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ORIGINAL ARTICLE

Extensive characterization of novel cellulosic biofiber from leaf sheath of *Licuala grandis* for biocomposite applications

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Abstract

Composite industries focus on utilization of natural resources to imbibe sustainability in their products. This investigation details the segregation and characterization of *Licuala grandis* leaf sheath fibers (LGLSFs) extracted from leaf sheath of *Licuala grandis* tree an agro-waste for utilization as raw material in composite industries. The characteristics of LGLSF were compared with other competitive natural fibers to ensure its suitability for reinforcement in composite industry. The characterizations include chemical, mechanical, morphological, and thermal methods. The Fourier transform infrared spectroscopy (FTIR) spectrum revealed the existence of functional groups in LGLSF. The surface texture of LGLSF observed through a scanning electron microscope (SEM) ensures its possibility of making better interfacial bonding characteristics with the matrix when reinforced in polymer composites. To support the industry on decision making process, the quantitative metrics such as cellulose content (49.13 wt.%), minimum wax (0.31 wt.%), lesser density (1.24 g/cm^3), higher crystallinity index (48%), tensile strength (102–179 MPa), and Young's modulus (1.3–5.4 GPa) of LGLSF were appraised. The thermal stability up to 223 °C and exothermic and endothermic behavior of LGLSF at higher temperatures were ensured through thermogravimetric (TGA/DTG) and differential scanning calorimetry (DSC) analysis, respectively. The appraised quantitative values, the thermal behavior, and chemical functionality of LGLSF ensure its use as reinforcement in polymer composites employed for low density structural applications.

Keywords Agro-waste · *Licuala grandis* · Bioreinforcement · Biocomposites

Highlights
- Biowaste *Licuala grandis* leaf sheath fibers (LGLSFs) characterized for reinforcement.
- Little wax (0.31 wt.%) and density (1.24 g/cm^3) of LGLSFs ensures better bonding.
- Thermal studies (TGA and DSC) confirm thermal stability of LGLSFs to 223°C.
- Uneven and rough surface texture of LGLSFs approves good interfacial bonding features.
- Specific assets attained favors LGLSFs reinforcement for bio-composite applications.

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1 Introduction

In the current business scenario, composite industries look for the possibilities of utilizing natural fiber reinforced polymer composites in the place of synthetic fiber reinforced polymer composites due to the need of day [1]. The directions of government and non-governmental organizations to incorporate sustainability in the products and processes of industries to save the environment and its living being have made the composite industries to take such initiatives. The preference given to natural fibers by composite industry is due to its availability in abundance, natural prevalence, availability of fibers from agro-waste at very low cost, lesser density and ease of processing which consumes less energy compared to synthetic fibers [2, 3]. Products made of natural fiber reinforced polymer composites which were already commercialized are door panels and windows for building interiors, furniture's for both domestic and commercial use, seats, dashboards, and

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other supportive structures for interiors of automobiles [4]. Natural fibers were sourced from almost all parts of the plant including roots, flower stalk, sheath, and peduncle as well as from animal and mineral sources [5–7]. The natural fibers were used in the design process to fabricate the natural fiber reinforced polymer composites of sufficient mechanical characteristics.

In spite of numerous advantages of natural fibers being utilized in composite industry, there are certain challenges that need to be addressed. The first and foremost challenge is the non-standard shape and size of natural fibers [8]. This varied shape and size of the natural fibers makes it more complicated to handle and fabricate natural fiber reinforced polymer composites to meet the requirements of specific applications. Another hurdle is the assurance to continuous supply of natural fibers to industries as raw materials to produce commercial products which are in continuous demand [9]. This is due to the threat that over harvesting of trees for natural fibers might lead to deforestation and paves another way for threat to sustainability. This can be addressed by focusing on the availability of fibers from agro-waste ejected both from farms and industry [10, 11]. These agro-wastes either remain as landfill or burnt in open air both causing environmental pollution to the society. The utilization of fibers from agro-waste can be economically beneficial to farmers and agro-industries. Finally, the hydrophilic nature of natural fibers extracted from plants was identified as a major cause for moisture absorption and degradation of composite [12]. This has been addressed by researchers through surface treatment of extracted natural fibers before being used as reinforcement in polymer composites.

