SODA AND SODA-ANTHRAQUINONE PULPING OF *ALBIZIA LEBBECK* FROM SUDAN

Tarig Osman Khider[1] , Osman Taha Elzaki[2], and Safaa Hassan Omer[3]

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Abstract

Wood samples of *Albizia lebbeck* (L) Benth. from Khartoum State in Sudan were studied to determine their suitability for pulp and papermaking. The physical properties, anatomical features, fiber dimensions, morphological indices, and chemical composition were evaluated. Pulping was carried out using soda and soda-anthraquinone processes. Paper hand sheets were formed and the pulp and papermaking characteristics were studied. The basic wood density for *A. lebbeck* (508 kg/m^3) and the average bark-to-wood ratio both by mass (10.5%) and by volume (8.8%) were in the normal range for commercial hardwoods. The average fiber dimensions and corresponding morphological indices indicated the potential of Albizia wood for making paper with good strength properties. The chemical composition was similar to that of the tropical hardwoods, with a lower lignin and higher pentosan content. The wood when pulped with a 17-22% alkali charge (as Na_2O) for 120 min at 170^{o}C gave bleachable Kappa values. The addition of 0.10% anthraquinone to the pulping liquor reduced the active alkali consumption by 2-4% and increased the pulp yield.

Keywords: ***Albizia lebbeck*, fiber dimensions, morphological indices, pulp characteristics, papermaking**

Introduction

The demand for paper products in Sudan has grown rapidly with the continuous development in the country. Wood as a raw material for the pulp and papermaking industry has offered precious services to mankind and has decisively contributed to development and civilization. Sudan is rich in different hardwood species which could be good sources of pulp production (Khristova *et al*., 1990).The Labakh or Dign elbasha (*Albizia lebbeck* L. Benth.) is a deciduous tree belonging to the family Fabaceae and subfamily Mimosoideae (Hegde and Relwani, 1988; Kennedy *et al*., 2002). It is native to tropical and subtropical regions of Asia and Africa. This fast-growing tree was introduced into Sudan as an ornamental and plantation tree. Therefore, it was of interest to find out how the wood of Sudanese *Albizia lebbeck* responds to pulping and papermaking.

[1] *College of Applied and Industrial Sciences, University of Bahri, Khartoum, Sudan. E-mail: tkhider@yahoo.com*
[2] *Institute for Technological Research, NCR, P.O. Box 2404, Khartoum, Sudan. E-mail: osmantaha2007@yahoo.com*
[3] *College of Natural Resources, University of Bahri, Khartoum, Sudan. E-mail: safaho@yahoo.com*

This study is aimed at a rational use of *Albizia lebbeck* wood as a source of fibers for pulp and papermaking in Sudan.

Materials and Methods

Five logs from 5-year-old *Albizia lebbeck* trees grown in Khartoum State were randomly selected according to TAPPI (2002) standards. The bark-to-wood ratio was determined as a proportion of the whole tree (including bark) both by volume and by mass. The basic density was measured as the oven-dry mass/green volume of the test specimens according to British Standards (1957). Fibers were macerated using 30% hydrogen peroxide and glacial acetic acid (1:1). Fiber measurements were carried out microscopically at ×100 and ×300 magnifications (Horn, 1978). Morphological indices including the coefficient of cell rigidity, Runkel ratio, flexibility coefficient, and felting ratio, were determined. Chips for pulping trials were manually prepared. A composite sample of chips was ground in a star mill and 40 by 60 mesh fractions were used for the chemical analysis. The chemical analysis was carried out in accordance with the standard methods of TAPPI (2002) except for the cellulose which was measured according to the Kurshner and Hoffer method (Obolenskaya *et al.*,1965). This included the content of the extraneous materials, ash, silica, cellulose, holocellulose, Pentosan, and lignin. Pulping was carried out in a 10-litre capacity rotating autoclave at a maximum temperature of 170°C for 2 h. The wood chips were cooked at different chemical charges of soda between 17-20% and15.5-19.4% (as Na_2O) for soda-anthraquinone (SAQ). The anthraquinone (AQ) addition will reduce the active alkali consumption, increase the degree of delignification, and increase the yield. A wood to liquor ratio of 1:4 was used (Holton, 1977).

