of paper in our country is one of the lowest in comparison to other developed countries of the world. As far as our country is concerned the per capita demand of paper is 3.2 kg per annum. With increased thrust toward education and divers uses being found for paper in packaging, the demand is expected to reach a per capita level of 5 kg per annum by the end of century (2).

The paper industries in India have mat the various challenges by adopting itself to the changed conditions. The country has total production demand for paper and board products of 25.70 Lac tons using different conventional and non conventional raw materials, where the total production of paper and board in 1995 was 20.96 Lac tons. The projection demand of paper and board will be 41.12 Lac tons by the end of century and the gap between demand and production will be 15.52 Lac tons by 2000 A.D. (2).

It is well known fact that in absence of planned program of plantation, the forest wealth of the country is fast dwindling. Therefore the present forest resources can not meet the demand of raw material, even with fuller utilization of agricultural based cellulosic fibrous raw materials. The supply position will be far from satisfactory for meeting the set target. Further the depleting forest cover and thrust to conserve ecological balance will force the industry to look alternative cellulosic fibrous raw materials other than wood and bamboo.

The following measures may be taken to bridge the extended gap between demand and supply upto some extent:

(1) The Indian paper industries are facing an acute shortage of conventional raw materials for pulp and paper making, therefore further investigations are required to identify the other non conventional cellulosic fibrous raw materials.

(2) By adopting high yield pulping technology.

(3) By recycling the waste paper using deinking technology.

(4) Implementation of various pollution abatement devices.

(5) By reducing the dependency of pulp and paper industry on forest based raw materials, by using agro-based cellulosic fibrous raw materials along with non woody fibrous raw materials.

Keeping in view, the utilities and their availability to meet the increasing paper demand of our country. It thought is worthwhile to investigate the suitability of a prominent non wood fibrous raw material to provide partially or fully substitute for costly wood pulp. Therefore in the present investigation, efforts have been made to systematic studies on

Saccharum spontaneum Linn for pulp and paper making. It has open structure and low lignin content, hence can be pulped rapidly with milder cooking conditions. It is fast growing in nature, so it can be available throughout the year.

S. spontaneum Linn

Its local name is Kans or Kas. It is a perennial grass with slender culms, growing in stools or forming continuous cane-brakes with most often aggressive rhizomatous tillering, distributed widely in the sub-tropical and topical parts of Asia, Africa and ascending up to an altitude of 1800 m. Culms green, gray, ivory or white, hard, and often hollow in the center, varying in diameter from 5 to 15 mm.; often rooting at the nodes; internodes usually long and nodes always thicker than the internodes; leaves long, linear, narrow or very narrow or sometimes reduced to the midrib, the 'leaf module' or ratio of breadth to length varying from 1:24 to 1: 300 or more in the different forms of the species; inflorescence a panicle varying in length and in color from pale or grayish white to purplish gray; spi kelets in pairs, one pedicelled and the other sessile, the pedicelled spikelet of the pair always blooming first; glumes always four and lodicules ciliate (1).

The forms of S. spontaneum show a wide range of variations in habit and in the morphological characters of stem, leaf and root. The Indian forms show, in general, a tufted habit and the Burmese and East Indian forms an erect habit, while there are also some forms which are almost prostrate. Some of the more robust and tall forms from Assam reach a height of 3-5 m. and are not very dissimilar to some of the North Indian canes (1).

Kans is a coarse grass normally not relished by cattle, and is generally used as fodder only in times of scarcity. Composition of the green (pre-flowering stage) and ripe grass, respectively, is as follows (dry wt. basis): crude protein, 5.30, 3.35; ether extr., 1.42, 1.16; crude fiber, 40.0, 40.2; N-free extr., 49.1, 48.00; calcium, 0.58, 0.42; and phosphorus, 0.67, 0.15%. The green grass is reported to compare favorably with guinea- and Napier-grasses while the ripe grass is comparable with rice- or wheat- straws. S. spontaneum growing in Jammu & Kashmir is reported to contain hydrocyanic acid in the green condition and to produce deleterious effect and sometimes death in livestock; hence it is dried and used sometimes as hay (1).

kans is used for thatching of roofs and its leaves are used for making ropes.

