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Mechanical properties and corrosion behavior of sugarcane Bagasse fiber reinforced Low Density Polyethylene composites

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ABSTRACT

In the recent decade, there has been an increase in global warming, environmental changes, and other issues. Environmentally friendly products, such as natural composite materials, are being developed by researchers and academics to protect life on the planet. The purpose of this research is to see if cellulose and cellulignin fibres obtained from sugarcane bagasse (SCB) waste may be used as reinforcing filler in a thermoplastic polymer matrix. The injection method was used to create the low density polyethylene (LDPE) and sugarcane bagasse (SCB) composites. Fiber loading was set to be varied from 10 to 30 wt%. To improve interfacial bonding, the fibres were chemically modified using an alkali treatment, and the effects on the fiber/matrix interaction were evaluated using scanning electron micrographs (SEM). Tensile, impact, and hardness were used to determine the mechanical properties and corrosion tests. The findings revealed that sugarcane bagasse fibers, like other natural fibers, strengthen polyethylene. It has been found that the tensile strength and tensile modulus of the treated SCB fibers have been improved significantly by about 13% and 196%, respectively, compared to neat LDPE. This was due to the observed enhancement in the interfacial adhesion between the fiber and matrix. The impact resistance and hardness of the composite enhanced by 55.28% and 26%, respectively, over neat LDPE. According to SEM analysis, the alkali treatment affected the morphology of fibers.

1. INTRODUCTION

Increased environmental awareness and societal interest have resulted in the widespread usage of environmentally friendly materials for example natural fiber as sugar cane bagasse, bamboo, banana, coir, cotton, flax, hemp, jute, and turmeric. Natural fiber is an environmentally friendly material with superior qualities over plastic. Natural fibers have several advantages over synthetic fibers, including low cost, low density, comparable specific tensile qualities, lower health risk, renewability, recyclability, and biodegradability [1–3]. Natural fiber composites are one of the most appealing replacements for non-biodegradable glass and carbon fibers in the fabrication of thermosetting and thermoplastic composites[4,5]. Researchers and industries prefer Vegetable fibers with better properties than synthetic fibers because of their wide range of applications in industries such as, fiberboard, cushion, paper, mattress, door, automotive, wall panel, air cleaner, dashboard, and insulation mat manufacturing, food-

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packaging, as well as construction and transportation[6].

The key to transferring stress from the matrix into the fibers through the interface is interface bonding between the fillers and the matrix. Natural fibers have several advantages, as indicated above. Still, they also have some disadvantages when used in polymer matrix composites, such as high moisture sorption variability in fiber characteristics and a tendency to agglomerate during processing[7–10]. Natural fiber has a high hydrophilic property since it is made up of lignocellulose, which contains numerous hydroxyl groups (-OH)[11]. As a result, these fibers are fundamentally incompatible with hydrophobic polymer matrix materials, with poor interfacial adhesion between hydrophilic natural fibers and typical resin matrices being particularly problematic.

The incompatibility may cause problems in the composite processing and material properties[12]. This causes a wetting issue, poor interfacial adhesion, and limited stress transmission between the two interfaces, all of which significantly impact strength growth. [13]. Thus, Numerous chemical treatments of plant fibers could be utilized to circumvent these constraints and increase compatibility with polymer matrices. [14]. One of the approaches that develop the inherent properties of natural reinforcements is the alkali treatment of the natural reinforcements. Alkali treatment is the simplest and most cost-effective method of altering natural fibers. It is a long-established commercial technology that involves treating the fibers with a sodium hydroxide solution[15–17]. The influence of chemical treatments on the mechanical properties of natural fiber-reinforced composites was examined by many researchers. Maryana et al. [18] investigated The chemical composition and structure of sugarcane bagasse after alkaline pretreatment. The properties of sugarcane bagasse before and after pretreatment have been studied. The treatment with NaOH had the lowest lignin level, according to the findings.

