

Biodegradability of oil palm cellulose-based bioplastics

Isroi^{1*}, A Rahman² and K Syamsu³

¹Indonesian Research Institute for Biotechnology and Bioindustry, Jalan Taman Kencana No. 1, Bogor 16128, Indonesia

²Program Study of Natural Resources and Environmental Management, Bogor Agricultural University, Bogor 16680, Indonesia

³Department of Agroindustrial Technology, Bogor Agricultural University, Bogor 16680, Indonesia

*E-mail: isroi93@gmail.com

Abstract. This study investigated biodegradation of the bioplastic composite based on oil palm cellulose in plantation soil as natural inoculum. The biodegradation rate was evaluated as carbon dioxide released during the biodegradation test. Biodegradation test of the bioplastic compared with starch-based bioplastic and conventional plastic samples were conducted in the glass jar for 45 days. The carbon dioxide generated from the biodegradation process absorbed by 0.1 N sodium hydroxide solutions. The carbon dioxide was titrated with 0.1 N HCl and using phenolphthalein followed by methyl orange as indicator. Biodegradation rate of the bioplastic was 0.1082 mg CO₂/day and total carbon dioxide for 45 days was 8.8mg. Biodegradation rate of the starch-based bioplastic was higher than the oil palm bioplastic that is 0.157 mg CO₂/day. There was no carbon dioxide released from the conventional plastic during the test. By calculation, total degradation of the bioplastic samples were 254 days and 207 days for the oil palm bioplastic and the starch-based bioplastic, respectively.

1. Introduction

The world conventional based plastic production has reached 322 million tons in 2015 [1] and accumulation of the plastic waste to the environment poses a global environmental problem. Plastic wastes discarded in the landfills are 40% of the 70 billion pound plastics annually produced. Several hundred tons of the plastic waste are annually disposed to the ocean and finally pile up in the oceanic regions [2]. Estimation of plastic waste discarding to the marine environment is one to three orders of magnitude greater than the reported mass of floating plastic debris in high-concentration ocean gyres. According to the report, Indonesia is the second biggest plastic marine debris producer in the world [3].

The conventional plastics are made from petroleum-based materials. These plastic materials are predominantly made through carbon to carbon binds which resist degradation by microorganisms. In the recent years, there has been a growing trend of public worries to the hazardous effects of the conventional plastics on the human, organism and environment. For this reason, the research and development of biodegradable bioplastics are suitable with the concept of ecologically safe sustainable industrial development.

Oil palm bioplastic has been developed in the previous research [4]. The bioplastic was a cellulose-starch based composite. Cellulose was purified and modified from oil palm empty fruit bunches



(EFB). Combined with cassava starch as biopolymer matrix and glycerol as a plasticizer, the oil palm bioplastic was successfully made into sheet and bag. Although all components in the bioplastic were biodegradable, the biodegradability of the bioplastic has not tested. This research aimed to test the biodegradability of the bioplastic in landfill soil by natural inoculum. Degradation of the bioplastic in aerobic condition by microorganism would release carbon dioxide as degradation result. The carbon dioxide was measured by titration methods.

2. Materials and Methods

2.1. Oil palm bioplastic and references plastic samples

Oil palm bioplastic was obtained from the previous research [5]. The oil palm bioplastic was a composite bioplastic containing cellulose from oil palm empty fruit bunches; cassava starch as matrix biopolymers; glycerol as plasticizer and compatibilizer. The bioplastic film was cut into small pieces about 1 cm to 1 cm square. Starch-based bioplastic and conventional plastic were used as reference material during the test. These plastic samples obtained from the local market. All the samples were cut into 1 cm to 1 cm pieces. All bioplastic and plastic samples keep in a desiccator to maintain the humidity before use.

2.2. Inoculum source

The inoculum used in the biodegradation test was a local plantation soil in Dramaga, Bogor, West Java, collected from the top soil 5 cm to 10 cm in deep. The soil was screened to remove debris and an organic material. Total plate count (TPC) of the soil was 21.3×10^5 colonies per gram of soil.

2.3. Biodegradation test

Biodegradation test was conducted in a 300 ml glass bottle arrangement as **Figure 1** according to the reference [6]. 100 g of the plantation soil was placed into the samples bottle. Each bioplastic and reference plastics samples (± 0.1 g) were placed and buried into the soil. A bottle without bioplastic or plastic samples was used as a control test to correct the carbon dioxide released during the test. Carbon dioxide was channelled using the tube to the other bottle with 50 ml of 0.1 N sodium hydroxide. The carbon dioxide would react with the sodium hydroxide. All experiment held in Duplo experiment and at room temperature (28°C) for 45 days. Every three days the sodium hydroxide was replaced and analysed for carbon dioxide.

