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Calotropis Procera: The Miracle Shrub in the Arabian Peninsula

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Abstract- Calotropis procera (Ait). Ait. shrubs were collected randomly from Hada Al-Sham village, about 120 km far from Jeddah, Saudi Arabia. They habitat in a sandy site located at a latitude of 21° 46'.839N and a longitude of 39° 39'.911E above the sea level by 206 m. Chemical, physical and anatomical characterizations were made for its wood and seed floss. The allocation of each of leaves, seeds and seed floss are 4, 0.56 and 0.28 kg/plant, respectively. The fiber length (Fl) of was about 24, 9.35 and 1.01 mm for seed floss, phloem and wood, respectively.

Calotrope wood is characterized by presence of prosenchyma cells of both vessels and fibers in a diffuse porous property. Fiber cells occupy most of the transverse section area. About 8-9 rows of relatively thin walled, less lignified fibers as well as axial parenchyma cells that were found in the transverse section. The vessels have simple transverse perforation plates and diffuse solitary scanty and appear mainly in long chains of radial multiples and in groups of irregular arrangements. The axial parenchyma is scantly scattered and inter-mixed with fibers. The rays are narrow, varying from uniseriate to tetraseriate and varied widely in their length. The presence of both upright and procumbent cells in the rays confirms heterogeneity of these rays. The mean values of radial and tangential diameters of vessel were found to be 124 and 86 μm, respectively. The difference in vessel diameter between both directions may be attributed to the environmental conditions and the nature of plant growth. The vessel density in the wood tissue is 14 vessels per mm.

Huge pores arisen from excluding lignin, wax and extractives are appeared in SEM micrographs for the chemically treated seed floss of the calotrope. Chemical constituents were found to be 61.2, 20.3, 9.16, 5.02 and 4.3 % for contents of hemicellulose, lignin, total extractives, ash and wax, respectively. However, the hemicellulose content is lower than that for common known about cotton linters and *Ceiba pentandra* seed floss.

This study reflects the importance of calotrope for sustainability that forces humans and nature to exist in a productive harmony permitting fulfilling the social, economic and other requirements of present and future generations.

Keywords- *Biomass; Calotropis procera; Hardwood; Fiber length; SEM; XRD; Chemical analysis.*

I. INTRODUCTION

Saudi Arabia is a vast arid desert with total area of about 2.25 million km^2 covering the major part of the Arabian Peninsula. Subsequently, xerophytic vegetation makes up the prominent features of the plant life in the Kingdom [1]. The family Asclepiadaceae composed of about 2,000 species of flowering herbaceous plants or shrubby climbers in more than 280 genera. Most family members have milky juice, pod-like fruits, and tufted silky-haired seeds that drift on wind currents to new locations for sprouting such as *Calotropis procera* Ait. f. commonly is a popular medicinal plant found throughout the tropics of Asia [2] and [3]. *C. procera* is an evergreen poisonous shrub. It is naturally and widely spread in different areas of Saudi Arabia [4]. It grows commonly around farms, agricultural areas, and in the sandy warm parts ([5], [6[and [7], especially in the Tehama plain [6]. The native existence of *Calotropis procera* covers South West Asia and Africa. It is considered to be one of the most drought tolerant desert plants [8] and [5]. Further, it is salt-tolerant to a relatively high degree, and through its wind and animal dispersed seeds, it quickly becomes established as a weed along degraded roadsides, lagoon edges and in overgrazed native pastures [5]. Generally, *C. procera* plays an important role in formation of its natural habitats as it contains the allelo-chemical compounds that enable the plant to compete with other species. This plant may change communities when recycled as a green manure in the soil for increasing organic materials in agro-ecosystems, where it inhibits crop growth and production [9]. Further, Hegazy et al [10] recognized *C. procera* Aiton at low altitude (100-500 m) during valuation of *C. procera* inside their area studied that was recorded by Al-Khamis et al [11] to be 102.8 %, with density of 0.003 plant/ m^2, frequency of 33 % and coverage of about 6.6 % . *C. prosera* was recorded in other region of the country but in with minor distribution indicating the significance of conservation strategy of protectorate area e.g. Ibex reserve in sustaining the terrestrial wildlife and keeping rare, threatened species, and their habitats.

It have reviewed by Al-Yemni et al [7] that *C. procera* has a high capacity for taking heavy metals into its tissues due to their abilities to absorb and tolerate heavy metals without serious physiological damage in Saudi Arabia. Further, calotope was suggested for phytostabiliation of Cu, Cd and Zn and the accumulation is higher for roots than leaves [12]. Accordingly, it can be a useful botanical monitor of pollution. The variations found in the concentrations of Br, Mn, Se, Cr and Zn between urban and suburban samples suggest that the plant has a good potential for the determination of these elements when it is exposed to them from any source, especially traffic pollution [13]. The development of alternative sources for energy and chemicals, particularly the use of plant biomass as a renewable source for fuel or chemical feedstocks, has received much recent attention. Bio-conversion of lignocellulosic biomass to ethanol in an integrated system incorporating the production of bio-gas and bio-fertilizer and sugar for industrial applications. Thermochemical and chemical conversion of biomass in small- and large-scale sectors to produce gaseous and liquid fuels and chemical feedstocks [14]. Furthermore, it was reviewed that dried whole plant material afforded 4.35% of hexane and 16.14% of methanol extracts. Hexane extract was found to be rich in hydrocarbons and the ratio of carbon to hydrogen was similar to that of crude oil and heat value content was comparable to that of crude oil, fuel oil and gasoline [14].