Sugarcane bagasse is abundant and has a softer structure than other types. Its availability as waste from agricultural waste and waste from the sugar mill's production process could reinforce the polymer [18]. Alexandre et al.[19] Examined Polypropylene (PP) and sugarcane bagasse fiber composites with and without alkali treatment. They also looked into the composites' thermal and mechanical properties. After the chemical treatment process, scanning electron microscopy (SEM) demonstrated improvements in the fiber's surface topography. The alkali treatment changed the fiber surface as well as the chemical composition, according to TGA and SEM data. They concluded that the mechanical and thermal properties of the material had improved. Santhanam & Chandrasekaran [20] attempted to make a composite using bagasse fiber and epoxy resin. Alkali treatment changed the surface of the fibers. They looked at the impact of fiber surface modification on mechanical characteristics, including tensile strength in composites made using milled fibers. The tensile strength of alkali-treated bagasse/epoxy composites was found to be greatly improved. The surface modifications also boosted the fiber-matrix interaction, according to SEM analysis. Mulinari et al. [21] tested Low Density Polyethylene (LDPE) composites reinforced with King Palm fibers for mechanical and thermal properties. Mechanical properties were determined using tensile, flexural, and impact specimens. SEM micrographs of broken surfaces and thermal analyses were used to evaluate the composites. The results showed that the reinforcement reduced the composites' thermal stability but increased their tensile, flexural, and impact strength significantly.

The goal of this research was to investigate the mechanical properties as well as the corrosion behavior of composites made from untreated and treated fibers. Scanning electronic microscopy was used to explore the effects of interfacial morphology and matrix–fiber interaction on the mechanical characteristics of produced composites within the framework (SEM).

2. MATERIALS AND METHODS

2.1. Materials

The Low Density Polyethylene (LDPE) (SABIC® LDPE HP20023) used as the starting matrix with a melting temperature of 112° C. Table 1 shows its physical and mechanical properties. The sugarcane bagasse (SCB) used as filler was directly obtained from sugar cane mills after being processed to extract sugar and liquor.

Table 1. Properties of low density polyethylene (LDPE).

Property	Polyethylene
Density (g/m^3)	923
Melt Flow Rate at 190°C and 2.16 kg	20 g/10 min
Tensile strength (MPa)	9
flexural strength	7
flexural modulus	175
strain at break	150
Izod Impact Strength(J/m²)	500
Hardness Shore D	45

2.2. Chemical treatment using sodium hydroxide.

Bagasse fibers were dried in the sun for one week to eliminate moisture content, then crushed into small pieces using a crusher machine. This fiber was immersed in a 3% aqueous sodium hydroxide solution for 8 hours at 30°C[22], with a liquor ratio of 15:1(w/v) [23], allowing hemicellulose, lignin, and other fatty components to be removed [24].The fibers were rinsed with water multiple times to eliminate any NaOH solution that had adhered to their surface. Treating SCB withsoduim hydroxide causes fibrillation, breaks SCB bundles and increase the surface roughness[25]. The fibers were then air-dried for 24 hours at ambient temperature before being oven dried for 24 hours at 80°C [26,27] as shown in figure 1.

(a) (b)

Figure 1. sugarcan bagasse fibers. (a) SCB soaked in NaoH (b) treated SCB

2.3. Fabrication of composite laminates

Polyethylene pellets were combined with ground SCB fibers. To avoid void generation, both bagasse fiber and LDPE were dried in an air oven before making composite samples. For each weight fraction, the required amount of fiber and matrix was weighed (10wt %, 20wt %, and 30wt %) of untreated and treated cellulose and cellulignin fibres. Sugarcane bagasse fibres were incorporated together with the matrix. The composites were injected directly into a mold with predetermined dimensions after mixing as shown in fig 2. The five heating zones had processing temperatures of 140, 160, 170, 200, and 220°C, respectively. There was a pressure of 100 bar. Tablel 2. listed the composition of the studied formulation. Treating SCB (TSCB) and untreating SCB (UTSCB).

Figure 2. injected specimens.

Table2 composition of the studied formulation.

Sample	LDPE (wt%)	Pre-treatment	Fiber content
Neat LDPE	100	-	-
UTSCB	90	None	10
	80	None	20
	70	None	30
TSCB	90	NaOH	10
	80	NaOH	20
	70	NaOH	30

2.4. Mechanical testing

2.4.1 Tensile test

The tensile tests were executed with Jinan Test Machine (WDW 100 KN) universal testing machine supplied from Jinan Xinluchang (Testing Machine Co., Ltd, Jinan City, Shandong Province, China). Tensile testing was carried out in accordance with (ASTM D638 type V). The test was run at 2 mm/min crosshead speed. The average tensile strength value of five samples for each composition was calculated.

2.4.2 Impact test

The Izod impact test was used to determine the impact strength and absorbed energy in accordance with ASTM D256. Impact tests were performed on V-notched specimens using an AVERY Denison impact machine. The pendulum has a 3.8 m/s falling velocity and a 15 J impact energy. The impact strength was determined by dividing the absorbed energy by the sample's original cross-section area.

