Characterization of a New Fiber From Cyperus Dichrostachus A.Rich Plant

BELETE BAYE GELAW(Lecturer) (astawl49@gmail.com)
Bahirdar University
Tamrate Tesfaye(D.r)
Bahir Dar University

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CHARACTERIZATION OF A NEW FIBER FROM *CYPERUS DICHROSTACHUS A.RICH* PLANT

Belete Baye[1], Tamrat Tesfaye[1, 2]

[1]Ethiopian Institute of Textile and Fashion Technology, Bahir Dar, Ethiopia

[2]Discipline of Chemical Engineering, University of KwaZulu-Natal, Durban, South Africa

Corresponding author. E-mail address: astawl49@gmail.com (Belete B.)

ABSTRACT: Natural fibers are of the good substitute sources for swapping synthetic fibers and reinforcing polymer matrices because of their contributions in maintaining of ecology, low energy requirement for processing and sustainability. The aim of this study is to characterize new fiber from Cyperus Dichrostachus A.Rich (CDA) plant. The CDA plant is a perennial non woody grass found in Ethiopian high lands and river basins. The fiber from this plant has good chemical composition of Cellulose (60.27 %), hemicellulose (22.72%), lignin (16.59%) contents. It is light fiber having a density of 1010kg/m^3 and good tenacity behaviour of 105.76cN/Tex with low elongation of 4.88%. The thermal stability of *Cyperus Dicrostachys A,Rich fiber* (CDAF) was studied using TGA and DTG analysis and revealed that the cellulose degraded at a temperature of 377.1°C. Fourier transform-infrared spectroscopy analysis confirmed that CDAF is rich in cellulose content. Furthermore, the properties of CDAF ensured that it can play a vital role as new reinforcement material and best alternative in bio composite industries. This will give competitive advantages when evaluated with other natural fibers reveals that there are significant potential benefits in implementation of "cleaner production" in textile material production industries. Specifically, replacement of synthetic fiber source with renewable biomass will reduce the environmental impact of these fibers. The future study will entail on investigating the possible valorization route especially in paper board, composite reinforcement and bio composite applications.

Key words: **-** Cyperus Dichrostachus A.Rich, Lignocellulosic fiber, Chemical composition Renewable biomass, Valorization.

1. INTRODUCTION

It has been obvious that numerous natural plants have been grown in different provinces of the world with fluctuating atmospheric conditions, grown in agricultural domains and after their lifetime, end up in landfills (Bartl et al., 2005, Lu and Hamouda, 2014), Some other plants have grown wild and spread around forest areas like CDA by their nature, some possess pharmaceutical properties, and others yield edible components (Jahangir Ali Fathima Benazir, 2010b).

Currently, perhaps, there have been many research works being put out recalling natural fibers in different application areas. Most research works ended with plant fibers as reinforcement in polymer matrices, home furnishings, and construction technology. They utilized even in apparel manufacturing applications. Yet, it is still obligatory to search and characterize, and add values on their current applications, with different modification techniques. Now days, new natural fibers (Vijay et al., 2019b, Gurukarthik Babu et al., 2019, Madhu et al., 2019, Vijay et al., 2019a, Manimaran et al., 2019, Liu et al., 2019, Subramanian et al., 2019, Prithiviraj an et al., 2019) for multidisciplinary applications in reinforcements (Djoudi et al., 2019, Senthamaraikannan et al., 2019), automotive engineering and packaging applications are utilized.

Starting from the 1980`s several natural fibers (Satyanarayana et al., 2007) including coir(Rencoret et al., 2013, Ash et al., 2006), sisal (de Andrade Silva et al., 2008, Morán et al., 2008, Barkakaty, 1976, Bismarck et al., 2001) pineapple (Mishra et al., 2004, Jose et al., 2016, Sapuan et al., 2011, Doraiswamy and Chellamani, 1993), jute (Thomas et al., 2015, Islam et al., 2017, Rahman et al., 2014, Ray and Sarkar, 2001), hemp (Shahzad, 2012, Wang et al., 2007), palm (Abdul Khalil et al., 2008, Al-Sulaiman, 2002, Ishak et al., 2011), banana (Guimarães et al., 2009, Deepa et al., 2011, Jayaprabha et al., 2011, Ganan et al., 2004), and other fibers have been characterized and employed for many applications just like reinforcement in polymer matrix of composites.

Ethiopia can nurture a diversity of naturally fiber-forming plants. One of the most common plant that is currently grown commercially and could be of interest for handcrafting, packaging and traditional equipment is *Cyperus Dichrostachus A. Rich*) plant (CDA)(Reid et al., 2014, Bayeh, 2013, Chekole, 2011, Larridon et al., 2011a). It is just a tough plant, traditionally used for the weaving of huts, mats, and baskets in Ethiopia and different countries in Africa (Debnath, 2020, Larridon et al., 2011b). It has a decorative nature used to weave baskets, sleeping and sitting mats, rolled twines, more traditionally

cereal and crop baskets, food baskets, crop and powder filters, covering equipment for cooking devices and other home apparatus.

Yet, apart from traditional craftworks, there are no research works done on this plant regarding the characterization and modification of its intrinsic properties. Therefore, adaptation of this fiber into valuable goods was the motivation of this research work with technologies employed to transform into beneficial products with characterized physical, mechanical, and chemical properties of the fiber. Most of these distinctive features were determined throughout the progress of the plant and successive fiber drawing out or extraction stages. The paper investigated the physical, morphological, chemical, thermal, and mechanical properties of CDA fiber with detailed scientific justifications.

Because, Even though there are trends in using and utilizing of CDA plants for different applications in different literatures, no one has tried to extract and characterize this plant for fibrous applications especially for textile and composite manufacturing applications. Therefore, the aim of this research work was at studying and characterizing CDA plant fibers for different applications as reinforcement for composite manufacturing, basketry, carpet making and in textiles based on the inherent characteristics.

