Extraction of ALBIZIA *amara* bark fiber for use as reinforcement in polymer composites.

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Abstract:

The goal of the current study was to comprehend the physicochemical characteristics of a novel natural fiber that was taken out of the bark of Albizia amara (AA). AA fibers' (AAFs') structural, thermal, and tensile characteristics were examined, along with their chemical makeup. According to the findings, AAF had a low-density of 1043 kg/m3, a crystallinity index of 63.78%, cellulose of 64.54 wt%, hemicellulose of 14.32 wt%, and lignin of 15.61 wt%. Fourier transform infrared analysis was used to identify the functional groups of the AAFs, and thermogravimetric analysis demonstrated that the AAFs were thermally stable up to 330.6°C. The AAFs showed a strain rate of 1.57 ± 0.04% and a tensile strength of 640 ± 13.4 MPa. According to this research, AAFs may be a good material to use as a reinforcing ingredient in natural fiber–polymer composites for a variety of uses.

Keywords: Albizia amara; chemical compositions; X-ray diffraction; thermogravimetric analysis; tensile strength

Introduction

Natural fiber composite materials have been the subject of increased research recently as a potential replacement for synthetic fiber composites because of their increased sensitivity to environmental changes. For many years, man-made fibers including carbon, glass, nylon, and aramid were used. These synthetic fibers have numerous drawbacks when it comes to the environment (Arpitha, Sanjay, and Yogesha 2014; Nacher et al. 2007). Due to their exceptional qualities, which include low cost, low density, eco-friendliness, easy availability, non-abrasion of processing equipment, and non-corrosiveness, natural fibers are said to be a likely replacement for synthetic fibers (Jawaid and Abdul Khalil 2011; Sanjay and Yogesha 2017, Sanjay et al. in press). In a number of technical domains, including automotive, construction, electrical, aerospace, marine, and home appliances, the use of natural fiber-reinforced composites is growing (Satyanarayana et al. 2007; Malkapuram et al. 2009; Sanjay et al. 2016). Plant fibers such as jute, Acacia leucophloea, and Cyperus pangorei have been effectively employed as reinforcement in polymer matrixes (Arthanarieswaran et al., 2016; Vijay and Singharevu, 2016; Madhu et al., 2017). Through the use of chemical analysis, Fourier transform infrared (FTIR) spectroscopy, X-ray diffraction (XRD), thermogravimetric analysis (TGA), and tensile testing, numerous researchers were able to reveal the properties of novel biofibers, including Acacia planifrons (Senthamaraikannan et al. 2016), Acacia arabica (Manimaran et al. 2016), Azadirachta indica (Manimaran et al. 2017), Furcraea foetida (Manimaran et al. in press), Ceiba pentandra (Kumar et al. 2017), Grewia serrulata (Mahesha et al. 2017), Heteropogon contortus (Rajesh Jesudoss Hyness et al. 2017), and Artisdita hystrix (Kathiresan et al. 2016).

Prior research has not examined the physic-chemical, tensile, or thermal properties of the recently recognized Albizia amara (AA) bark fiber. These plant fibers are intriguing because they can be scaled up with little resources and because they can thrive in arid conditions (Dabhade, Mokashe, and Patil 2016). We present the physicochemical properties of AAFs for the first time using tensile testing, Fourier transform infrared (FTIR) spectroscopy, thermogravimetric analysis (TGA), chemical analysis, and X-ray diffraction method. The results were compared to those of other known natural fibers.

Materials and methods

Materials

AA is a medium-sized, deciduous tree that resembles a planifrons Acacia. From AA plants in the Erasakkanayakanur, Uthamapalayam Taluk, Theni district of Tamil Nadu, India, the mature and robust barks were harvested. For two weeks, the AA plants' barks were submerged in water that had been stored in order to separate the fibers. Without undergoing any additional chemical processing, the isolated fibers were utilized after four days of drying at room temperature (Senthamaraikannan et al. 2016).

Chemical analysis of AAFs

Using standard testing techniques, the chemical makeup of the AAFs, including their cellulose, hemicellulose, lignin, wax, and ash levels, was evaluated. The Mettler-Toledo xsz05 balances method was utilized to determine the density of the AAFs, as reported by Sathik Kumar et al. (2012). An electronic moisture analyzer (Sartorious, model MA45) was used to determine the moisture content of the AAFs, and the amount of ash material was determined in accordance with the ASTM E1755-01 standard (Saravanakumar et al. 2014). The Conrad technique was used to compute the wax substance (Senthamaraikannan et al. 2016).

