Assessment of Fiber Characteristics and Suitability of ten Hardwood Species Grown in Sudan for Paper Production

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Introduction

Sudan is considered one of the rich African counties with great diversity of tree species; it encompasses about 3156 species belonging to 1137 genera and 170 families. However, Sudan is almost entirely dependent on imports to satisfy its needs for pulp and paper despite its richness in different hardwood species which could be good sources of pulp production. There is an urgent need to evaluate the locally available raw materials as potential sources for pulp and paper industry.

The present study was carried out to investigate the wood fiber characteristics of ten hardwood species growing in Sudan as well as to assess their fiber variation and suitability for pulp and paper making. The wood materials were collected from the low rainfall woodland savannah in Sudan, from two states namely: South Kordofan State and Sennar State. Fibers dimensions and their derived values were investigated and used to consider the suitability of the selected species for pulp and paper making.

Material and Methods

Materials:

The wood raw materials were collected from ten species each belongs to different family. The studied species were growing in low-rainfall savannah in Sudan, in three forests namely, Al-Dalang, Al-Faid Um Abdalla (located in South Kordofan State) and Al-Lambowa (located in Sennar State). Table 1, represents the scientific names, local names and the families of the selected species as well as the locations of collection.

Table 1. The studied species scientific names, local names, families and collection locations

Scientific Name	Local Name	Family	Collection locations
***Ailanthus excelsa* Roxb.**	Ailanthus	Simaroubaceae	Al-Dalang forest
***Albizia amara* (Roxb.) Boiv.**	Arrad	Fabaceae	Al-Faid Oum Abdala forest
***Balanites aegyptiaca* (L.) Delile**	Heglig	Balanitaceae	Al-Dalang forest
***Boswellia papyrifera* (Del) Hochst**	Gafal	Burseraceae	Al-Faid Oum Abdala forest
***Diospyros mespiliformis* Hochst. ex A. DC.**	Gughan	Ebenaceae	Al-Dalang forest
***Eucalyptus camaldulensis* Dehn.**	Ban	Myrtaceae	Al-Lambowa forest
***Euphorbia tirucalli* L.**	Engil	Euphorbiaceae	Al-Dalang forest
***Ficus sycomorus* L.**	Gameiz	Moraceae	Al-Lambowa forest
***Sterculia setigera* Delile**	Tartar	Sterculiaceae	Al-Faid Oum Abdala forest
***Tamarix aphylla* (L.) Karst.**	Tarfa	Tamaricaceae	Al-Lambowa forest
***Ziziphus spina-christi* (L.) Desf.**	Sider	Rhamnaceae	Al-Lambowa forest

Three healthy mature trees were randomly taken from each species. From each tree, two representative samples were obtained from the outer wood (sapwood) of the stem at breast height from opposite sides of the tree.

Methods:

Maceration procedure

Shultze maceration method was adopted to macerate the woody materials into individual cells using a strong agent (nitric acid 65 %).

Microscopic examination

Fiber length, diameter, and lumen diameter were measured using a light microscope (model: hund WETZLAR) with an 10x ocular lens provided with a measuring scale graduated into ten equal segments and each segment is then graduated into ten sub-segments (Figure 1). A total of forty fibers were randomly measured from each sample. The measured values were transformed into real values by calibrating the measuring scale using a calibration scale (one millimetre) having ten segments and each segment is graduated into ten sub-segments (Figure 2).

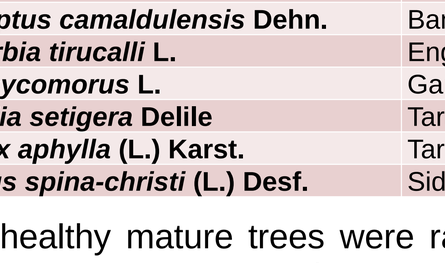

Figure 1: Fiber length measurement using measuring scale.

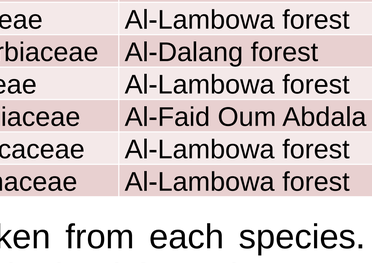

Figure 2: Calibration scale.

Fiber wall thickness was calculated as fiber diameter - fiber lumen diameter /2.
Three derived values were calculated using the measured fiber dimensions as follows:
Slenderness ratio as fiber length/fiber diameter,
Flexibility coefficient as fiber lumen diameter/ fiber diameter × 100 and
Runkel ratio as 2 × fiber cell wall thickness/lumen diameter.

