Physico-chemical and Thermal analysis of shell powder and fibres obtained from Tamarindus indica fruits

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ABSTRACT

To protect our mother nature, nowadays most of the synthetic products are replaced by natural products which are bio degradable. One such product is the composite material. These composite materials have various applications in industries such as automotive, construction, transportation, defence, furniture and so on. Composite materials may be made using manmade or natural fibres reinforced with resins. Natural fibre reinforced composites are the material of interest today because of its degradable nature. In the present work, Tamarindus indica (TI) fruits from Kanyakumari district are collected and their shells and fibres are seperated for investigation to be used as reinforcement in composite materials. They are characterized using p-XRD, FTIR, CHNS, SEM, TGA-DTA and chemical analysis. Also, the density of untreated and treated samples are found, so that it can be employed in making lightweight composites. The results indicated that the sample materials obtained from Tamarindus indica can be efficiently used as potential reinforcements in composites for attractive applications.

***Keywords**: natural fibres, bio degradable, composites, shells, light weight*

1. Introduction

Environmental challenges, the depletion of oil reserves, and issues with global garbage are all growing increasingly severe nowadays as modern society advances [1]. Scientists and researchers have recently been working to maximize the potential of natural fibres to create the most sustainable, bio degradable and high-quality natural fibre products [2]. The quality of natural fibres is greatly influenced by various factors like the age of the plant, species, growing environment, harvesting, humidity, quality of soil, temperature, and processing steps [3]. In various applications, natural fibres extracted from plants are used as reinforcements in both thermoplastic and thermoset resins [4]. Natural fibres now dominate the automotive, construction and sports industries by their superior mechanical properties [5]. Mechanical properties of natural fibres can be increased by giving surface treatments to fibres [6]. The major advantages of using natural fibres in composites are the cost of materials, their sustainability and low density as compared to glass fibres [7].

2. Materials and Methods

Tamarindus indica (TI) is most commonly known as Tamarind tree. Tamarindus indica (TI) tree is of medium to large size, it is evergreen, 12-18 m in height and 7 m in girth [8]. Tamarindus indica (TI) fruits are collected from the villages of Kollachal, Kanyakumari district of Tamil Nadu, South India. The shell is extracted and then it is washed and dried in sunlight for 6 to 8 hrs. It has to be blend to produce the powder. The fruit fibres of Tamarindus indica are washed and dried. Then they are cut into small pieces inorder to get the sample material [9].

2.1 Treatment of fibres

Hydrophilic nature of composites is reduced and their mechanical properties are improved by chemical treatment of fibres. Even its density value changes due to the surface treatment of fibres [10]. In this work, Tamarind shells are treated with sea water, alkali (KOH) and permanganate ($KMnO_4$) solutions.

3. Results and Discussions

3.1. p-XRD Analysis of untreated TI shell powder

The Percentage Crystallinity (% Cr), Crystallinity Index (CI) and Crystalline Size (CS) of natural fibres are measured by p-XRD analysis using the equations given below.

$$\text{Crystallinity \%} = \frac{I_{200}}{I_{200}+I_{am}} \text{ x } 100$$

$$\text{Crystallinity Index} = \frac{I_{200}-I_{am}}{I_{200}}$$

where, I_{200} and I_{am} are the crystalline and amorphous intensities at 2θ scale.

$$\text{Crystallite Size} = \frac{\kappa\lambda}{\beta cos\theta}$$

where, K = 0.9; λ = 1.54060 x 10^{-10} m; $\beta = \frac{\pi}{180} \times FWHM$; θ = Bragg's angle.

The increased crystal size in natural fibre makes the fibre more stable because the water absorption ability of the bio-fibre depends on their crystal sizes [11]. Increase in crystallite size tends to show decreased hydrophilic behaviour [12]. The chemical reactivity of the fibre also decreases with increase in crystallite size and thus mechanical strength gets increased [13]. The crystallite size is 25.822 nm and is comparable with the result obtained by Gaba et al. in the XRD analysis of pineapple leaf fibres [14].

