International Journal of Nanoelectronics and Materials
Volume 15 (Special Issue) December 2022 [375-382]

Investigation on Effect of Gas Concentration in Distinguishing Conventional Plastic and Bioplastic for Plastic Recycling

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ABSTRACT

Distinguishing type of plastic was important for the recycling process. In this project, the effect on gas concentration released from composite was studied to distinguish between conventional plastic and bioplastic. This project involved the fabrication of a composite from polypropylene (PP), empty fruit bunches (EFB), and recycle acrylonitrile butadiene rubber (NBRr), with PP used as a conventional plastic and PP/NBRr/EFB used as a bioplastic. Trans-polyctylene (TOR) was used as a compatibilizer to evaluate the effect on the PP/NBRr/EFB. Tensile testing and SEM were conducted to study the mechanical properties and morphological properties on the PP/NBRr/EFB and the PP/NBRr/EFB/TOR composite. The gas sensor (MQ135) was used in this study to detect the presence of NH_3 *and* CO_2 *released from heating conventional plastic and bioplastic. From the overall result, composite with TOR as compatibilizer has shown better performance than composite without TOR in mechanical, morphological and gas sensor testing. By using MATLAB software, it shows that from gas sensor testing, it can be verified to distinguish between conventional plastic and bioplastics for plastic recycling. The average classification obtained from the Probabilistic Neural Network (PNN) was 99.29 % accurate.*

Keywords: Plastic recycling, biodegradable plastic, renewable biomass, municipal waste streams

1. INTRODUCTION

Waste is now have become our global problem and it need our priority in order to manage it and to resolve the world's resource and energy challenges. Due to an increase in population, the generation of waste is getting enlarge day through day [1]. Unfortunately, most of the plastics will come to an end up enter municipal waste streams in the course of cease of service life inflating several environmental problems in current level of plastics usage and disposal [2][3]. A biodegradable plastic or bioplastic is made partly or fully from polymers derived from biological sources such as sugarcane, potato starch or the cellulose from trees & straws [4]. The Because of that, our country should have a proper waste management for dealing with the waste both through disposal or recycling of it. For examples of recycling activity is plastic recycling.

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Plastic recycling is a approach of amassing waste plastic and turning it into new and beneficial plastic products. Plastic is a material with a very wide range of applications in short-lived as well as long-lived products [5]. Furthermore, besides raw oil being the main constituent, many additives and fillers, and for instance reinforcing fibres, are used to optimize the material properties of plastic products[6]. There are many kinds of plastics that can we comprehended such as bio-based plastics, biodegradable plastics, engineering plastics, elastomers, thermoplastics, thermosets, conventional plastic and etc [7]. In this study, conventional plastics and bioplastics have been chosen to find the differences between these two sorts of plastics.

Bioplastic can be simply with plastic that made from plant or other biological material as an alternative of petroleum [8]. Bioplastic is derived from renewable biomass sources, such as vegetative fats and oil, corn starch or micro-biota and bioplastic also biodegradable material which can minimize the depleting fossil fuel and environment impact [9]. It is also known as bio-based plastic. Today, bioplastics play an important role in various industry applications such as food packaging and composting bags [10]. Vegetable oils are noticeably appropriate starting materials for polymers due to their abundance, low cost, biodegradability, environmental benefits and variety of functional groups [11][12].

Thus, this research is aimed to distinguish impact on odour between conventional plastic and bioplastic for recycling plastic. For obtain the purpose of this study, a composite will fabricate from Polypropylene (PP), Recycled synthetic rubber (NBRr), Empty Fruit Bunch (EFB) for represent as bioplastic sample. TOR will also use as compatibilizer on bioplastic composite. A sample from PP only will signify as a Conventional Plastic. Testing involve in this project are morphological and mechanical properties for bioplastic and effect of gas concentration by the usage of gas sensor is investigated in distinguishing between conventional plastic and bioplastic for plastic recycling.

2.MATERIALS AND METHODS

2.1 Material Preparation

The preparation of raw material such as polypropylene (PP), recycle Acrylonitrile butadiene rubber (NBRr), Empty fruit bunch (EFB), and trans-polyoctylene rubber (TOR) had been carried out before mixing process. PP were obtained with grade 6331 which have density of 0.9g/$cm3$ and meet flow index of 1.4g/min at 230℃. For NBRr, nitrile glove masticated quite a few times by via two roll mill machines. Then, it was grinded and sieved to obtain particle size for 150 μm. To prepared EFB, raw materials had been dewax using n-hexane as solvent, washed with distilled water and dried with 24hr at 60℃ in an air oven to removed extra physical impurities. Then, it was grinded and sieved to obtain particle <150 μm. The TOR was supplied from Sigma-Aldrich(M) Sdn. Bhd.

