Production of Fiber From Mesquite Plant (prosopis juliflora. L)

Howayda M. Mohammed, Taiseer Hassan M., Ahmed A. A. Youssif

Abstract*— The aim of this study is to investigate the chemical content of mesquite (prosopis juliflora) stalk, and the potential use in manufacture of sustainable fiber reinforced polymer composite, papermaking, plastics and textile industry. The raw mesquite stalk has 69% cellulose, 8% hemicelluloses, 0.53% lignin and 11.19% moisture content. The proportion of minerals in the samples were estimated by Inductively Coupled Plasma Emission (ICPE) spectrometer, the minerals in µg/L were, 24 Cu , 1.6 B , 70 Ca, ,42 Fe, 83 I, 1.5 K, 70 Mg, 1.1 Mn, 12 Na, 250 P, 15 Pb, 50 S, 26 Si and Ba concentration is less than µg/L. The production of vegetable fibers from the prosopis juliflora stalk was done through chemical extraction and water treatment. The produced fibers have 67% Cellulose, 5.47% lignin, 7.20% hemicelluloses and 0.09% ash. The fibers characterized by Fourier Transform infrared spectroscopy (FTIR), Density, porosity and Tensile strength. The density of the fiber was 0.50 g/cm3 and porosity 0.671. The FTIR spectrum show peaks at 3423.76, 2920.32, 781.20 and 1425.44 cm-1, attributed to O–H stretching, C–H stretching, C-O stretching and deformation vibrations of CH2 and CH groups respectively. The Tensile strength for three samples and elongation for each sample, were 1.09 kg, 3.76 kg , 1 kg, and elongation 1.09% , 1.03% , 0.56% respectively. The Morphological investigation was carried out using scanning electron microscope (SEM) and identifying elements zoom in 20 µm. By analyzing cross section of the sample, it was found to contain 80.6% oxygen and 19.4% calcium.

***Index Terms*— Prosopis juliflora, stalks, Cellulose, hemicelluloses, Fibers, chemical extraction, density, Tensile strength , lignin , SEM , FTIR.**

I. INTRODUCTION

Mesquite (Prosopis juliflora) an evergreen shrub, which has extensive root system which can reach up to 40 cm in just eight weeks, and grows quickly after germination.
This characteristic of *Prosopis* helps it to invade new regions. It is found as a *Prosopis* invasive weed in Ethiopia, Kenya, Sudan, Eritrea, Iraq, Pakistan, India, and Australia. It has become established as a weed in Asia, Australia, and elsewhere. It is fast-growing, nitrogen-fixing, and tolerant to arid conditions and saline soils [1].The *P. juliflora* genus, which belongs to the family Leguminosae (Fabaceae) and sub-family Mimosoideae, has 44 species [2]. All but 4 of these are native to the Americas [3]. Currently, *Prosopis* has become the worst weed in Pastoral and agro-pastoral communities of Ethiopia, Kenya and generally in the eastern part of Africa [4, 5]. According to assessment made by Ethiopia Institute of Agricultural Research (EIAR) and other national and international organizations, *Prosopis* is number one priority invasive weeds in Ethiopia [6].

IN SUDAN cut loose from its region of introduction to invade large areas of irrigated farmlands, degraded and abandoned lands, water courses, flood plains and high ways. The most common states of Sudan are Kassala and the Red sea. The total area of the feddan (4200 square meters) is 1009,600 feddans and the Red sea is 535,000 feddans [7].

Stalks of plants such as jute, flax, ramie, and hemp have traditionally been used to obtain natural cellulose fibers. These plants are almost exclusively grown as fiber crops and there is a growing concern on the future availability and price of the fibers from these crops due to the limitations of land, water, and energy needed to grow these crops. Therefore, attempts are being made to develop alternative sources for natural cellulose fibers. Byproducts of agricultural crops are being considered as inexpensive, abundant, annually renewable, and sustainable sources for natural cellulose fibers. The byproducts of major food crops including cornhusks, cornstalks [8, 9].

