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Soda Anthraquinone Pulping of Sudanese *Maerua crassifolia* (Sarah) Wood

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Abstract: This work aimed to determine the applicability of *Maerua crassifolia* Sarah wood for pulping with soda with or without anthraquinone. The availability of this raw material with minor uses can be attractive to produce pulp. Physical properties of wood, fiber dimension, morphological indices, chemical constituents, pulp yields and pulp strengths were determined. Three trials were carried out including soda and soda anthraquinone cooking. The screened yields were range between 38.3 - 47.5%, were promising ones, negligible amounts of rejects and bleachable Kappa number, the strength properties of pulps were acceptable to good specifically tensile strength, breaking length and burst. Although the fibers of Sarah were short but were flexible and produce good pulps. The chemical components of Sarah showed comparatively high ash, low extractives, and good cellulose content. The lignin content was relatively high 23.6%. Both basic and green densities were moderately high and suit the commercial pulp woods. The bark to wood ratios with volume and mass were low reducing the cost of transportation, handling and separation of bark from wood.

Key words: *Maerua crassifolia* · Sarah · Chemical Components · Fiber Dimension · Soda Pulping · Strength Properties

INTRODUCTION

Looking for new raw materials suitable for production of pulp and paper industry with minimal cost and application of environmentally friendly cooking methods is core of attention for most of the researchers of this field [1-7]. Soda with anthraquinone cooking is most method suits the non woody plants, agricultural residues and hard wood species, due to its low cost and easy applicability for small scale industry in developing countries [8-12]. The combination of introducing new raw materials with high availability, easy handling, pretreating and applicable pulping method such as soda anthraquinone will attracts investors to introduce pulp and paper industry in remote areas in Africa and Asia leading to improve economic conditions of rural people [13-15]. Sudan is one of developing countries considered as virgin land, thus there was no truly pulp and paper production, although all the basic factors to establish this industry are available as water, diversity of raw material and energy [16, 17].

Maerua crassifolia, family *Capparaceae* with local name Sarah, Arabic name Maure, distributed through African Sahara and sub-Sahara from west Africa Senegal and Mauritania, Mali, Niger, Nigeria, Egypt downwards to Sudan and east to Somalia and south to Tanzania. In Asia Sarah distributed through most of Arabian Sahara including Israel in west until Pakistan in east [18-20]. *Maerua crassifolia* is small tree resistant to drought ever green through the dry seasons [21]. Local healers use its leaves for treatment of aliments, it used as antidiarrheal and antipyretic and gastrointestinal activities [22],

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antimalarial agents [23, 24] and has nutritional value [25], to add value for Sarah wood plus charcoal and firewood, cooking for production pulp and paper will be rational.

The objective of present study is to investigate the suitability of *Maerua crassifolia* Sarah for pulping with soda with addition of anthraquinone, determination of physical properties, fiber morphology and chemical constituents of Sarah wood.

MATERIALS AND METHODS

Four trees of *Maerua crassifolia* Sarah seven years old, were felled and cleaned from debris, the selection of these trees was done randomly according to TAPPI standards [26] from area near Alobeid,, north Kordofan characterized by sandy soil and low annual rains. The small logs were cut into small discs and transported by bus to Khartoum (National Centre for Research) in February 2018. The discs were chipped manually, chips were left to dry by air according to TAPPI standard (T 257-cm- 02), stored in plastic bags for further analysis. Different parts of the *Maerua crassifolia* Sarah tree as leaves, flowers and bark were brought for identification and authentication by taxonomists of Medicinal and Aromatic Plants Research Institute National Center for Research, Sudan and referenced in Figure 1.

The bark-to-wood ratios by volume and mass were measured, basic and green densities were determined according to British Standards [27] and (TAPPI-258 Om-02). Fiber dimension evaluation as shown in Figure 2, was carried out after maceration with a mixture of 30% hydrogen peroxide and acetic acid (1:1), measured microscopically at 300x and 400x magnifications of 25 fibers after staining with aqueous safranin according to (TAPPI-232cm-01), morphological indices were calculated.

One kilogram of dried chips prepared for cooking was grinded in star mill and passed through mesh fraction of 40X60 and used for determination of chemical constituents of wood. The preparation was done according to (TAPPI-264-cm-97), testing for moisture (TAPPI-210cm-93), ash (TAPPI-212) hot water soluble (TAPPI-T- 207), solvent extractives (TAPPI 204 cm-97), 1% NaOH (T 212 om-98) lignin (TAPPI-222) cellulose Kurshner and Hoffer method [28].