Beating was carried out using a Valley-type beater. Pulps were evaluated by forming hand sheets of about 60 $g.m^{-2}$ prepared using a Rapid- Kothen sheet forming machine. The formed sheets were tested in accordance with TAPPI (2002) standards.

Results and Discussion

The average basic density of *Albizia lebbeck* was in the normal range of commercial pulp woods (Casey, 1980); at 508 kg m^{-3} (Table 1) this means it has a normal liquor- to wood ratio, normal impregnation and cooking periods, and a good pulp yield by digester volume. The bark- to wood ratio, both by volume 8.8% and by mass 10.5%, is in the lower range of commercial pulp woods. The average fibre length for *Albizia lebbeck* (Table 2) was in the range of tropical hardwoods at 0.98 mm, and the fibre width was medium in the hardwoods range (10-35 µm). The mediumthick wall was reflected in its density, a property that affects pulp strength properties. The lumen width was wide (15.68 µm) and so the fibres should have collapsed more easily upon beating, resulting in improved interfibre bonding in the pulp, and producing a compact and low- porosity paper sheet. This is supported further by the morphological indices obtained (Table 2). The flexibility index was 61.25, which positively correlated to the tensile strength, burst factor, and folding endurance using the Kohler-Molin method. However the felting power was 38.4 which is better than that of eucalyptus which was 46-73 (Khristova *et al.*, 2006). The Runkel ratio of 0.63 indicated good suitability for pulping .The wall fraction was 19.38%.

The ash content was in the normal range for tropical hardwoods at 1.77% (Table 3), while a negligible amount of silica implied that there were no chemical recovery problems. The good

Table 1. Physical properties of *Albizia lebbeck* wood from central Sudan

Physical property	
Basic density (kg/m^3)	508.0
Bark-to-wood ratio by mass (%)	10.5
Bark-to-wood ratio by volume (%)	08.8

cellulose measured by the Kurshner and Hoffer method of 46.25% indicated a good pulp yield was to be expected. The cold and hot water extractives were 6.88 and 7.77%, respectively, while the organic solvents extractives were 2.38 and 8.64% for alcohol cyclo-hexane and alcohol, respectively. As well the 1% NaOH solubles at 15.64% were rather normal to high due to the presence of many soluble polysaccharides and phenolic compounds and thus needed a higher alkali charge. This is further supported by the lignin content (25.14%) and pentosan content (18.60%) which were a bit higher compared with the normal range for tropical deciduous hardwoods (according to Hale's, (1959) classification).

The *Albizia lebbeck* was pulped with both soda and SAQ methods for comparison. The SAQ method, when compared with the conventional sulphate process, gives a similar yield of pulp with good properties but with a less complex recovery of chemicals and the elimination of the environmental damage caused by sulphur emissions (Holton, 1977). This process is also considered to have potential for small, economically viable mills (Palmer *et al*., 1989).

The soda (soda1, soda2, and soda3) and SAQ (SAQ4, SAQ5, and SAQ6) optimal pulping trials of *Albizia lebbeck* (Tables 4 and 5) with different active alkali levels resulted in acceptable to good screened yields of bleachable pulp (Kappa numbers 16-27 for soda pulps) and good to satisfactory screened yields. The promising bleachable Kappa numbers (13- 18) of SAQ pulps, supported by higher yields, could be attributed to the preservation of polysaccharides by the AQ. The AQ addition reduced the active alkali consumption by 1-2%, increased the degree of delignification, and increased the yield by 2-4%. Furthermore, it improved the strength properties of the pulp (Table 6). Hence the strength properties of SAQ pulps were much

Table 2. Fiber dimensions and morphological indices for *Albizia lebbeck* from central Sudan

Fiber dimensions		sd
Av. fiber length (mm)	0.983	0.086
Av. Fiber Diameter (μm)	25.60	0.334
Lumen diameter (μm)	15.68	0.307
Cell wall thickness (μm)	4.96	0.309
Morphological indices		
Flexibility coefficient (%)	61.25	
Wall fraction (%)	19.38	
Felting power	38.40	
Runkel ratio	0.63	