Natural fibers have become the main alternative source in the modern world industry. It can be applied in various ways from composite reinforcement, textile and even medical use [10]. Currently, in this 'environmental-friendly-era', natural fibers have definitely gained its place in many industries as it is biodegradable and most crucially renewable. textile materials in form of fibers, yarns and fabrics, are used in different civil engineering applications. A fiber is a unit of matter characterized by flexibility, fineness and a high ratio of length to thickness. As fibers have a high surface to volume ratio, they can be extremely strong materials. Fibers are normally made up of by long and chain-like molecules known as macromolecules or polymers, which may have an organic or inorganic nature [11].

II. MATERIALS AND METHODS

A. Materials

Mesquite *(Prosopis juliflora)* stalks were cultivated in Port Sudan, multiplied by vegetative propagation during winter 2018, and then transplanted into the experimental field on 1th October 2018 at a planting length of 25-50 cm the mesquite stalks washed with distilled water and naturally air dried.

All chemicals were reagent grade, used as received without further purification.

B. Methods

1. Chemical retting

Chemical fiber extraction was performed by applying the processing method developed, but with shortening of the immersion time in solution. 10 mesquite stalks *(Prosopis*

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juliflora), was used for each extraction. Each sample was weighed before processing and the moisture content of the samples were measured. The extraction method consisted of a pre-treatment in a bath filled with 250 ml of a 0.35% soda solution (3.5 g sodium carbonate, Na_2Co_3, per 1000 ml of water) at 100 ˚C for 1 hour, followed by treatment with 2% NaOH solution. After the pre-treatment, the stalk bark was completely peeled off. In the NaOH treatment stage, the bark was placed in a screw-cap glass bottle with 250 ml of 2% NaOH solution (20 g sodium hydroxide per 1000 ml of water). The glass bottles were hermetically sealed and placed in a stainless steel pot filled with water to cover the lower half of the bottles. Bottles were treated in boiling water for 50 min, and then fiber bundles were removed using pliers and placed on a brass wire strainer (12 wires per cm). Finally, fiber bundles were washed for 5–8 min with water under pressure and oven-dried for 48 hours at 60 C^o [12].

2. Water retting

A glass tank filled with (2 Liter) of well-water kept at 28 C^o, was used to ret stalk. The tank was covered with a transparent glass lid to maintain the water temperature constant.

200 - 300 g of stalks were placed in Liter of water and left there until the bark was easily removed from the core by rubbing the stalk with one's fingers. The stalks were then removed from the tank and dried at 60 ˚C for 48 hours [12].

$$\text{Fiber \%} = \frac{\text{total weight of dried fiber}}{\text{total weight of wet fiber)}} \times 100 \qquad (1)$$

3. Characterization of Raw Material

a. Moisture Content

5.8421g each of the sorbents was measured into a watch glass. The samples will be placed in the oven for 24 hours at 105 C^o. After 24 hours, the oven dried samples reweighted and the moisture content determined using 2 [13].

$$\text{Moisture Contents \%} = \frac{Wo - W1}{Wo} \times 100 \qquad (2)$$

Where Wo and W1 is the weight before and after drying respectively.

b. Ash content

One gram of the sample (C) was weighted into clean and dry porcelain crucible, and placed inside a muffle furnace at 550 ˚C for 3 hours, the oven dried samples were reweighted (B) and the ash content determined using 3.

$$\text{Ash contents \%} = \frac{C}{B} \times 100 \qquad (3)$$

c. Fiber chemical composition

Chesson (Datta 1981) method [14] was used for investigation of chemical composition of mesquite stalks. One grams dry sample **(**A**)** refluxed by 150 ml distilled water at 100°C. Then, the samples were filtered, washed by 300 ml hot water. Residues were dried in oven at 75°C until constant weight (B). 150 ml H_2SO_4 1N were added to the residues and refluxed at 100°C for 1 hour. The results were filtered, washed by 500 ml distilled water and dried in oven at 75°C until constant weight (C). The dried residues soaked in 100 ml H_2SO_4 72% at room temperature for 4hours, then added 150 ml H_2SO_4 1 N and reflux at 100°C for1 hour. The results were filtered; residues washed by 500mL distilled water, and dried in oven at 105°C until constant weight (D). Residues were ashed at 475°C for 3 hours and weighted (E). The hemicellulose, cellulose and lignin were calculated as follows:

