CELLULOSIC FIBER EXTRACTED FROM *ALSTONIA MACROPHYLLA* SEED PODS AS A POTENTIAL REINFORCEMENT FOR POLYMER COMPOSITES

ERUSAGOUNDER SAKTHIVELMURUGAN,* GANESAN SENTHILKUMAR,* SHETTAHALLI MANTAIAH VINU KUMAR* and HARWINDER SINGH**

*Department of Mechanical Engineering, Bannari Amman Institute of Technology, Sathyamangalam, Erode-638401, Tamilnadu, India

**Department of Textile Technology, Bannari Amman Institute of Technology, Sathyamangalam, Erode-638401, Tamilnadu, India

✉ Corresponding author: E. Sakthivelmurugan, sakthi.glen@gmail.com

Received December 6, 2022

The prime objective of the present work has been to investigate a novel natural fiber extracted from the seed pods of the *Alstonia macrophylla* (AM) tree. Chemical, physico-mechanical, and surface properties of untreated and alkali treated AM fibers were analysed. Chemical analysis confirmed that cellulose composition (78.31 wt%) of the AM treated fiber was improved as a result of alkali treatment, whereas other constituents, such as hemicelluloses, lignin and wax were decreased. This was supported by Fourier transform infrared (FTIR) analysis. Single fiber pull test showed that alkali treated AM fiber exhibited higher strength than untreated AM fiber. Scanning electron microscopy (SEM) studies revealed that surface roughness of the treated AM fiber was higher than in untreated AM fiber. Owing to an upsurge in the cellulose content, the tensile properties, crystallinity, and surface roughness of the AM treated fiber got enhanced, demonstrating that AM fiber could be potentially used as reinforcement for producing polymer composites for light weight applications.

**Keywords**: *Alstonia macrophylla*, alkali treatment, XRD, FTIR, SEM, Weibull distribution

**INTRODUCTION**

Currently, research efforts are dedicated to the exploration of new lignocellulosic materials from abundantly available natural resources. Natural fibers are composed of cellulose, hemicelluloses and lignin, and are the most abundant biomaterial on this planet. There is a huge potential in natural fibres to cater the demands of the forthcoming generations in one or another way. The prime advantages of natural fibers are their low cost, light weight, high specific modulus, renewability and biodegradability.

The major sector in which natural fibers are predominantly used as suitable alternatives for their synthetic counterparts is reinforced composites. As far as the comparison of the utility of natural fibers to that of synthetic fibers is concerned, no doubt the latter have gained more importance from the viewpoint of consistency in the fiber parameters, as well as overall properties of the composites. Despite the usefulness of synthetic fiber based composites, the main drawback is the difficulty of recycling at the end of the life cycle of the product. Meanwhile, composites fabricated by using natural fibers are environment-friendly to a large extent. The most challenging task for the researchers has been to improve the fiber matrix interphase, owing to the hydrophilic character of natural fibers. The most appropriate way to improve the interfacial adhesion between fibers and matrix is by subjecting the fibers to chemical treatments.

Lignocellulosic fibrous matter can be derived from bark, stem, flower, leaf, seed pods, fruit and roots of the plants and trees. The process of extraction of fibers from the fibrous assembly varies based upon the area from where it is to be extracted. The extraction of fibres from stem or bark is achieved by the retting process, whereas the extraction of fibers from leaves, stalk etc. can be done through alkali treatments or acid hydrolysis. Researchers have worked a lot globally to explore different lignocellulosic
resources, which were never introduced before, and their findings helped the utilization of those natural fibers in various end uses like automobile parts, furniture, packaging, and construction.\textsuperscript{8,9} Still, there are numerous natural fibrous materials that are yet to be explored in order to utilize their potential to the full extent. \textit{Alstonia macrophylla} (AM) tree is one of them, and it is majorly found in South East Asia. This tree is also referred to as hard alstonia, hard milkwood or big-leaved macrophyllum.\textsuperscript{10} To the best of the authors’ knowledge, no work has been reported on the extraction of fibers, as well as on the physico-chemical properties of fibers from \textit{Alstonia macrophylla}, so far.

