Morphological and chemical characterization of *Prosopis juliflora* (Sw.) and *Conocarpus lancifolius* Engl. in Sudan

Abdelwadoud A. Elkhalifa[1]

[1]College of Forestry and Range Science, Sudan University of Science and Technology, Khartoum, Sudan

DOI: 10.29322/IJSRP.11.01.2021.p10903
http://dx.doi.org/10.29322/IJSRP.11.01.2021.p10903

Abstract-The morphological characteristics and chemical composition of two fast growing, lesser-used wood species *viz*: *Prosopis juliflora* and *Conocarpus lancifolius* were investigated with the aim of assessing the suitability of these species as potential sources for pulp and paper making. Some fibrous materials, commonly used in pulp and paper production, were used as comparison, Fiber length, diameter, lumen width and cell wall thickness of *Prosopis juliflora* were measured as 1.20 mm, 19.0 (µm), 13.8 (µm) and 2.5 (µm), respectively, while for *Conocarpus lancifolius* they were found as 1.01 (mm), 15.2 (µm), 11.7(µm), and 2.2 (µm), respectively. The Runkel ratio, flexibility coefficient %, rigidity and slenderness values for *Prosopis juliflora* were calculated as, 0.37, 73%%, 0.26 and 3.1, respectively, while for *Conocarpus lancifolius* they were 0.3, 77.0%, 0.3 and 6.0. The chemical analysis of *Prosopis juliflora* showed that the hollocellulose, α-cellulose, lignin, pentosans and ash were 969.2%, 43.32%, 23.89, 114,86% and 2.12%, respectively, whereas, for *Conocarpus lancifolius* the chemical analysis revealed the hollocellulose as 76.94%, α-cellulose 47.31%, lignin 19.83%, pentosans 17.64 and ash 2.67%. Analysis of the morphological and chemical characteristics indicated that both *Prosopis juliflora* and *Conocarpus lancifolius* are suitable for pulp and paper production in Sudan.

***Keywords*:** Fiber dimensions, chemical composition, pulping, *Prosopis juliflora, Conocarpus lancifolius*

I. INTRODUCTION

Wood is the major fiber source for pulp and paper making and about 90 percent of all pulps are produced from wood (Bierman, 1996). Among many indices that made wood a valuable raw material valued for pulp and paper production, the anatomical and chemical composition of wood stand out (Riki *et al*., 2019). Anatomical characteristics form the basis for wood utilization in pulp and paper making industry (Emerhi, 2012). Analysis of the morphological characteristics of fibers and their derived indices are important factors in evaluating the quality of pulp of any fiber material (Dinwoodie, 1965; Ajala and Noah, 2019; Ogunwusi, 2001). Fiber characteristics that influence the quality of paper are: fiber length, fiber diameter, fiber lumen width, fiber cell wall thickness, Runkel ratio, Co-efficient flexibility, rigidity coefficient and slenderness (Sadiku and Abdukareem, 2019; Albert *et al.*, 2011). Long fiber lengths are preferable for manufacture of paper (Dutt and Tyagi 2011). Long fibers give a more open and less uniform sheet structure. Fiber length influences the tearing strength of paper (Oluwadare and Ashimiyu 2007, Wimmer *et al*. 2002). Strength properties of the papers are related to lumen width and cell wall thickness (Panshin and de Zeeuw, 1980).Fibers with large lumen and thin walls usually have good strength characteristics ((Oluwadare, 1998). The larger the fiber lumen width, the better will be the beating of pulp and paper with thin walled fiber will be dense and well formed. (Emerhi, 2012).

