Physico-Chemical and Thermal Analysis of Sodium Acetate Treated *Cocos nucifera* Fibres

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ABSTRACT

Recent years have seen an increase in the utilization of petroleum resources, while environmental rules have prompted research on composite materials that are renewable, recyclable, and biodegradable. From domestic to aerospace items, natural fibre reinforced with polymers is employed in a wide range of applications. Before being reinforced, plant fibres need to be studied thoroughly. In the present work, sodium acetate treated coir fibre is studied by exposing it to various physical, chemical and thermal characterization analysis. Physical characteristics such as diameter, density, linear density, aspect ratio, thermal conductivity and water absorption were found. The diameter of the treated coir fibre was 533µm. Aspect ratio of the treated fibre was found out. Thermal conductivity of the treated fibre was 0.041132 W/mK. The density of the treated fibre was 1.16 g/cm^3. The water absorption behaviour of treated fibres was very much reduced when compared to untreated coir fibres. The treated coir fibre has high cellulose content of about 60.39%. The activation energy of treated coir fibre was 56.3755 KJ/mol. The mass loss of treated fibre in all cases was below 352℃. Coir fibre has many properties and is eco-friendly and so it can be concluded that it can be used as reinforcement in bio composites for various applications.

Keywords: *Renewable, Sodium acetate, Coir, Cellulose, Bio composites*

1. Introduction

Natural fibres have a number of advantages over conventional reinforcement materials, including adequate specific strength, low cost, low density, and improved thermal and acoustic insulating qualities [1]. Natural fibres are a form of substance that resembles hair and are either permanent fibres or only come in clearly lengthy pieces, like lengths of thread. The final part's properties like strength and stiffness are improved while the weight is reduced because of the high tensile strength of the fibres in a composite that are held together by the matrix resin. Natural fibre is created or produced using both plant and animal hair [2]. Due to its higher specific strength, biodegradability and lack of itching, less natural fibre issues during manufacturing as compared to synthetic fibre, is now used more frequently in polymer matrix composites. The benefits of using natural fibre-based composites in a variety of applications are increasing [3]. The two main factors that favour the use of natural fibres as reinforcements are reduced mass fraction and density. The structural design of a product, which is predominately made of synthetic materials, is a significant component that affects its use and availability on the market. With their capacity to bend to a variety of designer configurations, natural fibre composites are now setting trends.

2. Materials and Methods

The Coconut fibres are extracted from the outer shell of coconut. The common name of the coconut fibre is coir. Scientific name is *Cocos nucifera*. The traditional method of retting is used to extract the coconut fibres. Fibre extraction or the separation of firmly linked fibres, can be accomplished manually or mechanically. The Cocos nucifera is collected from the village of Authivilai, Kanyakumari district of Tamil Nadu, South India. Fig. 1(a) shows the experimental fibres collected. The fibre is extracted from the husk and they are cleaned in distilled water and it is chemically treated. The treatment involves soaking the fibres in 0.1M of NaOH for10 minutes and the fibres are drained. The drained fibres are soaked in a solution of sodium acetate for 20 minutes. Fig.1(b) shows the experimental fibres under treatment. Then the fibres are dried in shade. Fig. 1(c) shows the experimental fibres are under drying process. After the fibres are dried, they are powdered for the purpose of characterization. This is done to determine how the treatment has altered their traits.

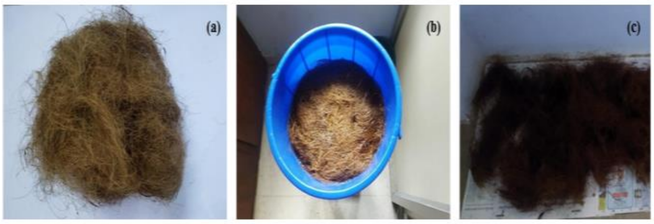

Fig. 1. Sodium acetate treatment of Cocos nucifera fibres

3. Results and Discussions

3.1. Physical properties of *Cocos nucifera* fibres

3.1.1. Length and Diameter analysis

The length is a crucial term used to find the linear density of the treated coir fibres. In order to determine the length, fifteen treated coir fibres are chosen. Using the ruler, the length of the fibre samples are measured. Finally, the average value is found out [4]. Similarly, microscope is used to find the diameter of the sample fibres. Table 1 shows the length and diameter of the sample.

Table 1. Physical properties of sodium acetate treated coir fibres

Parameters	Treated coir fibres
Length	19.94 cm
Diameter	533µm
Aspect ratio	374.101

Linear Density	1917 tex
Density	1.16 g/cc
Thermal Conductivity	0.041132 W/mK

3.1.2. Aspect Ratio

A higher aspect ratio is required for more efficient energy transmission between the matrix and fibre filaments upon impact. Because of their higher tensile strength, natural fibres with a high aspect ratio are advised. Fifteen fibres from Cocos nucifera samples that are sodium acetate treated are measured for their average diameter and length. The aspect ratio is found and is tabulated in Table 1. The following formula is used to find the aspect ratio of the natural fibre.

$$\text{Aspect Ratio} = L/D$$

Where L is the average length of the fibre and D is the average diameter of the fibre.

