International Journal of Nanoelectronics and Materials
Volume 15 (Special Issue) December 2022 [383-388]

Investigation on Effects of Light Transmittance in Distinguishing Conventional Plastics and Bioplastics for Plastic Recycling

Ragunathan Santiagoo[1,2,*], Razi Ahmad[1,3], Syakirah Afiza Mohammed[1,3], Abdul Ghapar Ahmad[1]
Vikneswaran Vijean[4], Wan Amiza Amneera[1,3], and Mustaffa Zainal[1]

[1]Fakulti Teknologi Kejuruteraan Awam, Universiti Malaysia Perlis, Komplek Pusat Pengajian Jejawi 3, 02600, Jejawi, Perlis
[2]Sustainable Environment Research Group (SERG), Center of Excellence Geopolymer and Green Technology, School of Material Engineering, Universiti Malaysia Perlis, Komplek Pengajian Jejawi 2, 02600 Arau, Perlis
[3]WAREG (Water Research Group), Universiti Malaysia Perlis, Komplek Pengajian Jejawi 2, 02600 Arau, Perlis
[4]BioSIM Research Group, Sport Engineering Research Center, Universiti Malaysia Perlis, Perlis, Malaysia

ABSTRACT

In order to recycle plastic materials, it is important to distinguish between conventional plastic and bioplastic. This project discussed on the effect of light transmittance to differentiate those types of plastics. It involved the fabrication of conventional plastic made by polypropylene (PP) and bioplastics made of polypropylene/ recycle acrylonitrile butadiene rubber / empty fruit bunch (PP/NBRr/EFB) which formed a thermoplastic elastomer composite. The bioplastics was treated using two types of treatments which were silane and stearic acid. All composite was tested for tensile test and SEM to determine the mechanical and morphological properties. As for light transmittance analysis, light sensor and light-emitting diode (LED) light were used to perform the test. Based on the overall result, composite with silane treated empty fruit bunch (EFB) have better performance in terms of mechanical and morphological properties. Meanwhile, that type of composite was analyzed to become high in crystallinity, therefore lead to low in light transmittance percentage. Besides, the light transmittance values have been verified by MATLAB simulation as a method in distinguishing conventional and bioplastics with 100 % accuracy.

Keywords: Bioplastic, light transmittence analysis, municipal waste streams, biodegradable, plastic pollution

1. INTRODUCTION

Plastics are the most inexpensive, lightweight, easy processing and with no trouble be moulded into a variety of products for a vast range of applications. The production of plastics has accelerated markedly over the last 60 years due to its benefits including effect of resistant is greater and break-free. Unfortunately, most of the plastics will end up enter municipal waste streams at some point of the end of service life. It inflicting numerous environmental problems in plastics utilize and disposal cutting-edge stage [1]. A biodegradable plastic or bioplastic is made partly or fully from polymers derived from organic sources such as sugarcane, potato starch or the cellulose from trees & straws [2]. The word bioplastic refers to the plastic that is bio-based which synthesized from biomass and renewable resources. Example of bioplastic are poly-lactic acid (PLA) and polyhydroxyalkanoate (PHA) that require oxygen, water, light and microorganisms and is a time-consuming process in a natural environment for degrade [3]. Meanwhile, conventional plastics or non-biodegradable plastics describe polymers that is unable to wreck down into a natural, environmentally secure condition over time by using biological processes [4].