The Runkel ratio is the ratio of fiber cell wall thickness to its lumen that determines the suitability of a fibrous material for pulp and paper production. Good quality wood for pulp and paper production must have a runkel ratio of ≤ 1 (Kpikpi, 1992; Enayati *et al*. 2006). The coefficient of flexibility, also referred to as elasticity coefficient, is derived from the ratio of lumen width to its fiber diameter. Bektas *et al*. (1999) classified fibers into four groups according to elasticity ratio: 1. Highly elastic fibers with flexibility ratio > 75%; 2. Elastic fibers with flexibility ratio 50-75%; 3. Rigid fibers with flexibility ratio 30-50%; 4. Highly rigid fibers with flexibility ratio < 30%. Elasticity coefficient was reported to influence the tensile strength and bursting properties (Vereris, 2004). Slenderness is the ratio of the fiber length to its diameter; it gives the tearing resistance of a paper (Emerhi, 2012).

The chemical composition of wood varies from species to species. Wood has three main chemical components, cellulose; which constitutes about 41–48%, in hardwood and 46 – 55% in softwood, hemicellulose; which is around 20% in deciduous trees but near 30% in conifers and lignin; at around 27% in coniferous wood vs. 23% in deciduous trees. Aside from the lignocellulose, wood consists of minor amount of extraneous materials, mostly in the form of organic extractives and inorganic minerals (ash) usually 4 – 10% (Panshin and de Zeeuw, 1980). Wood fiber characteristics and chemical composition are two important parameters which determine its suitability as raw material for the production of pulp and paper. The extractive content has a direct effect on the pulp yield, a high content reduce pulp yield. On other hand holocellulose, α-cellulose and lignin content are mainly related to pulping behavior. (Panshin and de Zeeuw 1980).

Prosopis sp. (mesquite) was introduced in Sudan since 1917 and is now vigorously spreading in all parts of the country (Abdel Bari, 1986). *Prosopis juliflora* is fast-growing multi-stemmed tree tolerant to arid conditions and saline soils (NAS, 1983). *Conocarpus lancifolius* (damas) of family combretaceae is native to Somalia and Saudi Arabia and was introduced in Sudan in 1950. It is considered as a fast growing wood species reaching a height of 10 – 20 m in 8 years. It is tolerant to extremely low rainfall and extreme heats (Bosshard and Wendroff, 1966). In Sudan, most forest tree species are under-utilized and only few of them have been studied as a suitable raw material for pulp and paper making (Saeed, *et al.*2017).The utilization of *Prosopis chilensis* and *Conocarpus lancifolius* has been limited to fuel wood and local constructions. The present study aimed at characterizing the fiber morphology and chemical composition of *Prosopis chilensis* and *Conocarpus lancifolius* in order to assess their suitability for pulp and paper production.

II. MATERIALS AND METHODS

Wood samples

Wood samples of *Prosopis juliflora* and *Conocarpus lancifolius* were obtained from Soba area south Khartoum (Lat. 15°36′ N, long. 36°55′ E). Three normal trees from each wood species were manually felled and 5 discs of 2.5 thick were cut down from each wood species. Disks were then taken to the laboratory in the College of Forestry and Range Science for chemical and anatomical analysis. Chips were cut out from the discs and were ground in a Wiley mill, air dried and stored at -24°C in sealed container until chemical analysis.

Fiber characteristics and derived values

Separation of wood fibers was carried out following Franklin method (Franklin, 1945). Small silvers of each wood species were macerated in a mixture (50/50, v/v) of glacial acetic acid and 30% hydrogen peroxide. The cook was allowed to boil in water for 1 – 2 hours. Some macerated fibers were randomly selected, stained with aqueous solution of safranin and mounted on slides using Canada balsam. After drying they were examined under a microscope. For each wood species 50 fiber dimensions were measured which included: fiber length, fiber diameter and lumen width. The derived indices values calculated were Runkel ratio (2× cell wall thickness/lumen diameter), coefficient of flexibility (lumen diameter/fiber diameter ×100), coefficient of rigidity (double cell wall thickness/fiber diameter) and slenderness ratio (fiber length/fiber diameter).