$$\text{hemicelluloses \%} = \frac{C - B}{A} \times 100 \qquad (4)$$

$$\text{cellulose \%} = \frac{D - C}{A} \times 100 \qquad (5)$$

$$\text{Lignin \%} = \frac{E - D}{A} \times 100 \qquad (6)$$

4. Characterization of produced fibers

a. Bulk, tapped and true densities

A portion of one gram was accurately weighted and poured into a 5 ml graduated cylinder. The cylinder was stoppered and the bulk volume V_o was recorded. For the tapped density, the cylinder was tapped on a hard surface to a constant volume (until no more settling of the material occured). The final constant volume (V1) was noted to be the tapped volume. The bulk and tapped densities D_{bulk} and D_{tap} were determined using 7 and 8 respectively.

$$\text{Bulk density } \left(\frac{g}{cm^3}\right) = \frac{W}{V_o} \qquad (7)$$

$$\text{Tap density } \left(\frac{g}{cm^3}\right) = \frac{W}{V_1} \qquad (8)$$

True density of the sample was determined by the liquid displacement method using xylene (a nonpolar liquid) as the immersion fluid.

$$\text{True density } \left(\frac{g}{cm^3}\right) = \frac{m}{v2 - v1} \qquad (9)$$

Where m mass of fiber, v1 is is volume of powder sample and v_2 volume of powder sample and liquid.

5. Porosity

The total porosity of a powder is made up of voids between the particles as well as pores within the particles. the porosity of the materials was calculated using 10[13].

$$\text{Porosity} = 1 - \frac{\text{Density (tap)}}{\text{Density (true)}} \qquad (10)$$

6. Tensile strength

Fiber Strength is considered to be next to fiber length and fineness in the order of importance amongst fiber properties. It denotes the maximum tension the fiber is able to withstand before breaking. It can be expressed as breaking strength or tenacity etc. It determines elongation percentage of fiber at break. Elongation is compared as a "percentage of the starting length". This is an important property of a fiber as it is this nature of fibers that makes them useable in the form of textile products. A Single Column (HT1000 (M1) testing machine was used for tensile strength measurements.

7. Scanning electron microscopy (SEM)

SEM analysis was carried out using tescan type vega 3xmu (230 v). The scanning electron microscope is used to obtain a high resolution image of the samples, the external shape, the crystalline environment, the chemical composition, and the distribution of the sample constituents. The high energy electron beam is used to excite the sample and the signals were collected and analyzed, so that the image can be constructed.

III. Results and Discussions

A. Chemical composition:

The Chemical composition of the plant gives an idea of how feasible as a raw material for production of fibers; cellulose is the principal component in cell walls and in fibers. The non-cellulose component of the cell wall includes hemicelluloses and lignin [15]. Chemical composition of mesquite stalk is presented in Table (1). The results showed that, the lignin and ash in mesquite stalk were 0.53 %, 0.027 % respectively, which is lower than Cotton stalk, while Alpha celluloses in mesquite stalk was 69.00 %, which is higher than cotton stalk [16]. The main constituents of the raw material (mesquite stalk) are holocellulose 77.00 % higher than Sudanese Cotton stalks [17].

B. Mineral content of the raw material (mesquite)

There are 19 minerals that are essential or useful for plant growth and development, low mineral content in the plant material is preferred for fiber production and a

Table 1. Chemical composition of Raw Material (mesquite stalk).

Parameter	Results
Ash	0.027
Lignin	0.53
Hemicellulose	8.00
α-Cellulose	69.00
Moisture content	11.19
Holocellulose	77.00

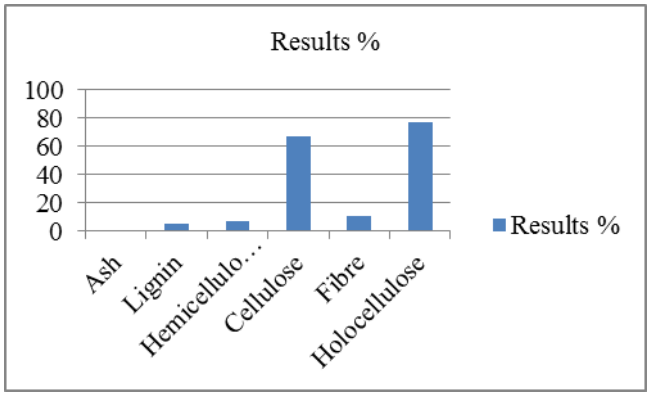


Figure 1 Chemical composition of Raw Material (mesquite stalk).