The physical and mechanical characteristics of lignocellulosic fibers extracted from plants are influenced by cellular arrangement, cell dimensions, chemical composition, microfibril angle, quality of fibers based on the extraction process, density, and maturity of the plant or part of plant from which the fiber is extracted [13–15]. The fibers extracted from *Citrullus lanatus* climber subjected to investigation exposes that it possesses a considerable cellulose content of 53.7 wt.% and density of 1227 kg/m^3 which is sufficient to contribute to its mechanical characteristics [16]. The crystallinity index of 33.33% reveals its hydrophilic nature and it's suggested for use as reinforcement in polymer composites subjected to lesser load applications. Another investigation on fibers extracted from *Calamus manan* revealed that it contained a cellulose content of 42 wt.% and possesses a maximum tensile strength of 273.28 ± 52.88 MPa identified through single fiber tensile test [17]. The thermally stable nature of *Calamus manan* fiber till 332.8 °C is adequate and is suggested for use as reinforcement in polymer composites. Amutha et al. [18] interrogated the fibers extracted from bracts attached to inflorescence of banana tree. The extracted bract fibers with 56.48% cellulose content possessed a tensile strength of 178.17 MPa. The thermal stability up to 200 °C and low wax content of 1.05% makes it a considerable choice to be used as reinforcement in polymer composites.

The *Licuala grandis L.* from Arecaceae family belonging to palm variety is mainly grown for ornamental purpose, and its wood is used in manufacturing of domestic products like umbrella handle, knife handles, and supporting stick for walking. The leaf sheath of *Licuala grandis L.* is currently unutilized and remains as landfill or burnt in open air. This agro-waste is rich in lignocellulosic fibers, and its appropriateness to be used as reinforcement in polymer composites needs to be investigated. In the current work, the novel natural fiber extracted from leaf sheath of *Licuala grandis L.* was interrogated for its physical, chemical, and thermal characteristics to distinguish its mechanical characteristics, chemical composition, and thermal behavior of fibers. The surface characteristics of LGLSFs were investigated through scanning electron microscope (SEM). The X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) spectrum of LGLSF was obtained to identify the crystalline nature and operational group, respectively. The interrogations ascertain that the LGLSF biofiber can be used as reinforcement in polymer composites to enhance its thermo-mechanical characteristics as well as remain as solution to manage agro-waste from farms and agro-based industries leading to more economical and sustainable environment.

2 Materials and methods

2.1 Gathering and extraction of LGLSF

The dried leaf sheaths of *Licuala grandis* were gathered from landfills of industrial and academic campuses in Coimbatore, Tamil Nadu, India. The gathered leaf sheaths were soaked in water for 3 days to loosen the fibers [19]. Then the soaked leaf sheaths were rinsed in running water 3 to 5 times to segregate LGLSF from the pulp and dust particles. The segregated LGLSFs shown in Fig. 1 were sundried for 3 days to reduce its moisture content and stored for further characterization process. The investigation ready LGLSFs were subjected to physical, chemical, mechanical, thermal, and morphological characterization to reveal its suitability to be used as bioreinforcement in polymer composites.

2.2 Characterization of LGLSF

The chemical constituents of LGLSF such as cellulose, hemicellulose, lignin, and wax content by weight percentage (wt.%) were identified by standard procedures adopted in the literature [20]. The moisture content and density of LGLSF were estimated by standard weight loss and mass volume technique, respectively. ASTM D3822-07

Fig. 1 Extraction of *Licuala grandis* leaf sheath fiber (**a**) *Licuala grandis* tree (**b**) Collected leaf sheaths of *Licuala grandis* and (**c**) Extracted *Licuala grandis* leaf sheath fibers

standard was adhered to conduct single fiber tensile test of LGLSFs [21]. The incidence of functional groups and crystalline characteristics of LGLSF were known from the Fourier transform infrared (FTIR) spectroscopy and X-ray diffraction (XRD) spectroscopy analysis, respectively [22]. The FTIR analysis was conducted at a scan rate of 32 per min with the resolution of 4 cm^{-1}. The XRD spectrum was observed in the Bragg angle (2θ) range of 10° to 80° at a goniometer speed of 5°/min. The surface characteristics of LGLSF were analyzed using a scanning electron microscope (SEM) of model SUPRA 55 Zeiss at an accelerated voltage of 8 kV [23]. The thermal behavior of LGLSF were known by conducting thermogravimetric analysis (TG & DTA) and differential scanning calorimetry (DSC) analysis at a temperature increase rate of 10° C/min within the temperature range of ambient to 550 °C and 450 °C, respectively [24].