2.4.3 Hardness testing

The fiber volume fraction and modulus have a significant impact on the hardness of a fiber-reinforced composite[28]. Hardness value determines the plastic material's resistance to being penetrated by the indenter. Hardness was measured by Hardness shore D Tester instrument in accordance with ASTM D 2240. Hardness was measured at eight different random points for each composite sample, the mean value of hardness was calculated.

2.4.4 Chemical resistance test

The Corrosion resistance test is usually performed for the primary acids, alkalis, and solvents. The most widely used chemicals in the category of the acid include: concentrated sulfuric acid (10wt% H_2So_4), determined resistance to alkalis is generally examined for the aqueous solution of sodium hydroxide (10wt% NaOH)[29]. However, a common solution, sodium chloride (3.5wt% NaCl), was utilized to investigate the chemical resistance of composites against the chemical solution. The materials are weighed and then immersed in chemical reagents for 24 hours in the standard experimental procedure. In most cases, the experiments are carried out at room temperature. The samples are removed, rinsed with distilled water, and dried between filter sheets after a 24-hour interval. After that, the samples were weighed to calculate the percentage of weight gain. The following equation was used to calculate the percentage of weight gain [30,31].

$$\%\ \text{weight gain of the sample} = \frac{\text{final weight} - \text{original weight}}{\text{original weight}} \times 100$$

2.4.5. Scanning electron microscopy (SEM)

Scanning electron microscopy (SEM) was used to evaluate fiber dispersion/distribution in the polymer matrix, Using an FEI Quanta 200i instrument to investigate the morphological behavior of the untreated and chemically modified fiber surface and the fractured surfaces of natural composites. Prior to each analysis, the surfaces of natural composite specimens were sputter-coated with gold.

2. RESULTS AND DISCUSSIONS

3.1. Tensile properties

Figure 3-5 displays the mechanical properties (tensile strength and Young's modulus (modulus of elasticity)) of neat LDPE , untreated and treated sugarcane bagasse composites with various SCB fiber loadings. The tensile strength of the alkali-treated SCB/LDPE composites was higher than that of neat LDPE and the untreated SCB/LDPE composites[32]. On the other hand, Untreated SCB had lower tensile strength than LDPE, which might be attributable to fiber pullout and debonding of the untreated SCB fibers from the LDPE matrix[32,6]. The tensile strength and Young's modulus characteristics were obtained as a result of this interaction. The tensile strength of treated SCB fiber reinforced with LDPE increased from 12.47 to 13.23 MPa for 10wt% to 30%, respectively. Generally, a high fiber-loading content develops the composites mechanical properties[24]. The tensile strength and Young's modulus showed a growing trend From 10 wt% to 30 wt% fiber loadings.The tensile strength and Young's modulus of 30 wt% alkali-treated fiber loadings exhibited a considerable increase by 13% and a 196%, respectively, over LDPE. In the meantime, the maximum tensile strength was attained at 30wt% SCB fiber loading in the LDPE matrix. The tensile strength of the 30 wt% SCB/LDPE composite increased by 13% compared with LDPE, whereas Young's modulus was 196% higher than that of LDPE. The failure of tensile specimens is a complete fracture into two parts in the specimen gage length across the cross section as shown in Figure 6. The mechanical strength and Young's modulus were influenced by the morphology of the untreated and treated SCB/LDPE composites. And would be also influenced by defects that occurred during the injection of the SCB/LDPE samples. Tensile strength and Young's modulus of tensile strength are listed in Table 3. the untreated SCB fibers had weak interfacial bonding with the LDPE matrix compared to the treated SCB/LDPE composite[34].