2.2 Mixing Process

To fabricate composite, all the materials have been blended using the Heated Two Roll Mill machine at temperature of 180℃ by referred the formulation of the sample given in Table 1. PP were melted first in this machine for 4 minutes followed by addition of NBRr. Then, EFB was added at minute of 6. In case of combined with TOR, the addition was done at minute of 9. In order to achieve stabilization torque, 3 minutes required for material mixed well. By that, the whole process was taken for 12 minutes. The composites were discharged when the total mixing was 12 min.

Table 1 The formulation of the sample

Material	Amount (phr)												
	Conventional plastic	Bioplastic without TOR						Bioplastic with TOR					
PP	100	100	80	70	60	50	40	100	80	70	60	50	40
NBRr	-	0	20	30	40	50	60	0	20	30	40	50	60
EFB	-	10	10	10	10	10	10	10	10	10	10	10	10
TOR	-	-	-	-	-	-	-	5	5	5	5	5	5

2.3 Sample Preparation

After blended process, the compound was compressed into 1mm thick using Hot Press machine model GT-7014-A300C at 180℃ for total preparation of 12 minutes. This process was started with 6 minutes preheating at 180℃, then compressed at 1000psi for 3minutes, and then cooled for 3 minutes. When the cooling process have been done, the composites were cut into dumbbell-shaped using a Wallace Die Cutter.

2.4 Testing and Characterization Analysis

All the bioplastics sample were tested in tensile testing, Scanning Electron Microscopy (SEM) and gas sensor. For gas sensor testing, the test was done on conventional plastic and bioplastic for distinguish this both type plastic. Tensile test for this research has been carried out using Universal Testing Machine (UTM) to resolve the tensile strength, Young's Modulus and elongation break. Tensile test for this research were conducted for mechanical properties according to ASTM D638 Standard Test Method. The morphology properties in this research have been using Scanning Electron Microscope (SEM) to evaluated the surface morphology sample of tensile fracture specimen.

Then, by using MQ135 gas sensor, gas sensor testing was conducted to distinguish the effect of gas concentration between conventional plastic and bioplastic. MQ135 was used as electronic nose to detect the NH_3 and CO_2 gases. This test done by heated the sample in the oven with temperature of 100℃, 125℃and 150℃in the fume hood. Each sample was heated in the identical condition which have the size of 2cm x 2cm. Artificial intelligence which was used MATLAB platform as a software program that helps in determined percent classification accuracy which mean to prove the rate of success in distinguishing conventional plastic and bioplastic by using this gas sensor and all data that have insert to MATLAB software.

3. RESULTS AND DISCUSSION

3.1 Mechanical Properties

Table 2, shown the result of tensile strength, young's modulus and elongation at break for PP/NBRr/EFB and PP/NBRr/EFB/TOR composite. From the result obtained, tensile strength and young modulus have been decreased with increasing of NBRr loading for both composite. This might due to low interaction between the matric and fillers. Besides that, with TOR as compatibilizer, it shows the higher tensile strength value compared to composite without TOR. With the addition of TOR, it will increases the adhesion at the interface of NBRr [13].

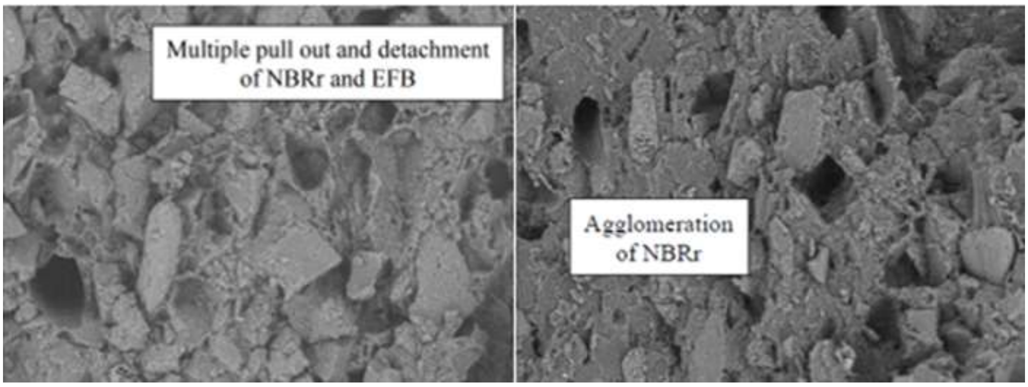
Table 2 Tensile testing for PP/NBRr/EFB and PP/NBRr/EFB/TOR