3 Results and discussions

3.1 Chemical analysis of LGLSF

The chemical constituents of natural fibers extracted from plants depend on the age of the plant or plant part from which the fiber is extracted, topography, and climatic condition in which the plant survives. The chemical characteristics of fibers directly influence the physico-mechanical, surface morphological, and hydrophilic characteristics of fibers [25]. The surface morphology of fibers plays a vital role in the interaction with the matrix when used as reinforcement in polymer composites. The reinforced fibers decide the functionality of natural fiber reinforced polymer composites. The chemical constituents of LGLSF in terms of wt.% is presented in Table 1. The considerable quantity of 49.13 wt.% cellulose content in LGLSF

Table 1 Chemical and mechanical characteristics of *Licuala grandis* leaf sheath fiber in association with other natural fibers used as reinforcement material in polymer composites [27–29]

Fiber name	Cellulose (wt.%)	Hemicellulose (wt.%)	Lignin (wt.%)	Wax (wt.%)	Density (g/cm^3)	Elongation at break (%)	Tensile Strength (MPa)	Young's modulus (GPa)
LGLSF*	**49.13**	**11.75**	**26.15**	**0.31**	**1.24**	**3.27 ± 0.9**	**140.82 ± 38**	**3.82 ± 0.7**
ACFPF	53.10	11.40	23.62	0.28	0.80–1.10	3.90–8.10	107–182	1.70–6.20
Jute	61	20.40	13	0.70	1.30–1.49	1.16–1.50	393–800	13–26.50
Flax	64.10	16.70	2	1.50–3.30	1.50	2.70–3.20	500–1500	27
Cissus quadrangularis stem	82.73	7.96	11.27	0.18	1.22	3.75–11.14	2300–5479	56–234
Raffia textilis	148–660	–	–	–	0.75	2	148–660	28–36
Areca Fiber	57.35	13–15.42	23.17–24.16	0.12	0.7–0.8	10.23–13.15	147–322	1.12–3.15
coir	32–43	0.15–0.25	40–45	–	1.20	30	593	4–6
Sisal	60–78	10–14.20	8–14	2	1.50	2–2.50	511–635	9–22
Hemp	74.40	17.90	3.70	0.80	1.47	2–4	690	70
Bagasse	55.20	16.80	25.30	–	1.20	1.10	20–290	19–27
Acacia leucophloea	76.69	3.81	13.67	0.13	1.43	1.91–5.88	357–1809	10.45–87.57
Sansevieria cylindrica	79.90	10.13	3.80	0.09	0.91	12.30–13.70	666–706	6–8
Grewiatili folia	67.90	17	15	–	–	2.0	75.30	5
Alfa	45.40	38.50	14.90	2	0.89	5.80	350	22
Ramie	76	15	0.70–1	0.30	1.50	2–3	220–938	44–128
Kenaf	45–57	14.33	8.18	0.80	1.31	1.60	427–519	23.1–27.1
Aramid	–	–	–	–	1.40	3.30–3.70	3000–3150	63–67
Carbon	–	–	–	–	1.40	1.40–1.80	4000	230–240
E-Glass	–	–	–	–	2.50	0.50	2000–3500	70

*Bolded row represents the present research work

which is comparable with its counterparts contribute to the mechanical characteristics of fiber. Higher the quantity of cellulose content in LGLSF, the better is the crystalline nature which results in sufficient hydrophobic characteristics of fiber to be used as reinforcement in polymer composites.