3.1.3. Linear Density

The linear density of the fibre is defined as the mass per unit length of the fibre. The values are tabulated in Table 1. The linear density of the treated coir fibre is calculated using the formula,

$$\text{Linear Density} = M/L \text{ g/km}$$

Where M is the average mass of the fibres; Lis the average length of the fibres [4].

3.1.4. Density using Pycnometer

Density is the important parameter of natural fibres. When employing a fibre as reinforcement in a composite, the density of the fibre is an essential factor in determining the fibre's potential to be a lightweight material [5]. The density of the treated coir fibre is tabulated in Table 1. The density of the treated coir fibre is calculated using the formula,

$$\rho_{Cnf} = \frac{(m_2 - m_1)}{(m_3 - m_1)-(m_4 - m_2)}\rho_b$$

Where m_1 is the mass of dry empty pycnometer (g); m_2 is mass of pycnometer + fibre (g); m_3 is mass of pycnometer + benzene (g); m_4 is mass of pycnometer + benzene +fibre (g); ρ_b is density of benzene (0.876g/cm^3); $\rho_{Cnf}$is density of sodium acetate treated Cocos nucifera fibre in g/cm^3.

3.1.5. Thermal conductivity using Lee's Disc

Lee's Disc instrument is used to find the thermal conductivity of the coir fibre. The ability ofa materialtotransfer orconductheatisknown asthemalconductivity. The thermal conductivity of the treated coir fibre is tabulated in Table 1. The following formula is used to find the thermal conductivity of the natural fibre:

$$K = \frac{mc(dT/dt)\ x}{piR^2 (T_2 - T_1)} \cdot \frac{R+2h}{2(R+h)} W/mK$$

K is the coefficient of the thermal conductivity of the sample; m is the mass of themetal disc; c is the heat capacity of the metal disc; dT/dt is the rate of cooling ofmetallic disc; X is the thickness of the sample; (T2-T1) is the temperature differenceover the thickness of the sample; R is the radius of the sample; h is the thickness ofthemetal disc. The graph is plotted time along the x axis and temperature along the y axis.

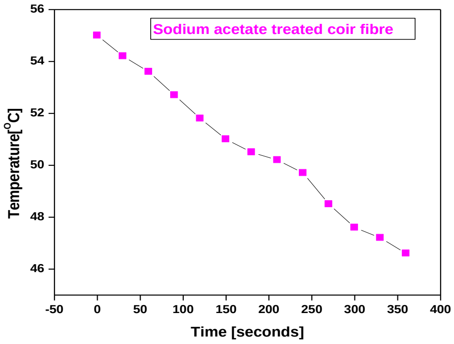

Fig. 2. Thermal conductivity of sodium acetate treated coir fibres

3.1.6. Water absorption behaviour

Studying the moisture absorption behaviour of composites made of natural fibres is crucial to comprehend the durability of composites based on the application sector. Water absorption of treated and untreated coir fibres is calculated using the formula,

$$\text{Water Absorption } \% = \frac{Weight\ after\ immersion - Weight\ before\ immersion}{Weight\ before\ immersion} * 100\ \%$$

The graph is plotted with time in x-axis and percentage of water absorption in y-axis. Fig. 3 shows the graphical data of untreated and sodium acetate treated coir fibre.

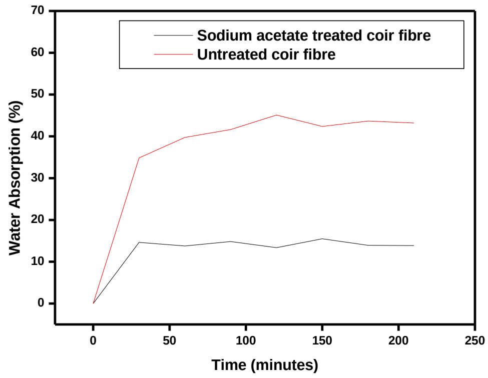

Fig. 3. Water absorption vs time graph of sodium acetate treated coir fibres

3.2. Chemical Analysis

The weight percentages of the different parts of a natural fibre, such as cellulose, lignin, wax, ash, moisture, pectin, and hemicellulose are found and are tabulated in Table 2 [6]. The physical and chemical treatments of plant fibers are known to change the cellulose content as well as degree of crystallinity. The amorphous content gets washed away due to chemical treatment with increasing the ratio of crystalline to amorphous regions. Thus, cellulose content of coir fibre increases after treatment. To assess the chemical make-up of each fibre sample traditional analytical techniques are applied [4].