The present research work has been carried out to gain in depth knowledge about the physico-mechanical and chemical properties of novel AM fiber. The fiber was subjected to alkali treatment, followed by characterization by various techniques, viz. X-ray diffraction, Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM) and tensile testing. The characteristics of the AM fibers were compared with those of other natural fibers.

**EXPERIMENTAL**

**Materials**

Fibers were extracted from the seed pods of \textit{Alstonia macrophylla} (AM) tree. Sodium hydroxide granules (98% purity) and acetic acid (98% purity and 98% concentration) were supplied from Sigma Aldrich Pvt Ltd., India.

**Fiber extraction**

\textit{Alstonia macrophylla} tree grown to a height of 30-meters and found in the region of Sathyamangalam Taluk, Erode district, Tamilnadu, India, was selected for the present investigation. Dry seed pods of \textit{Alstonia macrophylla} were collected and cleaned with regular water to remove any dust present in them. Dry seed pods were soaked in a water basin for 2 weeks for removal of the hard skin of the seed pods via biological retting.\textsuperscript{4,11} After two weeks of biological degradation, fibers were manually extracted, followed by cleaning with water and were subjected to drying in sunlight at room temperature for removing excess moisture from their surfaces. Stepwise extraction of fibers from the seed pods of \textit{Alstonia macrophylla} tree is presented in Figure 1.

**Alkali treatment of AM fiber**

Raw AM fibers were soaked in 5\% (w/v) aqueous solution for 60 minutes at room temperature (29 \degree C).\textsuperscript{12} Afterwards, these fibers were subjected to a neutralization process, where fibers were allowed to soak in water containing 1\% (w/v) acetic acid for eliminating any traces of NaOH present on the fiber surface.\textsuperscript{13,14} Alkali treated AM fibers were kept in air oven at 65 \degree C for 120 minutes. Finally, untreated and treated AM fibers were sealed in air-tight polyethylene covers until further studies were performed.

**Analysis of chemical composition**

Chemical constituents of both untreated and alkali treated AM fibers were computed in accordance with the standard procedures. The cellulose and lignin weight fractions of the AM fibers were determined as per Kurschner and Hoffer method, and Klason method.
respectively. The hemicellulose weight fraction was found by employing the neutral detergent fiber technique. The wax content of the AM fiber was measured by Conrad’s approach, whereas the ash content as per ASTM E1775-61 standard. The density of the AM fiber was determined using the pycnometer procedure in distilled water as an immersion medium. An electronic moisture analyser device was employed to quantify the moisture content in the AM fiber.

X-ray diffraction (XRD) analysis
An XPERT powder diffractometer (Panalytical) was employed to measure the crystalline index (CI) and crystallite size (CS) of the untreated and alkali treated AM fiber. Diffractograms for the AM fiber samples were recorded in the 2θ range 10° to 80° in the continuous scanning mode, with a step of 0.05 degrees. CI and CS were determined using Segal’s equations, respectively, as presented in Equations (1) and (2):

\[
CI = \frac{I_{200}}{I_{am}} \times 100
\]

where \(I_{200}\) and \(I_{am}\) represent the intensity of the peaks of the crystalline and amorphous region, respectively.

\[
CS = \frac{K \lambda}{\beta \cos \theta_0}
\]

where \(K\) is the Scherrer’s constant (0.89), \(\lambda\) is the wavelength of the radiation (0.154 nm) and \(\beta\) indicates the peak’s full width at half-maximum.

Fourier transform infrared spectroscopy (FTIR) analysis
Untreated and alkali treated AM fiber was subjected to FTIR to analyse the functional groups and types of bonding existing in them. The infrared spectra on the fiber specimens were recorded with an ABB Bomem MB3000 (Canada), with a capture rate of 16 scans per minute, covering the scan range from 4000 to 400 cm\(^{-1}\).

Single fiber tensile test
The tensile strength of the untreated and treated AM fiber was determined using a Zwick Roell universal testing machine (ASTM D3822-07), which was operated at a crosshead speed of 5 mm/min for the constant fiber gauge length of 50 mm. Twenty-five samples were tested for each untreated and treated AM fiber, and their average value was considered. Furthermore, Weibull analysis was performed for the fiber properties, namely: tensile strength, tensile modulus, and elongation at break.