The hemicellulose content in LGLSF is found to be minimum of 11.75 wt.% which favors the mechanical and bonding characteristics of fiber when used as reinforcement in polymer composites. The presence of 26.15 wt.% lignin in LGLSF acts as a binder and promotes the interaction with the matrix when used as reinforcement in polymer composites [26]. The fire-resistant behavior of LGLSF is endorsed by ash content of 1.62 wt.%. This also supports the thermal stability of LGLSF to resist damage to polymerization temperature when used as reinforcement in polymer composites. The tolerable wt.% of moisture content (11.05 wt.%) and wax content (0.31 wt.%) promotes its use as reinforcement in polymer composites.

3.2 FTIR analysis of LGLSF

The FTIR spectrum of LGLSF is displayed in Fig. 2 which indicates the presence of main functional groups. The troughs noticed in wavenumbers 423 cm^{-1}, 897 cm^{-1}, and 1032 cm^{-1} are affiliated to stretching vibrations of alkyl halide belonging to organic functional group [29]. The valleys identified in wavenumbers 1263 cm^{-1} and 1319 cm^{-1} represent the bending alkene organic functional group=C-H. The fluctuations in FTIR spectrum observed till the wavenumber of 1319 cm^{-1} are owing to the polysaccharides in cellulose of LGLSF. The ranging fluctuations of carbonyl operational group C-O is visible at 1418 cm^{-1}. The succeeding troughs in wavenumbers 1507 to 1594 cm^{-1} endorse the existence of lignin and hemicellulose in LGLSF, respectively [30]. The valley at 2922 cm^{-1} affiliates to C-H symmetric twisting effect of alkaline operational group. The wider trough observed at 3330 cm^{-1} corresponds to widening of OH in cellulose. The biochemical components identified through chemical analysis in LGLSF were verified through the troughs in the FTIR spectrum.

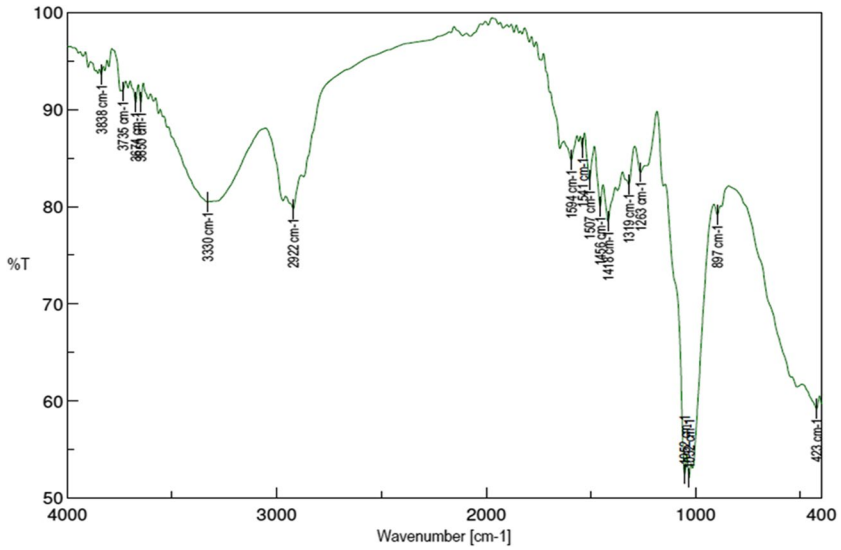

Fig. 2 FTIR spectrum of *Licuala grandis* leaf sheath fiber

Table 2 Physical characteristics of *Licuala grandis* leaf sheath fiber

Property	Value
Thickness of primary cell wall (µm)	0. 531 ± 0.001
Thickness of secondary cell wall (µm)	0.318 ± 0.001
Thickness of middle lamellae (µm)	2.453 ± 0.002
Thickness of cell lumen (µm)	5.610 ± 0.002
Fiber diameter (µm)	139.87 ± 23.02
Fiber density (g·cm^{-3})	1.24 ± 0.002

3.3 Morphological and anatomical analysis of LGLSF

Table 2 depicts the physical parameters of LGLSF. The secondary and primary cell wall of LGLSF is composed of lignin and cellulose which highly dictates the mechanical characteristics of fiber. The lignin and hemicellulose contained in lamellae serves as a connective tissue and connects the adjacent cells in LGLSF [31]. The empty space inside the cells of LGLSF is referred to as lumen which helps the natural fibers to retain lesser density and contributes to light weight of the polymer composite when reinforced with natural fibers.