* raguna@unimap.edu.my

There are so many kinds of conventional plastics, such as polypropylene (PP), polyethylene (PE), polystyrene (PS) and polyethylene terephthalate (PET). The existence of plastic has already taken the place of many usual materials, for instance wood, leather, paper, stone, glass, steel and ceramic. Nowadays, about third of plastic is used in packaging and any other third is relatively used in buildings structures such as for plumbing and piping system in developed nations [2]. Consequently, the use of plastics in so many ways has delivered to plastic pollution into a disaster. It has formed a massive part of municipal solid waste and induced surge environmental concerns, consequently lead to a strengthening of quite a few regulations that aimed to reduce the generated amount of plastic waste [5]. However, it has been believed that all of the generated plastics which typically regarded as a material that cannot be degraded able to be changed with the aid of degradable plastic called bioplastics [6][7]. In this study, a mixture of polypropylene (PP) and recycle acrylonitrile butadiene rubber (NBRr) will be introduced with oil palm empty fruit bunch (EFB) as to make it biodegradable. Oil palm EFB in this case act as filler. Filler is broadly used in the production process of plastic products and it is used to change the properties of the original plastic.

2. MATERIALS AND METHODS

2.1 Conventional Plastic and Bioplastic Fabrication

Conventional plastic was fabricated using 100 phr of PP while bioplastics have been from quite a few formulation of PP, NBRr and treated EFB as shown in Table 1. Those thermoplastic elastomer composites went via mixing process using 180 °C heated two rolls mill at 15 rpm for 10 minutes. In order to create the plastic sheet, the sample had been pressed using hot press with the same temperature at 1000 psi for 15 minutes.

Table 1 The formulation of thermoplastic elastomer composite

Material	Amount (phr*)					
	Conventional Plastic	Bioplastics				
PP	100	70	70	70	70	70
NBR	0	30	30	30	30	30
EFB (Stearic acid / Silane treatment)	0	5	10	15	20	30

*per hundred resin

2.2 Tensile Test

Each sample sheet used to be cut into dumbbell shape the used of Wallace Die cutter before tensile test is performed. The test was carried out via using Instron 3366 universal testing machine (UTM) in accordance to ASTM D638 in order to get the data for tensile strength, elongation at break and Young's modulus.

2.3 Scanning Electron Microscope (SEM)

The morphologies of the fracture sample (after tensile test) was analysed using Scanning Electron Microscope (SEM) machine model HITACHI TM 3000. During SEM testing, a focused electron beam with energies around 1 to 50 kV will scan over the specimen line by line in the evacuated microscope column and forms signals relying on the interactions between the beam and the sample which can be said electronically amplified.

2.4 Light Transmittance Test

Standard methods that have been referred were ASTM D1494 and E1348 as well as quite a few related journals. The test was carried out using self-built light transmittance sensor (hardware). The hardware was once connected to laptop that was installed with Arduino compiler. The data were obtained by using 5 V LED light source that was placed in different distance of light source to the composite sample ranging from 1 cm until 5 cm distance, denoted as Distance A and 1 cm, 3 cm and 5 cm distance of composite sample to the light sensor denoted as Distance B. The apparatus was set up in a dark room as shown in

Figure 1 using a sample with 20 mm^2 size. The data gained used to be computed in MATLAB software in order to achieve the desired data and accuracy in distinguishing each plastic.

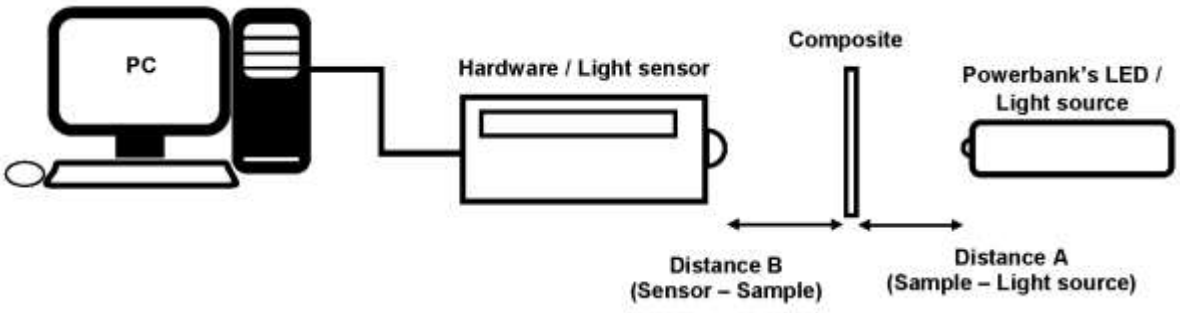


Figure 1. The apparatus set up for light transmittance test.