Stems produce a good charcoal, while the stem pith makes good tinder. White, silky, strong, cylindrical, flexible and durable stem fibre used for various purposes, such as for making ropes, to form cheap cots, gunny bags, bow strings, fishing nets, and in the manufacture of paper, pulp and duplicating stencils. The floss from the seeds, which is about 2-3.5 cm long, white silky and strong, is used as an inferior stuffing for mattresses and pillows as well as for weaving into a strong cloth. The floss may also substitute cotton wool for surgical purposes. Strong inner bark fibres produce a binding material and are processed into fabrics [5].

Stems are termite proof and used for roofing and building huts. The liquid latex of *C. procera* (containing 11-23% of rubber) can be used as a renewable source of hydrocarbons and intermediate energy resources [5]. Further, young pods, senescing leaves and flowers are eaten by goats, occasionally by sheep in times of need, and rarely by cattle and other livestock because they are slightly toxic [5].

X-ray diffraction (XRD) is based on the creation of an interference pattern by x-rays when they encounter a regularly spaced matrix. This process has been used to determine the average width of the cellulose microcrystals, the percent of crystalline cellulose within the wood [15] as well as other lignocellulosic materials.

II. MATERIALS AND METHODS

Raw material

Fifty shrubs of *Calotropis procera* (Ait). Ait. (Family: Ascelpiadaceace) were collected randomly from Hada Al-Sham village, about 120 km far from Jeddah, Saudi Arabia in a sandy site located at a latitude of 21° 46'.839N and a longitude of 39° 39'.911E above the sea level by 206 m during May-June 2011-2013. Reference sample were identified through flora of KSA [4]. The selected shrubs were cut just above the ground level. The collected plants were freshly weighed for each of whole plant and leaves (Figure 1) as well as seeds and seed floss (Figure 2).

Figure 1. Whole plant of Calotropis procera (Ait). Ait.

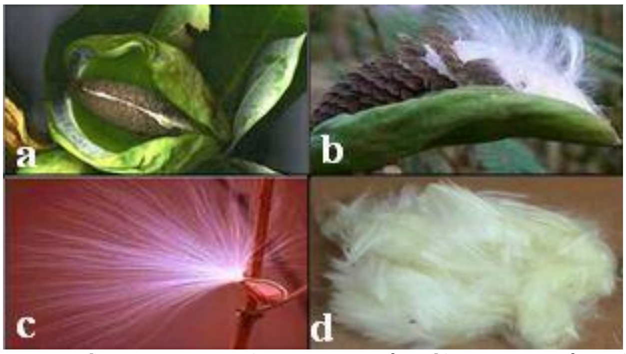

Figure 2. *Calotropis procera* : a) recent mature fruit, b) over-mature fruit, c) a seed still attached to its floss and d) ginned seed floss.

Subsequently, the samples were dried in the solar system shown in Figure 3 in a transparent minigreenhouse for 2 days under continuous suction unless at nights.

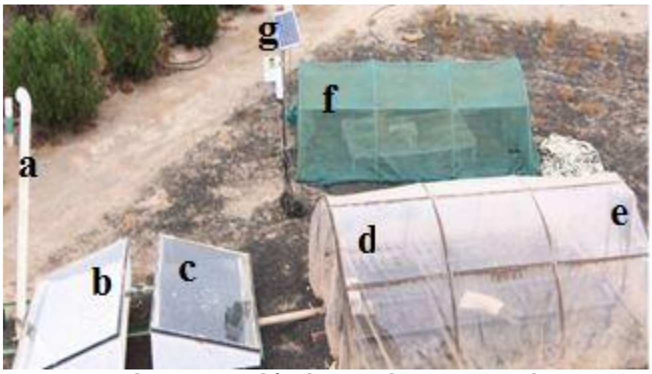

Figure 3. Solar system used for drying *Calotropis procera* biomass, a) ventilation stack, b&c) flat plate solar collector filled with NaCl and black gravels, respectively, d) transparent mini-greenhouse, e) exhaust fan, f) Shade cloth mini-greenhouse and g) Data logger for temperature and humidity measurements.

This can eliminate moisture and dry excreted latex that saturate all the tissues (Figure 4).

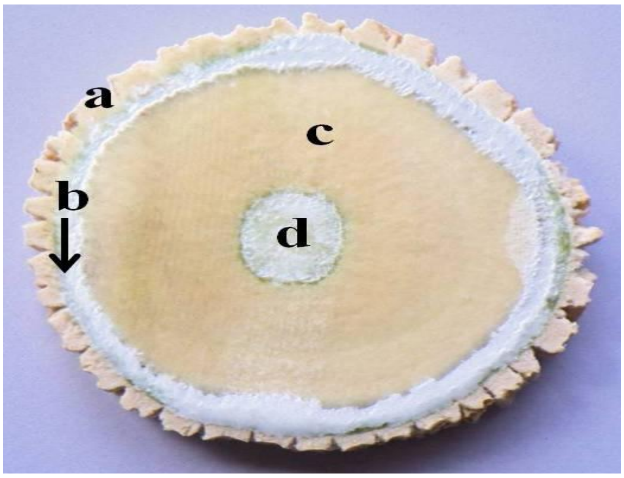

Figure 4. Cross-section of Calotropis procera wood: a) outer bark, b) inner bark naturally saturated with latex, c) wood and d) pith.

All preparations and determinations were carried out in the Central Laboratory at the Agricultural Research Center, King Abdulaziz University, at Hada Al-Sham (about 120 km far from Jeddah).