Fiber length distribution (FLD)
The fiber length distribution of the AM fiber was achieved by adopting a manual technique. Around 280 fiber samples were considered for the analysis, and obtained FLD data were fitted in the histogram using SigmaPlot software V12.0.

RESULTS AND DISCUSSION

Chemical analysis
The chemical properties of untreated and alkali treated AM fibers were determined and compared with those of other natural fibers, as shown in Table 1. It can be observed from the findings that the cellulose content of untreated and treated AM fiber is 72.59% and 78.31%, respectively. This improvement of 5.72% in the cellulose content as a result of the reduction in amorphous region may contribute to an enhancement of tensile strength, thermal stability and crystallinity properties of the fiber. These afore-said findings are in line with the results of the single fiber tensile test, XRD and TGA, which are described in the subsequent sections. Besides, alkali treated AM fiber exhibited lower content of lignin, wax, moisture and ash, in contrast with raw fiber, as detailed in Table 1. Higher wax content imparts poor interfacial strength between fiber and matrix. Meanwhile, the treatment reduces the wax content by 28.72%, which is favourable for the use of AM fiber as reinforcement in polymer composites. The ash content of the treated fiber decreased from 1.28% to 0.55%, which is far better than in any other natural fiber compared in Table 1. The density of the untreated fiber is 1.52 g/cc and that of the treated AM fiber is 1.32 g/cc. After the alkali treatment, density reduced by 13.16%, which is favourable for the fabrication of materials for light weight applications.

XRD analysis
X-ray diffractograms of the untreated and alkali treated AM fibers are presented in Figure 2. In this XRD plot, the untreated AM fiber exhibited two intense peaks in the 20 range between 18.54° and 22.63°, whereas alkali treated AM fiber – at 18.15° and 22.48°, and these peaks mainly represent the existence of amorphous components and cellulose, respectively. The crystalline index (CI) of the untreated and alkali treated AM fiber was computed using Equation...
and values of 35.87% and 40.54%, respectively, were obtained. This marginal improvement in CI implies that chemical treatment has reduced the amorphous constituents. Hence, there is an increment in the ratio of crystalline constituents. Fibers with higher CI tend to be brittle, but, at the same time, they possess higher tensile strength, and this has been confirmed in the subsequent section on tensile testing. Crystallite size (CS) of the untreated and treated AM fibers is 3.04 nm and 2.00 nm, respectively, which was determined by employing Equation (2). The significant reduction of 34.21% in the CS of the treated AM fiber is mainly attributed to the alkali treatment. This reduction in the CS effects the close packing of the crystals and improves the resistance to moisture penetration, in contrast to the untreated AM fiber, which has higher CS. Thus, the hydrophilic characteristics of the AM fiber are decreased. The obtained CI and CS of the AM fiber are compared with those of other natural fibers, as shown in Table 2.

