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Utilization of Pruned Branches from *Lawsonia inermis* (Henna) in Soda and Soda Anthraquinone Pulping

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Abstract: This study aimed to evaluate the suitability of pruned branches of *Lawsonia inermis* (Henna) for soda and soda anthraquinone pulping to add economic value for this small tree (shrub). The investigations were carried out to determine fiber dimensions, morphological indices, chemical constituents, cooking trials were done with and without anthraquinone according to Technical Association of Pulp and Paper Industry (TAPPI). The short fiber of Henna (0.628 mm) compensated with wide fiber and lumen (83 µm) and (71 µm) respectively. The high lignin 28.8% and good cellulose 47% resulted in total yield ranged between 36.9-40.6%.

Key words: *Lawsonia inermis* (Henna) · Pruned Branches · Chemical Constituents · Fiber Dimensions · Soda Pulping · Soda Anthraquinone Pulping · Pulp Properties

INTRODUCTION

Lawsonia inermis (Henna) family (*Lythraceae*), one of attractive plants for its multi-applications and uses [1-5]. Leaves are the parts take this attention and have great economical value due to medicinal, cosmetic and beauty applications [6-10]. Henna is distributed in subtropical, tropical areas and semi-arid zones in Africa and Asia, produced commercially in India, Iran, Pakistan, Sri Lanka, Libya, Egypt, Ethiopia and Sudan for its leaves [6, 11, 12]. Henna growth has different soil and climate zones, deep sandy and clay soil, arid, tropical and warm climatic conditions [13-15]. *Lawsonia inermis* is branched glabrous shrub or small tree with greyish-brown bark (Figure 1), young branches are green and red when become mature. Leaves opposite, entire, elliptic to broadly lanceolate, glabrous and acuminate; Flowers small and white [16-19].

Henna is used traditional medicine, in curing a lot of diseases and aliments, burn wound infections [20] skin diseases [21] the extracted oil used for inhibition cancer cell lines [22, 23] uterine diseases [24] henna extract considered as antibacterial especially against *Staphylococcus aureus* [25-27]. The main use of henna especially in Asia and Africa is pigment and dye for skin and hair for women [9, 28].

Fig. 1: General features of *Lawsonia inermis* (Henna).

The production of pulp and paper from pruned branches of Henna seemed rare as not available in previous literature according to authors' knowledge, the

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main objective of this work is to investigate the suitability of *Lawsonia inermis* (Henna) pruned branches for pulping with soda and soda anthraquinone methods.

MATERIALS AND METHODS

The small trees (shrubs) of *Lawsonia inermis* (Henna) were pruned in Alobeid city, the capital of, north Kordofan state in October 2018. About thirty three kilograms of these pruned branches were collected. The random selection was applied according to TAPPI standards 2002 [29]. The area characterized with sandy loam soil and low annual rains 200-800 mm. The pruned branched were packaged in bags, transported by bus and stored in National Centre of Research in Khartoum for preparations and analysis. The dried branches were chopped into 4-6 cm length.

Fiber dimension evaluation was done in College of Applied and Industrial Sciences, University of Bahri. The prepared chops were macerated according to (TAPPI-232cm-01), with a mixture of acetic acid and 30% hydrogen peroxide (1:1), the fibers were measured microscopically at 300x and 400x magnifications of 25 fibers after staining with aqueous safranin (Figure 2). The morphological indices were determined.

The determination of the chemical components of *Lawsonia inermis* (Henna) pruned branches were carried out according to Technical Association of Pulp and Paper Industry (TAPPI standards) except for Kurchner-Hoffer cellulose which done according Obolenskaya *et al*. [30] as mentioned in Table 1.

Due to lack of previous data on pulping of *Lawsonia inermis* (Henna) pruned branches, the research team decided the conditions according to the chemical constituents, the maximum temperature was kept constant 170°C, time at maximum temperature was 90 min, time to maximum temperature was 60°C. The liquor to wood ratio was varied 4-6 and the applied chemical charge was also varied 16-18% as NaOH on oven dry wood. The addition of anthraquinone was done in small quantities for one trial equal to 0.5% on oven dry wood as presented in Table 4. The cooking was done in 7l electrically heated digester with forced liquor circulation. The pulps were cleaned with water to remove the black liquor and impurities, screened to determine rejects and screened yields (as oven dry percentages), the total yields were calculated by adding rejects to screened yields. The disintegrator was applied to separate the accumulation of fibers at 1200 rpm for 30 min. Beating with Valley beater intervals zero, 5 and 10 min to study the quality of pulps according to