Chemical composition

The chemical analysis was carried out following TAPPI standard methods except for hollocellulose according to wise *el al*. (1946), and lignin according to Khristova and Gabir (1984). Tests were carried out according to the following methods: ash content via TAPPI T 211 om-93; α-cellulose via TAPPI T 203 cm-99; 1%NaOH TAPPI T 212 om-98; Alcohol/benzene via TAPPI T 204 cm-97; Hot water solubility via TAPPI T 207 cm-99; Pentosans via TAPPI 223 cm-01. All tests were carried out in three or more replicates.

III. RESULTS AND DISCUSSION

The results of the fiber dimensions of *Prosopis juliflora* and *Conocarpus lancifolius* and their comparison with other common pulp fibers are presented in Table 1. The average fiber length of *Prosopis juliflora* (1.20 mm) and *Conocarpus lancifolius* (1.01 mm) are in the range of hardwood fibers (1.0 – 1.8 mm, Hurter 1997) and are both longer than that of *E. tretecornis* (0.85 mm) and wheat straw (0.74 mm), but shorter than *P. patula* (2.37 mm). The fiber width of *Posopis juliflora* (19.04 µm) and *Conocarpus lancifolius* (15.24µm) are almost similar to those of *E. tretecornis*, wheat straw and kenaf. On the other hand, lumen diameter values of *Prosopis juliflora* (16.10 µm) and *Conocarpus lancifolius* (13.1 µm) are both higher than that of *E. tretecornis*, wheat straw and kenaf. Cell wall thickness of both *Prosopis juliflora (*1.97 µm) and *Conocarpus. lancifolius* (1.48 µm) are thinner than those of *P. patula*, *E. tretecornis*, wheat straw and kenaf. This result indicated that fibers of *Prosopis juliflora* and *Conocarpus lancifolius* are comparatively long, wide and have wide lumen with thin cell wall.

Table: 1 Fiber dimensions of *Prosopis juliflora* and *Conocarpus lancifolius* as compared to other pulp raw materials.

Fiber property	*Prosopis juliflora*	*Conocarpus lancifolius*	*Pinus patula*[1]	*Eucalyptus tretecornis*[2]	Wheat straw[3]	Kenaf[4]
Fiber length(mm)	1.20	1.01	2.37	0.85	0.74	1.29
Fiber width (µm)	19.0	15.20	40.32	16.14	13.20	22.10
Lumen width(µm)	13.80	11.70	29.09	6.10	4.00	12.70
Cell wall thickness(µm)	2.50	2.20	5.49	5.10	4.60	4.30

Source: [1]Modes *et al.,* (2019); [2]Dutt and Tyagi, (2011); [3]Deniz *et al*., (2004); [4]Ververis *et al*., (2004)

Table 2 presents the values of derived morphological indices of *Prosopis* j*uliflora* and *Conocarpus lancifolius* as compared to other fibrous materials. Runkel ratio of *Prosopis juliflora* (0.37) and *Conocarpus lancifolius* (0.38) are both lower than that of *E.tretecornis*, wheat straw and kenaf. Runkel ratio is recognized an important property in determining the suitability of fiber for pulp production. It is related to paper conformity and pulp yield (Emerhi, 2012). The fibers with Runkel ratio less than 1.0 are considered thin walled fibers and good mechanical properties are usually obtained when Runkel ratio is below 1.0 (Dutt and Tyagi,2011). This low Runkel ratio is expected to have a positive effect on tensile and bursting strengths as well as on folding endurance (Riki *et al*, 2019). The Flexibility coefficient was calculated as 73.0 and 77.0% for *Prosopis juliflora* and *Conocarpus lancifolius* respectively, which are higher than that of *E.tretecornis*, wheat straw and kenaf, but comparable to that of *P. patula.* According to Bektas *et al*. (1999) who classified fibers based on flexibility ratio, *Prosopis juliflora* is classified as elastic fibers (Flexibility coefficient 50-75%) whereas *Conocarpus lancifolius* has high elastic fibers (Flexibility coefficient >75%). Noah *et al.* (2015) reported that flexibility coefficient ≥ 50 are necessary for paper making because paper strength tends to improve with increasing flexibility coefficient. From the result obtained, the fibers of both wood species are flexible and will collapse easily to produce good surface contact or increased fiber-to-fiber bonding. Coefficient of rigidity of *Prospis juliflora* (0.26) and *Conocarpus lancifolius* ((0.3) were near to that of wheat straw and kenaf. Slenderness ratio of *Prospis juliflora* (63.1) and *Conocarpus lancifolius* (66.0) are both higher than that of *P. patula, E.tretecornis*, wheat straw, and kenaf. The acceptable values for slenderness values are > 33 (Xu *et al.* 2006). The overall morphological properties of *Prosopis juliflora* and *Conocarpus lancifolius*, as compared to other pulp raw materials, indicate the suitability of these two wood species for pulp and paper production.