Composite	Formulation	Tensile strength	Young's Modulus	Elongation at Break
PP/NBRr/EFB	100/0/10	25.52	907	4
	80/20/10	18.805	620	5.5
	70/30/10	16.061	473.7	6.4
	60/40/10	11.004	456	6.8
	50/50/10	8.714	420	7.2
	40/60/10	5.743	268	7.5
PP/NBRr/EFB / TOR	80/20/10/5	23.489	787.1	6
	70/30/10/5	19.327	723.28	6.7
	60/40/10/5	14.638	579.6	7
	50/50/10/5	9.207	427.6	7.5
	40/60/10/5	7.09	311.8	7.7

The elongation at break of PP/NBRr/EFB and PP/NBRr/EFB/TOR exhibit that it increased while increasing NBRr loading for all sample. Besides, the composite with the presence compatibilizer of TOR was higher than control even at the similar amount of filler. This might due to strong interaction of the composite with TOR compatibilizer. Besides that, this was caused by the stiffness of the composite decrease with the increasing content of elastomer [14]. With addition of TOR, it provided the high elasticity and flexibility on the bioplastic composite.

3.2 Morphological Properties

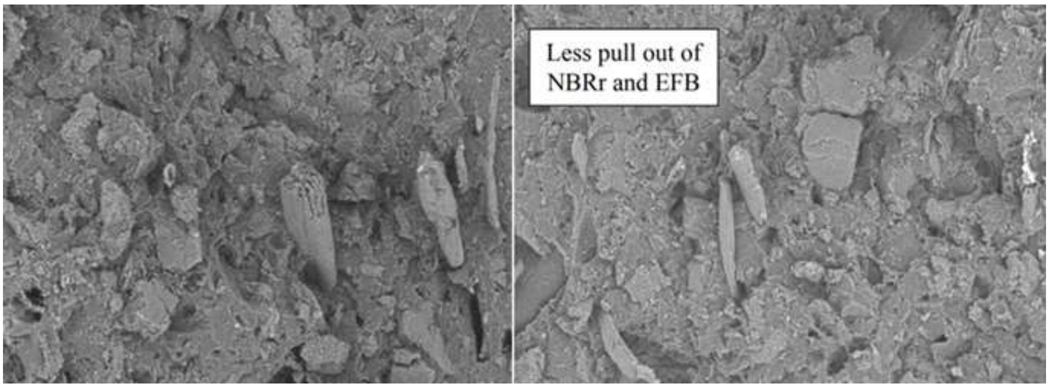
Figure 1 below shown SEM micrograph of fracture surface of PP/NBRr/EFB composite at the ratio of 70/30/10 and 60/40/10 respectively. From the observation, in both composites, there are holes and an uneven distribution of the NBRr. The pull out or detachment of the EFB filler, as well as the NBRr matrix, is the most common reason of the holes [14]. Besides that, this is due to low interaction between filler and matrix. In addition, it shown that the interfacial tension was existed between matrices and filler.



(a) (b)

Figure 1. SEM micrograph of fracture surface of PP/NBRr/EFB at (a) 70/30/10 and (b) 60/40/10

Figure 2 below shown the SEM micrograph of fracture surface of PP/NBRr/EFB/TOR composite at the ratio of 70/30/10/5 and 60/40/10/5 respectively. Both micrographs show that the composite was properly blended considering that there was less pull out of the EFB filler and the EFB filler was properly enclosed in the matrix. In addition of TOR as compatibilizer, the end result shown that, its haves better smooth surface compared to the composite without TOR.



(a) (b)

Figure 2. SEM micrograph of fracture surface of PP/NBRr/EFB/TOR at (a) 70/30/10/5 and (b) 60/40/10/5.