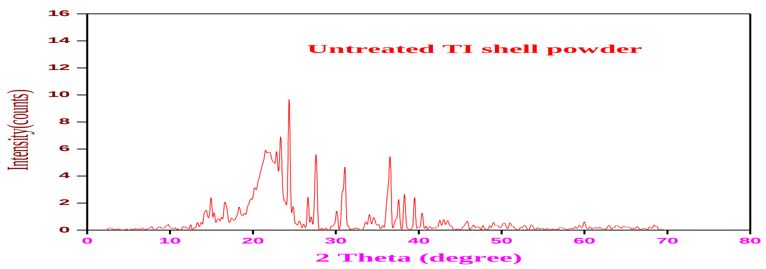


Fig 1. p-XRD pattern of untreated TI shell powder

Table 1. Crystallographic information obtained from p-XRD analysis

Parameters	**Untreated TI shell**
Crystallinity %	80.02
Crystallinity Index	0.7503
Crystallite Size (nm)	25.822

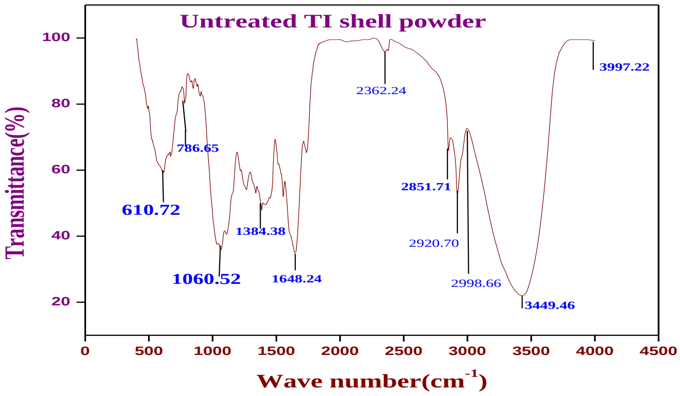
3.2. FTIR Analysis of untreated TI shell powder

The functional groups associated with untreated TI shell powder is determined using the Fourier transform infrared analysis. The FTIR spectrum of the experimental fibres were noted in the region between 4500- 400 cm^{-1}. The resolution was kept at 4 cm^{-1} [15].

Table 2. Vibrational band assignment of untreated TI shell powder

Wavenumber (cm^{-1})	**Vibrational band assignments**
3449.46	O-H stretching of cellulose
2998.66	C-H stretching of cellulose
2920.70	C-H stretching vibration of cellulose
2851.71	C-H symmetric stretching vibration of hemicellulose
2362.24	O=C=O stretching
1648.24	Carboxyl stretch of C-O, indicating the presence of acetyl group in hemicellulose
1384.38	Asymmetric COC stretching of lignin
1060.52	C-O stretching
786.65	CO stretching
610.72	Out of plane bending vibration involving ring structure

Fig 2. FTIR spectrum of untreated TI Shell powder



3.3. CHNS Analysis of untreated TI shell powder

The high percent of carbon indicates the hardness of the shell, high thermal & chemical stability and low density.

Table 3. Weight percent of C, H, N & S in untreated TI shell powder

S. No	Sample Name	N%	C%	S%	H%
1	Untreated TI shell powder	0.64	43.16	ND	6.52

ND: not detected

3.4 SEM Analysis of untreated TI shell powder

Surface morphology is a very important feature that decides whether the desired fibre material can act as a good reinforcement material or not [16]. The images of the sample surface is captured at different magnifications. Rough surface will have good adhesive nature with the smooth surface. The surface of tamarind shell powder is rough and so it can create good intermolecular bonding with the resin [17].

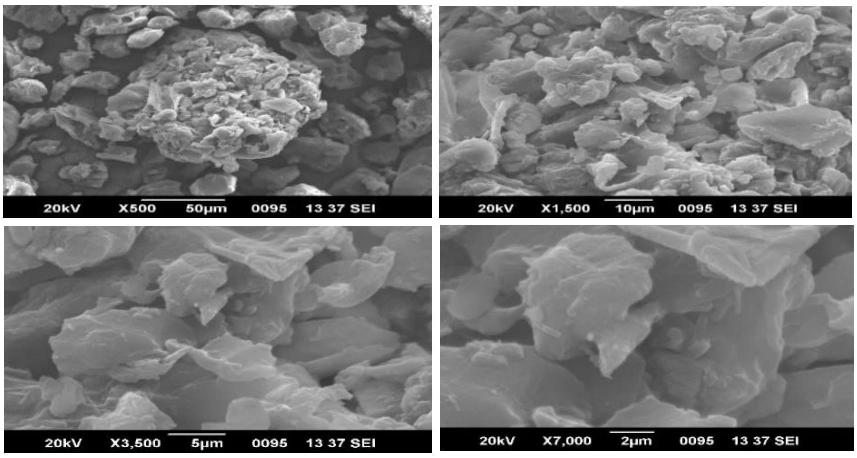
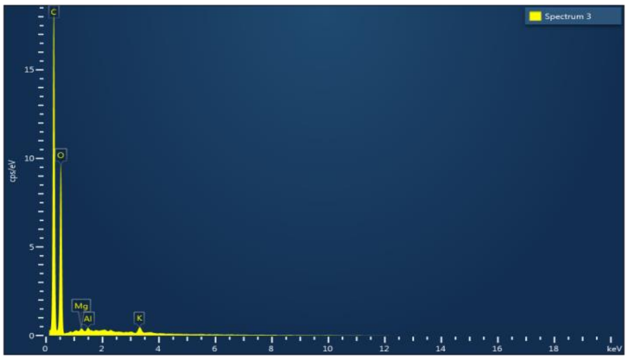