2. Materials and Methods

2.1. Materials

1. **CDA plants:** Well matured CDA grass fibers as shown in Figure 1 that have been used for this study were collected from Chiss Abay around the Blue Nile River, Bahir Dar, Ethiopia and extracted its stem for characterization.

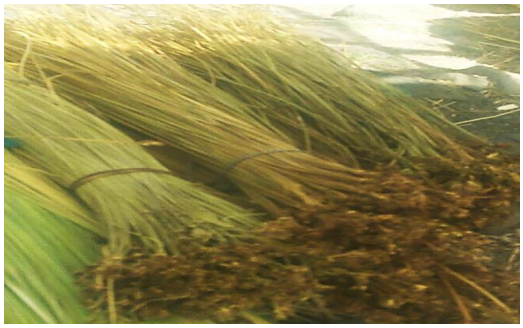

Figure 1: non woody CDA stems

2. **Equipment**: In this research, different equipment was utilized throughout the course of the study to study the chemical, physical and thermal properties of extracted CDAF.

3. **Chemicals and Reagents**: different chemicals have been used to achieve the objective of the research including sodium hydroxide, distilled water.

2.2. Methods

2.2.1. Extraction Methods:

The CDA fibers are extracted at optimum extraction process by considering four influencing factors of 1.7% NaOH, 30℃ temperature, 6:1MLR and 90-minute extraction time.

2.2.2. Characterization methods

In order to determine the suitability of using extracted CDA fiber as a renewable fiber source for the production of high-value materials, it was important to understand their physical and chemical properties. In this section methods of such comprehensive characterization are reported.

2.2.2.1. Physical properties

The characterizing of physical properties of the fiber was characterized well after the extraction process as described by the following sections

2.2.2.1.1. Fiber density

The density of the CDA fiber was measured using a liquid pycnometer and the chemicals used were distilled water, paraffin and acetone. Five replicates were performed for each sample type and the density were calculated using the **Error! R eference source not found.** as per ASTM-D1577–01, 2005 standard (*Arbelaiz et al., 2005)*

$$\rho\left(\frac{g}{cm3}\right) = \frac{m_2 - m_1}{(m_3 - m_1)(m_4 - m_2)}\rho t \quad (1)$$

Where ρt =is the density of distilled water $(g/cm3)$, m_1 =is the mass of empty pycnometer (g), m_2 = the mass of pycnometer with fibers (g), m_3 =the mass of pycnometer with distilled water (g) and m_4 = the mass of pycnometer with fibers and distilled water (g) (Indran, 2015).

2.2.2.1.2. Light Microscopic analysis

The aspect ratio, shape of the fiber, and diameter of the fiber were measured using optical microscope. For fiber diameter analysis, thirty five distinct fiber samples have been considered; and from the microscopic images were taken along the longitudinal direction (A. Arul Marcel Moshi, 2019). The diameter was measured by the microscope

built with video analyzer and camera. After calculating the average value of diameter, the diameter of extracted CDAF was compared with various plant fibers.

2.2.2.1.3. Linear density

The count of the extracted fibre was calculated in Tex units and measured by single-fiber weighing method through which the length of a single fiber was measured and the fiber was weighed as per the ASTM D 2257 standard. Then linear density (Tex) was estimated using **Error! Reference source not found.** to compare the fineness of the e xtracted fiber with other plant fibers.

$$\text{Fiber Count (Tex)} = \frac{\text{wt(g)} \times 1000}{\text{Length(m)}} \qquad (2)$$

2.2.2.1.4. Diameter

The diameter of CDA fibers obtained from the single cells was studied using an optical Microscope, built in video analyser LEIKA to measure the thicknesses of the single fibers as per the ASTM D3171 (1990) standard. Statistical analysis was done to compare the fiber diameter between CDAF and other fibers (*Arul, 2019*).

2.2.2.1.5. Tensile test

The tensile test was carried out using FAVIMAT+ FIBRE TEST machine as per the ASTM D 3822-07 standard. The test was performed with the fiber samples of gauge length value 20 mm on the normal room temperature environment with 65% relative humidity at a cross head speed of 20 mm/min. Twenty samples were tested and their average value has been noted as the nominal tensile strength value of the fiber (A. Arul Marcel Moshi, 2019)

2.2.2.1.6. Estimation of moisture regain and moisture content

Moisture regain of CDA fiber was measured according to the ASTM D 1776/D1776M-16. The samples were kept in humidity chamber at 65% RH and room temperature for a set period of time and by oven drying the fibers at 105°C. The moisture regain was calculated as the ratio of the amount of water absorbed to the dry weight of the sample and the moisture content calculated as the ratio of the amount of moisture absorbed by the fiber to the original mass of the fiber before oven drying.

$$\text{moisture regain}(\%) = \left(\frac{W}{O}\right) \times 100 \quad (3), \text{Moisture content}\ (\%) = \left(\frac{W}{(\text{original wt})}\right) \times 100 \quad (4)$$

Where;W =Weight of water in the fibers (g); O=oven dry fiber weight (g)

2.2.2.1.7. Thermal property analysis

A thermo-gravimetric Analyzer, TGA 4000 Perkin Elmer machine was used to measure the degradation characteristics, the mass and transformation of CDAFs in nitrogen atmosphere with flow rate of 20 ml/min (N. Saravanan1 2016, Senthamaraikannan, 2015, Indran, 2015). All the measurements were examined with aluminum crucible (Saravanakumar, 2013) for good coupling between the sample and the temperature measured by the thermocouple in a temperature range from 30°–700°C at a heating rate of 20℃/min.

