The Influences of Chicken Feather Loading on Tensile and Physical Properties of R-Hdpe/Eva/Cff Composites

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The Influences of Chicken Feather Loading on Tensile and Physical Properties of R-Hdpe/Eva/Cff Composites

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Abstract. PE/EVA blends are one of the popular existing commercial polymers which catch many attentions among researchers and manufacturing industry. This article is concerned with the mechanical properties, morphology, and functional groups towards recycled high density polyethylene (r-HDPE)/ethylene vinyl acetate (EVA) reinforced with chicken feather fiber (CFF). In this study, the r-HDPE/EVA/CFF composites with varies ratio of chicken feather (2.5, 5.0, 7.5, 10.0, and 12.5 phr) were moulded into compression moulding machine and tested using conventional universal testing machine. Morphology and functional groups properties were characterized using field emission microscope (FESEM) and Fourier transform infrared spectroscopy (FTIR), respectively. The results showed that the tensile and physical properties (water absorption and oven aging) of r-HDPE/EVA/CFF composites were slightly affected by the chicken feather fiber content.

Keywords: Organic filler reinforced composites, filler loading, mechanical properties, morphology, functional groups

1. Introduction

Presently, huge amount of chicken feather disposed by different poultry industry as a solid waste arise solid-agricultural dispose issues. Chicken feather has more than 90 % protein called keratin [1]. Keratin fibers is amino acid which able to crosslink with polymer matrix by forming disulfide or hydrogen bonds which enhance the fiber/matrix interaction to become stiff, strong, and lightweight properties [2]. Furthermore, the advantages of chicken feather fiber are strictly bio-compatible, non-abrasive, low density, and warmth retention which promotes in reinforcement of polymer composites (Meyers *et al.*, 2008). Recently, Jagadeeshgouda and co-researchers (2014) [3] investigated the properties of CFF as reinforcement fiber in plastic composites. The systematic fiber orientation and uniform dispersion of CFF instead of random will produced good fibrous nature and its morphological results [4].

Nowadays, one of the most widespread and general material in global economy is plastic. The demand of commodity plastic increase 8.7 % in plastics industry with the rapid growth of global population for 60 years from 1950 to 2012 [5]. High-density polyethylene (HDPE) is the third universally-used plastic material after polyvinyl chloride and polypropylene. High-density polyethylene is stronger than standard polyethylene, resistance to moisture and chemical and solid state at room temperature. High density polyethylene is the main polymer used for packaging which nowadays become the main source for plastic solid waste. Thus, they are recycled and reprocessed to reduce the production waste and consumption of raw material [6]. Due to the non-biodegradability of HDPE, HDPE is recycled to produce no harmful emissions and non-toxic chemical and its recycling symbol as no. 2. The recycled HDPE pellets and flakes are 31 % to 34 % cheaper than the virgin HDPE.

Recently, there are many publications about properties of PE/EVA blends. Among the existing commercial polymers, PE and EVA copolymers are good modifiers to improve flexibility, transparency and toughness [7]. Ethylene vinyl acetate (EVA) is a copolymer from polyolefin family that consists of hydrophobic ethylene group and hydrophilic vinyl acetate group. Ethylene vinyl acetate is a widely used polymer in industrial application various with vinyl acetate content as films and coatings [8]. Ethylene vinyl acetate has high strength, ductile, high elasticity flexibility, permeability to oxygen, and high-water absorption properties [9]. Thus, r-HDPE and EVA blends will produce novel type of thermoplastic which has the advanced properties of the blends.

Compatibilizers are addition agent added in fiber reinforced polymer composites to enhance the compatibility between interfaces of polymer matrix and fiber. Shokri and co-researcher (2015) [10] shown that present of compatibilizer keeps EVA molecules improves the compatibility of the HDPE/EVA blend. This is due to the present of compatibilizer encourage the interaction between EVA and HDPE. However, no study has been done towards chicken feather as reinforcement fiber in r-HDPE/EVA for composite product. Hence, in this research, chicken feather fiber has been utilized as reinforcement fiber in r-HDPE/EVA/CFF composites. As to achieve the main goal in this research, chicken feather reinforced composites have been moulded according to different amount of filler loading. Meanwhile, the morphology and functional groups properties of these composites was characterized using field emission scanning electron microscopy (FESEM) and Fourier transforms infrared (FT-IR), respectively.