Table 1

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Cellulose (wt%)</th>
<th>Hemicell. (wt%)</th>
<th>Lignin (wt%)</th>
<th>Wax (wt%)</th>
<th>Moisture (wt%)</th>
<th>Ash (wt%)</th>
<th>Density (g/cc)</th>
<th>Refs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia nilotica L.</td>
<td>56.46</td>
<td>14.14</td>
<td>8.33</td>
<td>0.85</td>
<td>-</td>
<td>4.93</td>
<td>1.16</td>
<td>25</td>
</tr>
<tr>
<td>Common reed fiber</td>
<td>64.56</td>
<td>12.57</td>
<td>10.84</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11</td>
</tr>
<tr>
<td>Piliostigma racemosa</td>
<td>60.3</td>
<td>0.27</td>
<td>30.76</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Shvetark</td>
<td>69.65</td>
<td>0.2</td>
<td>16.82</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Sida rhombifolia</td>
<td>75.09</td>
<td>15.43</td>
<td>7.48</td>
<td>0.49</td>
<td>12.02</td>
<td>4.07</td>
<td>1.32</td>
<td>28</td>
</tr>
<tr>
<td>Acacia leucophloea</td>
<td>68.09</td>
<td>13.60</td>
<td>17.73</td>
<td>0.55</td>
<td>8.83</td>
<td>0.08</td>
<td>1.38</td>
<td>28</td>
</tr>
<tr>
<td>Cyperus pangorei</td>
<td>68.50</td>
<td>-</td>
<td>17.88</td>
<td>0.17</td>
<td>9.19</td>
<td>-</td>
<td>1.10</td>
<td>28</td>
</tr>
<tr>
<td>Saharan aloe vera</td>
<td>67.4</td>
<td>8.2</td>
<td>13.7</td>
<td>0.24</td>
<td>5.8</td>
<td>-</td>
<td>1.32</td>
<td>29</td>
</tr>
<tr>
<td>Heteropogon contortus</td>
<td>64.87</td>
<td>19.34</td>
<td>13.56</td>
<td>0.22</td>
<td>7.4</td>
<td>-</td>
<td>0.602</td>
<td>28</td>
</tr>
<tr>
<td>Furcraea foetida</td>
<td>68.35</td>
<td>11.46</td>
<td>12.32</td>
<td>0.24</td>
<td>5.43</td>
<td>6.53</td>
<td>0.77</td>
<td>29</td>
</tr>
<tr>
<td>Coccinia grandis L.</td>
<td>62.35</td>
<td>13.42</td>
<td>15.61</td>
<td>0.79</td>
<td>5.64</td>
<td>4.38</td>
<td>1.24</td>
<td>29</td>
</tr>
<tr>
<td>Ficus religiosa</td>
<td>55.58</td>
<td>13.86</td>
<td>10.13</td>
<td>0.72</td>
<td>9.33</td>
<td>4.86</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td>Dichrostachys cinerea</td>
<td>72.4</td>
<td>13.08</td>
<td>16.89</td>
<td>0.57</td>
<td>9.82</td>
<td>3.97</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td>Ziziphus mauritiana</td>
<td>43</td>
<td>10.2</td>
<td>5.1</td>
<td>-</td>
<td>7.9</td>
<td>-</td>
<td>1.132</td>
<td>12</td>
</tr>
<tr>
<td>Phaseolus vulgaris</td>
<td>62.17</td>
<td>7.04</td>
<td>9.13</td>
<td>-</td>
<td>6.1</td>
<td>-</td>
<td>0.854</td>
<td>12</td>
</tr>
<tr>
<td>Untreated Alstonia macrophylla fiber</td>
<td>72.59</td>
<td>28.95</td>
<td>12.78</td>
<td>3.62</td>
<td>8.14</td>
<td>1.28</td>
<td>1.52</td>
<td>This work</td>
</tr>
<tr>
<td>5% Alkali treated Alstonia macrophylla fiber</td>
<td>78.31</td>
<td>11.78</td>
<td>10.55</td>
<td>2.58</td>
<td>6.88</td>
<td>0.55</td>
<td>1.32</td>
<td>This work</td>
</tr>
</tbody>
</table>

Figure 2: XRD results of untreated and alkali treated AM fiber

**FTIR analysis**

The FTIR spectra of untreated and alkali treated AM fiber are shown in Figure 3, revealing the changes in the various functional groups, as well as the reduction in the transmittance intensities after the treatment of the AM fibers. The untreated AM fiber shows a high intensity peak at 3425 cm⁻¹, unlike that of the alkali treated AM fiber. In the case of the alkali treated AM fiber, the reduction in intensity of the peaks
corresponding to 2860 cm⁻¹ and 2924 cm⁻¹ is attributed to the partial removal of the CH₂ vibration band in hemicellulosic components and CH band for cellulose.³⁹ The peak at 2360 cm⁻¹ is assigned to the stretching of the C=O of lignin and hemicellulose amide groups.⁴⁰ The peak at 1727 cm⁻¹, representing the acetyl or ester groups of hemicellulose, is missing in the spectra of alkali treated AM fiber, owing to the removal of hemicelluloses to a great extent after the alkali treatment.¹ In the case of untreated AM fiber, higher intensity characteristic peaks corresponding to lignin are observed at 1027 cm⁻¹ (ether linkage), 1288 cm⁻¹ (C–O stretching vibration of acetyl groups), 1350 (phenolic-OH stretching) and 1543–1620 cm⁻¹ (aromatic skeletal vibration) respectively.³¹,⁴² The decrease in the intensity of all the peaks corresponding to lignin in the spectrum of the alkali treated AM fiber is attributed to the delignification of fibers due to chemical treatment.⁴⁴