Table 3. Chemical Composition of *Albizia lebbeck* wood from central Sudan

Chemical composition	
Ash content (%)	01.77
Silica content (%)	00.06
Cold water solubility (%)	06.88
Hot water solubility (%)	07.77
Alcohol solubility (%)	08.64
Alcohol cyclohexane (%)	02.38
1% Sodium hydroxide (%)	15.64
Holocellulose (%)	78.60
Pentosan (%)	18.60
Cellulose, Kushner -Hoffer (%)	46.25
Acid insoluble lignin %	25.14
Cellulose / lignin ratio	01.80

Table 4. Pulping conditions and unbleached pulp evaluation for soda pulping of *Albizia lebbeck* from central Sudan

Pulping conditions	Soda1	Soda2	Soda3
Active alkali as Na_2O on oven-dry wood base (%)	17	18.6	20
Liquor / wood ratio	4 : 1	4 : 1	4 : 1
AQ on oven-dry wood base (%)	0	0	0
Time to reach maximum temperature.(min)	90	90	90
Pulping Maximum temperature (°C)	170	170	170
Time at max. temperature (min)	120	120	120
Total yield on oven-dry wood base (%)	45.10	44.19	42.13
Screened yield on oven-dry wood base (%)	44.29	43.54	41.95
Rejects (%)	0.81	0.65	0.18
Kappa number	27.43	22.75	16.61
Viscosity	746	785	769
Brightness	24.10	27.20	30.90
pH	12.72	13.06	13.27
Residual active alkali	4.46	9.92	10.04
Total solids	12.93	14.05	14.96

Table 5. Pulping conditions and unbleached pulp evaluation for SAQ pulping of *Albizia lebbeck* from central Sudan

Pulping conditions	SAQ4	SAQ5	SAQ6
Active alkali as Na_2O on oven-dry wood base (%)	15.5	18	19.4
Liquor / wood ratio	4 : 1	4 : 1	4 : 1
AQ on oven-dry wood base (%)	0.10	0.10	0.10
Time to reach maximum temperature. (min)	90	90	90
Pulping Maximum temperature (°C)	170	170	170
Time at max. temp. (min)	120	120	120
Total yield on oven-dry wood base (%)	48.73	47.39	46.29
Screened yield on oven-dry wood base (%)	48.09	47.17	45.42
Rejects (%)	0.64	0.22	0.04
Kappa number	17.32	14.02	13.58
Viscosity	796	751	693
Brightness	28.90	31.8	32.9
pH	12.91	13.09	13.19
Residual active alkali	4.96	7.56	8.93
Total solids	13.89	14.58	14.64

Table 6. Unbleached pulp hand sheets evaluation at different beating degrees for *Albizia lebbeck* from central Sudan

Pulping process	Soda Soda2				SAQ SAQ6			
Beating degree (SR)	18	30	34	41	17	27	34	40
Apparent density (g/cm^3)	0 .56	0.73	0.78	0.84	0.72	0.77	0.82	0.86
Tensile index, (Nm/g)	30	53	63	69	52	59	62	68
Burst index, ($kPam^2/g$)	1.30	3.30	4.30	5.20	2.96	4.33	4.72	5.18
Tear index, (mNm^2/g)	5.80	10.6	10.4	9.10	9.50	10.0	10.6	9.95
Folding Kohler (log)	0.80	2.10	2.30	2.60	1.99	2.49	2.90	2.92
Opacity (%)	99.7	99.7	99.5	99.2	98.9	98.6	98.60	98.3
Kappa number	22.57				13.58			
ISO brightness	27.20				32.90			

higher compared with the soda pulps' remarkable bonding properties (the tensile and burst indices). On the other hand the tear index was more or less similar for the beating degrees (30 -40).

Conclusions

From the above results the following conclusions could be drawn out: The physical and anatomical properties of *Albizia* lebbeck wood have shown that it could be a good material for pulp production without serious problems for liquor penetration. Bleaching of the produced pulp will be easy due to lower amounts of mineral matter in the wood.

The addition of 0.10% AQ to the pulping liquor reduced the alkali consumption and increased the pulp yield. The SAQ process gave better results than the soda process.

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