Kans becomes a very pernicious weed, once it is allowed to infest cultivated land so that sometimes cultivators have to abandon the land altogether. In Madhya Pradesh large cultivable areas have been abandoned consequent on infestation by this weed. Weedicides such as CMU are said to kill the weed for varying lengths of time from three months to one year depending upon concentration used after which the weed reappears again. Trails are said to have shown that ploughing to a depth of 20-35 cm. so as to bring up the rhizones and burning them later is the most efficient method of eradication by which about 95 per cent of the weed can be destroyed.

Pulps suitable for wrapping,writing, printing and grease-proof papers can be produced from the kans grass.

Pilot plant trials with the grass have shown that by the soda process, yields of 42 per cent of unbleached and 37.8 per cent of bleached pulps suitable for writing paper of satisfactory strength can be obtained. The grass can be used in admixture with other grasses. S. spontaneum can also be used for the production of hardboards, rayon-grade pulps and activated carbon (av. ash, c. 15%)

2. OBJECTIVE

The most serious problem for paper industry, is fibrous raw material shortage. Forest based raw materials are in short supply and the situation is deteriorating day by day. The country's forest wealth continues to erode, conforming that consumption is exceeding than generation. The short fall problem of forest based raw material for pulp and paper making, can be solved upto some extent by using agricultural residues along with different types of other non wood fibrous raw materials.

Taking into consideration various strategies including man made forest plantation, high yield pulping technologies, full utilization of agricultural residues for pulping, the supply position will still remain far from satisfactory for meeting the set target demand. Hence it will force the industry to look for an alternative i.e., non wood fibrous raw materials, among this category the S. spontaneum Linn is one of the most potentially untapped fibrous raw material for pulp and paper making, which is available abundantly as a result of natural growth in forest and river basins available through-out the year. Therefore the present studies have been centered to utilize this important non wood fibrous raw material. In the present studies of pulping and bleaching characteristics of S. spontaneum Linn, it is chemically analyzed for its various constituents to check its suitability for pulp and paper making followed by extensive studies on pulping, bleaching and evaluation of pulp.

3. PROXIMATE CHEMICAL ANALYSIS

3.1 Raw Material Procurement :

The plant raw material was collected from nearby regions of Saharanpur.

3.2 Raw Material Preparation :

The procured raw material was chopped by grass cutter. The chips were air dried under atmospheric conditions and packed in polythene bags.

3.3 Fiber Morphology :

For morphological studies the plant sample was subjected to a physicochemical maceration with a solution of potassium chlorite($KClO_3$) and concentrated hydrochloric acid (conc. HCl) to separate the individual fibers from each other without damage for removing most of the lignin and other binding materials. The results are reported in Table-1.

3.4 Proximate chemical Analysis :

The air dry chips were disintegrated in the laboratory wood mill. The portion passing through the 40 mesh but retained on a 80 mesh sieve, was utilized for proximate chemical analysis, which was carried out as per standard Tappi procedure. The results are reported in Table-2.

4. EXPERIMENTAL METHODOLOGY

4.1 Soda Pulping Studies :

Soda pulping of S. spontaneum Linn was carried out in WEVERK rotary, electrically heated digester of capacity 0.02 m^3. During the course of pulping, the wood to liquor ratio of 1:5 was maintained by followed the cooking conditions as mentioned in Table-3.

The pulping studies were carried out at different alkali dosage i.e. 6 to 14% (as Na_2o). In second set of experiment, the cooking was done at optimum alkali dose i.e. 12% with 0.1% anthra-quinone (on o.d. raw material basis). At the end of cooking the charge was then blown from the digester.

4.2 Washing and Screening :

The cooked chips were defibered through a refiner. The pulp was screened through a laboratory vibratory flat WEVERK screen of 0.15 mm slots, and washed on a laboratory flat washing system having double fold cloth(300 mesh) placed on the wire mesh, thoroughly with fresh water till the filtrates were colorless then the pulp pad was dewatered and slush dried (3), and then crumbled.

The screened rejects were collected and dried in the oven at 105 ± 2 ^{o}C. The screened pulp yield, rejects and the kappa number were determined. The results are reported in Table-4,5&6.

4.3 Oxygen Pre-Bleaching :

The unbleached soda-AQ pulp having kappa number 21, was pre-bleached with oxygen in a laboratory digester of capacity 0.02 m^3. First the pulp sample was mixed with magnesium sulphate (1%, on o.d. pulp basis) to avoid the cellulose degradation and then with sodium hydroxide (2%, on o.d. pulp basis) and water was added to give pulp concentration of 10% (4). The mixture was placed in the digester which was pressurized by oxygen to give an additional pressure of 5 kg/cm^2 at 45-55°C and heated to the maximum temperature under the conditions mentioned in Table-7.