The surface and cross-sectional view observed through SEM of LGLSF is presented in Fig. 3. The observations from Fig. 3a shows that the surface of LGLSF is rough with more crest and trough which favors the bonding of LGLSF with matrix when used as reinforcement in polymer composites. The surface of LGLSF with more crest and trough increases the surface area of contact between LGLSF and matrix when reinforced in polymer composites which is advantageous for having better interfacial bonding features [31]. The SEM images also portray the existence of binder material lignin and microfibrils connected with parenchyma cells. The mechanical characteristics of LGLSF were also influenced by the microfibril angle. Equation (1) [32] is used to compute the microfibril angle of LGLSF as 5.98° ± 26°.

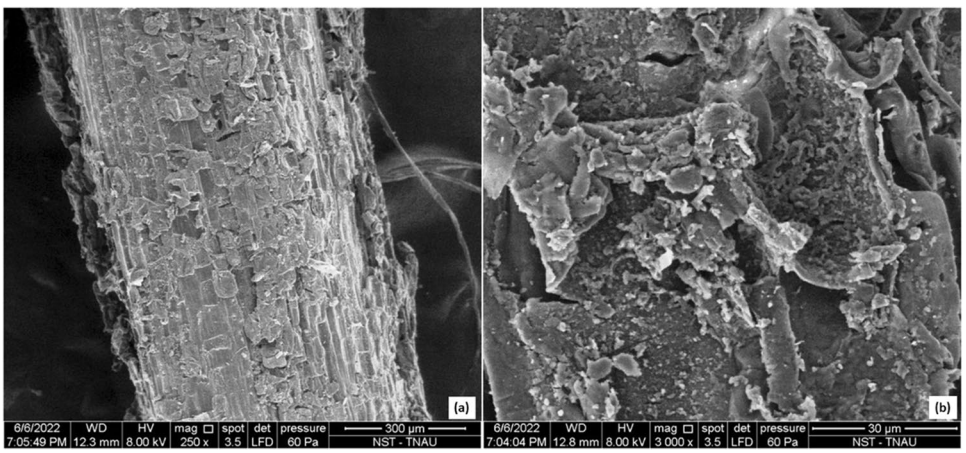

Fig. 3 SEM image of *Licuala grandis* leaf sheath fiber: **a** Parallel view 250X and **b** Sectioned view 3000X

$$\varepsilon = \ln\left[1 + \frac{\Delta L}{L_0}\right] = -\ln(\cos\alpha) \quad (1)$$

where ε is the strain, α is the microfibril angle (degree), ΔL is the Elongation at break (mm) and L_o is the gauge length (mm). Lesser the microfibril angle of LGLSF, the better is the transfer of stress between the LGLSF and matrix when reinforced in polymer composites.

3.4 XRD analysis of LGLSF

The XRD spectrum of LGLSF has been presented in Fig. 4. The robust peak at Bragg angle (2θ) of 22.6° reveals the semicrystalline characteristics of LGLSF. Subsequent peak of lesser intensity observed at Bragg angle (2θ) of 17.3° relates to the amorphous contents in LGLSF. Both the peaks at Bragg angles 22.6° and 17.3° for crystalline and amorphous contents in LGLSF affiliate to crystallographic planes (2 0 0) and (1 1 0), respectively [33]. The crystallographic plane (2 0 0) adheres to cellulose-I possessing monoclinic structure. Remaining variations in the XRD spectrum of LGLSF is due to the presence of impurities in the fiber.

The crystallinity index (CI) of the LGLSF was computed using the empirical equation (Eq. 2) [34] as 48%:

$$\mathrm{CI} = \frac{(I_c - I_{am})}{I_c} \quad (2)$$

where I_c is the maximum intensity of crystalline peak at $2\theta = 22.6°$ and I_{am} is the intensity of amorphous peak at $2\theta = 17.3°$. The calculated CI value endorses the sufficient mechanical characteristics of LGLSF and compact packing of LGLSF when reinforced in polymer composites.