3.3 Gas Sensor

Figure 3shows the gas concentration at a variety of temperature points of NH_3 and CO_2 for PP and

Figure 4 shown PP/NBRr/EFB/TOR composites. Three temperature points were evaluated, 100 ℃, 125 ℃and 150 ℃. Based on the result obtained, the range value of gas concentration released from PP for CO_2 and NH_3 on temperature 100 ℃, 125 ℃and 150 ℃is between 77.93 ppm to 78.90 ppm and 23.00 ppm to 24.08 ppm respectively. The range value of gas concentration released from PP/NBRr/EFB/TOR for CO_2 and NH_3 on temperature 100 ℃, 125 ℃and 150 ℃is between 56.43 ppm to 64.09 ppm and 6.87 ppm to 10.83 ppm respectively.

From the observation, it can be seen that the value of gas concentration for both PP and PP/NBRr/EFB/TOR increased with the increasing temperature. This is due to the fact the particles of gas released are moving with a greater energy when the temperature is increased, causing intermolecular collision. Yet, the value of gas concentration differs between both conventional and composite plastic, with the latter has lesser released gas concentration from the former. The result have been supported by Okoffo et al. [15] that study on micro-bioplastics (i.e., polylactic acid (PLA), polyhydroxyalkanoate, polybutylene succinate, polycaprolactone, and polybutylene adipate terephthalate (PBAT)) in environmental samples on a polymer-specific mass-based concentration. With the addition of TOR as compatibilizer, the composite's released gas concentration has been controlled to a reduced the value of gas concentration compared to conventional plastic. The observation from the figure also indicating that the emission of carbon dioxide was higher compared to ammonia. But, these concentrations are still below the recommended value by the Malaysian Department of Safety and Health (DOSH) for IAQ guideline, which are 25 ppm for NH_3 and 1000 ppm for CO_2 [16]. Having a clear disparity range between the gas concentrations for PP and PP/NBRr/EFB/TOR shows why these indications can be used to distinguish between conventional and composite plastics.