Table: 2 Derived morphological indices of *Prosopis juliflora* and *Conocarpus lancifolius* as compared to other pulp raw materials.

Derived values	*Prosopis juliflora*	*Conocarpus lancifolius*	*Pinus patula*[1]	*Eucalyptus tretecornis*[2]	Wheat straw[3]	Kenaf[4]
Runkel ratio (RR)	0.37	0.38	0.43	1.64	2.30	0.68
Flexibility coefficient (FC) %	73.0	77.0	72.1	38.0	30.0	57.0
Rigidity coefficient (RC)	0.26	0.30	_	0.63	0.35	0.39
Slenderness ratio (SR)	63.1	66.0	_	52.66	56.1	58.6

Source: [1]Modes *et al.,* (2019); [2]Dutt and Tyagi, (2011); [3]Deniz *et al*., (2004); [4]Ververis *et al*., (2004)

Table 3 shows the chemical composition of *Prosopis juliflora* and *Conocarpus lancifolius* and their comparison with *P. patula*, *E. tretecoronis*, wheat straw and kenaf. Hollocellulose content of *Prosopis juliflora* (69.20%) is lower than that of kenaf (76.5%) and wheat straw (74.5%), but near to that of *P. patula* (71.6%) and *E. tretecoronis* (66.5%). On the other hand, holocellulose content of *Conocarpus lancifolius* (76.94%) is higher than that of wheat straw and *P. patula* and is similar to that of kenaf. The α-cellulose content of *Conocarpus lancifolius* (47.31%) is higher than that of *Prosopis juliflora* (42.32). However both values are higher than those of *P. patula*, *E. tretecornis*, and wheat straw (40.0%, 45.04%, and 38.20%, respectively). α-cellulose content of *Conocarpus lancifolius* is similar to that of kenaf. The holocellulose content is a quantitative indication of fibrous raw material influencing consideration of its suability for pulp (Alen, 2000). Results on cellulose and hollocellulose content indicated that wood of both *Prosopis juliflora* and *Conocarpus lancifolius* are suitable raw materials for pulping. The lignin content of *Prosopis juliflora* (23.9%) is lower than that of *P. patula* (28.7%) and *E. tretecornis* (28.20%). However it is higher than that of kenaf (19.20%) and wheat straw (15.30%). On the other hand, lignin content of *Conocarpus lancifolius* (19.83%) is similar to that of kenaf, but lower than *P. patula* and *E. tretecornis*. However, these results are comparable with that of hardwoods (17-26) and lower than softwoods (25-32) (Ates, *at al*. 2008). Hot water extractive content of *Prosopis juliflora* (11.02%) and *Conocarpus lancifolius* (8.06%) are both higher than *P patula* (5.9%), *E. tretecornis* (4.01%) and kenaf (7.50%) but lower than that of wheat straw (14.0%). Alcohol-benzene solubility of *Prosopis juliflora* (7.82%) is more than twice that of Conocarpus *lancifolius*, *P. patula* and kenaf, but similar to wheat straw (7.80%). 1%NaOH solubility of *Prosopis juliflora* (24.83%) and *Conocarpus lancifolius* are both higher than that of *P. patula* and *E. tretecornis,* but lower than wheat straw and kenaf. Ash content of *Prosopis juliflora* (2.12%) and *Conocarpus lancifolius* (2.67) are higher than that of *P. patula* and *E. tretecornis* (1.01% and 1.12%, respectively), but lower than wheat straw (4.01

Table: 3 chemical composition of *Prosopis juliflora* and *Conocarpus lancifolius* as compared to other pulp raw material.

