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Research paper

Effect of Coconut Fiber Reinforcement on Mechanical Properties of Corn Starch Bioplastics

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Abstract

Plastic waste piling up in landfills is a serious threat to the environment. To minimize this type of waste, bioplastic made from various biodegradable sources is an option. In this work, bioplastic known as coconut fiber-corn starch bioplastic (CF-CSBP) is produced by incorporating a mixture of coconut fiber (CF), *Lates calcarifer* fish scale (FS) and glycerol, while the remaining is corn starch (CS). For a comparative study, a sample containing 0% CF known as corn starch bioplastic (CSBP) was also prepared. The effect of CF addition towards water absorption and mechanical characteristics; tensile strength, elongation and load to break were investigated. Results showed that CF-CSBP absorbed slightly more water (26.3%) after 24 hrs, but the addition of CF as a reinforcement improved the tensile strength and elongation to break the bioplastic. As for tensile, CF-CSBP was able to withstand higher force as compared to CSBP by 0.22 N/mm^2. However, CF-CSBP only recorded 19.55% of elongation. This research proves the feasibility of using CF as a reinforcement material in the bioplastic and CF-CSBP is comparable to available bioplastics.

Keywords: *Corn Starch; Coconut Fiber; Protein based Bio-plastic.*

1. Introduction

Many works reported on the shift of interest towards the application of biodegradable materials due to the drawbacks of petroleum-based materials. Malaysia's wide agricultural sector that produces high amount of waste provides opportunities to turn the waste into valuable goods, including bioplastics. The basic composition of bioplastic is plasticizer, natural fibers and bio filler. More importantly, the bioplastic is made up of proteins that degrade easily and it is a good gas barrier as well as having excellent mechanical properties. The corn starch usually used in bioplastic is widely available at low cost to ensure constant supply of the material [1]. Bioplastic offers several advantages to minimize the threat to the environment. They are non-toxic, easily compostable in soil and safe for human consumption. Combination of these materials enhances its properties to the extent of biodegradation potential of the product [2].

The transformation of corn starch into bioplastic for any application requires disruption of granules through heating in the presence of various plasticizers under specific conditions. Water, glycerol and sorbitol were commonly used to promote plasticity and flexibility of the plastic. The presence of these materials reduces the plastic's brittleness due to extensive interactions between the protein chains [3]. Few studies used starch-based materials due to its excellent oxygen barrier property. However, its application is limited due to its low tensile strength, poor moisture barrier and brittle. Improving its mechanical properties and water resistance is an important scope to be looked into. Commonly, the addition of reinforcement, including synthetic and natural fibers, is one of the approaches [4]. The use of fiber such as coconut fiber leads to excellent interaction between the corn starch matrix and the lignin. This is due to the strong polar bond and hydrophilic nature of coconut fiber [5]. Mechanical properties of the natural fiber reinforced composites were reported to be highly dependent on fiber and polymer matrix interface bonding.

The main drawback of natural fibers in composites is incompatibility with many hydrophobic polymer matrices and they can absorb high moisture. However, the fiber surface properties can be modified via chemical surface treatment to improve the fiber-matrix adhesion. Chemical treatments include de-waxing, alkali treatment, peroxide treatment, acetylation, acrylation, benzoylation, treatment with various coupling agents [6]. Alkaline treatment was chosen to modify the surface of the coconut fiber (CF) in this study due to its effectiveness.

Apart from CF, fish scales (FS) can be abundantly found in tropical areas such as Malaysia. They are known to be cheap and biodegradable and they were frequently reported to be used as fillers in bioplastic. Scales from fish is one of the crucial sources of calcium which is similar to constituent material: calcium-deficient hydroxyapatite (HAP). This component is able to increase the biodegradation rate of polymer [7]. However, works on the development of CF-CS bioplastic scarce.

Therefore, the aim of this study is to modify CF for corn starch bioplastic production as well as incorporating FS in the bioplastic. Mechanical properties and water absorption capability of the bioplastic produced by using these wastes will be thoroughly investigated in this work.

2. Methodology

2.1. Material

Lates calcarifer fish scale (FS) and coconut fiber (CF) were obtained from a local market at Masai, Johor, Malaysia. Oven-dried corn starch at temperature 105°C for 24 hours was used in this study where 50 g of the starch was used to prepare each sample. Meanwhile, 99% glycerol (Evachem) was used as plasticizer. Sodium hydroxide solution was used for alkaline treatment of CF at concentration of 0.1M.

2.2. Fish scale preparation

3.58 g of FS was rinsed prior to its usage to remove impurities. The scales were dried at temperature of 70°C for 24 hours. The product was then ground before reheated at 105°C until a constant weight was achieved. The FS was kept in a desiccator at room temperature prior to its use.