Sample preparation

One branch of each of the selected shrubs was chosen with a diameter outside bark of about 10 cm and cut at height of 10 cm above ground level. From each cut branch, one disc of about 60 cm along the grain was cut. From the heartwood of each removed disc, one bolt (about 2 cm tangentially and 60 cm long) was cut longitudinally. Subsequently, a diametric strip (nominal 2 cm tangentially and radially each and 60 cm longitudinally) was removed. Finally, the resultant strip was crosscut into subsequent cubic samples free of visible defects with an identifying order and was specified for the determination of wood properties. Each set of subsequent samples were specified to a property determination due the differences in wood characteristics were lower along the grain than those along the transverse direction.

Three subsequent wood samples as well as three adjacent phloem square samples (2x2 cm2) were randomly taken for the determination of the FL. In addition, three subsequent woody cubes were chosen for the light microscopic study and additional three cubes for the scanning electron microscopy (SEM) investigation.

The remainder mass of the heartwood from all the selected branches were ground, sieved and specified for the determinations of hexane extract content (HEC), methanol extract content (MEC), total extractives content (TEC), lignin content (LC), alpha cellulose (∞-C), hemicelluloses content (HeC) and ash content (AC). The air dry weight of each wood meal sample was about one gram except for that for TEC test subsequenty each of ∞-C and HeC that was about three grams.

Characterization

Fiber Length (FL)

Before maceration, a tertiary extraction step by ethanol-benzene mixture (2:1) and ethanol in a Soxhlet apparatus (Figure 5a) and hot water were applied for wood and phloem to eliminate the organic chemicals that may interfere with the maceration reagents used.

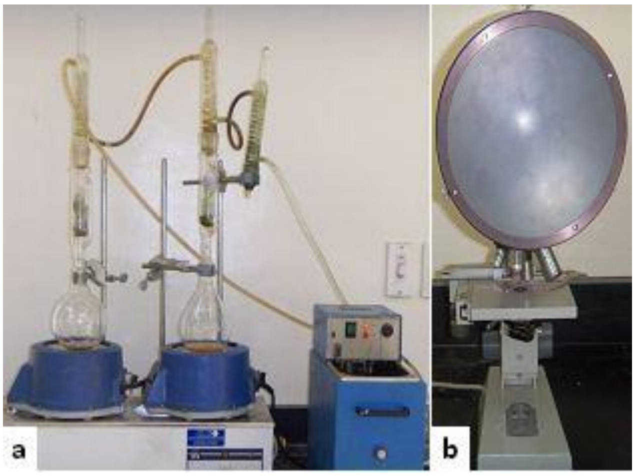

Figure 5. a) Soxhlet apparatus used for organic solvent-extraction and b) a projecting fiber suspension microscope.

For the preparation of the FL (Figure 5b), assigned thin chips were macerated by Franklin method using glacial acetic acid and 30 % hydrogen peroxide (v/v) in a ratio of 1:1 in a test tube as indicated by Hindi et al. [16]. The tube was plugged by a cotton stopper and maintained at 60C 5C for 48h and/or until fibers were separated and their yellow color into white. A drop of macerated sample was taken on a slide and the FL was measured under a projecting fiber suspension microscope after staining with 1 % aqueous safranine. The resulted measurements were corrected using a standard micrometer scale (0.01 mm). Twenty five fibers were measured for each of wood and phloem from each of the three slides prepared to represent each of the ten shrubs. For the seed floss, length was measured by an ordinary ruler just after extracting the seeds from its pod and before repulsion between the fibers due to their similar electrostatic charges.

Light microscopy

Three 20-μm-thick microtome sections (transverse, tangential and radial) were cut from each sample disc representing each shrub. The sections were stained with 1% aqueous safranin solution to enhance contrast, washed with deionized water, and placed on a warm plate at 75±5°C to dry. Each section was mounted on a glass slide with Permount. Differentiation of the anatomical elements and measuring of vessel density as well as tangential and radial diameters of their lumens were measured using a light microscope (Nikon E200), a color video camera (Sony N-50), and UTHSCSA Image Tool Version 3.0 software.

Scanning Electron Microscopy (SEM)

SEM study was used to study the surface morphology and types of anatomical features in the tangential plane samples of wood as well as the floss. The samples of each woody cubes (1cm3 each) or about ten fiberous floss were placed on the double side carbon tape on Al-stub and dried in air. Before examination, all samples were sputtered with a 15 nm thick gold layer (JEOL JFC- 1600 Auto Fine Coater) in a vacuum chamber. The specimens were examined with a SEM Quanta FEG 450, FEI, Amsterdam, and Netherland. The microscope was operated at an accelerating voltage ranged from 5-20 kV.

Physical Properties of wood

Specific Gravity (SG)

For SG of wood, nine defect-free samples (2 cm radially and tangentially and 2 cm longitudinally each) were used from each shrub. The green wood samples assigned for this test were accurately re-saturated by water under vacuum [17] and the saturated volume was measured by Pycnometric displacement of water. The SG was calculated based on oven-dry weight and saturated volume.

Volumetric shrinkage (VS)

Gross Heat of Combustion (GHC)

The GHC of wood was determined using an adiabatic oxygen bomb calorimeter (IKA, C 400) according to the procedures recommended by Parr instruction manual and in accordance with ASTM [18] and described clearly by Hindi et al [19]. Nine wood samples were selected from each tree.

Volumetric Shrinkage (VS)

The VS of wood was calculated as a percentage based on the green volume (Vg) measured by Pycnometric water displacement using the following equation: $VS=[(Vg-Vo)/Vo]x100$, where Vo is the oven dry volume of wood determined also by Pycnometric water displacement after immersing the oven-dried wood sample in molten wax with elimination of the excess wax from the sample surfaces [17].