4.4 Bleaching of Pulp :

The soda-AQ pulp was bleached by using single stage hypochloride bleaching sequence(H-Stage) as well as by multi-stage bleaching sequences viz HH, CEH and CEHH.

The oxygen pre-bleached pulp was bleached by using multi-stage bleaching sequences viz OCEoH, OCEopH, OC/DEoH, OC/DEoD, OC/DEoHD, OC/DEopH, OC/DEopD and OC/DEopHD. Under the conditions mentioned in Table-9, 10 & 11.

Chemical Oxygen Demand(COD) of effluents from each bleaching stage, was determined as per the standard Tappi procedure, the results are reported in Table-13.

4.5 Pulp Evaluation :

Unbeaten pulp sheets were prepared to evaluate the pulp brightness.

The pulp of each bleaching sequence was beaten to a freeness of 40 ± 1 °SR, in a stainless steel PFI mill under standard conditions as per ISO DP 5264 method (3) i.e.

Beating Pressure	-	17.7 N/cm
Relative Speed	-	6.0 m/s
Beating consistency	-	10% on weight basis

Handsheets of 60 GSM were prepared on a standard British Sheet Former and dried on plates in air dryer. These hand sheets were tested for various properties. The pulp evaluation results are reported in Table-14 & 15.

5. RESULTS AND DISCUSSION

5.1 Fiber Morphology :

It could be seen from the Table-1 that the fiber length of S. spontaneum Linn varies from 0.98 to 2.1 mm with an average of 1.6 mm as compared to 0.89 mm (average) in eucalyptus. The fiber width varies from 8 to 24 microns with an average of 16 microns. The above results indicate that the fiber collapses readily into ribbons like shape during sheet formation. These fibers tend to produce dense and uniform sheet with high burst and tensile strength.

5.2 Proximate Chemical Analysis :

The results of proximate chemical analysis as given in Table-2, indicate that total water solubles in S. spontaneum Linn are 10.2% which is towards on higher side. The water and alcohol benzene solubles come under the category of extractives and totally undesirable for pulp and paper making. The lignin content in S. spontaneum Linn is about 16%, It indicates that S. spontaneum Linn requires comparatively low cooking chemicals and shorter cooking cycle. The pentosans content is 19.40% which is towards on higher side. However the holocellulose in S. spontaneum Linn is 76.7% which is towards on higher side. The ash and silica contents in S. spontaneum Linn are 3.6 and i.8% respectively which are slightly higher in comparison to wood. The above results clearly indicate its suitability for pulp and paper making.

5.3 Soda Pulping :

The results of pulping studies as reported in Table-5, indicated that since the raw material is having low lignin content. Therefore the alkali requirement is low. The raw material can be pulped by using alkali doses from 11 to 13% to have pulp with kappa number from 30 to 24 correspondingly. The optimum cooking results were obtained at an alkali dose of 12%, pulp to had a kappa number 26.5 and the screened pulp yield 44% . As the bulk density of raw material is higher so the bath ratio requirement is higher (1:5) which is comparatively high in comparison to wood. It is to be expected that less amount of the material will be loaded per digester, thus the digester yield will be low, This can be compensated to some extent by carrying out more digester blows because the shorter cooking cycle, as a consequence of low H-factor requirement.

5.4 Soda-AQ Pulping :

Further to enhance the rate of delignification and to reduce the kappa number, an optimum dose of Anthra-Quinone (0.1%) was used as a result of which the screened pulp yield increased by 2.1%, while on the other hand the kappa number reduced from 26.5 to 21, thereby showing a net gain in bleaching requirement of pulp.

5.5 Oxygen Pre-Bleaching :

Further the soda-AQ pulp was pre-bleached with oxygen under conditions mentioned in Table-7, and the results are reported in Table-8. These results indicated that as a result of oxygen pre treatment the kappa number reduced from 21 to 8 (62% reduction) at the cost of reduction in pulp yield 44.0 to 38.5% (yield loss=5.5%).