2. Experimental Part

2.1 Materials and methods

Recycled high density polyethylene (r-HDPE) pellets were obtained from Mega Makmur Sdn. Bhd. Penang, Malaysia. The material has a melt flow index of 0.7 g/10 min at 190 °C, a density of 0.948 g/cm3, and melting temperature range from 110 °C to 140 °C with a peak at 131.5 °C with a heating rate of 10 °C/min. The EVA contains 18.1 wt% vinyl acetate (VA), with melt flow index of 2.5 g/ 10 min at 80 °C and a density of 0.925 g/cm3 are used. EVA was obtained from A. R. Alatan Sdn. Bhd., Kedah Darul Aman, Malaysia. The chicken feather was obtained from morning market, Kangar, Perlis. Sodium hydroxide (NaOH with molar mass = 40 g/mol) was supplied by A.R. Alatan Sdn. Bhd., Kedah Darul Aman, Malaysia.

2.2 Alkaline treatment

First, chicken feather was immersed in 1 mol of sodium hydroxide for 24 hours at 25 °C followed by washing with distilled water. The chicken feather was dried in oven at 80 °C for 24 hours. Then, the dried chicken feather was crushed using a laboratory mixer and sieved to obtain average fiber size 0.4 cm to 1 cm.

2.3 Composite preparation
The composites were prepared using z-blade mixer at temperature 180 °C and rotor speed of 30 rpm for 18 minutes until the mixture homogenous Recycled high density polyethylene (r-HDPE) and ethylene vinyl acetate (EVA) were mixed and loaded into mixing chamber for melt mixing. The blend of r-HDPE (70 wt.%) and EVA (30 wt.%) is preheated for 10 minutes then the chicken feather fibers only added into the soften mixture based on different fie loading (2.5, 5.0, 7.5, 10.0, 12.5 phr). The soften composites was discharged from mixing chamber and ready for future process.

2.4 Compression molding
Hydraulic hot press machine model GT 7014A was used to produce the composite in compressed sheet form. The temperature was set as 180 °C for both top and bottom plate. The empty mould was heated for 2 minutes. Then the compounds were put into the mould, preheat for 1 minutes followed by 3 minutes partially compression and fully compression for 2 minutes once the compound started become soften. After compression, the samples were cooled for 4 minutes. The moulded composites then ready for testing.

2.5 Mechanical testing
2.5.1 Tensile testing
The composites plate was cut into dumbbell shape with 50 mm length and 4 mm width by using Wallace die cutter for tensile testing. The Shimadzu Tensile Testing Machine model AG-XD plus was used for tensile test. According to ASTM D638, the crosshead speed is set as 50 mm/min. Five dumbbell shaped samples for each formulation were tested. The tensile strength, modulus of elasticity and elongation at break of samples were obtained from this tensile test.

2.6 Characterization
2.6.1 Morphology
The morphology of the tensile fracture on the samples were observed by using field emission scanning electron microscope (FESEM) model Supra 35-VP at School of Material and Mineral Resources, USM Engineering Campus. First, the fracture surface was mounted on aluminum stage to undergo sputtering coating. The samples were coated with 20 *n*m thin layer gold by using Auto Fine Coater and then observed under microscope.

2.6.2 Functional groups
Fourier transform infrared spectroscopy (FTIR) characterization was used to characterize the chemical structure or functional group of the composites. The spectra were obtained from Perkin-Elmer Spectrum One Series equipment. The sample was cut into small rectangular shape. The scanning range for selected spectrum resolution and wavelength are 4 cm^{-1} and 600-4000 cm^{-1}.

2.7 Physical testing
2.7.1 Water absorption
Three samples with dimension (20 x 10 x 1) mm for each formulation were used for water absorption test according to ASTM D570 - 98. First, the samples were weighted and totally immersed in distilled water for two months until the weight of samples were constant. After immersion, all samples were removed and wiped by filler paper to remove surface water. The amount of water absorbed was measured every week for two months. The final weight of samples was observed with 0.1 mg precision. The calculation for the percentage of water absorption is shown below:

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$$\% \, Mass \, absorb = \frac{W_2 - W_1}{W_1} \times 100\% \quad (1)$$

Where W_1 is the weight of dried sample and W_2 is the weight of the wet sample.