Scherrer's equation (Eq. 3) [34] was utilized to calculate the crystallite size (CS) of LGLSF as 1.26 nm.

$$\mathrm{CS} = \frac{K\lambda}{\beta\cos\theta} \quad (3)$$

where $K = 0.89$ is Scherrer's constant, λ is the wave length of radiation, β is the peak's full-width at half-maximum (FWHM) expressed in radians, and θ is the Bragg's diffraction angle. The adequate value of CS obtained for LGLSF denotes its sufficient hydrophobic nature for use as reinforcement in polymer composites.

3.5 Physico-mechanical analysis of LGLSF

The physico-mechanical characteristics of LGLSF have been presented in Table 1. In order to measure the density of LGLSF, powdered LGLSF samples were packed tightly in a cylindrical container whose weight is known. Thus, on mass-volume basis, the density of LGLSF was estimated as 1.24 g/cm^3. The lesser density of LGLSF ensures the light weight of natural fiber reinforced polymer composite when used as reinforcement [35]. The reinforcement of LGLSF in polymer matrix composites also helps to achieve specific characteristics for the fabricated composite. The diameter of LGLSF was measured using an Optical microscope interfaced with ImageJ software. The diameter of LGLSF ranged between 112.98 ± 17.21 µm and 156.36 ± 28.21 µm as presented in Table 3. In spite of being the non-uniform shape and size of the cross-section of LGLSF, in order to calculate the diameter using Eq. (4), it is assumed to be circular.

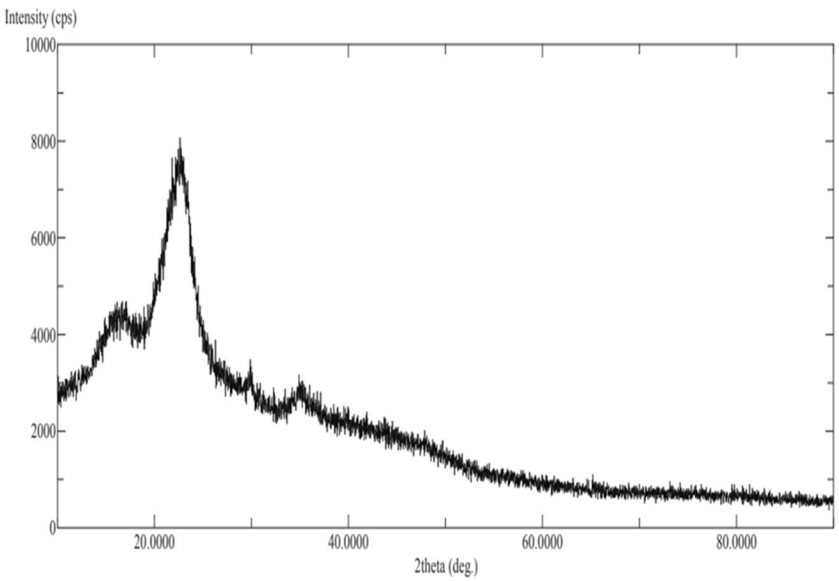

Fig. 4 XRD spectra of *Licuala grandis* leaf sheath fiber

Table 3 Mechanical properties of *Licuala grandis* leaf sheath fiber obtained as per ASTM standards

Gauge length (mm)	Tensile strength (MPa)	Young's modulus (GPa)	Strain to failure (%)	Diameter (μm)
10	102 ± 21	1.3 ± 0.2	4.2 ± 1.5	156.36 ± 28.21
20	124 ± 31	3.4 ± 0.5	3.6 ± 1.3	142.78 ± 22.36
30	156 ± 38	4.2 ± 0.6	3.1 ± 0.7	123.83 ± 19.81
40	179 ± 42	5.4 ± 0.7	2.4 ± 0.5	112.98 ± 17.21