The values of light transmittance were calculated using the formula (1) [8].

$$\%T = \left(1 - \frac{I_1 - I_2}{I_1}\right) \times 100\% \quad (1)$$

$$V = IR$$

Where;

T = light transmittance (%)
I_1 = reference current (mA)
I_2 = final current passing through the composite (mA)
V = voltage (V)
I = current (A)
R = resistance (Ω)

3. RESULTS AND DISCUSSION

3.1 Tensile Properties

Tensile test is used to determine the mechanical behavioural of a material under tension load. Table 2 shows the result of tensile test that has been carried out on 10 samples of PP/NBRr/EFB with different formulation and treatment. Silane and stearic acid are chemically bound to one surface and physically attracted to another material with respect formulation [9]. They attract different materials with impermanent physical bond and permanent chemical bonds. It shows that composite sample with silane treated EFB is seems to be greater in tensile strength as silane is better in surface modification of EFB compared to stearic acid. Tensile strength reduced due to the difficulty of the composite in achieving homogenous mixture during the mixing process for

the excessive fibre loading. Hence, the incorporation of EFB fibre in PP matrix brought on an interruption in stress transferring along the applied force and leads to decrease the tensile strength of the composites [10].

Table 2 The result of tensile test

Tensile Properties			
	Formulation	**Stearic acid treatment**	**Silane treatment**
Tensile Strength	70/30/5	15.141	18.058
	70/30/10	13.624	14.357
	70/30/15	12.916	12.724
	70/30/20	11.745	11.952
	70/30/30	10.683	11.327
Young's Modulus	70/30/5	589.7	601.3
	70/30/10	603.9	640.2
	70/30/15	611.2	708.1
	70/30/20	625.3	728.3
	70/30/30	739.1	760.2
Elongation at Break	70/30/5	7.1	6.7
	70/30/10	6.9	6.4
	70/30/15	6.2	5.7
	70/30/20	5.9	5.6
	70/30/30	5.6	5.2

3.2 Scanning Electron Microscope (SEM) Micrograph

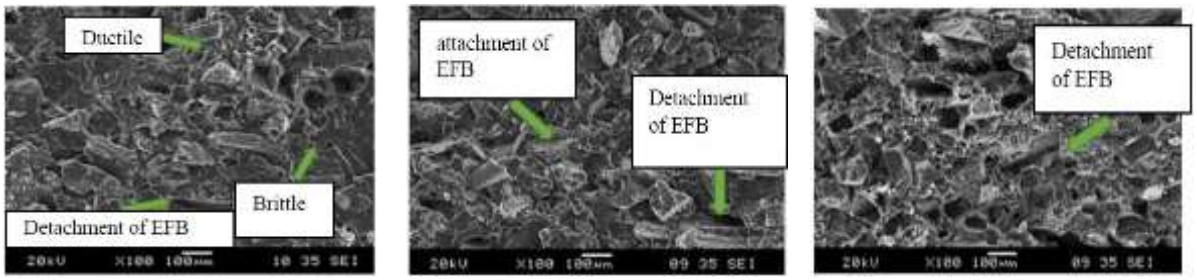
Figure 2 (a), (b) and (c) and

Figure 3 (a), (b) and (c) represent the composite of PP/NBRr/EFB which treated with stearic acid and silane in 70/30/5, 70/30/15 and 70/30/30 formulation respectively. The poor interfacial adhesion between EFB fibre and PP/NBRr matrices was once identified as some detachment of EFB mentioned in

Figure 2 (b) in which prompted the reduction of the tensile strength by increasing the EFB fibre loading. In