Oven aging
Five samples with dimension (20 x 10 x 1) mm for each formulation were used for oven aging test according to ASTM D3045 - 92. First, the samples were weighted and dried in oven at 80 °C for 48 hours. After that, all samples were removed and measured. The final weight of samples was observed with 0.1 mg precision. The calculation for the percentage of water retention is shown below:

$$\% \, Mass \, retention = \frac{W_1 - W_2}{W_2} \times 100\% \quad (2)$$

Where W1 is the original weight of sample and W2 is the final weight of the sample.

3. Results and discussion

3.1 Tensile properties
Figure 1 shows the effect of CFF loading on tensile strength of r-HDPE/EVA/CFF composites. Based on Figure 1, the addition of CFF loading in r-HDPE/EVA/CFF composites slightly enhanced the tensile strength of composites. This proved that CFF was performed the bridging effect which formed a network in the composite as reinforcement during loading condition to prevent crack propagation. This was due to keratin protein of CFF consists of 40 % hydrophilic and 60 % hydrophobic amino acid groups [11]. The keratin feather fiber was compatible with both hydrophilic and hydrophobic polymer matrix thus improved the interfacial adhesion with hydrophobic r-HDPE phase and ethylene in EVA and hydrophilic ester group in EVA.

However, the tensile strength of r-HDPE/EVA/CFF composites had no significant changed in trend by increasing of CFF fiber loading. The tensile strength at 12.5 phr fiber loading slightly decreased. This indicated 12 phr CFF is exceed the optimum fiber loading which cause agglomeration in r-HDPE/EVA matrix as stress concentration which weakening the polymer matrix-filler interaction. Bonser and Purslow (1995) [12] concluded that the function of CFF as reinforcement only efficient up to 10 % feather content.

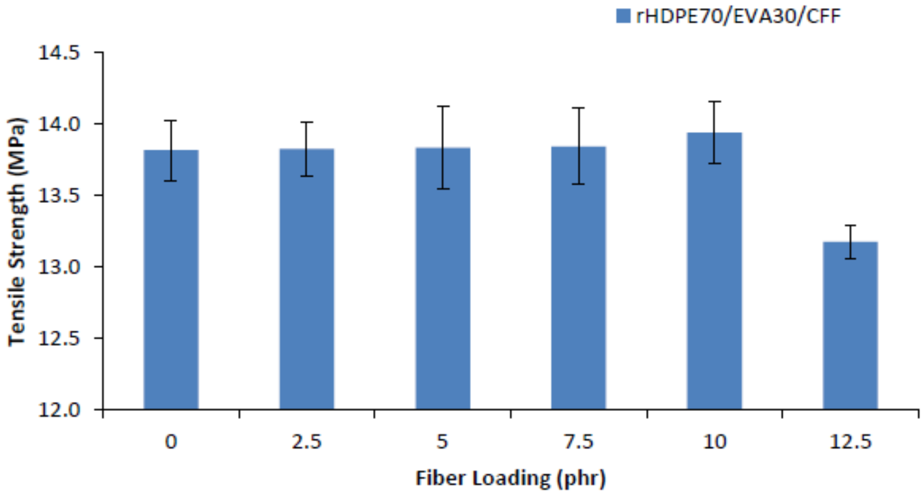


Figure 1. Effect of fiber loading on the tensile strength of r-HDPE/EVA/CFF composites

3.2 Modulus elasticity

Figure 2 shows the effect of CFF loading on the modulus of elasticity of r-HDPE/EVA/CFF composites. The trend shown that the addition of CFF loading in the composites gradually increased the modulus of elasticity of composites. This indicated that the CFF enhanced the strength and stiffness of r-HDPE/EVA/CFF composites which lead to reduce in ductility. The incorporation of CFF stiffed the r-HDPE/EVA matrix. The CFF filler was added into r-HDPE/EVA matrix to reduce the chain mobility of matrix and improve the rigidity of r-HDPE/EVA/CFF composites.