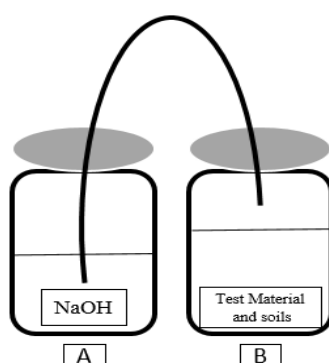


Figure 1. Experimental setup of the biodegradation test, (A) carbon dioxide trap with 0.1 N NaOH, (B) test material and plantation soil.

2.4. Carbon dioxide analysis

The carbon dioxide entrapped in the sodium hydroxide determined by titration with 0.1 N hydrochloric acid solutions. Phenolphthalein (PP) was used as a first indicator and methyl orange as the second indicator. Amount of hydrochloric acid needed to neutralize the solution into pink is proportional with the carbon dioxide releases during the biodegradation test.

3. Results and Discussion

3.1. Carbon dioxide released during the biodegradation test

Plantation soil rich in microorganisms and the total colony was 21.3×10^5 colonies per gram soil. In aerobic condition, the microorganism would degrade the organic materials into carbon dioxide, water and produce heat [7]. Evolution of the carbon dioxide during the biodegradation test was shown in **Figure 2**. The carbon dioxide released fluctuates. Carbon dioxide from the control experiment was carbon dioxide released from the native organic carbon source in the plantation soil. Carbon dioxide released from the samples experiments were sum of the carbon dioxide released from the samples and from the native organic carbon source.

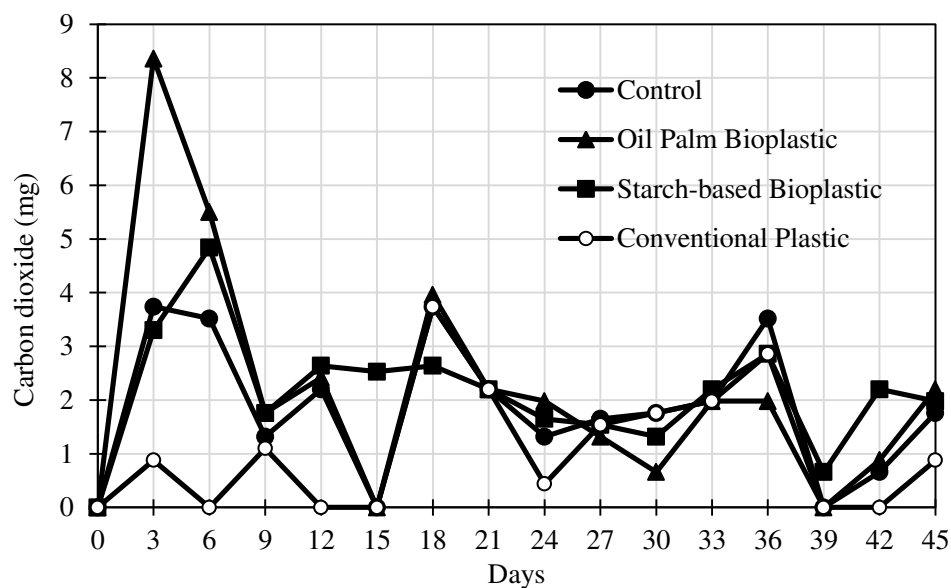


Figure 2. Carbon dioxide (mg) released during the biodegradation test.

During the first 9 days, the microorganisms were very active to decompose the organic carbon as shown by high carbon dioxide released. Evolution of the carbon dioxide gradually reduced and became more stable three weeks after incubation. Evolution of the carbon dioxide on the control and conventional plastics were lower than on the bioplastic samples. This evidence was supposed that no carbon dioxide released from the conventional plastic.

3.2. Biodegradation rate

Sum of the carbon dioxide released from the bioplastic samples and subtracted by the control experiment represent the biodegradation of the bioplastic samples. Accumulation of the carbon dioxide during the biodegradation test was shown in **Figure 3**. Carbon dioxide released in the conventional plastic was zero or negative values. The negative values were presented as zero values that mean no carbon dioxide released from the samples. In other words, no biodegradation detected in the conventional plastic experiment.