5.6 Bleaching Studies :

The results of bleaching studies as reported in Table-12, indicated that the soda-AQ pulps were bleached by single stage hypo-chlorite bleaching (H-Stage) as well as by multi-stage bleaching sequences viz HH, CEH and CEHH bleaching sequences.

Further the soda-AQ pulp was pre-bleached by oxygen and then further bleached by multi-stage bleaching sequences viz OCEoH, OCEopH, OC/DEoH, OC/DEoD, OC/DEoHD, OC/DEopH, OC/DEopD and OC/DEopHD.

The results of bleaching studies as reported in Table-14, indicated that the brightness level is comparatively low in conventional bleaching sequences as compared to oxygen based multi-stage bleaching sequences. It is evident from Table- 14 that all the pulps show excellent response to bleaching with low bleach requirement in all the multi-stage bleaching sequences based on oxygen pre-bleaching. The brightness of the pulps is about 80+%. The various brightness levels achieved as a result of various multi-stage bleaching sequences, are reported in Table-14. These results clearly indicated that the pulp with maximum brightness level can be obtained by using a multi-stage bleaching sequence OC/DEopHD.

5.7 Pulp Evaluation :

The bleached pulps were beaten in a stainless steel PFI mill upto a freeness level of 40 ± 1 °SR, the initial freeness levels of the various bleached pulps are indicated in Table-14.

The standard sheet of 60 GSM were evaluated for tensile, tear, burst and folding strengths. The pulp evaluation data is being reported in Table-15. These results indicated that there is not much variation in physical properties of pulps bleached by oxygen based multi-stage bleaching sequences.

These pulps can be utilized for making paper with high strength level along with long fiber stock (5).

6. SUMMARY AND CONCLUSION

From the present studies the following conclusions may be drawn:

(1.) The results of the present investigation indicated that the S. spontaneum Linn is a fast growing non wood fibrous plant available abundantly throughout the year, therefore it seems to be a potential non wood fibrous plant as the raw material for small scale industries.

(2.) The pulping chemical requirement is low with mild cooking conditions due to low lignin content and comparatively an open structure fiber.

(3.) The pulp showed good response toward oxygen pre-bleaching followed by bleaching with multi-stage bleaching sequences. The bleach chemical requirements were low in comparison of bleaching of wood pulps.

(4.) The pulps also showed good response towards beating as they having comparatively more hemicellulose content, thus requiring low energy for beating.

(5.) The S. spontaneum Linn is having comparatively short fiber, therefore blending with long fibered raw material/pulp, is essential to run it on high speed paper machine as well as to improve the tear and opacity values. It may be necessary to add high opacifying agents for the manufacture of quality paper.

(6.) The S. spontaneum Linn fibers have thin cell wall with wide lumen and possess good flexibility, such fiber collapse well to form ribbon like structure providing more bonding area among the fibers.

(7.) The results of the present study points out the promising potential of S. spontaneum Linn as an important source of fiber for pulp and paper making for tropical countries like India with high population density and limited land resources.

7. RECOMMENDATIONS

Due to the shortage of time during the present course of investigation, the detailed studies on pulping using different pulping parameters followed by detail bleaching studies could not be conducted.

The results of the present investigations indicated that S. spontaneum Linn may be one of the important non wood fibrous raw material for small scale pulp and paper industries. In our country therefore it is recommended that prior to its full utilization for pulp and paper making, the detailed investigation on pulping and bleaching, should be carried out.

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APPENDIX - I

TABLE- 1: FIBER MORPHOLOGY OF SACCHARUM SPONTANEUM LINN

Fiber Diameter, (μ)	16 (average)
	8 - 24 (min.-max.)
Fiber Length, (mm)	1.52 (average)
	0.98-2.10 (min.-max.)

TABLE- 2: PROXIMATE CHEMICAL ANALYSIS OF SACCHARUM SPONTANEUM LINN

Cold Water Solubility, (%)	7.8
Hot Water Solubility, (%)	10.2
Lignin, (%)	16.0
Pentosans, (%)	19.4
Holocellulose, (%)	76.7
Alphacellulose, (%)	38.0
Alcohol Benzene, (%)	5.8
Extractives, (%)	4.8
Ash, (%)	3.6
Silica, (%)	1.8

TABLE- 3: COOKING CONDITIONS IN SODA PULPING

Alkali Dose	6 - 14%
Bath Ratio	1:5
Cooking Temp., (°C)	155
Time to 105 °C Temp., (min.)	45
Time at 105 °C Temp., (min.)	5
Time to 155 °C Temp., (min.)	40
Time at 155 °C Temp., (min.)	60

TABLE- 4: RESULTS OF SODA COOKING USING ALKALI DOSES FROM 6 TO 14%.