2.3. Treatment of coconut fiber

The fiber was treated according to Diao et al. Firstly, the CF was oven dried at 50°C for 2 hours. The fiber was sliced to produce uniform in size (40 mm in length). It was then subjected to alkaline treatment to modify the fiber surface properties by soaking 7.14 g of CF in a 0.12 mL/mL of 0.1 M sodium hydroxide solution for 4 hours at room temperature. The process was followed by washing the fiber with distilled water until pH 7 was reached [7]. The alkali-treated fiber was dried at room temperature for 12 hours and before heating it to 50°C for 2 hours.

2.4. Composite preparation

In producing Coconut Fiber Corn Starch Bioplastic (CF-CSBP), corn starch (CS), glycerol, fish scale (FS) and coconut fiber (CF) were mixed according to the composition listed in Table 1. The mixture was then stirred on a hot plate at 80°C for two hours until precipitate was formed. The precipitate was then spread onto a petri dish to form a thin bioplastic sheet and the sheet was left to dry at room temperature for 24 hours. The same procedure was applied for the production of Corn Starch Bioplastics (CSBP), except that the mixture only contains CS, glycerol and FS.

Table 1: Composition of Bioplastic

	Composition (wt%)	
Material	**CSBP**	**CF-CSBP**
Corn Starch (CS)	67.5	60
Glycerol	30	28
Fish Scale (FS)	2.5	2.5
Coconut fiber (CF)	0	10

2.5. Characterization of composites

2.5.1. Water absorption

The water absorption of the CSBP was performed according to the ASTM standard method D570-98 [8]. The bioplastic was placed in an oven at 100°C for 2 hours before cooling it down in a desiccator. Next, the sample was weighed before it was submerged in 100 mL of distilled water for a duration of time, ranging from 0 to 120 mins. Remaining liquid on the surface of the sample was removed once the sample was taken out. The weight of the sample was immediately identified. Water absorption percentage (%) was calculated using equation (1).

$$\text{Water Absorption (\%)} : \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100 \quad (1)$$

2.5.2. FTIR analysis

Fourier-transform infrared spectroscopy (Bruker) was used to compare the functional group present in both, treated and untreated CF bioplastics. Samples were analysed from 400-4000 cm-1 with 64 scans.

2.5.3. Tensile strength test

Samples of bioplastics were prepared at uniform dimension of 27mm × 7mm × 3.5 mm using Universal Testing Machine (UTM) Instron 4301. In this test, the samples were subjected to 100 kN load cell, clamped at distance a of 35 mm. Deformation rate applied was 1 mm/min. Deformation 1% of the Young's modulus and 50 mm/min at higher deformations were used in this study. The test was repeated by using four samples from each type of bioplastic and the mean values as well as standard deviation were determined.

3. Results and Discussion

3.1 Water absorption

Water absorption capability of a bioplastic is an important parameter to be tested. In the present study, the absorption of water for CF-CSBP and CSBP was compared for a period of time (0 to 120 mins). The data collected is shown in Fig. 1. Based on the figure, both samples absorbed water at an increasing rate though the sample with 10 wt% CF showed lower absorption capacity with time. As time prolongs, CSBP showed significant increment of water absorption percentage (from 2.1% to 26.3%) while CF-CSBP recorded a maximum of 6.2% water absorbed at 120 mins. Steady increment of the amount of water absorbed as function of time was expected until the process reached equilibrium, as reported in previous study using corn starch [9]. High water absorption in bioplastic was contributed by the presence of corn starch. This is due to the hydrophilic character of the starch [10]. A lower water absorption by CF-CSBP is due to the presence of CF that gave less hydrophilic character to the bioplastic [11; 12]. Moreover, the use of glycerol as plasticizer in the bioplastic also contributed to higher amount of water absorbed. Glycerol is known to be soluble in water and hygroscopic in property, which was contributed by the three hydroxyl groups [13].