Results

Fibers characteristics and their variation:

The study results reveal that the fiber characteristics of the studied species are in the normal range for hardwoods species. The studied species fibers length ranged from short to medium. Regarding the fibers elasticity coefficient classification, most of the study species (7 species) are included in the elastic fiber group, one species is included in high elastic group and two species are included in rigid fiber group. Almost all the studied species have high slenderness ration of > 33. The Runkel ratio ranged from 0.34 to 1.21. Significant variations have been detected in fiber characteristics among the ten studied species. Table 2, represents the results of mean separation test of the studied species, the table includes also information about the studied species fiber length and Flexibility coefficient classification.

Table 2. Results of mean separation test of the studied species

Study species	Fiber Characteristics mean values						
	FL (mm) [C][1]	FD (µm)	FLD (µm)	FWT (µm)	RR	SR	FC.(%) [C][2]
Ailanthus excelsa	1.11^{b} [M]	29.7^{a}	22.70^{a}	3.51^{d}	0.34^{d}	35.1^{de}	75.9^{a} [HE]
Albizia amara	0.99^{bcd} [M]	29.7^{a}	22.70^{a}	4.77^{abc}	1.03^{abc}	51.1^{abc}	50.9^{de} [E]
Balanites aegyptiaca	1.04^{bc} [M]	19.6^{c}	10.04^{de}	5.29^{a}	1.14^{ab}	51.9^{abc}	48.8^{e} [R]
Boswellia papyrifera	0.91^{cde} [M]	20.6^{bc}	10.04^{de}	5.18^{a}	0.50^{d}	28.1^{e}	67.7^{b} [E]
Diospyros mespiliformis	0.98^{bcd} [M]	32.9^{a}	22.56^{a}	4.86^{ab}	1.21^{a}	50.2^{abc}	48.4^{e} [R]
Eucalyptus camaldulensis	0.76^{e} [S]	18.8^{c}	9.08^{e}	3.64^{d}	0.65^{bc}	44.1^{bcd}	62.8^{bc} [E]
Euphorbia tirucalli	0.83^{de} [S]	17.3^{c}	12.28^{cd}	3.51^{d}	0.58^{cd}	40.8^{cd}	66.1^{b} [E]
Ficus sycomorus	1.27^{a} [M]	21.0^{bc}	13.97^{bc}	4.28^{abcd}	0.61^{cd}	54.8^{ab}	64.0^{bc} [E]
Tamarix aphylla	0.75^{e} [S]	24.0^{b}	15.69^{b}	3.89^{cd}	0.65^{bc}	36.7^{d}	62.5^{bc} [E]
Ziziphus spina-christi	1.02^{bc} [M]	20.9^{bc}	13.01^{c}	3.92^{bcd}	0.77^{abc}	57.7^{a}	57.0^{cd} [E]

FL= fiber length, FD= fiber diameter, FLD= fiber lumen diameter, FWT= fiber wall thickness, RR= Runkel ratio, SR= Slenderness ratio and FCO. (%)= Flexibility coefficient. In the same Colum means with the same letter/s were not significantly different ($p \leq 0.05$). [1]Fiber length classification according to IAWA Committee (1989) where M = Medium and S = Short, [2]Coefficient, [3]Flexibility Coefficient classification according to Bektas et al. (1999) where HE = High elastic, E = Elastic and R = Rigid.

The Suitability for pulp and paper making:

The suitability of the studied species for pulp and paper making was assessed based on their fiber characteristics in comparison with literature (Table 3). Depending on the study results, eight species out of ten species have been ranked as good source for pulp and paper making. The rest two species have been ranked as poor source for pulp and paper making, however, mixing their fibers with those of softwood fibers or recycled paper pulps would enhance their use as a source for paper industry.

Table 3. Suitability of the studied species for pulp and paper making

Study species	Fiber characteristics mean values				Ranking
	Fiber Length (mm)	Flexibility Co*. (%)	Runkel ratio	Slendern -ess ratio	
Ailanthus excelsa	1.11	75.9	0.34	35.1	Good
Albizia amara	0.99	50.9	1.03	51.1	Good
Balanites aegyptiaca	1.04	48.8	1.14	51.9	Poor
Boswellia papyrifera	0.91	67.7	0.50	28.1	Good
Diospyros mespiliformis	0.98	48.4	1.21	50.2	Poor
Eucalyptus camaldulensis	0.76	62.8	0.65	44.1	Good
Euphorbia tirucalli	0.83	66.1	0.58	40.8	Good
Ficus sycomorus	1.27	64	0.61	54.8	Good
Tamarix aphylla	0.75	62.5	0.65	36.7	Good
Ziziphus spina-christi	1.02	57	0.77	57.7	Good

Co= coefficient.

Conclusion

The wood fiber characteristics of the studied species are in the normal range for hardwoods species. Significant variations have been detected in fiber characteristics among the ten studied species. The study results confirmed the suitability of using the studied species in paper production; however, mixing their wood with those of soft-wood is suggested to improve their properties.

References

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