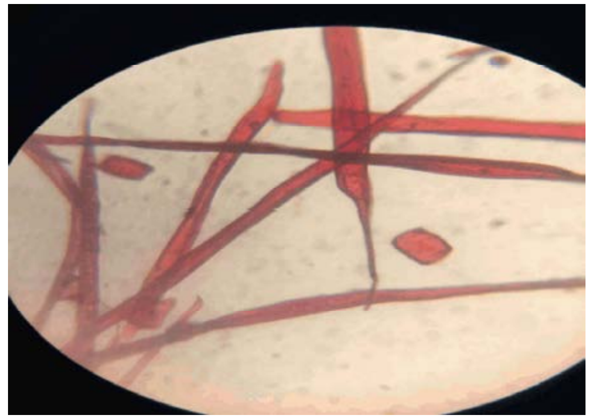

Fig. 2: Fibers of *Lawsonia inermis* (Henna) pruned branches under magnification (40X).

Table 1: The methods applied to determine the chemical constituents of *Lawsonia inermis* (Henna) pruned branches.

Chemical constituents	Method applied
Preparation for chemical analysis	TAPPI-264-cm-97
sampling and testing for moisture	TAPPI 210 cm-93
Ash	TAPPI 212
Hot water soluble	TAPPI-T- 207
Ethanol: Cyclohexane (1:2) soluble	TAPPI 204 cm-97
1% NaOH soluble	T 212 om-98
Kurchner-Hoffer cellulose	Obolenskaya *et al* [30]
Lignin	TAPPI-222

(TAPPI200-sp-01). The residual lignin in pulps was determined as Kappa number according (TAPPI-236 om-99), physical testing of pulp sheets (TAPPI-220-sp-01). Conditioning of testing atmosphere (TAPPI-402-sp-98), Burst strength (TAPPI403om-97), tensile and breaking length (TAPP-404-cm-92) and specific volume (TAPPI T 410 om98),

RESULTS AND DISCUSSION

Fiber Characterization of *Lawsonia inermis* (Henna) Pruned Branches: The fiber length of *Lawsonia inermis* (Henna) (0.628 mm) as mentioned in (Table 2) and shown in (Figure 2), was shorter compared to that fiber of *Gossypium hirsutum,* Cotton stalks [31] from Barakat area in Elgizera scheme (0.790 mm), but it was wider in fiber diameter (83 µm) and lumen diameter (71 µm) compared to those of *Gossypium hirsutum* (Cotton stalks) which were 18.3 µm and 11.6 µm respectively. The fiber wall thickness of *Lawsonia inermis* (Henna) was comparatively thin equal to 6 µm, the mentioned results indicated the flexibility of Henna fibers produced from pruned branches when compared with fibers of *Gossypium hirsutum* (Cotton stalks). The morphological indices showed high flexibility coefficient reached 85.54%, very low felting power about 7.57, low wall fraction 7.57% and very good Runkel ratio equal to 0.17 indicating these fibers would collapse easily and produce good surface contact between adjacent fibers during beating resulting in good to very good hand sheet properties.

Chemical Characterization of *Lawsonia inermis* (Henna) Pruned Branches: The ash of Henna pruned branches was 2.3% (Table 3), more or less similar to that of Cotton stalks 2.4% [31], the rapid growth of *Lawsonia inermis* may resulted of moderate ash content due to high need of nutrients during first stages of shrub or small tree life cycle. It seemed most extractives available in leaves as pruned branches contained small amounts of hot water soluble 2.9%, ethanol: cyclohexane (1:2) 3.1% and even 1% NaOH soluble was 15.0% compared to Cotton stalks 34.1%. However the Kurchner-Hoffer cellulose was 47% of Henna similar to that of Cotton stalks 46.9%, but lignin was far higher 28.8% compared to that of Cotton stalks 18.4%. When comparing the cellulose to lignin ratio of different trees and shrubs as *citrus limon* was 1.8 [32], *Maerua crassifolia* (Sarah) was 1.8 [33], *Albizia amara* (Arad) was 1.98 [34], *Acacia mellifera* (Kitter) was 2.1 [35], *Typha domingensis* southern cattail was 2.1[36] the *Lawsonia inermis* (Henna) had lowest ratio (1.6) indicating low yield and some difficulty during cooking due to relatively high lignin content.