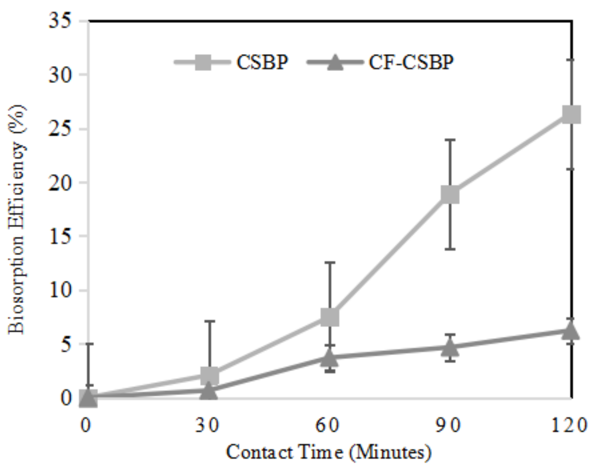

Fig. 1: Percentage of water absorption

3.2 Functional group

FTIR peaks obtained for treated and untreated CF are shown in Fig. 2. It was found that the functional group recorded in this study is similar to other organic fibers. The high absorption capacity of sample CF-CSBP is highly possible due to the existence of polar hydroxyl (-OH) group of CF. It is believed that the -OH in CF plays an important role in absorption as proved by Das et al., [14]. The -OH functional group formed hydrogen bond with water which enhance the water absorption rate. Additionally, CF consists of polysaccharide compounds (cellulose, hemi-cellulose) and macromolecule polyphenolic compound (lignin). The treatment of CF removes hemi- cellulose, lignin, waxes and oil. The only difference is treated CF has rough surface due to the fiber aggregation which can be removed by NaOH. The summary of FTIR peak is presented in Table 2.

Table 2: The functional group

Functional group	Wavelength (cm^{-1})
O-H stretching	3333.43
C-H stretching	2933.87
C=O	1731.65
CH_2	1418.95
CO	1230.27
C-H and C-O groups	1032.78

3.3. Tensile strength

Tensile strength test was conducted to identify the maximum pulling force that can be withstand by the bioplastic before it breaks. This study compared the performance of CSBP and CF-CSBP in terms of tensile strength and the data collected is shown in Fig. 3. The quantitative data displayed the influence of CF in the composite on maximum load that can be withstand by CSBP. The sample recorded 9.81N/mm^2 maximum load. Meanwhile, CF-CSBP showed better results where it can withstand 10.70 N N/mm^2 of load. Presence of CF in the composite improved the strength where load at break correlates with the trends for the tensile strength and young modulus of the organic bioplastics. However, the addition of CF should not extend up to 50% as it can reduce the tensile strength [15]. Tensile strength of bioplastic was reported to be reduced at high fiber content due to its inability to support stress transferred from the blend matrix. Moreover, particles could agglomerate at high fiber content. The results obtained is in line with Sen et al where it was reported that the high content of fiber causes its saturation as well as causing high porosity of the biocomposite [16].