Chemical Properties of wood and seed floss

Total extractives content (TEC) of each of wood and seed floss was determined according to the ASTM [20]. Then, each of the TEC samples was divided into three equal portions. In the case of wood, one third of them was assigned for LC determination, the second portion for ∞-C and the third one for hemicellulose (He) test. For the crude seed floss, half of the samples were extracted by ethyl ether to determine the wax content using Soxhlet apparatus and the remainder samples were totally extracted as previously indicated. The totally extracted seed floss samples were divided into two equal portions. One of them was assigned for lignin test and the other one for hollocellulose (Ho) determination. Lignin content of each of wood and seed floss was determined according to the ASTM [21] using H_2SO_4 (72 %). The ∞-C was determined based on the ASTM [22], while the HeC test was done according to ASTM [23]. The HoC was measured depending on Wise et al. [24]. To measure the ash content of each of wood and seed floss, air-dried samples were ignited at600 °C until all carbon is eliminated [25]. Ethyl ether extraction of seed floss, to separate waxes, was done in a manner similar to that described by ASTM [20] for the organic solvent extraction with the substitution of the solvent used by ethyl ether. Nine samples were tested per each tree.

X-Ray analysis of seed floss

The wide angle X-ray diffraction spectra of the fibers were recorded on a XRD 7000 Shimadzu diffractometer (Japan). The system has a rotating anode generator with a copper target and wide angle powder goniometer. The generator was operated at 30 KV and 30 mA. All the experiments were performed in the reflection mode at a scan speed of 4° /min in steps of 0.05°. All samples were scanned in 2? range varying from 4° to 30°. The crystallinity index of the fiber was determined [26] by using the following equation: $Ic=[(I_{002}-I_{am})/(\ I_{002})]x100$, Where: I_{002} represents the intensity of crystalline peak arising from hemicelluloses and alpha-cellulose while I_{am} is the crystallographic plane arising from such as lignin, hemicelluloses, pectin and amorphous cellulose.

Delignification of seed floss

Delignification process was achieved in a solution of 20% NaOH for 1 hour at a maximum pulping temperature of 165°C using an electric oil-bath apparatus (Figure 6). The ratio of liquor to oven-dried seed floss was 8:1 (w/w).

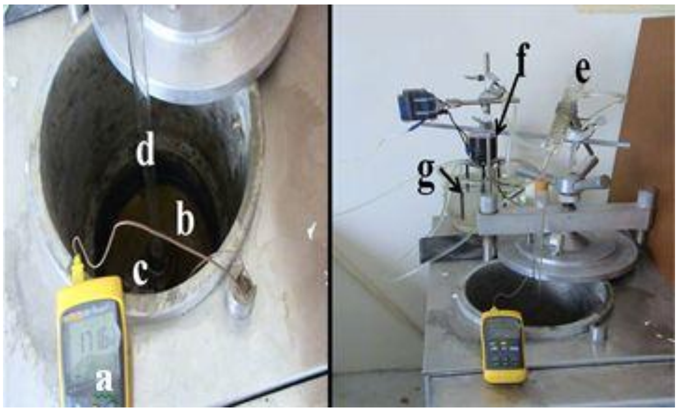

Figure 6. Electric oil-bath apparatus for delignification of seed floss of Calotropis procera: a) Thermocouple thermometer, b) oil-bath, c) spherical flask containing sample, d) Pyrex connection tube toward the condenser (e), f) hydro-pump and g) cold water for continuous cooling.

After the pulping period, the alkali-swollen was washed with distilled water until it is no more trace of NaOH. The product was kept at room temperature for 24 hours and then oven-dried under vacuum at 60 °C until constant weight was obtained.

Statistical analysis of the recorded data was done according to Steel and Torrie [27] using the analysis of variance procedure and least significant difference test (LSD) at $P \leq 0.05$.

III. RESULTS AND DISCUSSION

The average fresh weight of above ground biomass produced by one shrub of *C. procera* is presented in Figure 7. The total fresh weight (TFW) average of aerial parts was found to be about 35 kg/plant which is higher than that for neighbour sites.

The allocation of each of leaves, seeds and seeds floss are 4, 0.56 and 0.28 kg/plant, respectively. Accordingly, supposing we afforested 3 hectares of these shrubs with a fixed distance between them of 4 m, we can obtain about one ton of seeds and a half ton of their floss from only 1875 shrubs prevailing this area. In addition, about 7.5 tons of leaves can be collected from this area for sheep feeding, ethanol production, hydrocarbon extraction and/or compost making. Indeed, this concluding reflects the importance of calotrope for sustainability that forces humans and nature to exist in productive harmony permitting fulfilling the social, economic and other requirements of present and future generations.

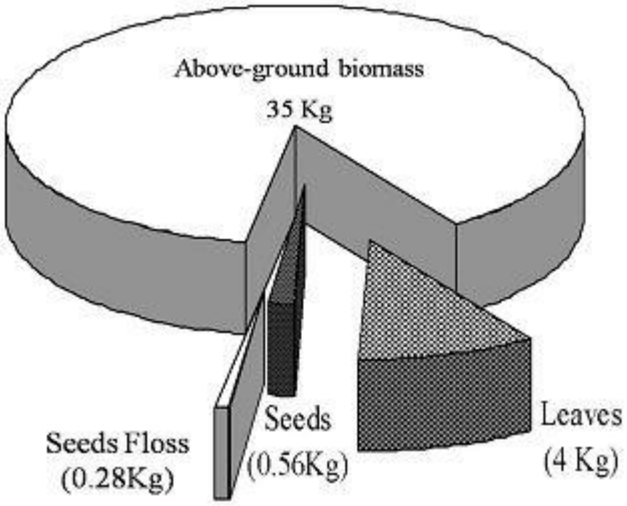

Figure 7. Fresh weights of above-ground biomass, leaves and seed floss of Calotropis procera.