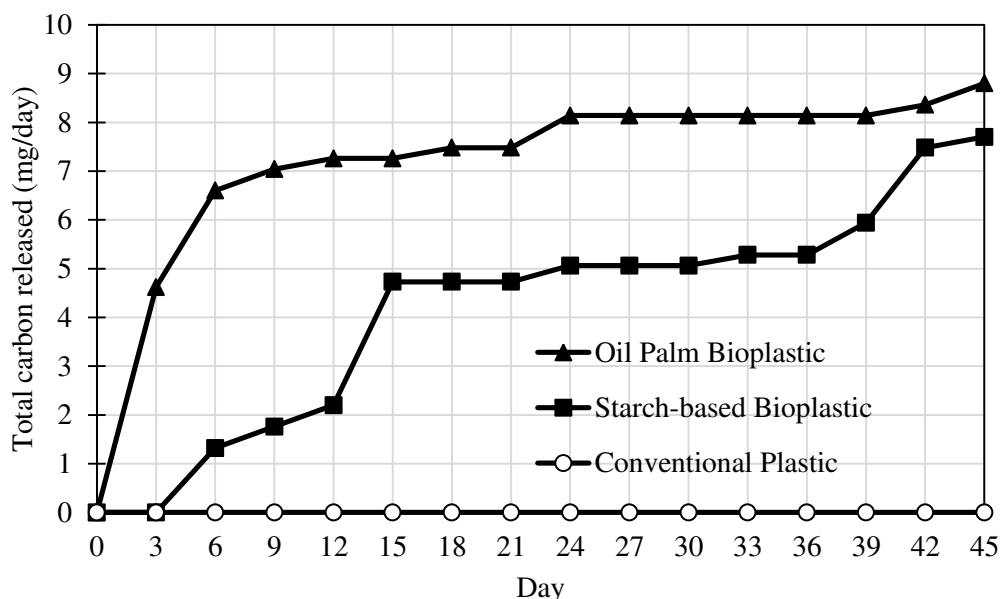


Figure 3. Total carbon dioxide (mg/day) released during the biodegradation test from the bioplastic and plastic samples corrected with the control experiment.

Biodegradation of the oil palm bioplastic was higher than the starch base bioplastic as shown in **Figure 3**. Oil palm bioplastic already biodegraded from the beginning until nine days, then the biodegradation rate slower and become stable after three weeks. The starch-based bioplastic initiated to biodegraded at the day three. The carbon dioxide released from the starch-based bioplastic was lower than from the oil palm bioplastic until 45 days.

Regression analysis of the biodegradation data could use to predict the biodegradation rate of the bioplastic samples. Biodegradation rates of the bioplastic samples were 0.1082 mg CO₂/day and 0.1568 mg CO₂/day for the oil palm bioplastic and the starch-based bioplastic, respectively. It means that the starch-based bioplastic is easier to be biodegraded by microorganisms than the oil palm bioplastic. Total carbon dioxide released during the biodegradation test was 8.80 mg CO₂ and 7.7 mg CO₂, respectively. By calculation, total degradation of the bioplastic samples was 254 days and 207 days, respectively. Resume of the biodegradation test presented in **Table 1**. The oil palm bioplastic contains cellulose derivative. The cellulose is more stable to biodegradation than starch even though the building blocks are the same. Lower biodegradation rate of the oil palm bioplastic than the starch-based bioplastic could be caused by the cellulose content in the bioplastic.

Table 1. Resume of the biodegradation test of the bioplastic samples

	Theoretical CO ₂ (mg)	Biodegradation rate (mg CO ₂ /day)	Prediction of the total biodegradation (day)
Oil palm bioplastic	31.11	0.068	244
Starch based bioplastic	31.98	0.173	200

4. Conclusions

Advantages of the bioplastic compared to the conventional plastic are biodegradability in the natural environment. This study is successfully shown the biodegradation of the bioplastic in plantation soil. Oil palm bioplastic and starch-based bioplastic could be biodegraded by microorganisms in the plantation soil. On the other hand, conventional plastic could not be biodegraded by the microorganisms. Biodegradation rate of the oil palm bioplastic was lower than the starch base

bioplastic. The lower degradation rate of the oil palm bioplastic is possibly caused by cellulose content in the bioplastic.

5. Acknowledgements

This research is funded by Oil Palm Fund Management Agency with the Oil Palm Grant Research programme in 2015.

6. References

- [1] PlasticsEurope, “World Plastics Production 1950 – 2015,” 2017. [Online]. Available: [https://committee.iso.org/files/live/sites/tc61/files/The Plastic Industry Berlin Aug 2016 - Copy.pdf](https://committee.iso.org/files/live/sites/tc61/files/The%20Plastic%20Industry%20Berlin%20Aug%202016%20-%20Copy.pdf)
- [2] Jafari-Sales A, Shahniani A R, Bagherizadeh Y, Alizadeh S, Jahangiri-Hoseinabad M, Abdoli-Seuejani M, Bamzadeh Z and Rasi-Bonab F 2017 *Electron. J. Biol.* **13** 3
- [3] Jambeck J R, Geyer R, Wilcox C, Siegler T R, Perryman M, Andrady A, Narayan R and Law K L 2015 *Sci.* **347** 768
- [4] Isroi, Cifriadi A, Panji T, Wibowo N A and Syamsu K 2017 *IOP Conf. Ser. Earth Environ. Sci.* **65** 12011
- [5] Isroi, Cifriadi A and Panji T 2016 Bioplastic Production from Oil Palm Empty Fruit Bunch *International Conference on Biomass 2016, 10-11th October 2016*.
- [6] Khaswar S, Setyowati K and Khoiri A A 2008 *J. Teknol. Pertanian* **4** 4
- [7] Adhikari D, Mukai M, Kubota K, Kai T, Kaneko N, Araki K S and Kubo M 2016 *J. Agric. Chem. Environ.* **5** 23