Table 2
Thermal and crystalline characteristics of AM fiber and those of other cellulosic fibers reported in the literature

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Thermal stability (°C)</th>
<th>Max. thermal degradation (°C)</th>
<th>Crystallinity, CL, %</th>
<th>CS, nm</th>
<th>Kinetic activation energy (kJ/mol)</th>
<th>Refs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common reed</td>
<td>230</td>
<td>370</td>
<td>49.02</td>
<td>-</td>
<td>-</td>
<td>11</td>
</tr>
<tr>
<td>Heteropogon contortus</td>
<td>220</td>
<td>337.7</td>
<td>54.1</td>
<td>-</td>
<td>-</td>
<td>28</td>
</tr>
<tr>
<td>Shwetark</td>
<td>225</td>
<td>350</td>
<td>72.81</td>
<td>3.00</td>
<td>-</td>
<td>27</td>
</tr>
<tr>
<td>Acacia nilotica L.</td>
<td>210</td>
<td>339</td>
<td>44.82</td>
<td>3.21</td>
<td>69.73</td>
<td>25</td>
</tr>
<tr>
<td>Cissus quadrangularis stem</td>
<td>270</td>
<td>342.1</td>
<td>47.15</td>
<td>3.91</td>
<td>74.18</td>
<td>32</td>
</tr>
<tr>
<td>Sansevieria ehreberfitti</td>
<td>223</td>
<td>232</td>
<td>52.27</td>
<td>-</td>
<td>-</td>
<td>33</td>
</tr>
<tr>
<td>Ficus religiosa</td>
<td>325</td>
<td>400</td>
<td>42.92</td>
<td>5.18</td>
<td>68.02</td>
<td>14</td>
</tr>
<tr>
<td>Prosopis juliflora bark</td>
<td>217</td>
<td>331</td>
<td>46</td>
<td>15</td>
<td>76.72</td>
<td>34</td>
</tr>
<tr>
<td>Lygeum spartum L.</td>
<td>220</td>
<td>338</td>
<td>46.19</td>
<td>-</td>
<td>68.77</td>
<td>17</td>
</tr>
<tr>
<td>Juncus effusae L.</td>
<td>200</td>
<td>300</td>
<td>33.4</td>
<td>3.6</td>
<td>-</td>
<td>35</td>
</tr>
<tr>
<td>Napier grass strands</td>
<td>220</td>
<td>383</td>
<td>62.4</td>
<td>2.83</td>
<td>-</td>
<td>36</td>
</tr>
<tr>
<td>Pliostigma racemosa</td>
<td>244</td>
<td>327</td>
<td>56.69</td>
<td>5.25</td>
<td>67.91</td>
<td>24</td>
</tr>
<tr>
<td>Phaseolus vulgaris</td>
<td>250</td>
<td>328</td>
<td>43.01</td>
<td>4.0</td>
<td>-</td>
<td>22</td>
</tr>
<tr>
<td>Catharanthus roseus</td>
<td>203</td>
<td>296</td>
<td>25.9</td>
<td>-</td>
<td>-</td>
<td>37</td>
</tr>
<tr>
<td>Cereus hildmannianus</td>
<td>285</td>
<td>356.7</td>
<td>40.19</td>
<td>28.27</td>
<td>-</td>
<td>38</td>
</tr>
<tr>
<td>Untreated Alstonia macophylla fiber</td>
<td>274</td>
<td>373</td>
<td>35.87</td>
<td>3.04</td>
<td>62.79</td>
<td>This work</td>
</tr>
<tr>
<td>5% Alkali treated Alstonia macophylla fiber</td>
<td>269</td>
<td>375</td>
<td>40.54</td>
<td>2.00</td>
<td>73.48</td>
<td>This work</td>
</tr>
</tbody>
</table>

Figure 3: FTIR spectra of untreated and alkali treated AM fiber
Single fiber tensile test