After meetings and negotiations with research team, it was decided the cooking conditions as mentioned in Table 1 and steps of preparing of chips and pulps were shown in Figure 3.

Cooking was carried out in 7l electrically heated digester with forced liquor circulation, all the parameters were kept constant except the active alkali charge and addition of anthraquinone were the two variable parameters, thus maximum temperature was 165°C, liquor to wood ratio was 4, time to maximum temperature was 60 min and time at maximum temperature was two hours. Three cooking trials were done varied in alkali charge as (NaOH, 15-17% on oven dry weight of Sarah wood) as it is well known the most effective parameter during cooking is alkali charge. The pulps were washed after cooking to remove the black liquor, screened to determine the rejects and screened yield on oven dry basis, disintegrator was used to separate the fibers at 1200 rpm for 30 min. the pulps of the three trials were treated with Valley beater at intervals zero, 5 and 10 min to investigate the quality of beating on studied pulps according to (TAPPI200-sp-01). The Kappa number was determined according to (TAPPI-236 om-99), physical testing of pulp sheets (TAPPI-220-sp-01), conditioning of testing atmosphere (TAPPI-402-sp-98), grammage and apparent density (TAPPI T 410 om-98), burst strength (TAPPI403om-97), tensile and breaking length (TAPP-404-cm-92).

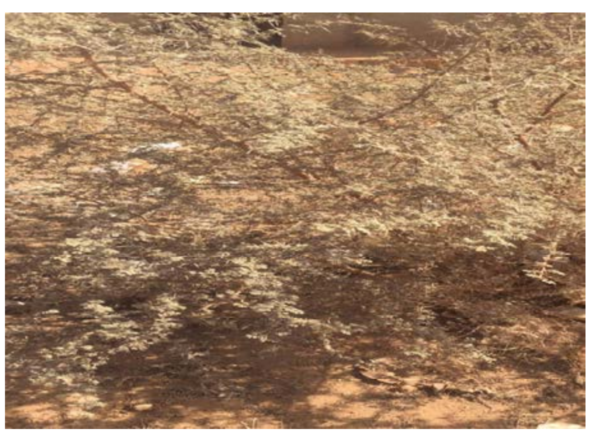


Fig. 1: General features of *Maerua crassifolia* (Sarah)

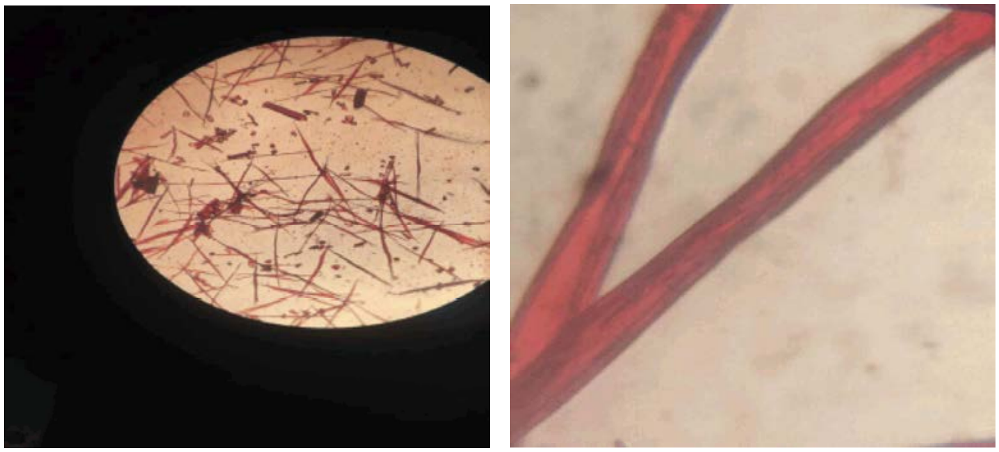
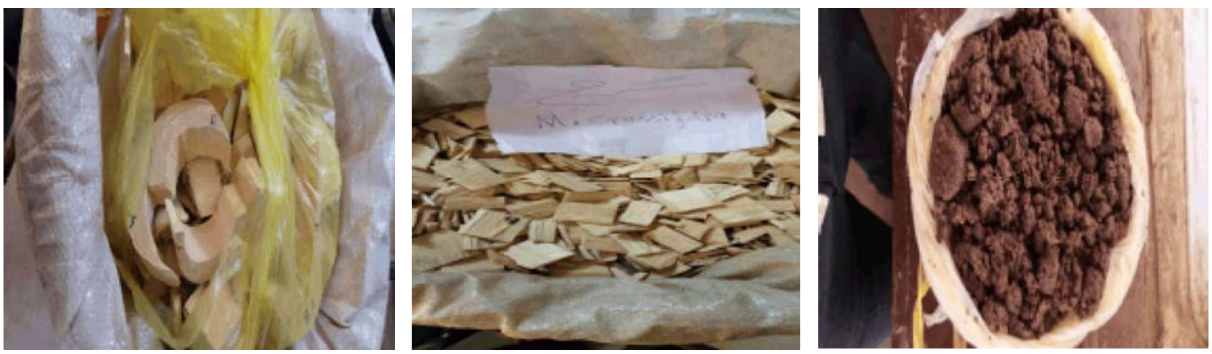