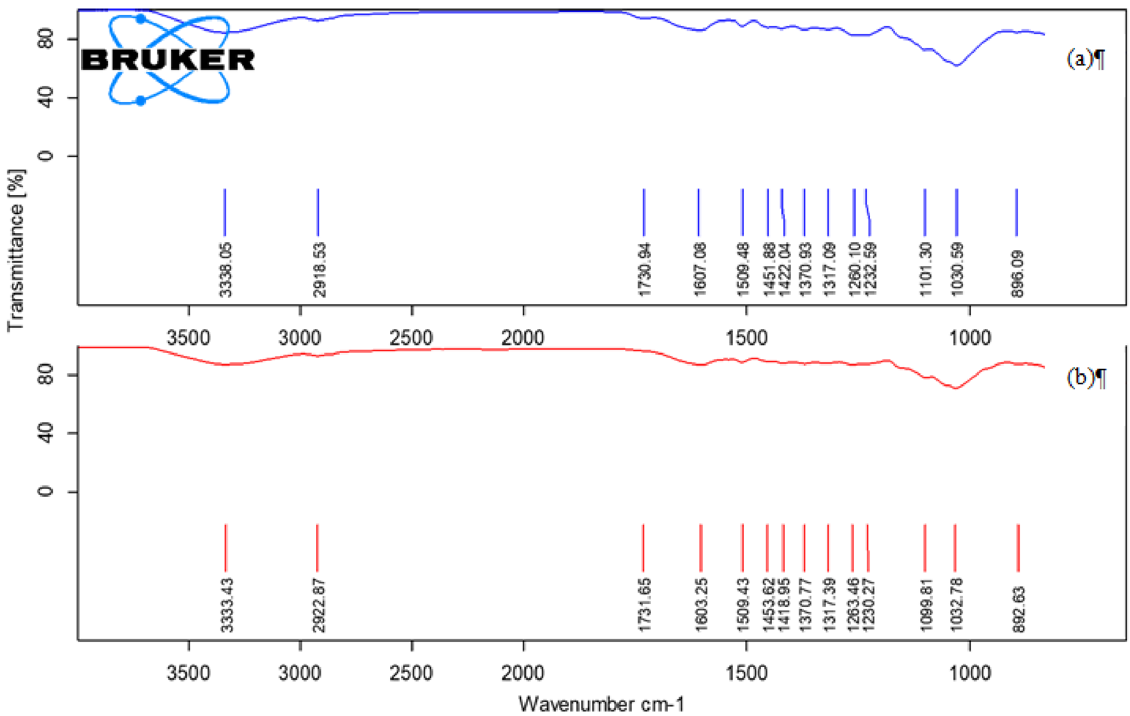

Fig. 2: FTIR analysis of (a) untreated CF (b) treated CF

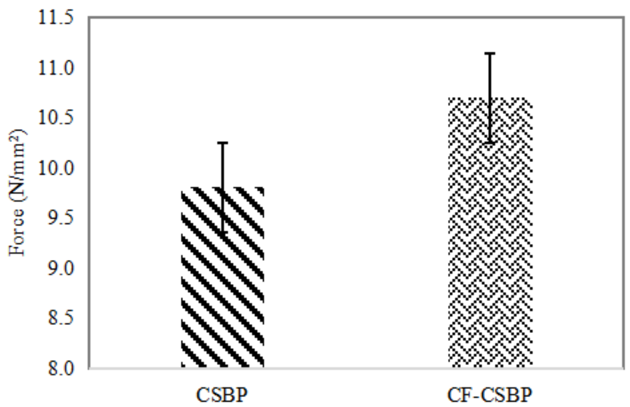

Fig. 3: Maximum force of bioplastics

A displacement test of the bioplastic was conducted to measure the maximum force that can be applied before it breaks. Data collected for CSBP and CF-CSBP is presented in Fig. 4. Based on the figure, maximum displacement force decreases slightly with the addition of CF. The maximum displacement obtained from sample CSBP is 2.10 mm while the maximum displacement for CF-CSBP is 1.95 mm. Such data was recorded as fiber reduces the plasticity of bioplastic [17].

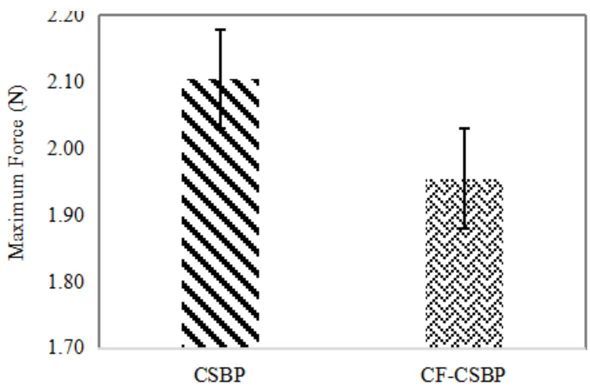

Fig. 4: Maximum displacement of bioplastic

The strain on a sample when it breaks is called elongation-to-break or ultimate elongation. The data collected in this study was represented in percentage. Fig. 5 shows the maximum elongation for CSBP and CF-CSBP. Sample CSBP recorded maximum elongation at 30.07% while sample CF-CSBP can only elongates at 19.55%. The percentage of elongation was found to decrease as the CF was added. This is due to the effect of stiffness of the compound with the incorporation of CF [18].

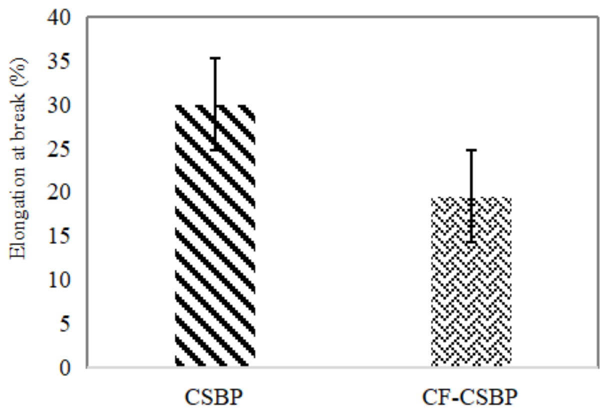

Fig. 5: Maximum elongation of bioplastics.

4 Conclusions

Effects of CF as a reinforcement material in corn-starch bioplastic were investigated in this study. It was found that the interfacial adhesion between the CF and the CS can significantly affect the mechanical properties of the bioplastic. The result of the study showed that the increased in percentage of coconut fiber increases the load at break. The addition of CF in the CSBP showed higher tensile strength by 0.22 N/mm2 but counterproductive when elongates. In terms of water absorption, it can be concluded that with the presence of CF showed good results due the role of –OH group that form a hydrogen bond with water.

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