The growth parameters studied of calotrope shrubs are presented in Table 1. The shrub height (3.49 m) was higher than the average scale reported by (Orwa et al.2009). The differences in the TFW as well as the growth parameters, namely SH, DOB and NB values of calotrope comparing with our neighbour sites and those previously reported may be due to either responses of shrubs to the types soil and/or claimatic conditions in their site or genetic potential of those shrubs.

TABLE. 1. MEAN VALUES OF SHRUB HEIGHT (SH), DIAMETER OUTSIDE BARK (DOB), BRANCHES NO. (BN), VESSEL DENSITY (VD) AND VESSEL DIAMETER (VD) OF *CALOTROPIS PROCERA* GROWN AT HADA AL-SHAM.

Value	SH (m)	DOB (cm)	BN	VD (unit/mm^2)	VD (µm)	
					R[1]	T[2]
Mean	3.49	10.03	10	14	124	86
Sd[3]	0.47	1.3	1.7	1.2	32	19

[1]Radial, [2] Tangential and [3] Standard deviation

of calotrope products

Fiber length (FL)

Characterization of the FL of calotrope wood is presented in Figure 8. The Fl of seed floss had the highest value (24 mm) which is comparable to that for many varieties of cotton. For more illustration, cotton fibers differ in lengths from 1.27 mm to 5.08 mm. This finding encourages its utilization in many purposes and fibrous industries either in its crude state such as oil spill sorption or after chemical treatments to purify the cellulose such as pulp and paper, cellulose derivatives synthesis like cellulose acetate and as a precursor for cellulose nanocrystal production. The uses of calotrope seed floss as an oil spill sorbent is a relatively a new gate for this raw material in cleaning our environment, since its naturally wax coated-fibers are hydrophobic.

In addition, as shown in Figure 8, the FL of macerated fibers of calotrope phloem (9.35 mm) was much higher than that for wood (1.01 mm). The FL of calotrope wood is in the range of tropical hardwood (0.7-1.5 mm) as well as many Saudi natural resources [16]. The variations in wood fiber length may be attributed to the changes resulting from the aging of cambium and modifications imposed on cambium activity by environmental conditions [28].

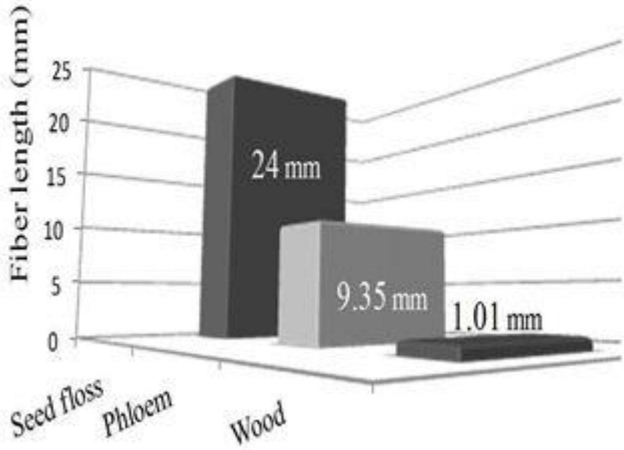

Figure 8. Fiber length of the three fiberous resources of Calotropis procera.

Since, the length of fiber greatly affects the strength of the pulp and the paper made from it, paper made from long fiber-species is expected to show higher quality than the others with shorter fibers [16]. Accordingly, blending fibers of phloem and wood of calotrope can improve paper or fiberous product quality. However, more studies, especially on the phloem fibers and seed floss, must be focused to find the best economic utilization of these potential resources.

Wood characterization

Light microscopy

The anatomical features of calotrope wood naturally grown at Hada Al-Sham habitat is presented in Figure 9 (I-IV) for transverse (I and II), radial (III) and tangential (IV) sections.

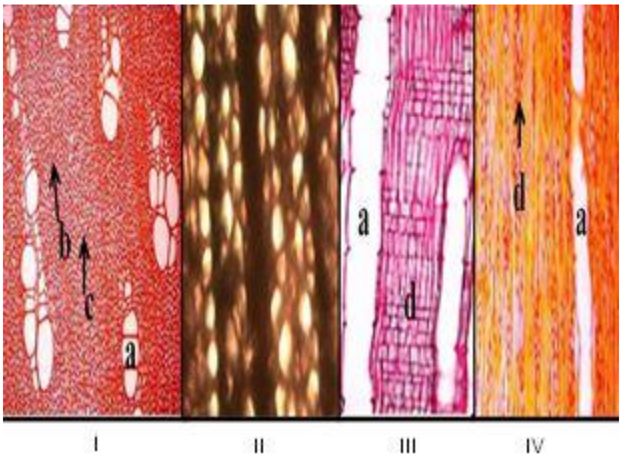

Figure 9. Micrographs of *Calotropis procera* wood sections of I&II), transverse, III) tangential and IV) radial, where a) vessel, b) axial parenchyma, c) fibers and d) a fusiform ray.