Qualitative Results

Sample Name	1823					
Date/Time of Analysis	3/20/2019 08:43:45 Ö					
Comment						
1000mg/L <=						
1mg/L <=						
1ug/L <=	B 1.6	Ca 70	Cu 24	Fe 42	I 83	K 1.5
	Mg 70	Mn 1.1	Na 12	P 250	Pb 15 +	S 500
	Si 26	Sr 1.8	Zn 2.8			
< 1ug/L	Ba 0.11					
Not Detected ug/L	Ag < 3.1	Al < 21	As < 20 +	Au < 1.9	Be < 0.07	Bi < 9.5
	Cd < 1.1	Ce < 5.1	Co < 4.0	Cr < 3.5	Cs < 450	Dy < 1.6
	Er < 2.3	Eu < 0.25	Ga < 4.0	Gd < 2.9	Ge < 4.0	Hf < 9.2
	Hg < 1.7	Ho < 1.4	In < 29	Ir < 65	La < 0.94	Li < 0.04
	Lu < 0.49	Mo < 9.9 +	Nb < 4.8	Nd < 3.1	Ni < 5.8	Os < 25
	Pd < 8.5	Pr < 3.7	Pt < 43 +	Rb < 770	Re < 7.5	Rh < 12
	Ru < 8.7	Sb < 14	Sc < 0.25	Se < 29	Sm < 5.1	Sn < 16
	Ta < 9.4	Tb < 3.9	Te < 27	Th < 18	Ti < 0.81	Tl < 32
	Tm < 1.8	U < 26	V < 0.50	W < 33	Y < 0.29	Yb < 0.17
	Zr < 1.2					

Figure 2. Mineral content

desired quality raw material. The Method by ICPE 9000 Development Assistant generates measurement conditions based on the qualitative analysis. Mesquite stalk elemental content was shown in Figure. 2. The results illustrated in two parts, measurement in (µg/L) and less than (<µg/L). The minerals in µg/L were, 24 Cu , 1.6 B , 70 Ca, ,42 Fe, 83 I, 1.5 K, 70 Mg, 1.1 Mn, 12 Na, 250 P, 15 Pb, 50 S, 26 Si and Ba concentration is less than µg/L.

C. Chemical composition of the produced fibres

Chemical composition of mesquite fiber were presented in Table (2). Mesquite fiber contains 67.11% cellulose, which is higher than Kenaf fiber. An important amount of lignin in mesquite fiber is similar Hemp (ranging 3.7–13 %) and sisal (7-11 %), hemicellulose 7.20 %, is similar Ramia (ranging 5-16.7 %) [18, 19], and 11% fibres.

D. Fourier Transform InfraRed Spectroscopy (FT-IR)

The FT-IR spectrum of mesquite fiber (figure 4) indicates that, it contains the following peaks; 3423.76, 2920.32, 781.20, 1425.44 and 1049.31cm^{-1}. The characteristic band of the O–H group occurred in 3423.76 cm^{-1} [20], whereas the peaks C–H stretching at 2920.32 cm^{-1} [21]. The peaks at 781.20 cm^{-1} are attributed to C-O stretching [20].

Table 2. Chemical composition of the produced mesquite fiber.