2.2.2.2. **Analysis of Chemical Composition**

Chemical analysis was performed to determine the contents of cellulose, hemicellulose lignin, wax, moisture, and ash of CDAFs by following conventional chemical analysis techniques as stated in **Error! Reference source not found.** (A. Sluiter, 2008, HYPERLINK \l "_ENREF_52" \o "reaffirmed, 2006 #18" reaffirmed, 2006). Chemical analysis of the extracted CDAF was performed by adapting TAPPI methods (Effland, 1977, Macmillan et al., 1952)

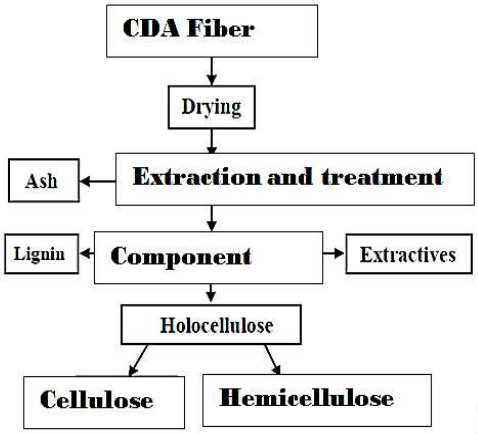

Figure 2: Schematic representation of chemical analysis of CDA fiber

2.2.2.2.1. **Estimation of Lignin content**

The TAPPI T222 method (Pleitner et al., 2019) was with pre-hydrolysis of the extracted sample with 72 wt. % sulfuric acid at room temperature for 2 hrs to determine content of acid-insoluble lignin (Pleitner et al., 2019, Effland, 1977, Ioelovich, 2015, Jahangir Ali Fathima Benazir, 2010a). Then the concentrated acid was diluted with distilled water, and the sample was hydrolyzed with dilute 3% acid at boiling temperature for 4 hrs. Thereafter, the acidic dispersion of lignin was filtered through filter paper having average pore size of 11 µm. The residue of lignin was washed on the filter with hot

water up to neutral pH followed by drying at 105oC to constant weight. Accordingly the extracted CDAF sample 3 g was mixed with 150 mL of 72 % sulfuric acid in 500-ml flask and pre-hydrolyzed at room temperature for 2 hrs. (Jahangir Ali Fathima Benazir, 2010a). The concentrated acid was diluted with 3450 mL distilled water and the sample was hydrolyzed with dilute acid on a heating plate at boiling temperature for 4hours using flask beakers. After cooling at room temperature for 30 min, the acidic dispersion of lignin settle overnight and the liquid phase becomes transparent. There is an evidence that from sedimentation experiments under the used sediment time, a minimum particle radius of acid-insoluble lignin is estimated at 100 nm (Ioelovich, 2015). The sediment of lignin was washed with hot water and with distilled water to a neutral media, separating the liquid phase from lignin by sedimentation followed by filtration with a filter paper. The washed lignin was dried with aluminum sheet at 105^{o}C to constant weight. The percentage of acid-insoluble lignin (AIL) in the extracted fiber sample was calculated by the equation 5 below (Ioelovich, 2015):

$$\mathrm{AIL} = \frac{\mathrm{P} - \mathrm{Pt}}{\mathrm{Ps}} 100\% \quad (5)$$

Where P is weight of dry acid-insoluble lignin with Aluminum sheet; Pt. is weight of empty aluminum sheet; and Ps is weight of extracted and dried CDAF sample.

2.2.2.2.2. Estimation of Cellulose and Hemicellulose content

The determination of cellulose and hemicellulose was based on the separation of holocellulose which contain both cellulose and hemicelluloses. First the extracted CDAF sample, 2 g, was placed into 200ml flask, and then160 mL distilled water, 2.0 g sodium chlorite ($NaClO_2$) and 4 mL glacial acetic acid were added into the flask. The flask was covered with Petri dish and put into a water bath with a temperature of 90^{o}C and treated for 1hr though magnetic stirring. Then to the flask an additional portion of 2.0 g sodium chlorite and 4 mL acetate buffer was added, and the treatment was continued again for an hour. After cooling at room temperature for 45 min, a dispersion of holocellulose was poured out into 500mL beaker and settled overnight. The sediment of holocellulose was washed with hot water, and finally with distilled water up to a neutral pH, separating the liquid phase from holocellulose by sedimentation overnight. The washed holocellulose was dried in the Aluminum sheet at 105^{o}C to constant weight. Then the percentage of holocellulose in the extracted CDAF was calculated by equation 6:

$$HC = \frac{P - Pt}{Ps} \times 100 \qquad (6)$$

Where P is weight of dry holocellulose together with Aluminum sheet; Pt. is weight of empty Aluminum sheet; and Ps is weight of extracted and dried CDAF sample (Pleitner et al., 2019, Ioelovich, 2015). Then the content of cellulose was achieved from holocellulose hydrolyzed with dilute hydrochloric acid to remove hemicelluloses based on the TAPPI T201 wd-76 and TAPPI T 9, wd-75 standards (Effland, 1977; Macmillan et al., 1952; Sluiter, 2008; Reaffirmed, 2006; Loelovich, 2015; Pleitner et al., 2019).

The dried holocellulose sample was mixed with 180 mL of 2% HCl in 500-ml flask, and the sample was hydrolyzed with the dilute acid at boiling temperature for 2 h followed by cooling at room temperature for 30 min. then the acidic dispersion of cellulose was segmented overnight for 1hr. The sediment of cellulose was washed with hot water, and finally with distilled water to a neutral pH, monitored by separating the liquid phase from cellulose by sedimentation and filtration with a filter paper. Then the cellulose was dried in aluminum sheet at 105^{o}C to constant weight. The percentage of cellulose and hemicelluloses in the extracted CDAF was calculated as cellulose(C) and hemicellulose (H) in the extracted CDAF respectively:

$$C = \frac{HC*(p-Pt)}{Ps} \ldots (7) \quad \text{and} \quad H = HC - C \ldots (8)$$

Where HC is percentage of holocellulose; P is weight of dry cellulose together with flask; Pt. is weight of empty flask; and Ps is weight of extracted and dried biomass sample.