Component%	*Prosopis juliflora*	*Conocarpus lancifolius*	*Pinus patula*[1]	*Eucalyptus tretecornis*[2]	Wheat straw[3]	Kenaf[4]
Ash	2.12	2.67	1.01	1.12	4.7	1.41
Solubility in :						
Hot water	11.02	8.96	5.90	4.01	14.0	7.50
Alcohol benzene	7.82	2.39	3.10	3.16	7.8	3.20
1% NaOH	24.38	20.27	14.60	12.50	40.6	28,50
Lignin	23.89	19.83	28.70	28.2	15.3	19.20
Holocellulose	69.20	76.94	71.68	66.50	74.5	76.50
α-cellulose	42.32	47.31	40.00	45.04	38.20	46.70
Pentosanes	14.86	17.64	11.90	12.03	-	29.90

Source: [1]Walia *et al. (2009);* [2]Dutt and Tyagi (2011); [3]Deniz *et al.* (2004); [4]Karakua and Roy (2001).

IV. CONCLUSIONS

The analysis of fiber dimensions showed that the fibers of *Prosopis juliflora* and *Conocarpus lancifolius* are relatively longer and with thinner cell walls than those of some wood fibers. Both wood species have higher flexibility coefficient (> 70) compared to some other non-wood fibers and are therefore classified as elastic fibers. Each wood species have Runkel ratio of < 1 acceptable value for pulp and paper production. Hollocellulose, α-cellulose and lignin content of *Prosopis juliflora* and *Conocarpus lancifolius* were comparable to that of other fibrous materials suitable for pulp and paper production. The results of morphological and chemical characteristics of *Prosopis chilensis* and *Conocarpus lancifolius* compared favorably with other fibrous raw materials indicating the suitability of these two wood species for pulp and paper making. However, this research covered only the basic wood properties, therefore, more investigations in pulp yield and quality are needed for further evaluation of these species.

REFERENCCES

Abdel Bari, E. (1980). The identity of the common mesquite *Prosopis species*. Forestry research Centre, Khartoum, Sudan

Albert, S.; Padhair, A.; and Gndhi, D. (2011). Fiber properties of Sorghum halepense and its suitability for paper production. *Journal of Natural Fibers*, 8(4), 263-271.

Alen, R. (2000). *Structure and composition of wood, Fabet Jyvaskyla*, Finland, pp11-23.

Ajala, O. O.; and Noah, A. S. (2019). Evaluation of fiber characteristics of *Aningeria robusta* A. CHEV. wood for its pulping potentials. *Journal of Forestry Research and Management, Vol.16(1),90-97 –*

Ates, S.; Ni, Y.; Akugl, M. and Tozluoglu, A. (2008). Characterization and evaluation of *Paulownia elongota* as a raw material for paper production. *African Journal of Biotechnology*, 7(22).

Bektas, I.; Tutus, A. and Eroglu, H. (1999). A study of the suitability of Calabrian pine (*Pinus brutia* Ten.) for pulp and paper manufacture. *Turkish J. Agric. For., 23: 589-597*

Bierman, J. C. (1996). *Handbook of pulping and paper making*. 2nd edition, Academic Press, California, USA.

Bosshard and Von Wendroff. (1966). *Conocarpus lancifolius* and its possibilities in Sudan Forestry Research Centre, Sudan.