It is clear that the calotrope is a hardwood species as characterized by presence of prosenchyma cells of both vessels and fibers. Fiber cells with the thin walls and wide lumens were found to occupy most of the transverse section area (Figure 10-I and II). Further, the calotrope wood is a diffuse porous (Figure 10-I) in which the vessels or pores are even-sized, so that the water conducting capability is scattered throughout the ring instead of collected in the earlywood. In addition, the transverse sections (Figure 10-I and II) show presence of about 8-9 raws of relatively thin walled, less lignified fibers as well as axial parenchyma cells. The vessels are diffuse solitary scanty and found primarily in long chains of radial multiples and in groups of irregular arrangements of large and small pores which are circular and oval in cross section and thin walled (Figure 10-I) with a simple transverse perforation plate (Figure 10-III). The axial parenchyma is scantly scattered and inter-mixed with fibers. The rays are narrow, altered from uniseriate to tetraseriate and short to very long in height (Figure 10-IV), heterogeneous in which containing both upright and procumbent cells (Figure 10-III). As shown in Table 1, the mean values of radial and tangential diameters of vessel were found to be 124 and 86 µm, respectively. The difference in vessel diameter between both directions may be attributed to the environmental conditions and the nature of plant growth. The vessel density in the wood tissue is 14 vessels per mm.

Scanning Electron Microscopy (SEM)

Wood characterization

The SEM tangential micrographs of calotrope wood are presented in Figures 10-13. Based on Figure 10, flakes can be seen that produced from dried latex when it flooded from pores to the outer atmosphere adjacent to the cut surface. Furthermore, Figure 11 shows a high broad multiseriate ray contacting with dried latex flakes. Further, parenchyma cells and fusiform ray are also included in the micrograph.

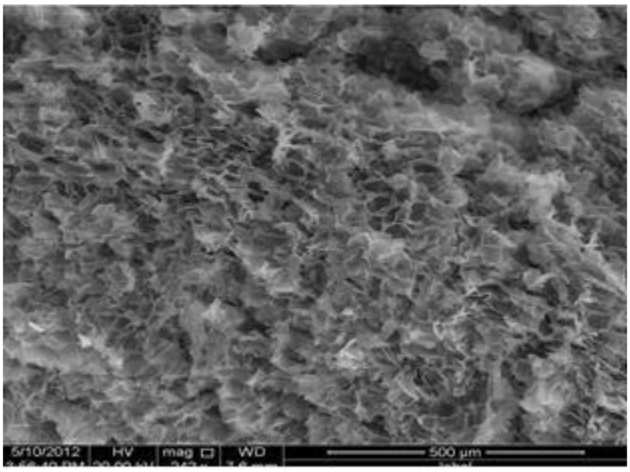

Figure 10. SEM micrograph of *Calotropis procera* wood in a cross section showing dried latex flakes.

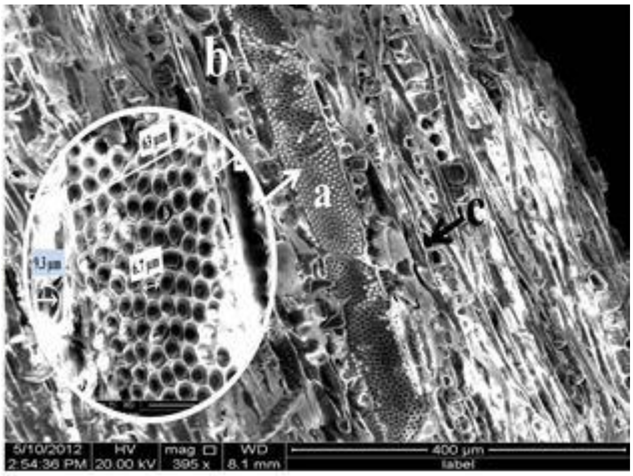

Figure 11. SEM micrograph of *Calotropis procera* wood in a tangential section showing, a) a vessel with scalariform border pits, b) a fusiform ray and c) transverse parenchyma cell.

Extending to this investigation, Figure 12 shows the same phenomenon of drying and solidification of latex when contacting the outer atmosphere adjacent to the cells of an axial parenchyma.

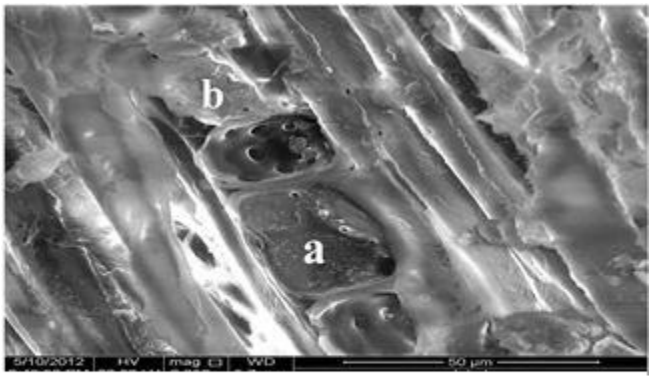

Figure 12. SEM micrograph of *Calotropis procera* wood in a tangential section showing, a) parenchyma cell and b) solidified latex flakes.

With a higher magnification, Figure 13 shows the solidified latex from a parenchyma cell constituted of a fusiform ray.