Table 2. Chemical composition of sodium acetate treated coir fibres

Chemical Composition	Untreated coir fibres [7]	Sodium Acetate treatedCoir fibres (%) (present work)
Cellulose	37	60.39
Hemicellulose	-	31.61
Lignin	42	24.19
Pectin	-	3.98
Moisture	11.36	11.37
Wax	-	0.88
Ash	-	2.77
Density(g/cc)	1.2 [8]	1.16

3.3. Thermal Analysis

Thermal analysisisoneofthemostwell-knownandfrequently employed methods for analysing the decomposition of solid materials. Depending on the nature and chemical makeup of the naturalfibres, the heat degradation takes two tothreeprocesses. TG plot is generated with the temperature along the x-axis and the weight loss percentage along they-axis. Table3 indicates the mass loss of treated fibre in al lcases below 352℃. Major mass loss (30 - 50 wt%) occurs above 243℃ and is caused by the breakdown of cry stalline cellulose.

Table 3. Thermal study of sodium acetate treated coir fibre

Fibre Type	Temperature during mass loss (℃)	Mass Loss	Residual mass At 700 ℃ (%)	Activation Energy (kJ/mol)
Treated coir fibre	0 - 154	4%	22.42%	56.3755
	154 - 243	2%		
	243 - 352	49%		

The highest peak of deterioration is identified using the DTG curve. The peak values on the TG curve are consistent with it. As a result, the thermal stability of the fibre has been perfectly evaluated. Table 4 examined the mass loss at T_{max} of treated coir fibres. DSC profiles of treated coir fibres are indicated in Fig. 4 (c). The treated coir fibre's lignified compartment is released by an exothermic peak at 361 °C [9].

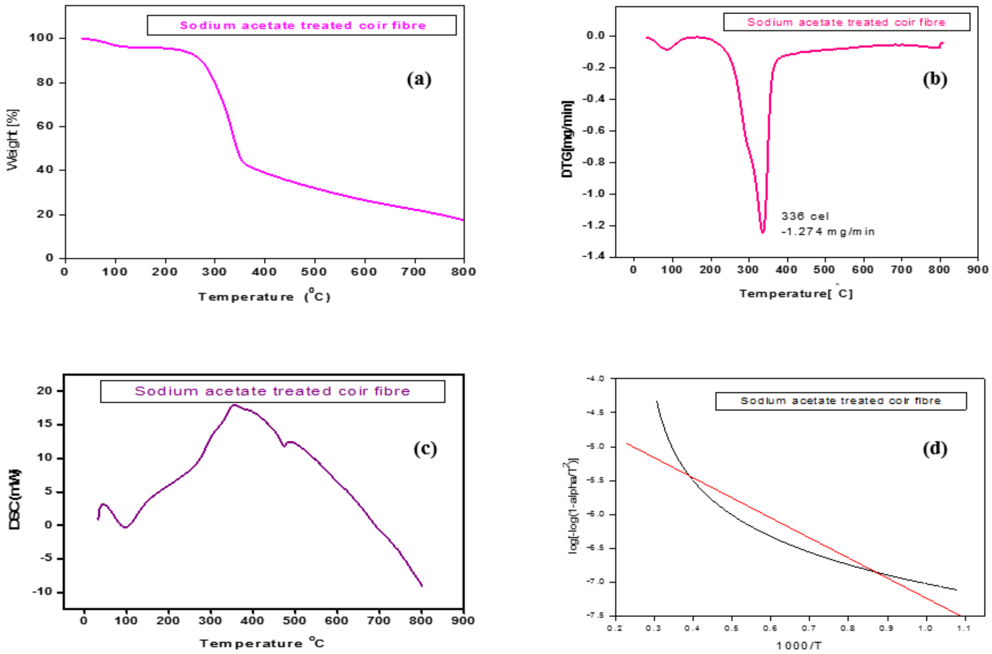

Fig. 4 (a) TG curve of sodium acetate treated coir fibres (b) DTG curve of sodium acetate treated coir fibres (c) DSC Curve of sodium acetate treated coir fibres (d) Activation energy curve of sodium acetate treated coir fibres

TheActivation energy of treated coir fibreis calculated from Coasts - Redfern approximation.

$$\log[\frac{-\log(1-\alpha)}{T^2}] = \log\frac{AR}{\beta E_a}[1 - \frac{2RT}{E_a}] - \frac{E_a}{2.303\,RT}$$

Table4. Mass loss at Tmax of treated coir fibres

Sample	Total mass loss (%)			Max. Temperature Limit (°C)	T (50%) (°C)
	First stage	Second stage	Third stage		
Treated coir fibre	4%	6%	55%	352	342

Conclusion

Coir fibre has many beneficial properties and is eco-friendly and so it can be concluded that it can be used as reinforcement in bio composites for various applications. The sodium acetate treatment on this fibre material enhances its qualities and so it can be use in a variety of matrixes for many applications. In order to take care of our mother nature such natural fibre reinforced composites must be used rather than man-made fibre composites, since these composites are biodegradable even after its use.

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