Fig. 2: Fiber structure of *Maerua crassifolia* (Sarah) wood under different magnification of optical microscope



A. Wood B. Chips C. Pulp

Fig 3. Steps of cooking of *Maerua crassifolia* (Sarah) with Soda-AQ pulping

Table 1: Pulping Conditions of *Maerua crassifolia* (Sarah)

Cooking conditions	Soda	Soda-AQ 1	Soda-AQ2
Active alkali charge as NaOH %	17	17	15
Anthraquinone, %	0	0.5	0.5
Liquor to Meru (Sarah) wood ratio	4	4	4
Maximum temperature, °C	165	165	165
Time to maximum temperature, min	60	60	60
Time at maximum temperature, min	120	120	120

RESULTS AND DISCUSSION

The wood of *Maerua crassifolia* (Sarah) from seven years old were examined for physical properties (Table 2) as moisture content was 9.3% suited the dry conditions of Sudan, with similar basic density and green density were 530 and 537 Kg m^{-3} respectively, moderate to high density and within the commercial pulp wood according to Bin and Casey classification [29, 30]. High density positively correlated with wall thickness and pulp yield, thus *Maerua crassifolia* (Sarah) wood, could expected to produce good yield under normal cooking conditions. The presence of the bark during cooking affect negatively in pulp quality and yield, bark to wood ratio of *Maerua crassifolia* (Sarah) were low on basis of volume or mass 3.93 and 5.31% respectively, indicating low cost of handling, removing of bark and transportation.

When comparing the fiber dimensions of *Maerua crassifolia* (Sarah) wood with those of *Ziziphus spina-christi* [31]. Sarah fibers were shorter, narrower fiber diameter, wider lumen diameter and thin wall thickness (Table 3). The short fiber length of Sarah was (0.70 mm) typical for tropical hard wood, fiber length is directly related to tear strength while the flexibility influences the burst and tensile strengths. The thin wall of Sarah (2.50 µm) and comparatively wide lumen (10.12 µm)

Table 2: Physical properties of *Maerua crassifolia* (Sarah) wood

Physical properties, %	*Maerua crassifolia* (Sarah) wood
Average age of tree (years)	7
Moisture content	9.33
Basic density (oven dry) Kg m^{-3}	530
Green density Kg m^{-3}	537
Bark to wood ratio by volume	3.93
Bark to wood ratio by mass	5.31

Table 3: Fiber dimensions and morphological indices of *Maerua crassifolia* (Sarah) compared to fibers of *Ziziphus spina-christi*

Hardwood	*Maerua crassifolia* (Sarah)	*Ziziphus spina-christi* [31]
Fiber dimension		
Average fiber length, mm	0.70	0.88
Average fiber diameter, µm	15.12	17.40
Average lumen diameter, µm	10.12	6.20
Average wall thickness, µm	2.50	5.60
Morphological indices		
Runkel ratio	0.49	0.56
Flexibility coefficient, %	66.93	35.63
Wall fraction, %	16.53	31.64
Felting power (slenderness ratio)	46.30	44.77

Table 4: Chemical components of *Maerua crassifolia* (Sarah) from north Kordofan state, compared to those of *Ziziphus spina-christi*

Chemical composition, %	*Maerua* crassifolia (Sarah)	*Ziziphus spina-christi*
Ash	4.1	1.0
Solubility in		
Hot water	5.1	7.8
Cold water	7.6	3.1
Ethanol: Cyclohexane (1:2)	1.2	3.8
1% NaOH	14.7	22.4
Kurchner-Hoffer cellulose	44.1	48.5
Lignin	23.6	19.1
Cellulose to lignin ratio	1.8	2.5

indicating the fiber of Sarah will collapse easily produce good surface contact between adjacent fibers during beating. The wall fraction was 16.53% less than that of *Ziziphus spina-christi* (31.64%), it seemed the fibers of Sarah (66. 93%) more flexible than those of *Ziziphus spina-christi* (35.63%), and both Runkel ratios were less than one unit indicating their suitability for pulp and paper production.