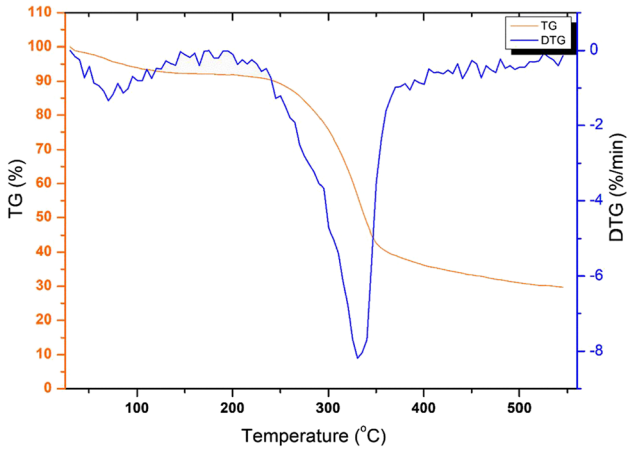

Fig. 5 TGA-DTG curve of *Licuala grandis* leaf sheath fiber

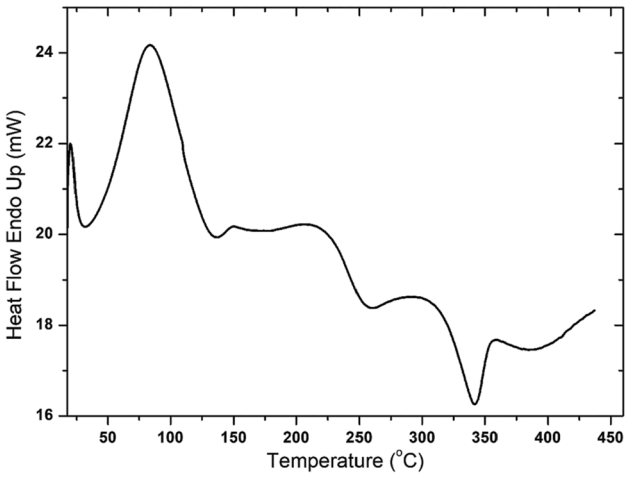

Fig. 6 DSC plot of *Licuala grandis* leaf sheath fiber

$$\mathrm{Df} = \sqrt{\frac{L_f}{9000 \times M_d \times 0.7855}} \tag{4}$$

where D_f is the diameter of LGLSF, L_f is the linear mass density of LGLSF in denier which is a quantity of fineness of LGLSF evaluated as per ASTM D1577-07 standard, and M_d is the mass density in g/cm^3. The diameter of LGLSF calculated using Eq. (4) is 137.92 μm which lies within the range of values obtained through ImageJ software.

The LGLSF possesses a tensile strength which ranged between 102 ± 21 MPa and 179 ± 42 MPa as depicted in Table 3. The tensile strength values of LGLSF are comparable with other natural fibers used as reinforcement in polymer composites. The difference in physical characteristics of LGLSF noted over the change on gauge length is due to variation in size and shape of cross-section of LGLSF along its length [36]. The better load withstanding capacity of LGLSF is revealed from lesser Young's modulus and greater elongation at break values of LGLSF. The computed and measured physico-mechanical characteristics of LGLSF ensure its competency to be used as reinforcement in polymer composites. In natural fiber reinforced polymer composites, being natural fibers the main load carrying member, the LGLSF with better tensile characteristics can be a suitable reinforcement material.

3.6 TGA analysis of LGLSF

The thermal behavior of LGLSF with rise in temperature is presented in Fig. 5. The reduction in weight of LGLSF observed till 109 °C indicates the evaporation of moisture content from the fiber [37]. Subsequently, for further rise in temperature, the LGLSF was thermally stable with negligible weight loss witnessed till 223 °C. Further rise in temperature initiates the degradation of lignin, cellulose, and hemicellulose in addition to the depolymerization process. This is attributed to the weight loss of around 14.2% until 288 °C. A substantial loss of weight witnessed for LGLSF sample from 289 to 392 °C denotes the complete degradation of cellulose in LGLSF [38]. Further rise in temperature showcases certain reduction in weight of LGLSF sample which relates to decomposition of wax and parts of lignin. The DTG curve indicate an infliction point at around 328.6 °C along with variation in mass of 52.73% representing the pyrolysis and disintegration of molecular arrangement in the cellulose [39]. The char residue of 14.69% obtained at 550 °C represents fire resistant behavior of LGLSF. The kinetic activation energy (E) of the LGLSF sample was obtained using the Broido's equation (Eq. 5) [40] as 73.82 kJ/mol.