2.2.2.3. **Fourier Transform Infra-red (FTIR) Spectroscopy**

FTIR Spectrometer, Spectrum (Perkin Elmer) was employed to identify the functional groups present in the CDA fiber (N. Saravanan1 2016, NagarajaGanesh, 2016). The sample was compressed using a mechanical pressure pellet maker for 1 minute at 65 kg/cm^2 pressure condition to form pellets of small sizes. The spectrum was recorded in the range of 4000 to 400 cm^{-1} with 32 scans per minute and with the resolution of 4 cm^{-1}.

3. RESULTS AND DISCUSSION

3.1. Physical properties

3.1.1. Diameter

The diameter of the fiber was found to 9.85±7.16µm (**Error! Reference source not found.** and Figure 3). From this value, we have concluded that the fiber has ability of excess removal of non-cellulosic particles like lignin, wax and other impurities with some fibrous particles during extraction. The fibers exhibited non-uniform diameter from end to end indicates that the non-uniformity of fiber girth thickness may affect the spin ability and flexibility of the fiber in end use applications.

Table 1: Physical properties of CDAF by different extraction methods

Parameter	Results for the extracted fiber
Diameter (μm)	9.85±7.16
Strength(cN/Tex)	247±87.68
Moisture regain (%)	12.83±1.99
Linear density(g/km)(tex)	0.51±0.244
Fiber density (g/cm^3)	1.22±0.52
Elongation (%)(single test)	7.75±1.84
Density (Kg/m^3)	1010±269

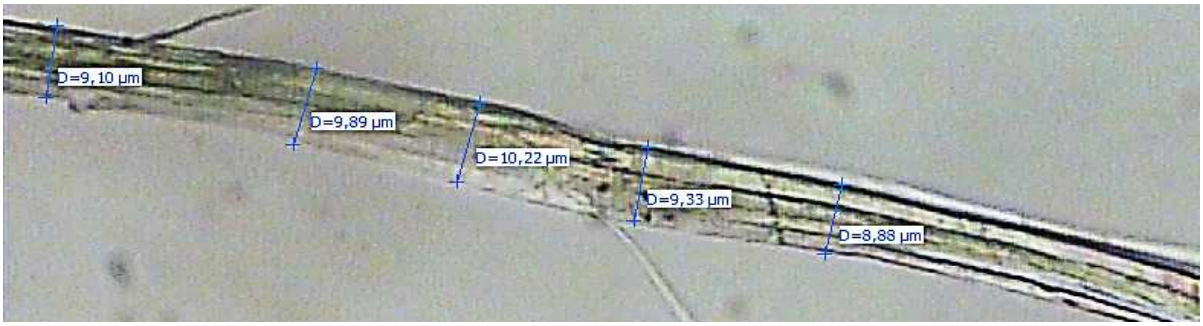

Figure 3: Fiber diameter under optical microscope

3.1.2. Tensile Strength

The bundle test results showed that the tensile strength of 140.55 CN and elongation 3.6% has greater resistance against tensile loading and exhibited higher tensile properties. The fiber has high number of OH-groups in the fiber and removal of non-fiber parts that give additional strength and elongation for the fiber. On the other hand the tensile strength of a single CDA fiber was found to be 105.76±87.68 cN/Tex with

8.95±2.64% of elongation for each individual test. As compared to the tensile strengths of other fibers like flax (88-1500 Mpa), Hemp (550-900 Mpa), jute (400-800 Mpa), kenaf (240-600 Mpa), and nettle (650-1594Mpa), CDAF has better strength for varied applications.

3.1.3. Fiber density

The fiber density was found with 1010kg/m^3. Density measurement was given equal importance to the mechanical property study since it highlights the natural fibers from synthetic fibers. From this fact, we can understand that the fiber has lightweight for different home furnishing applications, composites and roof layering. The density of the new fiber is very nearest to the natural fibers obtained from Bagasse (1200 kg/m^3), Coir (1250 kg/m^3), Jute (1300 kg/m^3) (A. Arul Marcel Moshi, 2019), Cyperus pangorei (1102 kg/m^3), and Bamboo 600-1100 kg/m^3) (Marimuthu2, 2011, Fatin . Mahir, 2019). When compared with other natural fibers; the density of the CDA fiber was less than that of Banana fiber (1350kg/m^3), pineapple leaf fiber (1400kg/m^3), Kenaf fiber (1310kg/m^3), Cotton fiber (1600kg/m^3), sisal (1330 kg/m^3), Flax (1400kg/m^3), and higher than Coconut (800 kg/m^3), and palm fibers (920 kg/m^3) (A. Arul Marcel Moshi, 2019, P.G.Baskaran, 2017, Mabrouk Maache, 2017) as shown in table 2.

3.1.4. Longitudinal and cross-sectional property of the fiber

The longitudinal interface of the fibre under a Microscope, Built in Video analyser LEIKA ((NagarajaGanesh, 2016) showed that the fibre has some convolution and twisted structures along its length with smooth, uniform and good appearance and cross-section. The cross-sectional view showed some hollow and peak structure that shows the fibre may have irregular cross-section as illustrated in figure 4.

Figure 4: Longitudinal view of the fiber

3.1.5. Moisture regain

The moisture regain of CDAF was 12.40±1.75 and the moisture content was 11.01± 1.38%. CDA fiber has a good and comparable moisture property like other natural fibres. The comparison of the physical properties and tensile properties of CDAF with other few natural fibers is presented in table 2.