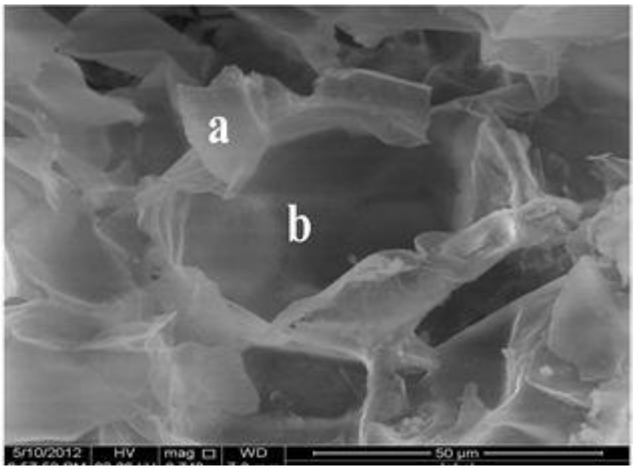

Figure 13. SEM micrograph of *Calotropis procera* wood in a tangential section showing, a) dried latex flake and b) cavity of a transverse parenchyma cell of a fusiform ray.

The SEM micrographs of calotrope seed floss are presented in Figures 14-15. It can be seen from Figure 14 that the diameter of seed floss of calotrope is 4.7 µm which is much lower than that for cotton which ranged from 15 to 20 microns [29]. However, this difference in fiber width is due to genetic potential difference between both plants.

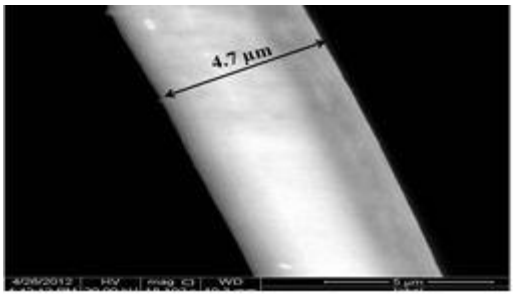

Figure 14. SEM micrograph of crude seed floss of *Calotropis procera*.

Extracted and delignified seed floss

A SEM image was picked up after completely extraction and subsequent soda-delignification of the calotrope seed floss. It is clear from Figure 15 (magnification of 351X) the changing in appearance and brightness of the chemically treated seed floss of calotrope. Further, the seed floss was shrinkaged for some extent due to losing significant part of its construction (wax, extractives and lignin) as a result of the chemical treatment. With a higher magnification ranged from 2934X to 16572X, huge shrinkage occurred in certain sites along the fibrous floss causing holes like pits. However more advanced research must be considered this finding due to its importance for purify and increasing permeability of the seed floss which has great importance in fibrous and composites industry.

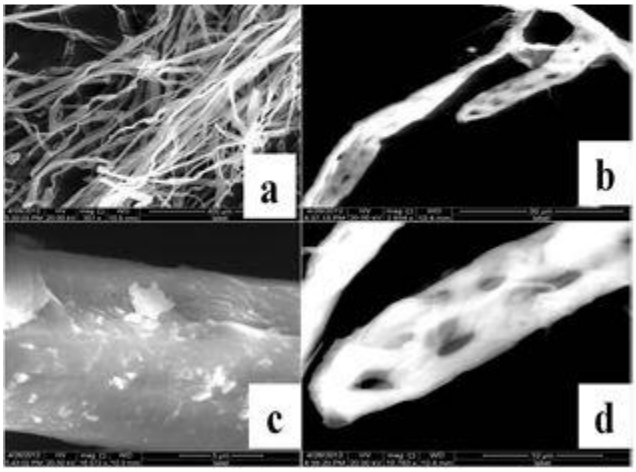

Figure 15. SEM micrographs of completely extracted seed floss of *Calotropis procera*.

X-ray diffraction characterization

X-ray diffraction (XRD) depends on creation of an interference pattern by this rays when they encounter a regularly spaced matrix such as wood. This process has been used to determine among other things the average width of the microcrystals, the percent of crystalline regions within the wood, and can be used to examine the changes in these parameters during degradation.

The wide angle X-ray diffraction pattern of the crude seed floss is shown in Fig. 16. The low angle reflections at the average of 18° were found to be broad whereas the reflection (22°) is sharp and intense. These reflections are attributed to amorphous components of the calotrope seed floss (I_{am}) and crystalline components (I_{002}) crystallographic plane arising from hemicelluloses and alpha-cellulose, respectively (Wang et al 2003). When the crystalline cellulose content is high, this peak is more pronounced, and when the fabric contains large amounts of amorphous material (such as lignin, hemi-celluloses, pectins and amorphous cellulose), this peak is smeared and appears with lower intensity [26], [30] and [31].

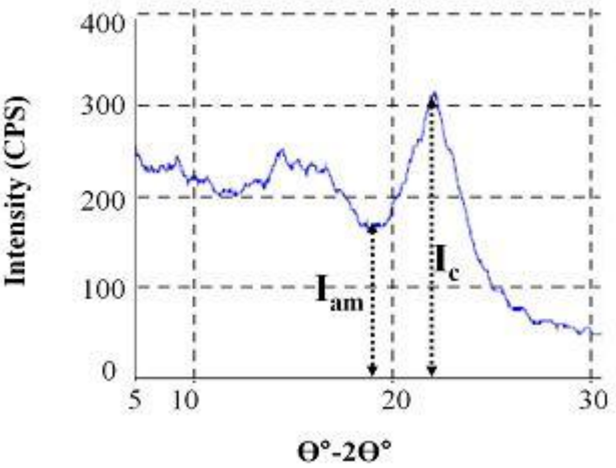

Figure 16. X-ray diffraction pattern of seed floss of *Calotropis procera* with a crystallinity index (I_c) of 46.2%.