Pulping of *Lawsonia inermis* (Henna) Pruned Branches

I t was well known during cooking with soda the screened yield decreasing with increase of alkali charge when other parameters such as liquor to wood ratio, maximum temperature, time to maximum temperature and time at maximum temperature, kept constant, that obviously clear when comparing the cooking results of *Lawsonia inermis* (Henna) Pruned Branches (Table 4) that increase of alkali charge to 17% from 16% as NaOH produced screened yield lower compared to that of 16% soda at more or less similar rejects, although the Kappa number of 17% soda was lower compared to that of 16% soda both were at bleachable Kappa number. The addition of anthraquinone in very small amount (0.05%) had very marginal effect by reducing the Kappa number to 18.5 may produce pulps for easy bleaching, however the addition of anthraquinone had not increase the yield, may be to very low amount applied. It seemed the application of 6:1 ratio of liquor to pruned branches suited *Lawsonia inermis* (Henna) instead of 4:1 ratio.

Table 2: Fiber dimensions and morphological indices of *Lawsonia inermis* (Henna) compared to those of *Gossypium hirsutum* (Cotton stalks).

Hardwood	*Lawsonia inermis* (Henna)	*Gossypium hirsutum* (Cotton stalks) [31]
Fiber dimension		
Average fiber length, mm	0.628	0.790
Average fiber diameter, µm	83	18.20
Average lumen diameter, µm	71	11.6
Average wall thickness, µm	6	3.3
Morphological indices		
Runkel ratio	0.17	0.57
Flexibility coefficient, %	85.54	63.7
Wall fraction, %	7.23	18.1
Felting power (slenderness ratio)	7.57	43.4

Table 3: Chemical components of *Lawsonia inermis* (Henna) from north Kordofan state, compared to those of *Gossypium hirsutum* (Cotton stalks)

Chemical composition, %	*Lawsonia inermis* (Henna)	*Gossypium hirsutum* (Cotton stalks) [31]
Ash	2.3	2.4
Solubility in		
Hot water	2.9	15.7
Ethanol: Cyclohexane (1:2)	3.1	4.4
1% NaOH	15.0	34.1
Kurchner-Hoffer cellulose	47.0	46.9
Lignin	28.8	18.4
Cellulose to lignin ratio	1.6	2.5

Table 4: Pulping conditions and yield results of *Lawsonia inermis* (Henna)

Pulping Process Cook code	Soda LI1	Soda LI2	Soda-AQ LI3
Pulping conditions			
Active alkali as NaOH on oven dry wood, %	17	16	18
Anthraquinone on oven dry wood, %	0	0	0.05
Liquor to pruned branches ratio,	6	6	4
Maximum temperature, °C	170	170	170
Time to maximum temperature, min	60	60	60
Time at maximum temperature, min	90	90	90
Yield results			
Total yield, %	37.0	40.6	36.9
Screened yield, %	32.8	36.2	34.7
Rejects, %	4.2	4.4	2.2
Kappa number	19	22.2	18.5

Evaluation of pulps properties *Lawsonia inermis* (Henna) Pruned Branches: The pulps properties of *Lawsonia inermis* (Henna) Pruned Branches were presented in (Figures 3-6). Tensile index and breaking length were increasing with increasing of beating and soda- AQ pulps had the best tensile index and breaking length due to the preservation of hemicelluloses during cooking especially stable xylan resulted in good pentosans, improved the beating by imbibe water inside the fibers (Figures 3 & 4). Burst index (Figure 5) had the same pattern of tensile

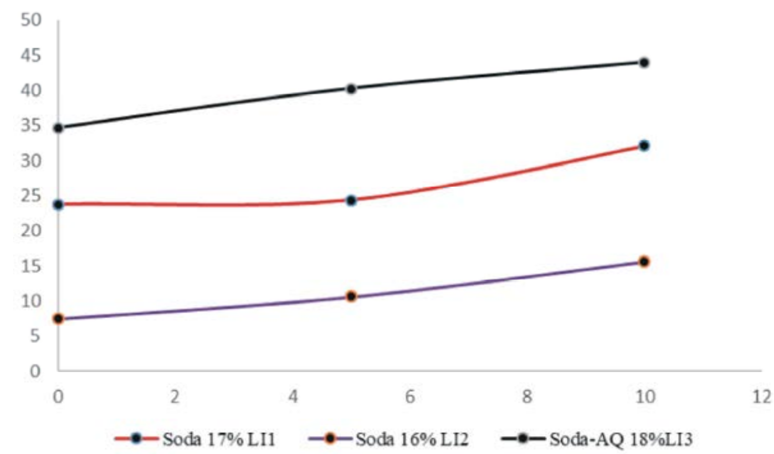

Fig. 3: Tensile index, (Nmg^{-1}) vs. beating time (min) of unbleached *Lawsonia inermis* (Henna) pulps