S.No.	Alkali Dose(%)	Kappa Number	Total Yield(%)	Rejects (%)	Screened Yield(%)	Residual Alkali(%)
1.	6	40.0	48.7	10.4	38.3	0.08
2.	8	38.3	46.3	5.8	40.5	0.51
3.	10	32.5	46.0	2.6	43.4	0.93
4.	12	25.6	45.5	1.5	44.0	1.40
5.	14	17.0	41.1	0.9	40.2	1.81

TABLE- 5: RESULTS OF SODA COOKING USING ALKALI DOSES FROM 11 TO 13%.

S.NO.	Alkali Dose(%)	Kappa Number	Total Yield(%)	Rejects (%)	Screened Yield(%)	Residual Alkali(%)
1.	11.0	30.6	45.3	2.5	42.8	1.180
2.	11.5	28.4	45.7	2.1	43.6	1.280
3.	12.0	26.5	45.7	1.8	43.9	1.390
4.	12.5	26.3	44.7	1.3	43.4	1.479
5.	13.5	24.6	42.3	1.1	41.2	1.590

TABLE- 6: RESULTS OF CONVENTIONAL SODA COOKING AND SODA-AQ COOKING UNDER SAME ALKALI CHARGE.

Pulping	Alkali Dose(%)	Kappa Number	Total Yield(%)	Rejects (%)	Screened Yield(%)
Soda (conventional)	12	26.5	45.7	1.8	43.9
Soda (AQ)	12	21.0	46.9	0.9	46.0

TABLE- 7: PROCESS CONDITIONS FOR OXYGEN PRE-BLEACHING.

Alkali charge, (%) (o.d. pulp basis)	2.0
$MgSo_4$ Charge, (% (o.d. pulp basis)	1.0
Consistency, (%)	10
Oxygen Pressure, kg/cm^2 (additional)	5
Temp. at which Oxygen Charged, (^oC)	45-55
Maximum Temp., (^oC)	105 ± 2
Time to 105 ^oC Temp., (min.)	75
Time at 105 ^oC Temp., (min.)	30

TABLE- 8: RESULTS OF OXYGEN PRE-BLEACHING.

Kappa Number of Unbleached pulp	21
Unbleached Pulp Yield, (%) (on o.d. raw material basis)	44
Kappa Number of Oxygen Pre-Bleached Pulp	8
Oxygen Pre-Bleached Pulp Yield, (%) (on o.d. raw material basis)	38:5
Yield Loss, (%) (on o.d. raw material basis)	5.5
Kappa Number Reduction, (%) (initial Kappa Number basis)	62

TABLE- 9: CONDITIONS FOR BLEACHING OF PULP AT DIFFERENT STAGES WITH CHLORINE OR CHLORINE COMPOUNDS

STAGE	C	C/D	H	H	H	D
Consistency, (%)	2.5	10	10	10	10	7
Temp., (^{O}C)	ambient	70	45	45	45	70
Time, (min.)	60	90	120	60	120	180
pH	2-3	3-4	10.5-11.0	10.5-11.0	10.5-11.0	4-4.5
Final pH	-	3	9.5-10.0	9.5-10.0	9.5-10.0	3

TABLE-10: CONDITIONS FOR BLEACHING OF PULP AT DIFFERENT STAGES WITH OXYGEN AND HYDROGEN PEROXIDE

STAGE	O	Eo	Eop
Naoh, % on o.d. pulp	2	0.9	0.9
$MgSo_4$, % on o.d. pulp	1	-	-
H_2O_2, % on o.d. pulp	-	-	0.25
EDTA, % On o.d. pulp	-	-	0.5
Oxygen Pressure, kg/cm^2 (additional)	5	2	2
Consistency, (%)	10	10	10
Temp., (^{O}C)	105 ± 2	70	70
Time to Temp., (min.)	75	-	-
Time at Temp., (min.)	30	60	60
pH	11 ± 1	10	10

TABLE-11: CONDITIONS FOR BLEACHING OF PULP AT E-STAGE

STAGE	E
Consistency, (%)	10
Temp., (^{O}C)	70
Time, (min.)	60
pH	11
Final pH	10.0-10.5