Fig 3. SEM images of untreated TI shell powder

3.4.1 EDAX Analysis of untreated TI shell powder

EDAX can be used to determine the amount of elements present on the surface of the sample.

Table 4. Weight % and Atomic % of elements present in untreated TI shell powder



Elements	Untreated TI Shell powder	
	Wt %	At %
C	56.05	49.61
O	42	49.52
Mg	0.45	0.26
Al	0.42	O.22
K	1.08	0.39

Fig 4. EDAX spectrum of untreated TI shell powder

3.5. TGA-DTA Analysis of untreated TI shell powder

Physical properties of the material is affected due to the change in temperature [18]. The maximum degradation peak is found from DTG curve.

Table. 5 Thermal studies of untreated TI shell powder

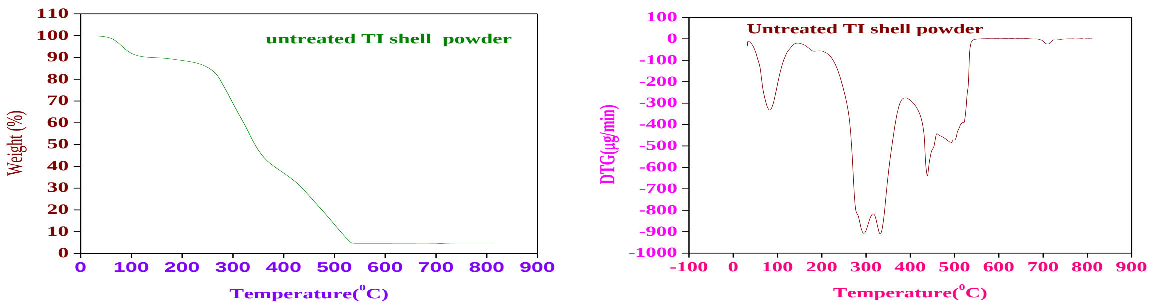


Fig 5. TG and DTG curve of untreated TI shell powder

3.6. Chemical Analysis of untreated TI shell powder

Sample	Temperature during mass loss (^{0}C)	Mass loss (%)	Residual char at 800^{0}C	Maximum Temperature limit (^{0}C)
Untreated TI shell powder	36-230	12.94	3.69	537
	230-384	47.61		
	384-537	34.42		

Different constituents of fibres have influence on various physical properties of the fibres.

Table 6. Chemical Composition of TI shell powder

On the whole, from analysis of the chemical composition of Tamarindus indica shell powder, it can be concluded that the percentage of chemical constituents of TI shell powder matches with many other natural fibres and also it has many advantageous properties.

3.7 Density of Tamarindus indica fibres

Density for fibres obtained from *Tamarindus indica* before and after chemical modifications is tabulated here.

Table 7. The Density of different fibres obtained from Tamarindus indica

Samples	Untreated Shell Powder	Sea water treated Shell Powder	KOH treated Shell Powder	$KMnO_4$ treated Shell Powder	Fruit fibres
Density (g/cm^3)	1.22	1.04	1.15	1.31	1.09

4. Future Directions

Tamarind shells from different localities and from different ages of Tamarind trees can be obtained and examined for its properties. Hybrid composites can be prepared by using other natural fibre materials along with tamarind shell powder and its properties can be analysed by various studies.

5. Conclusion

Untreated TI shell powder exhibits good thermal and mechanical characteristics which are the most crucial needs for a natural fibre to be used as reinforcement in composites. Sea water treated sample is found to have the least density. Fruit fibres have the second least value. Therefore both these samples are advantageous to be used in the preparation of light weight

Chemical Composition	Cellulose (wt.%)	Hemi cellulose (wt.%)	Lignin (wt.%)	Pectin (wt.%)	Wax (wt.%)	Ash (wt.%)	Moisture (wt.%)
Untreated TI Shell Powder	55.23	21.63	10.72	15.62	0.65	2.96	10.80

biocomposites rather than other natural fibre samples.

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