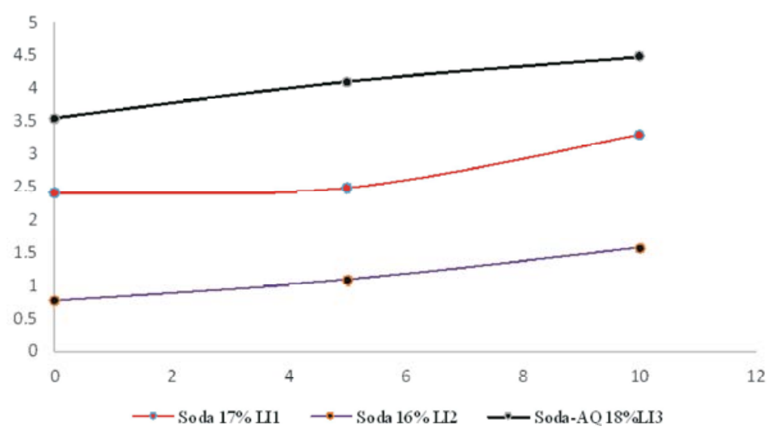

Fig. 4: Breaking length, (Km) vs. beating time (min) of unbleached *Lawsonia inermis* (Henna) pulps

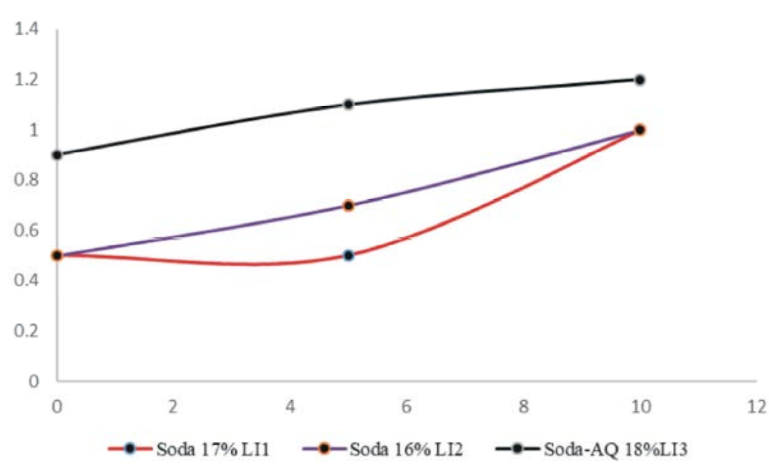

Fig. 5: Burst index, (K Pa m^2 g^{-1}) vs. beating time (min) of unbleached *Lawsonia inermis* (Henna) pulps

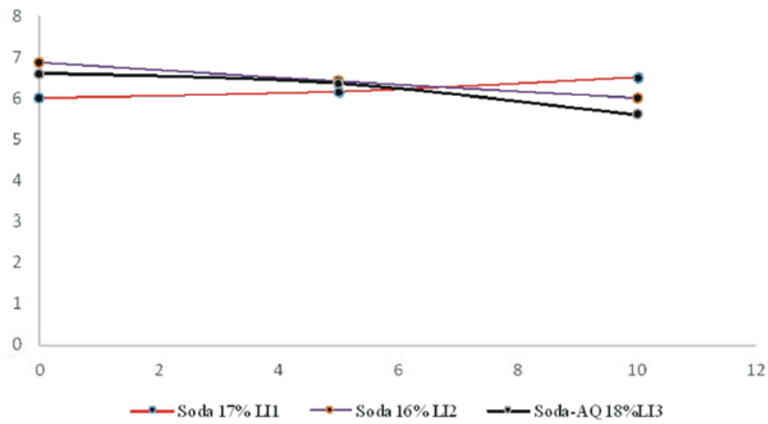

Fig. 6: Specific volume $cm^3\ g^{-1}$ vs. beating time (min) of unbleached *Lawsonia inermis* (Henna) pulps

index which indicated the superiority of anthrquinone in improving the strength properties. The specific volume which inverse of sheet density was decreasing with increasing of beating (Figure 6), however the pulps with anthraquinone showed the best strength properties.

CONCLUSION

Production of pulps from pruned branches of *Lawsonia inermis* (Henna) could be added value to the attractive plant, its leaves sources for medicines and cosmetic drugs. The wood especially the pruned branches which removed annually to improve the quality of the small tree, could be good source for pulps. Application of soda cooking suited the raw material due to easy handling and preparation. Addition of anthraquinone with appropriate amount could improve the yield and quality of the pulp produced. The pulps from pruned branches of *Lawsonia inermis* (Henna) could be blended with long fibers pulps to get pulps with better strength properties.

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