X-ray diffraction analysis

An investigation method called X-ray diffraction (XRD) was primarily employed to identify a crystalline material's phase. With an X'Pert-Pro diffractometer equipment, the XRD analysis of AAFs was examined (powder XRD). Using the peak height method, the crystalline index (CI) of the cellulosic materials was determined.

Fourier transform-infrared spectroscopy

The Shimadzu spectrometer (FTIR 8400S, Japan) was used to record the FTIR spectra of the AAF. A ball mill was used to compress the AAF samples into a fine powder. This powder was combined with crystals of potassium bromide, and pressure was used to turn it into a pellet. When using the attenuated total reflectance mode, FTIR data were obtained at a scan rate of 32 scans/min and a resolution of 2 cm−1 for the frequency range of 4000 to 500 cm−1.

Thermogravimetric analysis

The degradation of natural fibers as a function of temperature or duration in regulated air was investigated using TGA. An STA 449 F3 setup with a controlled nitrogen gas environment purge was used to perform the TGA. An alumina crucible with a lid was used for the experiment, and the temperature range was set to range from room temperature to 1000°C.

Tensile testing

Using an Instron universal testing machine and a single fiber tensile test in accordance with the (ASTM D3379 2002) Standard protocol, the maximum tensile strength

was determined. AAFs' (n = 25) tensile strength was calculated using a crosshead speed of 1 mm/min and a gauge length of 50 mm.

Results and discussion

Chemical analysis of AAFs

Table 1 lists the chemical compositions of AAFs that were examined and contrasted with those of other plant fibers. Chemical analysis is influenced by various aspects such as plant age, growth location, soil properties, extraction settings, and chemical composition identification methodologies (Batra 1985). Cellulose (64.54 wt%), hemicellulose (14.32%), and lignin (15.61 wt%) were present in the assessed AAFs. Compared to other biofibers like Cyperus pangorei (1102 kg/m3) (Mayandi et al. 2016), Acacia leucophloea (1385 kg/m3) (Arthanarieswaran, Kumaravel, and Saravanakumar 2015), and Sida rhombifolia (1320 kg/m3) (Gopinath et al. Gopinath), the density of AAFs was significantly lower at 1043 kg/m3. AAF's low density could be useful for creating composite constructions that are lightweight.

XRD analysis

The typical XRD band of AAFs is displayed in Figure 1. The initial peak at 2θ = 15.46° is assigned to (2 0 0) crystallographic plane. The principal peak at 2θ = 22.55° is recognized to be (1 1 0) plane of crystallography (cellulose type I). On the other hand, a metric called the crystallinity index (CI) is employed to specify the proportion of crystalline material in cellulose. An estimate of the crystallinity index was 63.78%. Prosopis juliflora (46%) (Saravanakumar et al. 2013), Acacia leucophloea (51%) (Arthanarieswaran, Kumaravel, and Saravanakumar 2015), Perotis indica (48.3%) (Prithiviraj et al. 2016), Acacia arabica (51.72%) (Manimaran et al. 2016), and Artistida hystrix (44.85%) (Kathiresan et al. 2016) were all lower than the evaluated CI value. Nonetheless, the AAFs' crystallite size was determined to be 15 nm. The AAFs' determined crystallite size value indicates that the fiber's chemical reactivity and water inclusion capabilities have diminished.