TABLE-12; BLEACHED PULP YIELD OF EACH SEQUENCE

S.No.	Sequence	Yield During Bleaching (on o.d. Soda-AQ pulp basis)	Yield Over all (on o.d. raw mat. basis)
1.	H	79.1	36.4
2.	HH	78.2	36.0
3.	CEH	67.8	31.2
4.	CEHH	66.7	30.7
5.	OCEoH	62.5	28.8
6.	OCEopH	64.2	29.5
7.	OC/DEoH	69.7	32.1
8.	OC/DEoD	68.2	31.4
9.	OC/DEoHD	68.0	31.3
10.	OC/DEopH	75.0	34.5
11.	OC/DEopD	71.0	32.7
12.	OC/DEopHD	68.5	31.5

TABLE-13: CHEMICAL OXYGEN DEMAND(COD) OF EFFLUENT FROM EACH BLEACHING SEQUENCE

Details	COD
H SEQUENCE	
H-Stage	571
HH SEQUENCE	
H -Stage	-
H -Stage	892
CEH SEQUENCE	
C-Stage	229
E-Stage	1219
H-Stage	448
CEHH SEQUENCE	
CE-Stages as above	
H -Stage	-
H -Stage	476
OCEoH SEQUENCE	
O-Stage	4665
C-Stage	228
Eo-Stage	876
H-Stage	457
OCEopH SEQUENCE	
OC-Stages as above	
Eop-Stage	895
H-Stage	331
OC/DEoH SEQUENCE	
O-Stage as above	
C/D-Stage	376
Eo-Stage	501
H-Stage	260
OC/DEoD SEQUENCE	
OC/DEo-Stages as above	
D-Stage	341

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contd.

Details	COD
OC/DEoHD SEQUENCE	
OC/DEo-Stages as above	
H-Stage	323
D-Stage	430
OC/DEopH SEQUENCE	
OC/D-Stages as above	
Eop-Stage	1656
H-Stage	385
OC/DEopD SEQUENCE	
OC/DEop-Stages as above	
D-Stage	269
OC/DEopHD SEQUENCE	
OC/DEop-Stages as above	
H-Stage	309
D-Stage	874

TABLE-14: BLEACHED PULP PROPERTIES OF SACCHARUM SPONTANEUM LINN

S.No.	Sequence	Pulp Brightness	Initial °SR	Final °SR
1.	H	62.9	13.5	40
2.	HH	64.6	12.5	40
3.	CEH	77.3	13.5	40
4.	CEHH	78.1	15.0	40
5.	OCEoH	81.2	14.0	40
6.	OCEopH	82.5	12.5	40
7.	OC/DEoH	82.8	13.0	40
8.	OC/DEoD	83.2	12.0	40
9.	OC/DEoHD	84.1	14.5	40
10.	OC/DEopH	83.9	12.5	40
11.	OC/DEopD	84.5	13.0	40
12.	OC/DEopHD	85.6	13.0	40

TABLE-15: PAPER PROPERTIES OF SACCHARUM SPONTANEUM LINN WITHOUT ANY ADDITIVE

S.No.	Sequence	Brightness	Opacity	Breaking Length (meter)	Tear Factor	Burst Factor	Folding
1.	H	61.7	82.06	7450	81.67	60.00	132
2.	HH	63.2	81.32	7330	73.33	56.67	125
3.	CEH	74.2	74.19	7000	66.67	51.67	52
4.	CEHH	74.5	73.62	6890	71.67	50.00	65
5.	OCEoH	78.0	75.84	7100	76.67	48.33	67
6.	OCEopH	79.4	72.47	7000	73.33	46.67	60
7.	OC/DEoH	79.8	74.01	7200	70.00	56.67	89
8.	OC/DEoD	80.1	74.67	6890	76.67	48.33	90
9.	OC/DEoHD	81.3	74.03	6330	76.67	50.00	65
10.	OC/DEopH	80.9	71.28	6890	60.00	48.33	81
11.	OC/DEopD	81.8	72.77	6550	70.00	46.67	82
12.	OC/DEopHD	82.9	73.71	5440	66.67	35.00	38

FIG.-1. ALKALI DOSE Vs SCREENED YIELD, KAPPA NUMBER AND REJECTS