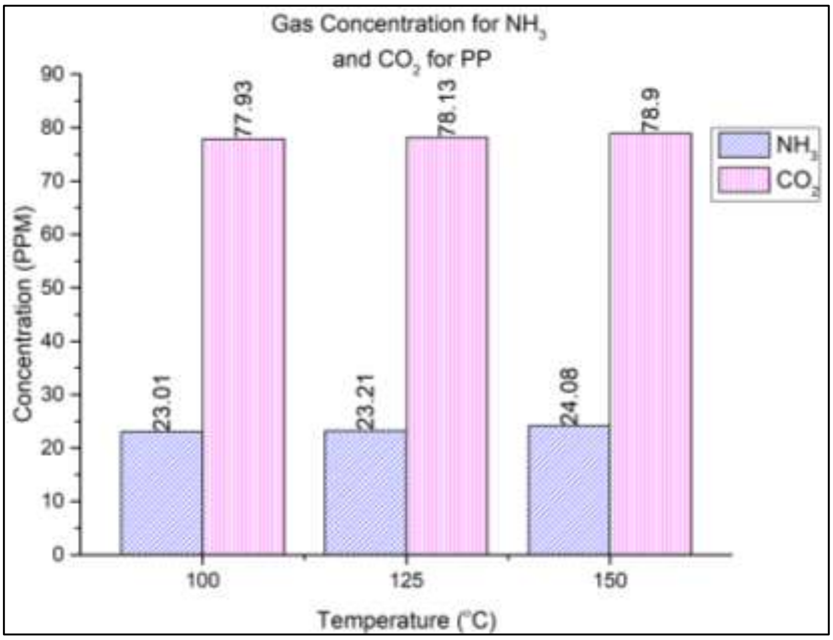


Figure 3. Gas concentration of NH3 and CO2 vs Temperature for PP

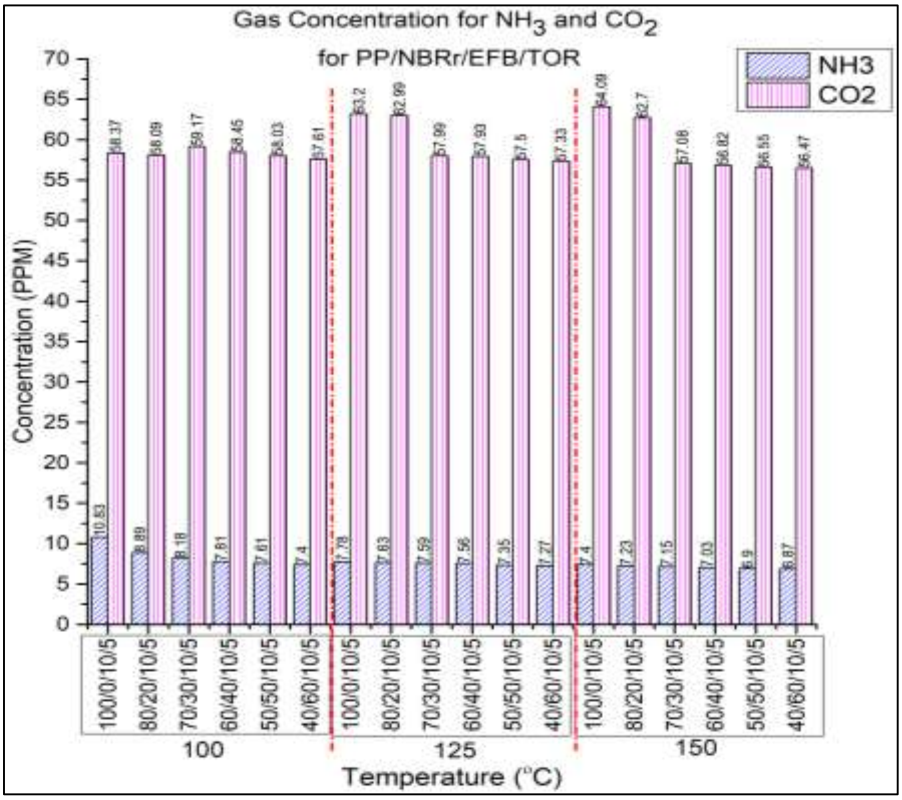


Figure 4. Gas concentration of NH3 and CO2 vs Temperature for PP/NBR/EFB/TOR composite.

3.4 MATLAB Analysis

Table 3 shows the Probabilistic Neural Network (PNN) classification result in classifying the conventional plastic and bioplastic. The test was conducted in MATLAB software for 50 repetitions, 10 times repetitions for 5 trials. The number of input neurons are 7, indicating the inputs given to the PNN algorithm to classify. The 7 inputs are gas reading in voltage (G_V), gas reading in resistance (G_R), humidity (H), environmental temperature (T_{EN}), oven temperature (T_{OV}), ammonia in ppm and carbon dioxide in ppm. The values are captured at real time using the gas sensor array fabricated for this experiment. There are 2 output neurons for this model, indicating 2 possible output which is conventional or bioplastic composite. The other parameters required by the PNN model are as shown in Table 3. A total number of 2730 data samples were taken for the classification, consist of 60 % data for training the model and 40 % data to test the model. The average minimum classification of accuracy recorded from all the data set was 98.72 %. The average maximum classification of accuracy recorded from all the data set was 100 % and the average mean classification of accuracy recorded from all the data set was 99.29 %. Based on result shown in the table, it can be clearly state that the PNN model successfully distinguish the conventional plastic and bioplastic, and thus, can be used in plastic recycling application. The Mohanraj et al [17], using probabilistic neural system is created to characterize the portioned rice picture.

Table 3 Probabilistic Neural Network Classification Result

Number of Input neuron: 7 **Number of Output neuron: 2** **Spread factor: 0.015** **Testing tolerance: 0.001** **Number of samples used for training: 1638** **Number of samples used for testing: 1092** **Total number of testing samples: 2730** **Repetitions: 10 times each trial**			
Trial	**Classification Accuracy**		
	Minimum classification (%)	**Maximum classification (%)**	**Mean classification (%)**
1	98.72	100	99.29
2	98.72	100	99.04
3	98.72	100	99.29
4	98.72	100	99.62
5	98.72	100	99.23
Average	98.72	100	99.29

4. CONCLUSION

As a conclusion, composite with TOR as compatibilizer has shown better overall performance than composite without TOR in mechanical properties, morphological properties and gas sensor testing. From gas sensor testing, the result shown that, bioplastic have lower concentration for both gases NH_3 and CO_2 compared with conventional plastic. Furthermore, with increasing of temperature, the value of gas concentration increased too. With the analysis from MATLAB, it shows that from gas sensor testing, it can verify to distinguish between conventional plastic and bioplastic for plastic recycling. The result shown that the average classification obtained from the Probabilistic Neural Network (PNN) was 99.29% accurate.

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).

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