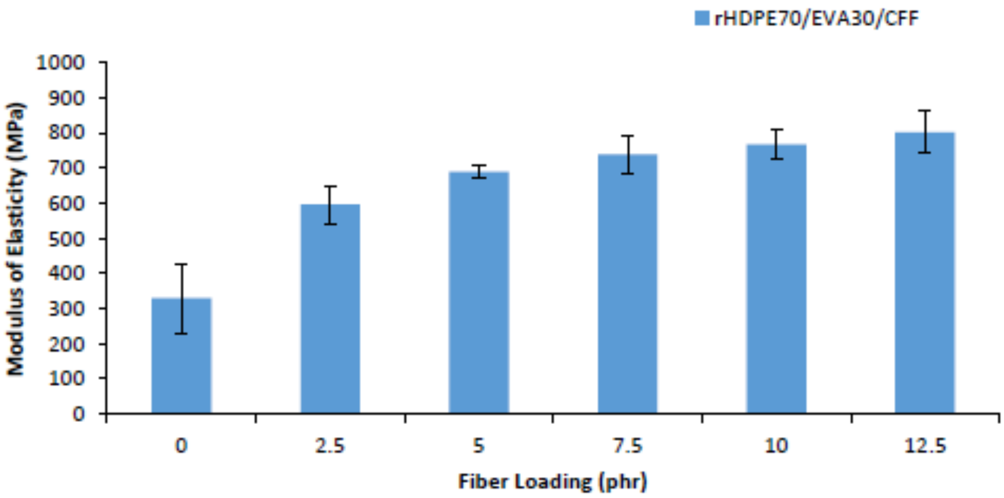


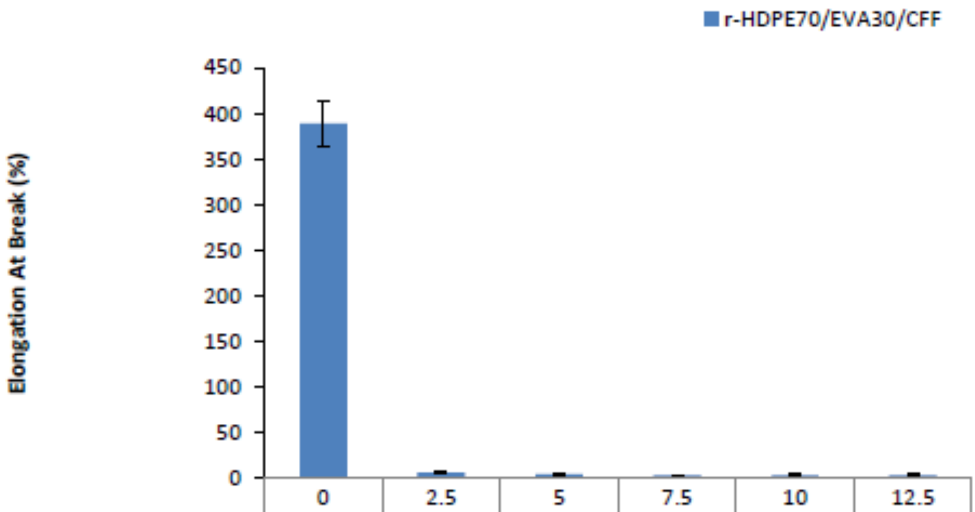
Figure 2. Effect of fiber loading on the modulus of elasticity of r-HDPE/EVA/CFF composites

Cheng and co-researchers (2009) [13] investigated that the tensile modulus of CFF reinforced composites is higher than pure PLA matrix. The fibrous CFF filler able to carry the tensile load and restrict the deformation ability of r-HDPE/EVA matrix in elastic zone thus improved the adhesion between r-

HDPE/EVA and filler and Young's Modulus. Arpitha and Yogesha (2017) [14] stated fibers in the composites are the load-bearing element and provide strength and rigidity while the polymer matrices protect them against the environment.

3.3 Elongation at break

Figure 3 presented the effect of CFF fiber loading on the elongation at break of r-HDPE/EVA/CFF composites. As the addition of CFF in r-HDPE/EVA/CFF composites increased, the elongation of break of composites significantly decreased. This proved that CFF stiffened the r-HDPE/EVA/CFF composites by hindering the chain mobility of r-HDPE/EVA matrix. The restriction of chain mobility led to higher breaking tendency and lower deformation of r-HDPE/EVA/CFF composites. By increasing the CFF fiber loading in the composites, the transition of composites changes from ductile to brittle [15,16]. This caused the enhancement in brittleness and decrement in ductility of composites and eventually led to reduction in toughness and elongation at break of r-HDPE/EVA/CFF composites.