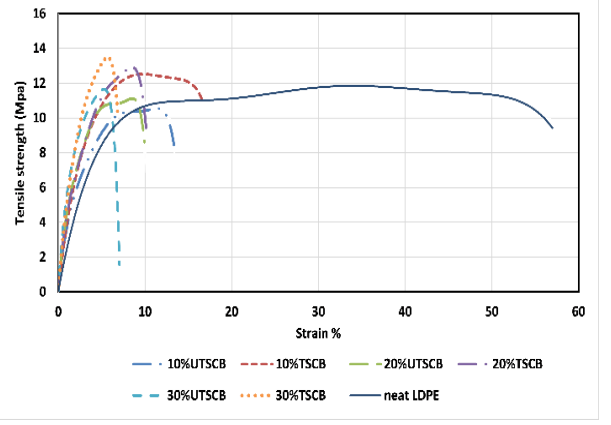


Figure 3. the stress- strain curve of SCB fiber-reinforced composites

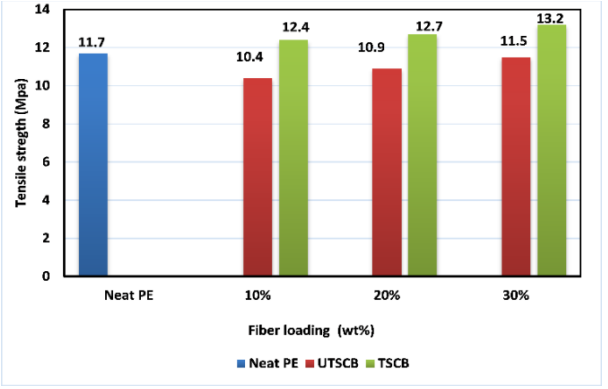


Figure 4.Tensile strength of SCB fiber-reinforced composites.

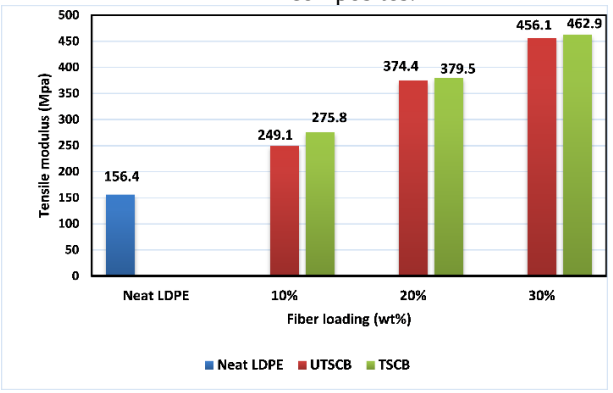


Figure 5. Tensile modulus of SCB fiber-reinforced composites.

Figure 6. Common failure modes for tensile test specimens

Table 3. tensile strength and modulus of SCB reinforced LDPE.

sample	Tensile strength(Mpa)	Tensile modulus(Mpa)
Neat LDPE	11.71676	156.4
10%UTSCB	10.43788	249.149
20%UTSCB	10.94705	374.47
30%UTSCB	11.513	456.15
10%TSCB	12.47454	275.8
20%TSCB	12.72912	379.598
30%TSCB	13.23829	462.91

The treated SCB fibers were embedded in LDPE, whereas the untreated SCB fibers were pulled out. [35]. The interfacial adhesion and flow of LDPE within SCB fibers were primarily responsible for this result. The alkali treatment improved the surface adhesion of the fibers, which is beneficial for greater compatibility between fiber and matrix.

3.2. Impact properties

The failure of impact specimens is a complete fracture into two parts in the specimen gage length across the width as shown in Figure 7. The results of the Izod impact test are reported in table 4 and impact strength values disply in Fig.8. The effects of bagasse fibers on the impact strength are examined and discussed in this part. It can be seen that there was an improvement in the impact strength due to the inclusion of bagasse fibers[36]. The strength increased from 64.4 to100 KJ/m² for neat LDPE and 30 wt% treated SCB composite, respectively. From the present observations, it can be concluded that there was an enhancement in the impact strength with increase in the percentage of SCB fiber loading[37]. This is attributed by the higher energy need to be supplied to the fiber to pull out at higher filler content and good interfial bonding between the fiber and the matrix [38].

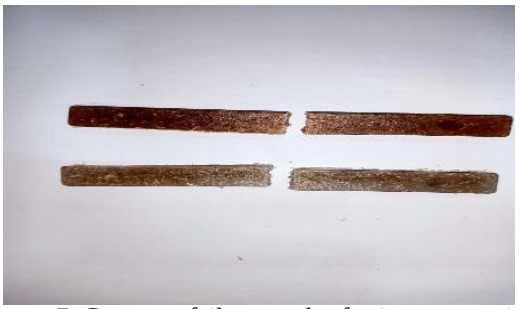


Figure 7. Common failure modes for impact specimen.

Table 4. the Impact strength of SCB fiber-reinforced composites.