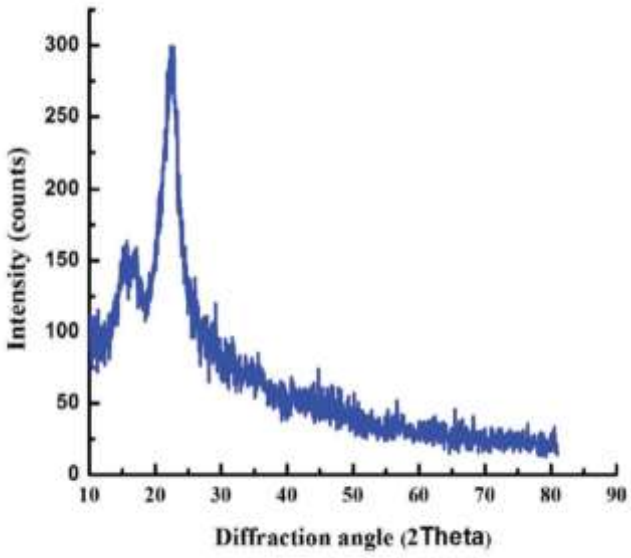


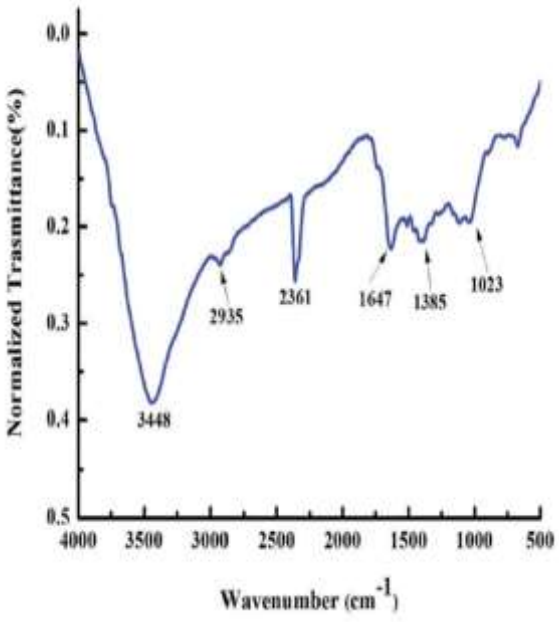
Figure 1. XRD of AAFs.

Table 1. Comparison of chemical compositions of raw AAFs with various plant fibers.

Fiber name	Cellulose (wt.%)	Hemicelluloses (wt.%)	Lignin (wt.%)	Wax (wt.%)	Moisture content (%)	Density (kg/m³)	Ash (wt.%)	References
AAF	64.54	14.32	15.61	0.56	9.34	1043	4.1	Present work
Acacia planifrons	73.1	9.41	12.04	0.57	8.21	660	4.06	Senthamaraikannan et al. (2016)
Acacia arabica	68.10	9.36	16.86	0.49	-	1028	-	Manimaran et al. (2016)
Artistida hystrix	59.54	11.35	8.42	-	-	540	-	Kathiresan et al. (2016)
Cyperus pangorei	68.5		17.88	0.17	9.19	1102	-	Mayandi et al. (2016)
Acacia leucophloea	68.09	13.60	17.73	0.55	8.83	1385	0.86	Arthanarieswaran, Kumaravel, and Saravanakumar 2015
Sida rhombifolia	75.89	15.43	7.48	0.49	12.02	1320	4.07	Gopinath et al. (c)
Prosopis juliflora	61.65	16.14	17.11	0.61	9.48	580	5.2	Saravanakumar et al. (2013)
Perotis indica	68.4	15.7	8.35	0.32	9.54	785	4.32	Prithiviraj et al. (2016)

FTIR analysis

Figure 2 shows the chemical groups of the AAF spectrum. The O–H stretching of cellulose in the fiber is characterized by a wide absorption band at 3448 cm−1 (John 2000; Amar and Vijay, 2009). The peak at 2918 cm−1 is ascribed to cellulose's C–H stretching. Another distinct peak, located at 2361 cm−1, is attributed to the wax component's symmetrical stretching of CH2. The alpha keto carboxylic acid in lignin or the ester group of hemicellulose exhibits C=O stretching at 1647 cm−1. The band located at 1385 cm−1 is attributed to polysaccharide-derived t-butyl stretching. According to Sathishkumar et al. (2013), lignin's symmetric C–OH stretching is responsible for the typical peak at 1023 cm−1.



Figure

2. FTIR of AAFs

Thermogravimetric analysis

The thermal stability of AAFs was examined using TGA. Figure 2 depicts the heat deterioration of AAFs. The evaporation of moisture from the AAFs is the cause of the initial weight loss that was seen at 91.7°C (Arthanarieswaran, Kumaravel, and Saravanakumar 2015). A little thermal peak that was associated with the thermal degradation of hemicellulose was detected at 274°C and showed a weight loss of 12.29%. The thermal breakdown of cellulose causes a peak that may be seen at 330.6°C, with the largest weight loss being approximately 34.49%. Other natural fibers such Artisdita hystrix (298.8°C) (Kathiresan et al. 2016), Prosopis juliflora (331.1°C) (Saravanakumar et al. 2013), and Perotis indica (339.1°C) (Prithiviraj et al. 2016) also showed similar peaks.

Conclusions

The physicochemical parameters of AAFs, including their tensile strength, thermal stability, chemical composition, and crystallite characteristics, were assessed in this study. AAFs' low microfibrile angle and high cellulose content (64.54 weight percent) give the fibers a significantly higher tensile strength (640 ± 13.4 MPa). Interestingly, AAFs are suitable for lightweight composite preparations due to their reduced density (1043 kg/m3) in comparison to other natural fibers. AAFs were thermally stable to 330.6°C aside from that. The aforementioned findings support the use of AAFs as a reinforcing material in composites for a range of applications, including bricks, ceilings, door panels, furniture panels, and interior panels. With this fiber, there is a lot of potential to create natural fiber–polymer composites and investigate their mechanical and thermal characteristics, which could provide more useful information for future product development.

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