Table 2: Comparison table of physical and tensile properties of CDAF with other natural fibers

Fiber	Tensile Strength (MPa)	Young's Modulus (GPa)	Density (g/cm3)	Elongation at break %	Reference
Flax	88-1500	60-80	1.4	1.2-1.6	(Fatin . Mahir, 2019) (A. Arul Marcel Moshi, 2019) (Marimuthu2 , 2011, Fatin . Mahir,
Hemp	550-900	70	1.48	1.6	
Jute	400-800	10-30	1.46	1.8	
Ramie	500	44	1.5	2	
Coir	220	6	1.25	15-25	
Sisal	600-700	38	1.33	2-3	
Cotton	400	12	1.51	3-10	
Kenaf	295	-	1.2	2.7-6.9	
Bagasse	20-290	19.7-27	1.2	1.1	
Pine apple	170-1672	82	1.5	1-3	
Banana	355	33.8	1.35	53	
Coconut	131-175	4-13	0.8	15-40	
Borassus	65.2	4.918		47.2	
Piassava	134-142	1.07-4.59		6.4-21.9	
Bamboo	503	35.91	0.6-1.1	1.4	

Palm	97-196	2.5-5.4	0.92	2-4.5	2019)
Nettle	650	38		1.7	
Cyperus pangorei	196±56	11.6±26	1.102	1.69	
CDAF	**951.84±789**	106.35	**1.010**	**4.88±2.64**	**This work**

3.1.6. Thermo gravimetric Analysis

It is obvious that natural fibers encompass cellulose, hemicellulose, and lignin, by which their amount contributes for the thermal stability of the fibers. Consequently, the degradation temperatures of these components of CDA fiber play a noteworthy role to assess the thermal stability of its constituents. Moreover, the thermal stability of the CDA fiber components was studied to estimate the opportunity of its application as reinforcement in composite and other manufacturing sectors. The thermogravimetric analysis (TGA) and derivative thermogravimetrics (DTG) of CDA fiber is shown in figure 5. The initial degradation of the fiber is noticed (at 82.2°C) between room temperature and 109°C; this was due to the dehydration of the fiber (M. Prithiviraj, 2016). The succeeding foremost degradation evolved from the temperature region of 110-410.5°C in which a peak quite close to 167.6°C related to thermal depolymerisation of hemicelluloses, and some fraction of cellulose and lignin components(Yang et al., 2007) with 22.9% of mass loss. Hemicellulose started its decomposition easily, with the weight loss mainly happened at 220–330℃(Yang et al., 2007). A very prominent peak at 377.1°C revealed a major mass loss of about 66.3% due to the breakage of glycoside bonds of cellulose and alpha and beta alkyl ether linkages of lignin (Kommula et al., 2016) lead to the degradation of cellulose. Similar results were also observed at 331.1°C for Prosopis juliflora, 321°C for bamboo, 308.2°C for hemp, 298.2°C for jute and 309.2°C for Kenaf fibers (M. Prithiviraj, 2016).

Figure 5 show that there is little difference only in % mass loss rate of the CDA fiber. This shows that part of the foreign matter and organic components have been removed by the alkali treatment and increase the percent loss and contribute for some amount of mass loss rate in the fiber.