Sample	Impact energy (Joule)	Impact strength (KJ/m²)
Neat LDPE	2.9	64.4
10%UTSCB	3.6	80
20%UTSCB	3.8	84.44
30%UTSCB	4.2	93.33
10%TSCB	3.7	82.22
20%TSCB	4	88.89
30%TSCB	4.5	100

3.3. Hardness

Figure 9 reveals the effect of percentage of sugarcane bagasse on a polymer matrix composite's hardness property. At 30 wt% fibre, LDPE reaches its maximum

hardness value. A significant improvement in the hardness value of the composites was indicated with increasing fibre content, as shown by the results. The findings were likewise in agreement with what was published in [39]. The material hardness increases by rising its resistance deformation. When more filler is added, the hardness of the materials improves.

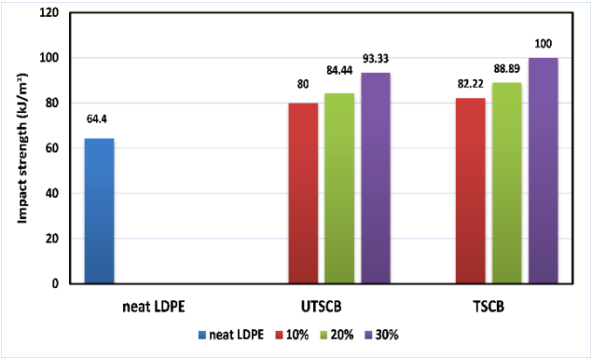


Figure 8. Impact strength of SCB fiber-reinforced composites.

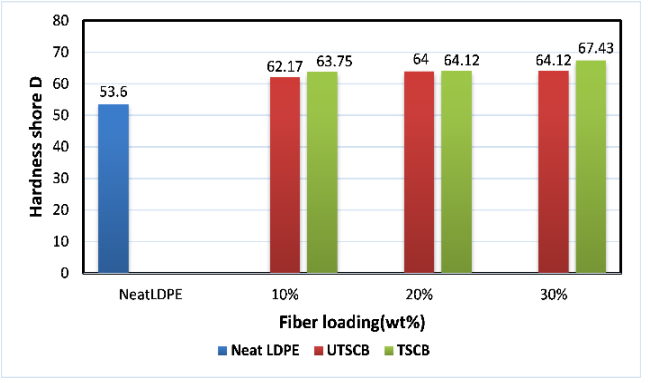
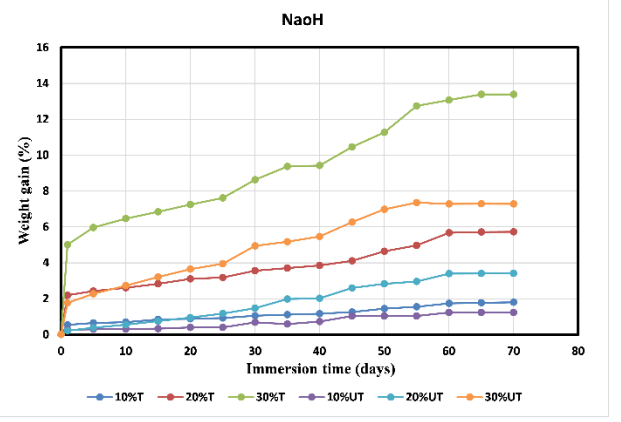


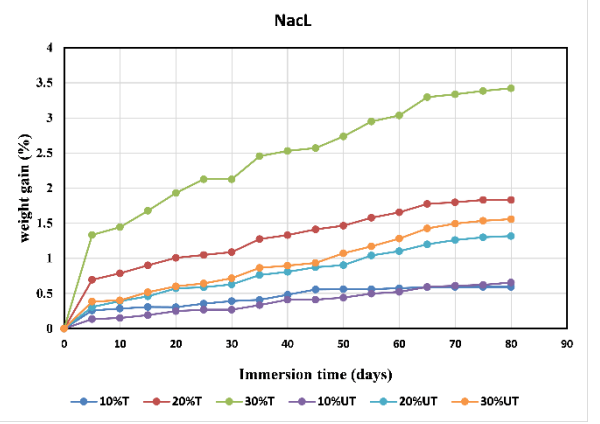
Figure9. Hardness shore D of SCB fiber-reinforced composites.