Figure 4 depicts the tensile stress–strain curves for untreated and alkali treated AM fibers. The determination of the tensile strength of fiber plays a very important role, as it provides an insight into crack propagation and failure of composites reinforced with such fibers. From the plot, it can be seen that the maximum tensile strength of the untreated and alkali treated AM fibers is 239.45 +12.89 MPa and 324.89 ± 29.41 MPa, respectively. As far as the tensile modulus of the AM fiber is concerned, untreated fiber displays 2.07 GPa, whereas for the treated one, it is 2.43 GPa. This deviation in the tensile strength of AM fiber is due to its non-uniform inherited characteristics. A nearly 35.68% increment in the tensile strength and a 17.39% increment in tensile modulus of the treated AM fiber over those of the raw AM fiber are mainly due to the elimination of the amorphous constituents by the chemical treatment. During the tensile testing of the alkali treated AM fiber, few of the specimens endured a lower strain rate than untreated AM fiber, which may be attributed to the improvement in the stiffness of the AM fiber as its crystallinity content is increased due to the alkali treatment, which has been supported by the XRD analysis. Weibull distribution plots of the tensile properties for both untreated and treated AM fiber specimens are presented in Figure 5. As can be observed from the plot, all aforementioned parameters have followed the Weibull distribution pattern, with the Weibull slope being higher than 1 (β>1).

Fiber length distribution (FLD)

Mechanical properties of the fiber reinforced polymer (FRP) composites, such as strength, Young’s modulus and fracture toughness, depend on the fiber length distribution. It is clearly evident from the literature survey that the inclusion of short fibers into a polymer matrix may not ensure an improvement in mechanical properties. This may be explained by a decline in the reinforcement efficiency when the fiber content in composites is increased beyond its optimal level, resulting in a FLD increment due to intense fiber-fiber interaction. In this work, the FLD of the Alstonia macrophylla fiber is depicted in Figure 6. It is clearly seen that maximum number of fibers were in the ranges of 28-32 mm and 37-41 mm. In contrast, the minimum number of fibers were in the ranges of 18-23 mm and 41-46 mm, and thus it can be deduced that the novel AM fiber would be suitable for the fabrication of continuous fiber reinforced polymer composites.

![Figure 4: Single fiber tensile strength of untreated and alkali treated AM fiber](image)

SEM analysis

In order to study the effect of chemical (alkali) treatment on AM fiber morphology, untreated and alkali treated AM fibers were observed by SEM under different magnifications (x350, x500, and x700) and the respective images are shown in Figure 7. The diameter of the AM fiber was measured using SEM and its value was found in the range of 78.2 µm to 111.5 µm. SEM images of the untreated AM fiber revealed its smoothness and shiny surface characteristics, as compared to
that of treated AM fiber. This may be owing to

Figure 5: Weibull plots of single fiber (a) tensile strength, (b) Young’s modulus, and (c) elongation at break (%)

More importantly, micrographs exposed the

Figure 6: Fiber length distribution

presence of pores in the untreated AM fiber, but

of amorphous constituents, such as wax and others. Hence, treated AM fiber could be a good

after the chemical treatment, the pores were

choice as a reinforcement element in producing

significantly reduced – this may be the reason for

polymer matrix composites for structural

the lower density property of the fiber.

Moreover, the alkali treatment of AM fiber has

applications, as interfacial adhesion between fiber and matrix would increase due to the high

promoted a rougher surface due to the elimination

cellulose content and high surface roughness.
CONCLUSION
In the present study, natural fibers were successfully extracted from a new source – the seed pods of *Alstonia macrophylla*, and their chemical, physico-mechanical, and surface roughness characteristics are reported. Chemical analysis results confirmed that alkali treated AM fiber has higher cellulose content than the raw AM fiber. The density of fibers was reduced by 13.16% after the alkali treatment. XRD results conveyed that the crystallinity index (CI) and crystal size (CS) of the alkali treated AM fiber were improved from 40.26% to 48.86%, and from 5.25 nm to 3.09 nm, respectively. Furthermore, this improvement in the crystallinity of the AM fiber was supported by FTIR. Tensile strength and tensile modulus of the alkali treated AM fiber increased from 239.45 ± 12.89 MPa to 324.89 ± 29.41 MPa, and from 2.09 GPa to 2.43 GPa, respectively. SEM morphology analysis revealed an improvement in the roughness characteristics of AM fiber. Finally, it can be concluded that alkali treated AM fiber is a promising fiber to be potentially applied as reinforcement in manufacturing continuous fiber reinforced polymer composites, exclusively for light weight applications.

REFERENCES
2. A. K. Mohanty, M. A. Khan and G. Hinrichsen,