$$\ln\left[ln\left[\frac{1}{y}\right]\right] = -\left(\frac{E}{R}\right)\left[\left(\frac{1}{T}\right) + K\right] \quad (5)$$

where R is the universal gas constant (8.314 J·mol^{-1} K^{-1}), T temperature in Kelvin, y normalized weight (w_t/w_o), w_t weight of the sample at any time t, w_0 initial sample weight, and k Boltzmann's constant (1.3806×10^{-23} J·K^{-1}). The calculated E value ensures the ability of LGLSF to withstand polymerization temperature for fabrication of the polymer composites.

3.7 DSC analysis of LGLSF

The DSC plot of LGLSF has been displayed in Fig. 6. The DSC curve of LGLSF portrays the order of exothermic and endothermic reactions that happens with rise in temperature. The endothermic part of DSC curve of LGLSF designates the evaporation of water particles that are loosely packed as well as connected to cellulose. The evaporation of water particles that are connected to cellulose happens at a comparatively greater temperature above 100 °C related to loosely packed water particles in LGLSF [41]. The vaporization of both loosely packed and cellulose linked water particles were observed till 122.68 °C in the endothermic area of DSC plot of LGLSF. The disintegration of wax from the LGLSF is represented by the exothermic and endothermic process witnessed at 137.62 °C and 219.74 °C, respectively. The disintegration of cellulose in LGLSF is indicated by the endothermic crest at around 296.49 °C. On the other hand, the strong exothermic crest witnessed at 339.68 °C denotes the dehydration and pyrolysis of hemicellulose and lignin in LGLSF [42]. The further exothermic and endothermic reactions beyond 350 °C represent the degeneration of hemicellulose and lignin in LGLSF. The witnessed exothermic and endothermic trough and crests, respectively, in the DSC curve of LGLSF endorse the use of LGLSF embedded polymer composites in desert regions which holds higher environmental temperature.

4 Conclusions

The quantitative and qualitative results of characterization of novel LGLSF agro-waste confirm its utilization as reinforcement in polymer composites to improve the sustainability of products and processes of composite industries. The adequate cellulose weight percentage of 49.13 wt.% with coarse surface nature of LGLSF provides sufficient mechanical features and helps in achieving better bonding characteristics with matrix, respectively, when used as reinforcement in polymer composites. The specific strength of LGLSF is revealed through its tensile strength of 140.82 MPa and minimum density of 1.24 g/cm^3. This encourages the use of LGLSF reinforced polymer composites as support structures requiring lesser weight. The sufficient hydrophobic nature and prevalence of functional groups of LGLSF were confirmed through XRD and FTIR analysis, respectively. This promotes the use of LGLSF reinforced polymer composites in moist operating conditions. The thermal behavior of LGLSF at higher temperatures ensures its use as reinforcement in polymer composites exposed to industrial atmospheres having higher ambient temperature. The utilization of LGLSF reinforced polymer composites in industries will improve the sustainability in their products and process and helps in managing the agro-waste from plant sources which otherwise remains as landfills. The polymer composites reinforced with LGLSF agro-waste best suits for structural applications requiring low cost and light weight.

Author contribution Antony Sagai Francis Britto: investigation (lead), resources and supporting. Joseph Selvi Binoj: investigation; writing, original draft; reviewing. Bright Brailson Mansingh: writing — original draft. Paulvin Navin Jass: investigation (support), resources and supporting.

Data availability This is an ongoing research work, and hence, the data cannot be shared at this moment.

Declarations

Ethics approval and consent to participate All the authors demonstrate that they have adhered to the accepted ethical standards of a genuine research study. Also, individual consent from all the authors was undertaken to publish the data prior submitting to journal.

Consent for publication Written formal consent ensures that the publisher has the author's permission to publish research findings.

Competing interests The authors declare no competing interests.

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