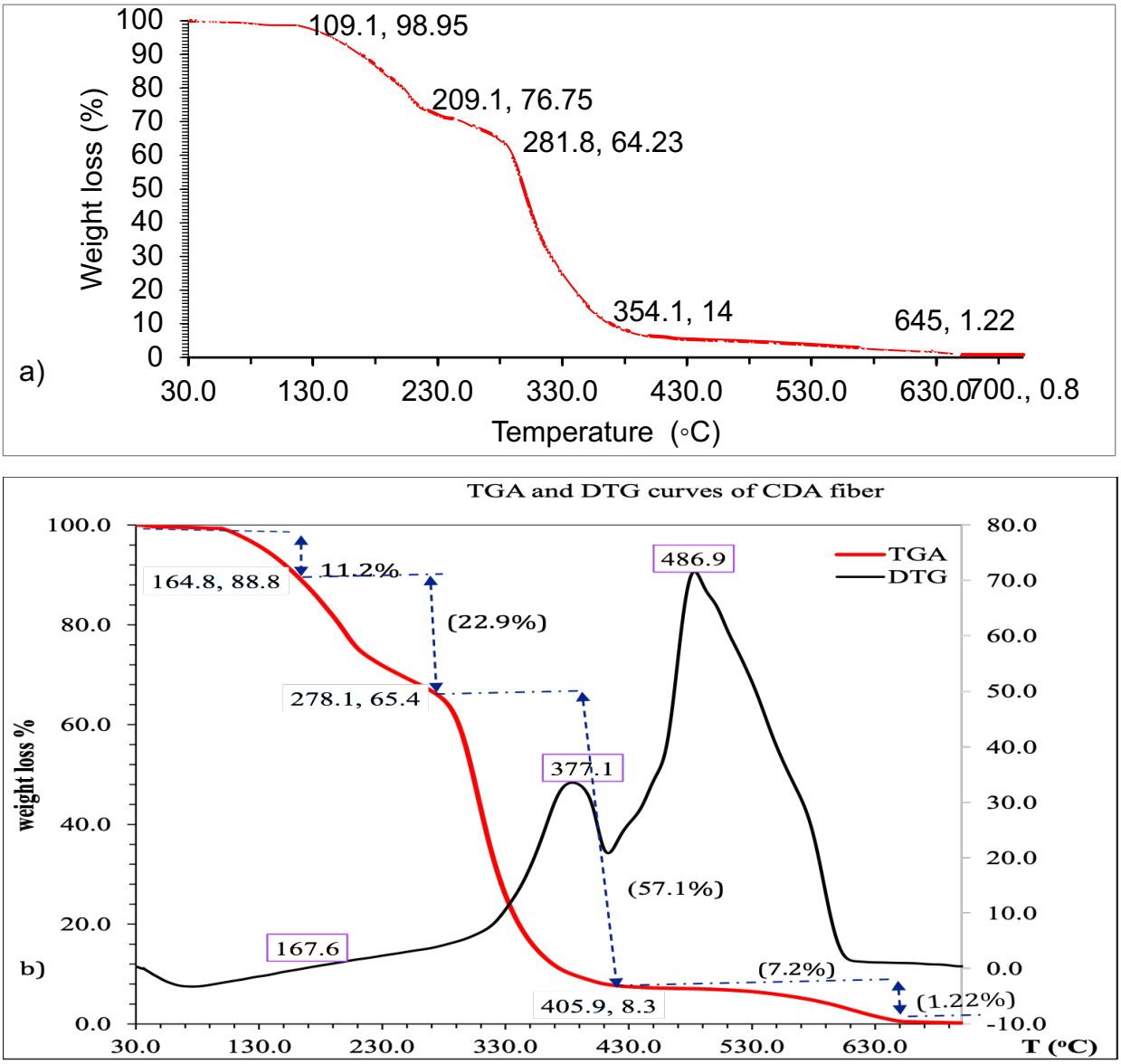

Figure 5: Thermogravimetrics of HWECDA fibers

TGA (a) and DTG vs TGA (b)

Moreover, the differential thermo gravimetric (DTG) curve contribute a more complete determination of temperatures of the onset and termination of the peak about temperature of the maximum rate of combustion reaction of the fiber (Titok et al., 2006). From the analysis of the DTG curve of CDA fiber, it has shown that after moisture removal from the sample, the primary decay peak was in the temperature range of 268.2-410.5°C (the maximum at 377.1.°C) that corresponds to the thermal destruction of cellulose components(Yao et al., 2008).

The second peak was positioned within the range of 410.5-607.5°C with the maximum at 486.9°C that follows the maximum rate of lignin thermal destruction(Murugan et al., 2008, Draman et al., 2014). Therefore, from the DTG curve it can be justified that the fiber has more amount of cellulose than hemi-cellulose and lignin components. The summary is shown in Table 3 below.

Table 3: Summary of TGA result

Temperature /peaks	Stage of degradation	Degraded/decomposed Component	Reference
Between room temperature and 109°C	Initial degradation of the fiber (at 82.2°C)	Dehydration of moisture present in the fiber (11.2 %)	*Prithiviraj, 2016*
110°-410°C	Thermal depolymerisation	Hemicelluloses, and some fraction of cellulose and lignin components	*Yang et al., 2007*
220–330℃	Decomposition	Loss (22.9%) of Hemicellulose	*Yang et al., 2007*
377.1°C	Breakage of glycoside bonds of cellulose and α and β −aryl-alkyl-ether linkages of lignin	Degradation (57.1%) of cellulose	*Prithiviraj, 2016* (Kommula et al., 2016)

3.2. Analysis of chemical composition

The chemical composition of CDAF is presented in table 4. CDAF has estimated cellulose content of 60.27±9.3% which is higher than that of kenaf (53.14%), Bamboo (26 – 43%), Wheat straw (51%), Coconut tree leaf sheath (27%), Piassava (28.6%), and Kudzu (33%), Sea grass (57%. The CDAF has 22.72±9.61% of hemicellulose, which is greater than Flax (18.6-20.6 %), Ramie (13-16 %), Hemp (15– 22.4), Bamboo (30%), Wheat straw (15-31 %), Coconut tree leaf sheath (14%), Piassava (25.8%), sisal(12%), Prosopis juliflora (16.14%), and less than Napier grass strands (31.27%) (A. Arul Marcel Moshi, 2019, TP.Sathishkumar, P.G.Baskaran, 2017, Mabrouk Maache, 2017).

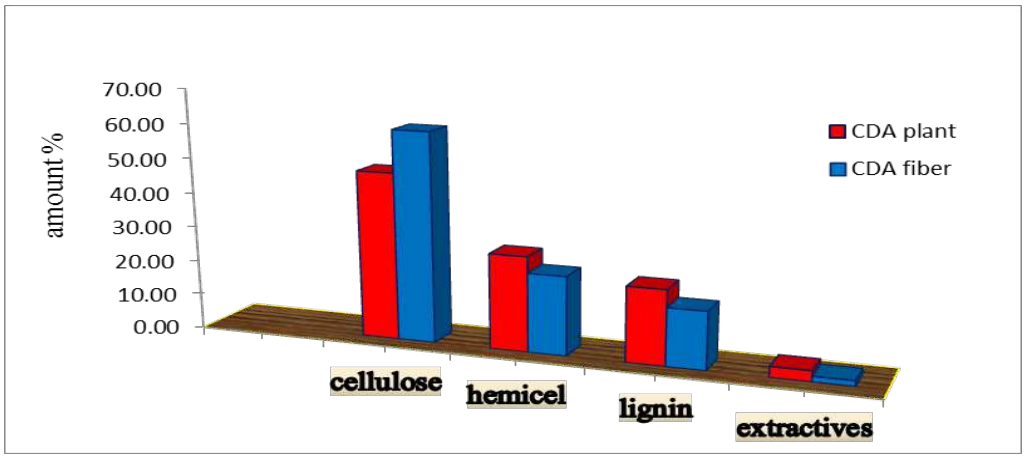

Figure 6: Chemical composition of CDA plant before and after extraction of the fiber

The above **Figure 6** shows that there is a significant difference in chemical composition of the CDA plant before extraction and the chemical composition of the extracted fiber. This shows that part of the lignin and hemicellulose components have been removed by the alkali treatment and increase the number of OH groups and contribute for the high amount of cellulose in the fiber.