The ash content of *Maerua crassifolia* (Sarah) wood (4.1%) was high compared to that of *Ziziphus spina-christi* (1.0%) as mentioned in Table 4, reflecting some pitch problems, and difficulty during recovery of chemicals. The hot water extractives (5.1%), ethanol: Cyclohexane (1:2) (1.2%), 1% NaOH (14.7%) were all less than the correspondents of *Ziziphus spina-christi* although the cold water of Sarah (7.6%) was higher than that of *Ziziphus spina-christi*. the overall Sarah soluble materials were rather high due to the presence of many soluble polysaccharides and phenolic compounds. The moderate Kurchner-Hoffer cellulose (44.1%) indicated reasonable pulp yield could be expected, however the relatively high lignin content (23.6%) may resulted in more alkali charge to be applied to dissolve the lignin. The cellulose to lignin ratio was less than two (1.8%) predicating comparatively aggressive cooking conditions may be needed (high alkali charge).

Fig. 4: Prepared hand sheets from pulp of *Maerua crassifolia* (Sarah) wood for physical properties

A lot of literature documented the positive effect of anthraquinone on soda pulping, increasing yield, improving the pulp properties, reducing the chemical consumption, accelerating the rate of delignification and reducing air pollution [32-40]. The strength properties and pulping yields of three trials of cooking with and without anthraquinone were shown in Table 5 and steps of preparation chips and pulping. The pulping of *Maerua crassifolia* wood with soda- AQ was attractive, when alkali charge as NaoH 15% the screened yield was very good 47.5% with negligible rejects and bleachable Kappa number 19.7. When soda cooking was done without AQ with 17% alkali charge as NaOH, the screened yield reduced to 38.3% with large amount of rejects reach to 12% with similar Kappa number, during application of the same amount of chemical 17% as NaOH the screened yield was potentially increased to 44.4 with astonishing bleachable Kappa number 17.7.

The strength properties of the three trials were increasing with increasing of beating time, gave promising breaking length, burst strength and tensile index especially for soda –AQ pulps, the apparent density was kept more or less similar during beating process. One of drawbacks of soda cooking is imparting darkening during sheet formation due to accumulation of condensed and degraded lignin, which obviously showed in the initial brightness of sheet formed during cooking of the three trials (Figure 4).

Table 5: Pulping results and strength properties of hand-sheets obtained from *Maerua crassifolia* (Sarah) wood

Pulping process		17% Soda	17% Soda-AQ1	15% Soda-AQ2
Puling results				
Screened yield, %		38.3	44.4	47.5
Rejects, %		12.0	0.3	0.2
Total yield, %		50.3	44.7	47.7
Kappa number		19.4	17.7	19.7
ISO brightness, %		22	20	20
Strength properties				
Beating time,	min			
Specific volume, $cm^3 g^{-1}$	0	6.5	6.5	6.7
	5	6.4	6.5	5.9
	10	6.7	5.5	5.7
Apparent density, g cm^3	0	0.15	0.15	0.15
	5	0.15	0.15	0.16
	10	0.15	0.18	0.17
Breaking length, Km	0	3.1	3.1	3.2
	5	3.7	3.5	3.7
	10	4.0	4.2	4.6
Tensile index, m N $m^2 g^{-1}$	0	30.6	30.7	32.3
	5	36.1	39.8	41.3
	10	39.6	41.4	45.3
Burst index, K Pa $m^2 g^{-1}$	0	0.9	0.9	1.2
	5	1.3	1.4	1.6
	10	1.5	2.0	2.2

CONCLUSION

The pulping of *Maerua crassifolia* Sarah wood with soda anthraquinone, look attractive due to availability of the raw materials, easy handling and low cost of application, suited the conditions of developing countries like Sudan. The yield of *Maerua crassifolia* Sarah wood is good especially when soda-AQ used. However the short fibers of *Maerua crassifolia* Sarah wood can be compensated with blending of pulp from long fiber non woody plant *Oxytenanthera abyssinica* (Bamboo) which also available in Sudan in large amount.

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