	0	2.5	5	7.5	10	12.5
r-HDPE70/EVA30/CFF	389.0896667	7.01575	4.78524	4.1855	4.1569725	3.833485

Figure 3. Effect of fiber loading on the elongation at break of r-HDPE/EVA/CFF composites

3.4 Morphology analysis

Figure 4 shows the r-HDPE/EVA/CFF composites illustrated the improvement in interfacial adhesion between the r-HDPE and EVA matrix. This indicated that CFF is compatible with r-HDPE/ EVA matrix due to keratin protein of CFF consists of hydrophilic and hydrophobic amino acid groups improved the interfacial adhesion with hydrophobic r-HDPE phase and ethylene in EVA and hydrophilic ester group in EVA and enhanced fiber/matrix interaction. The addition of 12.5 phr of CFF contributed to poor distribution which illustrate weak fiber/polymer interaction. This indicated the CFF was overloaded in the composites which promoted fiber-fiber interaction cause agglomeration of CFF in r-HDPE/EVA matrix. The agglomeration of CFF promoted the stress concentration which weakening the polymer matrix -filler interaction and eventually break fairly when stress was applied and reduction in tensile strength [11].

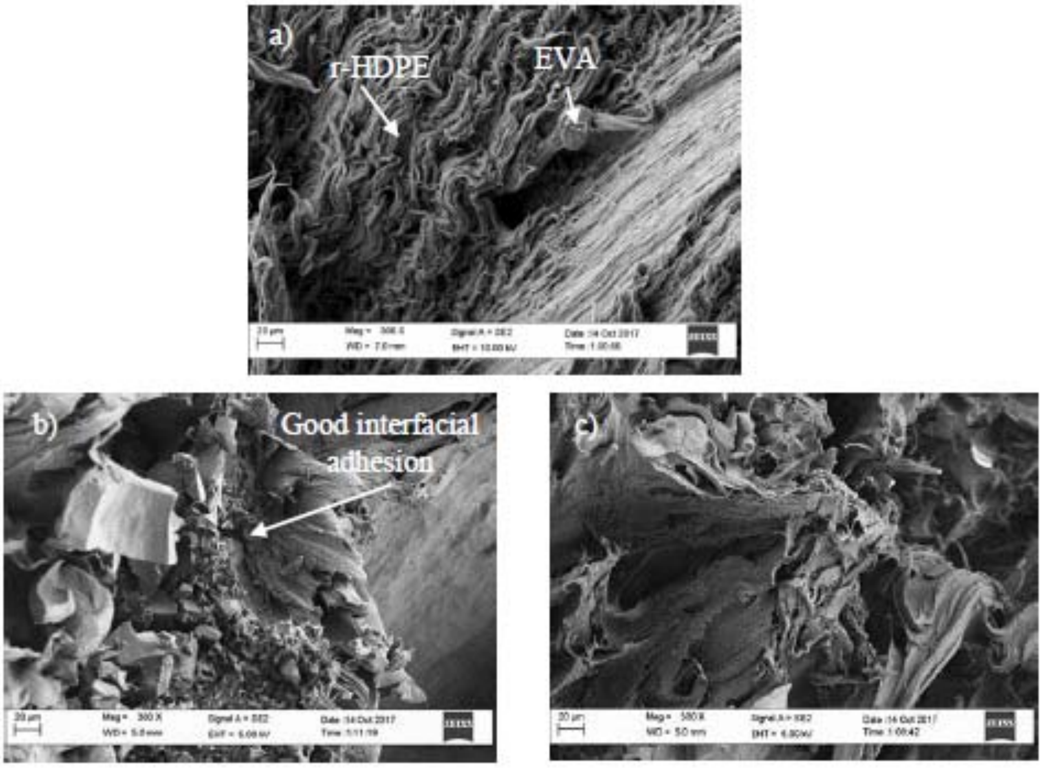


Figure 4. Scanning Electron Microscopy micrographs of tensile fractured surfaces of a) r-HDPE/EVA-30 b) r-HDPE/EVA/CFF-10 composite c) r-HDPE/EVA/CFF-12.5 composites at 300 x magnification

3.5 Functional group analysis

Figure 5 displayed the infrared spectrum of a) r-HDPE, b) r-HDPE/EVA blends and c) r-HDPE/EVA/CFF composites. The addition of CFF into the r-HDPE/EVA matrix significantly enhanced the peaks at 3379.69 cm−1 indicated NH stretch from hydro halides amine group which provide hydrophilic properties for chicken feather fiber. The peaks at 2914.64, 2848.85, 1461.83, 1370.83 and 718.67 cm-1 were the absorption bands for aliphatic group in r-HDPE and ethylene group in EVA while the 1737.71 cm-1, 1239.80 cm-1 and 1019.95 cm−1 peaks were represented the vinyl acetate group in EVA polymer [17,18].