Table 4: Chemical composition of CDA before and after extraction

	Cellulose (%)	Hemicellulose %	Lignin %	Extractives %	Ash%	Moisture content %
CDA plant	48.12	27.36	21.53	3.05	---	2.88
CDA fiber	60.27±9.3	22.72±9.61	16.59±0.32	1.55±0.003	1.30	11.01±1.38

As shown in the above table; CDAF contains optimum hemicellulose (22.72±0.32%) and high lignin (16.59±0.32%) contents. The optimum hemicellulose content has gave good contribution for biodegradation, moisture absorption, and thermal decay of the fiber, *(Mabrouk Maache, 2017).* Higher ranges of lignin help to retain water within the fiber, which safeguards the fiber from biological attacks (P.G.Baskaran, 2017);

Furthermore CDA fiber has 1.55±0.003% extractives of wax and pectic substances which comprises less portion of wax content that enhance easier composite production for the fact that the bond between the matrix and the fiber become higher for fabricating of the composite structures with this fiber. When compared with other natural fibers just like Flax (1.5-1.7 %), Sisal (2%), Nettle (3.1–4.2%), Okra (3.9%) and Abaca fibers (3%) have comparably higher percentages of wax content than CDAF which has 1.55% of wax. The lesser percentage of wax enables chemical treatment, and it can also afford

an improved cohesive bonding between the fiber and composite matrix (Jahangir Ali Fathima Benazir, 2010a).

The ash content (1.3 %) of CDAF was found to be lower when compared to other natural fibers like *Cyperus pangorei* (3.56%), *Prosopis juliflora* (5.2%). The data showed that lighter composites can be prepared by using CDAF in polymer matrices. CDA fiber has similar properties in composition with *Cyperus pangorei* fibers of *(*68.5% cellulose, 17.88% lignin, 0.17% wax, 9.19% moisture content and 1102kg/m^3 density (M. Prithiviraj, 2016).

More importantly the chemical composition of the CDAF has compared with different plant fibers as shown in Table 5 and revealed that the fiber has comparable chemical composition in all aspects.

Table 5: Comparison of chemical composition of CDAF

Fiber	Cellulose (%)	Hemi Cellulose (%)	Lignin (%)	Wax (%)	Reference
Bamboo	26-43	30	21-31	----	(Fatin . Mahir, 2019)
Ramie	76	15	1 - 8.0	----	(A. Arul Marcel Moshi, 2019, N. Sgriccia a, 2008)
Flax	71	18.6-20.6	2.2	1.5	(Fatin . Mahir, 2019, N. Sgriccia a, 2008)
Kenaf	72	20.3	9	----	(Fatin . Mahir, 2019, N. Sgriccia a, 2008)
Jute	61-71	14-20	12-13	0.5	(Fatin . Mahir, 2019)
Cotton	82.7	5.7	----	----	(Fatin . Mahir, 2019)
Hemp	68	15	10	0.8	(Fatin . Mahir, 2019)
Ramie	68-76	13-16	0.6-0.7	0.3	(Fatin . Mahir, 2019)
Abaca	56-63	20-25	7-9	3	(Fatin . Mahir, 2019)
Sisal	65	12	9.9	2	(Fatin . Mahir, 2019)
Coir	32-43	0.15-0.25	0-45	----	(Fatin . Mahir, 2019)
Wheat Straw	38-45	15-31	12-20	----	(Fatin . Mahir, 2019)
Rice husk	35-45	19-25	20	----	(Fatin . Mahir, 2019)
Rice straw	41-57	33	8-19	8-38	(Fatin . Mahir, 2019)
Henequen	60	28	8	0.5	(Rajini, 2019)
Agave	68.42	4.85	4.85	0.26	(Fatin . Mahir, 2019)
Banana	60–65	6–8	5–10	----	(Fatin . Mahir, 2019)
Nettle	53–86	4–10.3	3.5–9.4	3.1–4.2	(Fatin . Mahir, 2019)
Prosopis juliflora	61.65	16.14	17.11	0.61	(Fatin . Mahir, 2019)

Cyperus pangorei	68.5	----	17.88	0.17-1.7	(Fatin . Mahir, 2019)
Napier grass	47.12	31.27	20.63	----	(Reddy et al., 2012, Fatin . Mahir, 2019)
CDAF	*60.27±9.3*	*22.72±9.61*	*16.59±0.3*	*1.55*	*This work*

3.2.1. FTIR Analysis

Fourier-transform infrared spectroscopy is utilized for characterizing lingo cellulosic fiber to identify chemical compounds in a wide range of capacities, by considering the infrared features and transmittance bands of their constituents (Vignesh et al., 2016). The FT-IR spectrum of CDA fiber is presented in Figure 7and the detailed is shown in Table 6.

Table 6: The functional group analysis result with FTIR

Peaks (cm^{-1})	Functional Group	Composition	References
3751 3344	Strong O-H stretching	Cellulose and its structure	Reddy et al., 2009
2906	Vibration of methyl and methylene groups, C-H stretching vibration	Cellulose and hemicellulose molecules	Reddy et al., 2009)
2504	CH_2 symmetrical stretching	Wax	Sarikanat et al., 2014
1923	Carbonyl group	Hemicelluloses	Sarikanat et al., 2014
1739	C=O group stretching vibration of the ester group	Hemi-cellulose or carboxylic acid in lignin	Sarikanat et al., 2014
1440 1337 1318	CH2 deformation, CH_2 wagging, and CH_3 bending,	Lignin	Yang et al., 2007, maheswari et al., 2012
1241	Stretching of C-O due to the vibration of the acetyl group	Lignin	Maheswari et al., 2012
1164	C-O-C groups asymmetric bridge stretching,	Hemicellulose and cellulose molecules	Maheswari et al., 2012
1055	C–O aromatic ring and skeletal vibration of C-O-C	Cellulose	Kommula et al., 2016
895	B-glycosidic linkages between the sugar units	Hemicellulose and cellulose molecules	Suryanto et al., 2014
690	C–H bond of aromatic hydrogen	Lignin compound	Suryanto et al., 2014

523	Out of plane bonding of OH		Kommula et al., 2016

The spectral graphs create the functional group sketch of the fiber, a distinguishing molecular fingerprint that can screen out and scan samples for diverse components of the fiber, and detect functional groups, distinguish the covalent bond relationship figures. In general, from the FTIR result of CDAF, we can concluded that the fibre has very well-known chemical compounds the can be depicted from their functional groups. Its composition of the functional groups is comparable with other well-known natural cellulosic fibres.