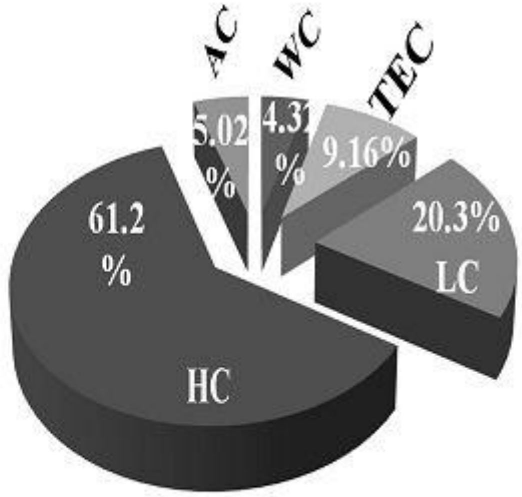

Figure 17. Holocellulose (HC), lignin content (LC), total extractives content (TEC), wax content (WC), ash content (AC) of calotrope seed floss.

Chemo-physical characterization of seed floss and wood

Chemical constituents of the calotrope seed floss and wood are shown in Figures 17 and 18. It is clear from both figures that the seed floss and wood have high contents of ash (5.02% and 5.4%, respectively), lignin (20.3% and 18.5%, respectively) and low contents of total extractives (9.16% and 11.9%, respectively) and holocelluloses (61.2% and 64.2%, respectively). It must be noticed that the holocellulose content of wood (64.2%) as shown in Figure 18 is summarized in the discussion as a sum of ∞-cellulose and hemicelluloses. However, the chemical parameters show a decrease in the fiberous quality of the calotrope than some of other conventional natural fibers such as cotton and kapok (*Ceiba pentandra*). This is due to high content of ash will negatively impact the chemical recovery process and, therefore, could constitute a serious drawback [32]. In addition, both fiberous resources contained a relatively low level of the TEC which add an important benefit to their utilization since the presence of high extractives into biotissues may interfere with the maceration reagents used to separate the fibers [16].

Furthermore, lignin content level of both resources are comparable to that for hard- and softwood. Pulping materials with low content of lignin are characterized by short pulping time and chemical charge compared to those of other non-wood raw materials [33] and [34]. Furthermore, higher contents of lignin are predicted to consume more chemicals upon the pulp industry [35]. Irrespective of their higher contents of lignin and ash as well as relatively lower content of holocelluloses, seed floss and wood of *Calotropis procera* could become important sources for fibers, chemicals and other industrial products.

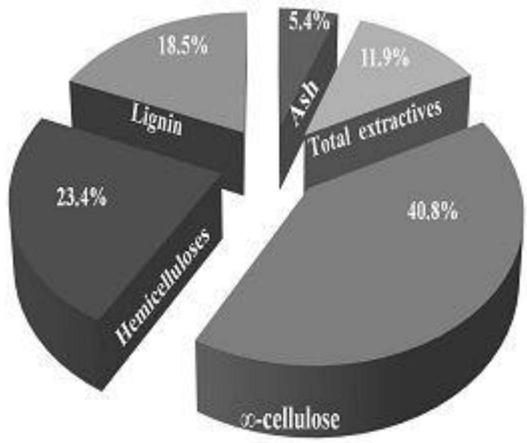

Figure. 18. ∞-cellulose, hemicelluloses (He), total extractives content (TEC), ash content (AC) and lignin content (LC) of calotrope wood.

It can be seen that from Table 2 that calotrope wood has low specific gravity (0.405) and subsequently high porous material (0.702 cm^3/g). Accordingly, the wood can be forced towards the industries that require low density and more permeabilitis for woody raw materials such as particleboards or pulp manufactures. It well known that woody materials with low SG permit to pulping reagents to penetrate more easily into their lignocellulosic tissues through a short time. However, the quality of a final fibrous product and the cost of production control the required SG level of a parent raw material [16].

The volumetric shrinkage (VS) of wood is a critical property that controls the utilizing of such woody material in industry. This is because it affect the final dimension stability of the product. The VS of calotrope wood (14.9%) was found to be present in the normal scale of the economical wood species. The referred scale ranges between 8.5 and 18.8% [36]. To overcome this defect, calotrope wood must be dried to a moisture content equals the prevailing relative moisture humidity or using suitable dimension stability treatments before or during manufacturing.

For the gross heat of combustion (GHC) of wood, it is clear from Table 2 that calotrope has a GHC (4647 cal/g) that comparable to those for hard- and softwood species. Accordingy, it can be used as fuelwood in rural village and domestic uses. It was indicated by Hindi et al [37] that wood is used as a source of energy in Saudi Arabia by direct burning especially in the remote areas, villages and during Muslim pilgrimage at Mena and Araft camps to provide heat for cooking and other conventional uses. Further, Firewood along with charcoal are sold commercially in different regions of Saudi Arabia at big public markets as well as conventional supermarkets. The wide utilization of firewood in KSA arises from Saudi habits and their preferring to the Arabic cooking flavour [37].

TABLE. 2. MEAN VALUES OF SPECIFIC GRAVITY (SG) AND VOID VOLUME (VV), VOLUMETRIC SHRINKAGE (VS), GROSS HEAT OF COMBUSTION (GHC), COLD WATER SOLUBILITY (CWS) AND HOT WATER SOLUBILITY (HWS) OF WOOD AND YIELD OF EXTRACTED SEED FLOSS (YESF) OF CALOTROPIS PROCERA.

Items	SG	VV cm^3/g	VS %	GHC cal/g
Mean	0.405	0.702	14.9	4647
Sd	0.64	0.83	1.04	157

1 Standard deviation

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