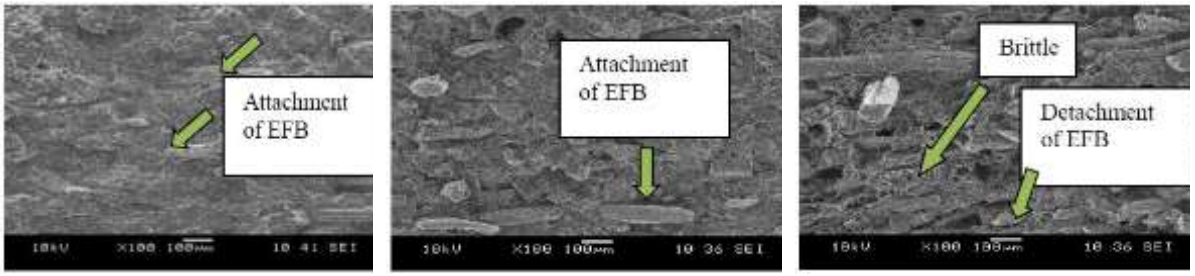
Figure 2 (a)**,** it can be seen that there are ductile and brittle surface of the composite as well as the detachment of EFB fibre from PP/NBRr matrices. This event is due to the EFB fibre started restricting to be pulled out from the PP/NBRr matrices. By referring to

Figure 3, less detachment site is discovered and less gap presented between EFB fibre and PP/NBRr matrices due to the better adhesion and improved wetted between the EFB fibre and PP/NBR matrices [11]. Therefore, the tensile properties of polymer composite mixed with silane treated EFB is barely better than the stearic acid treatment.



(a) (b) (c)

Figure 2. SEM of PP/NBRr/EFB treated with stearic acid at composition (a) 70/30/5, (b) 70/30/15 and (c) 70/30/30.



(a) (b) (c)

Figure 3. SEM of PP/NBRr/EFB treated with silane treatment at composition (a) 70/30/5, (b) 70/30/15 and (c) 70/30/30.

3.3 Light Transmittance Test

According to

Figure 4, it shows that high crystalline polymers give high density to the composite, therefore the speed of light trying to pass through the composite will reduce causing the sample low in light transmission [12]. This is due to the more EFB added causing crystallization of the intermolecular chains providing a mechanism via which the material hardens under deformation.

As referred to the graph, the highest percentage of light transmittance is generated from PP at 1 cm of Distance A which is 99.5 %. However, the value is decreased as the distance increase. This is because, the light receives dimmer when it is moved away from the incident surface inflicting the irradiation power decrease. By placing the composite sample in between the light source and the sensor, irradiation power generated from the LED light source decreased even more [13]. The graph of light transmittance for 3 cm and 5 cm of Distance B had been also in the same pattern as

Figure 4. Through MATLAB simulation, 100 % accuracy has been achieved via 50 repetitions.