Deniz, I., H. Kirci & S. Ates. (2004). Optimization of wheat straw (*Triticum durum*) kraft pulping. *Ind. Crops Prod. 19: 237–243.*

Dinwoodie, J.M. (1965). The relationship between fiber morphology and paper properties: A Review of Literature. *Tappi Journal 48: 440- 447.*

Dutt, D. and Tyagi, C. H. (2011).Comparison of various morphological, chemical, making characteristics I*ndian Journal of Chemical Technology 18(2):145-* 151

Emerhi, E. A. (2012). Variations in anatomical properties of *Rhizophora racsmosa* (Leeem) and *Rhizophora Harrisonii* (G. mey) in Nigerian mangrove forest ecosystem. *International Journal of Forest, Soil and Erosion. 2(12).*

Enayati, A.A., Hamzeh, Y. Mirshokraie S.A. and Molaii. M. (2009). Papermaking potential of Canola stalks. *BioResources 4: 245– 256*

Franklin, G. L. (1954). A rapid method of softening wood for anatomical analysis. *Tropical Woods 88: 35–36.*

Hurter, R. W. (2006). Agricultural residues. *TAPPI, Nonwood Fibers Short Course Notes*

Karakus, S. and Roy, D. N. (2001). Physical, chemical, soda pulping and paper making properties of Kenaf as a function of growth. *J. Wood Chem. Technol. 21: 157-167*.

Kpikpi W.M. (1992). Wood structure and paper making potentials of *Ricinodendron heudelotii* and *Albizia zygia* in relation to *Gmelina arborea* in Nigerian. *Journal of Botany, 5: 41-50.*

Modes, K. S.; Ludwig, R. L.; Magnos Alan Vivian, M. A. and Stolberg, J. (2019). Wood quality of *Pinus patula Schltdl* & Cham for the pulp production. *Rev. Arvo Vol.43no.2*

NAS (1983). Firewood crops. Vol. 1, NAS Washinngton.

Ogunwusi, A. A. (2001). Variation in pulp characteristic of *Pinus caribaea*, Department of Resources Management, University of Ibadan, Ibadan, Nigeria,

Oluwadare, A. O.; Ashimiyu, O. S. (2007). The Relationship between fiber characteristics and pulp-sheet properties of *Leucaena leucocephala* (Lam.) De Wit. *Middle-East Journal of Scientific Research Vol. 2 (2): 63- 68.*

Panshin, A. J. and de Zeeuw, C. (1980). *Textbook of wood technology*. 4th edition McGraw Hill, New York.

Riki, J.T.B.; Sotannde, O. A. and Oluwadare, A. O. (2019). Anatomical and chemical properties of wood and their practical implications in pulp and paper production: A review. *Journal of Research in Forestry, Wildlife & Environment. Vol. 11(3).*

Sadiku, N. A. and Abdukareem K. A. (2019). Fiber morphological variations of some Nigerian Guine savannah timber species. *Maderas. Ciencia technologia 21(2). 239- 248*

Saeed, H. A. M.; Liu, Y.; Lucia, L. A.; Chen, H.. (2017). Characterization and evaluation of pulp and paper from Sudanese wood species for pulp and paper making. *International Journal of Recent Scientific Research, Vol 8, issue 8.*

Ververis, C., K. Georghiou, N. Christodoulakis, P. Santas & R. Santas. (2004). Fiber dimension, lignin and cellulose content of various plant materials and their suitability for paper production. *Ind. Crops Prod.19: 245–254.*

Walia, Y. K.; Kishore, K.; Vasu, D.; Gupta, D. K. (2009), Physio-chemical analysis of *Ceiba pentandra* (Kapok). *International Journal of Theoretical and Applied Sciences*, 1(2),15-18

Wimmer, R., Downes, G.M., Evans, R., Rasmussen, G. and French, J. (2002). Direct effects of wood characteristics on pulp and paper hand sheet properties of *Eucalyptus globulus*. *Holzforschung*, 56: 244-252

AUTHORS

Author: Dr. Abdelwadoud A. Elkhalifa, College of Forestry and Range Sciences, Sudan University of Science and Technology, Sudan

Email: Abdelwadoudelkhalifa@gmail.com