Parameter	Results %
Ash	0.09
Lignin	5.47
Hemicelluloses	7.20
Cellulose	67.11
Fibre	11.00

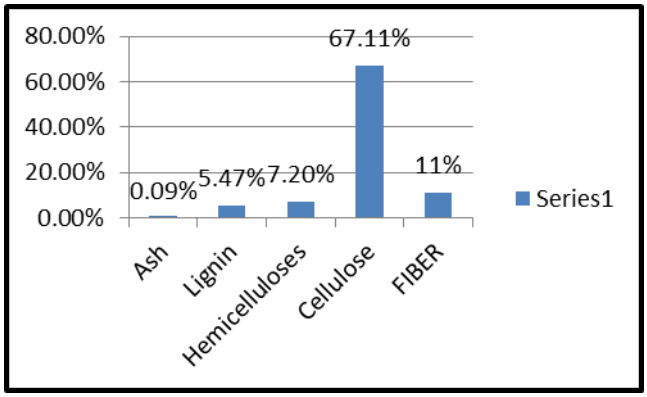


Figure 3. chemical composition of the produced mesquite fiber.

The peak at 1425.44 cm^{-1} attributed to deformation vibrations of CH_2 and CH groups and band at 1049.31cm^{-1} characteristic for cyclic mono saccharide and correspond to valent vibrations of the C-C ring structures [22].

E. physicochemical characteristic of mesquite fibres

1. Bulk, Tab and true density

The physicochemical properties of the mesquite fiber are reported in Table 3. The bulk density gives an estimate of the ability of the material to flow, while tap density is a measure of how well a powder can be packed in a confined space on repeated tapping [23]. In general the higher the bulk and tapped densities, the better the potential for a material to flow and re-arrange under compression [24]. The Bulk density in

mesquite fiber was 0.50 g/cm^3 and Tap density was 0.75 g/cm^3, which is lower than hemp fiber. The true density is 2.01 g/cm^3 which is higher than hemp fiber [25].

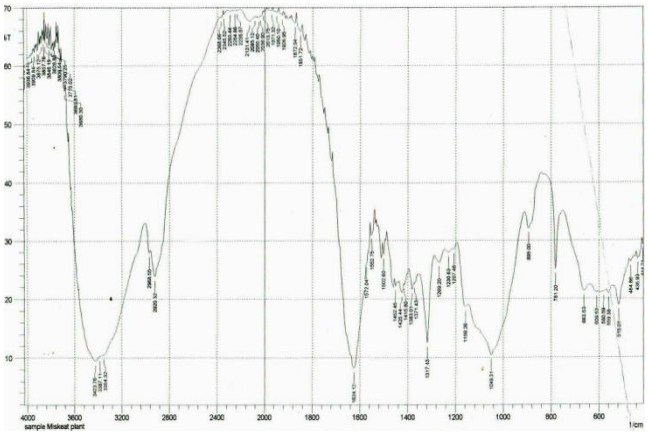


Figure 4. : FTIR spectrum of mesquite fibers.

Table 3. Physicochemical properties of Mesquite fiber.

Constituents	Results (g/cm^3)
Bulk density	0.50
Tap density	0.75
True density	2.01

2. Porosity

The porosity of mesquite fibers was 0.6271 %, which is lower than [26].

3. Tensile testing

The Tensile of fibers was shown in Table (4). The tensile tester instrument speed is 50mm/s, the fiber length is 3.5cm. Three samples were extracted to measure the strength of the resulting mesquite fiber (Tensile strength) and elongation for each sample. The obtained tensile strength for the sample was 1.09 kg, 3.76kg and 1kg. The elongation of fibers was 1.09%, 1.03%, 0.56% is similar pineapple fibers (ranging 0.8-1.6 %) [26].

Table 4. Tensile testing three sample of mesquite fiber.

Fibre	Maximum force Kg	Displacement	Elongation Rate %
Sample1	1.09	1.10	1.09
Sample2	3.76	1.40	1.03
Sample3	1	0.57	0.56
Mean	2.20	1.02	0.89