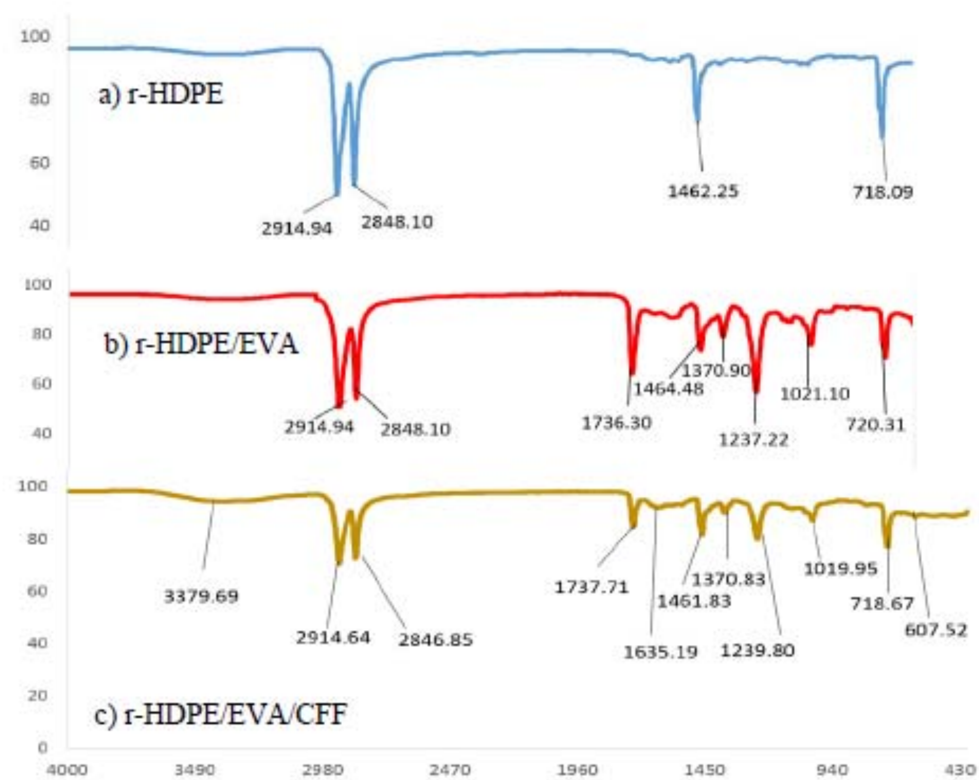


Figure 5. The FTIR spectra of a) r-HDPE b) r-HDPE/EVA blends c) r-HDPE/EVA/CFF composites

3.6 Water absorption properties

Figure 6 revealed the effect of CFF fiber loading on the water absorption properties of r-HDPE/EVA/CFF composites. The results showed the higher the CFF filler loading in r-HDPE/EVA/CFF composites, the higher the water absorption of r-HDPE/EVA/CFF composites. This proved CFF has hygroscopic amino acids which enhanced the interaction with water molecules that lead to high water absorption properties. The hydrophilic groups with free O-H group and N-H group in amino acid increased as CFF loading increased in the composites. The O-H group formed hydrogen bonding with water molecules which lead to more water absorption in r-HDPE/EVA/CFF composites [19]. This promoted the water molecules in r-HDPE/EVA/CFF composites.