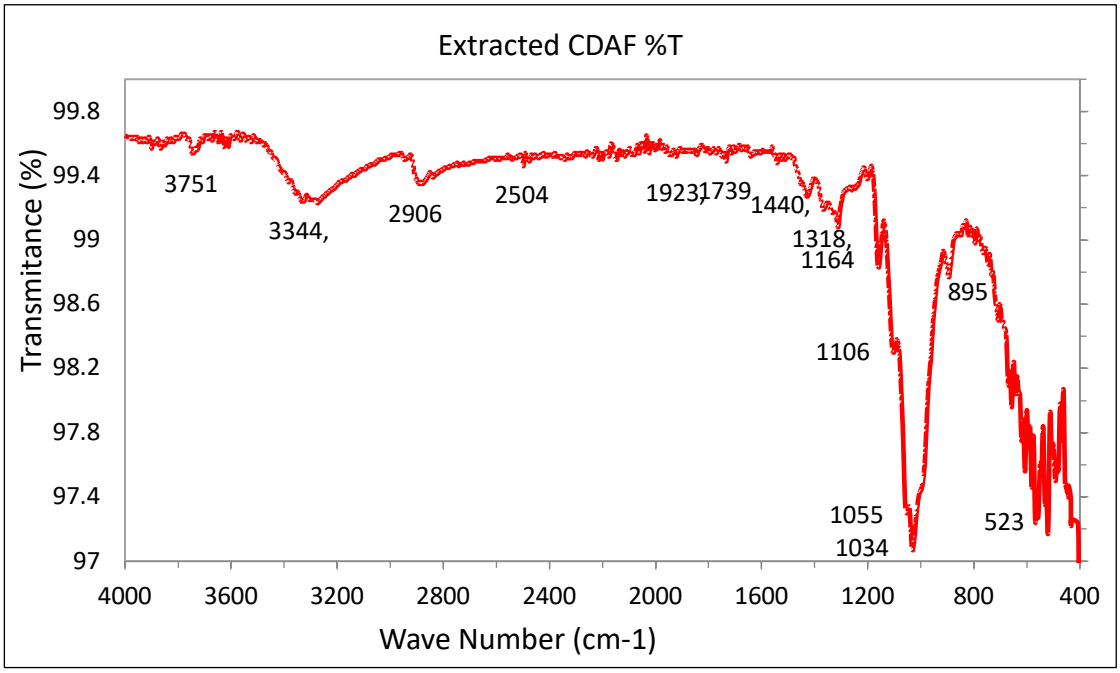

Figure 7: FTIR spectral Analysis curve for extracted fibers

Figure 7 shows that there is a significant difference only in % transmission of the CDA fiber prepared from the two extraction methods. This shows that part of the foreign matter pectic components have been removed by the microbial action and increase the percent transmission in CWEF and give for the high amount of transmission in the fiber.

4. Conclusions

Now days, the need for recyclable, renewable and sustainable materials has brought about the amplified consumption of natural fibers for reinforcing polymers to outfit a wide variety of applications. This study was mainly focused on the extraction and characterization of the lignocellulosic fiber derived from *Cyperus Dichrostachus A.Rich* plant. On the progress of this study, the new natural lignocellulosic fiber was

successfully demonstrated to be an alternative source for producing fiber for varied applications. The fiber was extracted warm water extraction techniques at different NaOH concentrations. The influence of alkali treatment with correlated factors and extraction techniques on the chemical composition, morphological, structural, thermal and tensile properties of the fiber was studied well.

The elimination of hemicellulose from the fiber strands on this fiber was proved by chemical analysis and FT-IR studies. The thermal stability of the fiber strands was found to be better-quality for warm water extracted fiber treated with NaOH. CDA fiber can prove to be a promising raw material as reinforcement in the fabrication of bio composites.

In general, the physical properties, chemical composition, thermal degradation, and mechanical properties of CDAF were characterized and based on the results, the following conclusions were drawn:

- The results showed higher percentage of cellulose content (60.27±9.3%), Lignin content (16.59±0.32%), and insignificant presence of ash content (1.3%) and moisture content (11.02±1.38%) which are the required properties for applications as a reinforcing material in composite manufacturing.

- The density of the CDAF (1.01±0.53 g/cm^3) is low compared to other natural fibers; this makes CDAF best alternative material in manufacturing of light weight polymer composite products.

- The CDAF indicates high cellulosic content when compared with other natural fibers, which is markedly evident for good tensile properties. The CDAF shows low extractive content (1.5%), make it best choice for good interfacial bonding between reinforcement and matrix in the composite manufacturing.

- The high tensile strength of CDAF and the lower density (1010±534.62 kg/m^3) make the fiber a good alternative for synthetic fibers and effective reinforcement for fabricating the thermosetting polymer composites and important constituent in

making shock absorbing products, lightweight materials like, mats, pillows, cushions, doors, furniture etc.

- It can be concluded that the CDA fiber is versatile and have engineering potential that can be used as effective reinforcement for a wide variety of applications.

- In addition, the CDA plant could be abundantly available in river basins, garden areas and making industrial chains provide to extract CDA fibers and to manufacture polymer composites for various industrial applications with benefits in cost and employment, for society and environment.

- The high biomass output of the CDA plant can provide large amounts of non-wood fibers, that can substitute for most of the pulp in Ethiopia

Future works will involve studies on the possible beneficiation route of the CDA fiber in textile industry and composite manufacturing. The possibility for paper and pulp production would be also analyzed.

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