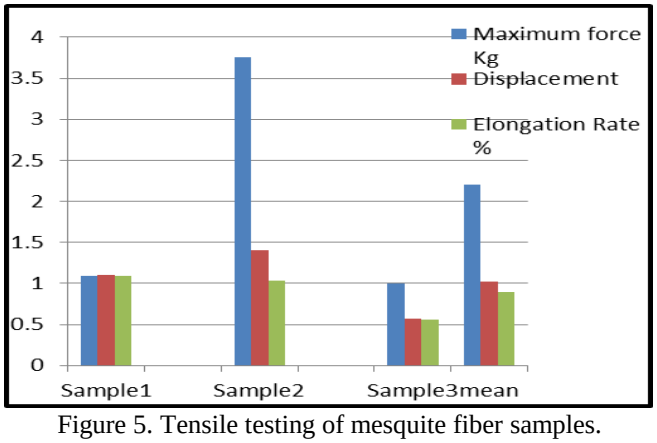
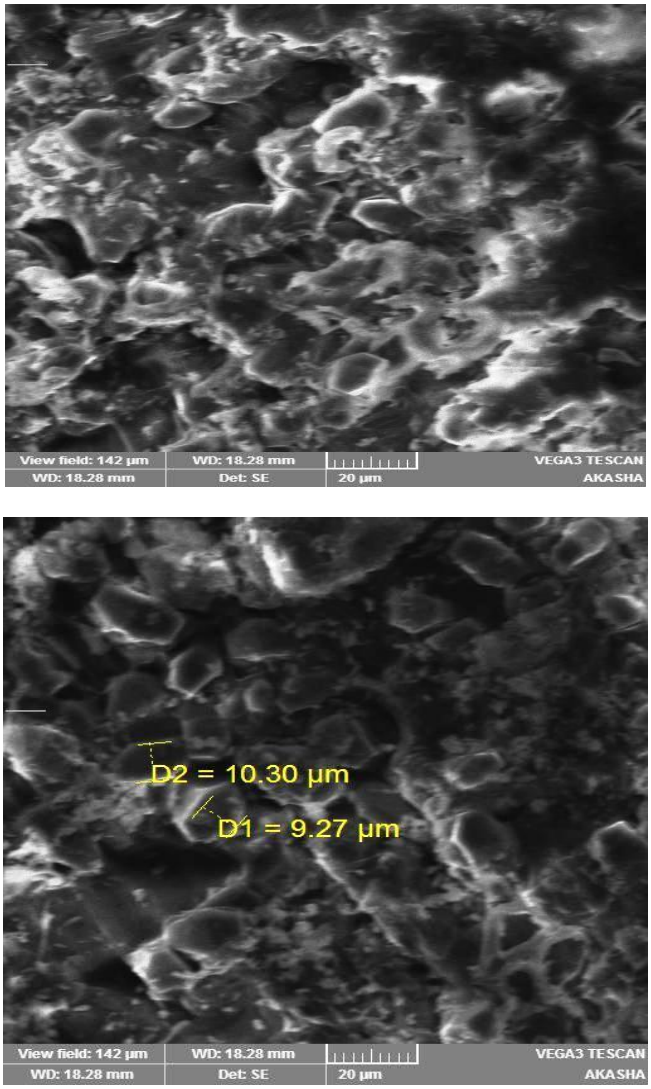


Figure 5. Tensile testing of mesquite fiber samples.

4. Morphological analysis

The morphology of fibers was presented in Figure. (6). The scanning electron micrograph shows that the morphology of the fiber is rough with aggregates of irregular shaped fibrils. Cracks and damages were also observed at the surface and may be due to the removal of cementing materials (hemicelluloses and lignin) around the fiber bundles. The fiber diameter average was 9.5± 10.5µm.

Elemental analysis SEM-EDX revealed that the extracted fibers from mesquite stalk contain as main chemical elements, 80.6% oxygen, and 19.4% calcium (Ca), probably originated from the washing water.



Figures (6). SEM micrograph of mesquite fibers.

Conclusion

Plant Fibers was successfully produced from mesquite stalk (*Prosopis juliflora*) by chemical extraction. The raw materials were studied and the chemical content was evaluated. Elemental analysis in the mesquite plant (*Prosopis juliflora)* was done by ICPE. The produced fibres were analysed in respect of chemical composition and physiochemical characters. The morphology of mesquite was investigated using tescan type vega 3xmu (230 v). The produced fiber is suitable for manufacture of sustainable fiber reinforced polymer composite, papermaking, plastics and textile industry.

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