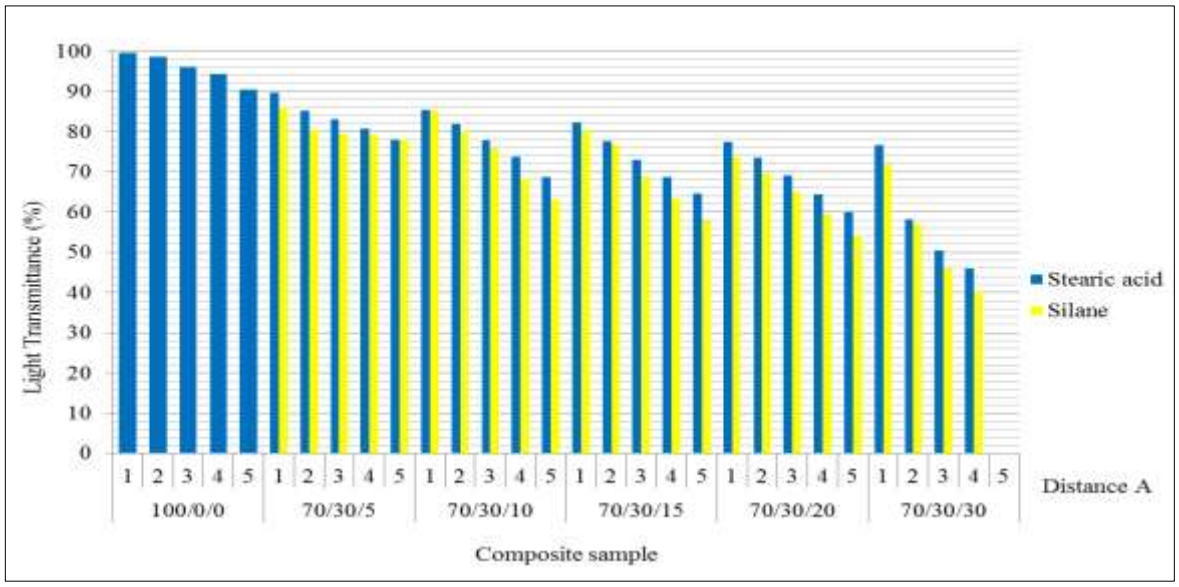


Figure 4. The graph of light transmittance analysis within 1 cm of distance A.

CONCLUSION

As the conclusion, light transmittance in unit percentage definitely can help in distinguishing conventional plastic and bioplastics. This has been proved with 100 % accuracy of the data that have been tested in MATLAB simulation. Better attachment of EFB fiber to PP/NBRr matrices by silane treatment has brought on the polymer composite to end up high in density with respect to the amount of EFB fiber added. Therefore, the amount of light that passed through the sample is reduced. By using light as an indicator, this will help ease the process of plastic recycling as it has the capability in distinguishing conventional plastic and bioplastics. The conventional plastic has the highest percentage of light transmittance as it contained amorphous intermolecular chain that help in lowering the density of the polymer composite and enhancing light transmittance.

ACKNOWLEDGMENTS

A special thanks to the Ministry of Education Malaysia for the funding of this research work through the grant Fundamental Research Grant Scheme (FRGS/1/2020/TK0/UNIMAP/02/67).

REFERENCES

[1] Hashem, A.O.A. et al., Water quality status of Sungai Petani River, Kedah, Malaysia,. In: IOP Conference Series: Earth and Environmental Science. (2021).

[2] Mohd Sabri, S.N.A. et al., Assessment of drinking water quality in water distribution system at new and old residential area at Kangar, Perlis,. In: IOP Conference Series: Earth and Environmental Science. (2020).

[3] Khoo, H.H., Tan, R.B.H., Int. J. Life Cycle Assess., vol 15, issue 4, (2010), pp. 338–345.

[4] Coppola, G. et al., Bioplastic from Renewable Biomass: A Facile Solution for a Greener Environment. (2021), 5, pp. 231–251.
[5] Mohammed, S.A. et al., Sustain., vol 13, issue 14, (2021), pp. 8031.
[6] Ahmad, R. et al., Adv. Sci. Technol. Eng. Syst., vol 3, issue 5, (2018), pp. 166–170.
[7] Kasim, N.N. et al., Demineralization of oil palm empty fruit bunch (EFB) intended as a high quality bio-oil feedstock,. In: IET Conference Publications. (2016).
[8] Li, Y. et al., Mater. Res. Express, vol 6, issue 1, (2019).
[9] Ho, N.A.D., Leo, C.P., Environ. Res., (2021).
[10] Khalid, M. et al., Mater. Des., vol 29, (2008), pp. 173–178.
[11] Alias, N.F. et al., Iran. Polym. J. (English Ed., (2021).
[12] Deng, J. et al., Microsystems Nanoeng., (2022).
[13] Aromaa, M.K. et al., Eur. J. Prosthodont. Restor. Dent., vol 25, issue 3, (2017), pp. 131–135.