3.4. Chemical resistance

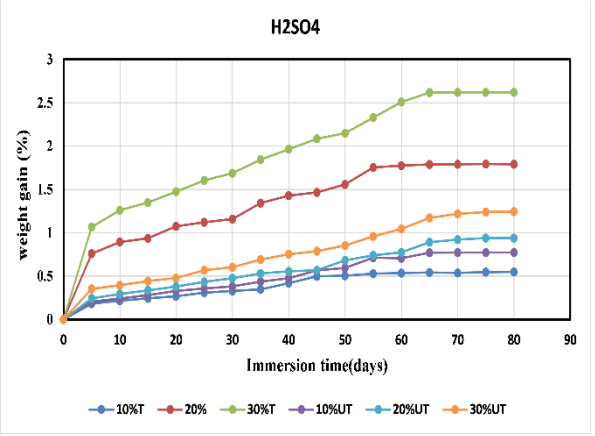
Figure 10 illustrates the percentage absorption of SCB/LDPE composites. In most chemicals, increasing the fiber content increases the percentage absorbance of SCB/LDPE composite. It implies that when fiber content rises, their chemical resistance collapses. Because more fibers are exposed to chemicals, so the chemical resistance decreases[40]. In general, the increase in weight gained occurred due to the hydrophilicity of lingocellulosic fibers for the water or aqueous solutions. It was observed that in all cases the percentage of weight gained was greater in the samples containing treated fibers[41]. In these, the OH groups in cellulose were more exposed, and this increases the hydrophilicity of the system. From the figures, it is obvious that weight gain is detected for almost all chemical reagents used when the natural fibers of the composite were pretreated with alkali[31]. The percentage of absorption For untreated SCB compostite is lower then treated SB composite because there are awaxy layer prevents chemicals from pentration. Increasing the weight gain of the samples indicates there is good interaction between the fiber and the chemical solutions. Therefore, there is a poor chemical resistance of the substance, so the lower the absorption, the better the resistance. It is the general principle behind the analysis. Amongest all the chemicals, samples have shown maximum absorption for NaOH. In general, the calculation absorption was larger for aqueous solutions, and this was to be expected due to the fiber's hydrophilicity. This conclusion is supported by the weight increase in the presence of these liquids with increasing fiber content. [40]. The percentage of absorption For untreated SCB compostite is lower then treated SCB composite because there are awaxy layer prevent chemicals from pentration.



(a)



(b)

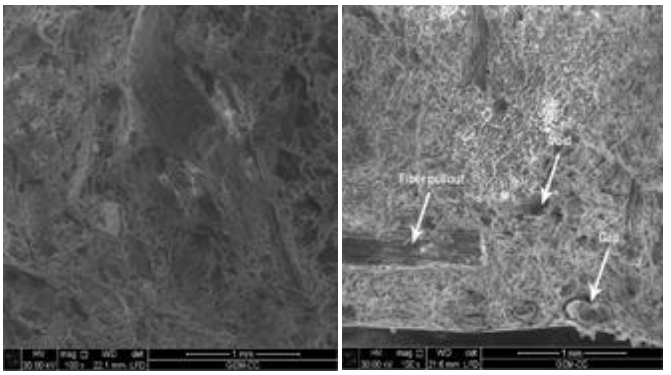


(c)

Figure10. Chemical resistance of SCB fiber-reinforced composites. a)NaOH b) NaCl C) H2SO4

3.5. SEM

Figure11 shows SEM images of the fractured surface of a treated SCB reinforced LDPE composite with alkali-treated SCB fibers. Fiber distribution and dispersion in the matrix were found to be satisfactory. Additionally, alkali treatment eliminates waxes from the surface of the fiber and creates a strong chemical interaction between the fibres and the matrix. Untreated SCB, however, had significant agglomerates of fibers on the fracture surfaces. The presence of decohesion between the fiber and the matrix confirms this.



(a) (b)

Figure11 SEM tensile fracture surface of sugarcane bagasse reinforced LDPE (a)treated (b)untreated

4. CONCLUSIONS

From this research paper, the investigation of the effect of chemical treatment on the mechanical properties of SCB fibers was achieved and presented. It has been found that:

1. The alkali treatment of SCB significantly improves the tensile strength and modulus of all the fabric-reinforced composites compared to untreated SCB fibers.
2. The alkalization treatment of SCB also improves the impact and hardness properties of the SCB/LDPE composite significantly compared to untreated SCB fibers.
3. Chemical resistance decreased with an increased fiber content from 10 wt% to 30 wt% fiber .
4. Composites have shown maximum absorption in NaOH solution.

Acknowledgments

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