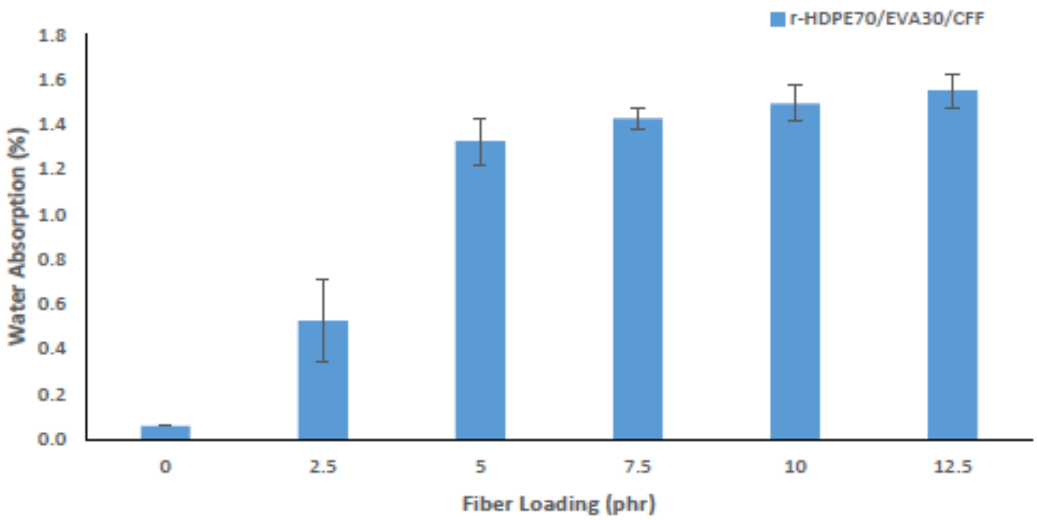


Figure 6. Effect of CFF fiber loading on the water absorption properties of r-HDPE/EVA/CFF composites

3.7 Oven aging properties

The effect of CFF fiber loading on the weight loss of r-HDPE/EVA/CFF composites had shown in Figure 7.

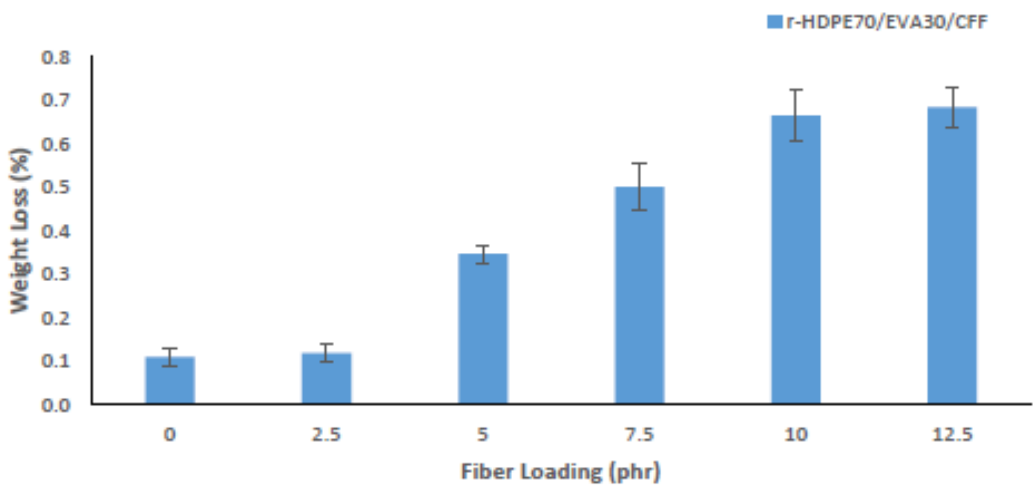


Figure 7. Effect of CFF fiber loading on the weight loss of r-HDPE/EVA/CFF composites

The weight loss of r-HDPE/EVA/CFF composites was increased as the CFF fiber loading increased in the composites. Keratin protein of CFF consists of 40 % hydrophilic amino acid groups which enhance permeability to oxygen and water uptake in the composites. The present of hydrophilic amine group in CFF is proved by 3379.64 cm−1 peaks which indicated the free amine NH2 group in r-HDPE/EVA/CFF composites through Figure 7 c. This proved CFF has hygroscopic amino acids which enhanced the interaction with water molecules that lead to high moisture contents [19]. This promoted the water molecules in r-HDPE/EVA/CFF composites. Thus, the evaporation of water had occurred during oven aging that cause the weight loss in the composites.

4. Conclusion

1. The mechanical performance such as tensile strength, tensile modulus, and elongation at break of r-HDPE/EVA/CFF composites were slightly increased with increasing chicken feather fiber loading up to 10 phr.
2. The addition of EVA in r-HDPE/EVA/CFF composites was proved to enhance the compatibility and adhesion towards r-HDPE matrix, where all the studied mechanical properties show positive increment as the filler loading increase.
3. Husbandry by-product such as chicken feather will be an alternative and vital reinforcement filler towards manufacturing composites because the global supply of conventional fiber is becoming limited in developed countries. Chicken feather seems to have potential to create composites which is suitable for use in the construction and green furniture industries in the future.

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